# SOME FACTORS INFLUENCING THE BEHAVIOUR OF THE OPTICAL PROPERTIES OF CARBONISED MACERALS

## VOLUME III

## APPENDICES

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(a) Low-rank vitrinite (carbon = 80.0% daf)

(i) Fresh (Plate 3a): dark grey, mostly structureless collinite, but with some particles exhibiting cellular structure; a little sporinite and also some streaks of semifusinite are present: isotropic.

(ii) 400°C (Plate 5a): greyish white, angular, development of small vacuoles of about 1um to 3um diameter with 3um vacuoles mainly present in the carbonised residue at the fast rate of heating; sporinite is still present, but has lost original dark brown colour, becoming light brown: isotropic.

(iii) 450°C: greyish white, angular, development of vesicles of 2.5 to 25 um, the size of the vacuoles increasing with rate of heating; complete disappearance of sporinite: isotropic.

(iv) 500°-575°C (Plates 6 to 8a): white, angular particles at 1°C/min and well rounded at 60°C/min; at the fast rate of heating particles consist of a thick rim and a network of thin-walled vacuoles (Plate 8a); the size of vacuoles varies, but generally increases with rise of heating rate from 2.5um to 50 um diameter; this vitrinite at the slow rate of heating does not plastically deform, retaining original angular form of its particles, but at the fast rate of heating the particles become plastic and rounded: isotropic.

(v) 600°-700°C (Plates 6 to 8b and c): white to creamy white, still angular at 1°C/min, but riddled by small vacuoles (about 2.5 um diameter); at 10°C/min the particles are plastically deformed, but still some of the particles keep their angular shape and do not develop vacuoles, even at 700°C, although they have a puffy appearance; at the fast rate of heating, particles develop typical 'cenosphere' appearance (Newell and Sinnat 1924 and Street *et al.* 1969): partially weakly anisotropic at 1°C/min, weakly anisotropic at 10°C and 60°C/min.

(vi) 750-950°C (Plates 6 to 8d): creamy white to creamy yellow at 1°C/min with particles slightly rounded, vesiculated, slightly swollen and with a puffy appearance; particles at 10°C/min are vesiculated and rounded and show a high relief typical of fusinite; at 60°C/min particles are swollen and the thin frame is broken in many places, due to volatile release (Plate 8d); the particles are very weakly anisotropic at the slow rate of heating, but at the 10°C/min they develop partial strong anisotropy in the vicinity of vacuoles, but otherwise are weakly anisotropic, anisotropy increases at 60°C/min and small particles develop strong basic anisotropy and in general particles display strain anisotropy.

(b) Caking-coal vitrinite (carbon = 85.4% daf)

(i) Fresh (Plate 3b): medium to light grey, uniform, structureless vitrinite with particles occasionally contaminated by sporinite, and angular particles of inertinite and pyrite globules, no cellular structure visible: very weakly anisotropic.

(ii) <u>$400^{\circ}C$ (Plate 5b):</u> grey to greyish-white, angular, but slightly rounded at $10^{\circ}C$/min and $60^{\circ}C$/min; sporinite still present, but has lost its original dark colour, some streaks of inertinite also present: isotropic.

(iii) <u>$450^{\circ}C$ (Plates 9 to 11a):</u> greyish white, non-coherent, but rounded; vesiculated isotropic residues at $1^{\circ}C$/min; coherent, vesiculated residue softened at $10^{\circ}C$/min; disappearance of sporinite: development of partial fine-grain mosaic in particles, but some still isotropic; the isotropic particles are cemented together by a fine-grained mosaic: partially anisotropic.

(iv) <u>$500^{\circ}$-$575^{\circ}C$ (Plates 9 to 11b):</u> white, semi-coke shows rounded and vesiculated particles at $1^{\circ}C$/min around $500^{\circ}C$, but develops coherent, fused, vesiculated residue at $550^{\circ}C$ and $575^{\circ}C$; at $10^{\circ}$ and $60^{\circ}C$/min the residues are coherent, vesiculated; the carbonised products at $1^{\circ}C$/min develop a partial fine-grained mosaic, but the majority of particles develop very weak non-granular basic anisotropy; at $10^{\circ}C$/min, semi-coke shows flow-lines in the vicinity of vacuoles and develops fine-to medium-grained mosaic (Plate 10b), but at $60^{\circ}C$/min the residue consists mainly of coarse-grained and/or flow type mosaics: intensity of anisotropy increases with the temperature and rate of heating.

(v) <u>600°-700°C (Plates 12 to 14a and b)</u>: white-creamy yellow, softened, coherent, fused semi-coke; the carbonised residue consists of a fine-grained mosaic at 1°C/min (Plate 12a); fine and/or medium-grain mosaic at 10°C/min (Plate 13a) and medium-grained to flow-type texture at 60°C/min (Plate 14b); large domains of anisotropic areas developed at 60°C/min (Plates 50 a and b) with also typical nematic structure of 'playes a noyeaux' (see Hartshorne and Stuart 1970): intensity of anisotropy increases with temperature and rate of heating.

(vi) 750°-950°C (Plates 15-17): creamy-white, to creamy, coherent, fused, vesiculated coke; the mosaic structure at 1°C/min consists of fine-grained mosaic with even some particles without granularity; at 10°C/min a strong granular anisotropy develops of fine to coarse-grain (Plate 16); at 60°C/min the residue shows strong preferred orientation (Plate 17) with strong 'pleochroism'.

(c) <u>Low-rank coking coal vitrinite (carbon = 87.9% daf)</u>

(i) <u>Fresh (Plate 3c)</u>: light grey, homogeneous but some microspores and/or fragments of inertinite; no cellular structure present under crossed polars: slightly anisotropic.

(ii) <u>400°C (Plate 5c)</u>: light grey, non-coherent, angular residue; development of vesicles of 5 to 20μm diameter, the size of vesicles increasing with the heating rate; sporinite still present: isotropic.

(iii) 450°C (Plates 18 to 20a): greyish white, semi-angular to rounded but noncoherent residues at 1°C; coherent residue at 10°C and 60°C/min; development of partial fine-grained mosaic structure in residue carbonised at all heating rates, but some particles still isotropic: the isotropic particles are cemented together by fine-grained mosaic texture; isotropic spherical bodies of up to 20 um diameter present in residue carbonised at the rate of 10°C/min (Plate 47a).

(iv) 500°-575°C (Plates 18 to 20b): white to creamy white, non-coherent, residue at 1°C/min but softened and coherent residues at 10°C/min and 60°C/min; at 550°C particles carbonised at 1°C/min become rounded and agglomerated with granular mosaic texture of units of about 1 um diameter; non-vesiculated; the carbonised residues are coherent and vesiculated at 10°C/min and 60°C/min, with mosaic textures consisting of fine and/or medium-grained texture at 10°C/min and medium-grained to flow-type at 60°C/min; the spherical bodies of up to 100 um diameter present in residues carbonised at 500°C at the rate of 10°C/min (Plate 47b); the residue at 60°C/min develops high relief and large vacuoles of about 100 um diameter and also exhibits strong preferred orientation with increase of temperature; large domains of highly anisotropic material present at 550°C: anisotropic.

(v) 600°-700°C (Plates 21 to 23a and b): white-creamy white, softened, coherent residue at all three heating rates; increase in amount and size of vesiculation with increase of temperature at 1°C/min (Plate 21a) and the mosaic texture consisting mainly of fine-grained and mosaic textures; the carbonised residue at 10°C/min develops high relief and also exhibits large domains of anisotropic material (Plate 51b) which show regular anisotropy and mainly consist of fine to medium-grained mosaic texture; at 60°C/min the carbonised residue consists mainly of coarse-grained and/or flow-type mosaic texture; also large domains of anisotropic material are present (Plates 51a and c): semi-coke shows strong partial anisotropy.

(vi) <u>750°-950°C (Plates 24 to 26):</u> creamy white to creamy; the carbonised residue at 1°C/min develops vesiculation and consists of mainly fine and/or medium granular mosaic showing strong and regular anisotropy with increase of temperature; at 10°C/min the coke is swollen and consists of different types of mosaic texture, but fine and/or medium-grained mosaics are predominant; mosaic structures within different areas develop similar optical extinctions with undulose extinction present; the carbonised residue is cracked, vesiculated and swollen at 60°C/min and different types of mosaic textures are present; the granular mosaics align themselves parallel to each other at the peripheries of vacuoles (Plate 26) indicating extensive ordering of molecular structure.

(d) <u>High-rank coking coal vitrinite (carbon = 90.0% daf)</u>

(i) <u>Fresh (Plate 3d):</u> pale grey, homogeneous, but some particles have sporinite and inertinite contamination; no cellular structure visible under crossed polars; weakly anisotropic.

(ii) 400°C (Plate 5d): greyish-white, angular; no significant morphological differences between the residues produced at the three different rates of heating at this temperature level: development of vesicules of 2.5 to 5 um diameter, indicating beginning of softening; sporinite still present, but in some particles is depolymerised and has lost its original dark brownish-grey colour to light brownish-grey: isotropic.

(iii) 450°C (Plates 27 to 29a): greyish-white to white, vesiculated, disappearance of sporinite; non-coherent residues at 1°C, 10°C and 60°C/min; at 1°C/min the residue develops a granular mosaic and partial anisotropy, but some particles are still isotropic; at 10°C and 60°C/min the carbonised residue develops granular mosaic of fine to medium-grain, but the intensity of anisotropy varies for different particles; carbpmosed resodies at 60°C/min exhibit plant-cell structure (Plate 57a): isotropic.

(iv) 500°-575°C (Plates 27 to 29b): white, non-coherent, non-vesiculated at 1°C/min; coherent, fused, vesiculated residues at 10°C and 60°C/min; residue develops fine-grained mosaic and occasionally medium-grained at 1°C/min, whereas at 10°C/min at 500°C spherical bodies of up to approximately 160 µm across (Plates 48 and 49) develop; small spherical bodies show 'pleochroism extinction', e.g. a dark bar moves across the surface of the body (Plate 48); spherical bodies exhibit the poles and normally the smaller bodies are attached to larger spherical bodies (Plate 49a); mosaic structure of medium-grained, flow-type also form in carbonised residues at 10°C and 60°C/min at about 550-575°C; development of flow-lines in the vicinity of vacuoles at 10°C and 60°C/min; development of nucleated domains in residues carbonised at 60°C/min (Plates 52a and 53a and b); carbonised residues also exhibit plant-cell structures (Plates 55, 56a and 57b and c) which show fine-grained mosaic structure, but the cellular structures have lost their original shape and have flowed in the vicinity of vacuoles at 60°C/min (Plate 57b); granular anisotropy, with the intensity of anisotropy increasing with rise of temperature and rate of heating.

(v) <u>600°-700°C (Plates 30 to 32a and b)</u>: white to creamy white, non-coherent, non-vesiculated at 1°C/min but coherent, cracked, fused and vesiculated at 10°C/min and 60°C/min; the carbonised residue mainly develops granular mosaic at 1°C/min, but at 10°C/min shows medium-grained to flow-type mosaic textures (Plates 31a and b), whereas at 60°C/min, the mosaic structure mainly consists of coarse-grained and/or flow-type textures (Plates 32 a and b); large anisotropic domains also present in residues carbonised at 60°C/min (Plates 52a and b and 53c); it appears that the mosaic units are partially aligned perpendicular to the vacuoles (Plate 52b) showing a common orientation; plant-cell structures are also present (Plates 55, 56b and 57a):

anisotropic, with the anisotropy increasing with rise of temperature and rate of heating.

(vi) <u>750° - 950° (Plates 33 to 35)</u>: creamy white to creamy at 1°C/min; the carbonised residue is non-coherent, vesiculated, whereas coherent vesiculated cracked coke is produced at 10°C/min and 60°C/min; the carbonised residue consists of granular mosaic at 1°C/min (Plate 33), but mainly medium to coarse-grained mosaic and occasionally flow-type mosaic (Plate 34) at 10°C/min and coarse-grained to flow type at 60°C/min (Plate 35); large domains of anisotropic structure present at 10°C/min and 60°C/min, showing high degree of anisotropy (Plate 54); plant structures still present (Plates 55, 56a and 58), with the intensity of granular anisotropy increasing with rising temperature and rate of heating.

(e) <u>Low-rank anthracitic vitrinite (carbon = 93.5% dmmf)</u>

(i) <u>Fresh (Plate 4)</u>: greyish white, uniform, structureless with some angular-shaped and/or streaks of inertinite and occasionally some pyrite inclusions; plant structures visible under crossed polars: anisotropic.

(ii) <u>550° - 600°C (Plate 36)</u>: white-creamy, uniform, structureless and angular with development of vesicles of about 1 to 25um diameter indicating the onset of plastic deformation; size of vesicles increases with rise of temperature and rate of heating (Plate 36c); bandings visible under crossed polars: anisotropic.

(iii) 625° - 700°C (Plate 37): creamy to creamy white, angular; development of extensive cracking and fracturing at periphery of particles at 10°C and 60°C/min (Plates 37 b and c); vesicles of about 2.5 to 25 um diameter, the extent of cracking and fissuring and vesicle development increasing with rate of heating and temperature, banding more easily visible under crossed polars: anisotropic.

(iv) 750° - 950°C (Plates 38 to 41): creamy-yellow, yellow, puffy appearance, cracked, fractured and vesiculated; extent and size of vesicles and fissuring increase with increase in heating rate and rise of temperature (Plate 38) and at 60°C/min particles are riddled with vesicles of 2.5 to 25 um diameter up to about 900°C when the amount of small vesiculation is reduced (Plates 39; 40); under crossed polars some particles exhibit granular structure (Plate 41a); also banding visible with inertinites recognisable by the local high reflectance of surrounding vitrinite, which also exhibits a high degree of anisotropy (Plate 41c); cutinite present showing a higher degree of anisotropy than surrounding vitrinite (Plates 41b and c); anisotropic, the intensity of anisotropy increasing with temperature and rate of heating.

(f) High-rank anthracitic vitrinite (carbon = 94.2%)

(i) Fresh (Plate 4 ): greyish white, uniform, structureless, streaks or angular fragments of inertinite, banding visible under crossed polars: strongly anisotropic.

(ii) <u>$550^{\circ}$ - $600^{\circ}$C (plate 42):</u> white to creamy, development of fractures and limited vesiculation of about 2.5 um diameter; carbonised residues at three rates of heating essentially similar to one another and to the fresh vitrinite; banding visible (Plate 42a) under crossed polars; megaspore structure (Plate 42b) clearing displayed; inertinite also present (Plate 42a): anisotropic.

(iii) <u>$625^{\circ}$ - $700^{\circ}$C (Plate 43):</u> creamy to creamy white, high relief, development of vesicles of about 2.5 to 25 um diameter which is more common at the slowest rate of heating but the number of vesicles is limited; particles at $60^{\circ}$C/min develop a system of fracture under crossed polars; the banding is very clearly visible (Plate 43b and c): anisotropic.

(iv) <u>$750^{\circ}$ - $950^{\circ}$C (Plate 44 to 46):</u> creamy yellow, puffy appearance, angular, vesiculated (2.5 to 25 um diameter); only at $60^{\circ}$C/min do particles develop a system of fractures; kcutinite (Plates 44b and 45b), megaspore (Plate 45c) and inertinites are present; anisotropy is stronger at the periphery of inertinite (Plate 44c); three types of microlithotype can be recognised; vitrinite, clarite and durite (Plate 44); at $10^{\circ}$C/min, some particles exhibit fine granular material (Plate 45d) as well as at the periphery of inertinites; bandings still visible under crossed polars and apparently the anisotropy of fine bands of vitrinites in some particles is increased: anisotropic.

Plate 3 Fresh vitrinite, plane-polarised light, x 190

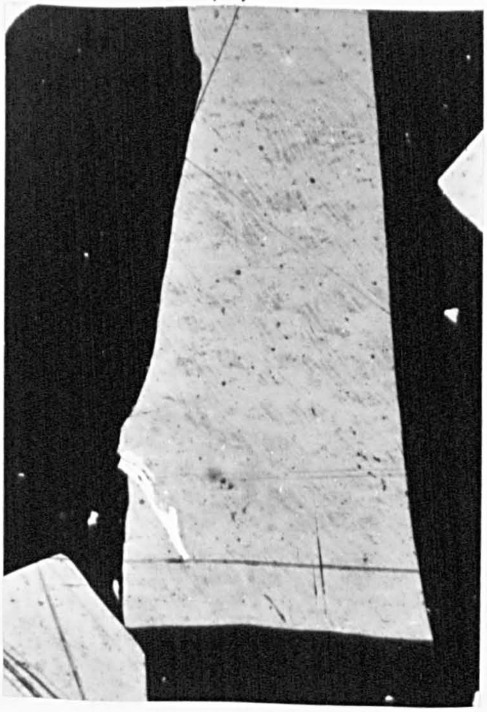
(a) low-rank bituminous (carbon = 80.0% daf)

(b) caking-coal (carbon = 85.4% daf)

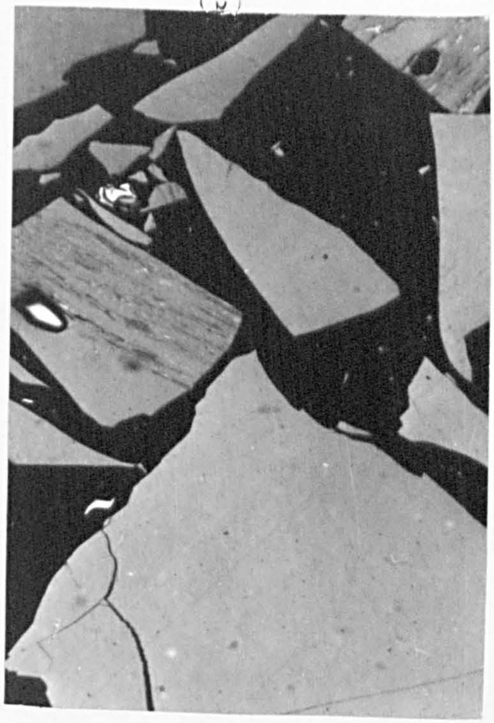
(c) low-rank coking-coal (carbon = 87.9% daf)

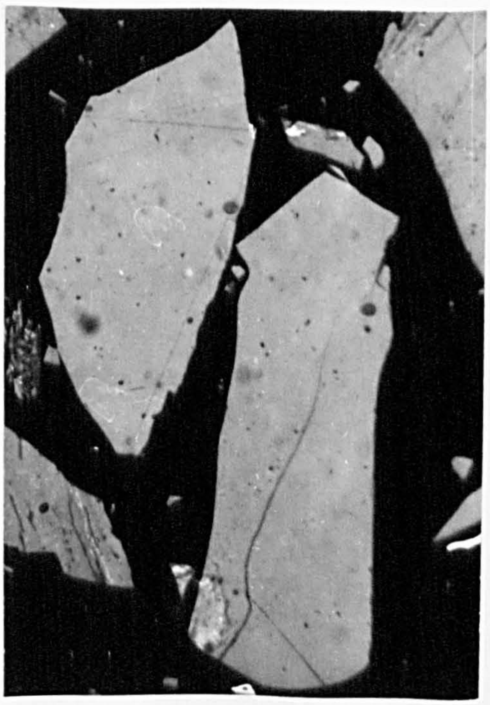
(d) high-rank coking-coal (carbon = 90.0% daf)

(a)

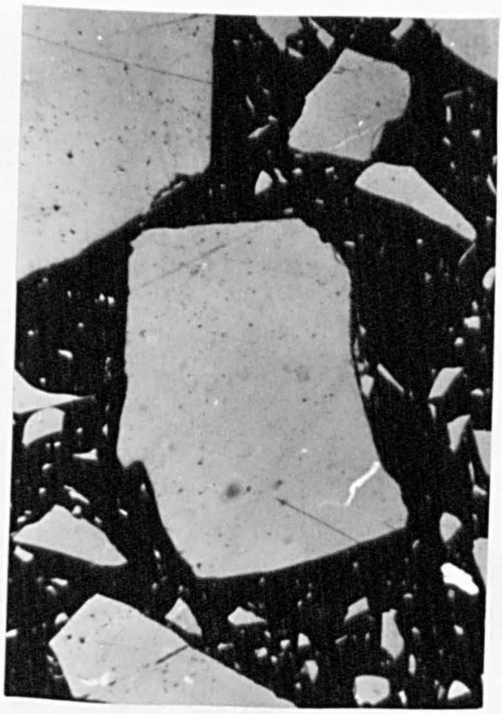


(b)





(c)



(d)

Plate 4 Fresh vitrinite, x 190

(a) low-rank anthracitic (carbon = 93.5% dmmf)

(i) plane-polarised

(ii) crossed polars

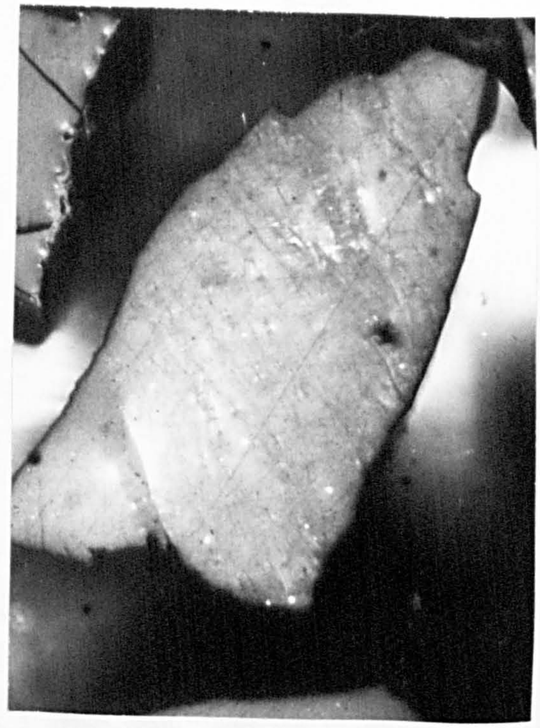
(b) high-rank anthracitic (carbon = 94.2% dmmf)

(i) plane-polarised

(ii) crossed polars

(a) (i)

(a) (ii)



(b) (i)

(b) (ii)

Fig 5 Vitrinites of bituminous-rank carbonised at 400°C plane-polarised light, x 180

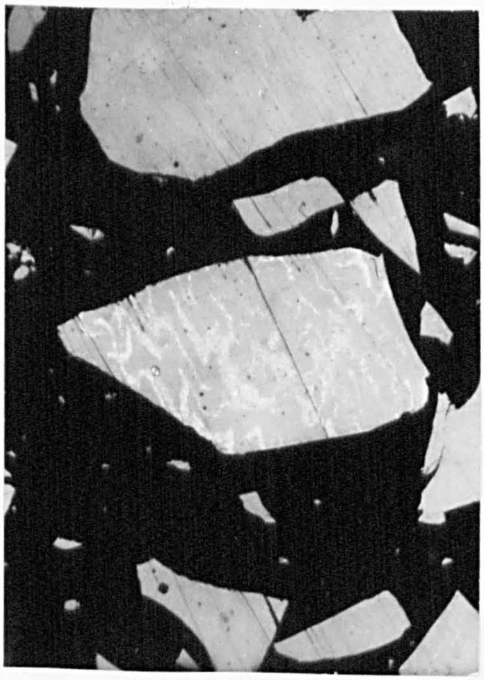
(a) low-rank (carbon = 80.0% daf)

(b) caking (carbon = 85.4% daf)

(c) low-rank coking (carbon = 87.9% daf)

(d) high-rank coking (carbon = 90.0% daf)

(a)



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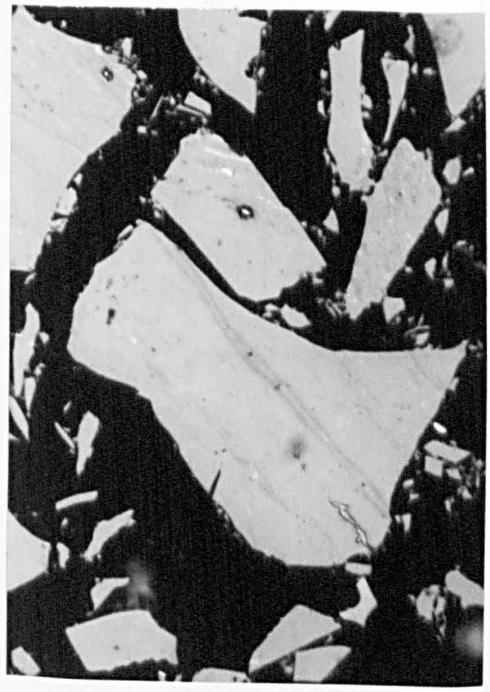
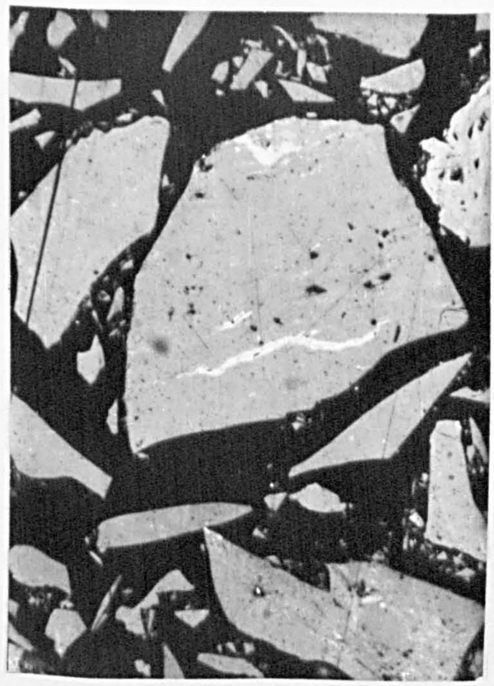


(c)

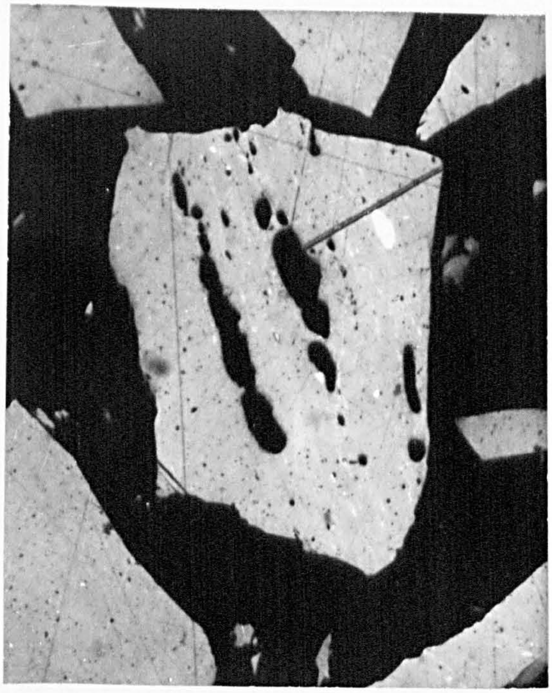


(d)

Plate 6 Low-rank bituminous vitrinite (carbon = 80.0% daf) carbonised at a heating rate of 1°C/min, plane-polarised light, x 190

(a) 500°C
(b) 600°C
(c) 700°C
(d) 800°C

(a)



(b)

(c)

(d)

Plate 7 Low-rank bituminous vitrinite (carbon = 80.0% daf) carbonised at a heating rate of 10°C/min, plane-polarised light, x 190

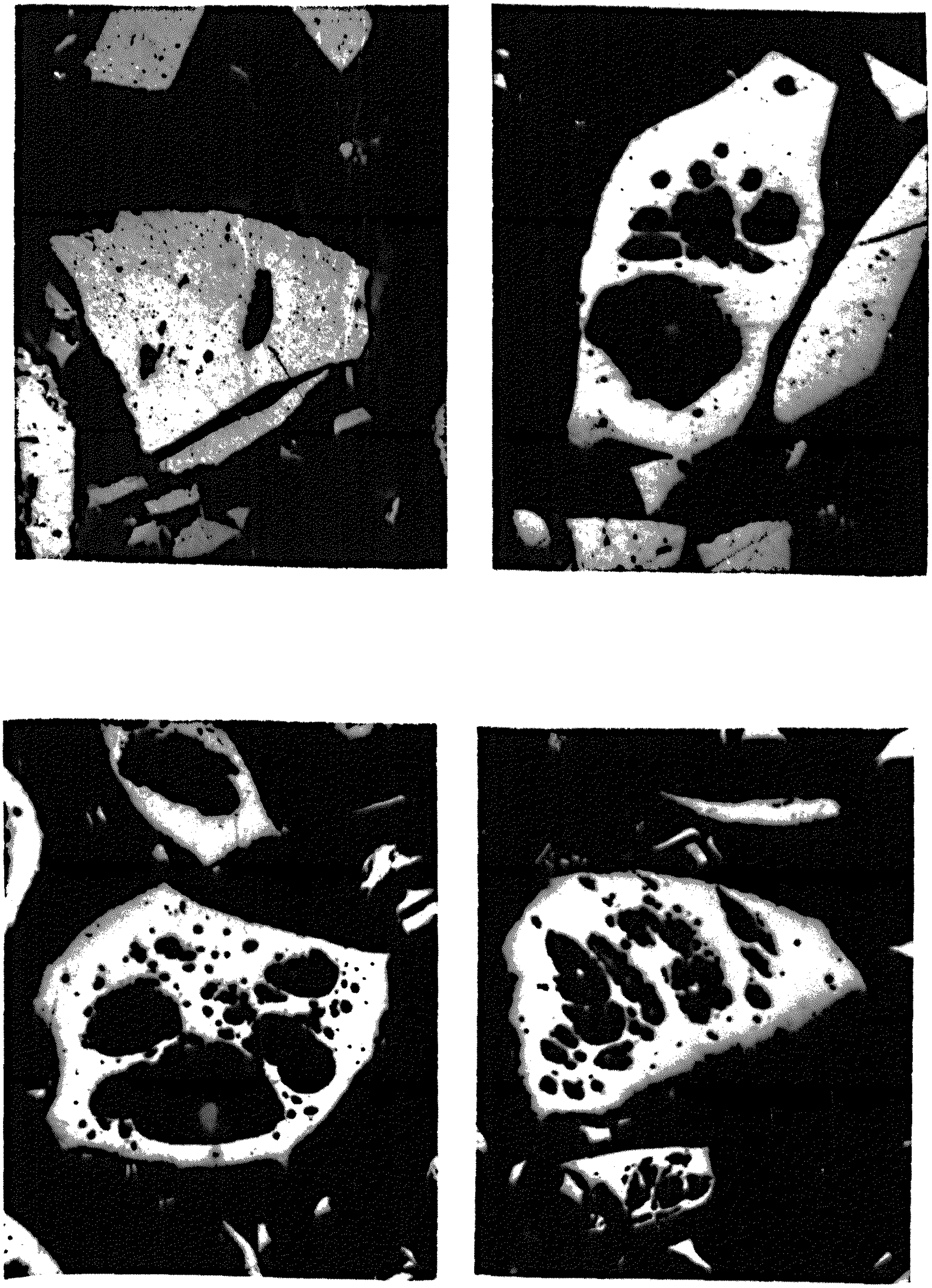
(a) 500°C

(b) 600°C

(c) 700°C

(d) 800°C

(a) (b)

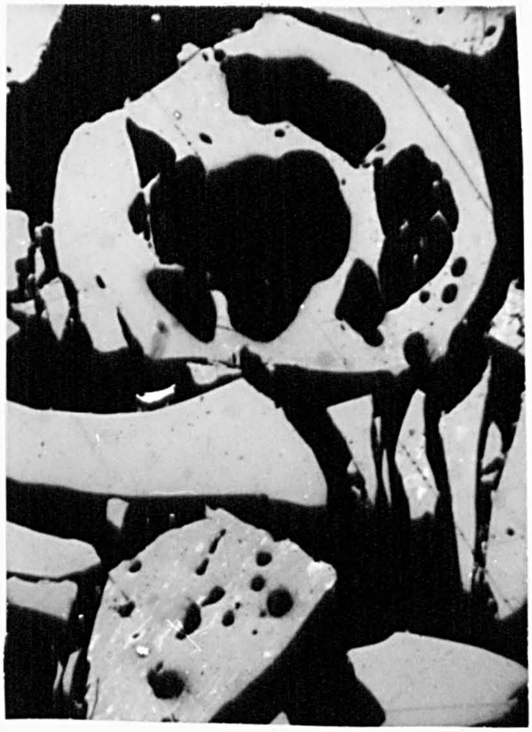


(c) (d)

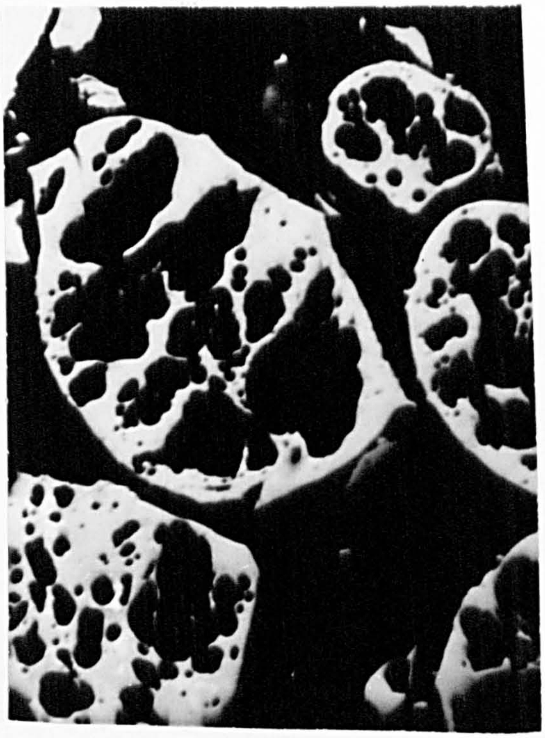
Plate 8 Low-rank bituminous vitrinite (carbon = 80.0% daf) carbonised at a heating rate of 60°C/min, plane-polarised light, x 190

(a) 500°C
(b) 600°C
(c) 700°C
(d) 800°C

(a)



(b)



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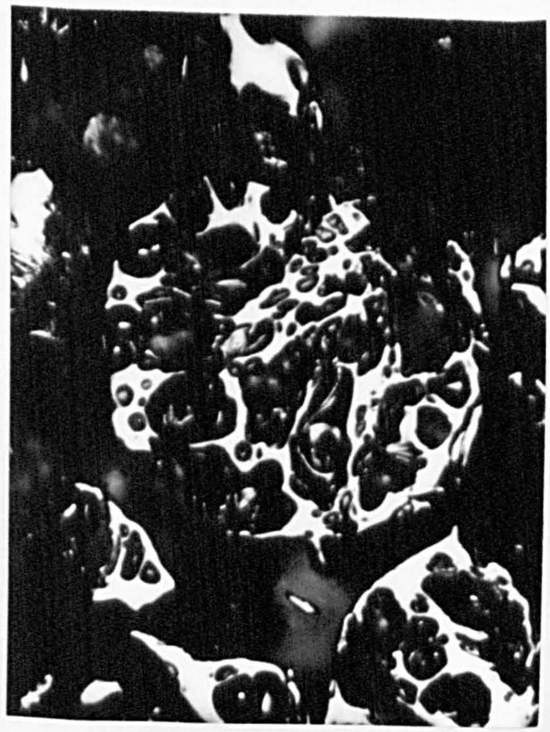
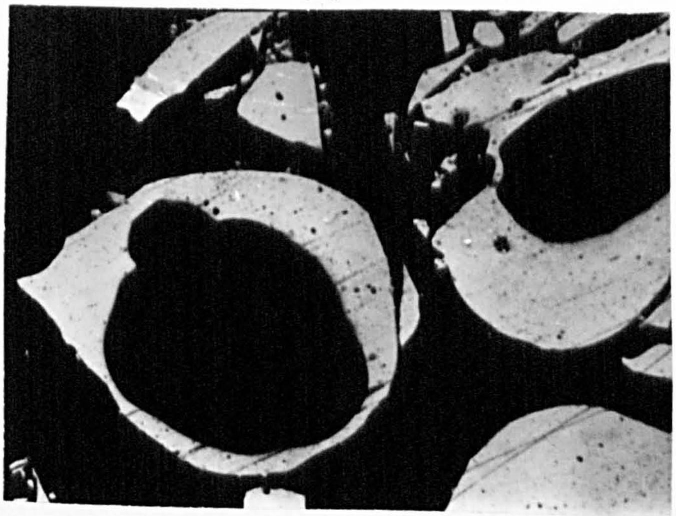


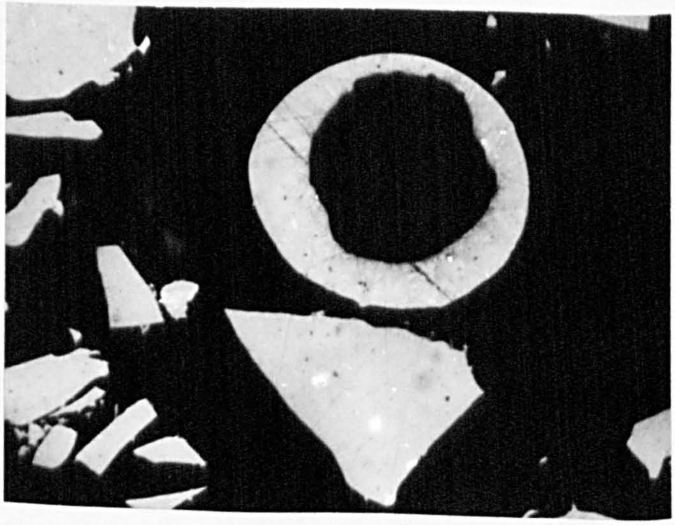
(d)

Plate 9 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of $1^{\circ}C/min.$, x 180

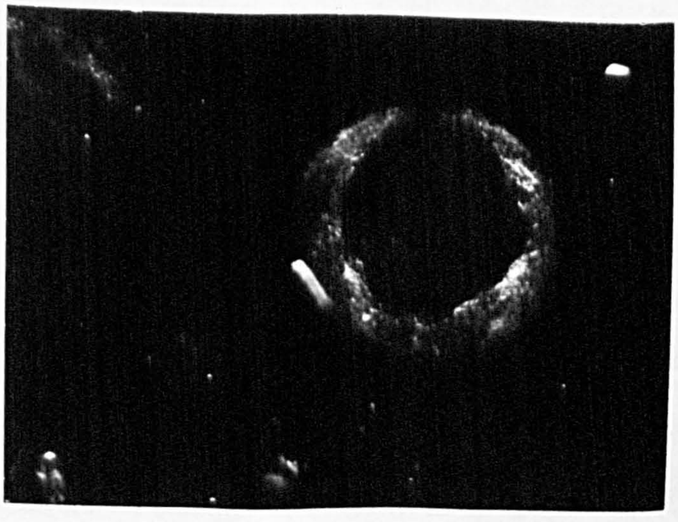
| | | | |
|---|---|---|---|
| (a) | $450^{\circ}C$ | | plane-polarised light |
| (b) | $500^{\circ}C$ | (i) | plane-polarised light |
| | | (ii) | crossed polars |

(a)





(b) (i)



(b) (ii)

Plate 10 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of $10^{\circ}C$/min., x 185

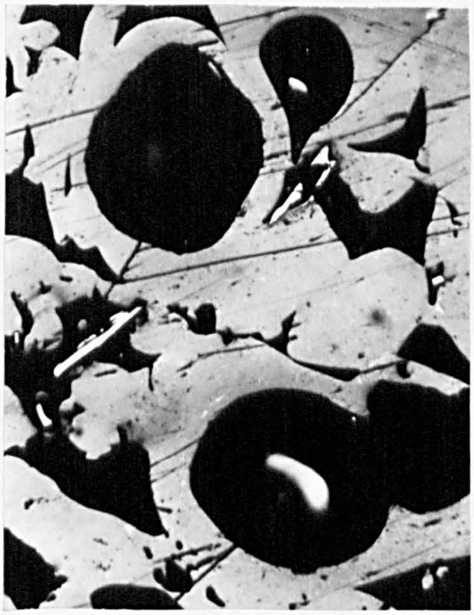
(a) $450^{\circ}C$ (i) plane-polarised

(ii) crossed polars

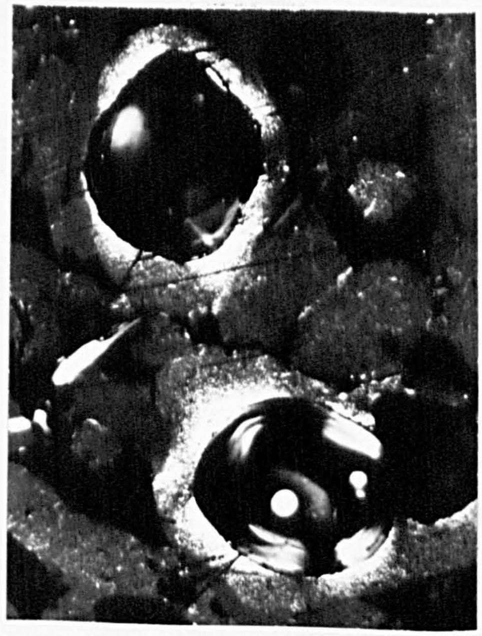
(b) $500^{\circ}C$ (i) plane-polarised

(ii) crossed polars

(a) (i)



(a) (ii)



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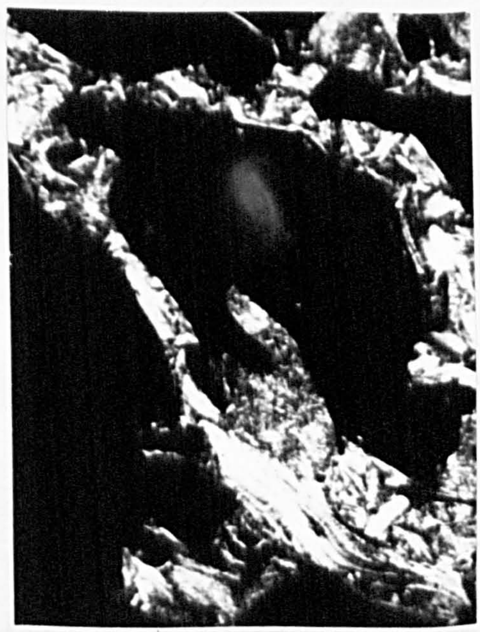


(b) (ii)

Plate 11 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of 60°C/min., x 180

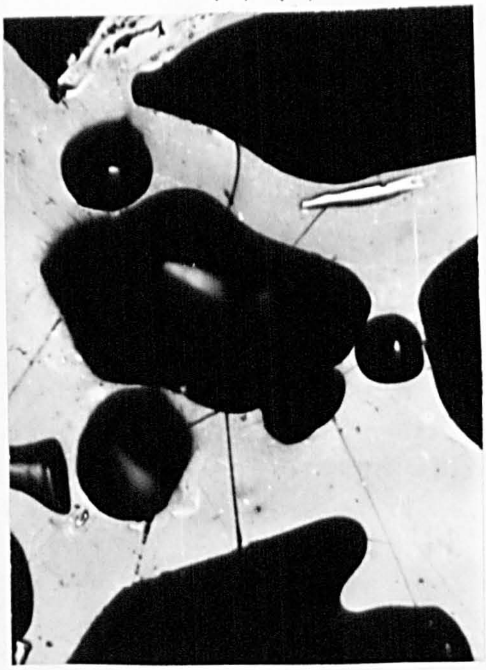
(a) 450°C (i) plane-polarised light

(ii) crossed polars

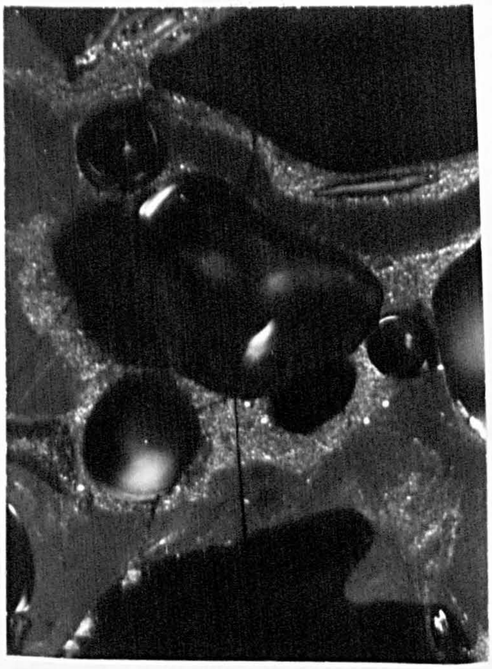
(b) 500°C (i) plane-polarised light

(ii) crossed polars

(a) (i)



(a) (ii)



(b) (i)

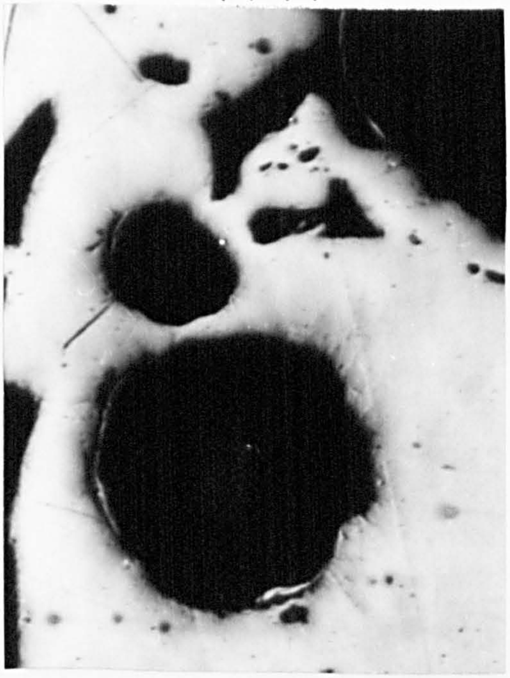
(b) (ii)

Plate 12 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of 1°C/min., x 190

(a) 600°C (i) plane-polarised light
(ii) crossed polars

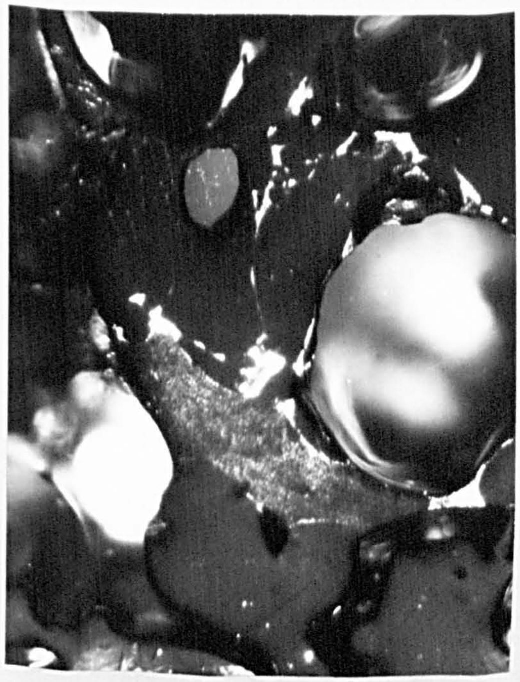
(b) 700°C (i) plane-polarised light
(ii) crossed polars

(a) (i)



(a) (ii)

(b) (i)



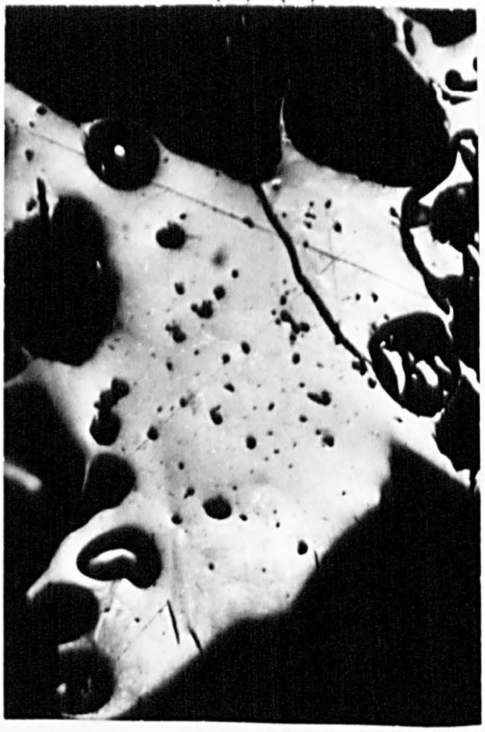
(b) (ii)

Plate 13 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of 10°C/min., x 190

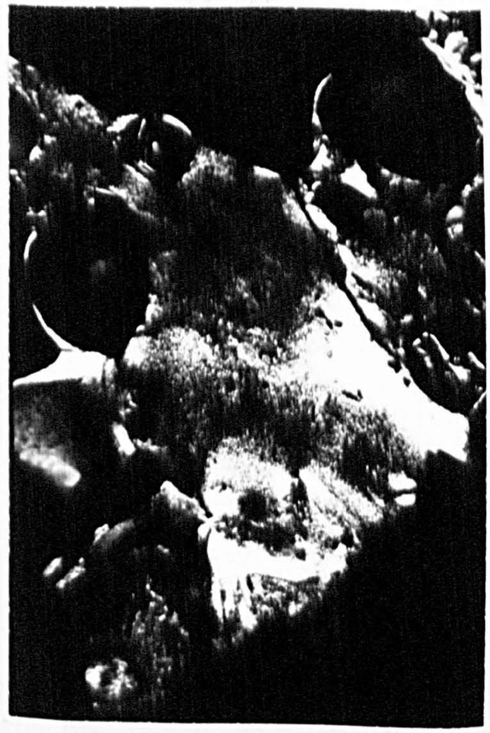
(a) 600°C (i) plane-polarised light
(ii) crossed polars

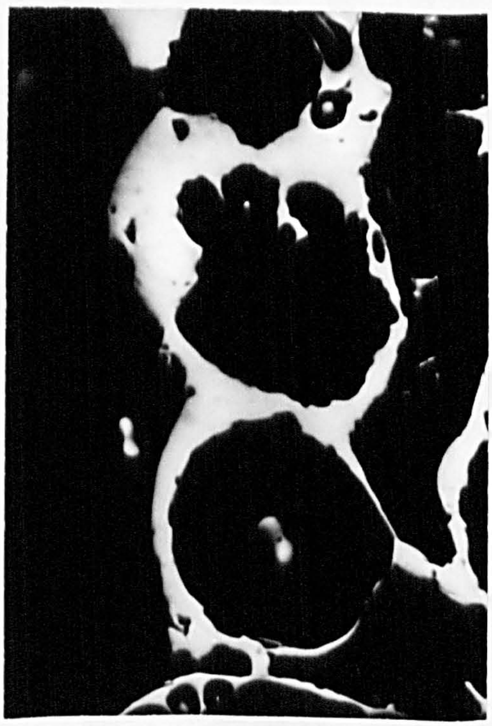
(b) 700°C (i) plane-polarised light
(ii) crossed polars

(a) (i)

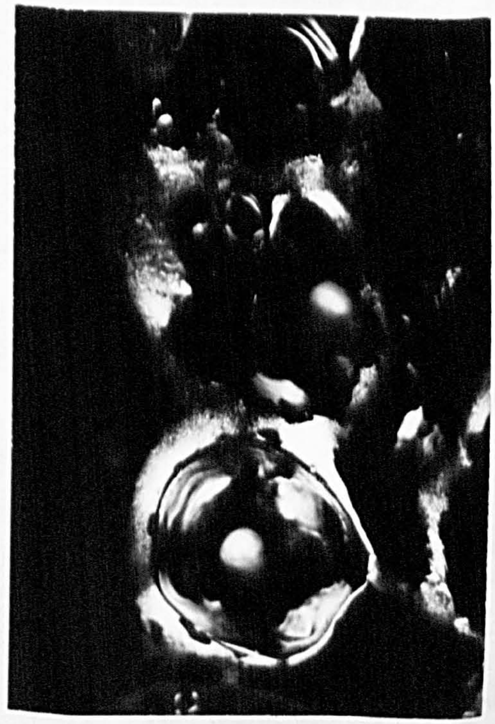


(a) (ii)





(b) (i)



(b) (ii)

Plate 14 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of $60^{o}C$/min., x 190

(a) $600^{o}C$ (i) plane-polarised light

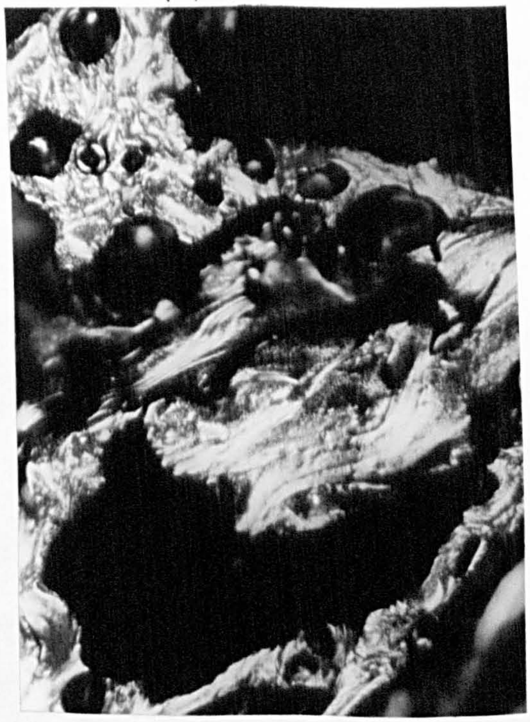
(ii) crossed polars

(b) $700^{o}C$ (i) plane-polarised light

(ii) crossed polars

(a) (i)

(a) (ii)



(b) (i)

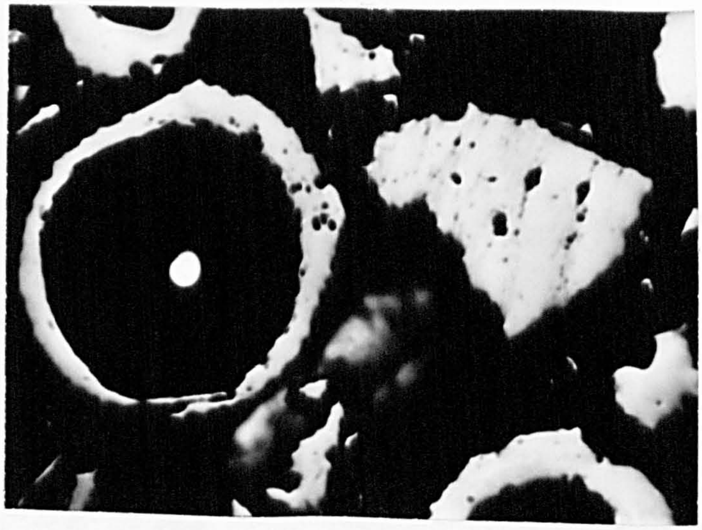
(b) (ii)

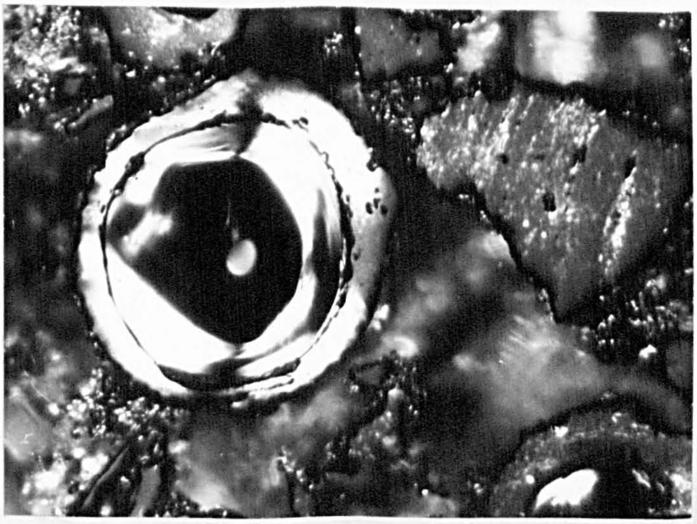
Plate 15 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at 800°C at a heating rate of 1°C/min., x 185

(i) plane-polarised light

(ii) crossed polars

(i)





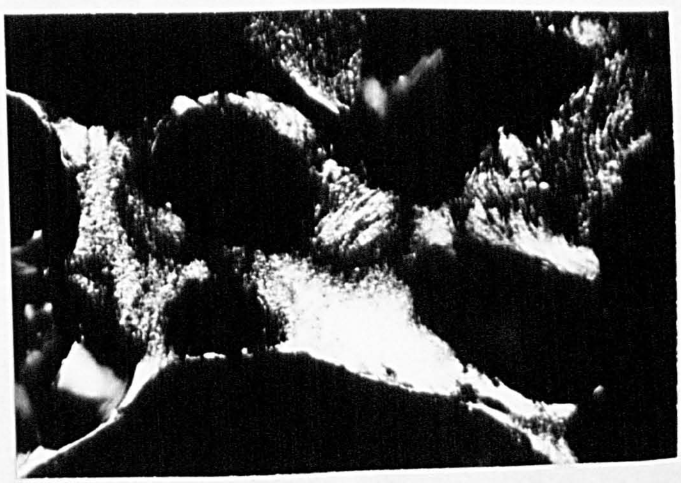
(ii)

Plate 16 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at 800°C at a heating rate of 10°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)



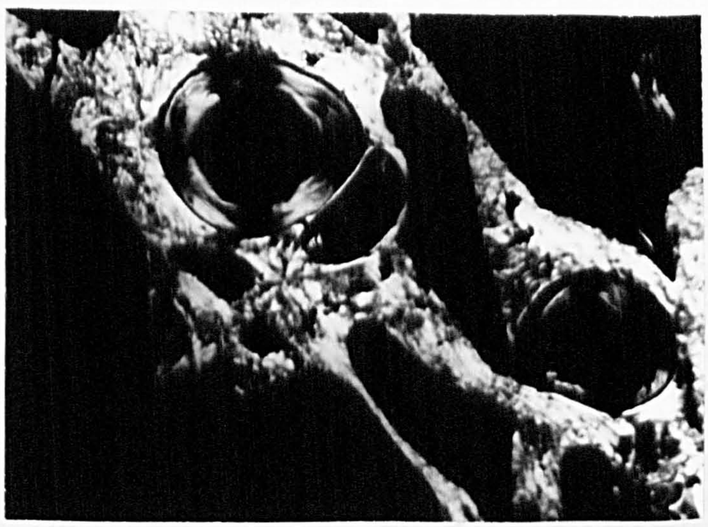
(ii)

Plate 17 Caking-coal vitrinite (carbon = 85.4% daf) carbonised at $800^{\circ}C$ at a heating rate of $60^{\circ}C$/min., x 195

(i) plane-plarised light

(ii) crossed polars

(i)



(ii)

Plate 18 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of $1^{\circ}C/min.$, x 190

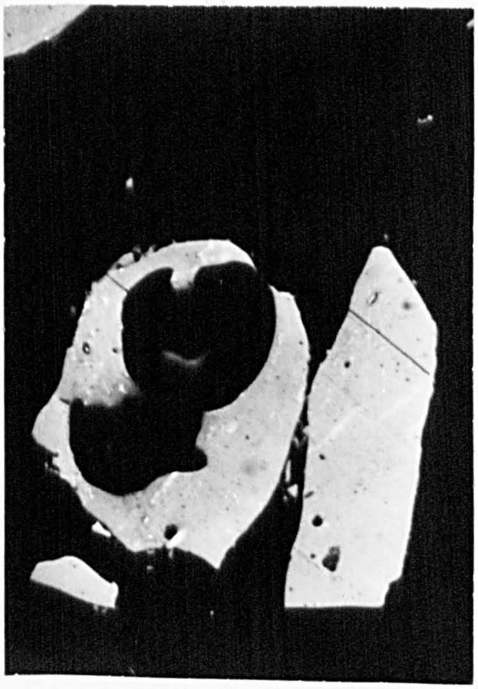
(a) $450^{\circ}C$ (i) plane-polarised light

(ii) crossed polars

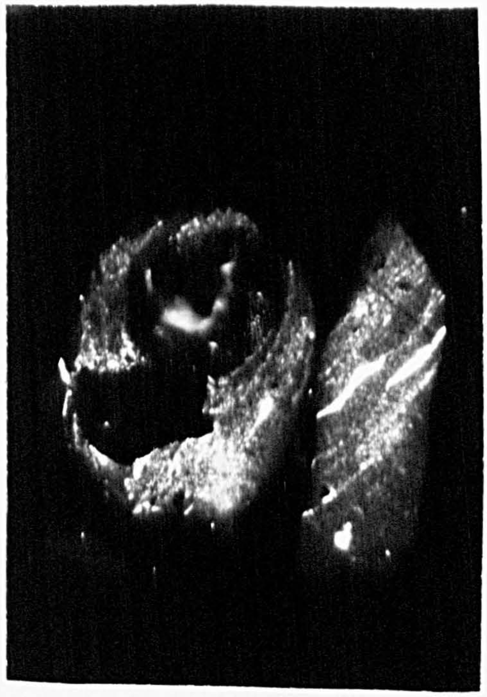
(b) $500^{\circ}C$ (i) plane-polarised light

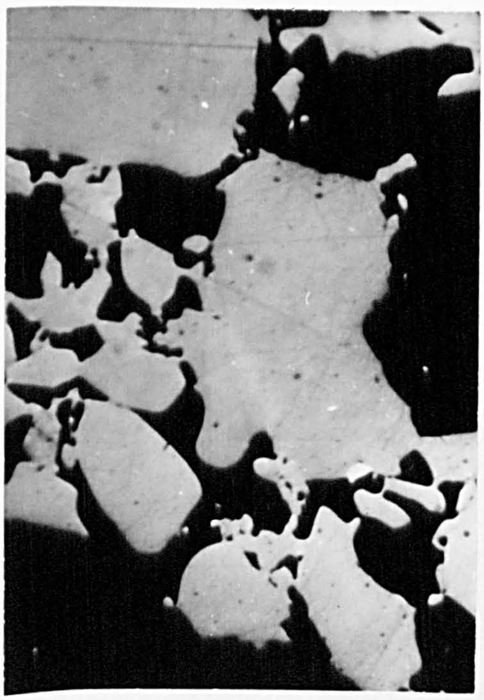
(ii) crossed polars

(a) (i)

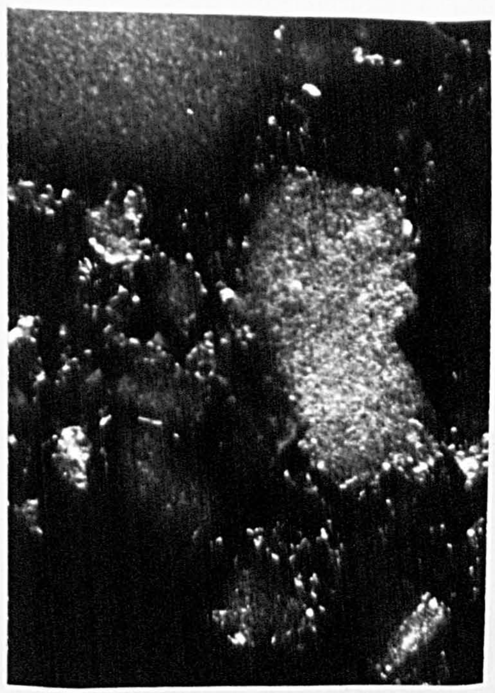


(a) (ii)





(b) (i)



(b) (ii)

Plate 19 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of 10°C/min., x 190

(a) 450°C (i) plane-polarised light

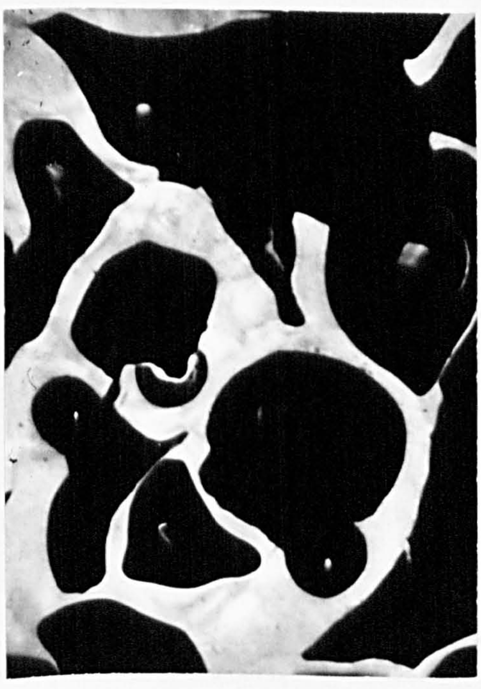
(ii) crossed polars

(b) 500°C (i) plane-polarised light

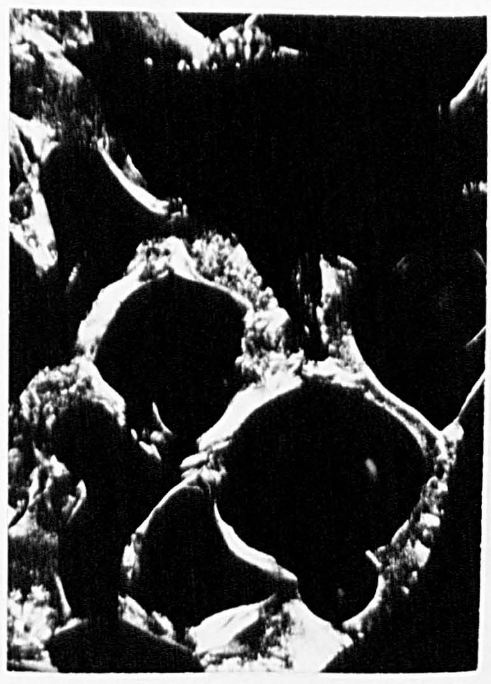
(ii) crossed polars

(a) (i)

(a) (ii)



(b) (i)



(b) (ii)

Plate 20 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of 60°C/min., x 190

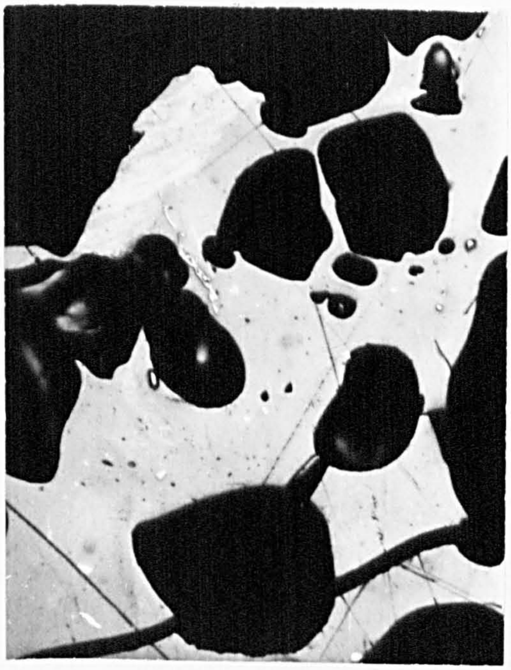
(a) 450°C (i) plane-polarised light

(ii) crossed polars

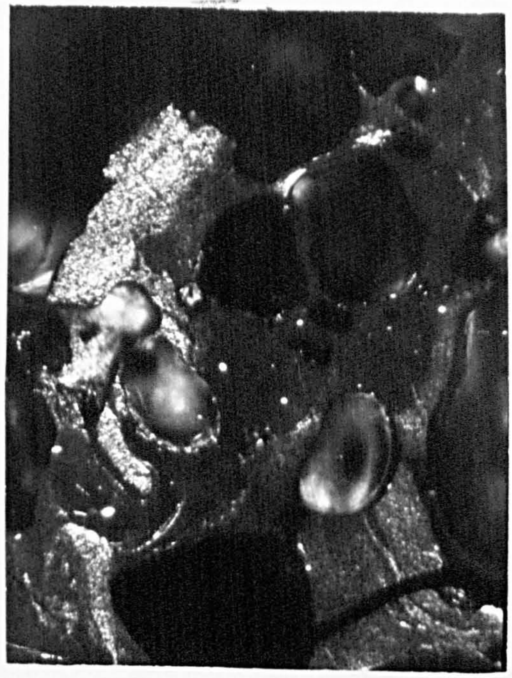
(b) 500°C (i) plane-polarised light

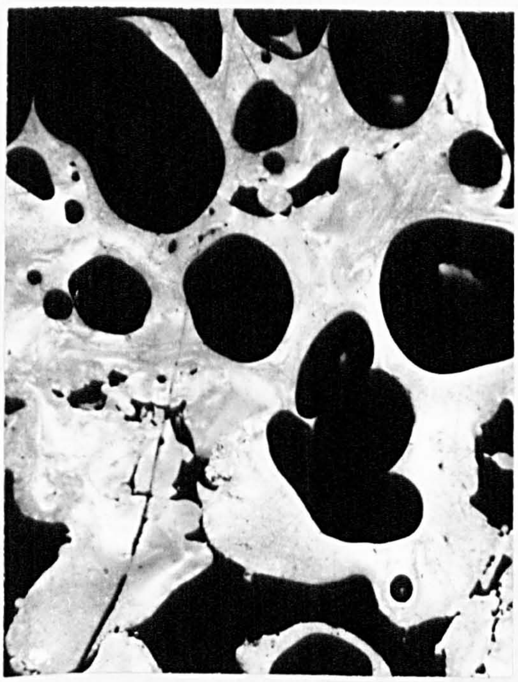
(ii) crossed polars

(a) (i)

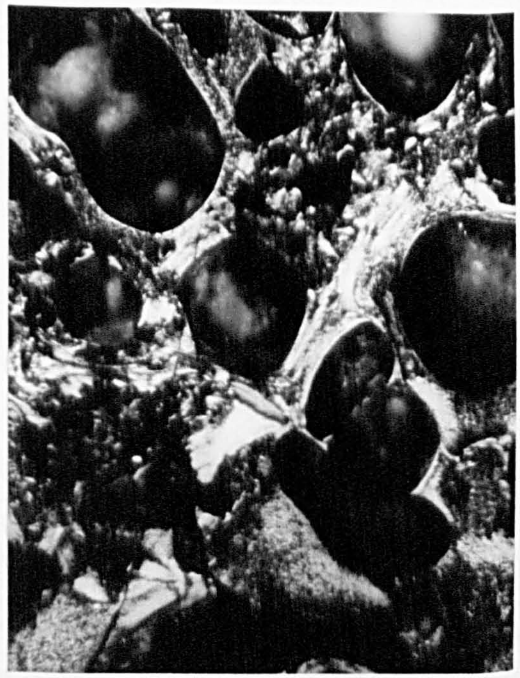


(a) (ii)





(b) (i)



(b) (ii)

Plate 21 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of 1°C/min., x 180

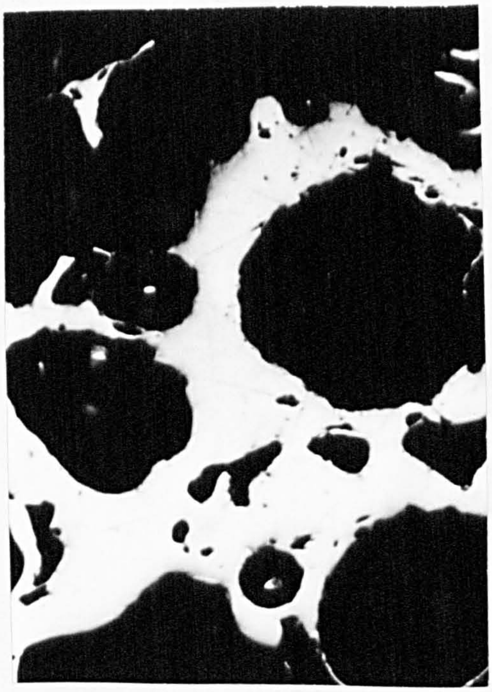
(a) 600°C (i) plane-polarised light

(ii) crossed polars

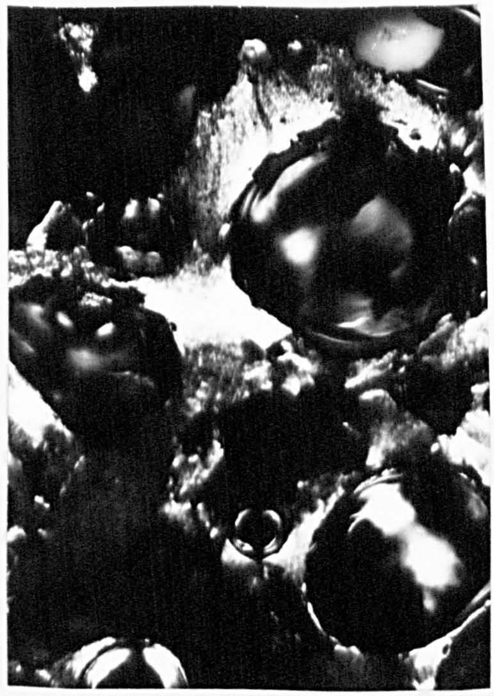
(b) 700°C (i) plane-polarised light

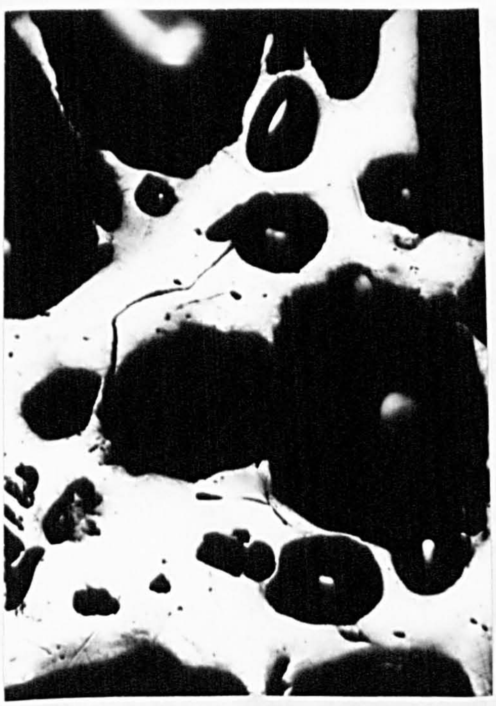
(ii) crossed polars

(a) (i)



(a) (ii)





(b) (i)

(b) (ii)

Plate 22 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of 10°C/min., x 190

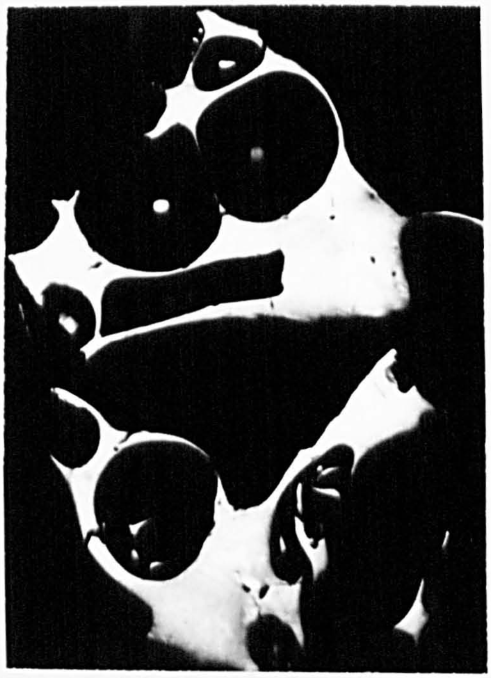
(a) 600°C (i) plane-polarised light

(ii) crossed polars

(b) 700°C (i) plane-polarised light

(ii) crossed polars

(a) (i)



(a) (ii)

(b) (i)

(b) (ii)

Plate 23 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at a heating rate of $60^{\circ}C$/min., x 200

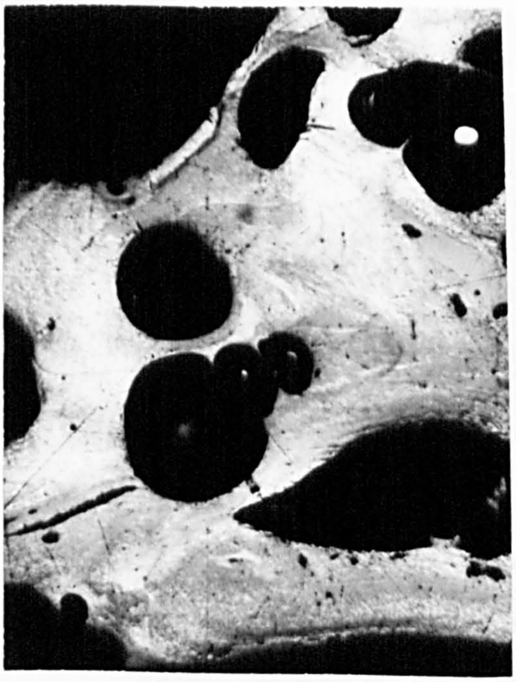
(a) $600^{\circ}C$ (i) plane-polarised light

(ii) crossed polars

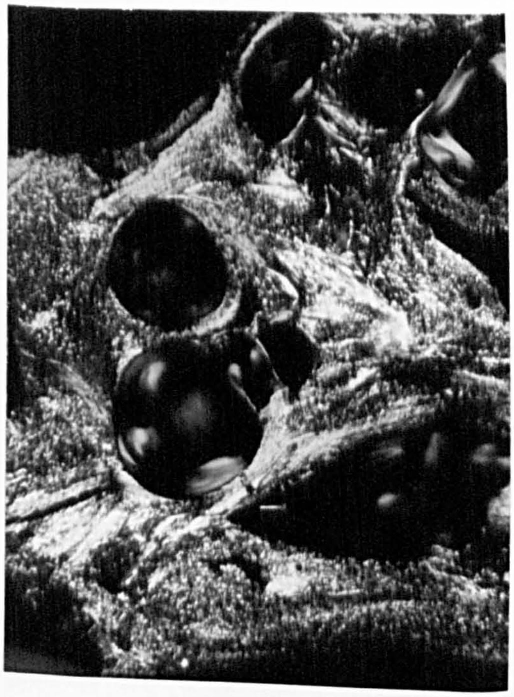
(b) $700^{\circ}C$ (i) plane-polarised light

(ii) crossed polars

(a) (i)



(a) (ii)



(b) (i)

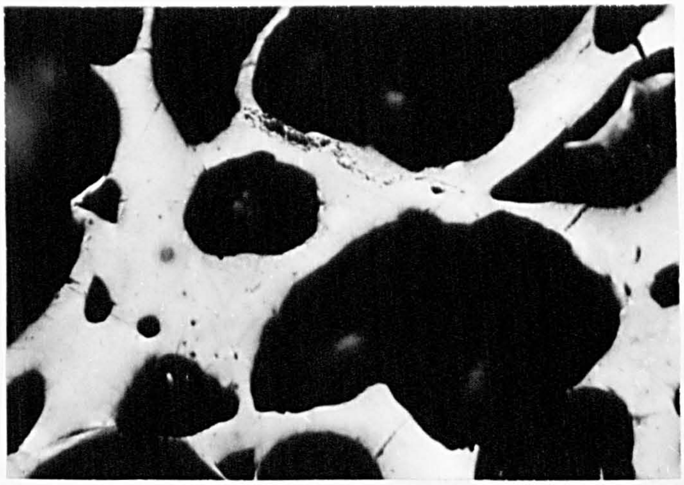
(b) (ii)

Plate 24 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at 800°C at a heating rate of 1°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)



(ii)

Plate 25 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at 800°C at a heating rate of 10°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)

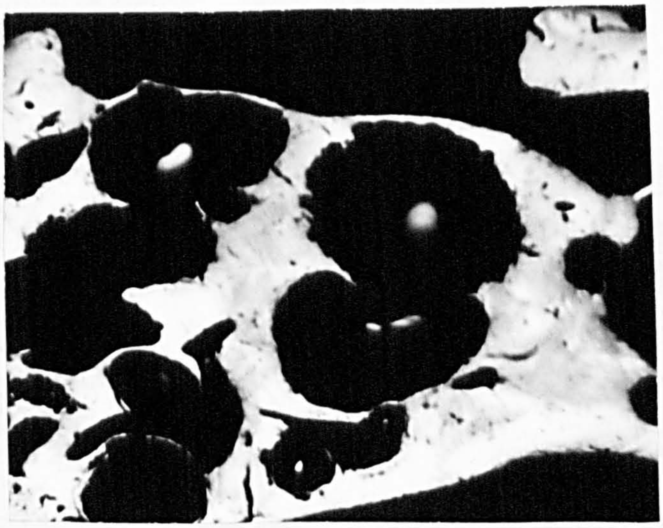
(ii)

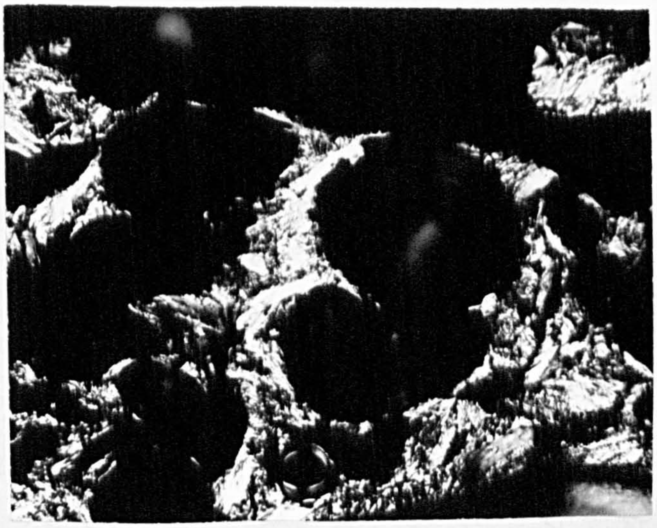
Plate 26 Low-rank coking-coal vitrinite (carbon = 87.9% daf) carbonised at 800°C at a heating rate of 60°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)





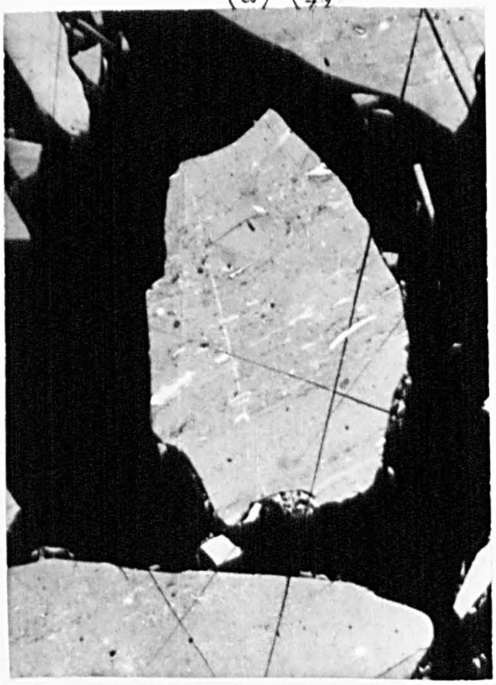
(ii)

Plate 27 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 1°C/min., x 190

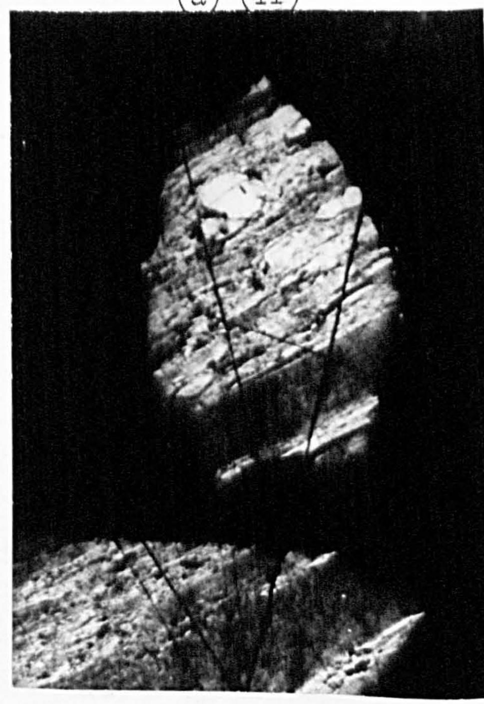
(a) 450°C (i) plane-polarised light
(ii) crossed polars

(b) 500°C (i) plane-polarised light
(ii) crossed polars

(a) (i)



(a) (ii)



(b) (i)

(b) (ii)

Plate 28 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 10°C/min., x 190

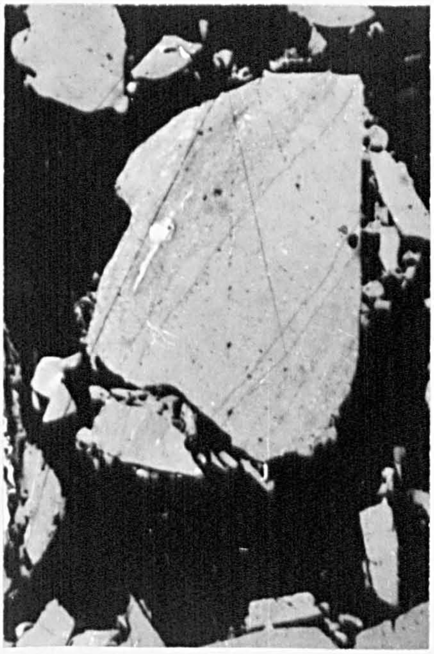
(a) 450°C (i) plane-polarised light

(ii) crossed polars

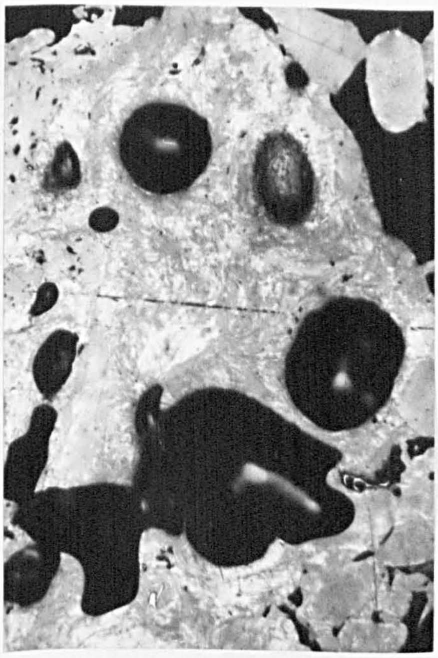
(b) 500°C (i) plane-polarised light

(ii) crossed polars

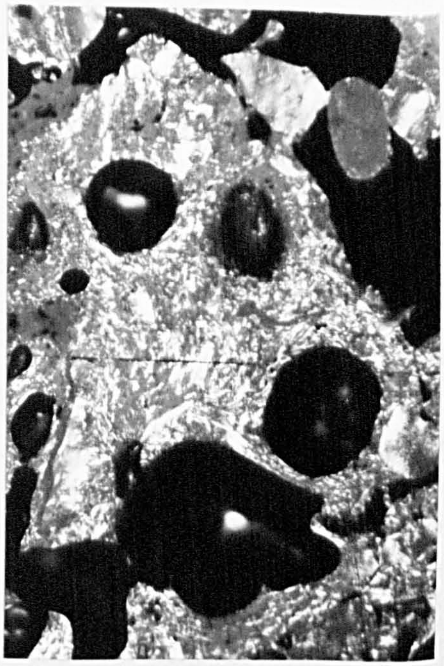
(a) (i)



(a) (ii)



(b) (i)



(b) (ii)

Plate 29 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 60°C/min., x 180

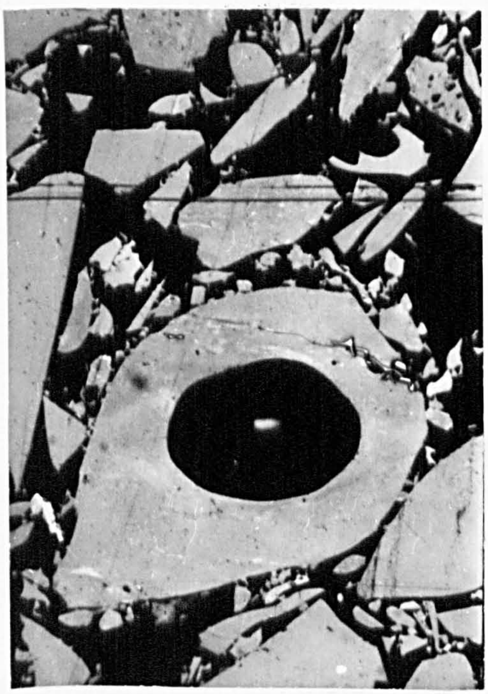
(a) 450°C (i) plane-polarised light

(ii) crossed polars

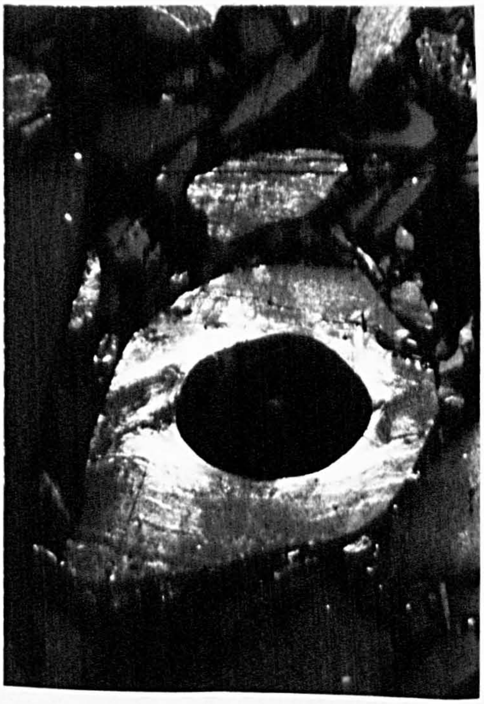
(b) 500°C (i) plane-polarised light

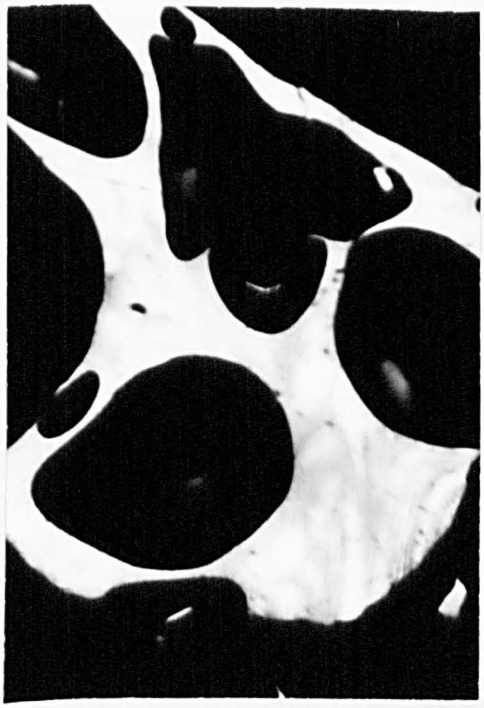
(ii) crossed polars

(a) (i)

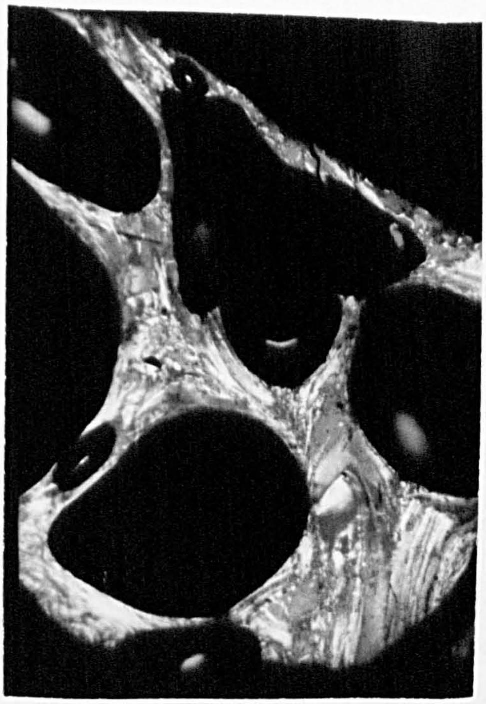


(a) (ii)





(b) (i)



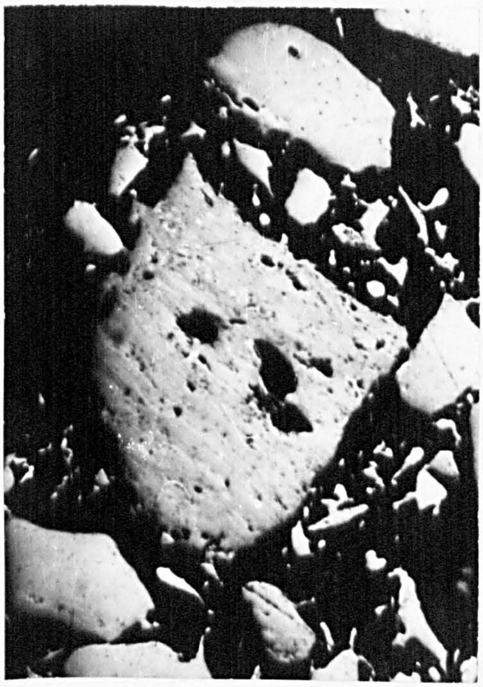
(b) (ii)

Plate 30 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 1°C/min., x 190

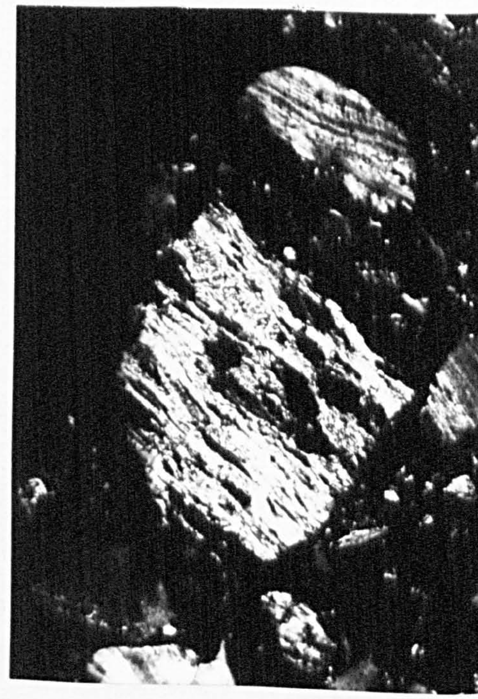
(a) 600°C (i) plane-polarised light
(ii) crossed polars

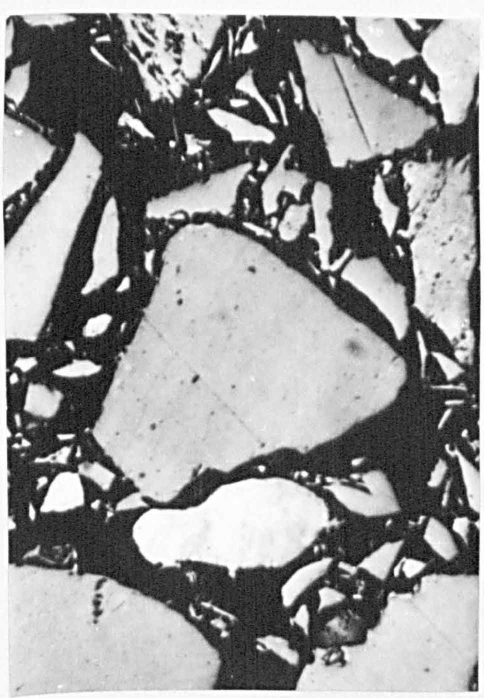
(b) 700°C (i) plane-polarised light
(ii) crossed polars

(a) (i)



(a) (ii)





(b) (i)

(b) (ii)

Plate 31 High-rank coking coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 10°C/min., x 190

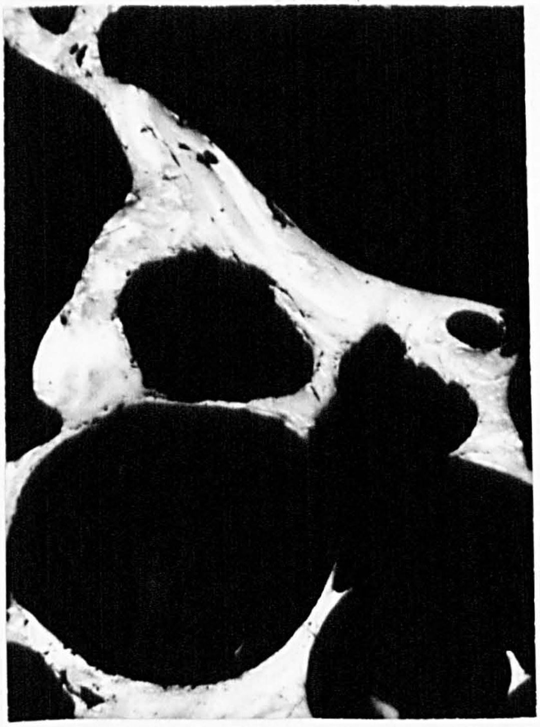
(a) 600°C (i) plane-polarised light

(ii) crossed polars

(b) 700°C (i) plane-polarised light

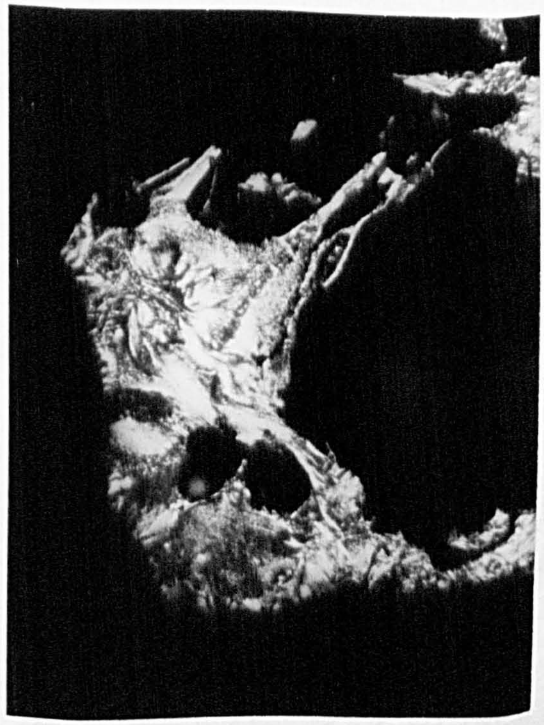
(ii) crossed polars

(a) (i)



(a) (ii)

(b) (i)



(b) (ii)

Plate 32 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 60°C/min., x 200

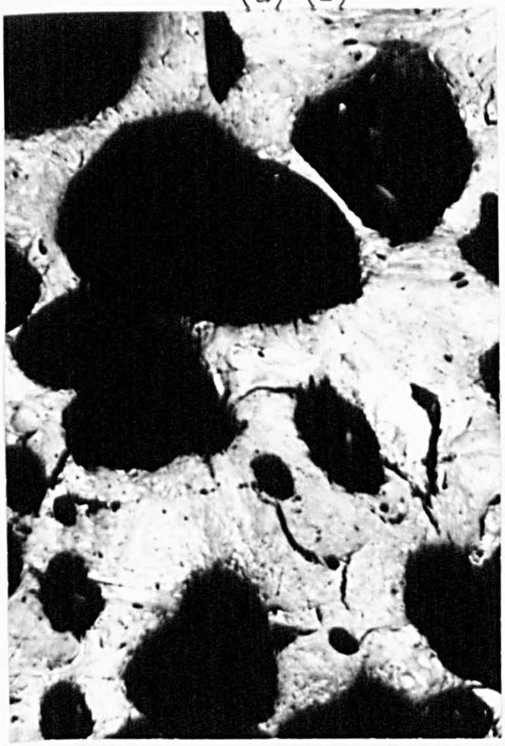
(a) 600°C (i) plane-polarised light

(ii) crossed polars

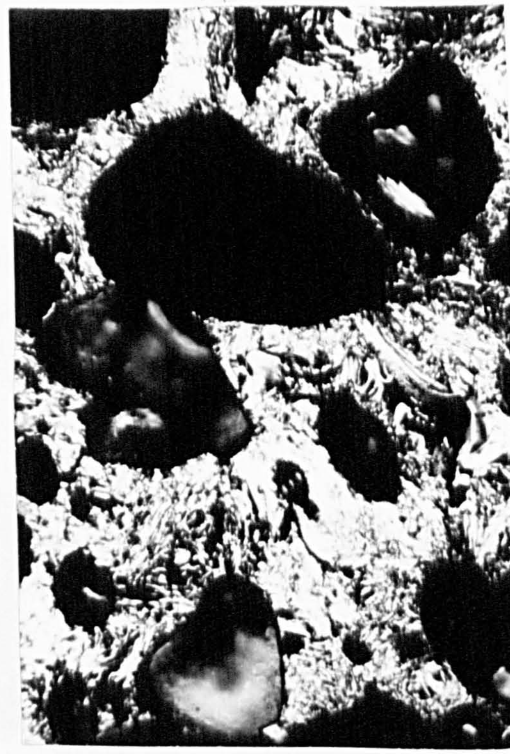
(b) 700°C (i) plane-polarised light

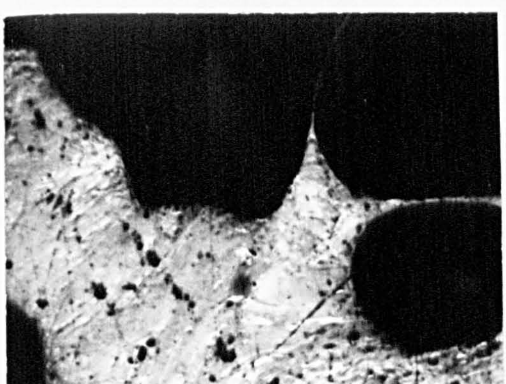
(ii) crossed polars

(a) (i)

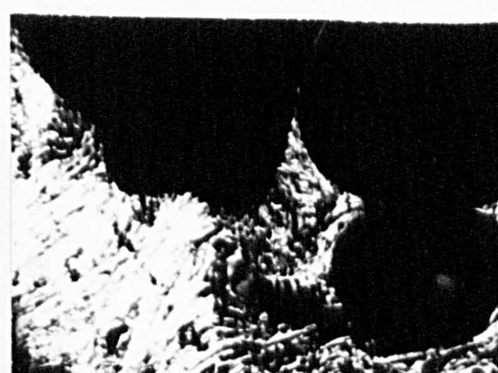


(a) (ii)





(b) (i)



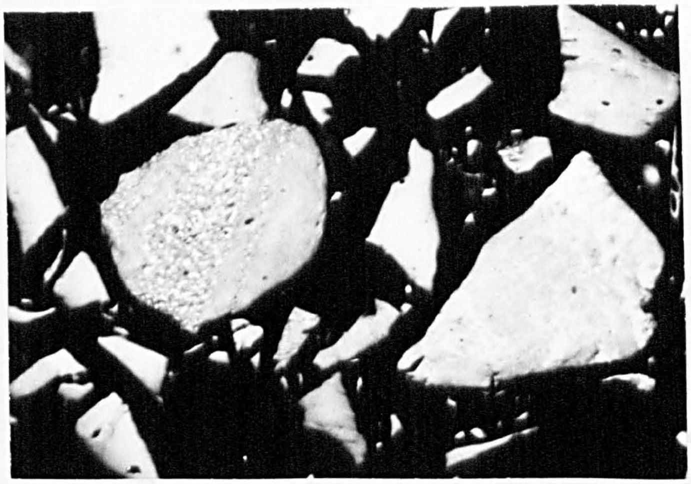
(b) (ii)

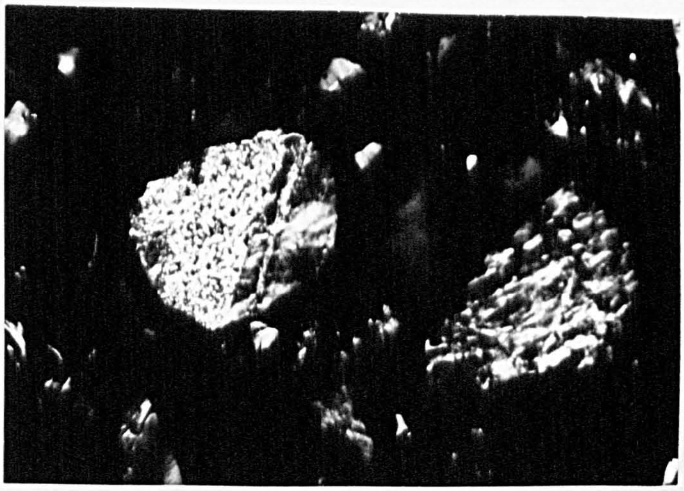
Plate 33 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at 800°C at a heating rate of 1°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)





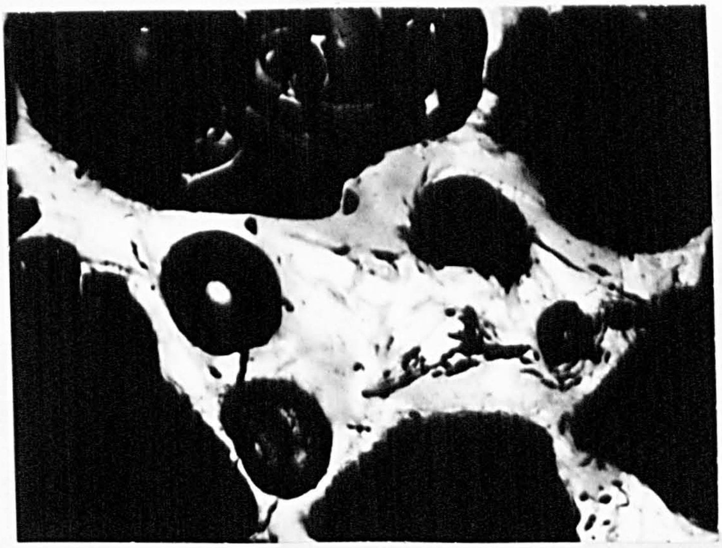
(ii)

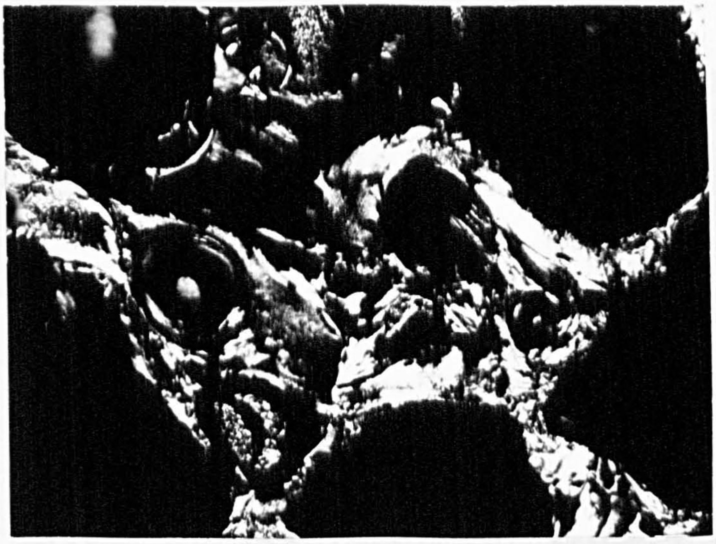
Plate 34 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at 800°C at a heating rate of 10°C/min., x 190

(i) plane-polarised light

(ii) crossed polars

(i)





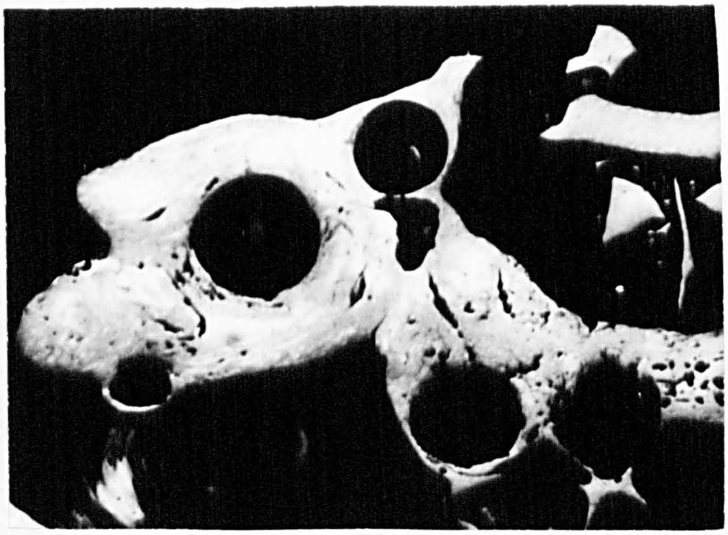
(ii)

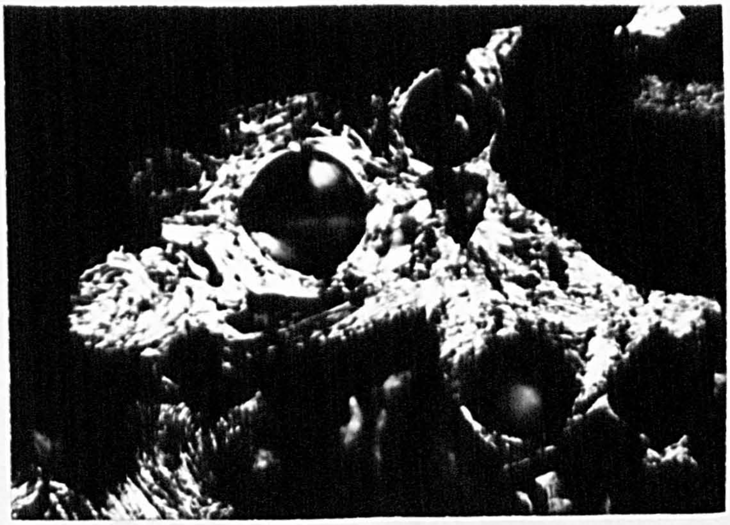
Plate 35 High-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at 800°C at a heating rate of 60°C/min., x 195

(i) plane-polarised light

(ii) crossed polars

(i)





(ii)

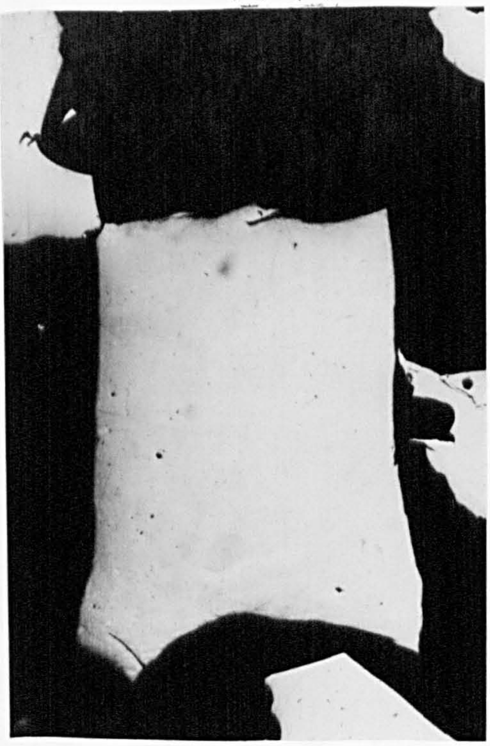
Plate 36 Low-rank, anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at 600°C at different heating rates, x 200

(a) 1°C/min (i) plane-polarised light
(ii) crossed polars

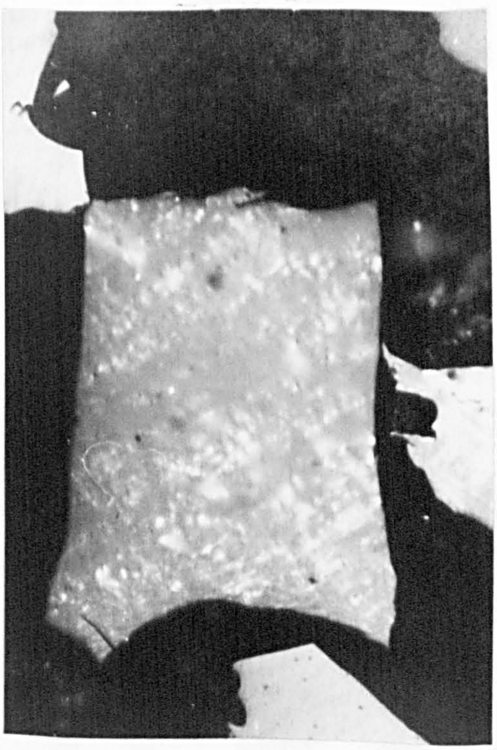
(b) 10°C/min crossed polars

(c) 60°C/min crossed polars

(a) (i)



(a) (ii)



(b)

(c)

Plate 37 Low-rank anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at 700°C at different heating rates, x 200

(a) 1°C/min plane-polarised light

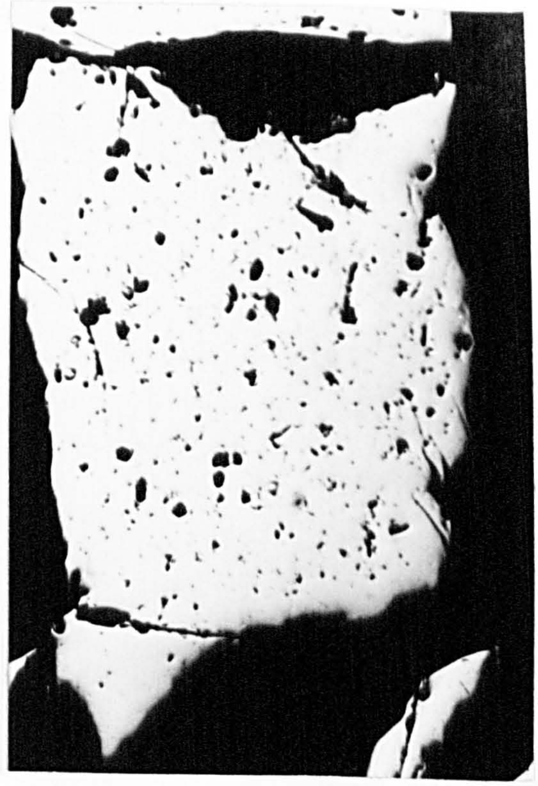
(b) 10°C/min plane-polarised light

(c) (i) 60°C/min plane-polarised light

(ii) 60°C/min crossed polars

(a)

(b)



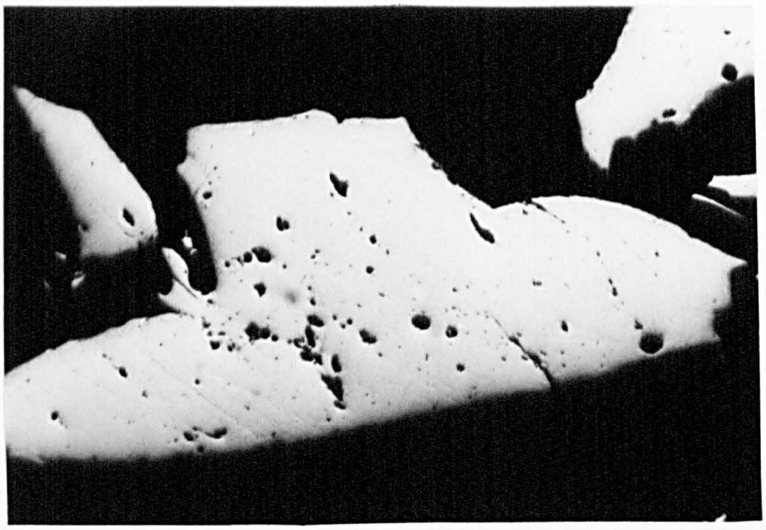
(c)

(d)

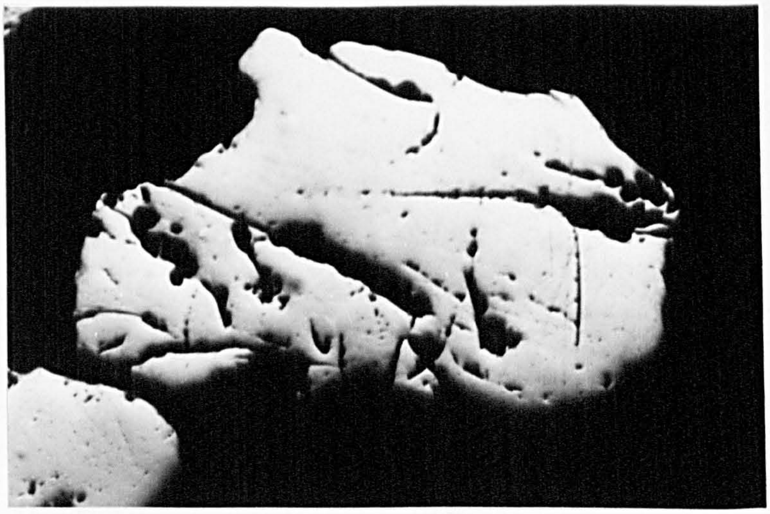
Plate 38 Low-rank anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at 800°C at different heating rates, plane-polarised light x 200

(a) at 1°C/min
(b) at 10°C/min
(c) at 60°C/min

(a)



(b)



(c)

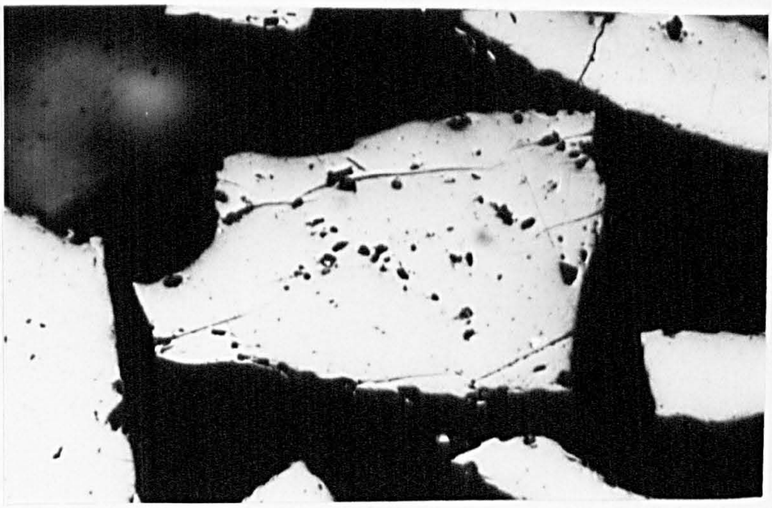


Plate 39 Low-rank, anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at 900°C at different heating rates, x 200

(a) at 1°C/min

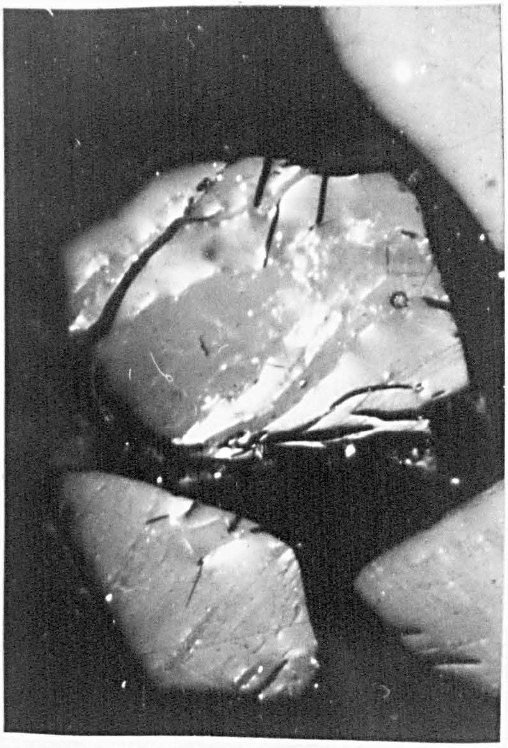
(i) plane-polarised light (ii) crossed polars

(b) at 10°C/min

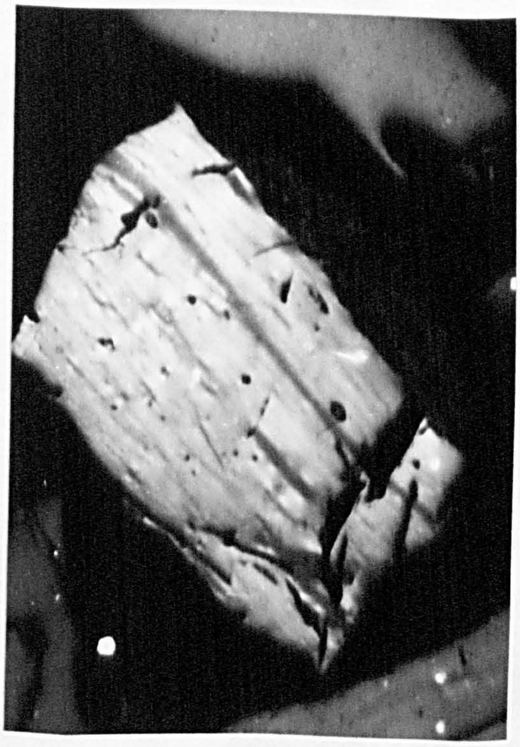
(i) plane-polarised light (ii) crossed polars

(a) (i)

(a) (ii)



(b) (i)



(b) (ii)

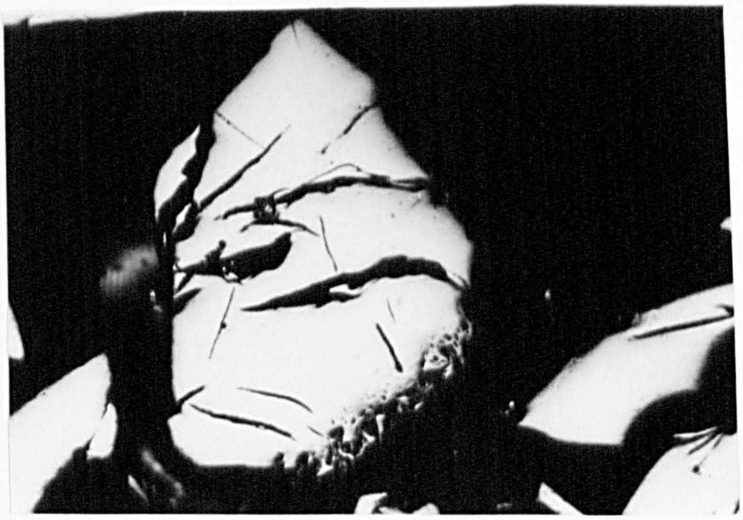
Plate 40 Low-rank anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at 900°C at different heating rates, x 200

(a) at 10°C/min plane-polarised light

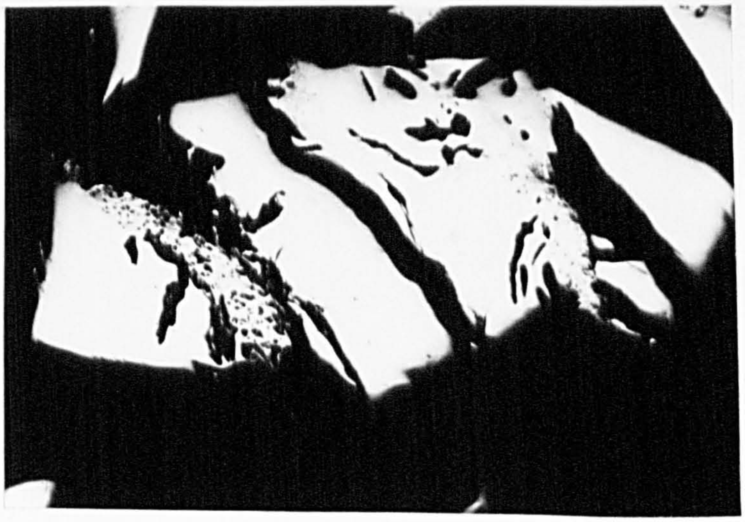
(b) at 60°C/min (i) plane-polarised light

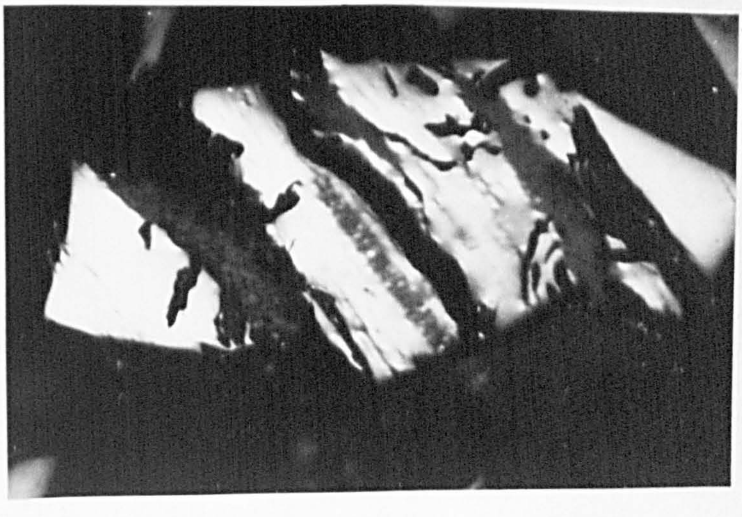
(ii) crossed polars

(a)



(b) (i)





(b) (ii)

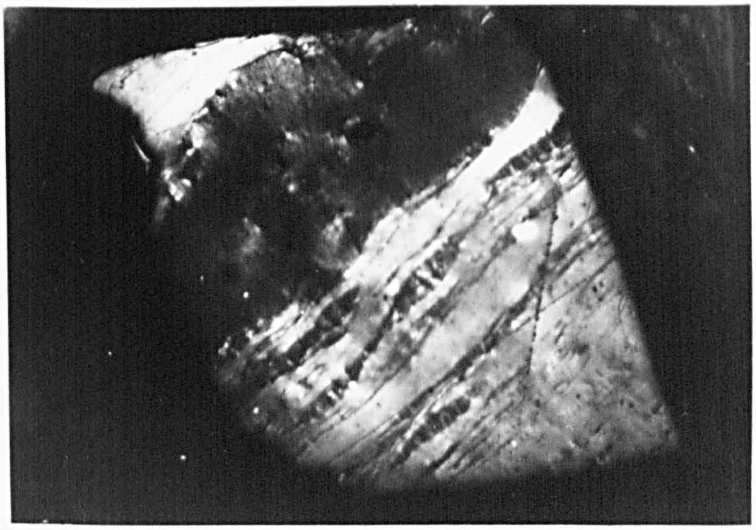
Plate 41 Low-rank, anthracitic vitrinite (carbon = 93.5% dmmf) carbonised at different heating rates, crossed polars, x 200

(a) 1°C/min at 950°C showing possible granular structure

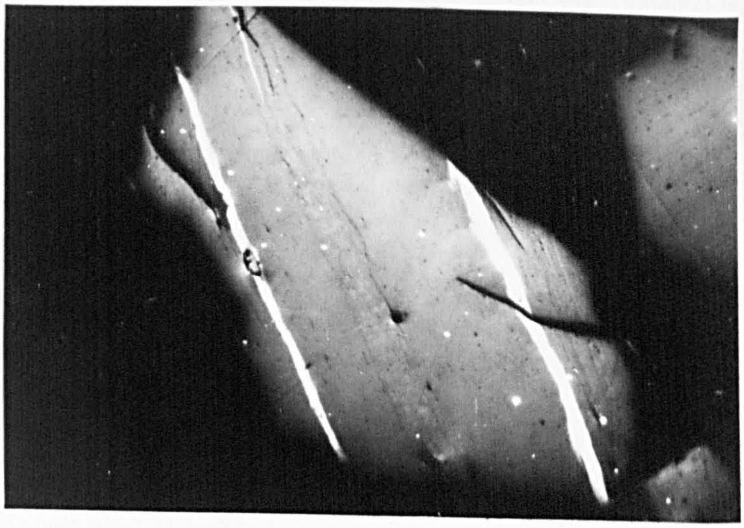
(b) 10°C/min at 900°C showing possible highly anisotropic material

(c) 60°C/min at 950°C showing possible highly anisotropic cutinite

(a)



(b)



(c)

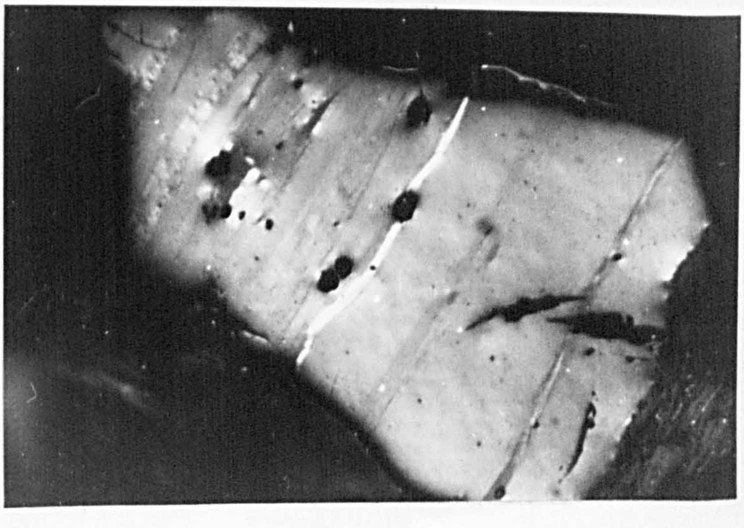
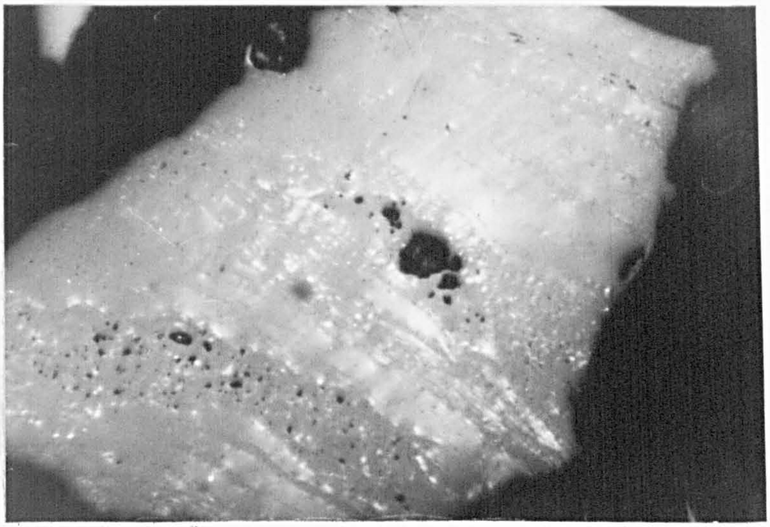


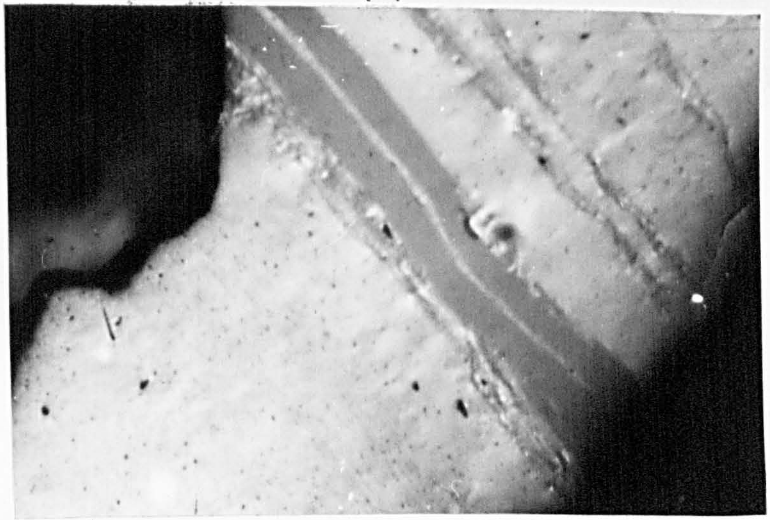
Plate 42 High-rank anthracitic vitrinite (carbon = 94.2% dmmf) carbonised at 600°C at different heating rates, crossed polars x 210

(a) 1°C/min
(b) 10°C/min, note part of megaspore
(c) 60°C/min

(a)



(b)



(c)

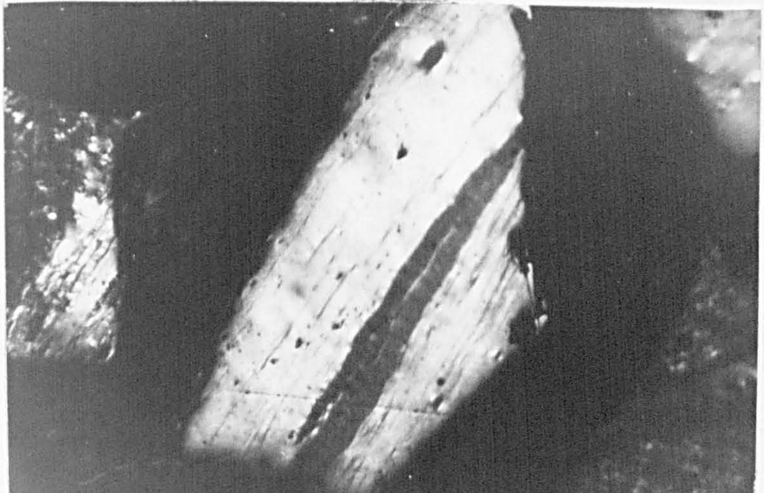


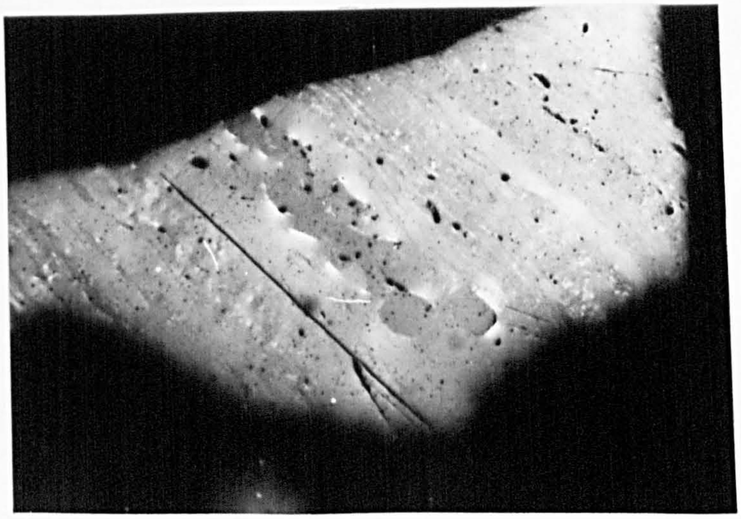
Plate 43 High-rank, anthracitic vitrinite (carbon = 94.2% dmmf) carbonised at 700°C at different heating rates, crossed polars x 200

(a) 1°C/min, note the rounded resinoid-type structure

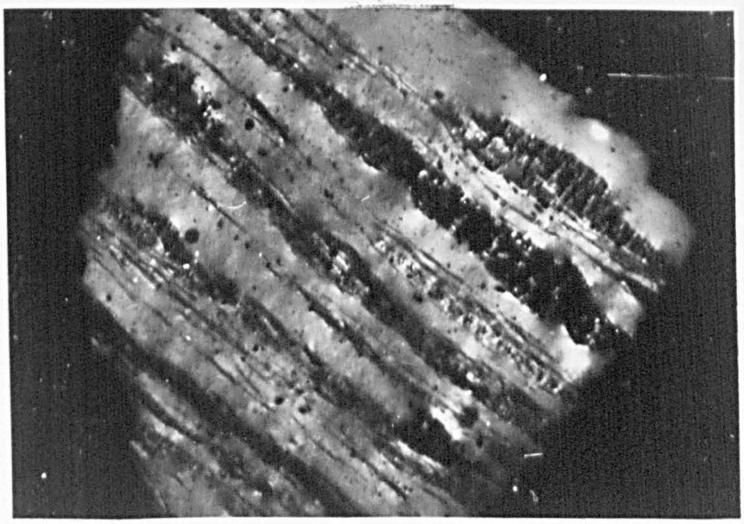
(b) 10°C/min

(c) 60°C/min

(a)



(b)



(c)

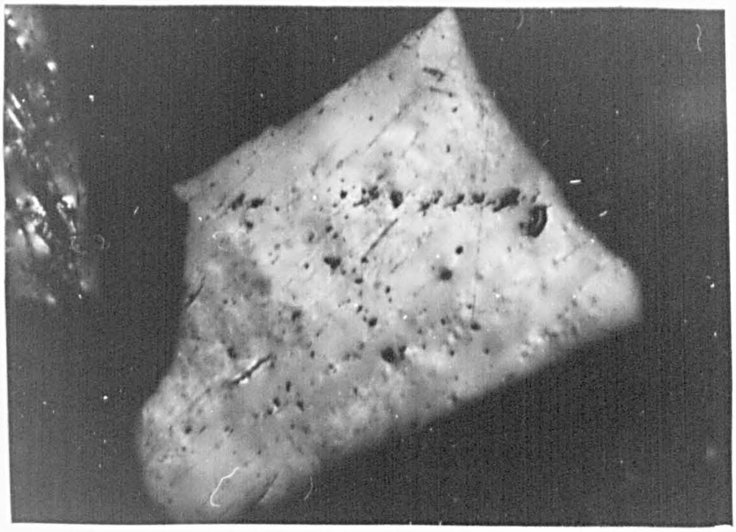
Plate 44 High-rank, anthracitic vitrinite (carbon = 94.2% dmmf) carbonised at 800°C at a heating rate of 60°C/min showing different microlithotype, crossed polars x 200

(a) Vitrinite

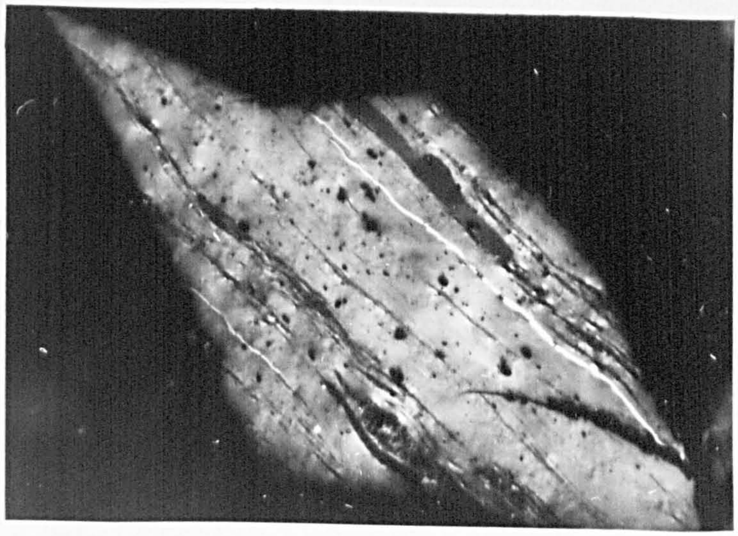
(b) Clarite - note possible highly anisotropic cutinite

(c) Durite

(a)



(b)



(c)

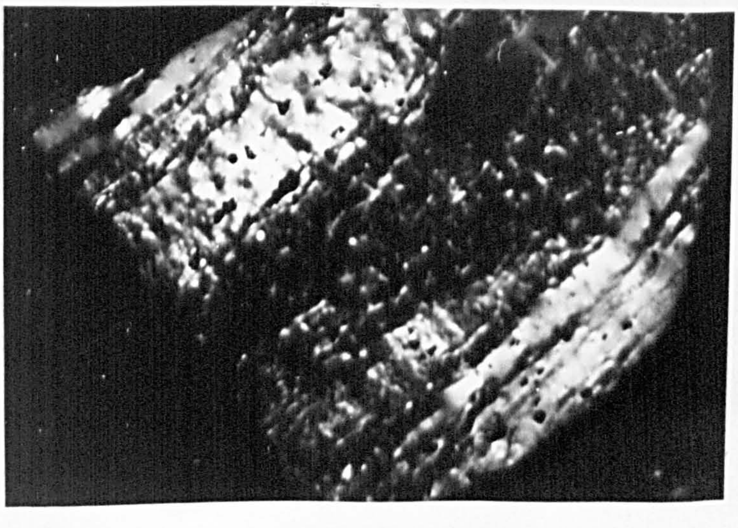


Plate 45 High-rank anthracitic vitrinite (carbon = 94.2% dmmf) carbonised at different heating rates, crossed polars x 210

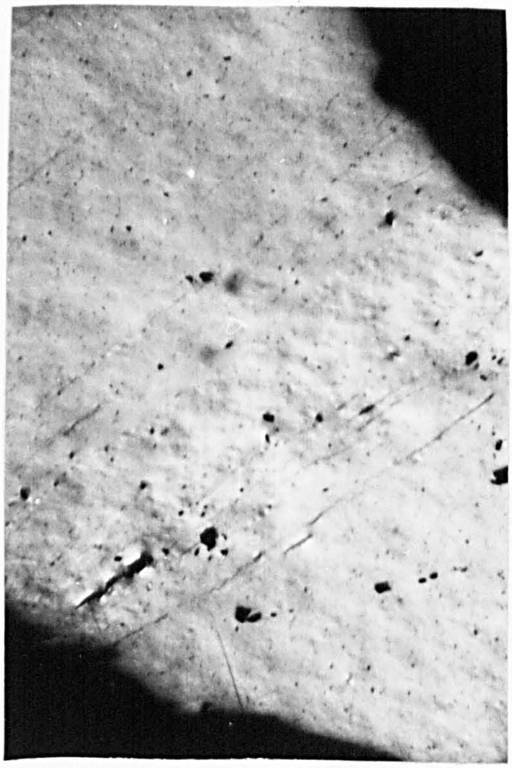
(a) 1°C/min at 800°C

(b) 10°C/min at 800°C showing cutinite

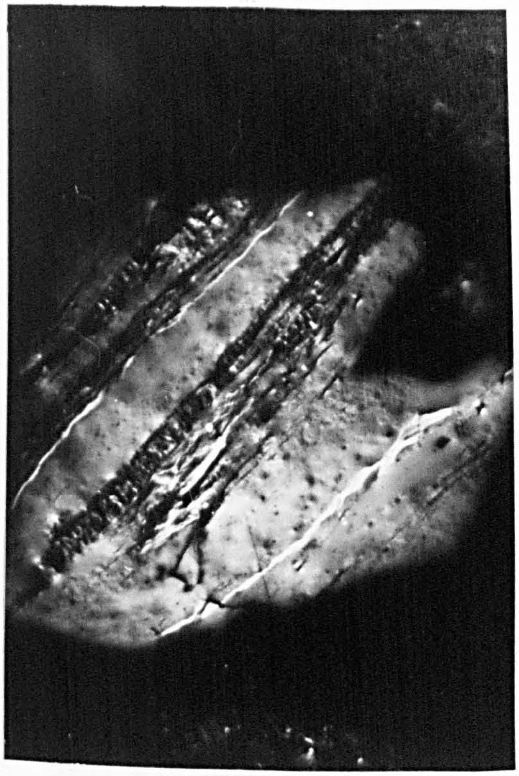
(c) 1°C/min at 850°C showing megaspore

(d) 10°C/min at 900°C showing granular structure

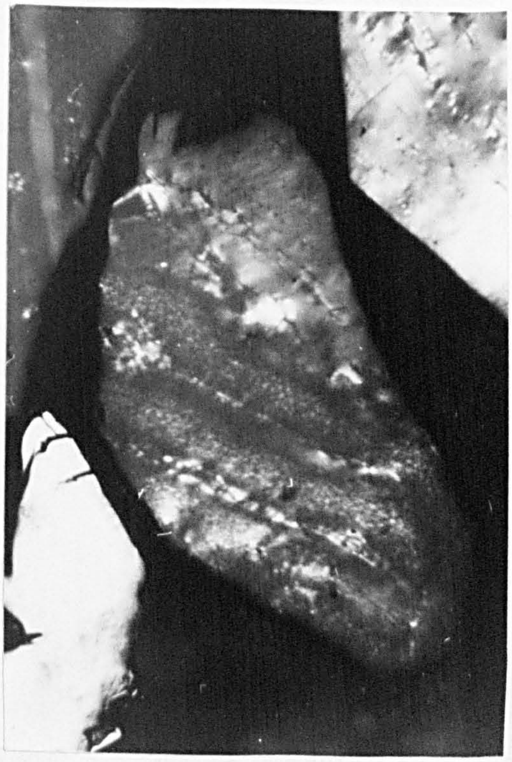
(a)



(b)



(c)

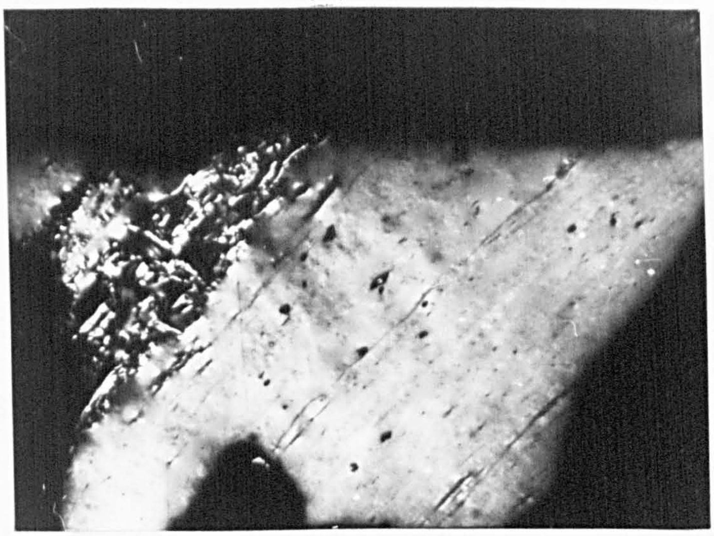


(d)

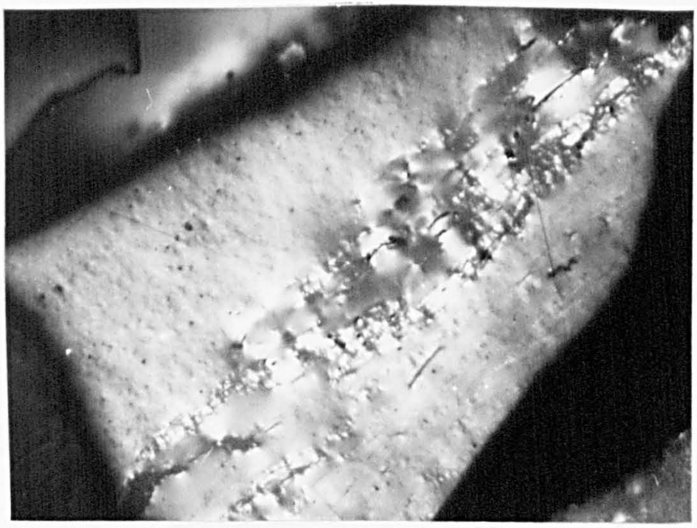
Plate 46 High-rank anthracitic vitrinite (carbon = 94.2% dmmf) carbonised at 900°C at different heating rates, crossed polars x 200

(a) 1°C/min
(b) 10°C/min - note strong granular anisotropy
(c) 60°C/min

(a)



(b)



(c)

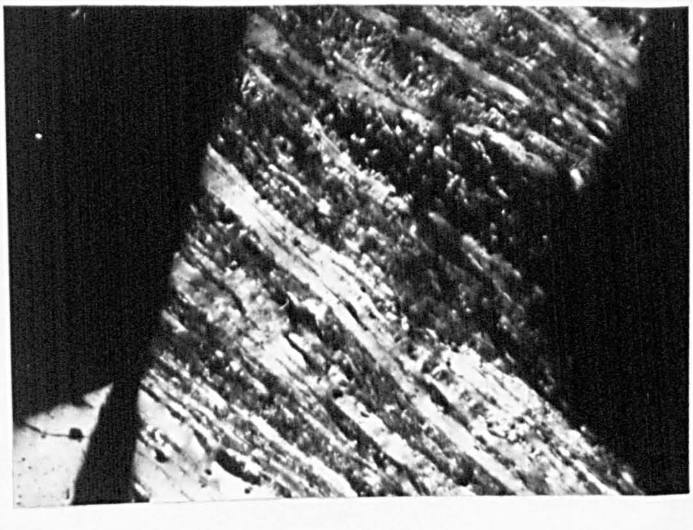


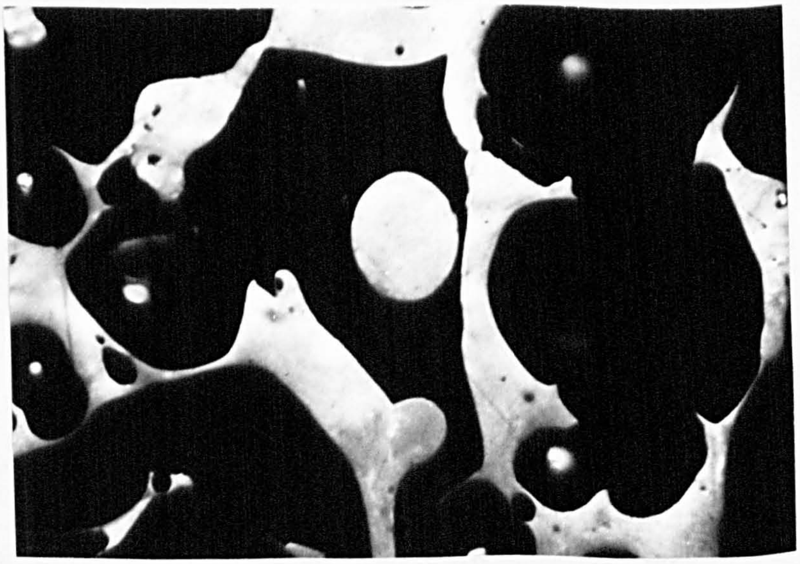
Plate 47 Development of spherical bodies (mesophase?) in low-rank coking-coal vitrinite (carbon = 87.9% daf) x 220

(a) 450°C plane-polarised light

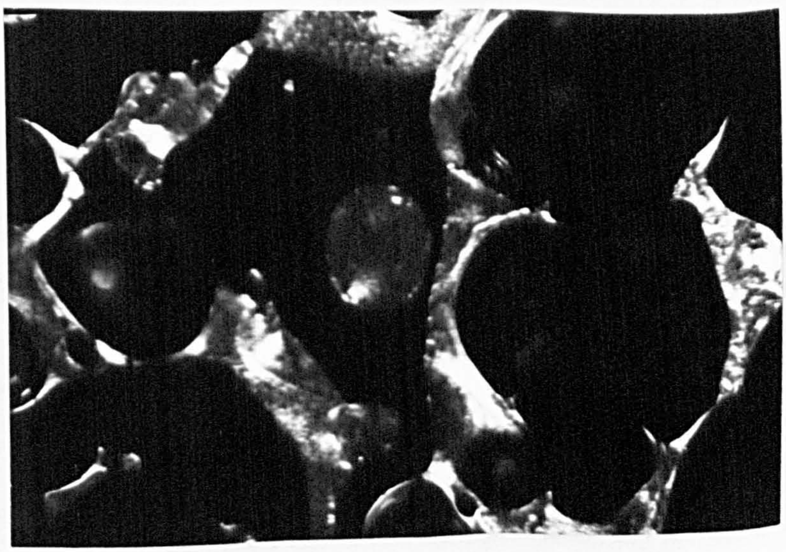
(b) 500°C (i) plane-polarised light

(ii) crossed polars

(a)



(b) (i)



(b) (ii)

Plate 48 Development of spherical bodies in high-rank, coking coal vitrinite (carbon = 90.0% daf) carbonised at 500°C at a heating rate of 10°C/min x 200

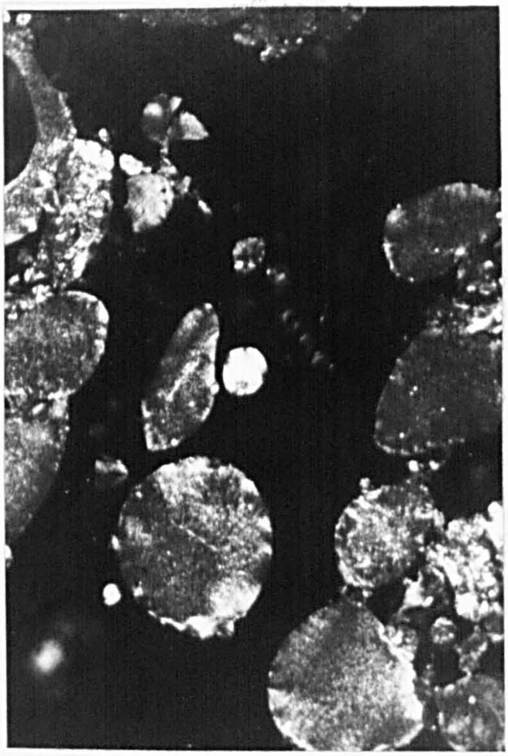
(a) spherical body in centre of photograph showing extinction

(i) crossed polars (ii) 45°C position

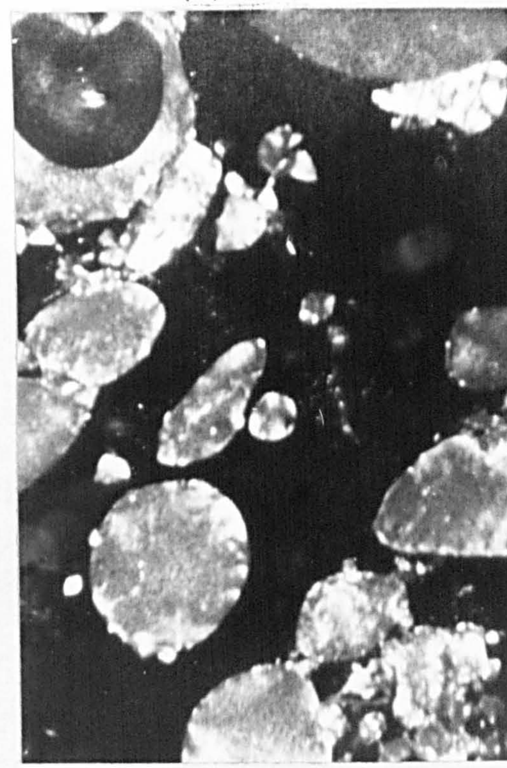
(b) spherical body in centre of photograph showing extinction cross,

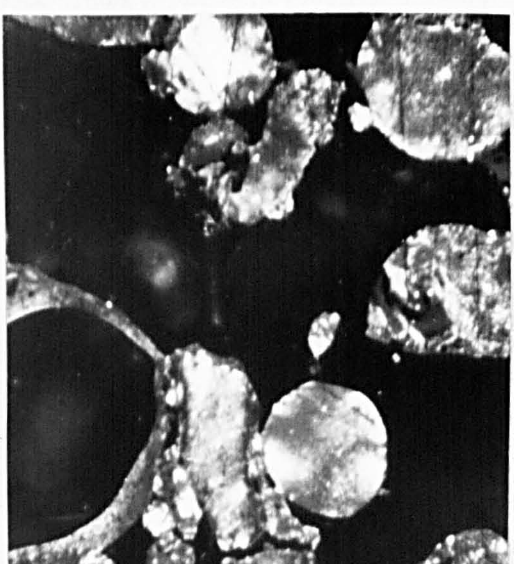
(i) crossed polars (ii) 45°C position

(a) (i)

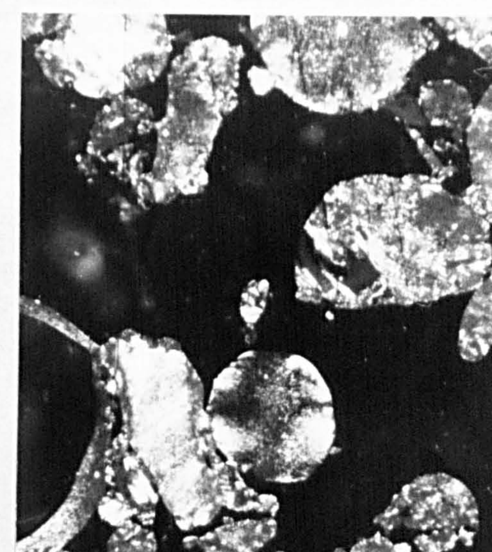


(a) (ii)





(b) (i)



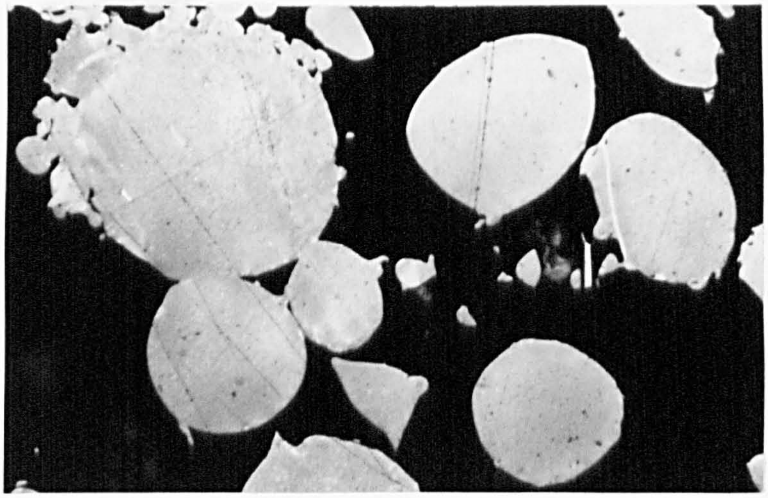
(b) (ii)

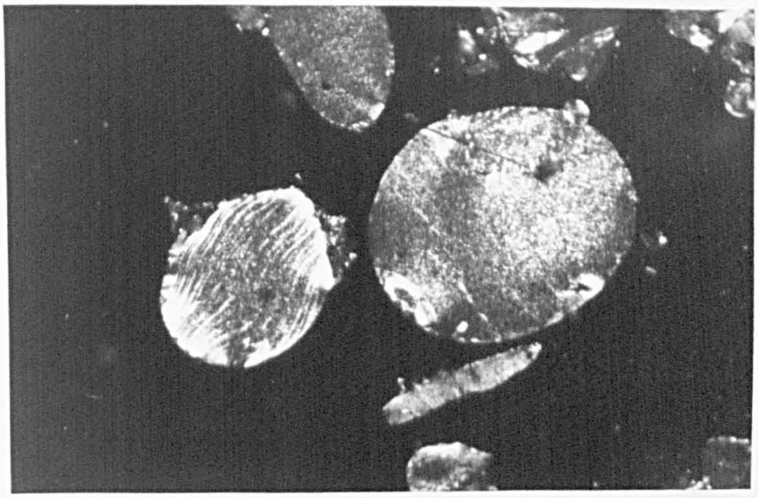
Plate 49 Development of spherical bodies in high-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at 500°C at a heating rate of 10°C/min, x 200

(a) spherical body showing 'poles'; note the attachment of smaller spherical bodies to the larger spherical bodies, plane-polarised light.

(b) spherical bodies showing fine-grained mosaic structure and distorted cellular structure; note the attachment of smaller spherical bodies to the larger spherical bodies, crossed polars

(a)





(b)

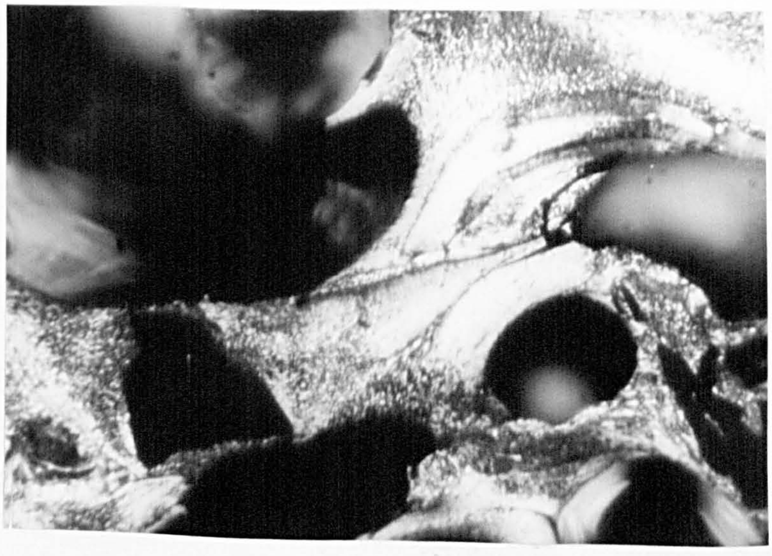
Plate 50 Development of nucleated domains in caking-coal vitrinite (carbon = 85.4% daf) carbonised at a heating rate of 60°C/min x 540

(a) 600°C, crossed polars

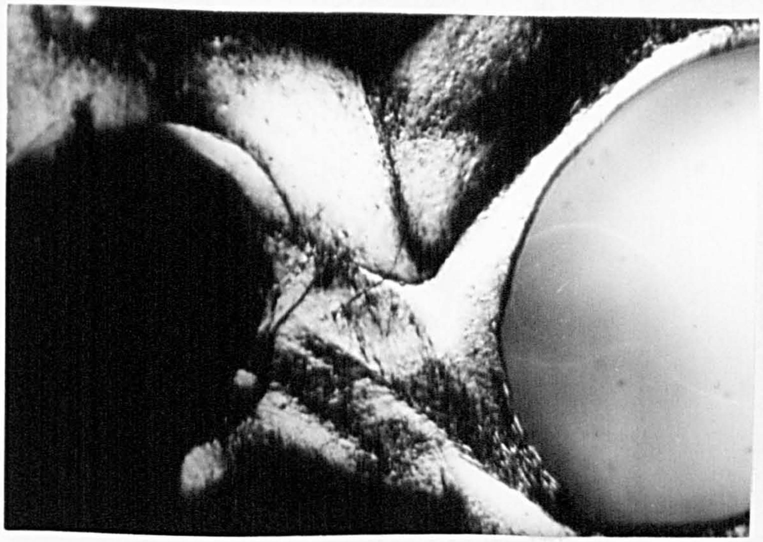
(b) 650°C (i) plane-polarised light

(ii) crossed polars

(a)



(b) (i)



(b) (ii)

Plate 51 Development of nucleated domains in the carbonised residues of low-rank, coking-coal vitrinite (carbon = 87.9% daf) x 480

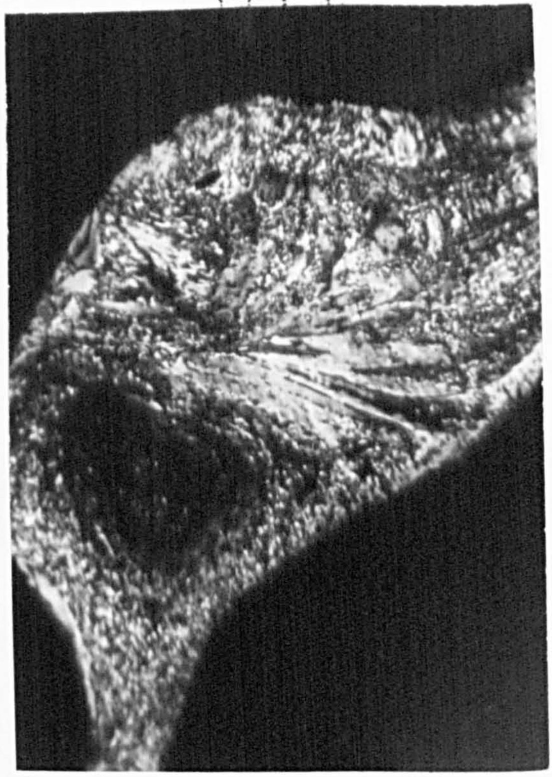
(a) 550°C at a heating rate of 60°C/min showing 'node' type extinction
(i) plane-polarised light (ii) crossed polars

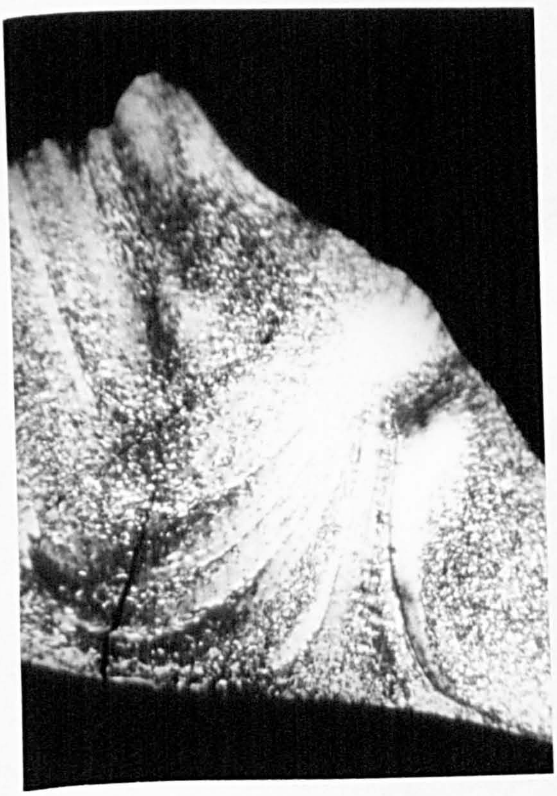
(b) 600°C at a heating rate of 10°C/min, crossed polars

(c) 600°C at a heating rate of 60°C/min showing a helical arrangement, plane-polarised light

(a) (i)

(a) (ii)





(b)

(c)

Plate 52 Development of nucleated domains in a high-rank coking-coal vitrinite (carbon = 90.0% daf) carbonised at a heating rate of 60°C/min, crossed polars, x 210

(a) 550°C showing large anisotropic domains and long fibrous structure

(b) 600°C showing the development of long and parallel fibrous structure

(c) 650°C showing a long fibrous structure

(a)

(b)

(c)

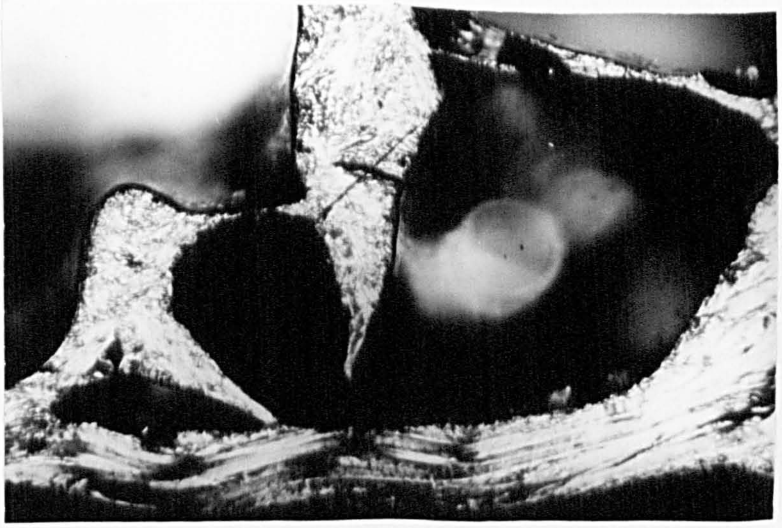
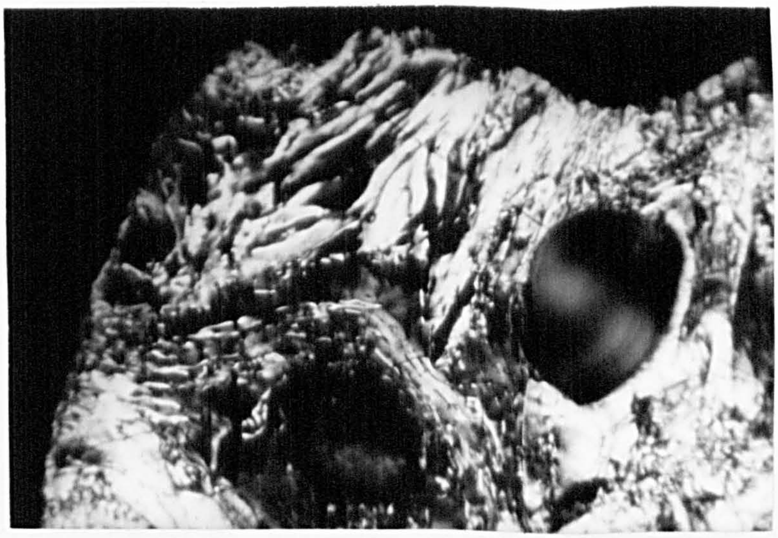


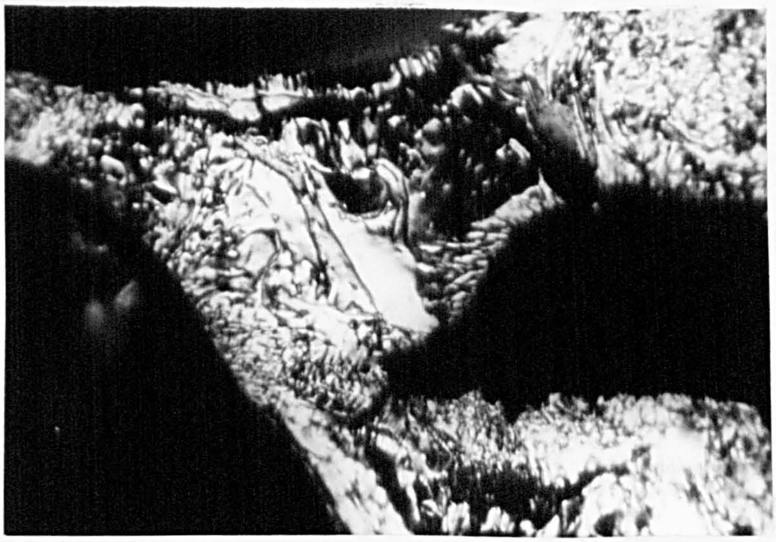
Plate 53 Development of nucleated domains in high-rank coking-coal vitrinite carbonised at a heating rate of 60°C/min, crossed polars, x 540

(a) 550°C showing a 'Y' type node structure
(b) 575°C showing a large anisotropic domain
(c) 650°C showing 'O' type node structure

(a)



(b)



(c)

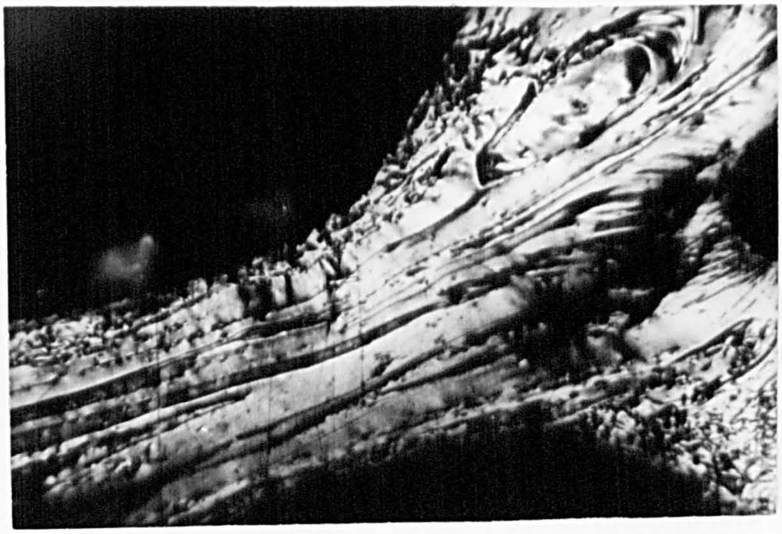
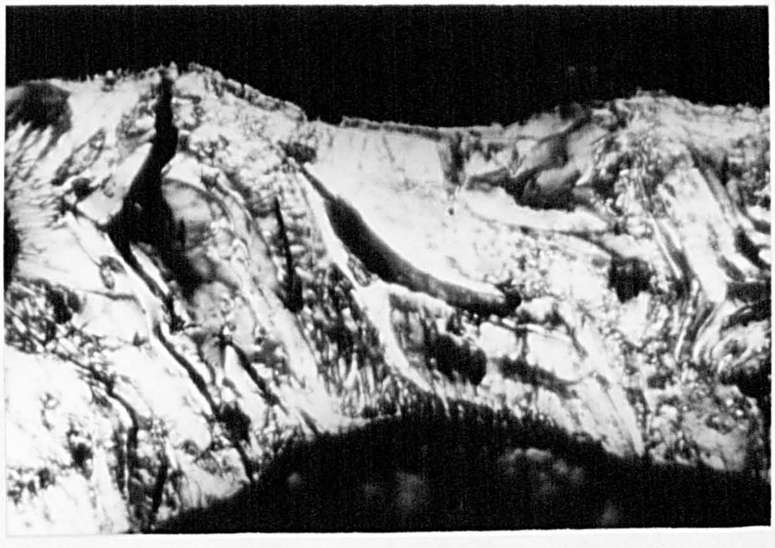


Plate 54 Development of nucleated domains in high-rank coking-coal vitrinite carbonised at a heating rate of $60^{\circ}C/min$, crossed polars, x 540

(a) $800^{\circ}C$ showing a 'U' type node structure
(b) $900^{\circ}C$ showing large anisotropic domains

(a)



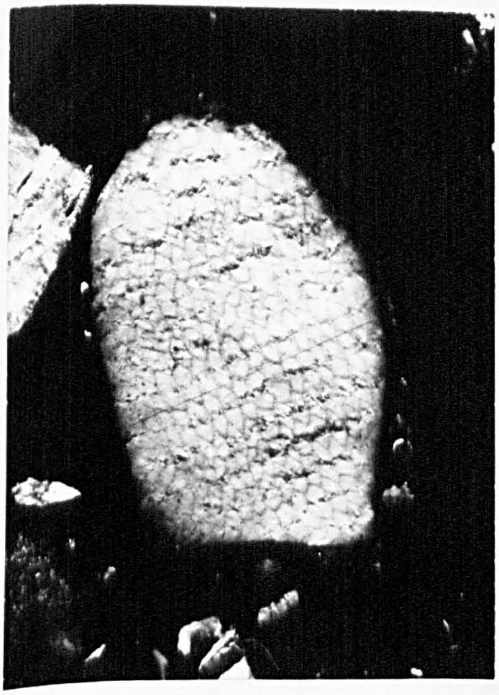
(b)

Plate 55 Cell-structure in residues of high-rank, coking coal vitrinite (carbon = 90.0% daf), carbonised at a heating rate of 1°C/min. Note the almost unchanged cell-structures under crossed polars, x190

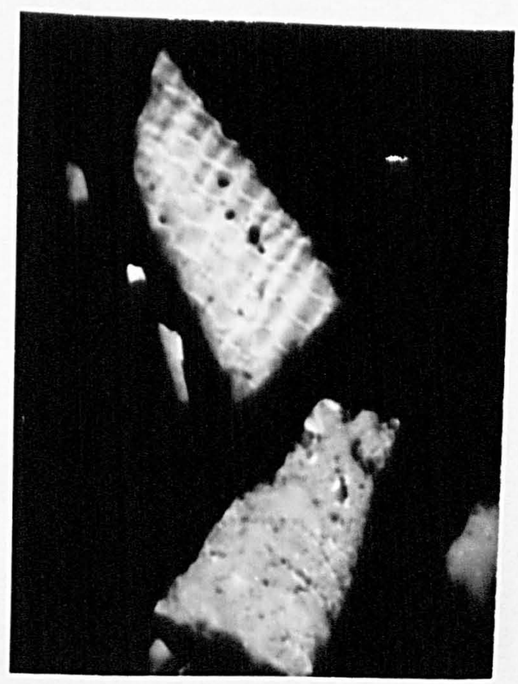
(a) 500°C
(b) 600°C
(c) 700°C
(d) 800°C

(a)

(b)



(c)

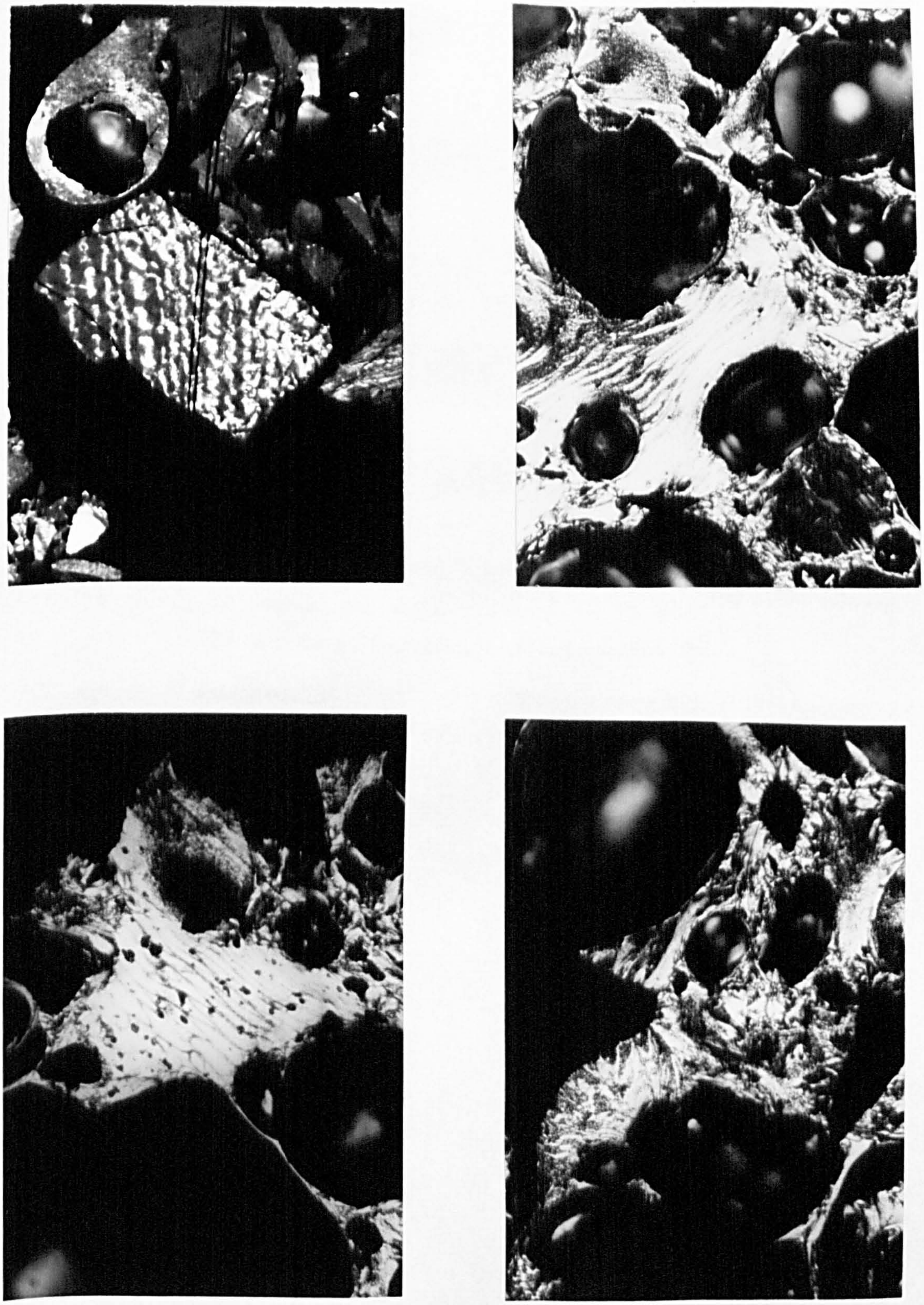


(d)

Plate 56 Cell-structure in residues of high-rank, coking coal vitrinite (carbon = 90.0% daf), carbonised at a heating rate of 10°C/min. Note the deformation of original cell-structures, crossed polars, x210

(a) 500°C
(b) 600°C
(c) 700°C
(d) 800°C

(a) (b)

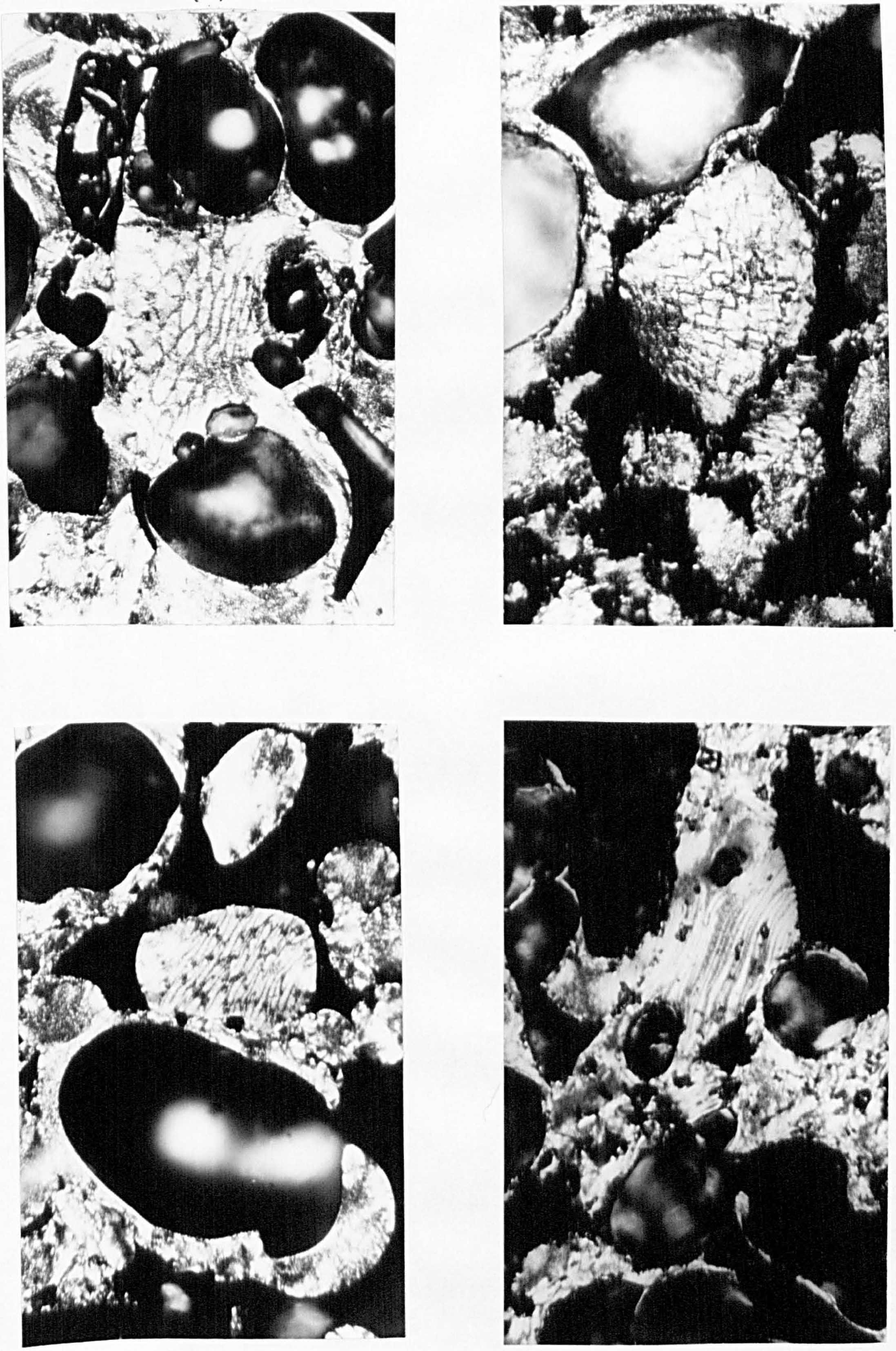


(c) (d)

Plate 57 Cell-structure in residues of high-rank, coking coal vitrinite (carbon = 90.0% daf), carbonised at a heating rate of 60°C/min. Note the almost complete distortion of cell-structures, crossed polars, x190

(a) 450°C
(b) 500°C
(c) 550°C
(d) 600°C

(a) (b)

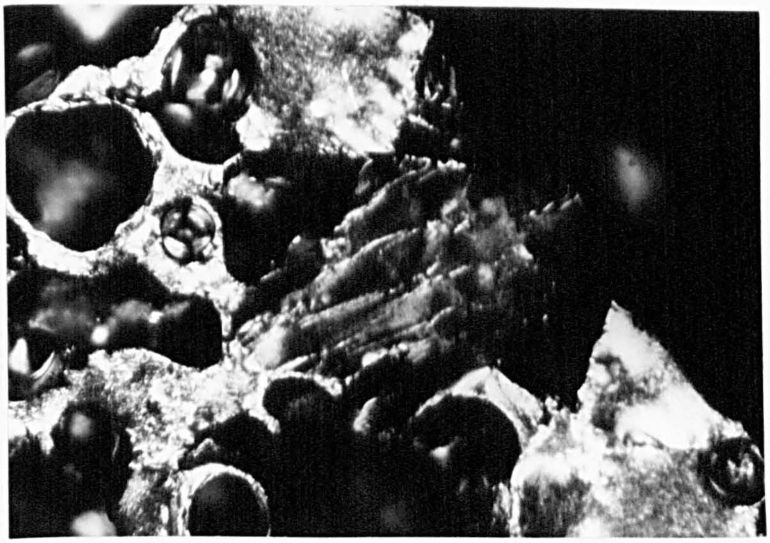


(c) (d)

Plate 58 Cell-structure in residues of high-rank, coking coal vitrinite (carbon = 90.0% daf), carbonised at a heating rate of 60°C/min, crossed polars, x190

(a) 700°C, showing almost unchanged cell-structure
(b) 800°C, showing almost completely distorted cell-structures

(a)



(b)

## APPENDIX II THE EFFECT OF DIFFERENT HEATING PERIODS BELOW DECOMPOSITION TEMPERATURE ON THE OPTICAL PROPERTIES OF VITRINITES.

(a) Low-rank bituminous vitrinite (carbon 77.0% daf)

(i) Fresh (Plate 59a): dark grey, structureless vitrinite with sporinite, but some inertinite and/or granular micrinite contamination; occasional vitrinite particles exhibit cell structure; isotropic.

(ii) 150°C

A. 1-16 weeks (Plates 61a and b): dark grey to grey, angular particles with residues becoming brighter with increase in holding time; development of occasional cracking in particles, exinite still present; some particles exhibit cellular structure; the residues become slightly swollen with progressive increase in holding time; with some particles after 16 weeks holding time developing narrow rims of slightly higher reflectivity than the central zone ( oxidation rims ?); sporinite present in the rim keeps its original dark colour: isotropic.

B. 32 weeks (Plate 61c):, grey, angular, slightly cracked, microspores disappearing; cell structure visible in some particles; some particles exhibit slightly higher reflecting rims: isotropic.

(iii) 350°C

A. 1-16 weeks (Plates 62a and b): grey to greyish-white, angular, development of vesicles of about 2.5 to 10 µm diameter; sporinite loses original dark brownish grey, becoming light brownish grey and finally disappearing with progressive increase in holding time: isotropic.

B. <u>32 weeks (Plate 62c):</u> greyish white, angular to subangular with development of long lenticular-shaped vacuoles, up to 10 um diameter in some particles, due to devolatilisation of sporinite; disappearance of sporinite: isotropic.

(b) <u>Low-rank bituminous vitrinite (carbon = 82.3% daf)</u>

(i) <u>Fresh (Plate 57b):</u> dark grey, mostly structureless collinite with some sporinite and inertinite contamination; some particles exhibit mottled appearance: isotropic.

(ii) <u>150°C</u>

A. <u>1-16 weeks (Plates 63a and b):</u> grey, angular, slightly cracked; sporinite is still present; cell structure visible: isotropic.

B. <u>32 weeks (Plate 63c):</u> light grey, angular, slightly cracked but no vesicles present; cell structure very distinct; sporinite becomes brighter; some vitrinite particles develop slightly brighter and wide rims: isotropic.

(iii) <u>350°C</u>

A. <u>1-16 weeks (Plates 64a and b):</u> grey to greyish white, angular, homogeneous; development of 2.5 to 15 um diameter vesicles; sporinite becomes brighter with progressive increase in holding time and partially disappears at about 16 weeks: isotropic.

B. 32 weeks (Plate 64c): light grey, homogeneous; vitrinite particles become slightly subangular, development of vesicles of 2.5 to 20 μm diameter; sporinite completely disappeared: isotropic.

(c) Caking coal vitrinite (carbon = 85.4% daf)

(i) Fresh (Plate 59c): medium to light grey, uniform, structureless vitrinite, with particles occasionally contaminated by sporinite, and angular particles of inertinite and pyrite globules; no cellular structure visible: very weakly anisotropic.

(ii) 150°C

A. 1-16 weeks (Plates 65a and b): grey to light grey; angular; particles occasionally developing up to 2.5 um diameter vesicles; small particles cracked, whereas larger particles remain unchanged, but with increase of holding time even larger particles become cracked; at 16 weeks holding time, rims of higher reflectivity are developed on peripheries of particles (oxidation rim?); cell-structure visible in some particles; sporinite becomes brighter with length of holding time: weakly anisotropic.

B. 32 weeks (Plate 65c): greyish white, angular, development of vesicles of up to 25 μm diameter; not many fractures; sporinite becomes even brighter: weakly anisotropic.

(iii) 350°C

A. 1-16 weeks (Plates 66a and b): grey to greyish white, slightly subangular; development of vesicles of up to 25 um diameter, the size and amount of vesicles increasing with length of holding time; complete disappearance of sporinite and long but small oval shaped vacuoles developed due to devolatilisation of sporinite: weakly anisotropic.

B. 32 weeks (Plate 66c): greyish white, angular to rounded particles; the rounded particles develop large central vacuoles of up to 50 um diameter; slight increase in intensity of anisotropy.

(d) Low-rank, coking coal vitrinite (carbon = 87.9% daf)

(i) Fresh (Plate 59d): light-grey, homogeneous but some microspores and/or fragments of mertinite; no cellular structure present under crossed polars; slightly anisotropic.

(ii) 150°C

A. 1-16 weeks (Plates 67a and b): light grey, angular particles; development of vesicles of up to 5 um diameter, particularly at maceral boundaries; particles fractured; sporinite loses original brownish grey colour and is partially devolatilised, developing lenticular vacuoles: anisotropic.

B. 32 weeks (Plate 67c): greyish, white, angular: few vacuoles present with only slight fracturing; further brightening of and disappearance of sporinite: anisotropic.

(iii) 350°C

A. 1-16 weeks (Plates 68a and b): greyish white, angular, homogeneous; occasional development of fractures, small vesicles of about 2.5 um diameter after 4 weeks holding time; disappearance of sporinite: anisotropic.

B. 32 weeks (Plate 68c): greyish white to white, angular; completely rounded particles; vesicles of about 5 um diameter are common; banding visible under crossed polars; development of partial fine-grained mosaic texture: anisotropic.

(e) High-rank coking coal vitrinite (carbon = 90.0% daf)

(i) Fresh (Plate 60a): pale-grey, homogeneous, but some particles contaminated by sporinite and inertinite; no cellular structure visible, even under crossed polars: weakly anisotropic.

(ii) 150°C

A. 1-16 weeks (Plates 69a and b): greyish white, angular, fractured, with occasional vesicles of about 2.5 um diameter; sporinite develops similar reflectivity to that of surrounding vitrinite and disappears with progressive increase in holding time: anisotropic.

B. 32 weeks (Plate 69c): greyish white, angular, slightly fractured, with occasional vesicles of up to 5 um diameter; disappearance of sporinite: anisotropic.

(iii) 350°C

A. 1-16 weeks (Plates 70a and b): greyish white, angular, homogeneous; occasional development of fractures, small vesicles of 2.5 um diameter after four weeks' holding time, but development of larger vesicles of about 50 um after 16 weeks; some particles develop narrow rims of slightly higher reflectivity (oxidation rim?); disappearance of sporinite: anisotropic.

B. 32 weeks (Plate 70c): greyish white to white, angular, completely rounded particles, vesicles of about 5 um diameter common; banding visible under crossed polars; development of partial fine-grained mosaic texture: anisotropic.

(f) High-rank anthracitic vitrinite (carbon = 94.2 dmmf)

(i) Fresh (Plate 60b): greyish white, uniform, structureless; streaks or angular fragments of inertinite; banding visible under crossed polars: strongly anisotropic.

(ii) 150°C

1-32 weeks (Plates 71a and b): greyish white, angular, no morphological changes apparent with samples essentially similar to fresh anthracite: strongly anisotropic.

(iii) 350°C

1-32 weeks (Plates 72a and b): greyish white, angular development of system of fracturing in particles; banding visible: strongly anisotropic.

Plate 59 Fresh vitrinite, plane-polarised light, x 190

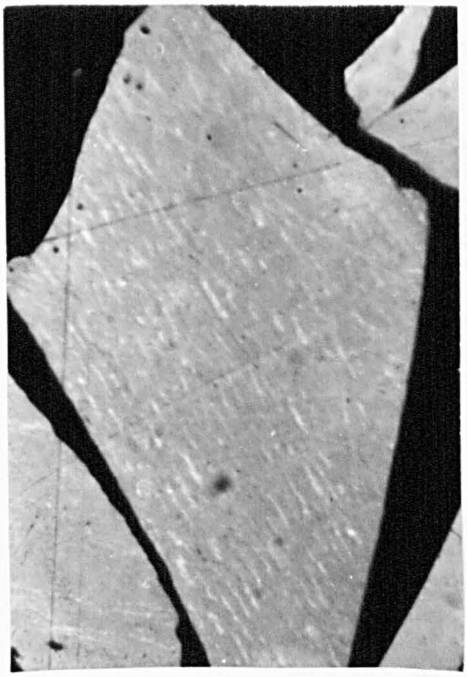
(a) sub-bituminous (carbon = 77.0% daf)

(b) low-rank bituminous (carbon = 82.3% daf)

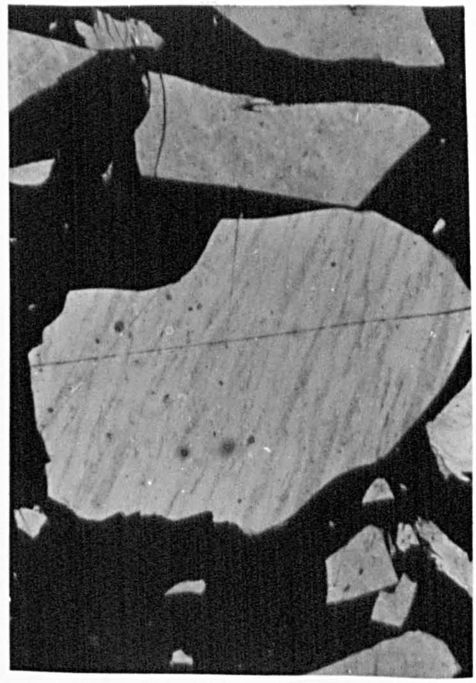
(c) caking coal (carbon = 85.4% daf)

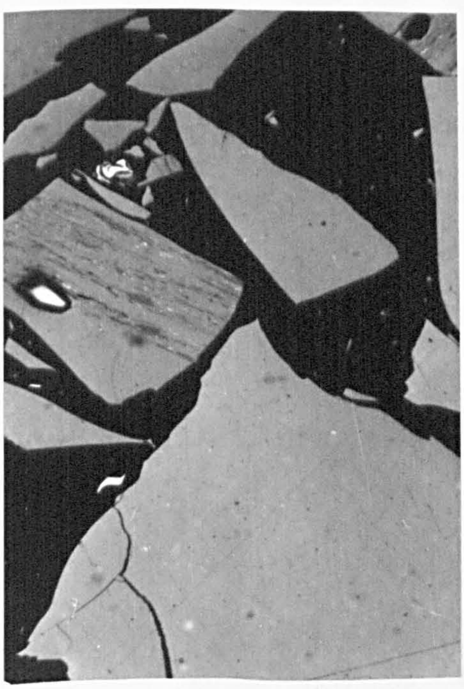
(d) low-rank coking coal (carbon = 87.9% daf)

(a)



(b)





(c)

(d)

Fig 60 Fresh vitrinite, x185

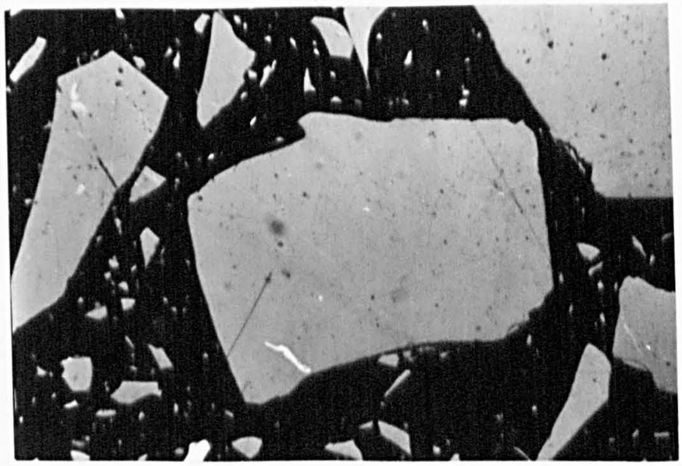
(a) high-rank, coking coal (carbon = 90.0% daf), plane-polarised light

(b) anthracitic (carbon = 94.2% dmmf),

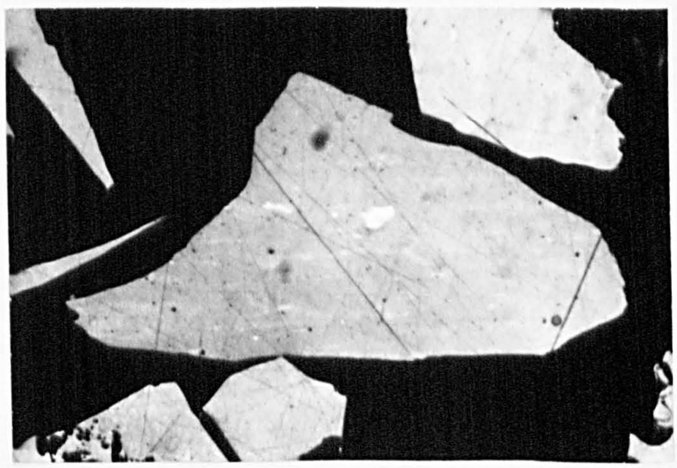
(i) plane-polarised light

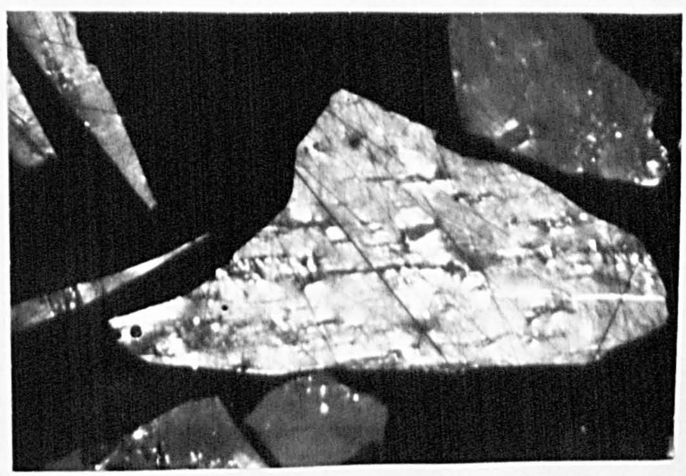
(ii) crossed polars

(a)



(b) (i)



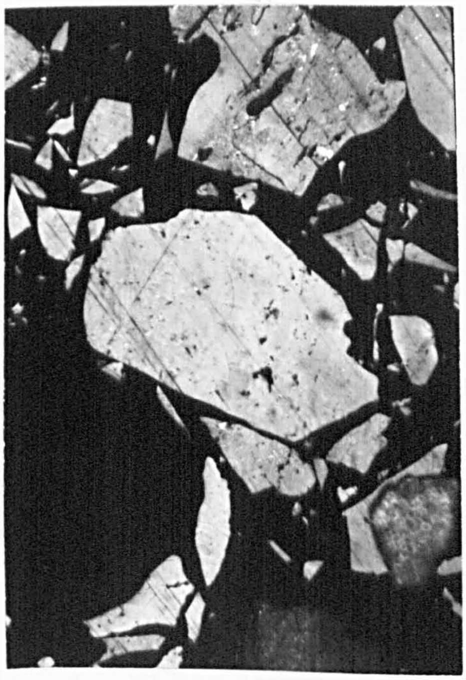


(b) (ii)

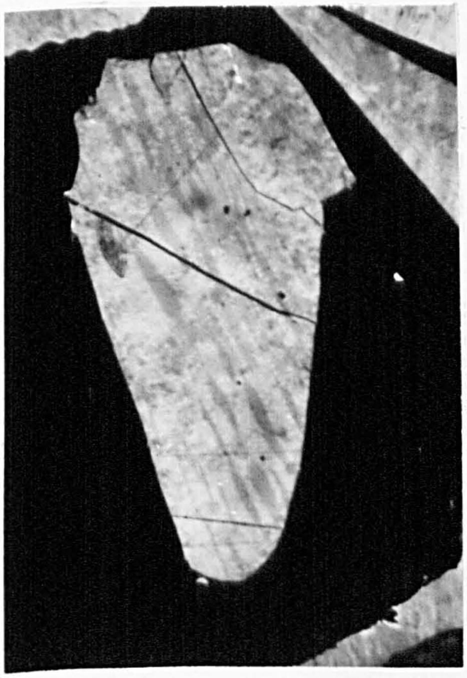
Plate 61 Sub-bituminous vitrinite (carbon = 77.0% daf) heated at 150°C, plane-polarised light, x 190

(a) 1 week
(b) 16 weeks
(c) (i) & (ii) 32 weeks

(a)



(b)



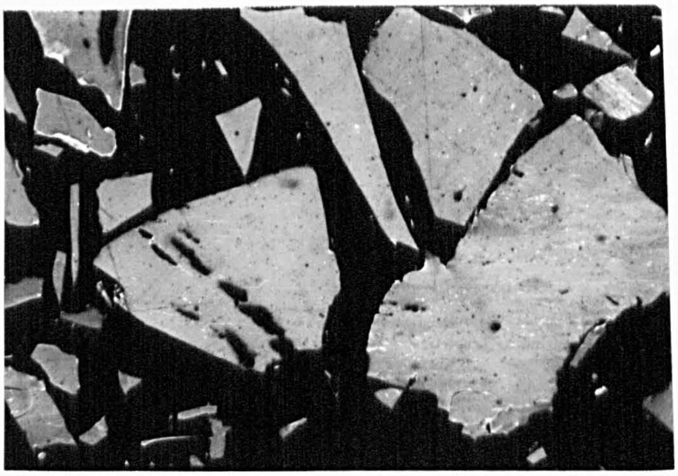
(c) (i)

(c) (ii)

Plate 62 Sub-bituminous vitrinite (carbon = 77.0% daf) heated at 350°C, plane-polarised light, x 180

(a) 1 week
(b) 16 weeks
(c) 32 weeks

(a)



(b)

(c)

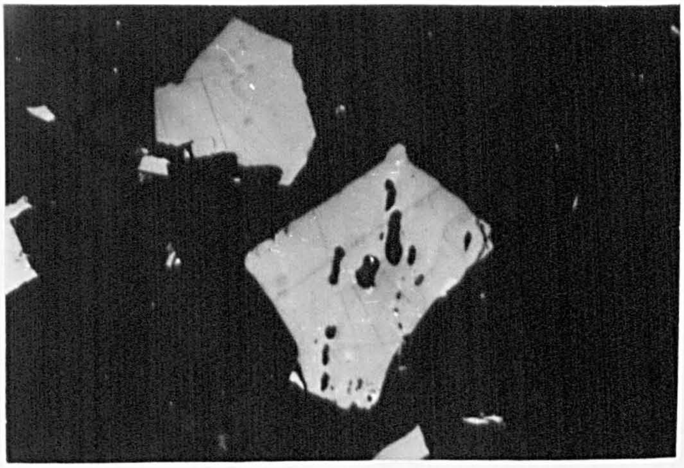


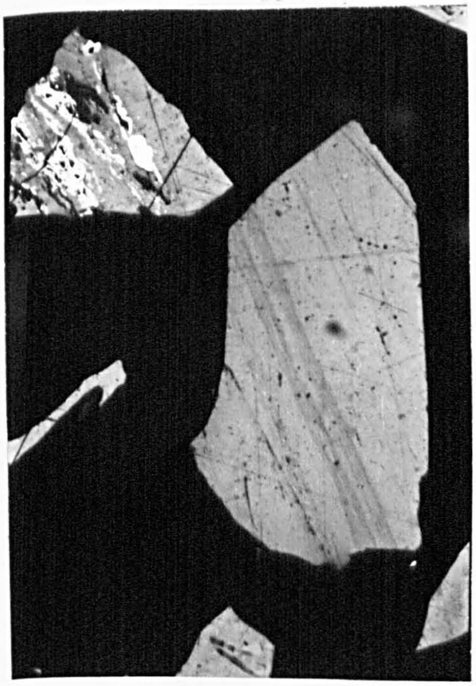
Plate 63 Low-rank bituminous vitrinite (carbon =82.3% daf) heated at 150°C, plane-polarised light, x 190

(a) 1 week

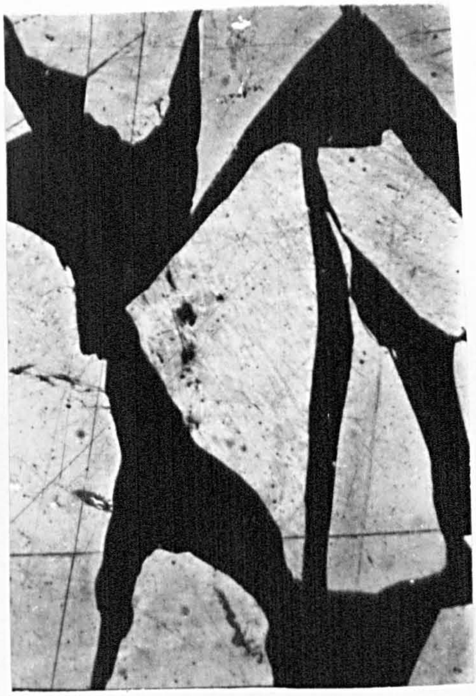
(b) 16 weeks

(c) (i) & (ii) 32 weeks

(a)



(b)



(c) (i)

(c) (ii)

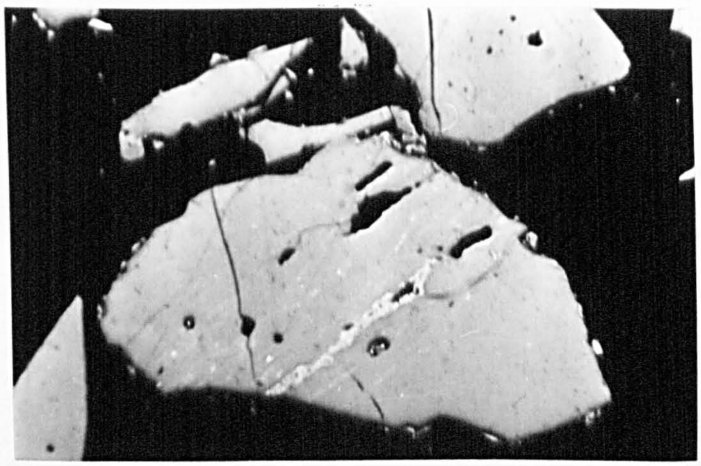
Plate 64 Low-rank bituminous vitrinite (carbon = 82.3% daf) heated at 350°C, plane-polarised light, x 180

(a) 1 week

(b) 16 weeks

(c) 32 weeks

(a)



(b)

(c)

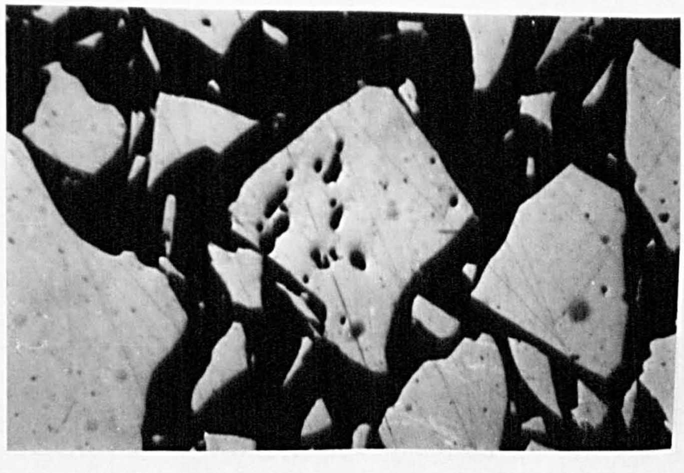


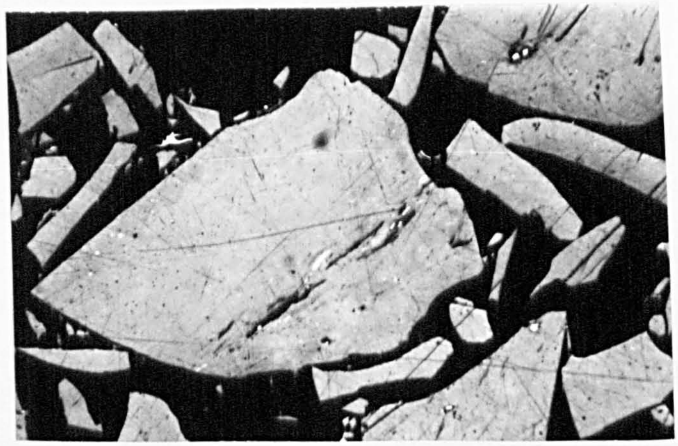
Plate 65 Caking coal vitrinite (carbon = 85.4% daf) heated at 150°C, plane-polarised light, x 180

(a) 1 week

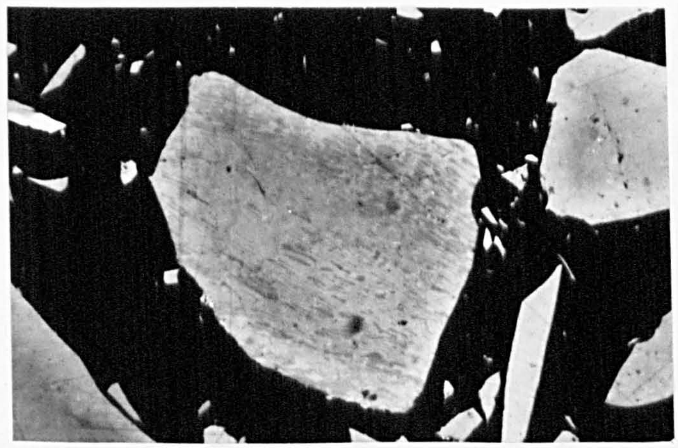
(b) 16 weeks

(c) 32 weeks

(a)



(b)



(c)

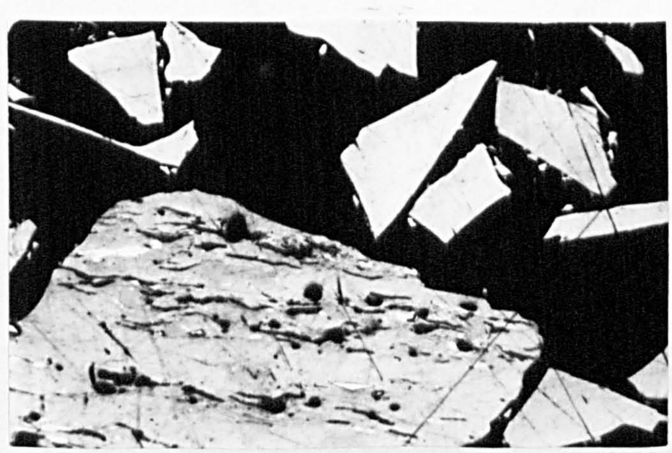


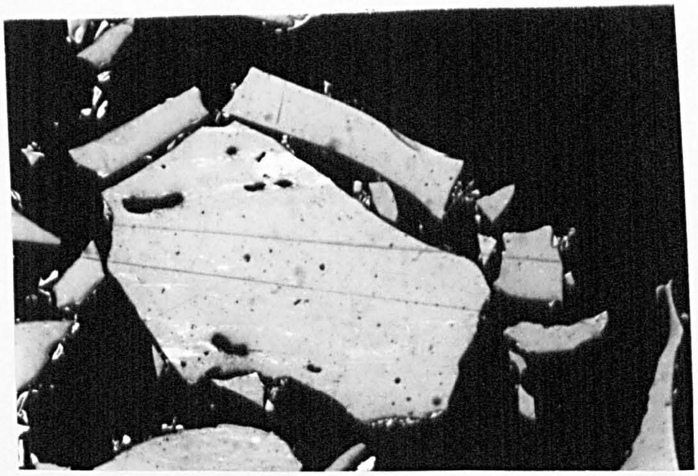
Plate 66 Caking coal vitrinite (carbon = 85.4% daf) heated at 350°C, plane-polarised lightx x 180

(a) 1 week

(b) 16 weeks

(c) 32 weeks

(a)



(b)

(c)

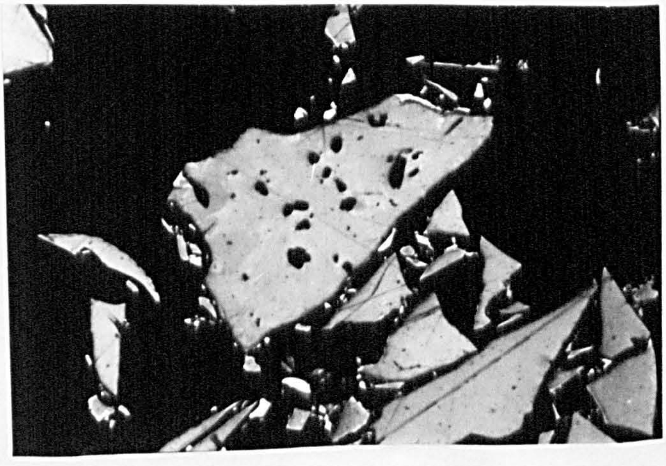
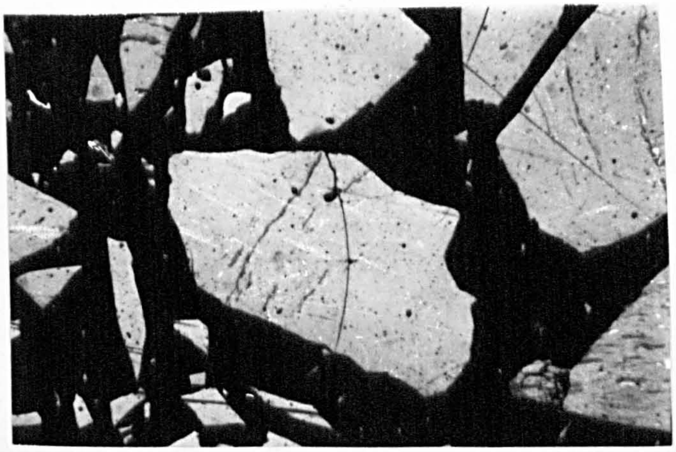


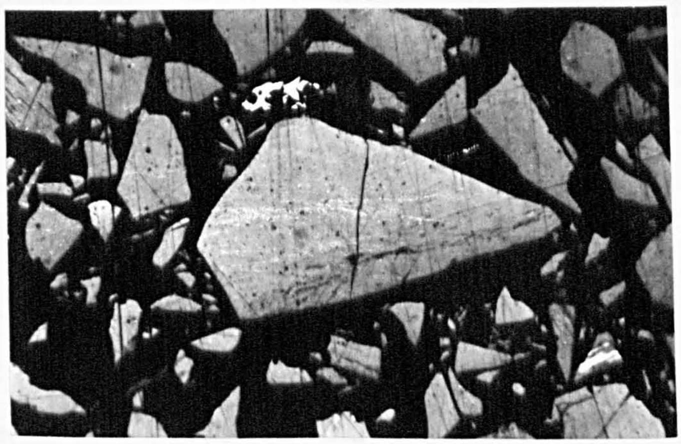
Plate 67 Low-rank, coking coal vitrinite (carbon = 87.9% daf) heated at 150°C, plane-polarised light, x 180

(a) 1 week
(b) 16 weeks
(c) 32 weeks

(a)



(b)



(c)

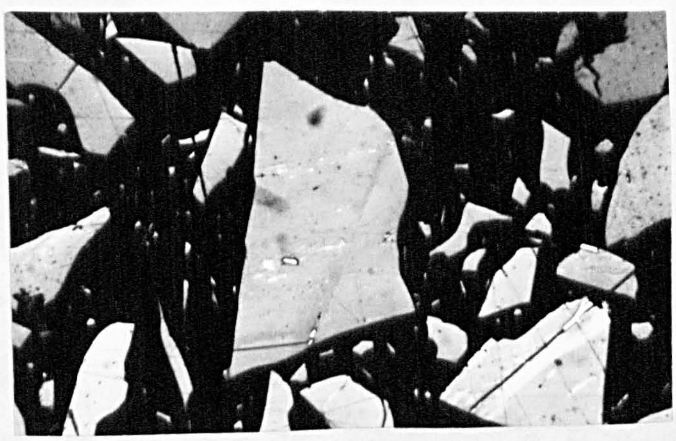


Plate 68 Low-rank, coking coal vitrinite (carbon = 87.9% daf) heated at 350$^{o}$C, x 185

(a) 1 week, poane-polarised light

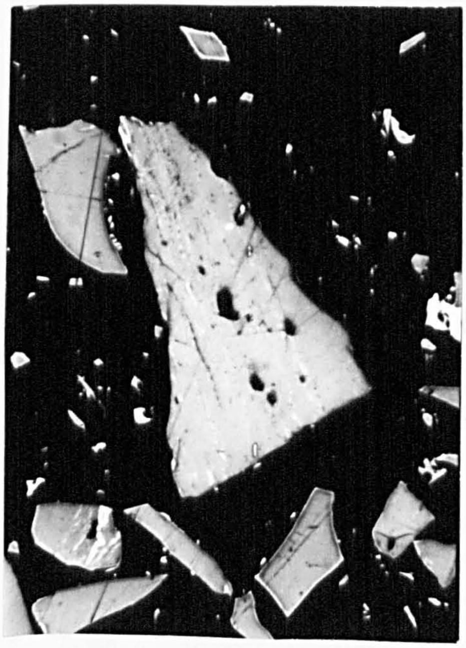
(b) 16 weeks, plane-polarised light

(c) 32 weeks,

(i) plane-polarised light

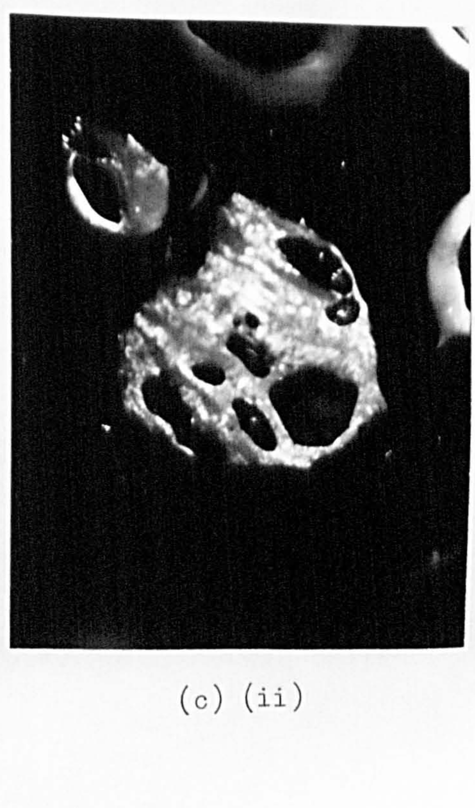
(ii) crossed polars

(a)



(b)

(c) (i)

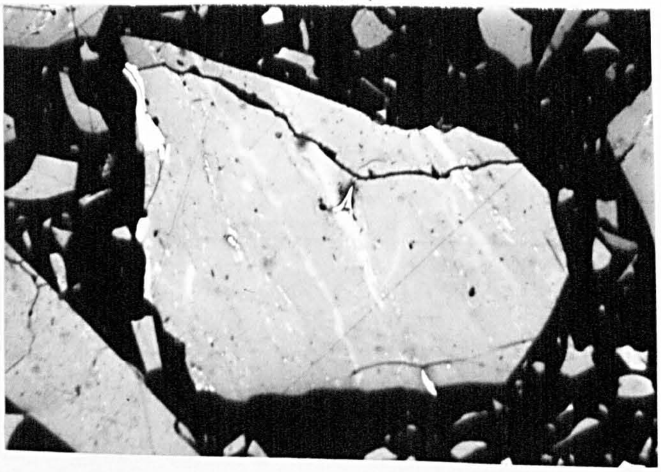


(c) (ii)

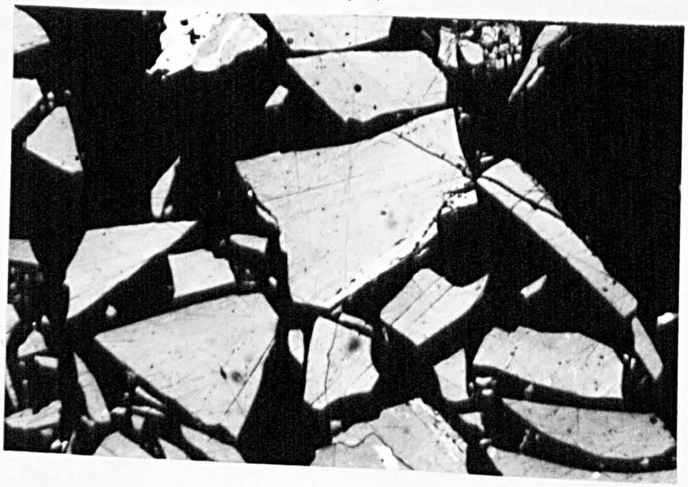
Plate 69 High-rank, coking coal vitrinite (carbon = 90.0% daf) heated at 150°C, plane-polarised light, x 190

(a) 1 week
(b) 16 weeks
(c) 32 weeks

(a)



(b)



(c)

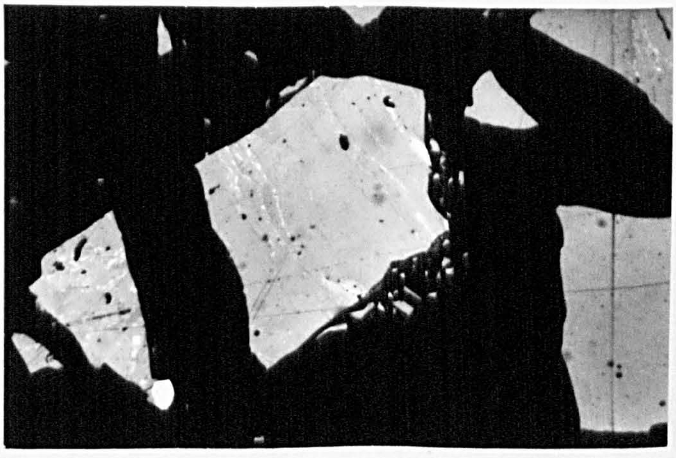


Plate 70 High-rank coking coal vitrinite (carbon = 90.0% daf) heated at 350°C, x 185

(a) 1 week, plane-polarised light

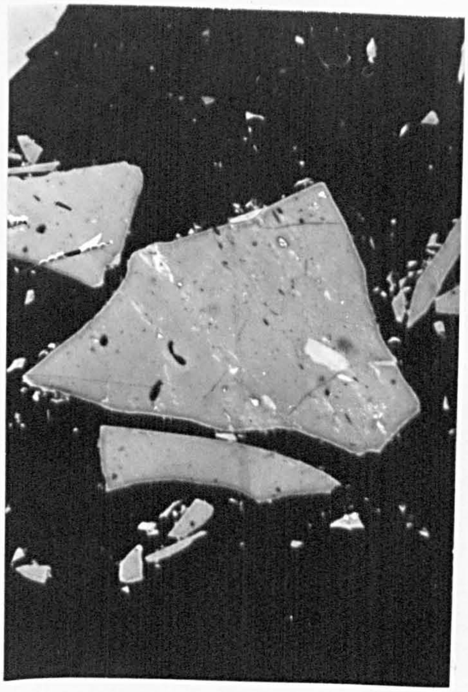
(b) 16 weeks, plane-polarised light

(c) 32 weeks

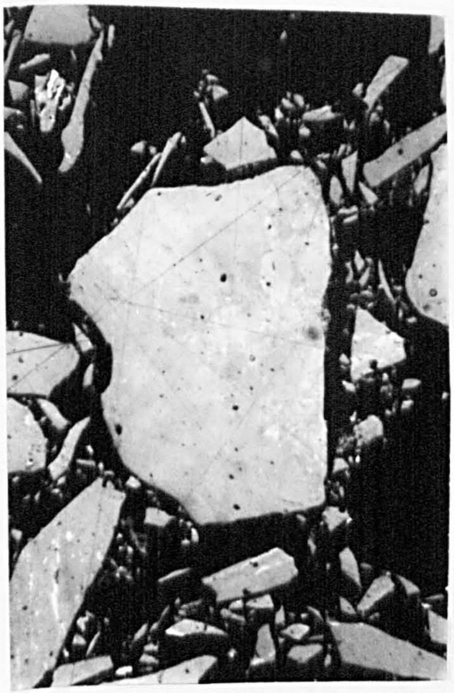
(i) plane-polarised light

(ii) crossed polars

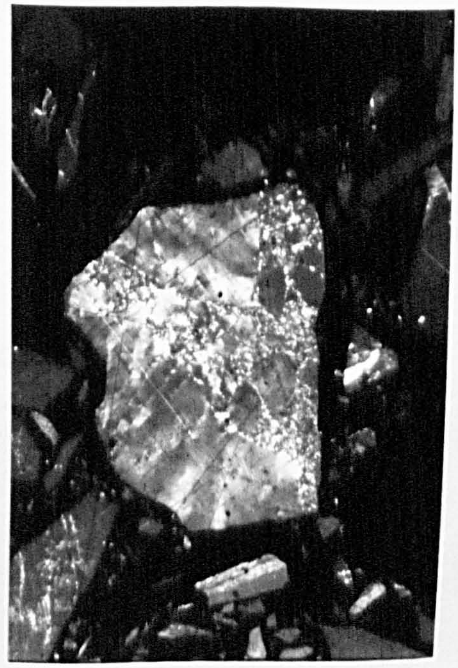
(a)



(b)



(c) (i)



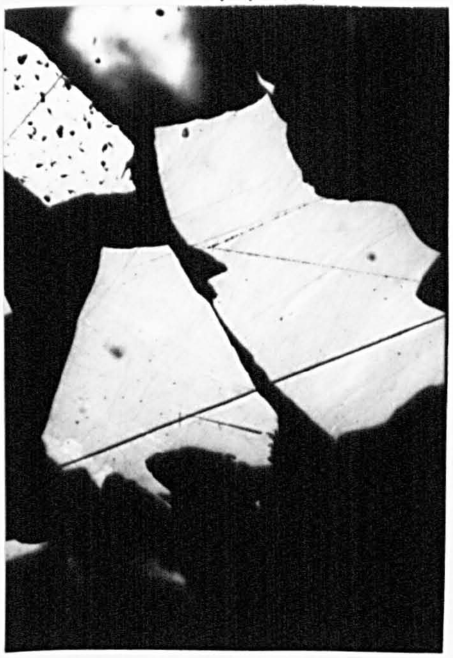
(c) (ii)

Plate 71 Anthracitic vitrinite (carbon = 94.2% dmmf) heated at 150°C, x 190

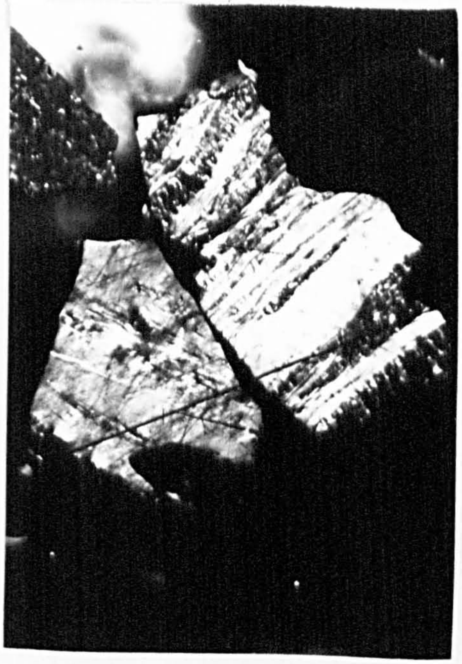
(a) 1 week (i) plane-polarised light (ii) crossed polars

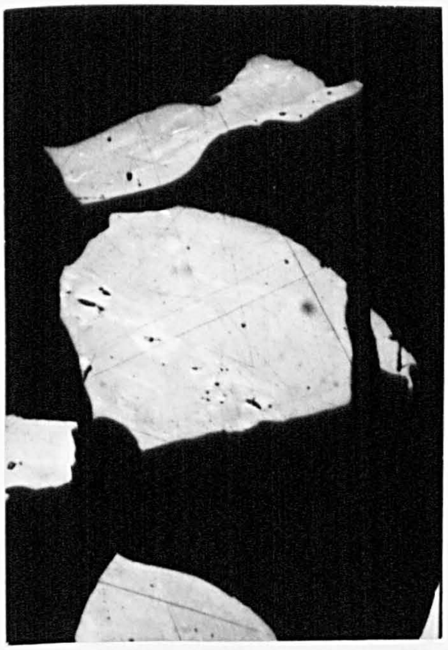
(a) 32 weeks(i) plane-polarised light (ii) crossed polars

(a) (i)

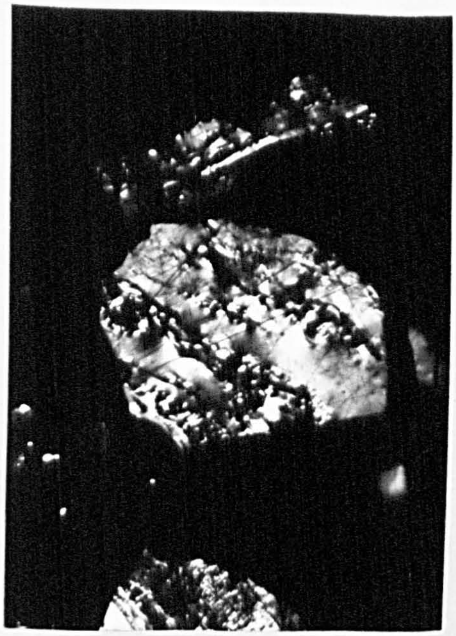


(a) (ii)





(b) (i)



(b) (ii)

Plate 72 Anthracitic vitrinite (carbon = 94.2% dmmf), heated at 350°C, x190

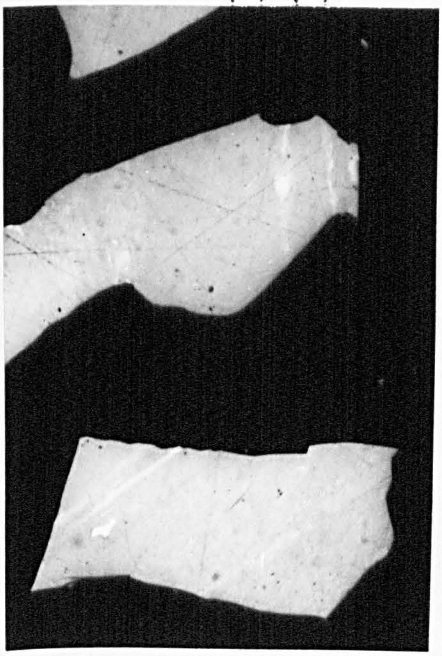
(a) 1 week (i) plane-polarised light

(ii) crossed polars

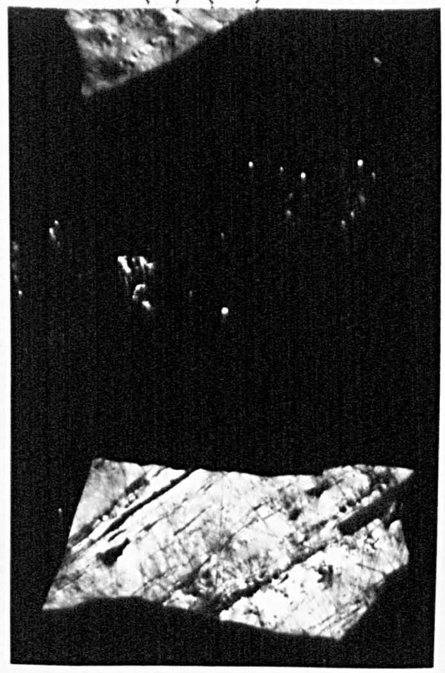
(b) 32 weeks (i) plane-polarised light

(ii) crossed polars

(a) (i)



(a) (ii)



(b) (i)

(b) (ii)

# APPENDIX III OPTICAL PROPERTIES OF CARBONISED SPORINITES

(a) Low-rank sporinite (sporinite: carbon = 83.0% daf)

(i) Fresh (Plate 73a): dark brown, large sporinite particles of ca 30um diameter with reddish-brown colour; some particles are contaminated by inertinite and/or vitrinite: isotropic.

(ii) 300°C similar to fresh sporinite but slight increase in reflectance.

(iii) 400°C (Plate 73b): coherent, vesiculated, cracked; sporinite melts and develops a greyish brown residue: isotropic.

(iv) 450°C (Plate 73c): yellowish white, coherent, vesiculated with development of very fine-grained mosaic texture: anisotropic

(v) 475° - 575°C (Plate 74a): white, creamy white, coherent, vesiculated; fine-grained mosaic texture: anisotropic.

(vi) 600° - 700°C (Plates 74b and 75a): creamy white, coherent, vesiculated; cracked residue showing fine-grained mosaic: anisotropic.

(vii) 750° - 950°C (Plates 75b and 76): creamy white to yellowish white, coherent, vesiculated, cracked; residue shows fine-grained mosaic texture; mosaic units exhibit common orientation: anisotropic

Medium-rank sporinite (sporinite: carbon = 87.1% daf)

(i) Fresh (Plate 77a): brownish grey, sporinite particles contaminated by inertinite and/or vitrinite: isotropic.

(ii) 400°C (Plate 77b): light brown, softened, coherent; cracked and vesiculated residue; inertinite contamination shows yellowish-white colour: isotropic.

(iii) 450°C (Plate 77c): white, coherent with development of large vacuoles; fine to medium-grained mosaic texture: anisotropic.

(iv) 475°-575°C (Plate 78a): white, coherent, with development of large vacuoles of about 100 µm; fine to medium-grained mosaic textures and occasional coarse-grained mosaic at peripheries of vacuoles: anisotropic.

(v) 600°-700°C (Plates 78b and 79a): yellowish-white to creamy, coherent, with development of vacuoles of varied sizes; the number of small vacuoles of ca 5 µm diameter increases; at ca 675°C the sample is riddled with such vacuoles; mainly fine to medium-grained mosaic texture, but coarse-grained mosaic also present.

(vi) 750°-950°C (Plates 79b and 80a and b): creamy-white, coherent, showing strong pleochroism and development of large vacuoles; also small vacuoles of ca 2.5 µm diameter; fine to medium-grained mosaic, but amount of coarse-grained mosaic at peripheries of vacuoles increases; coarse-grained mosaic displays flow-type pattern; mosaic units show common orientation.

Plate 73 Fresh and carbonised residues of sporinite from low-rank bituminous coal (sporinite : carbon = 83.0% daf), x 195

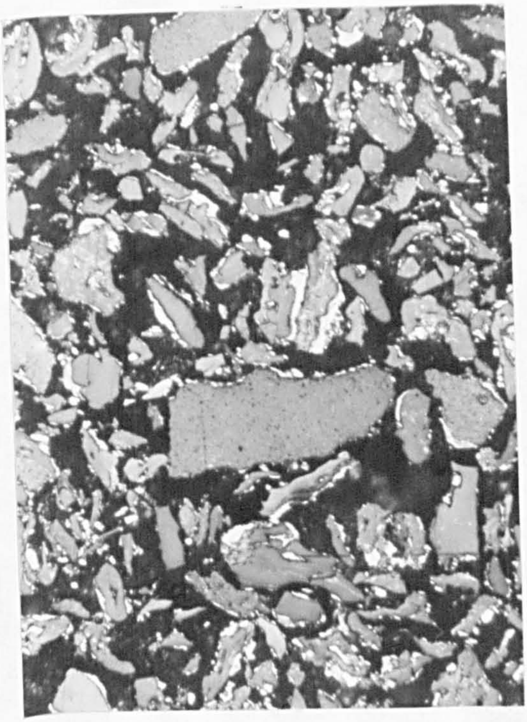
(a) fresh sporinite, plane-polarised light

(b) 400°C, plane-polarised light

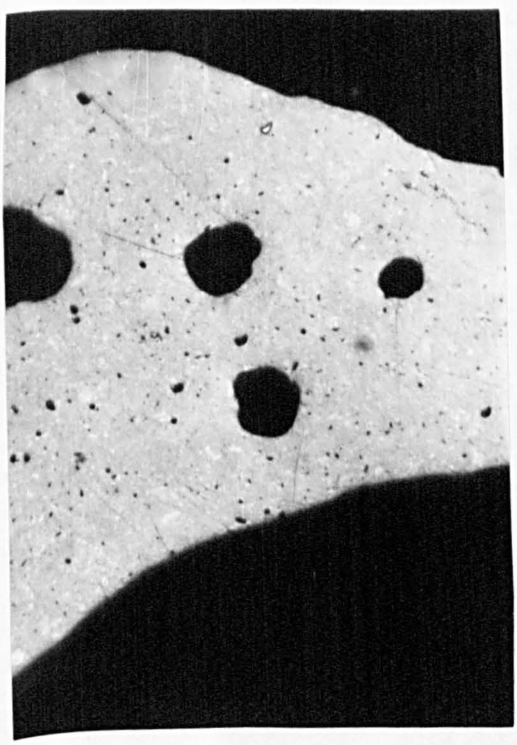
(c) 450°C, (i) plane-polarised light

(ii) crossed polars

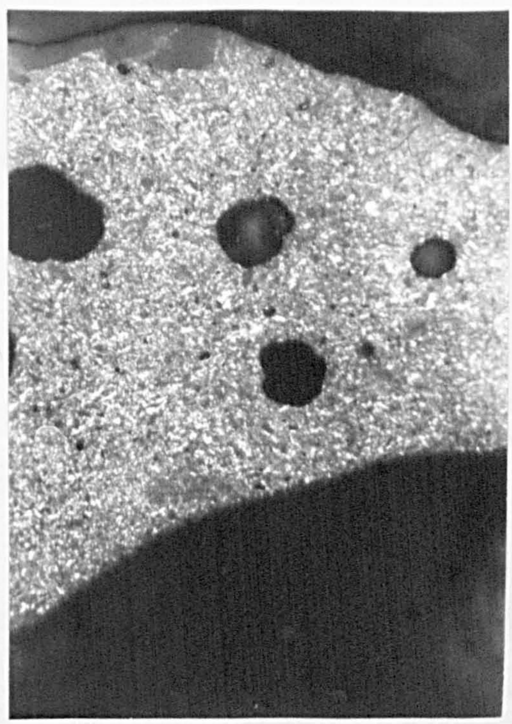
(a)



(b)



(c) (i)



(c) (ii)

Plate 74 Sporinite from low-rank bituminous coal (sporinite: carbon = 83.0% daf) carbonised at x195

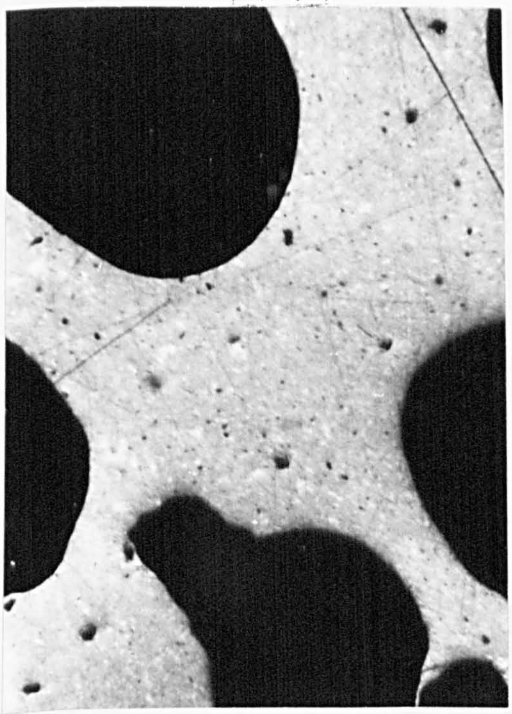
(a) 500°C (i) plane-polarised light

(ii) crossed polars

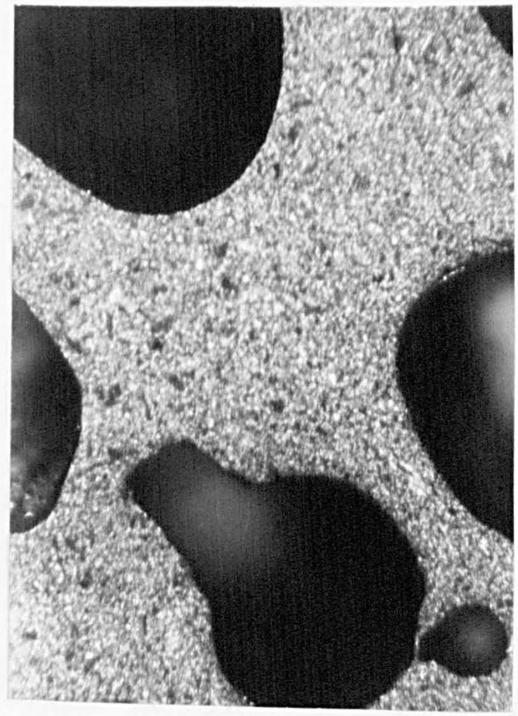
(b) 600°C (i) plane-polarised light

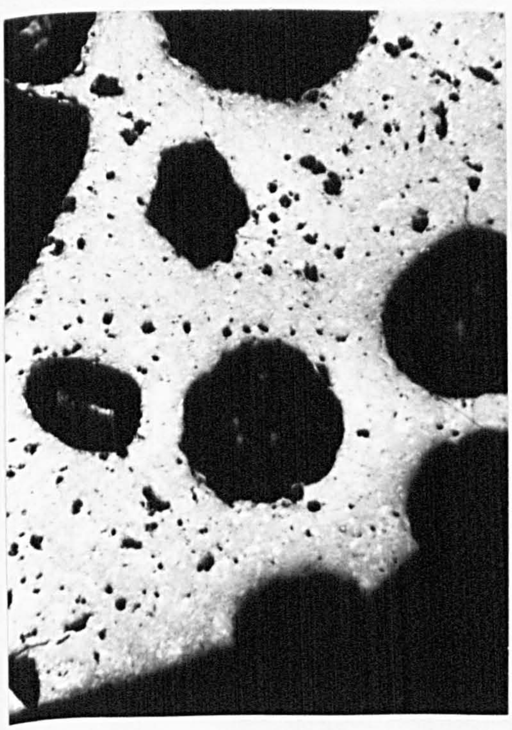
(ii) crossed polars

(a) (i)

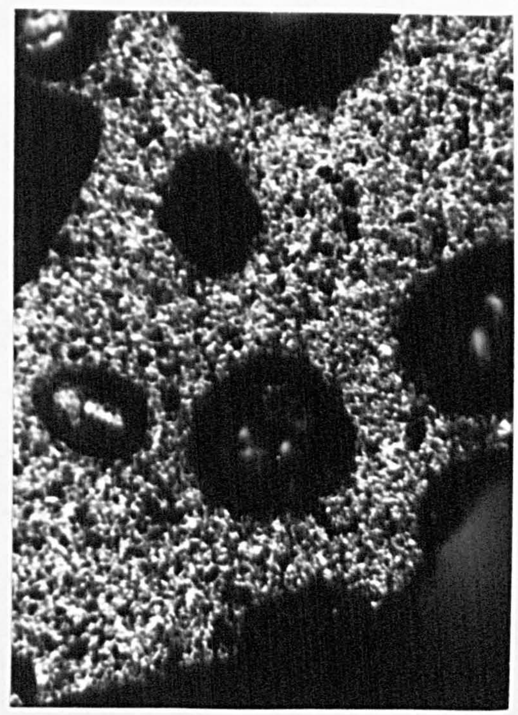


(a) (ii)





(b) (i)



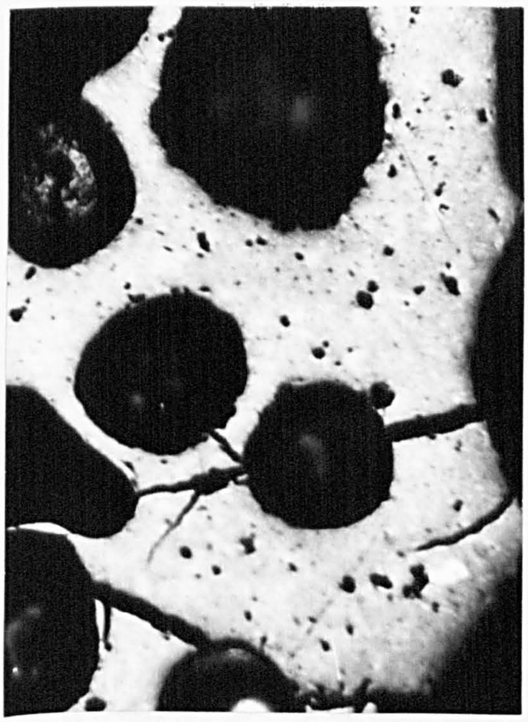
(b) (ii)

Plate 75 Sporinite from low-rank bituminous coal (sporinite: carbon = 83.0% daf) carbonised at x195

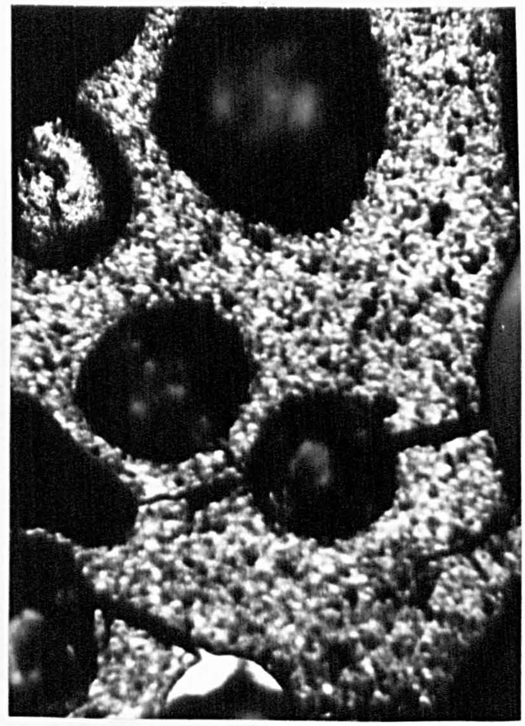
(a) 700°C (i) plane-polarised light
(ii) crossed polars

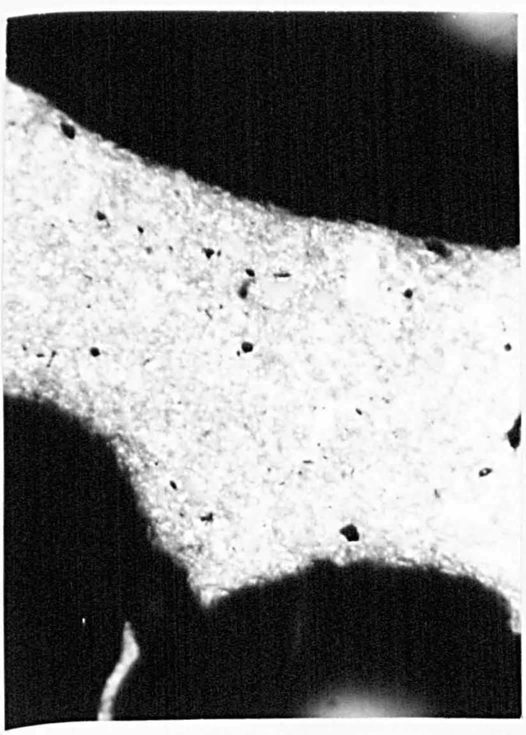
(b) 800°C (i) plane-polarised light
(ii) crossed polars

(a) (i)

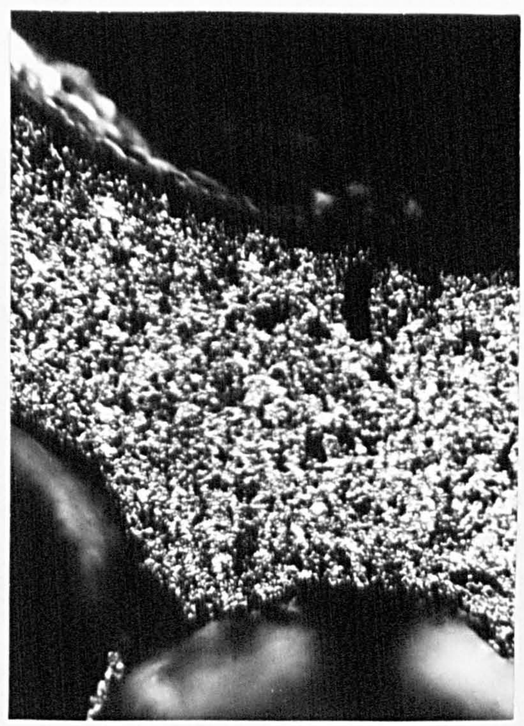


(a) (ii)





(b) (i)



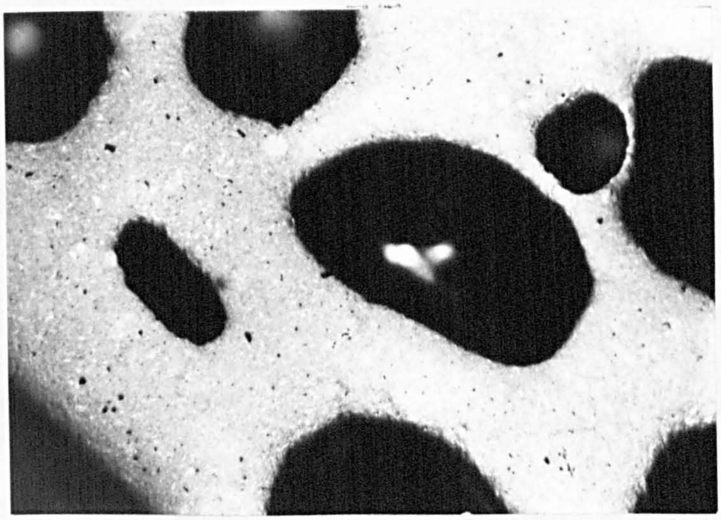
(b) (ii)

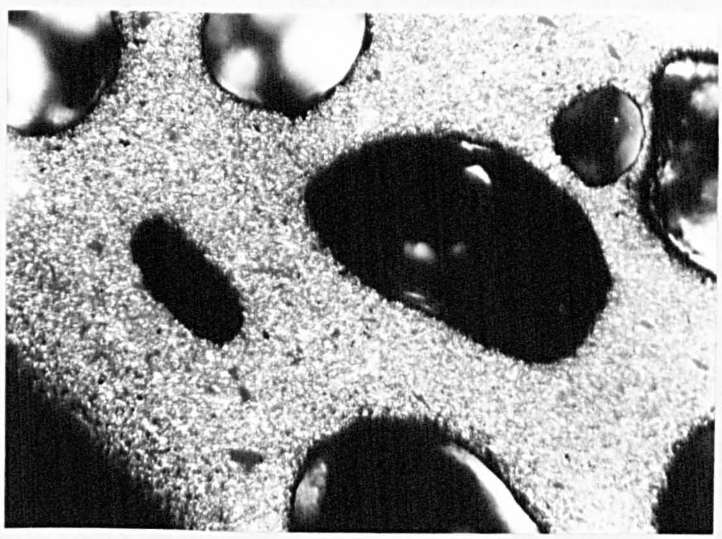
Plate 76 Sporinite from low-rank bituminous coal (sporinite: carbon = 83.0% daf), carbonised at 900°C, x 190

(i) plane-polarised light

(ii) crossed polars

(i)





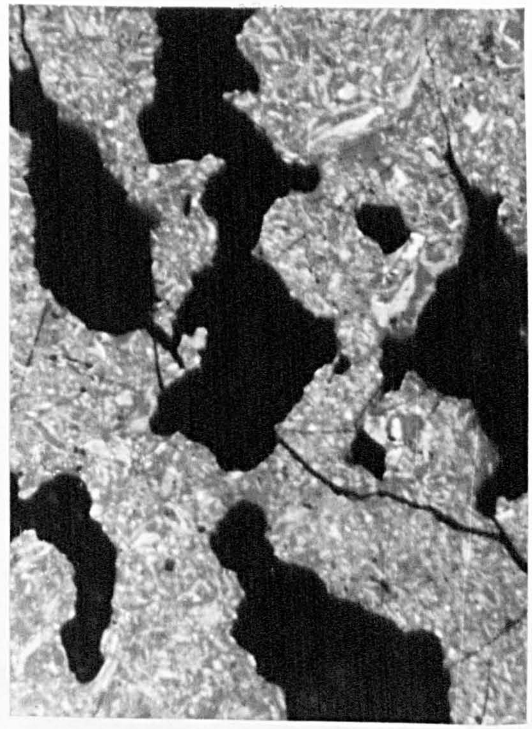
(ii)

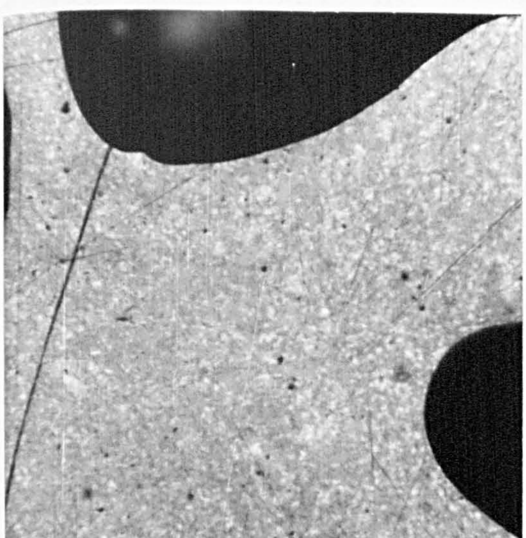
Plate 77 Fresh and carbonised residues of sporinite from medium-rank, bituminous coal (sporinite: carbon = 87.1% daf), carbonised at x195

(a) fresh, plane-polarised light
(b) 400°C, plane-polarised light
(c) 450°C (i) plane-polarised light
(ii) crossed polars

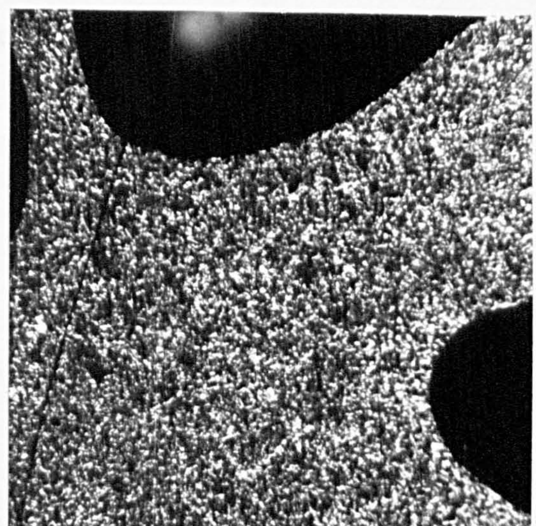
(a)

(b)





(c) (i)



(c) (ii)

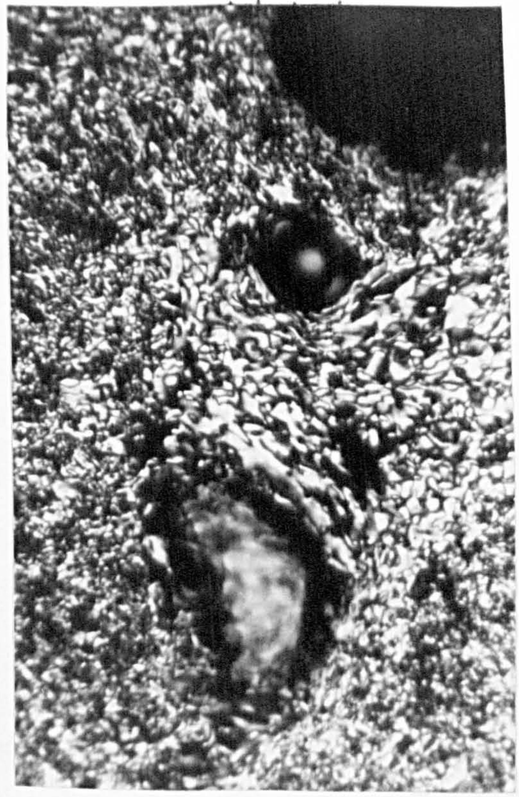
Plate 78 Medium-rank sporinite (carbon = 87.1% daf) carbonised at x580

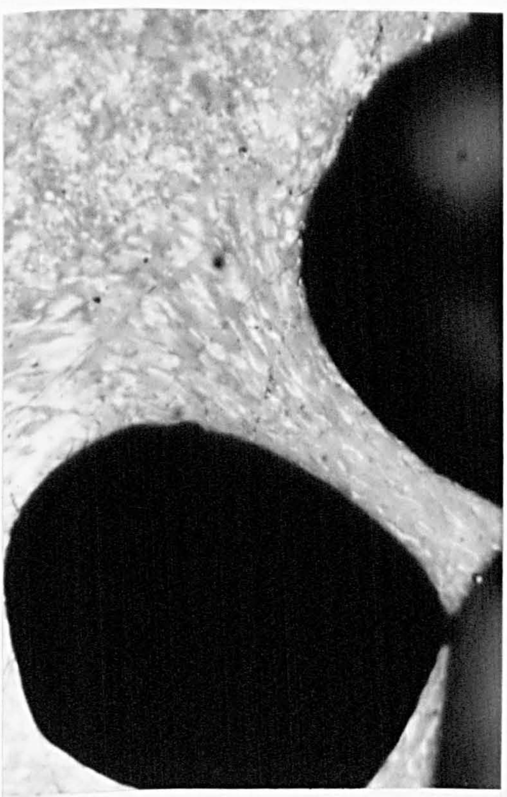
(a) 500°C (i) plane-polarised light (ii) crossed polars

(b) 600°C (i) plane-polarised light (ii) crossed polars

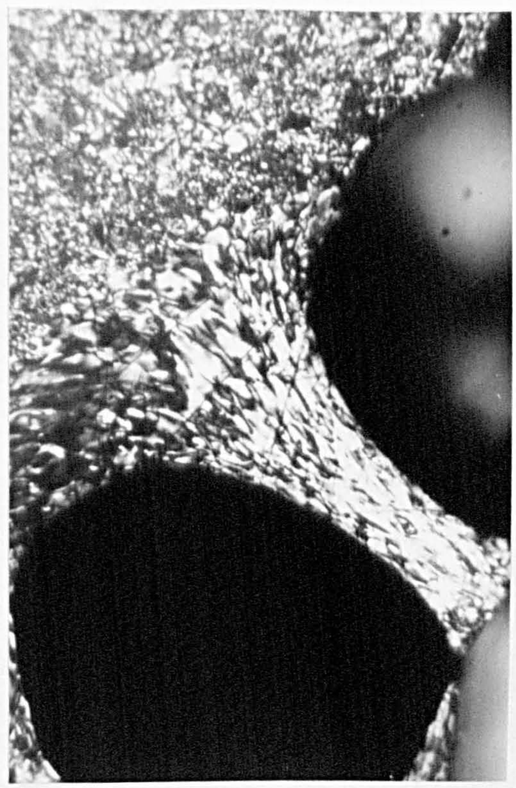
(a) (i)

(a) (ii)





(b) (i)



(b) (ii)

Plate 79 Sporinite from medium-rank coal (sporinite: carbon = 87.1% daf) carbonised at x580

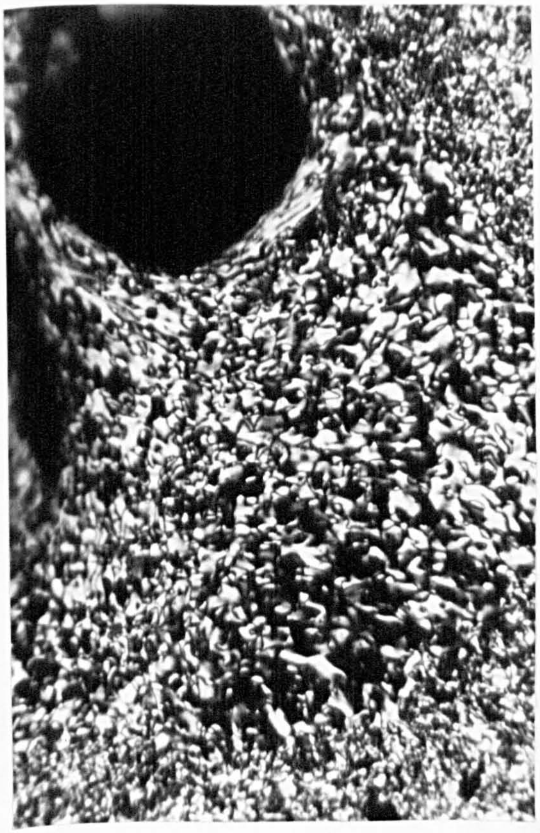
(a) 700°C, crossed polars

(b) 750°C, crossed polars

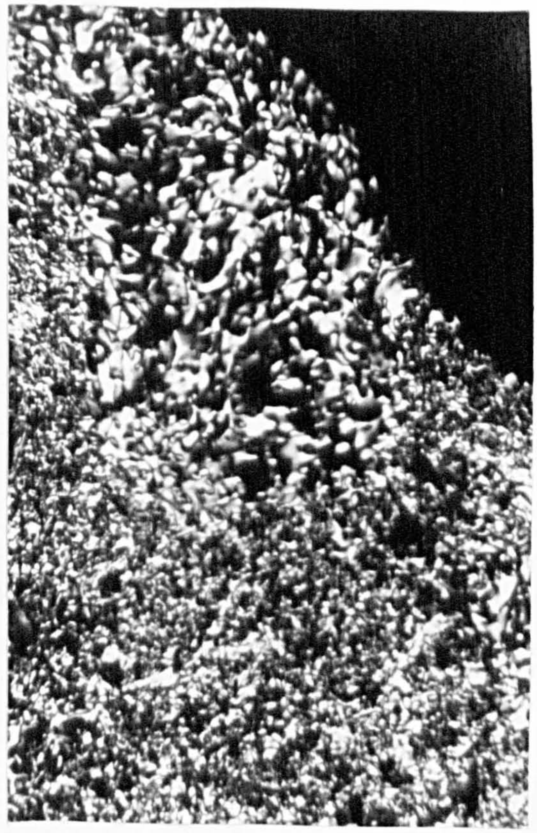
(c) 800°C, (i) plane-polarised light

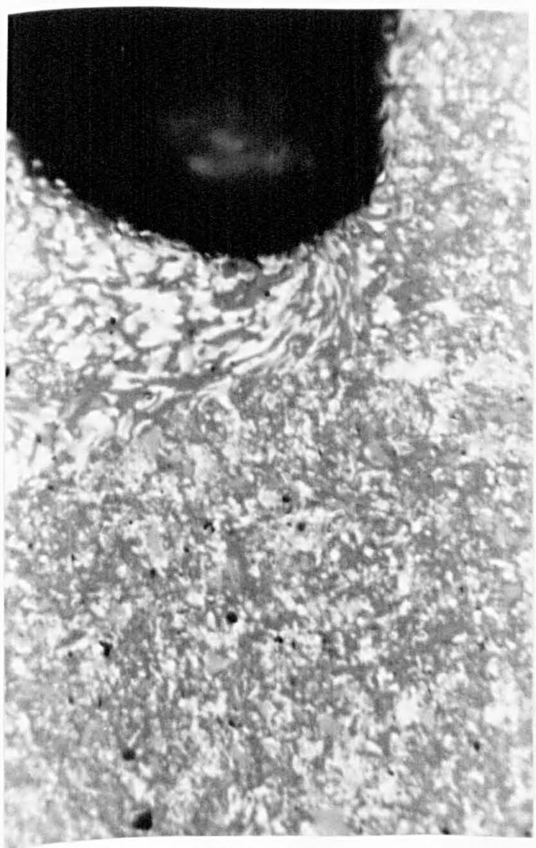
(ii) crossed polars

(a)

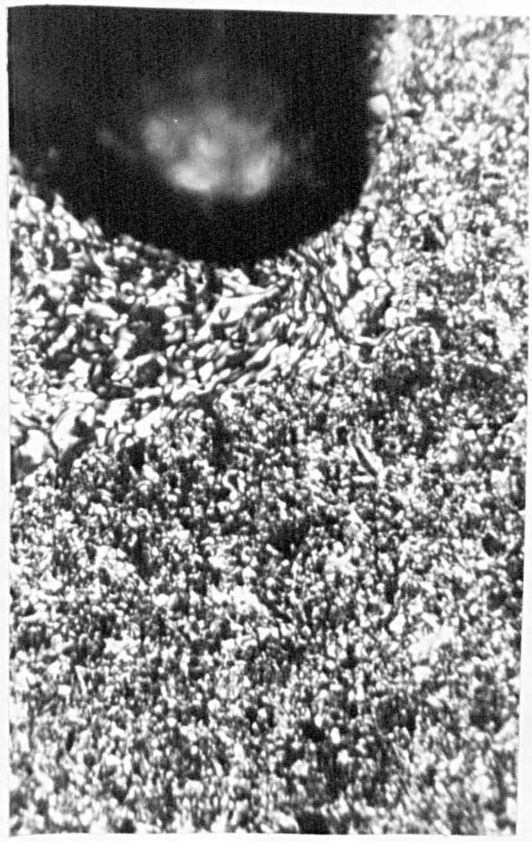


(b)





(c) (i)



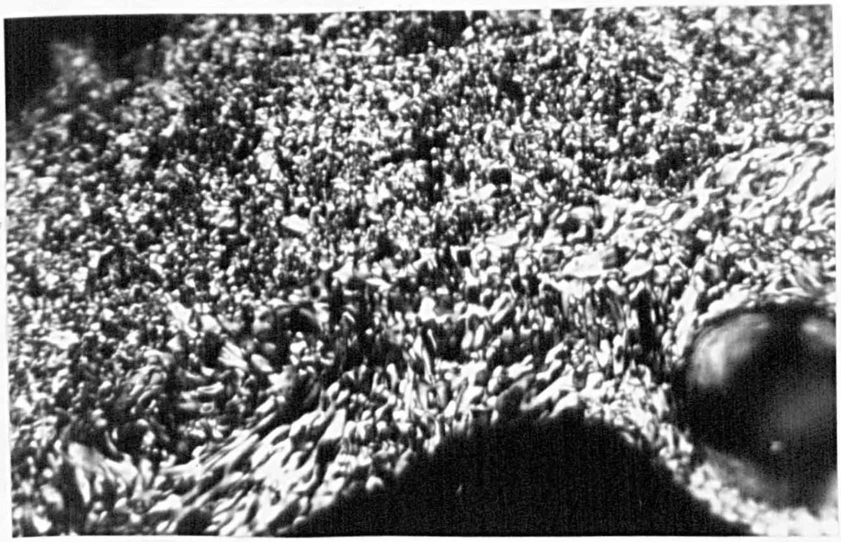
(c) (ii)

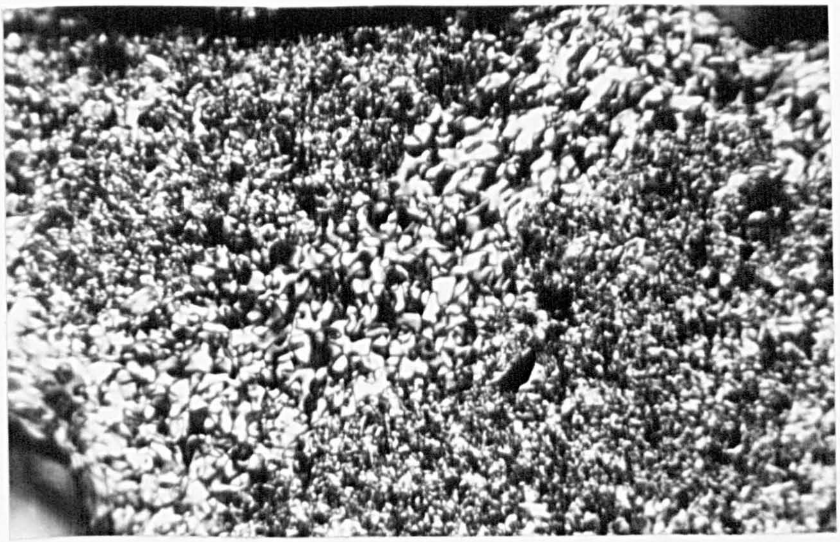
Plate 80 Sporinite from medium-rank coal (sporinite: carbon = 87.1% daf) carbonised at x560

(a) 850°C, crossed polars

(b) 900°C, crossed polars

(a)





(b)

## APPENDIX IV. OPTICAL PROPERTIES OF CARBONISED MIXTURES OF SPORINITES AND VITRINITES OF DIFFERENT RANK.

(a) Low-rank blend (vitrinite: carbon = 79.6% daf)

(i) Fresh Vitrinite (Plate 81a): dark grey mainly structureless colinite, but some particles exhibit cell structure: isotropic.

(ii) 300°C : non-coherent, residues; individual particles of sporinite and/or vitrinite essentially similar to fresh macerals, except becoming slightly brighter: isotropic.

(iii) 400°C (Plate 81b): coherent, vesiculated, cracked residue; vitrinite particles (light-grey) cemented to one another by softened sporinite residue; vitrinite develops vesicles of ca 5 μm diameter; softened sporinite forms greyish to brown homogeneous pitch in some areas, but commonly sporinite heavily contaminated by inertinite; inertinite shows higher reflectivity; vitrinite particles retain original angular shape, only becoming slightly subangular: both macerals isotropic.

(iv) 450°C (Plate 81c): coherent, vesiculated; the vitrinite keeps original angular identity, developing vesicles frequently up to 15 um diameter; isotropic light grey vitrinites cemented to one another by anisotropic, yellowish white sporinite; large irregular vacuoles develop from sporinite, the irregularity due to the position of vitrinite particles in the mixture; sporinite develops fine-grained mosaic structure.

(v) 500°-575°C (Plate 82a): coherent sporinite (yellowish white) shows granular structure, whereas vitrinite (whitish-grey) displays a homogeneous surface, developing vesicles of up to 15 u m diameter: large irregular vacuoles develop in sporinite; sporinite residues are fine-grained and anisotropic, whereas vitrinite particles retain their original angular shape and are isotropic; differentiation between the two residues becomes increasingly difficult under polarised light with rise of temperature.

(iv) <u>$600^{o}$-$700^{o}$C (Plates 82b and c, 83a):</u> creamy white, coherent; vesiculated isotropic particles develop small vacuoles up to 5 um diameter; vitrinite still retains original angular shape with particles cemented to one another by granular sporinite.

(vii) <u>$750^{o}$-$950^{o}$C (Plates 83b and 84):</u> coherent vesiculated vitrinite (creamy-white) still shows original angular shape and/ or becomes slightly subangular; occasional development of vacuoles of up to 5 um diameter, whereas sporinite residue (yellowish-white) shows ganular mosaic; vitrinite only slightly anisotropic.

(b) <u>Medium-rank blend (vitrinite: carbon = 86.6% daf)</u>

(i) <u>Fresh Vitrinite (Plate 85a):</u> light gray, uniform, structureless vitrinite; no cellular structure visible: weakly anisotropic.

(ii) <u>$400^{o}$C (Plate 85b):</u> softened, coherent, vesiculated and cracked residue, with vitrinite (light grey) and sporinite (dark grey) softened; sporinite forms isotropic pitch which cements vitrinite particles together; development of vacuoles in sporinite; neither vitrinite nor sporinite develop granular mosaic structure: isotropic.

(iii) <u>450°C (Plate 85c):</u> coherent, vesiculated residue; both vitrinite and sporinite develop granular mosaic texture; sporinite shows fine to medium-grained mosaic texture, vitrinite only a very fine-grained mosaic and even some particles isotropic; some isotropic vitrinite interacts with sporinite and develops a fine-grained mosaic at peripheries of particles; size of granular mosaic units decreases from sporinite towards vitrinite.

(iv) <u>500°-575°C (Plate 86a):</u> coherent residue with vacuoles up to 80 um diameter; vitrinite develops white to creamy homogeneous appearance; still partially isotropic, whereas sporinite (yellowish-white to creamy-white) develops fine to medium-grained mosaic and is anisotropic: small particles of vitrinite develop fine granular mosaic and are anisotropic.

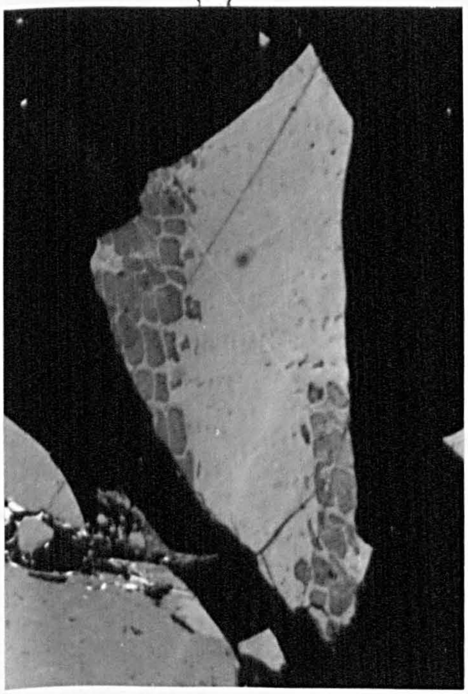
(v) <u>600°-700°C (Plates 86b and c):</u> coherent vesiculated residue; interaction between sporinite and vitrinite increases, but isotropic vitrinite still present; some vitrinite particles lose original angular shape and are completely converted to fine granular mosaic to produce a homogeneous residue with surrounding sporinite; degree of anisotropy of vitrinite residue is less than that of sporinite; some vitrinite shows strong anisotropy at vacuole peripheries; interaction between sporinite and vitrinite becomes greater with increase of temperature.

(vi) <u>750°-950°C (Plates 87 to 89):</u> coherent vesicles up to 20 um diameter; vitrinite (creamy-yellow to creamy-white) mainly develops small vacuoles of up to 5 um diameter, but occasional vitrinite particles keep their original identity, remaining partially isotropic, although majority of particles are granular and develop strong anisotropy; intensity of anisotropy and size of granular mosaic decreases from sporinite towards vitrinite; interaction between vitrinite and sporinite increases with temperature and the number of vitrinite particles showing granular anisotropy increases rapidly at about 850°C with the anisotropy of vitrinite approaching that of sporinite; the intensity of anisotropy of some vitrinite particles increases without developing mosaic texture, but the majority of vitrinite particles develop granular mosaic and high anisotropy.

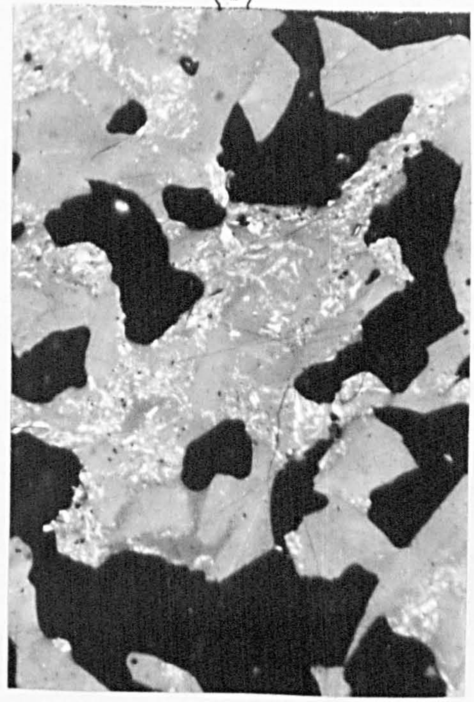
Plate 81 Fresh vitrinite and mixture of sporinite and vitrinite from low-rank bituminous coal (vitrinite: carbon = 79.6% daf), carbonised at x195

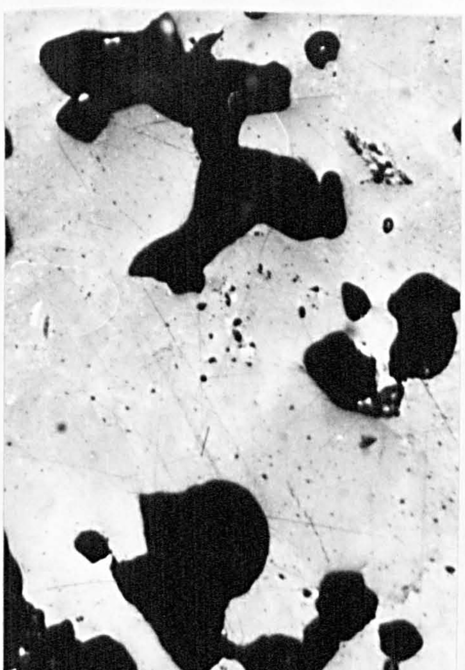
(a) fresh vitrinite, plane-polarised light
(b) 400°C, plane-polarised light
(c) 450°C, (i) plane-polarised light
(ii) crossed polars

(a)

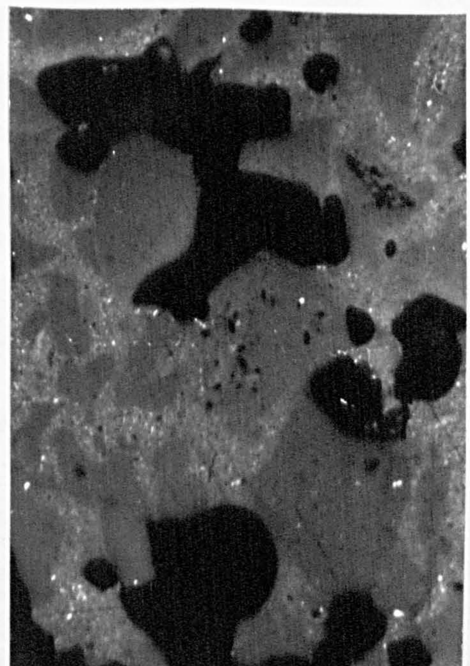


(b)





(c) (i)



(c) (ii)

Plate 82 Mixture of sporinite and vitrinite from low-rank bituminous coal (vitrinite: carbon = 79.6% daf) carbonised at x195

(a) 500°C (i) plane-polarised light

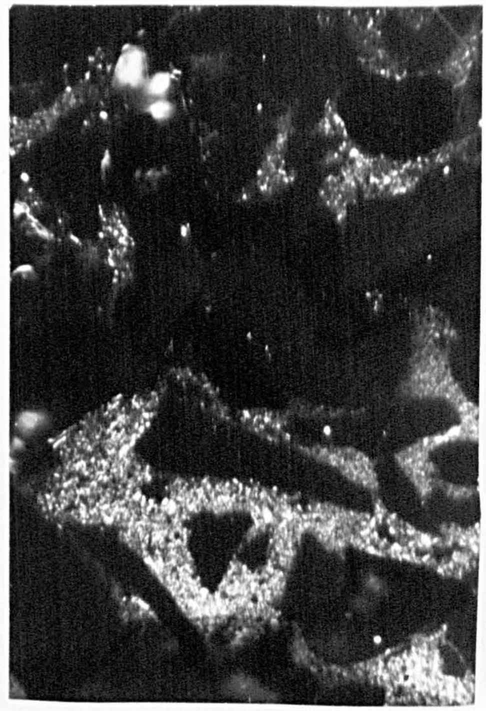
(ii) crossed polars

(b) 600°C (i) plane-polarised light

(ii) crossed polars

(a) (i)

(a) (ii)



(b) (i)

(b) (ii)

Plate 83 Mixture of sporinite and vitrinite from low-rank bituminous coal (vitrinite: carbon = 79.6% daf), carbonised at x195

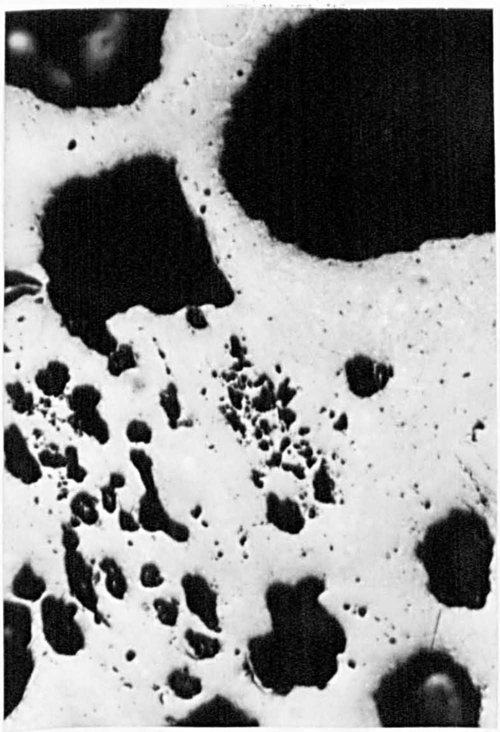
(a) 700°C (i) plane-polarised light

(ii) crossed polars

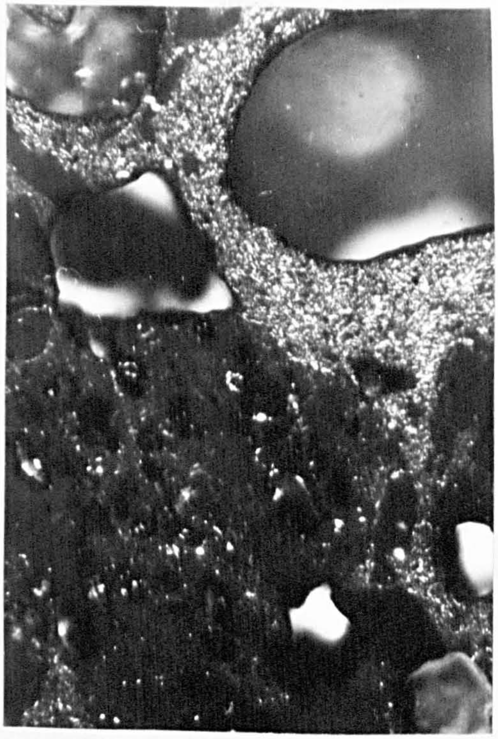
(b) 800°C (i) plane-polarised light

(ii) crossed polars

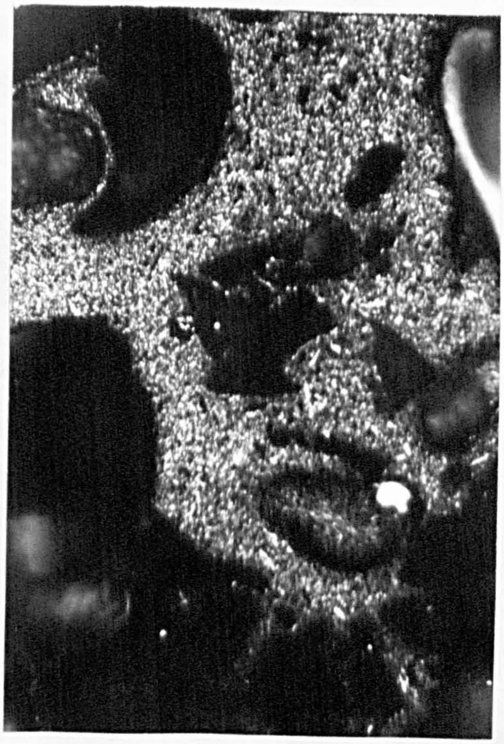
(a) (i)



(a) (ii)



(b) (i)



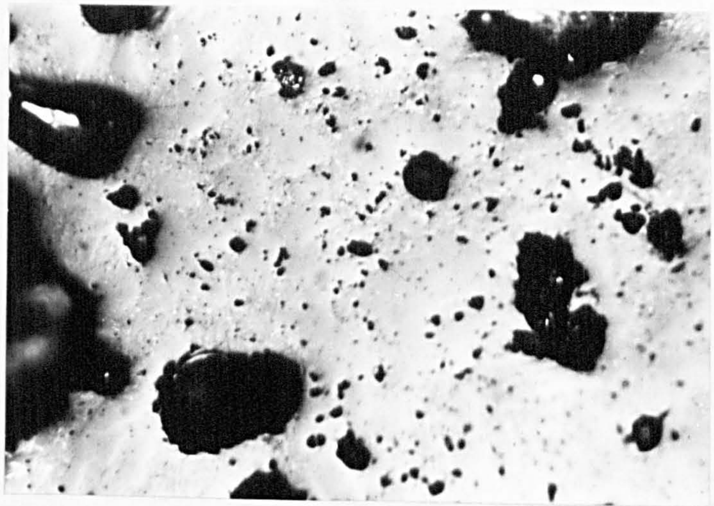
(b) (ii)

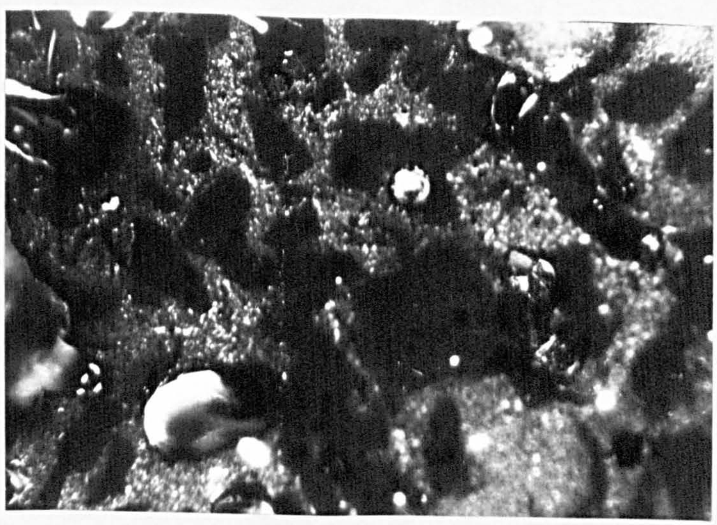
Plate 84 Mixture of sporinite and vitrinite from low-rank bituminous coal (vitrinite: carbon = 79.6% daf), carbonised at 900°C, x195

(i) plane-polarised light

(ii) crossed polars

(i)





(ii)

Plate 85 Fresh vitrinite and mixture of sporinite and vitrinite from medium-rank bituminous coal (vitrinite: carbon = 86.6% daf), x195

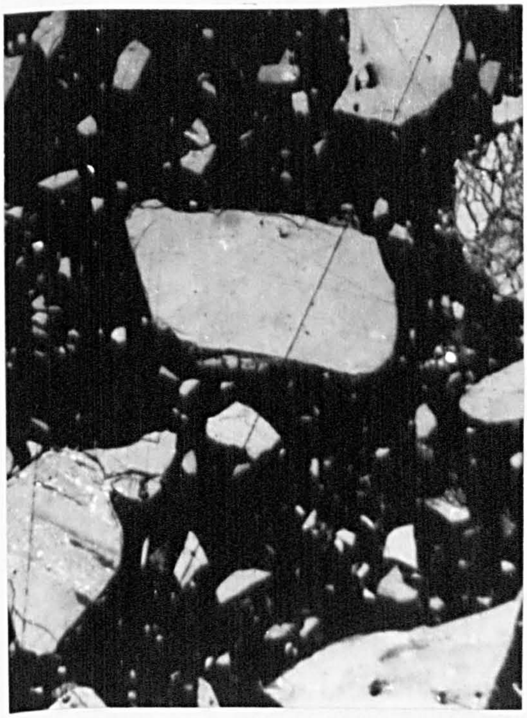
(a) fresh vitrinite, plane-polarised light

(b) 400°C, plane-polarised light

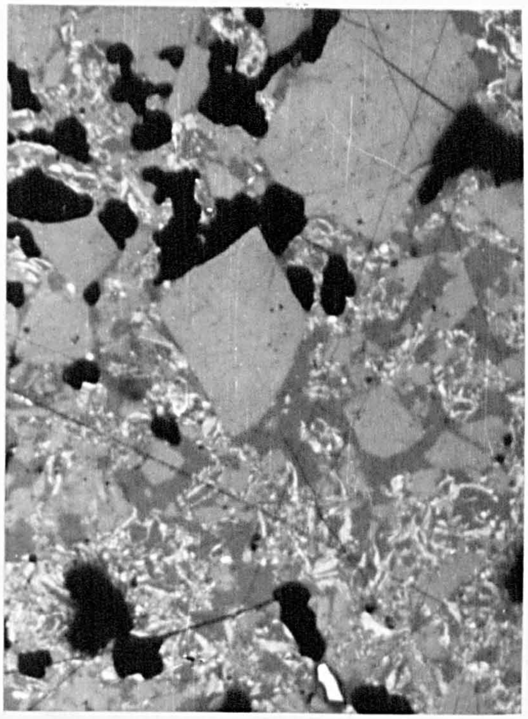
(c) 450°C, (i) plane-polarised light

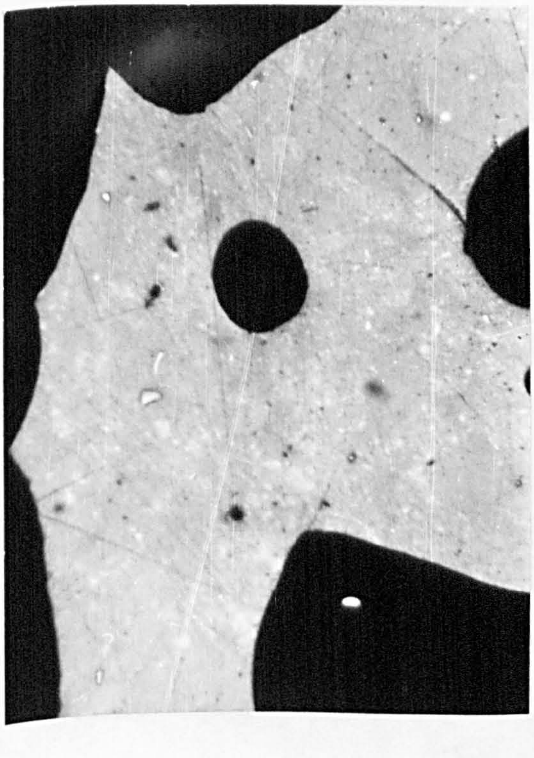
(ii) crossed polars

(a)

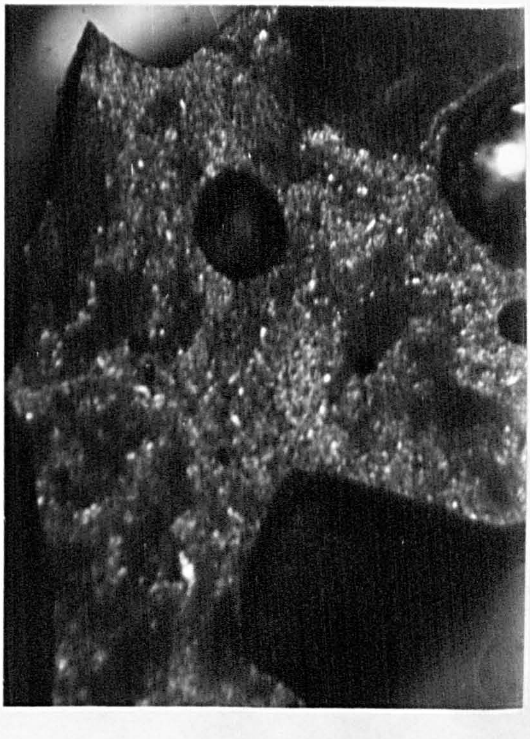


(b)





(c) (i)



(c) (ii)

Plate 86 Mixture of sporinite and vitrinite from medium-rank bituminous coal (vitrinite: carbon = 86.6% daf), carbonised at x530

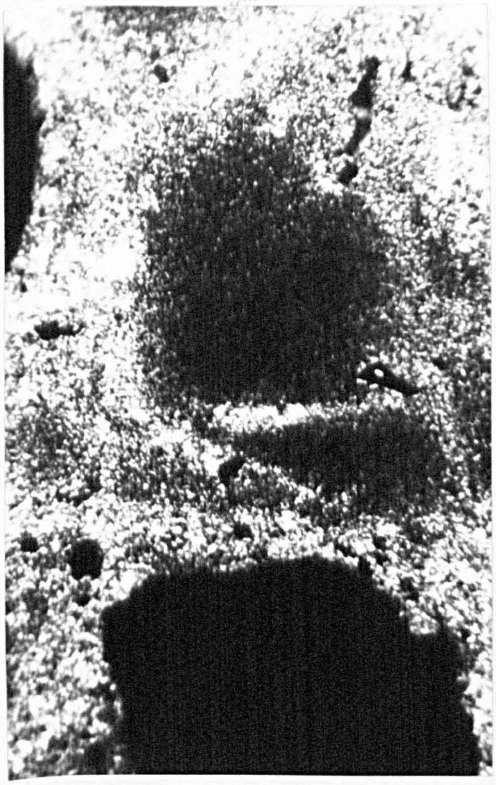
(a) 500°C, crossed polars

(b) 600°C, crossed polars

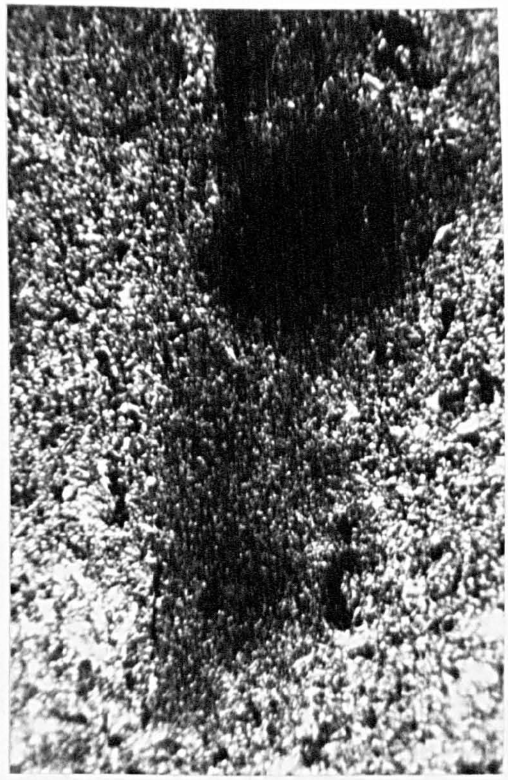
(c) 700°C, (i) plane-polarised light

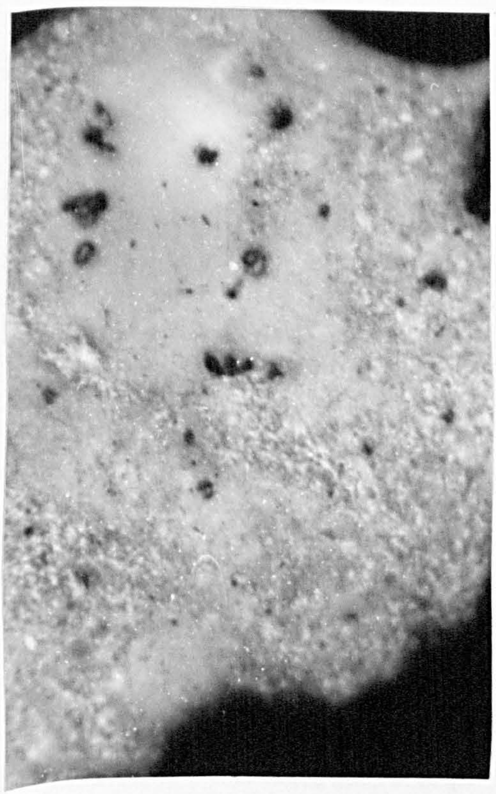
(ii) crossed polars

(a)



(b)





(c) (i)

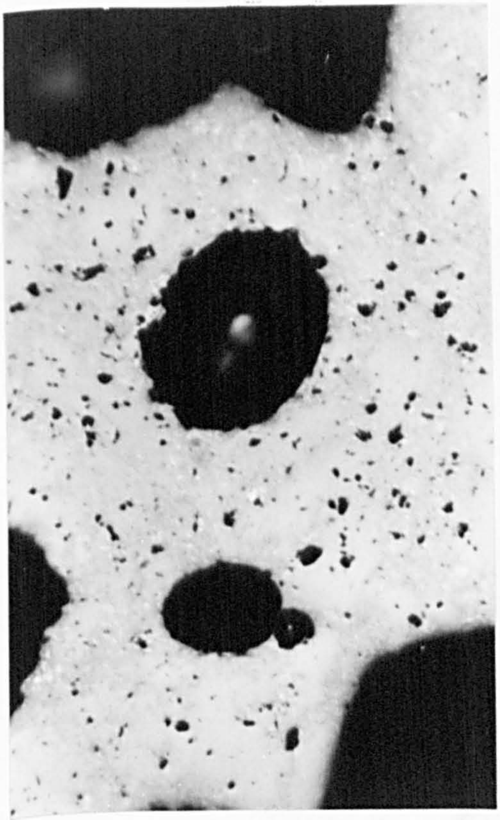
(c) (ii)

Plate 87 Mixture of sporinite and vitrinite from medium-rank bituminous coal (vitrinite: carbon = 86.6% daf), carbonised at x570

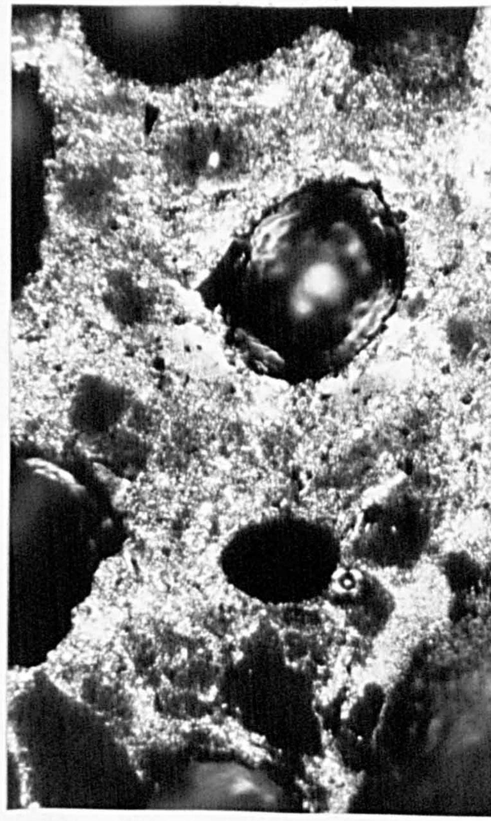
(a) 750°C (i) plane-polarised light
(ii) crossed polars

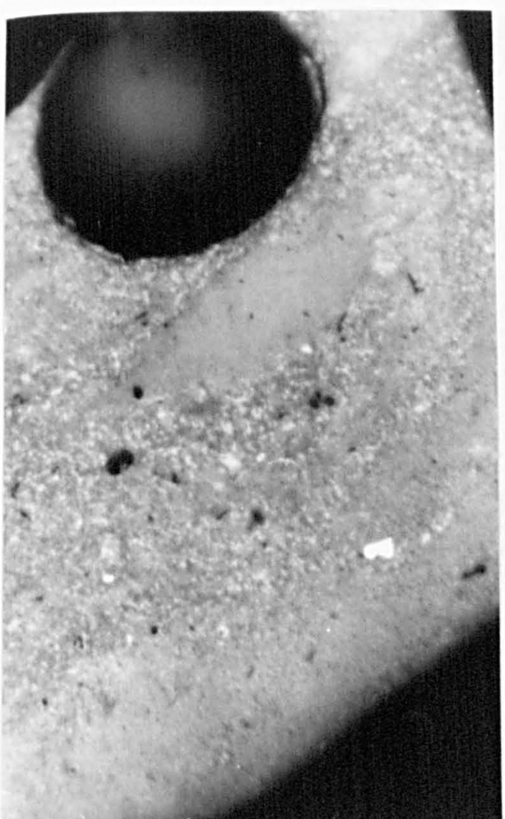
(b) 800°C (i) plane-polarised light
(ii) crossed polars

(a) (i)

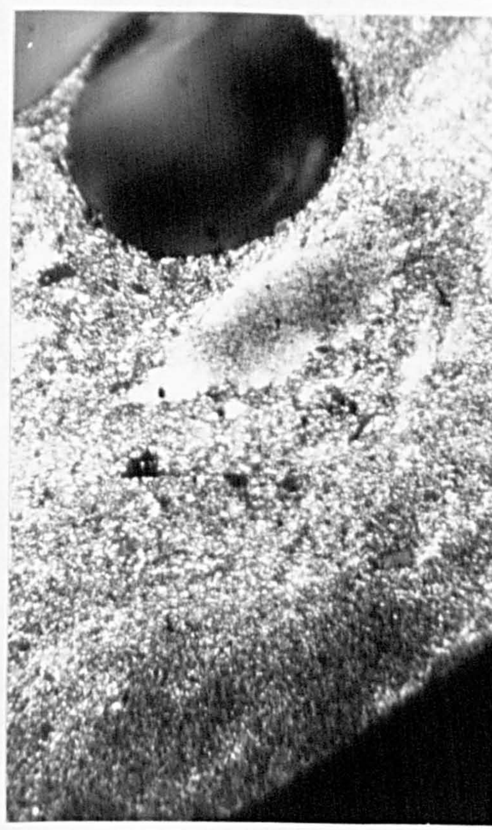


(a) (ii)





(b) (i)



(b) (ii)

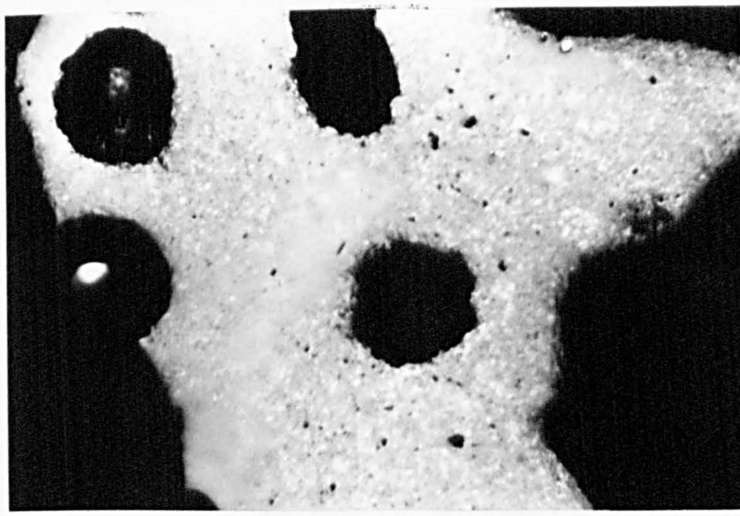
Plate 88 Mixture of sporinite and vitrinite from medium-rank bituminous coal (vitrinite: carbon = 86.6% daf), carbonised at

(a) 850°C (i) plane-polarised light, x200

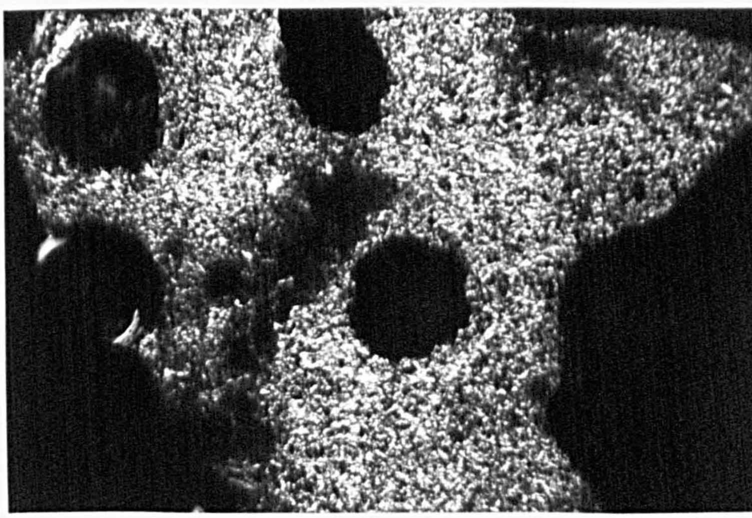
(ii) crossed polars, x200

(b) 900°C crossed polars, x540

(a)(i)



(a) (ii)



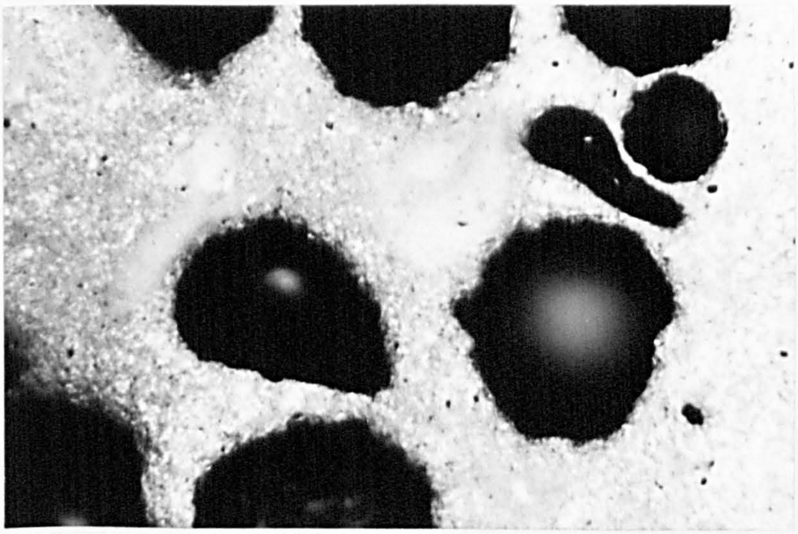
(b)

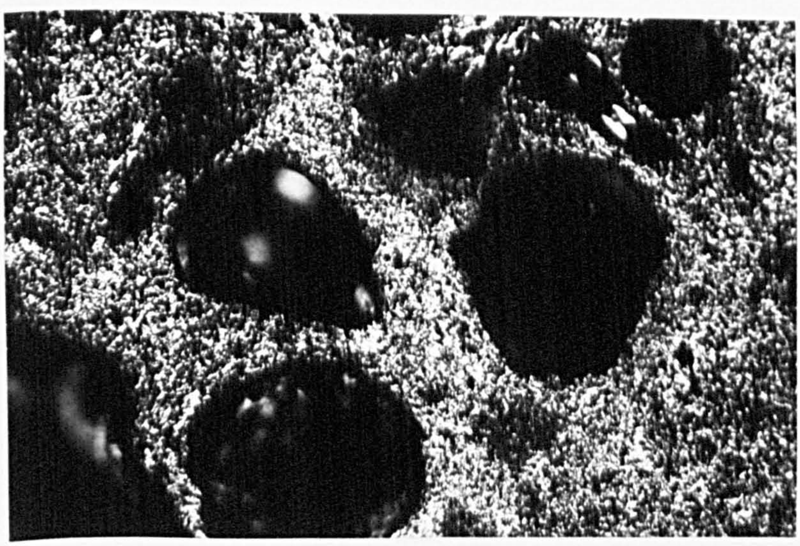
Plate 89 Mixture of sporinite and vitrinite from medium-rank bituminous coal (vitrinite: carbon = 86.6% daf), carbonised at 950°C, x220

(i) plane-polarised light

(ii) crossed polars

(i)





(ii)

## APPENDIX V. OPTICAL PROPERTIES OF VITRINITES CARBONISED AT DIFFERENT PRESSURES OVER RANGE OF TEMPERATURES.

(a) <u>Low-pressure runs</u>

(i) <u>3000 psi (Plates 91 and 92):</u> vitrinite becomes isotropic at ca. 400°C; vitrinite anisotropy increases only slightly to a lower level than that for fresh vitrinite up to 500°C; reflectivity generally rises also, but vitrinite remains essentially structureless; between 500° and 550°C the vitrinite enters the softening phase, producing mosaic which increases in size to become coarse-grained to flow-type at 600°C; devolatilisation, evidenced by vacuoles, occurs between 550° and 600°C.

(ii) <u>5000 psi (Plates 93 and 94):</u> samples only remain almost isotropic up to 450°C, the reflectivity rising; decomposition occurs between 450° and 500°C with a mosaic developing ; by 500°C devolatilisation has occurred and the mosaic structure gradually becomes coarse-grained up to 600°C.

(b) <u>Runs starting at 23000 psi (high pressure) (Plates 95 to 97)</u> original vitrinite structure and its angular identity maintained up to 400°C with slight rise in reflectivity (Plate 95a), but devolatilisation already occurring (see numerous small vacuoles) and the vitrinite almost isotropic at 400°C; at 450°C devolatilisation is more severe and a fine-grained mosaic develops; this mosaic does not increase much in size up to 600°C and is much smaller than in either of the low-pressure runs at any particular temperature.

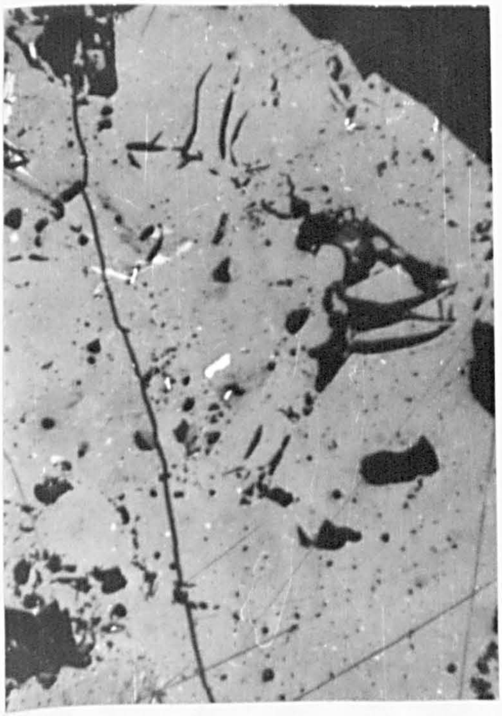
(c) Runs starting at 3000 psi with rising pressure (intermediate pressure)(Plates 98 to 100): vitrinite isotropic at ca. 350°C (14500 psi), becoming only slightly anisotropic at 400°C (18000psi); at 400°C heavy devolatilisation (see vacuoles), but vitrinite not otherwise affected; by 450°C (22000 psi) mesophase develops, partially transformed to mosaic units (Plates 98b, 99a) mosaic then increases a little in size to become fine to medium-grained; with temperature rises some orientation in mosaic which is greater than in runs either at higher or lower pressures; mosaic, however, is coarser at any particular temperature than in high pressure runs.

(d) Carbonisation at atmospheric pressures (Plates 101 to 102): the carbonised residues, after becoming isotropic, indicative of plasticity, partially develop a fine-grained mosaic at 450°C and a fine to medium-grained mosaic between 500°C and 600°C, the orientation of mosaic units becoming more regular with rising of temperature.

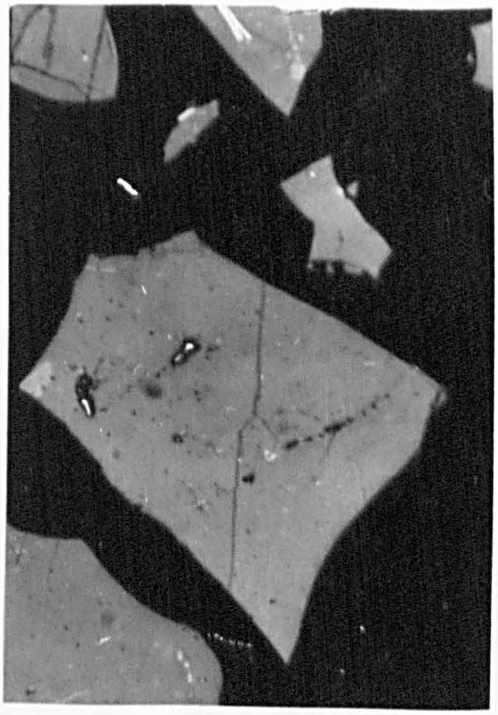
Plate 91 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under pressure of 3000 psi, plane-polarised light, x200

(a) 350°C
(b) 400°C
(c) 450°C
(d) 500°C

(a)



(b)



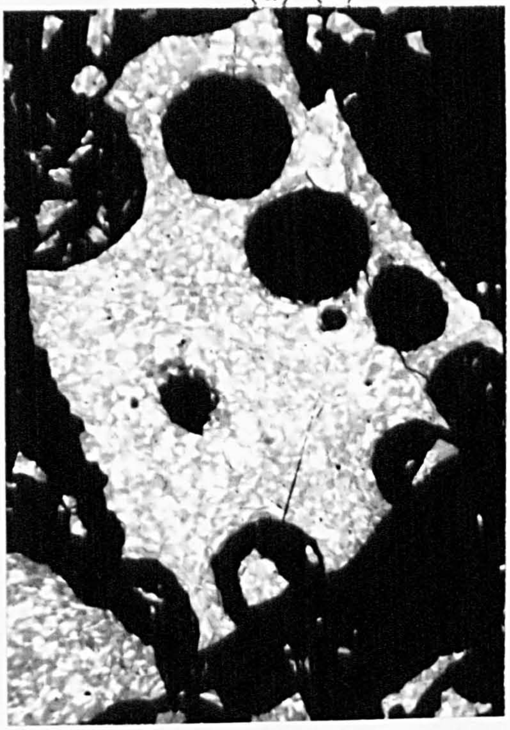
(c)

(d)

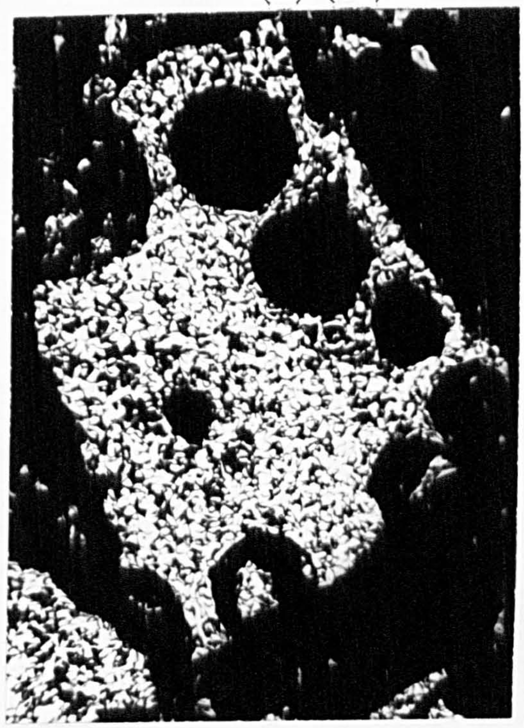
Plate 92 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under pressure of 3000 psi, x205

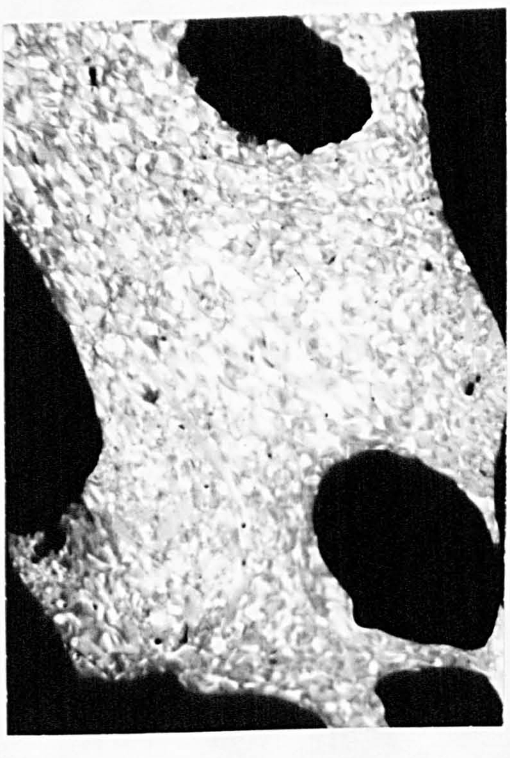
(a) 550°C (i) plane-polarised light
(ii) crossed polars
(b) 600°C (i) plane-polarised light
(ii) crossed polars

(a) (i)

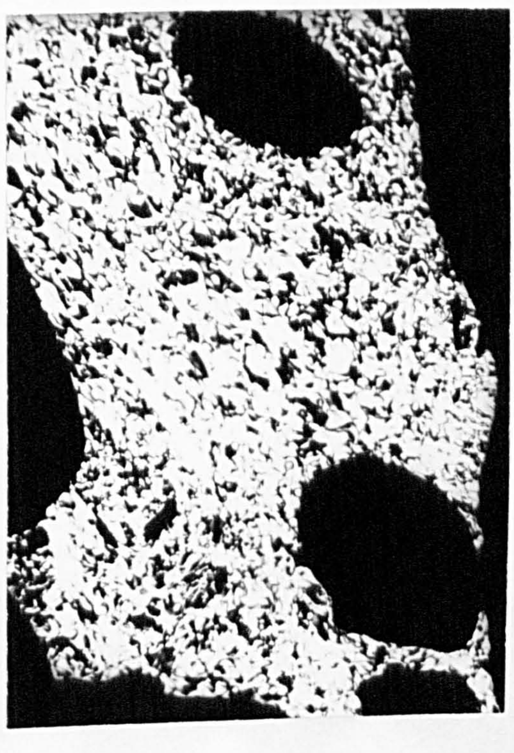


(a) (ii)





(b) (i)

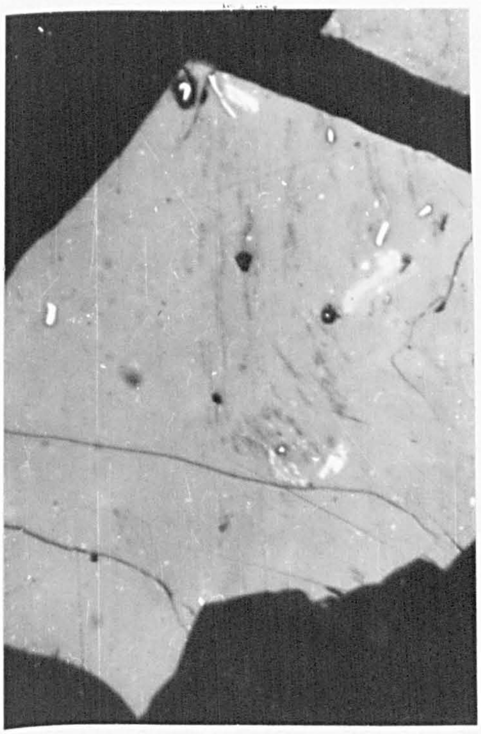


(b) (ii)

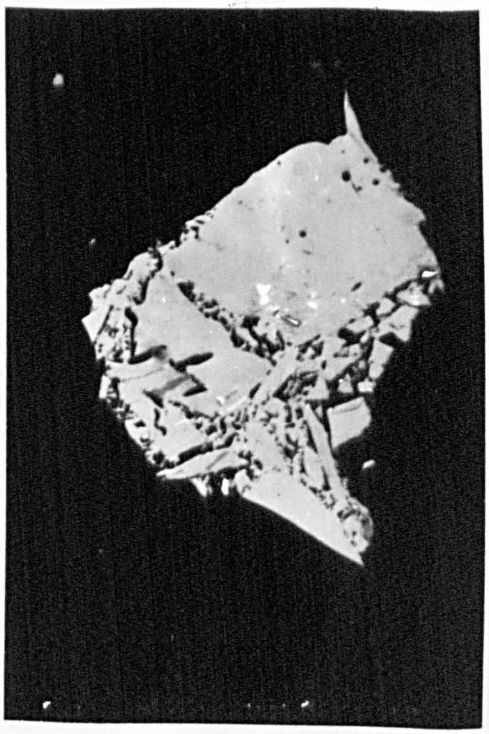
Plate 93 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under pressure of 5000 psi, x200

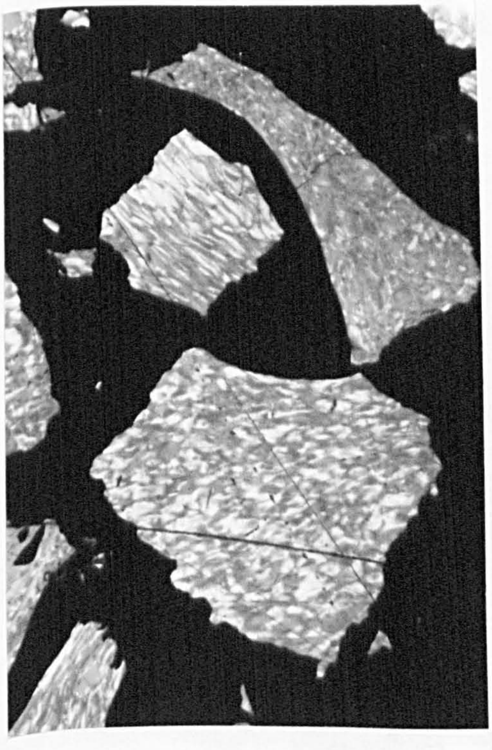
(a) 400°C, plane-polarised light
(b) 450°C, plane-polarised light
(c) 500°C, (i) plane-polarised light
(ii) crossed polars

(a)

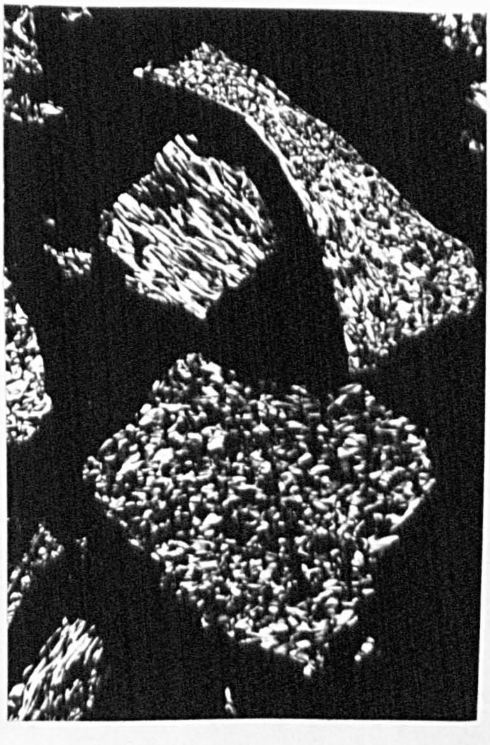


(b)





(c) (i)



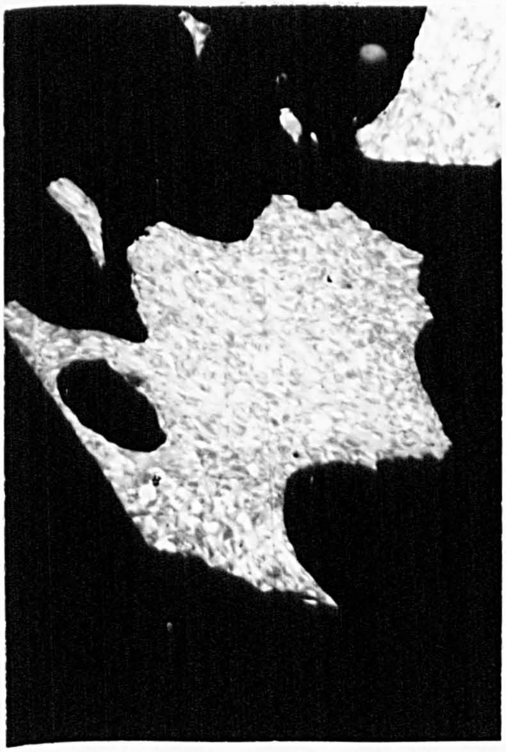
(c) (ii)

Plate 94 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under pressure of 5000 psi, x200

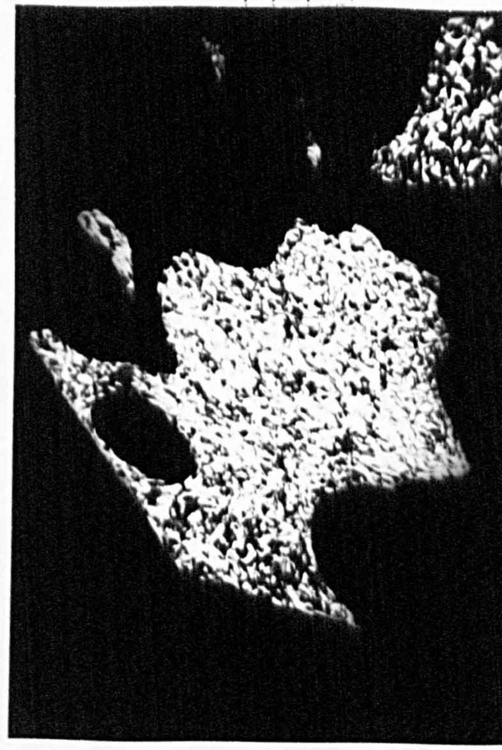
(a) 550°C (i) plane-polarised light
(ii) crossed polars

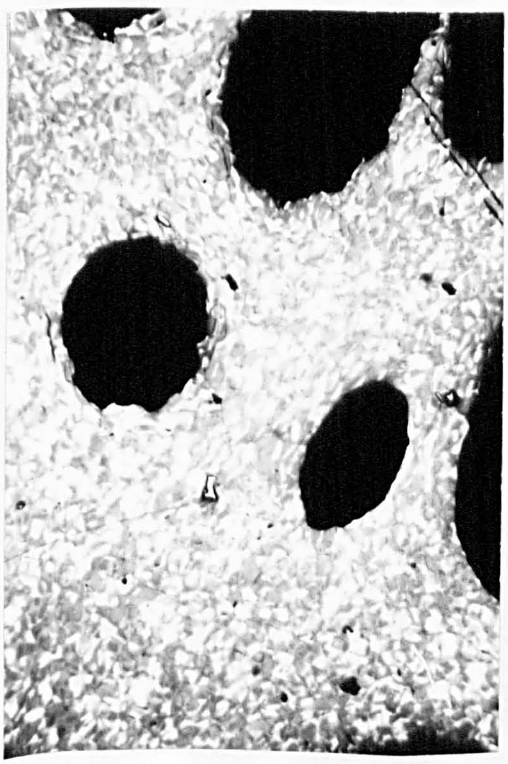
(b) 600°C (i) plane-polarised light
(ii) crossed polars

(a) (i)

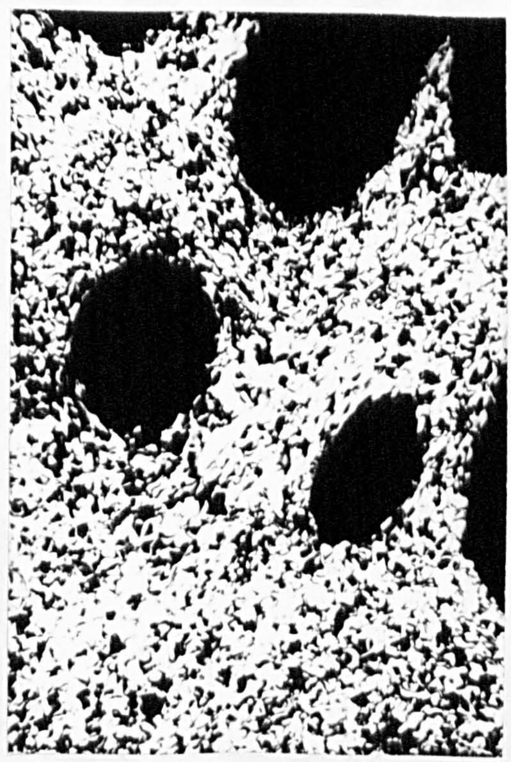


(a) (ii)





(b) (i)



(b) (ii)

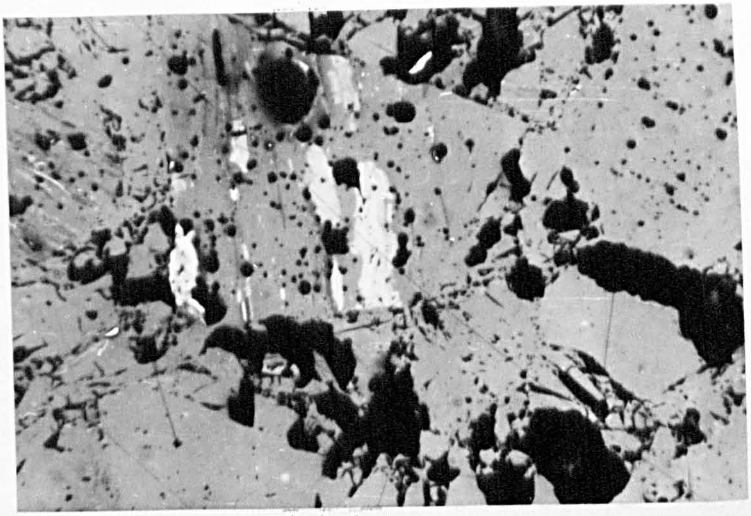
Plate 95 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under high pressure, x200

(a) 400°C (42000psi), plane-polarised light

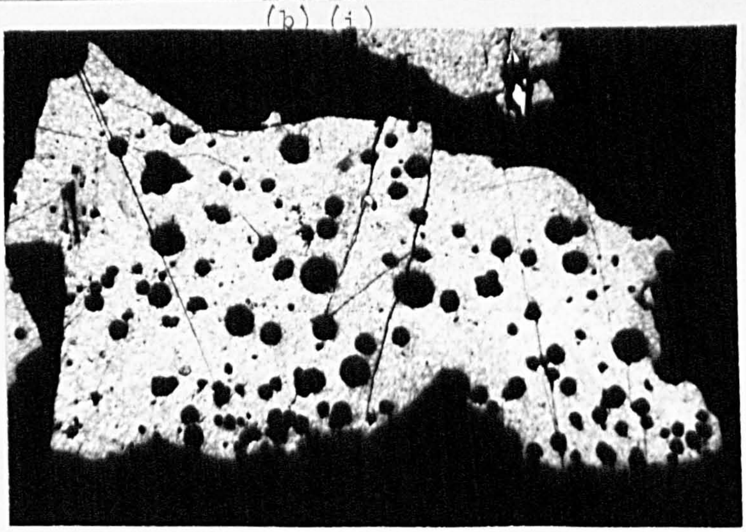
(b) 450°C (43500psi), (i) plane-polarised light

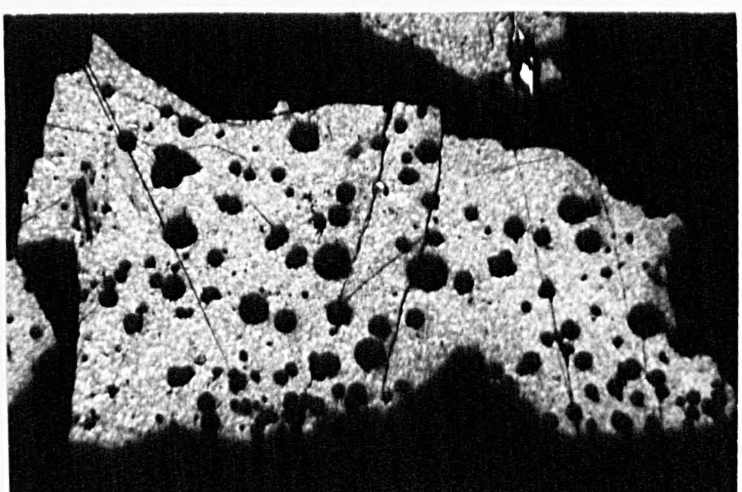
(ii) crossed polars

(a)



(b) (i)



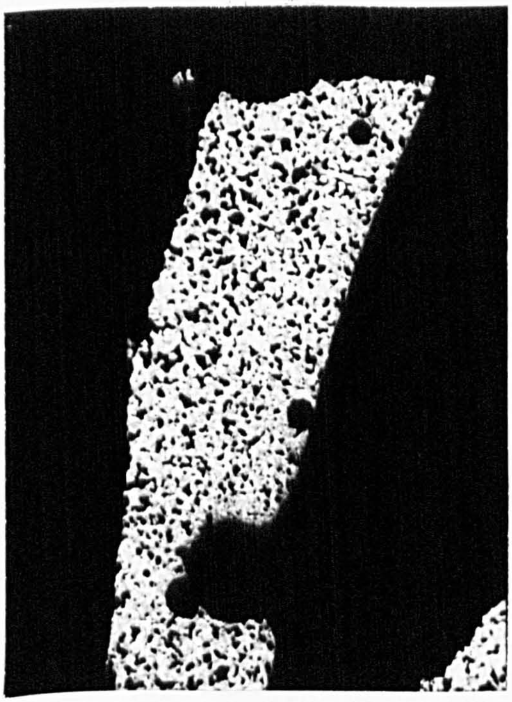


(b) (ii)

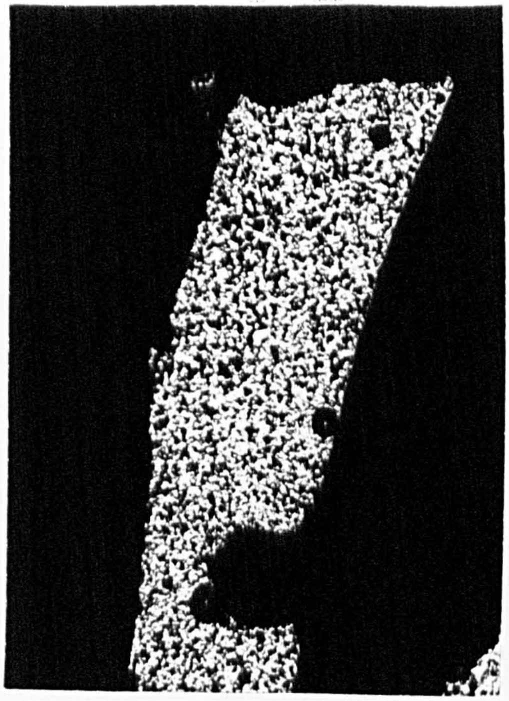
Plate 96 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under high pressure, x190

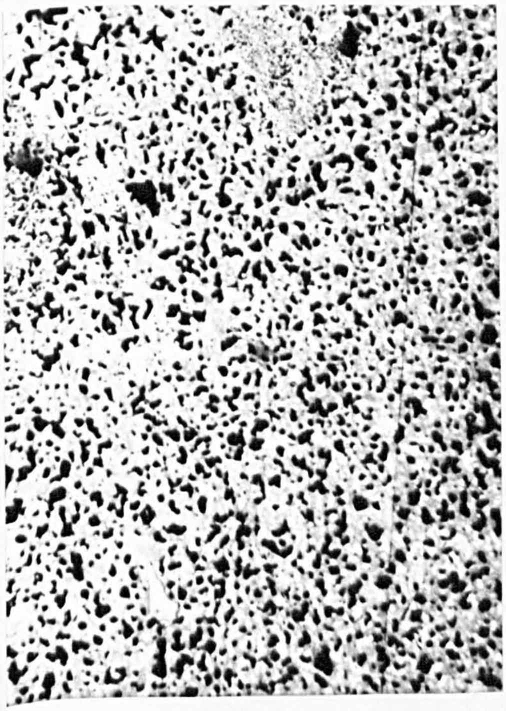
| | | |
|---|---|---|
| (a) 500°C (44200psi) | (i) | plane-polarised light |
| | (ii) | crossed polars |
| (b) 550°C (45000psi) | (i) | plane-polarised light |
| | (ii) | crossed polars |

(a) (i)

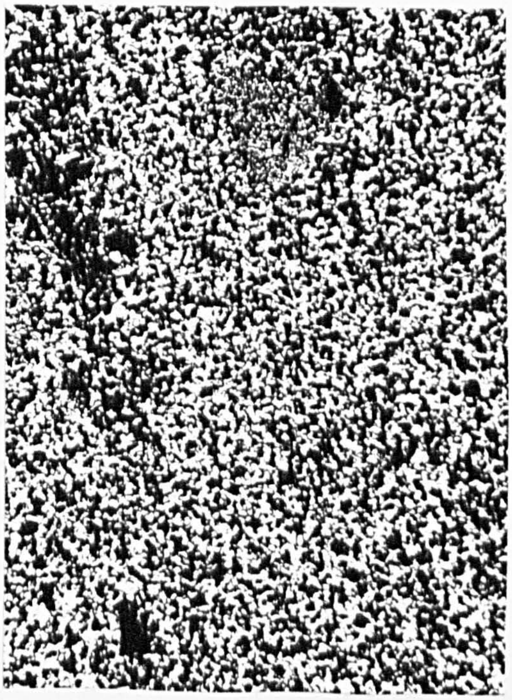


(a) (ii)





(b) (i)

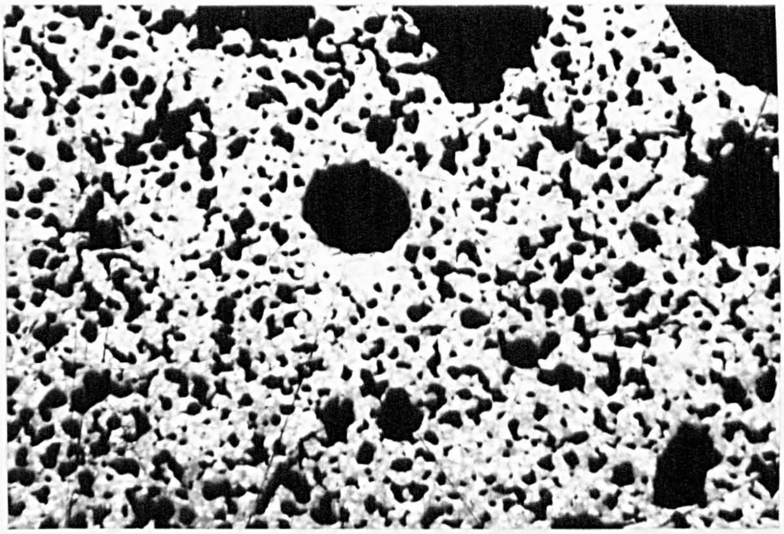


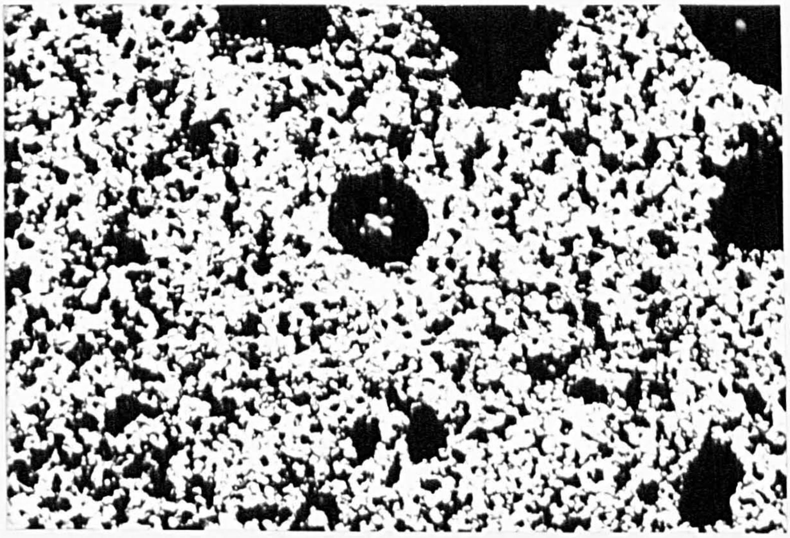
(b) (ii)

Plate 97 Coking coal vitrinite (carbon = 87.9% daf), carbonised at 600°C in a 'bomb' under high pressures (45000 psi), x220

(i) plane-polarised light
(ii) crossed polars

(i)





(ii)

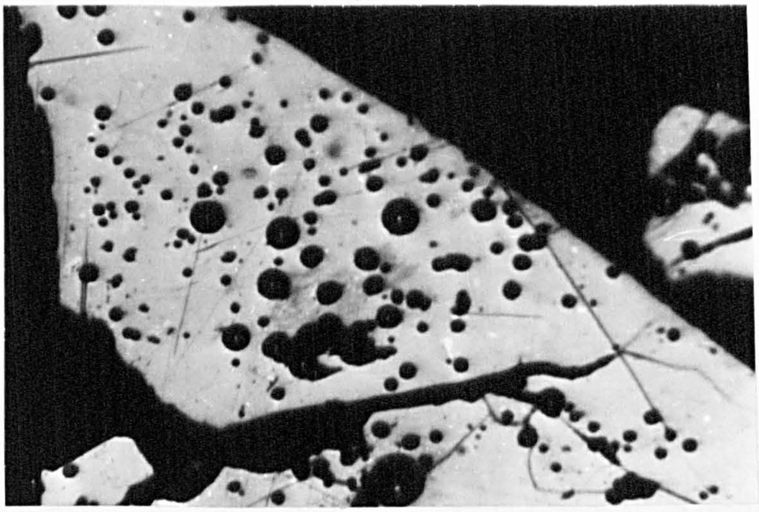
Plate 98 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under intermediate pressures

(a) 400°C (18000psi) plane-polarised light, x205

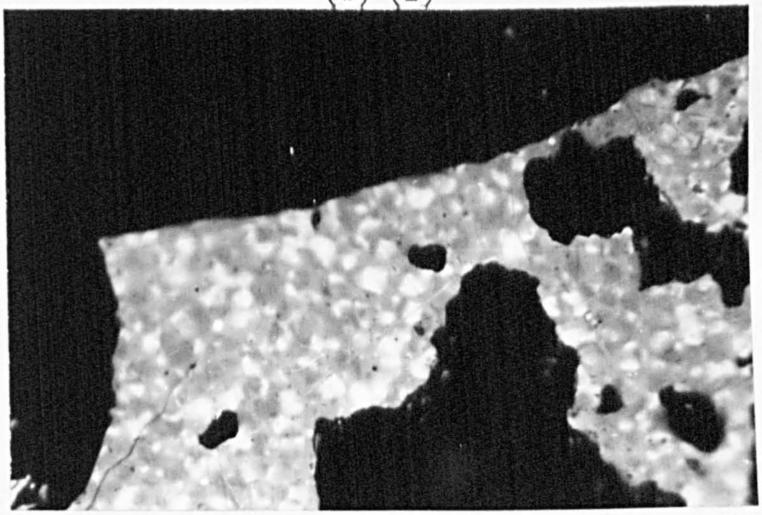
(b) 450°C (22000psi) (i) plane-polarised light, x524

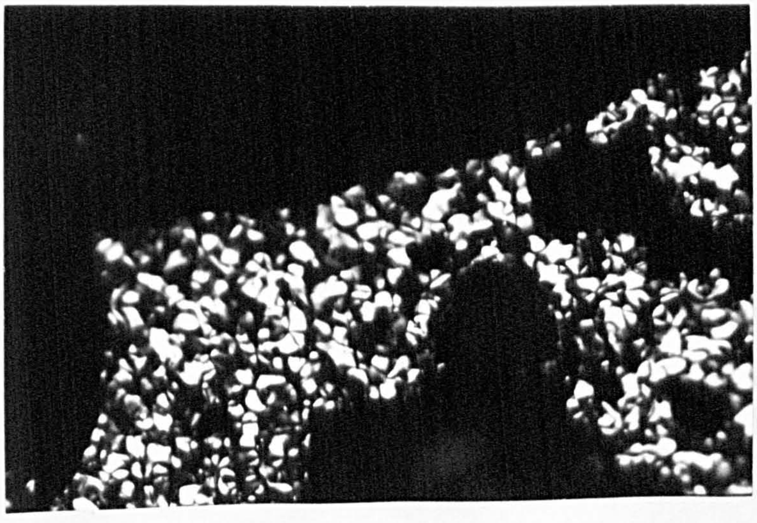
(ii) crossed polars, x524

(a)



(b) (i)





(b) (11)

Plate 99 Coking coal vitrinite (carbon = 87.9% daf), carbonised in a 'bomb' under intermediate pressure x200

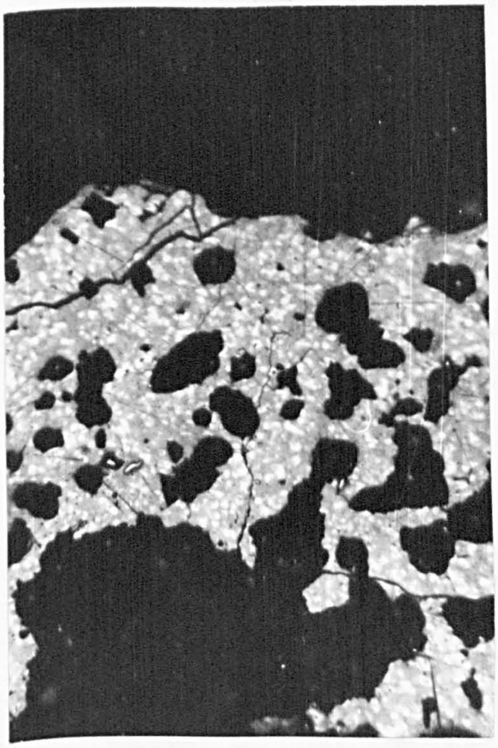
(a) 450°C (22000psi) (i) plane-polarised light

(ii) crossed polars

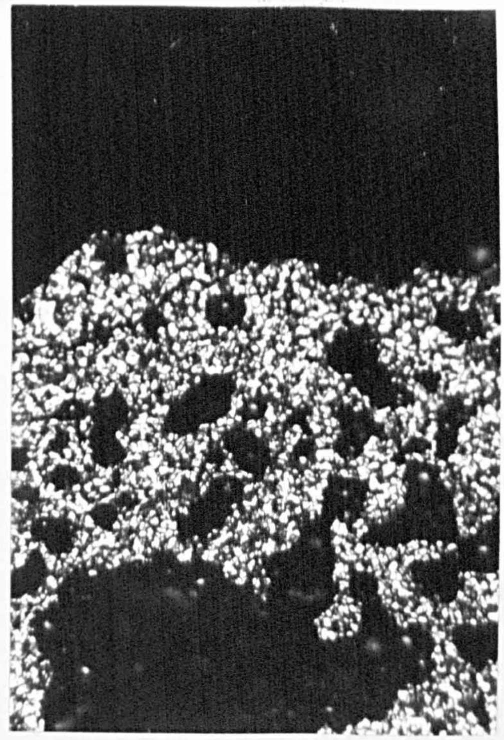
(b) 500°C (24500psi) (i) plane-polarised light

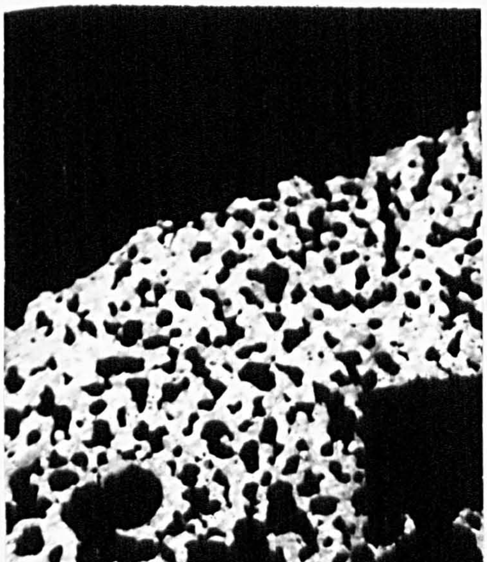
(ii) crossed polars

(a) (i)

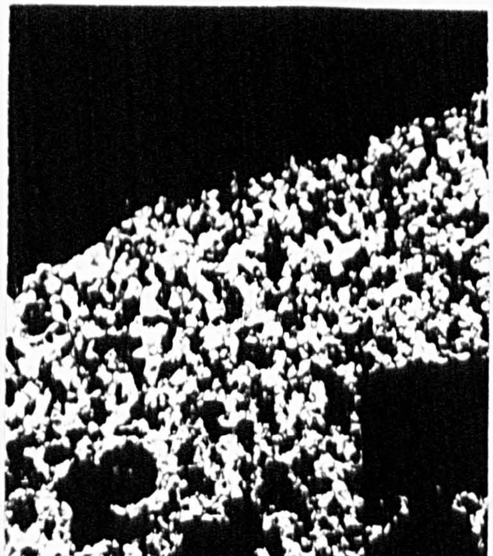


(a) (ii)





(b) (i)



(b) (ii)

Plate 100 Coking coal vitrinite (carbon = 87.9%daf) carbonised in a 'bomb' under intermediate pressure, x200

(a) 550°C (27500psi) (i) plane-polarised light

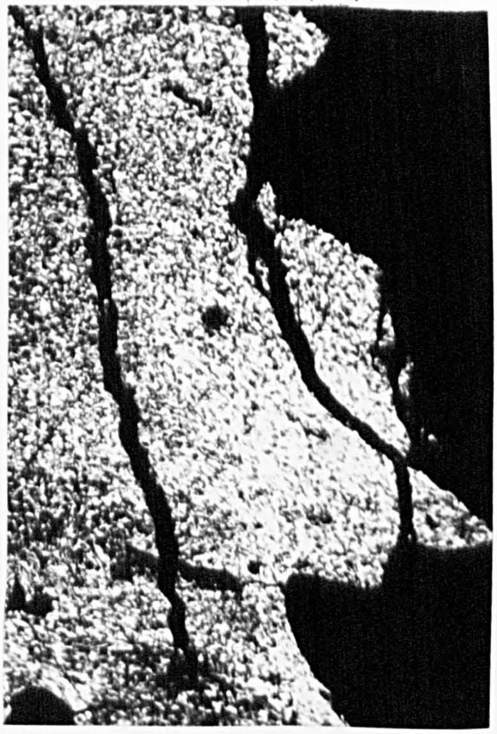
(ii) crossed polars

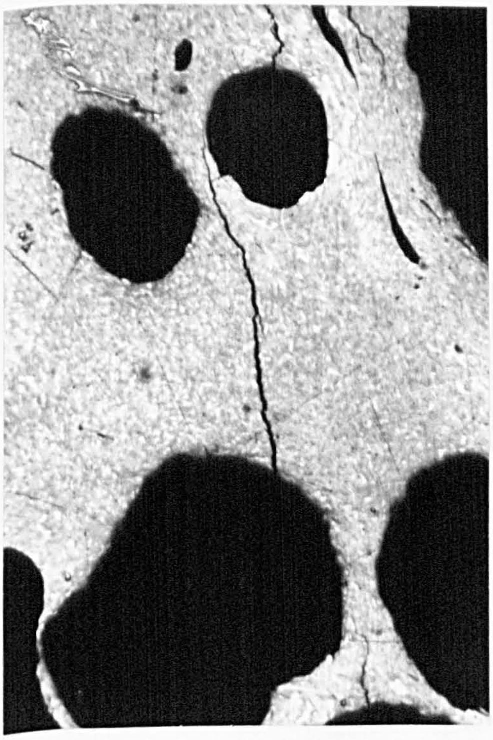
(b) 600°C (30000psi) (i) plane-polarised light

(ii) crossed polars

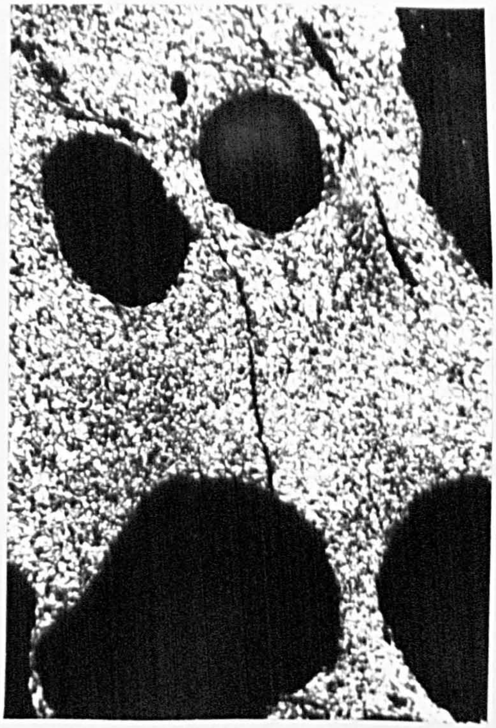
(a) (i)

(a) (ii)





(b) (i)



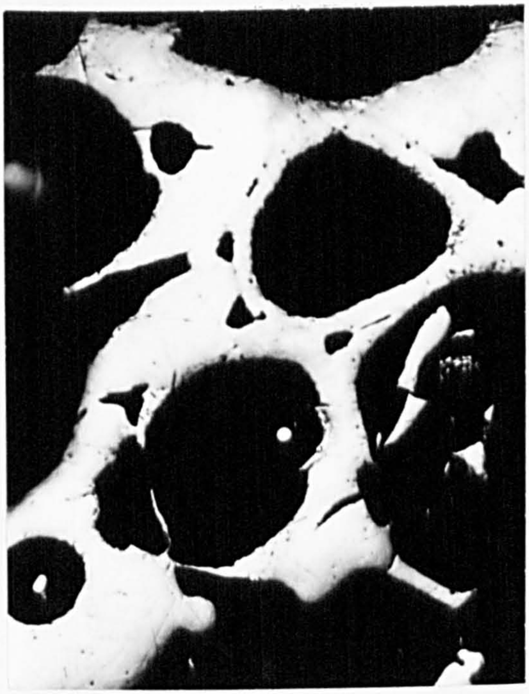
(b) (ii)

Plate 101 Coking coal vitrinite (carbon = 87.9% daf) carbonised at atmospheric pressure, x185

(a) 450°C (i) plane-polarised light
(ii) crossed polars

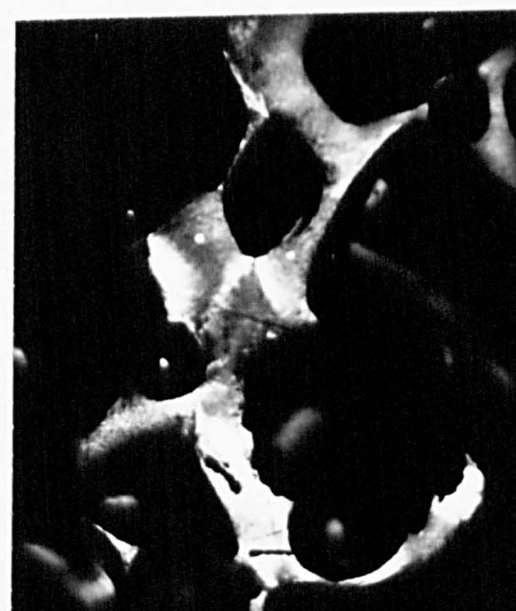
(b) 500°C (i) plane-polarised light
(ii) crossed polars

(a) (i)



(a) (ii)

(b) (i)



(b) (ii)

Plate 102 Coking coal vitrinite (carbon = 87.9% daf) carbonised at atmospheric pressure, x190

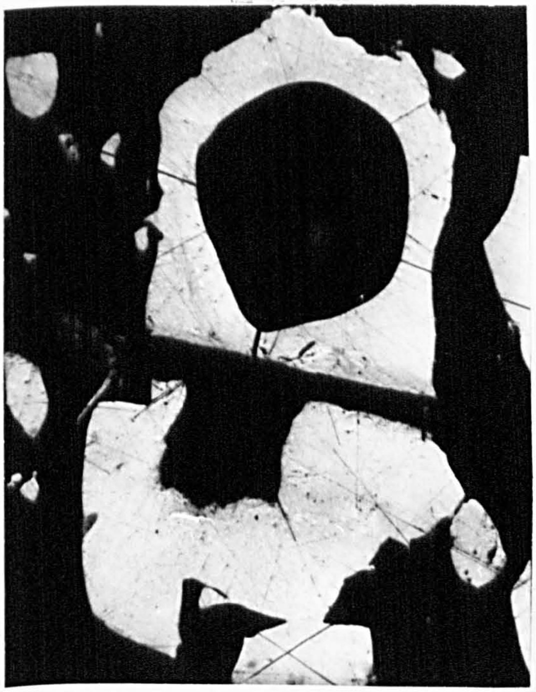
(a) 550°C (i) plane-polarised light

(ii) crossed polars

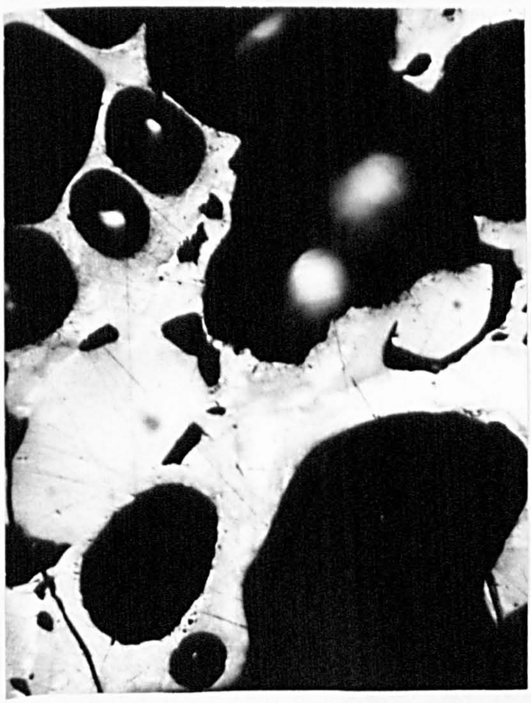
(b) 600°C (i) plane-polarised light

(ii) crossed polars

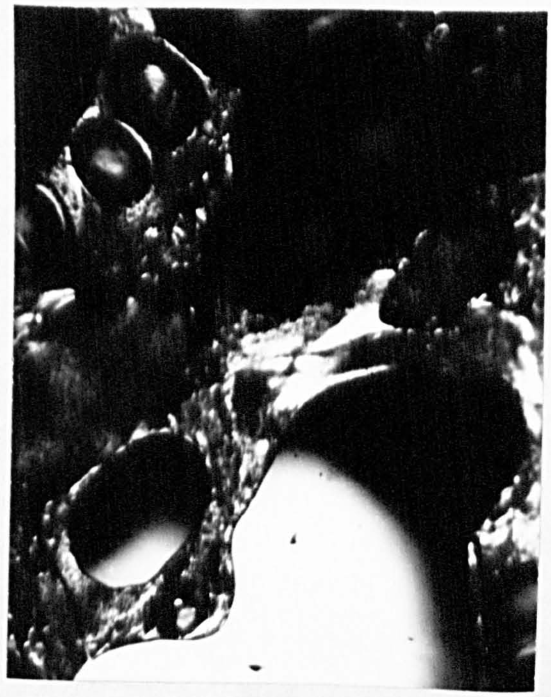
(a) (i)



(a) (ii)



(b) (i)



(b) (ii)

# APPENDIX VI. OPTICAL PROPERTIES OF VITRINITES TREATED AT HIGH TEMPERATURES.

1. OPTICAL MICROSCOPY

2. STEREOSCAN MICROSCOPY

## 1. OPTICAL MICROSCOPY

### (A) Low-rank bituminous vitrinite (carbon = 80.0% daf)

(i) Fresh (Plate 103a): dark grey, mostly structureless collinite, but with some particles exhibiting cellular structure; a little sporinite and also some streaks of semifusinite are present: isotropic.

(ii) $1000^{\circ} - 1400^{\circ}C$ (Plate 104): creamy yellow to creamy white, vesiculated; vacuoles up to 70 $\mu$m diameter, subangular, rounded and anisotropic residues; development of highly-reflecting isotropic material with high relief at about $1100^{\circ}C$, the amount increasing with rise of temperature to ca $1250^{\circ}C$, when the particles are covered by a 'shell' of this material (Plate 105a); amount of material decreases with further rise of temperature, until at $1400^{\circ}C$ the sample completely free: anisotropic.

(iii) $1500^{\circ} - 2000^{\circ}C$ (Plate 106): creamy, homogenous, vesiculated, subangular, rounded residues; disappearance of highly-reflecting isotropic substance; anisotropic with intensity of anisotropy increasing with rise of temperature.

(iv) $2400^{\circ}C$ (Plate 107): creamy, homogenous, vesiculated, sub-rounded residue; some particles show strong basic anisotropy without development of vesiculation: highly anisotropic.

(B) <u>Coking coal vitrinite (carbon = 87.9% daf)</u>

(i) <u>Fresh (Plate 103b):</u> light grey, homogeneous but some microspore and/or fragments of inertinite; no cellular structure present under crossed polars: slightly anisotropic.

(ii) <u>1000°-1400°C (Plates 108 and 109):</u> creamy white, vesiculated, cracked residues; fine-grained, flow-type mosaic texture; granular mosaic develops highly regular orientation with development of higher level of anisotropy at boundaries of particles; anisotropic with intensity of anisotropy decreasing with rise of temperature.

(iii) <u>1500° - 2000°C (Plate 110):</u> creamy yellow to yellow, vesiculated, cracked residues; mainly fine-grained mosaic; granular mosaic develops common orientation and intensity of anisotropy decreases with rising temperature; surfaces of residues not homogenous, appearing rough after polishing.

(iv) <u>2400°C (Plate 111):</u> yellow, vesiculated, cracked residues; residues display a 'burnt' appearance; granular mosaic units are apparently shrunk, resulting in a heterogeneous surface: anisotropic.

(C) <u>Anthracitic vitrinite (carbon = 94.2% dmmf)</u>

(i) <u>Fresh (Plate 103c):</u> greyish white, uniform, structureless, streaks of angular fragments of inertinite, banding visible under crossed polars: strongly anisotropic.

(ii) <u>$1000^{\circ}$ – $1400^{\circ}$C (Plates 112 to 114):</u> creamy to creamy white, subangular, slightly vesiculated; vacuoles up to 5 µm diameter; number of small vacuoles up to 2.5 µm diameter increases with rise of temperature to $1250^{\circ}$C then falls slightly with rise of temperature; particles develop perforated edges (Plate 113) at ca. $1300^{\circ}$ – $1400^{\circ}$C (Plate 114); at $1100^{\circ}$C some particles develop small patches of highly-reflecting, high-relief isotropic material; amount of isotropic substance increases with rise of temperature and at $1200^{\circ}$C the particles are covered with this substance, resulting in an uneven surface (see also Plate 113); then amount of isotropic material decreases with further rise in temperature; banding visible under crossed polars; anisitropic with anisotropy increasing with rise of temperature.

(iii) <u>$1500^{\circ}$ – $2000^{\circ}$C (Plates 115a and b):</u> creamy-white, homogenous, subangular, cracked, non-vesiculated, but occasionally developing vacuoles of up to 2.5 µm diameter; disappearance of isotropic material; banding visible under crossed polars; anisotropic; anisotropy increases with rise of temperature.

(iv) <u>$2400^{\circ}$C (Plate 115c):</u> creamy, subangular, non-vesicular, only slightly cracked: strongly anisotropic.

2. STEREOSCAN MICROSCOPY

(A) Low-rank bituminous vitrinite (carbon = 80.0% daf)

(i) Unpolished samples (Plate 118a): non-coherent structure up to 2400°C.

(ii) Polished samples (Plates 116 to 118):

(a) 1000° - 1400°C (Plate 116): polished surfaces at 1100°C show two types of area, one smooth, one uneven with relief.

(b) 1500° - 2000°C (Plates 117): two types of area on surfaces have disappeared; botryoidal structure is evident in cavities of particles (Plate 117b).

(c) 2400°C (Plate 118b): homogenous surface; botryoidal structure in cavities not visible.

(B) Coking coal vitrinite (carbon = 87.9% daf)

(i) Unpolished samples (Plates 119 and 120): coherent vesiculated structure up to 2400°C; no botryoidal structure visible.

(ii) Polished samples (Plates 121 to 123):

(a) 1000° - 1400°C (Plate 121): vesiculated, smooth, homogenous surface; botryoidal structure evident in some cavities (Plate 121a).

(b) 1500° - 2000°C (Plates 121b and 122): vesiculated, smooth, homogenous appearance; botryoidal structures are only evident at high magnification in cavities of residues (Plate 122b).

(c) <u>2400°C (Plate 123):</u> virtually same appearance as samples at lower temperatures.

(C) <u>Anthracitic vitrinite (carbon = 94.2% dmmf)</u>

(i) <u>Unpolished samples (Plate 124):</u> non-coherent structure even at 2400°C.

(ii) <u>Polished samples (Plates 125 and 126)</u>

(a) <u>1000° - 1400°C (Plate 125a):</u> two types of surface area, similar to low-rank vitrinite, evident at about 1100°C.

(b) <u>1500° - 2000°C (Plates 125b and 126a):</u> disappearance of two types of areas at 1500°C; vacuoles with uneven, perforated edges (Plate 125b); uneven edges of the particles disappear at approximately 1800°C (Plate 126a).

(c) <u>2400°C (Plate 126b):</u> practically the same morphological features as at 1800°C are evident.

Plate 103 Fresh vitrinite, x190

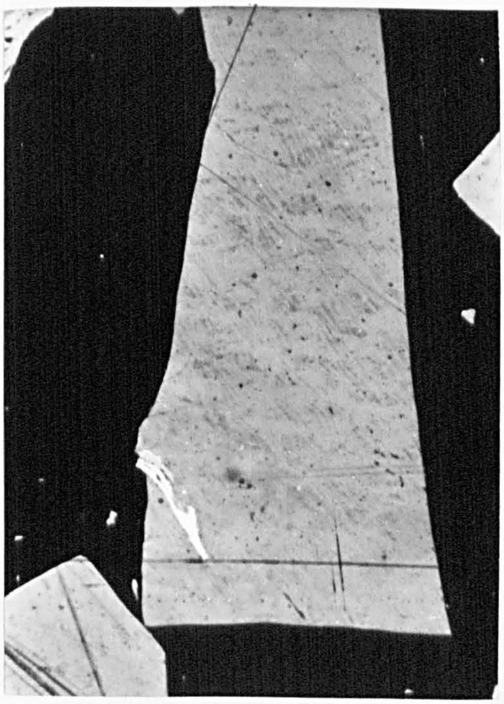
(a) low-rank bituminous (carbon = 80.0% daf), plane-polarised light

(b) high-rank bituminous (carbon = 87.9% daf), plane-polarised light

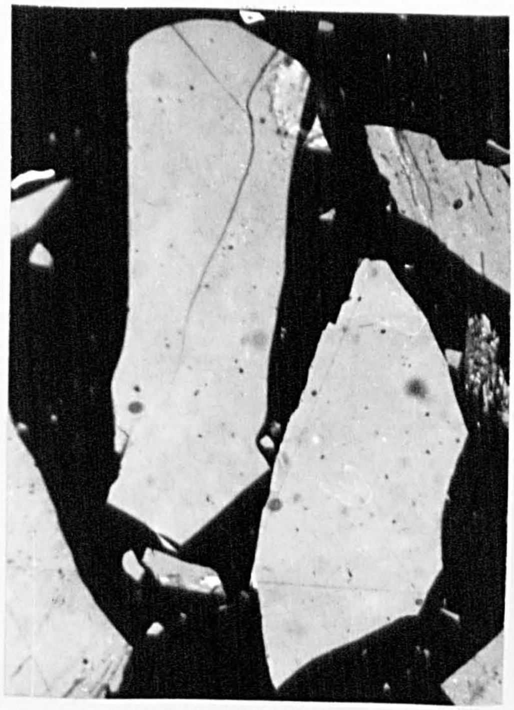
(c) anthracitic (i) plane-polarised light

(ii) crossed polars

(a)



(b)



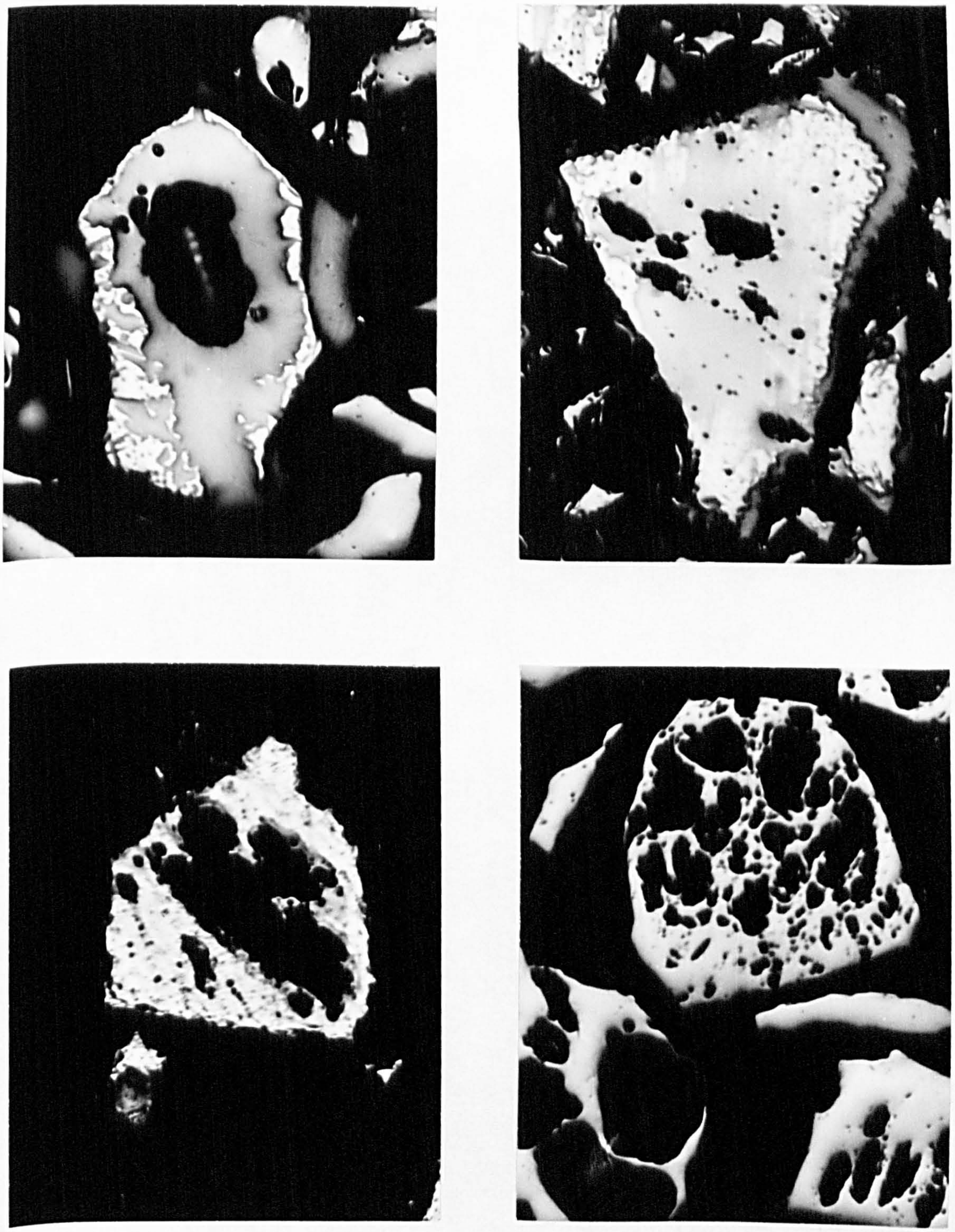
(c) (i)

(c) (ii)

Plate 104 Heat-treated residues of low-rank bituminous vitrinite (carbon = 80.0% daf), plane-polarised light, x190

(a) $1100^{\circ}C$
(b) $1200^{\circ}C$
(c) $1300^{\circ}C$
(d) $1400^{\circ}C$

(a) (b)



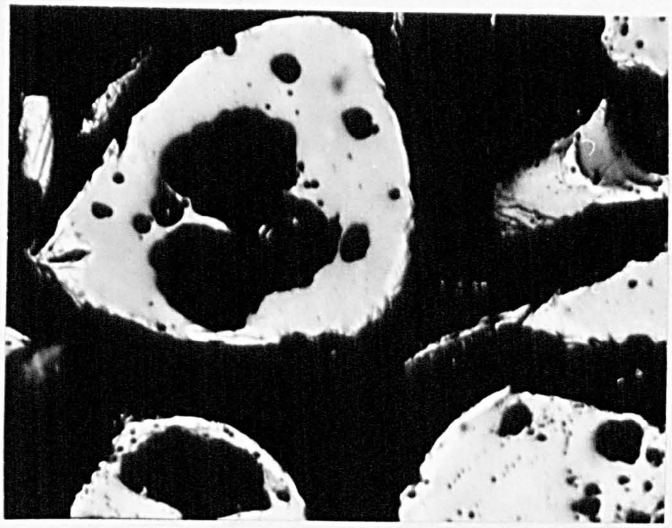
(c) (d)

Fig 105 Low-rank bituminous vitrinite (carbon = 80.0% daf), heat-treated at 1350°C, plane-polarised light,

(i) polished with conventional slow-rotating laps, x 190

(ii) polished with fast-rotating laps, x 470

(i)



(ii)

Plate 106 Heat-treated residues of low-rank bituminous vitrinite (carbon = 80.0% daf), x185

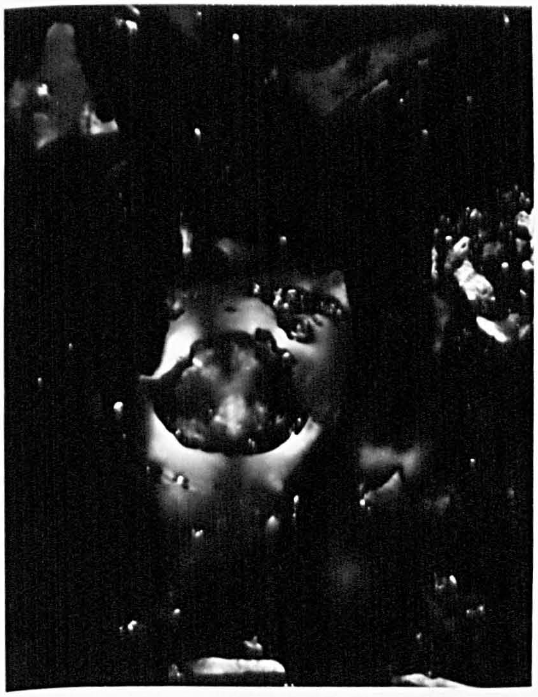
(a) 1800°C (i) plane-polarised light

(ii) crossed polars

(b) 2000°C (i) plane-polarised light

(ii) crossed polars

(a) (i)



(a) (ii)

(b) (i)

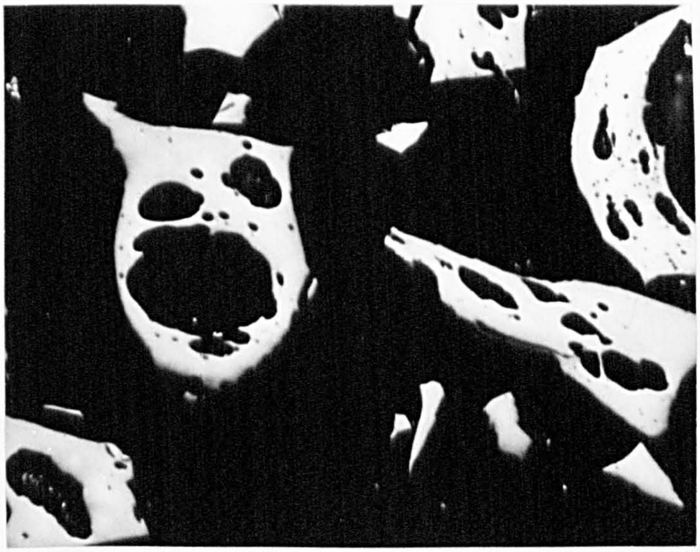
(b) (ii)

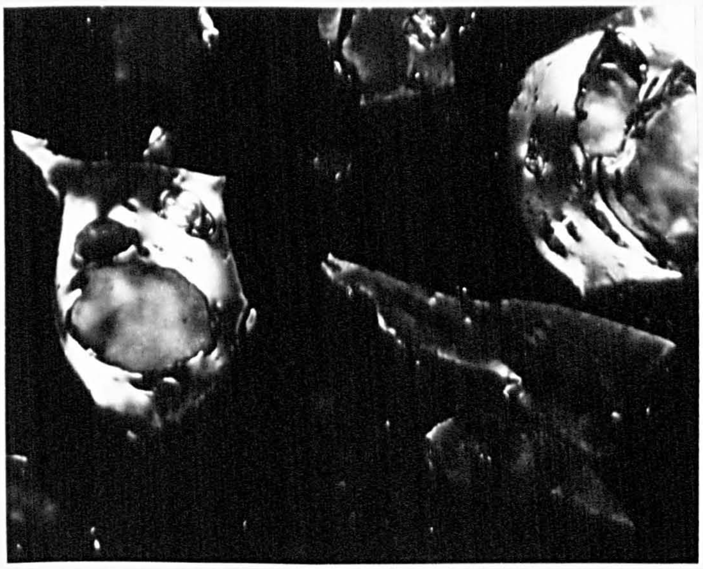
Plate 107 Low-rank bituminous vitrinite (carbon = 80.0% daf) heat-treated at 2400°C, x190

(i) plane-polarised light

(ii) crossed polars

(i)





(ii)

Plate 108 Heat-treated residues of high-rank biuminous vitrinite (carbon = 87.9% daf), x190

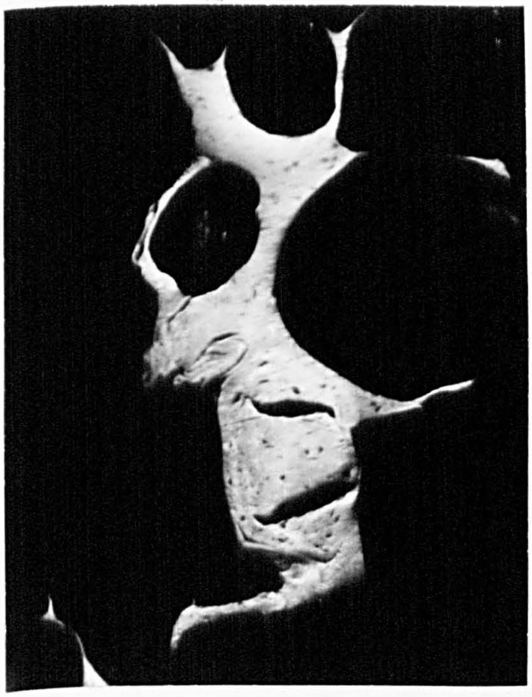
(a) 1100°C (i) plane-polarised light

(ii) crossed polars

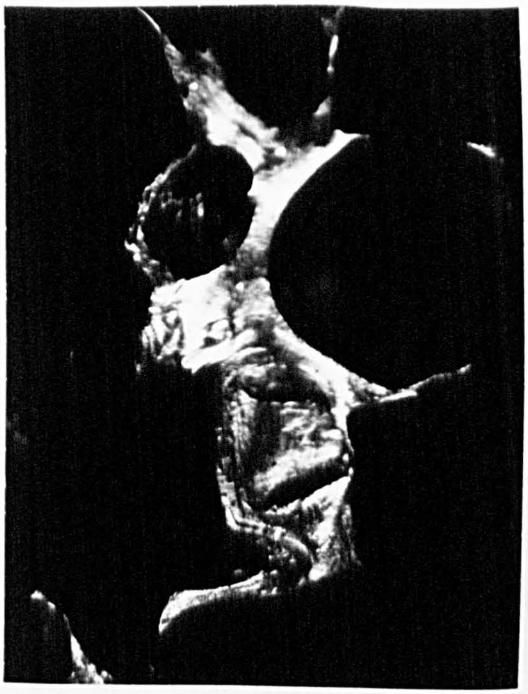
(b) 1200°C (i) plane-polarised light

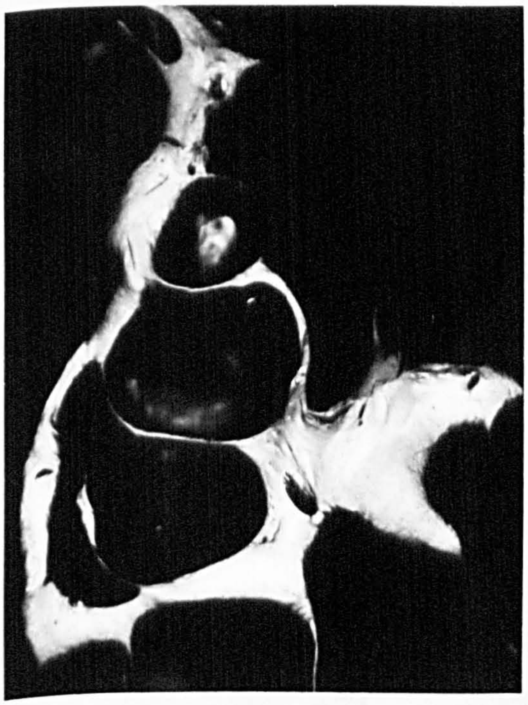
(ii) crossed polars

(a) (i)



(a) (ii)





(b) (i)

(b) (ii)

Plate 109 Heat-treated residues of high-rank bituminous vitrinite (carbon = 87.9% daf), x180

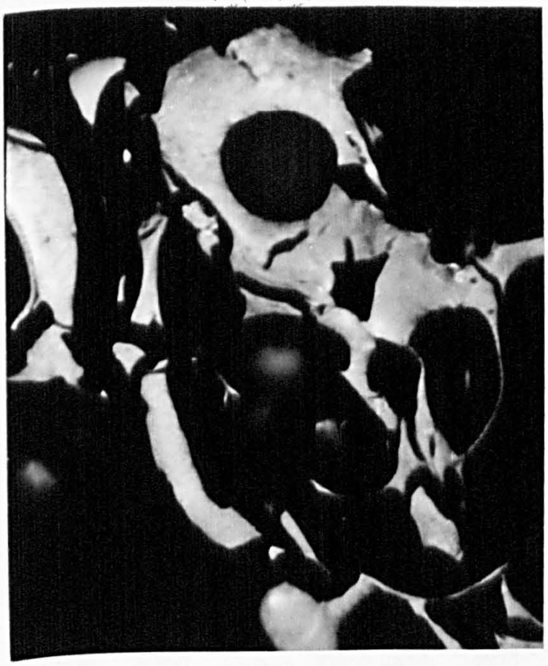
(a) $1300^{\circ}C$ (i) plane-polarised light

(ii) crossed polars

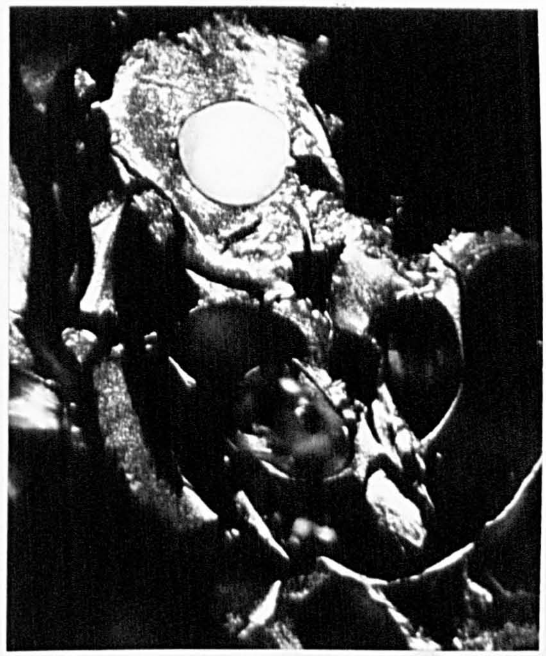
(b) $1400^{\circ}C$ (i) plane-polarised light

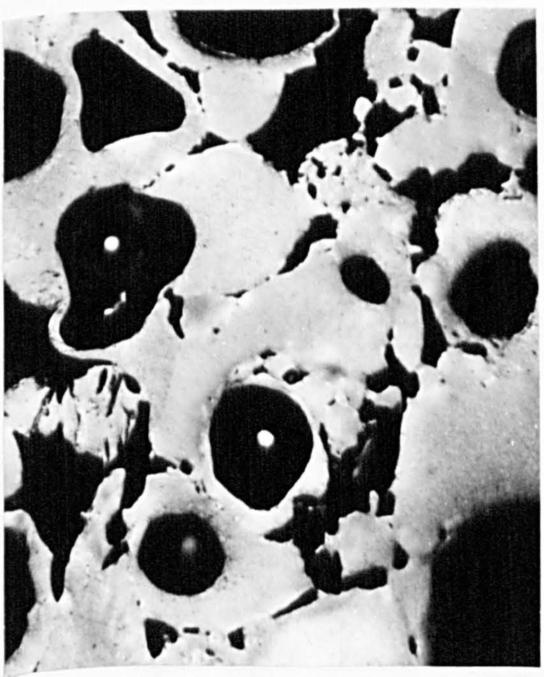
(ii) crossed polars

(a) (i)

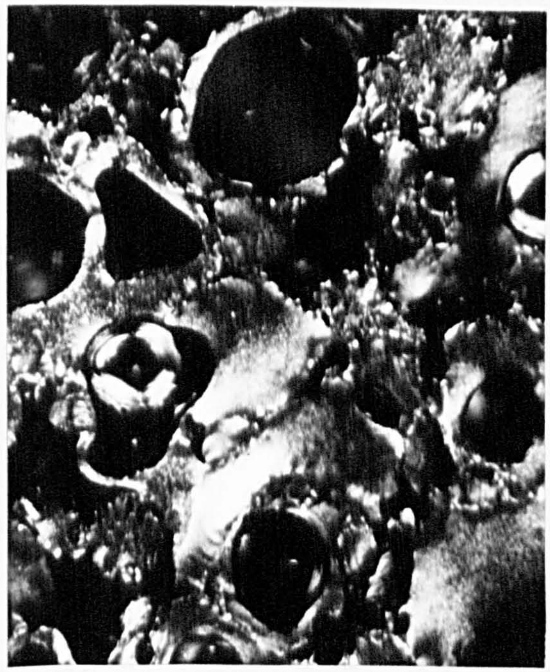


(a) (ii)





(b) (i)



(b) (ii)

Fig 110 Heat-treated residues of high-rank bituminous vitrinite (carbon = 87.9% daf), x180

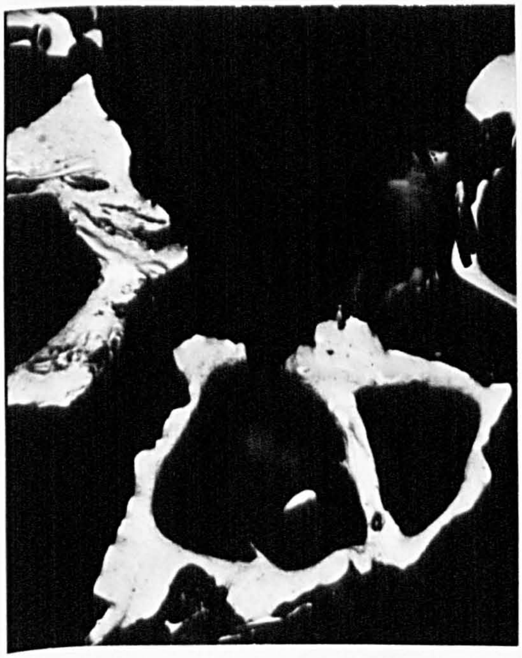
(a) 1800°C (i) plane-polarised light

(ii) crossed polars

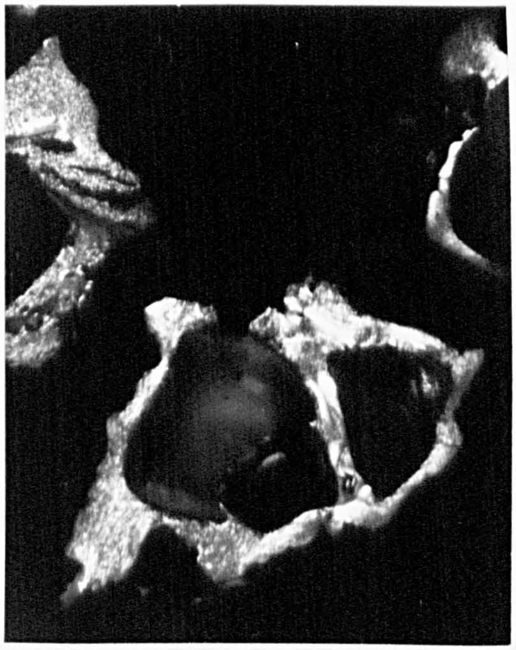
(b) 2000°C (i) plane-polarised light

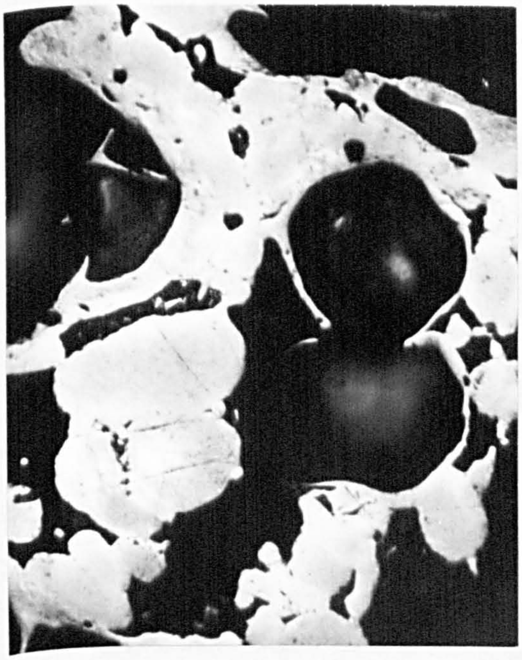
(ii) crossed polars

(a) (i)

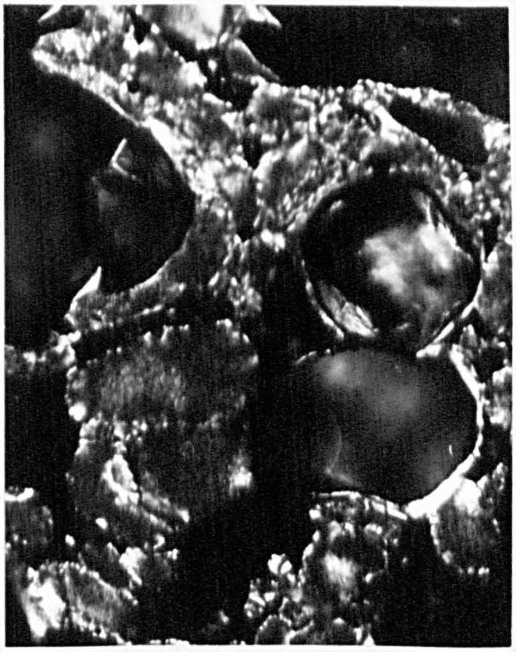


(a) (ii)





(b) (i)



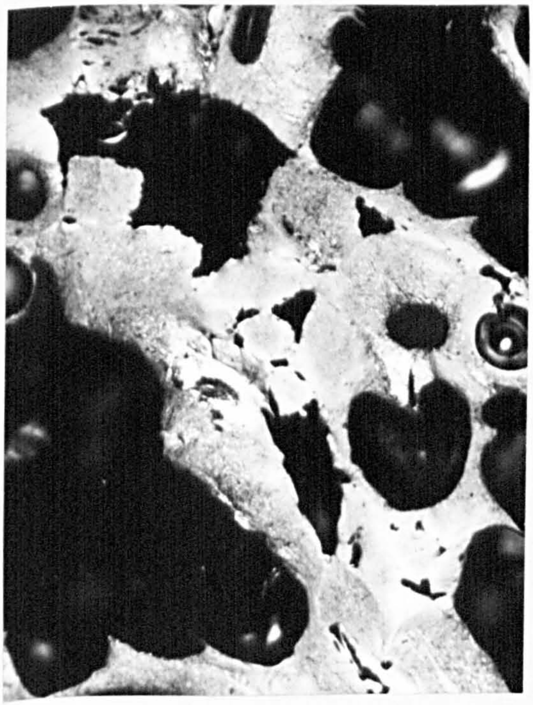
(b) (ii)

Plate 111 Heat-treated residues of high-rank bituminous vitrinite (carbon = 87.9% daf)

(a) 2400°C, x190 (i) plane-polarised light
(ii) crossed polars

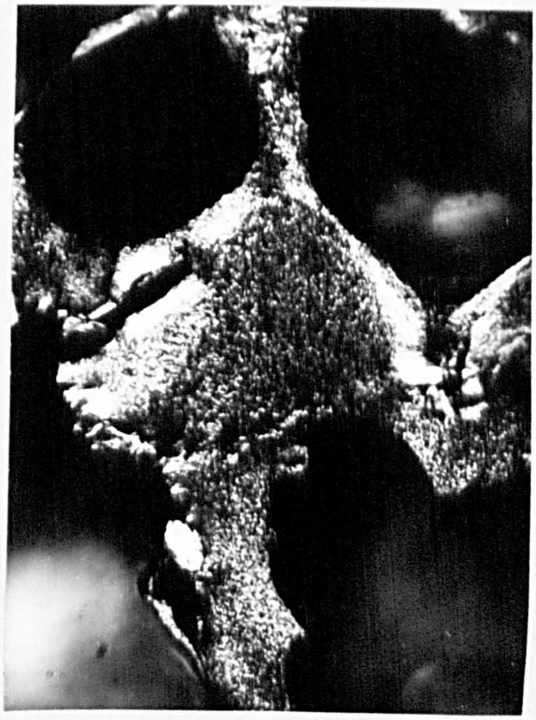
(b) 2400°C, x500 (i) plane-polarised light
crossed polars

(a) (i)



(a) (ii)

(b) (i)



(b) (ii)

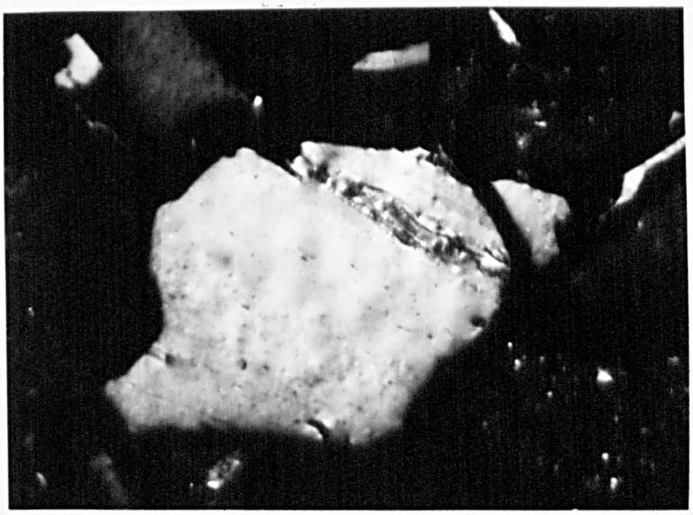
Plate 112 Heat-treated residues of anthracitic vitrinite (carbon = 94.2% dmmf), x190

(a) $1000^{\circ}C$, crossed polars

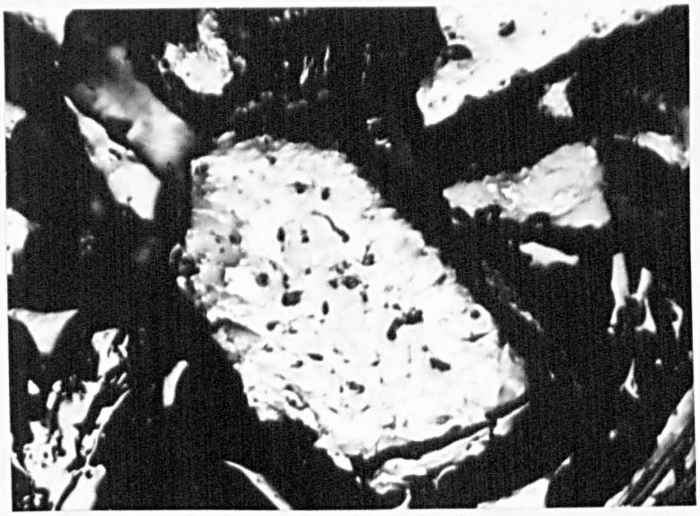
(b) $1100^{\circ}C$, (i) plane-polarised light

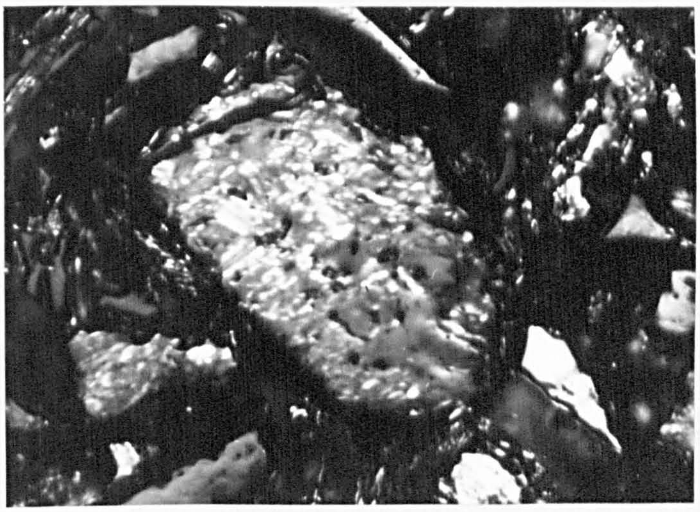
(ii) crossed polars

(a)



(b) (i)





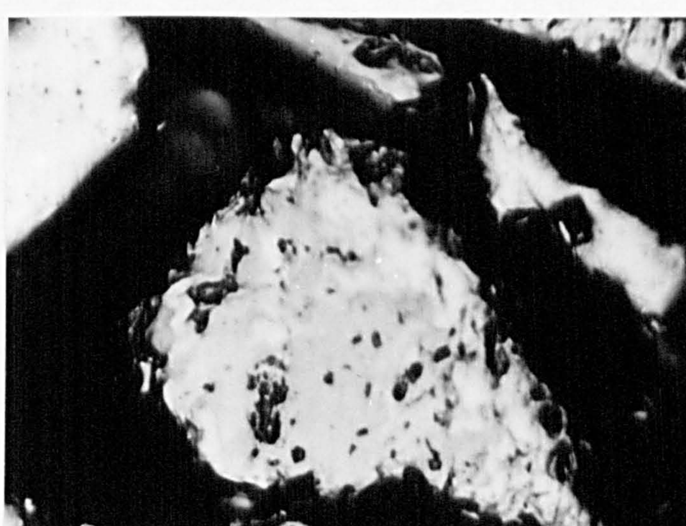
(b) (ii)

Plate 113 Anthracitic vitrinite (carbon = 94.2% dmmf), heat-treated at 1200°C, plane-polarised light,

(i) x190

(ii) x480

(i)



(ii)

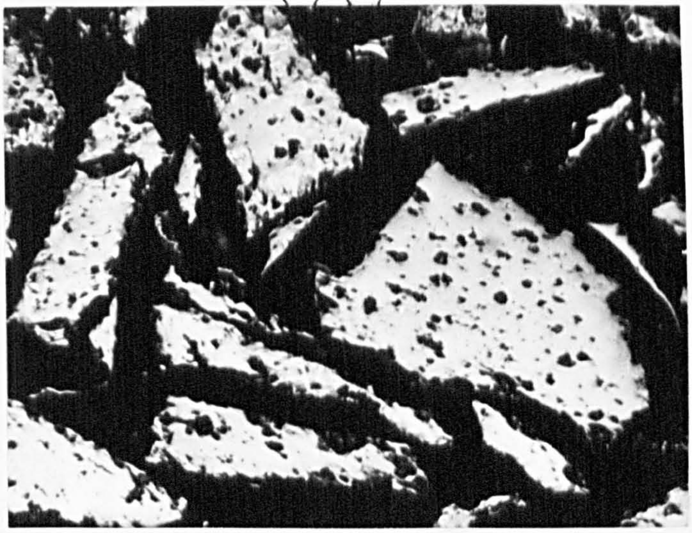
Plate 114 Heat-treated residues of anthracitic vitrinite (carbon = 94.2% dmmf), x190

(a) 1300°C (i) plane-polarised light

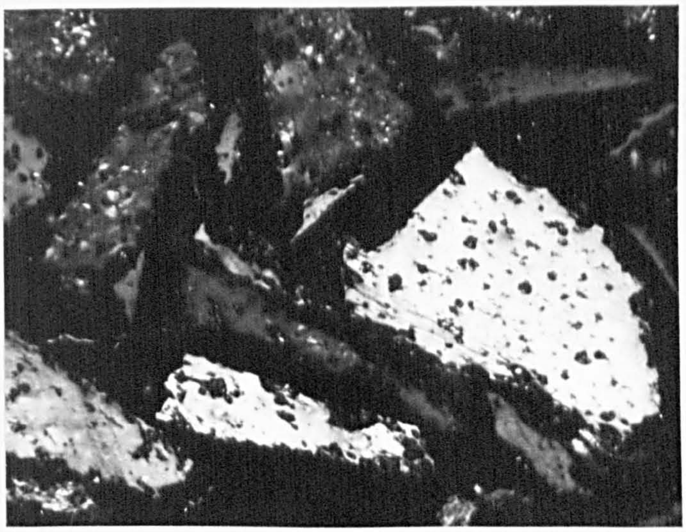
(ii) crossed polars

(b) 1400°C crossed polars

(a) (i)



(a) (ii)



(b)

Plate 115 Heat-treated residues of anthracitic vitrinite (carbon = 94.2% dmmf), x190

(a) 1800°C, crossed polars

(b) 2000°C, crossed polars

(c) 2400°C, (i) plane-polarised light

(ii) crossed polars

(a)

(b)

(c) (i)

(c) (ii)

Plate 116 'Stereoscan' electronmicrographs of polished surfaces of heat-treated low-rank vitrinite (carbon = 80.0% daf)

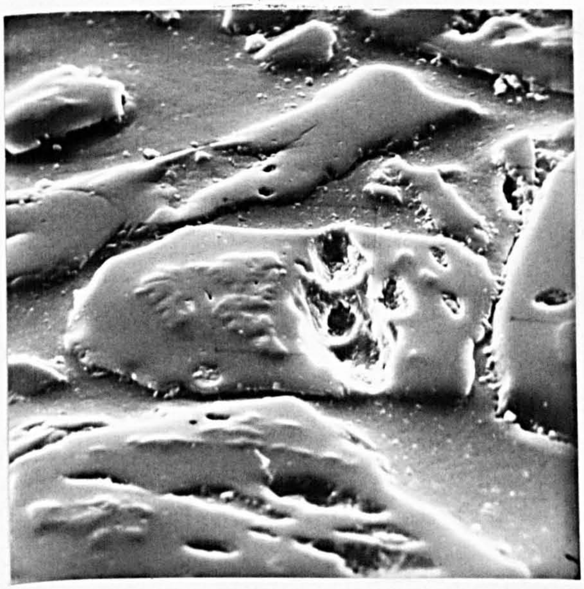
(a) 1100°C (i) x375

(ii) x1500

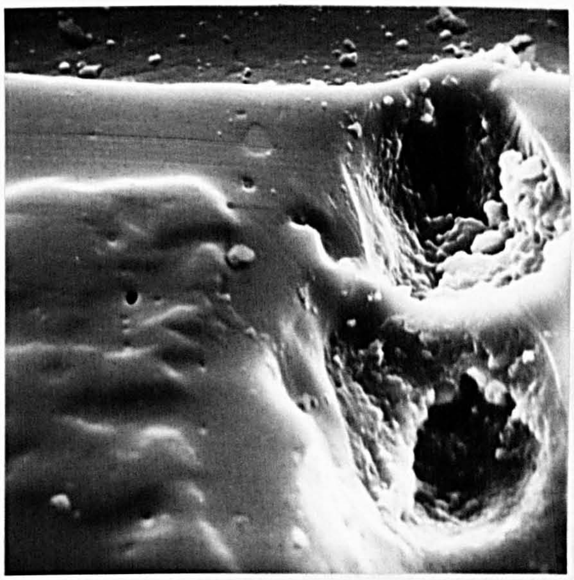
(b) 1100°C (i) x375

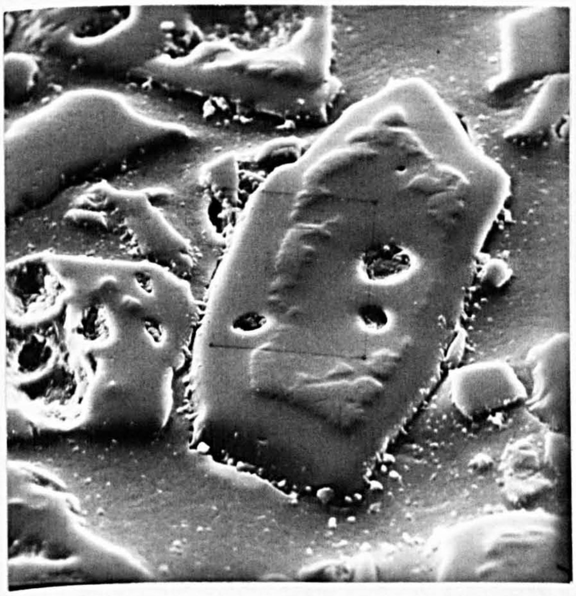
(ii) x1500

(a) (i)



(a) (ii)





(b) (i)

(b) (ii)

Plate 117 'Stereoscan' electronmicrographs of polished surfaces of heat-treated low-rank bituminous vitrinites (carbon = 80.0% daf)

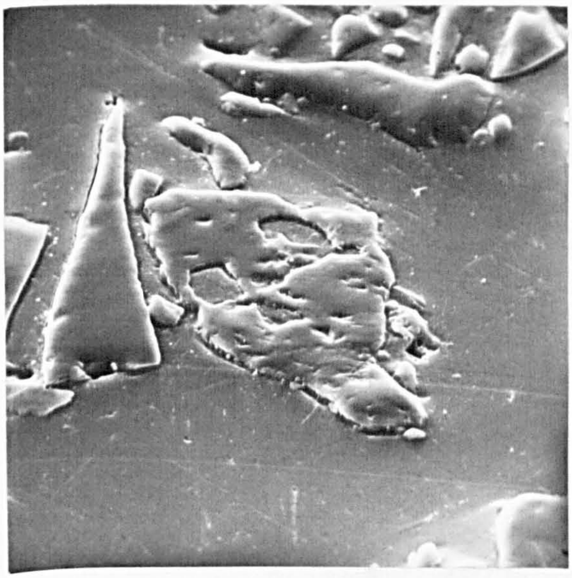
(a) 1500°C (i) x375

(ii) x1500

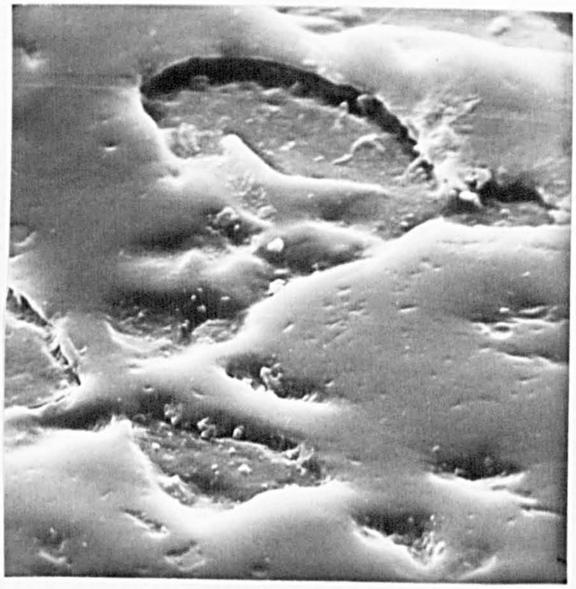
(b) 1800°C (i) x1540

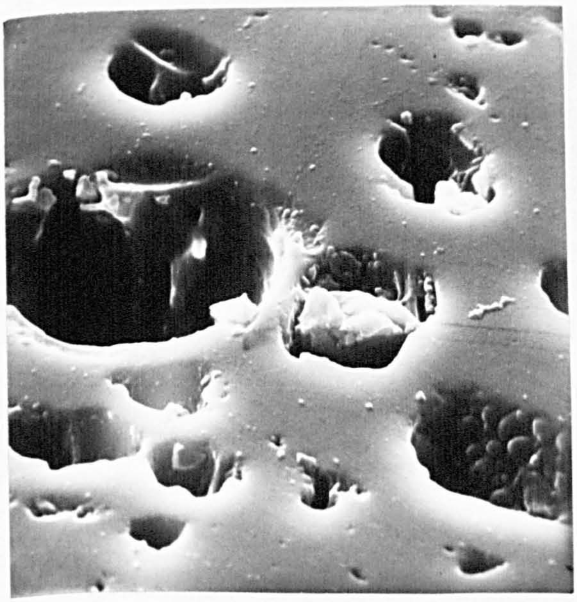
(ii) x3800

(a) (i)

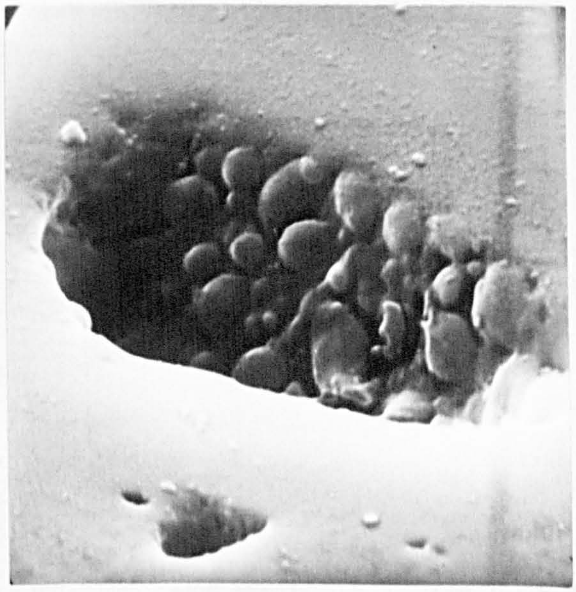


(a) (ii)





(b) (i)



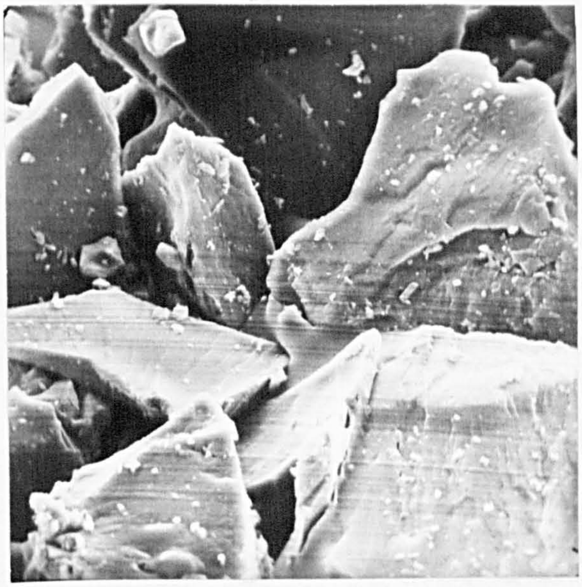
(b) (ii)

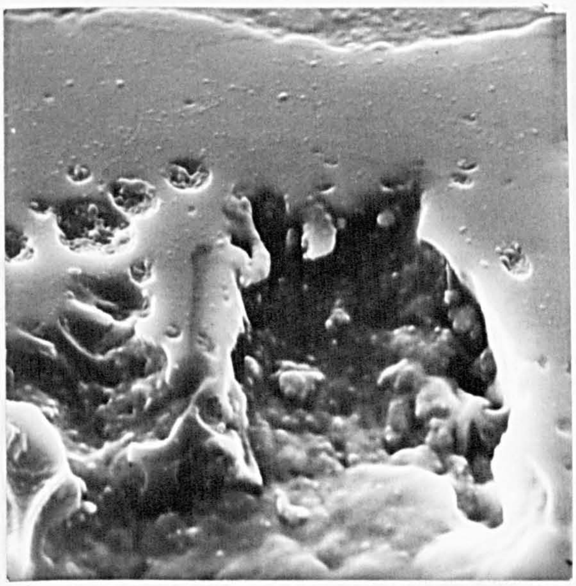
Plate 118 'Stereoscan' electron micrographs of low-rank bituminous vitrinite (carbon = 80.0% daf), heat-treated at 2400°C

(i) unpolished surface, x340

(ii) polished surface, x1540

(i)



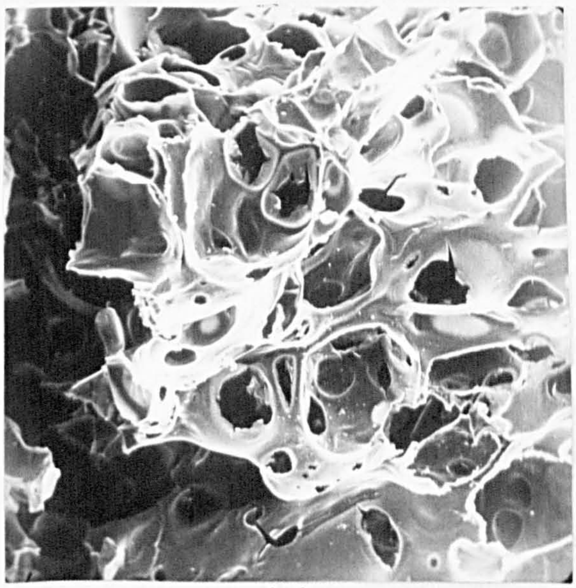


(ii)

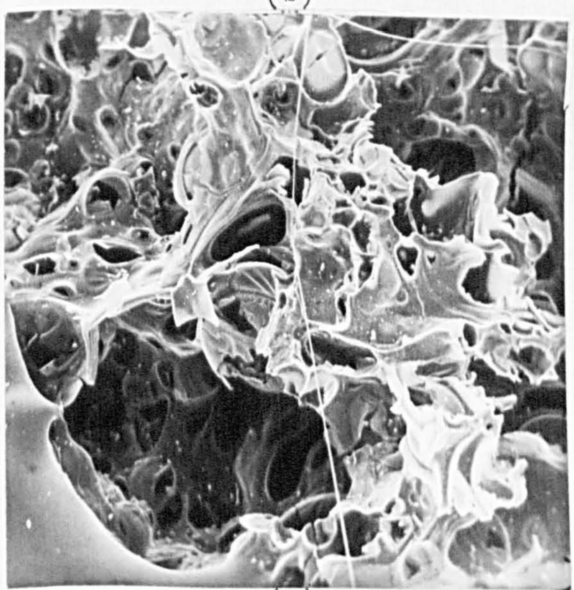
Plate 119 'Stereoscan' electronmicrographs of unpolished surfaces of heat-treated high-rank bituminous vitrinite (carbon = 87.9% daf), x72

(a) 1100°C
(b) 1500°C
(c) 1800°C

(a)



(b)



(c)

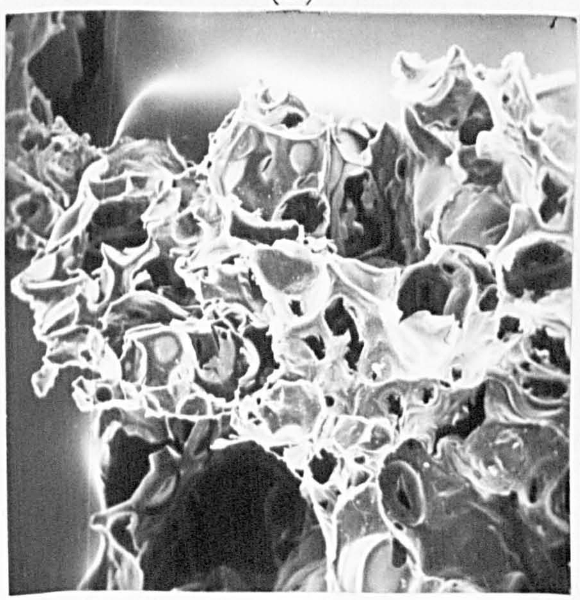


Plate 120 'Stereoscan' electronmicrographs of unpolished surfaces of heat-treated high-rank bituminous vitrinite (carbon = 87.9% daf), x370

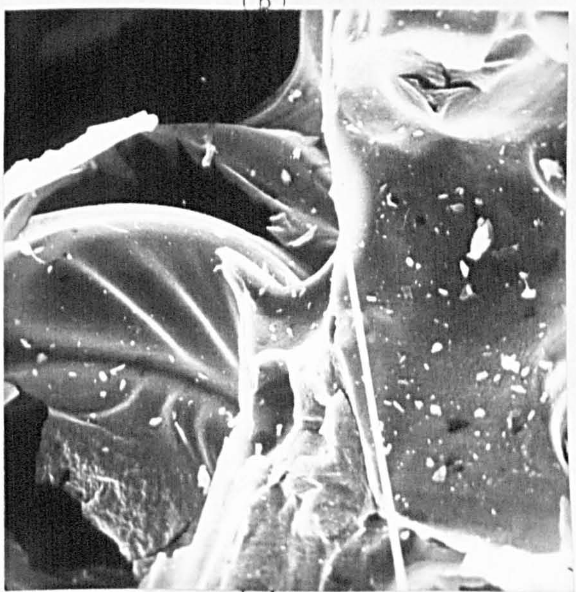
(a) 1100°C

(b) 1500°C

(c) 1800°C

(a)

(b)



(c)

Plate 121 'Stereoscan' electronmicrographs of polished surfaces of heat-treated high-rank bituminous vitrinite (carbon = 87.9% daf)

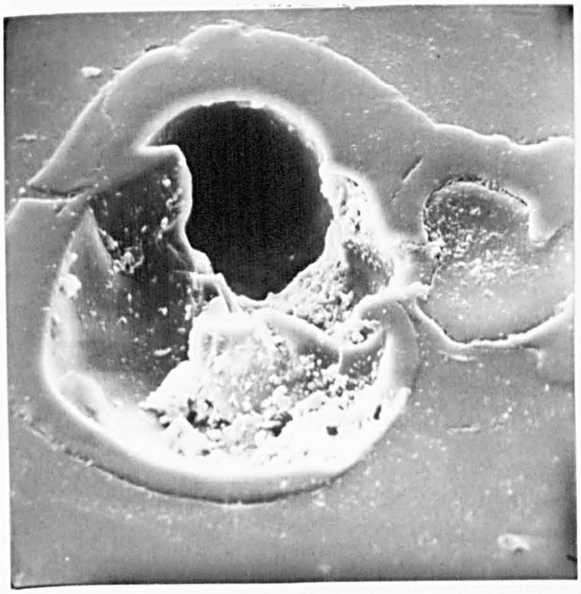
(a) 1100°C (i) x390

(ii) x1575

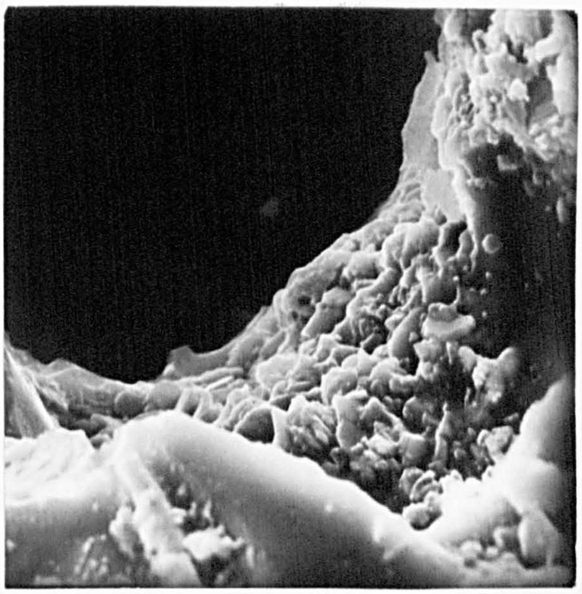
(b) 1500°C (i) x370

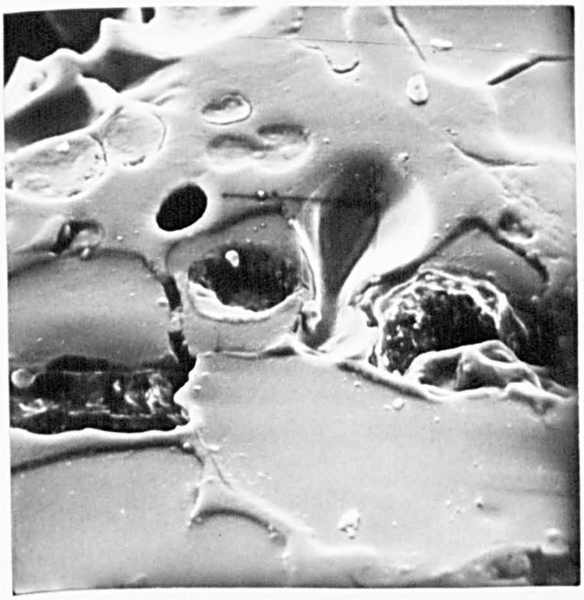
(ii) x1560

(a) (i)

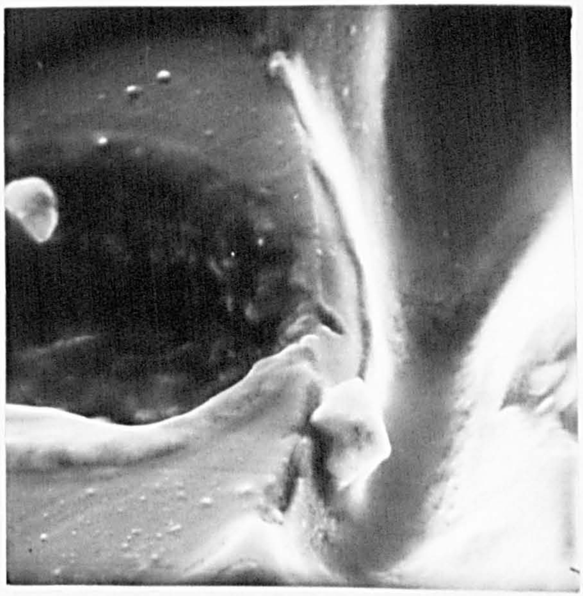


(a) (ii)





(b) (i)



(b) (ii)

Plate 122 'Stereoscan' electronmicrographs of polished surfaces of high-rank bituminous vitrinite (carbon = 87.9% daf) heat-treated at 1800°C

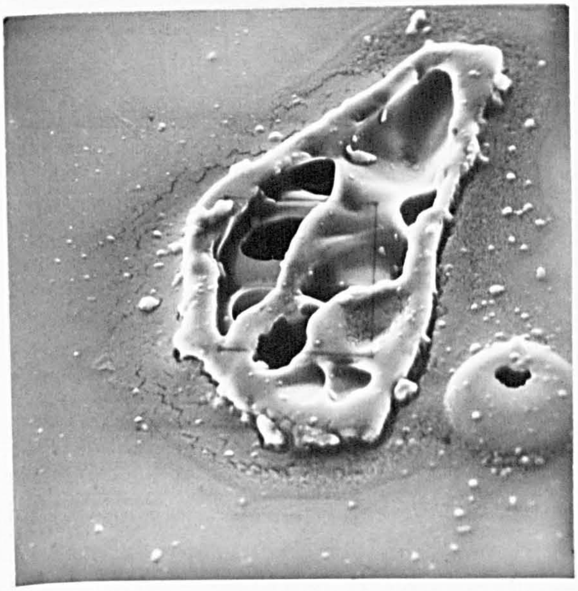
(a) (i) x375

(ii) x1500

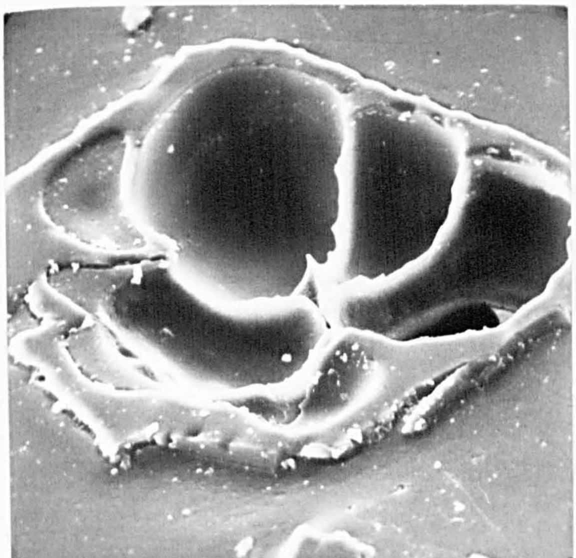
(b) (i) x375

(ii) x1500

(a) (i)



(a) (ii)



(b) (i)

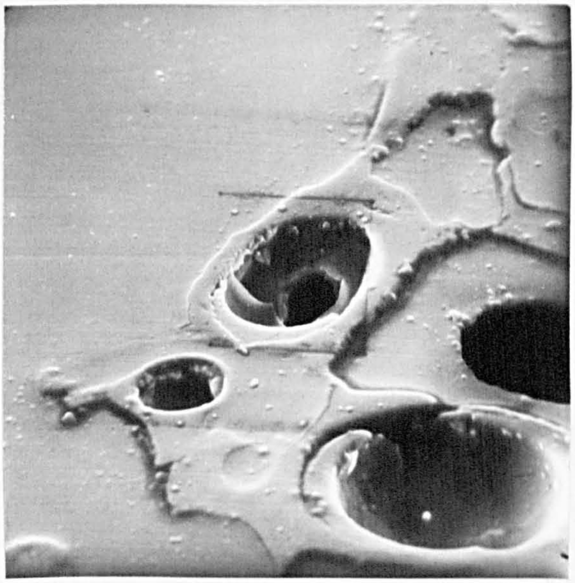
(b) (ii)

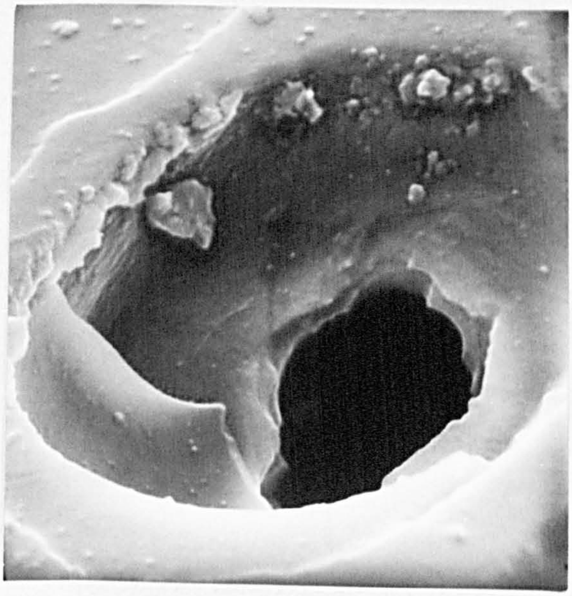
Plate 123 'Stereoscan' electronmicrographs of polished surfaces of high-rank bituminous vitrinite (carbon = 87.9% daf), heat-treated at 2400°C

(i) x375

(ii) x1500

(i)



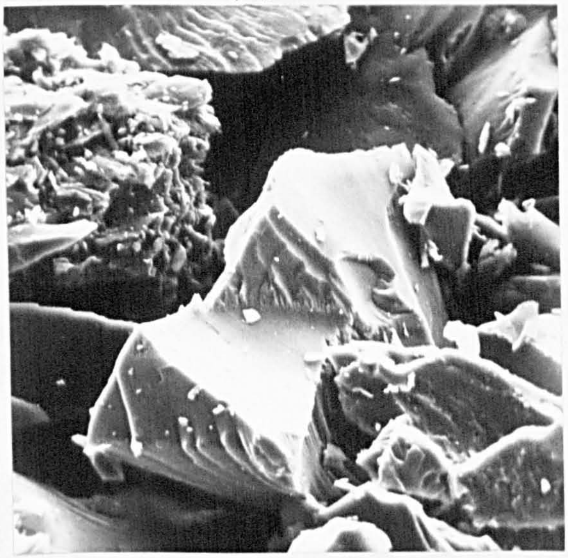


(ii)

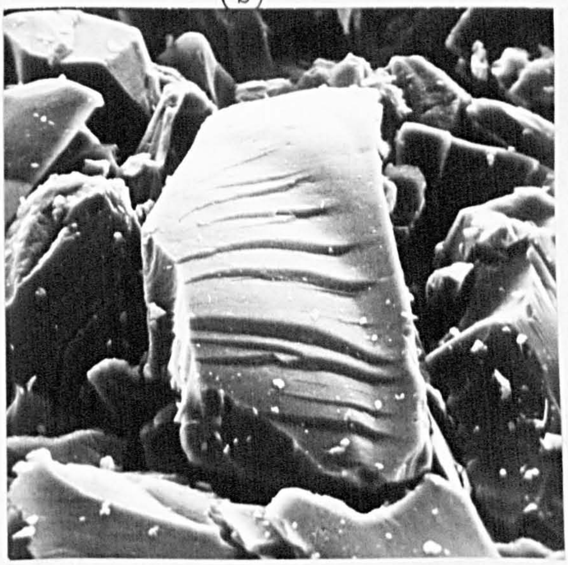
Plate 124 'Stereoscan' electronmicrographs of unpolished surfaces of heat-treated anthracitic vitrinite (carbon = 94.2% dmmf)

(a) 1100°C, x320
(b) 1500°C, x330
(c) 2400°C, x360

(a)



(b)



(c)

Plate 125 'Stereoscan' electronmicrographs of polished surfaces of heat-treated anthracitic vitrinite (carbon = 94.2% dmmf)

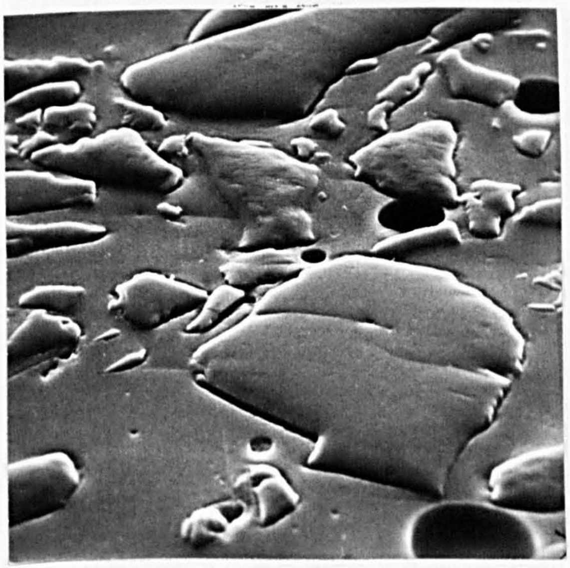
(a) 1100°C (i) x370

(ii) x1470

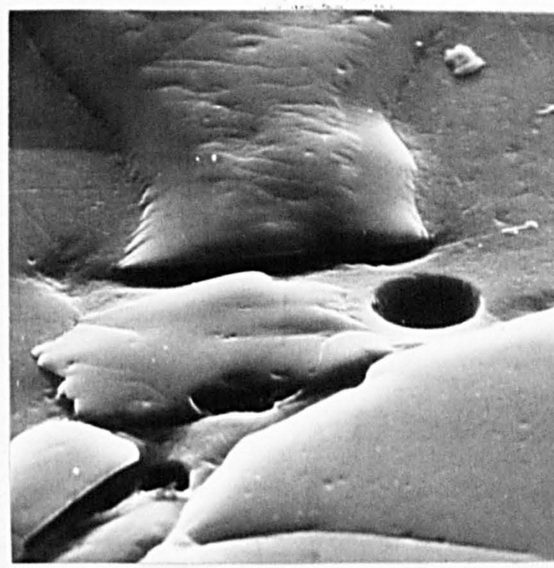
(b) 1500°C (i) x390

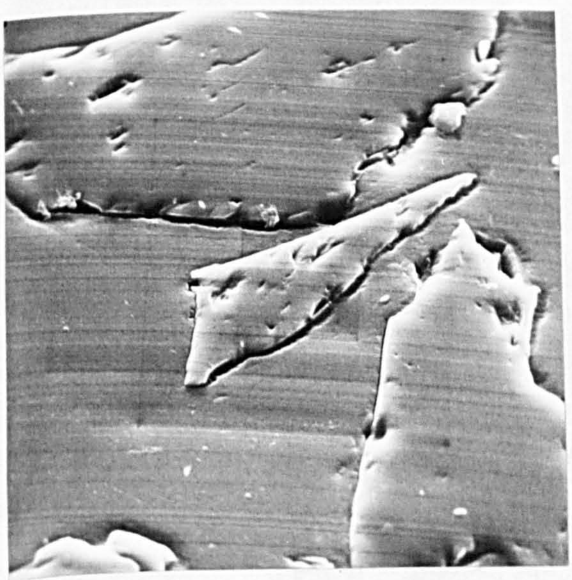
(ii) x1560

(a) (i)

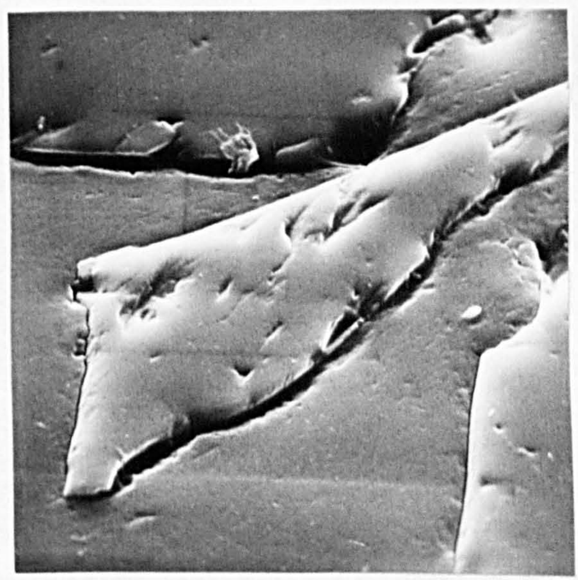


(a) (ii)





(b) (i)

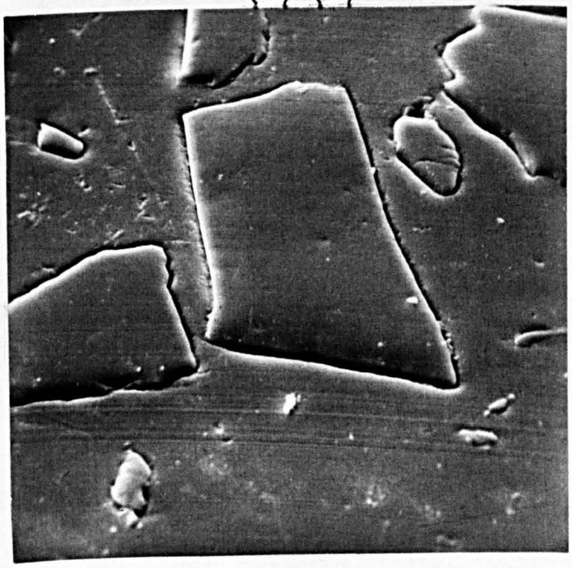


(b) (ii)

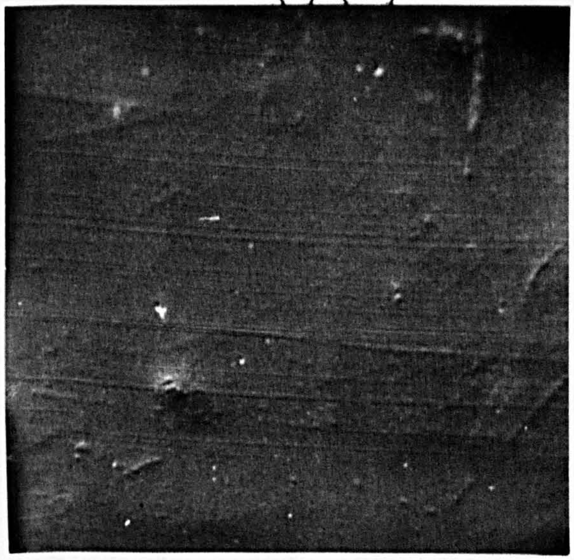
Plate 126 'Stereoscan' electronmicrographs of polished surface of heat-treated anthracitic vitrinite (carbon = 94.2% dmmf)

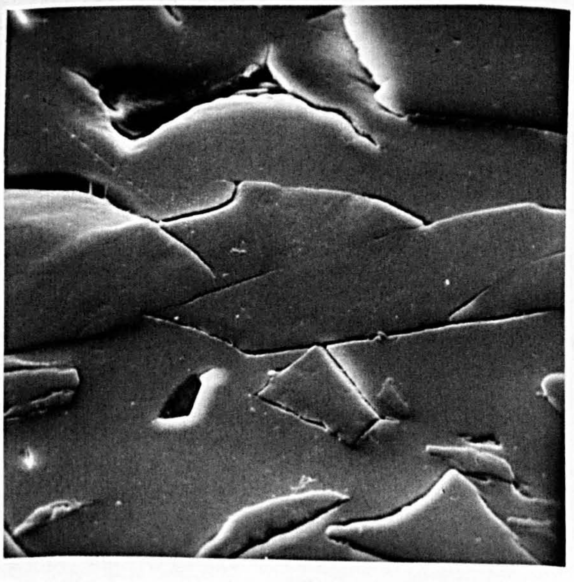
| | | |
|---|---|---|
| (a) 1800°C | (i) | x400 |
| | (ii) | x1600 |
| (b) 2400°C | (i) | x390 |
| | (ii) | x1560 |

(a) (i)

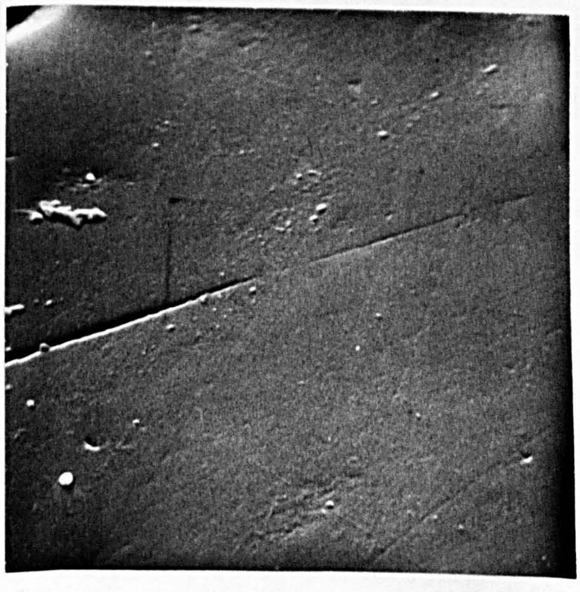


(a) (ii)





(b) (i)



(b) (ii)