Diagenesis and Mineralogy of the British Liassic Ironstones

S. J. James Ph.D. 1980 Volume II (II)

PHOTOGRAPHIC PLATES

PHOTOGRAPHIC PLATES

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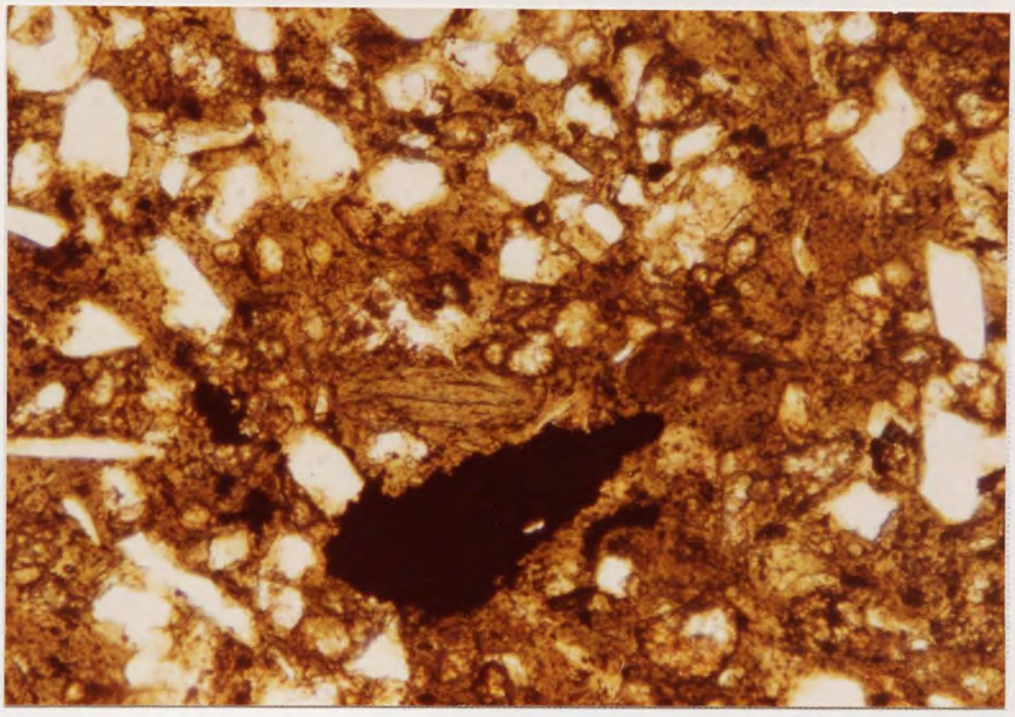
CHAPTER 2

THE FRODINGHAM IRONSTONE

Plate 2.1. Chamosite mudstone. Lamellae of depositional chamosite mud with a low proportion of detrital quartz (white) tend to alternate with more quartzose chamosite mud lamellae. Note the presence of a chamosite book with rounded and ragged ends. The opaque phase is pyrite. PPL, x200.

Plate 2.2 Chamosite mudstone intraclast armoured with quartz grains. PPL, x31.25.



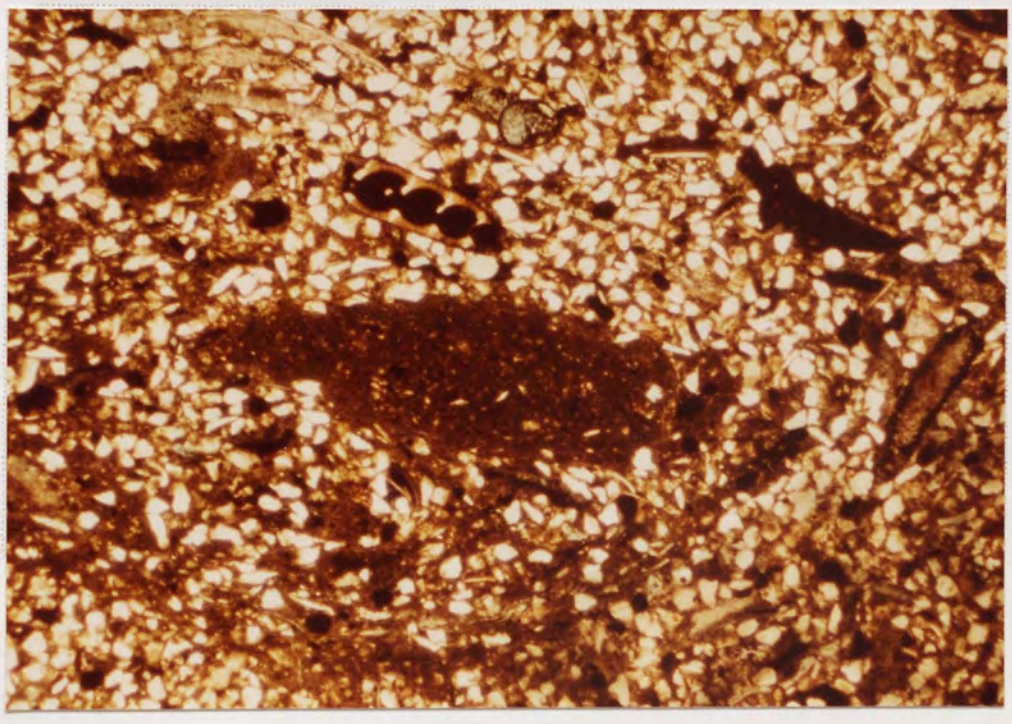
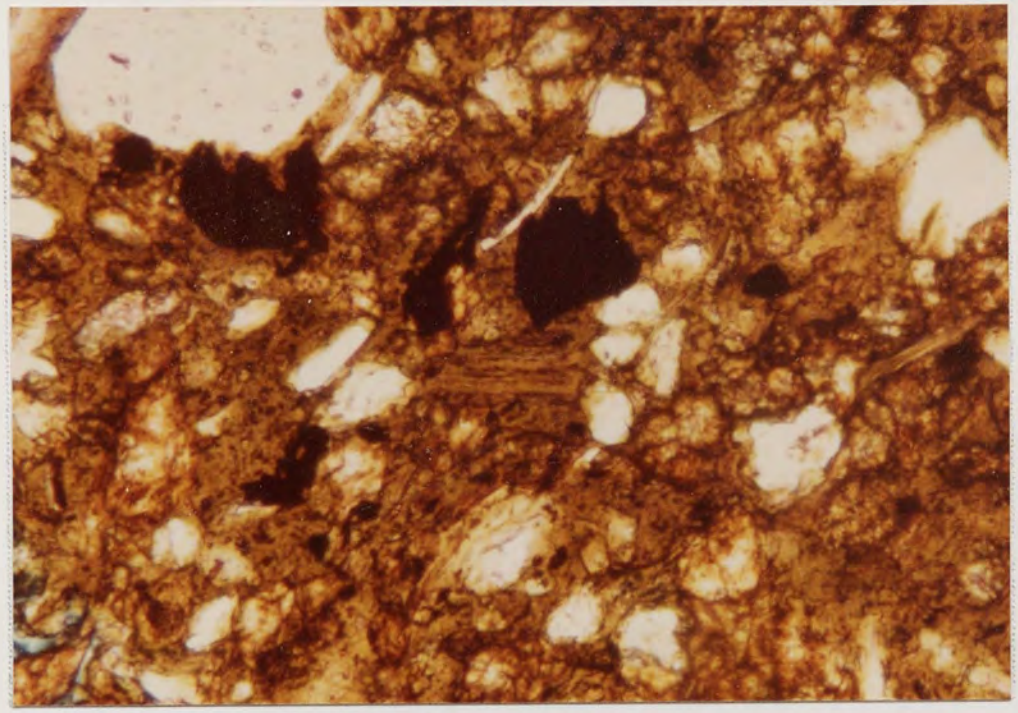
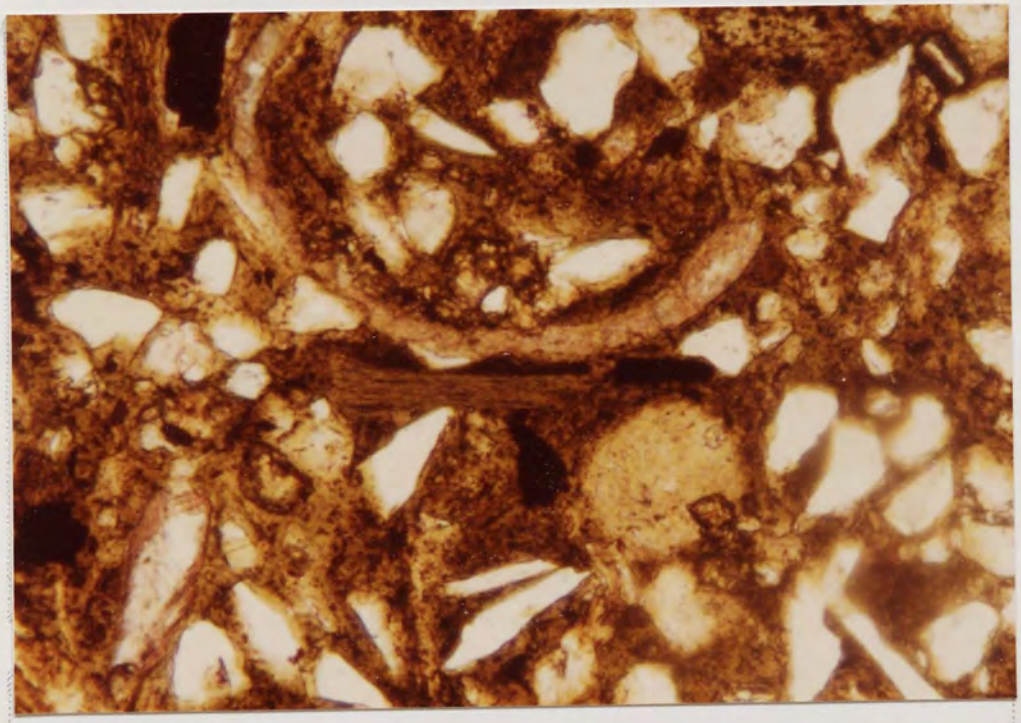


Plate 2.3a Olive green chamosite book with ragged terminations and oriented with the (001) cleavage parallel to bedding. The opaque phase is pyrite. PPL, x200.

Plate 2.3b Grass green chamosite books with terminations which are much less ragged than those of the book seen in Plate 2.3a. The opaque phase is pyrite. PPL, x200.





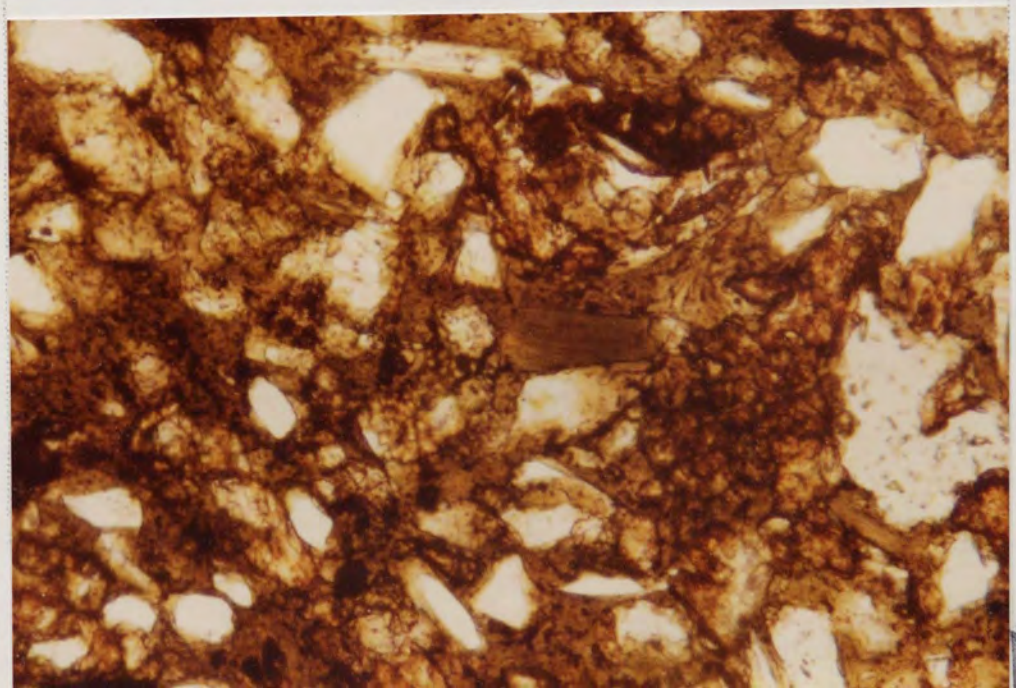
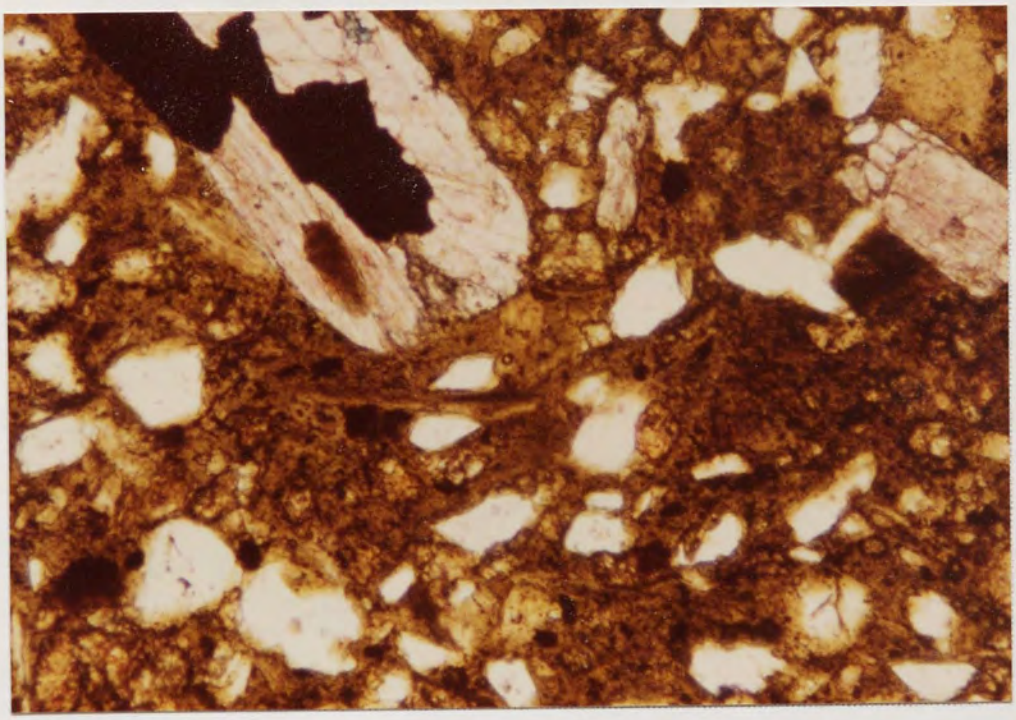


Plate 2.3b Grass green chamosite books often appear to have had their growth controlled by the presence of quartz grains (PPL) and pass with optical continuity into small patches of non-structured authigenic chamosite (XP, 45° position). The opaque phase is pyrite. x60.



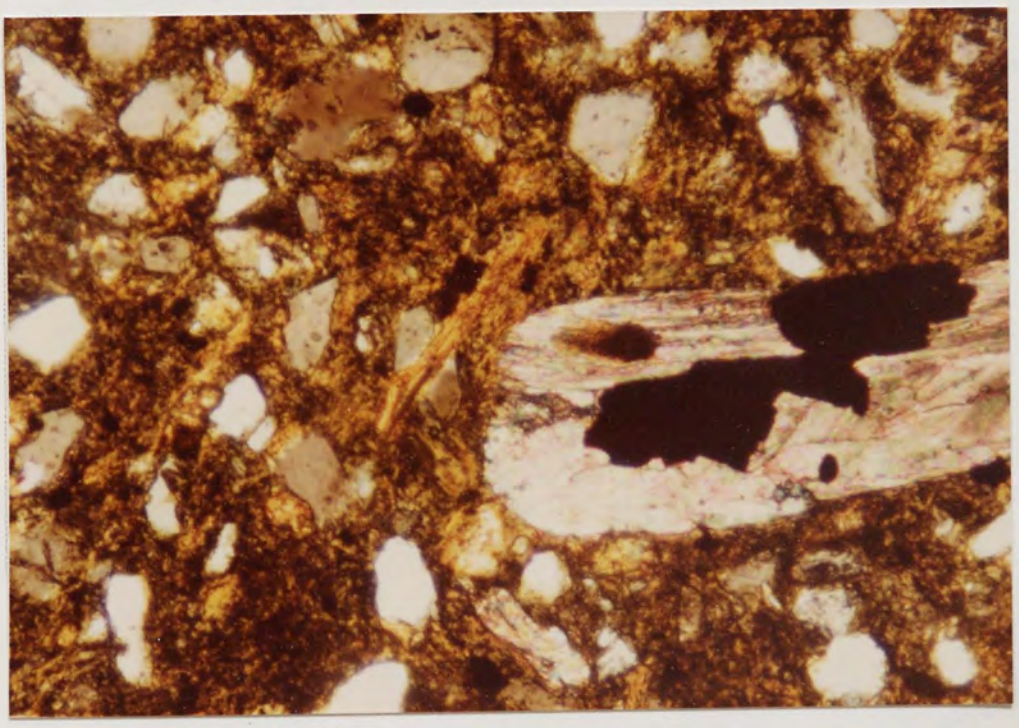
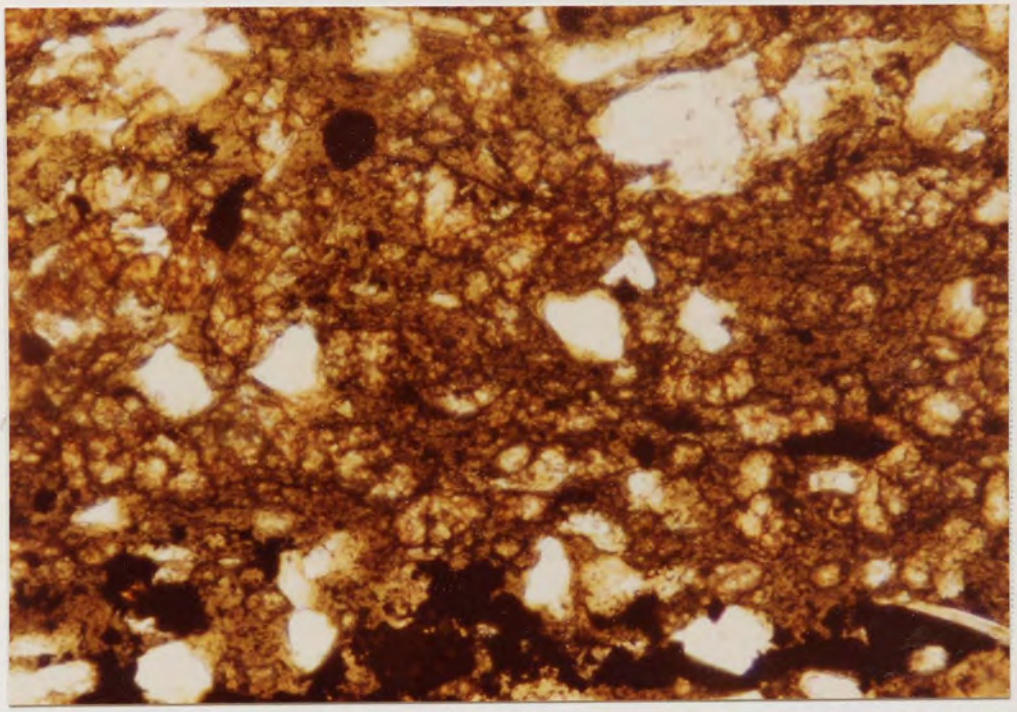


Plate 2.4 Trains of equant siderite anhedra (white, high relief, slightly iron-stained) parallel and sub-parallel to lamination. The opaque phase is pyrite. PPl, x160.

Plate 2.5 Chamosite mudstone sub-type (iii). Quartz is absent. The abundance of siderite anhedra (white, high relief) obscures any original chamosite mud fabric. PPL, x125



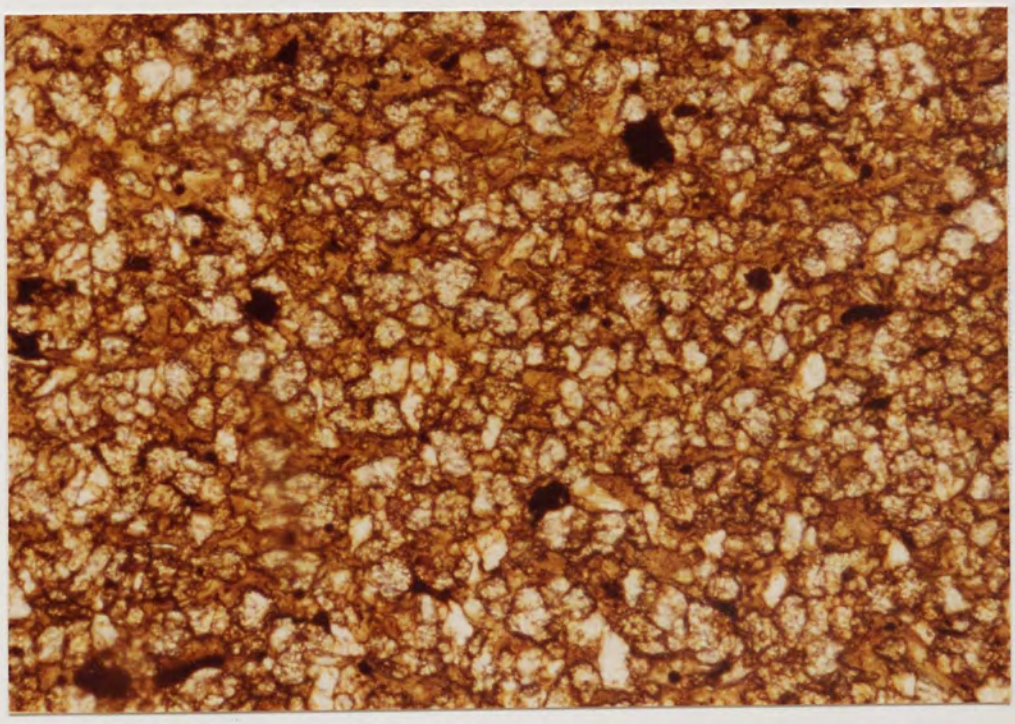
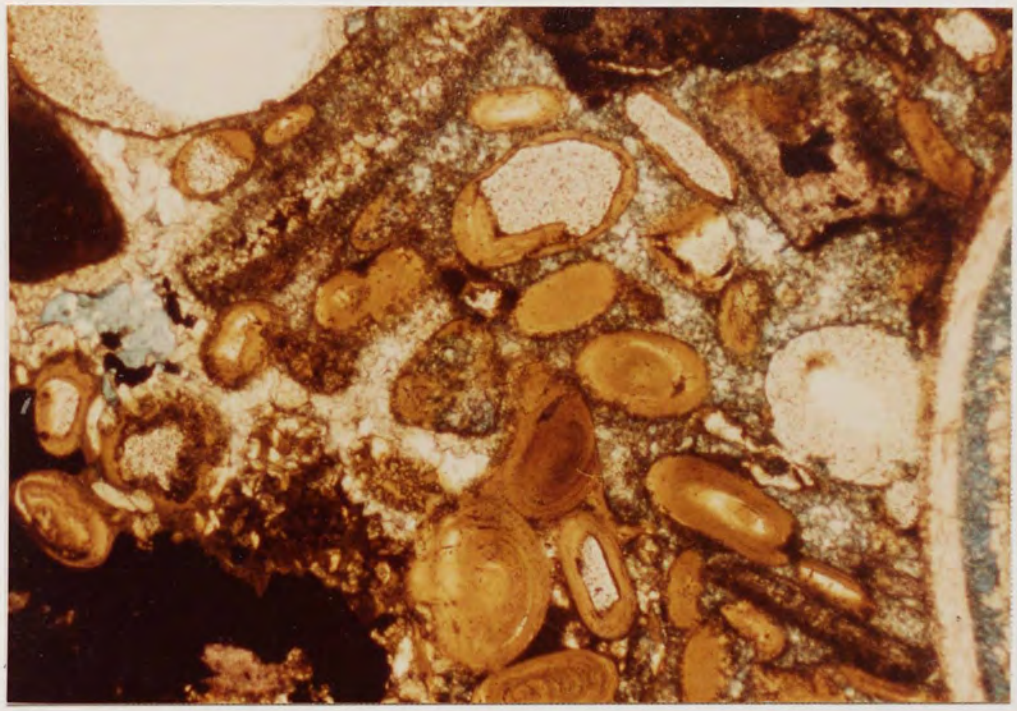


Plate 2.6 Chamositic chamosite oolite. Much of the original chamosite mud has been removed leaving remnants interstitial to chamosite ooids. Note the thick micrite envelope to an originally aragonite shell fragment (top left). Stained section, PPL, x31.25.

Plate 2.7 Chamosite ooid. Stained section, PPL, x125.



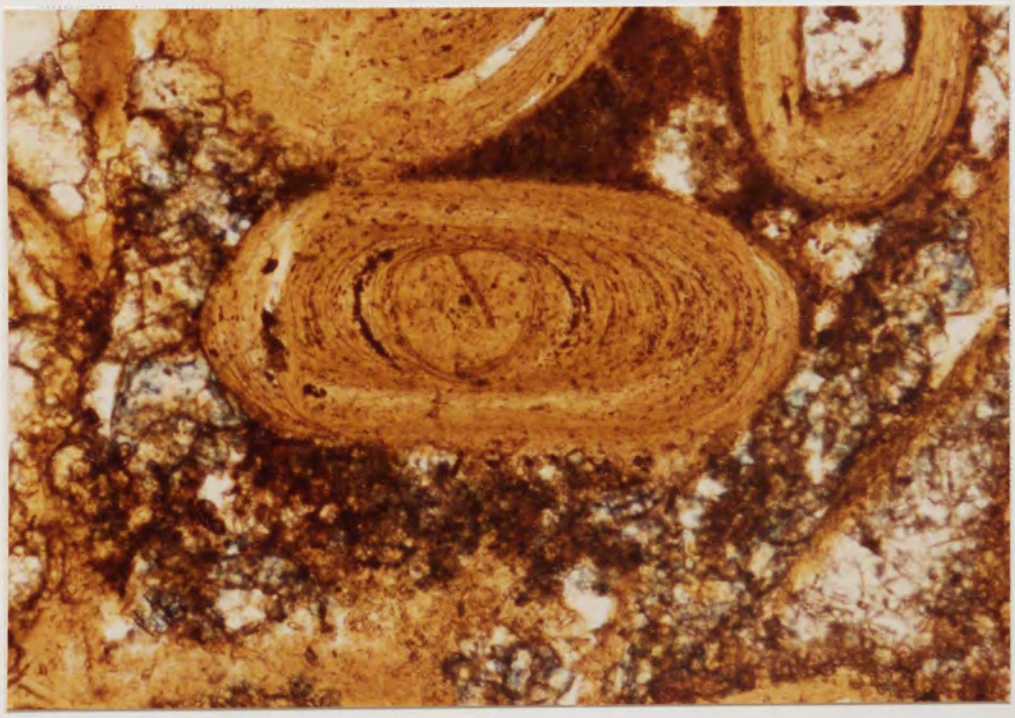


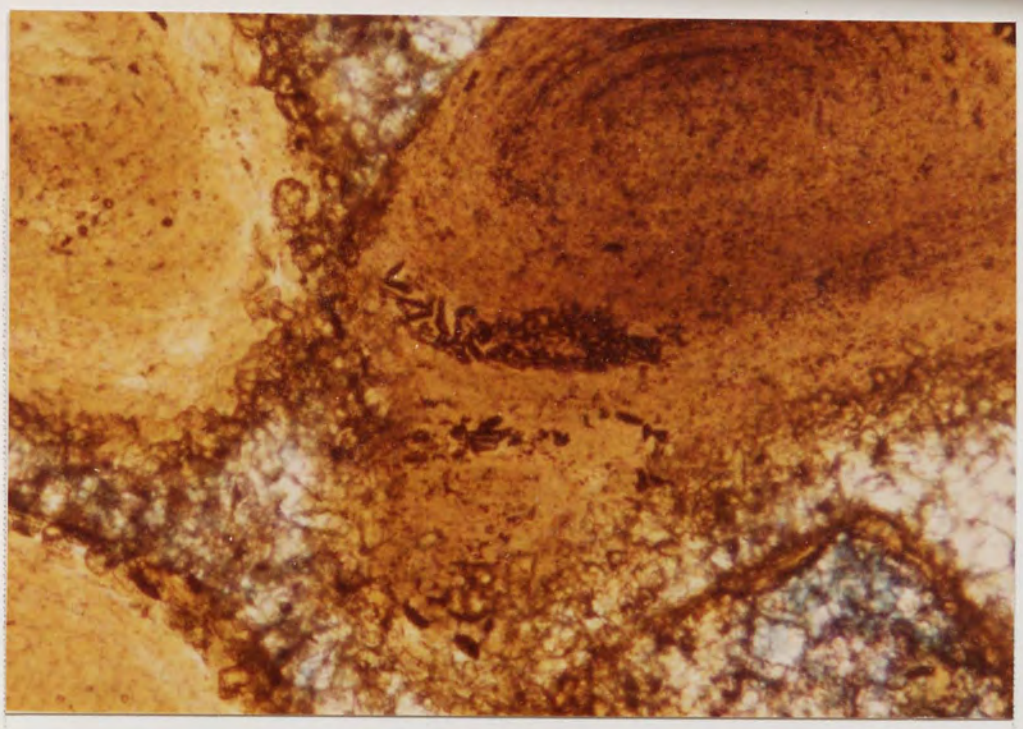
Plate 2.8a Chamosite ooid with pseudo-uniaxial extinction cross. Stained section, XP, x125.

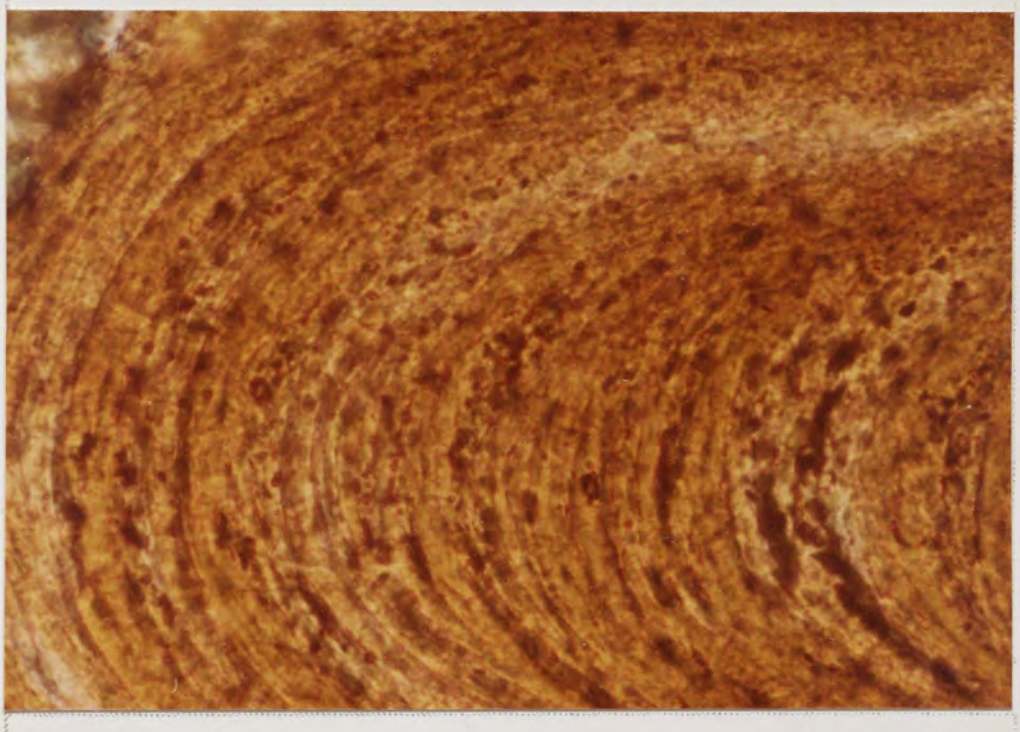
Plate 2.8b With a sensitive tint plate a positive optic sign fo chamosite ooids is obtained. Stained section, XP, mica plate, slow direction NW-SE, x125.

Plate 2.9a Concentrations of black filamentous tubular inclusions are found in ooid envelopes. They have a dominant orientation with their long axes sub-parallel to the ring structure. Stained section, PPL, x200.

Plate 2.9b Sub-parallel orientation of black filamentous inclusions at ring contacts. In some cases these are abundant and merge to form a single irregular band. Stained section, PPL, x500.

Plate 2.10 Cross-cutting burrows, thought to be algal borings, occur in ooids and are infilled with chamosite and occasional black filamentous material. PPL, x 500.





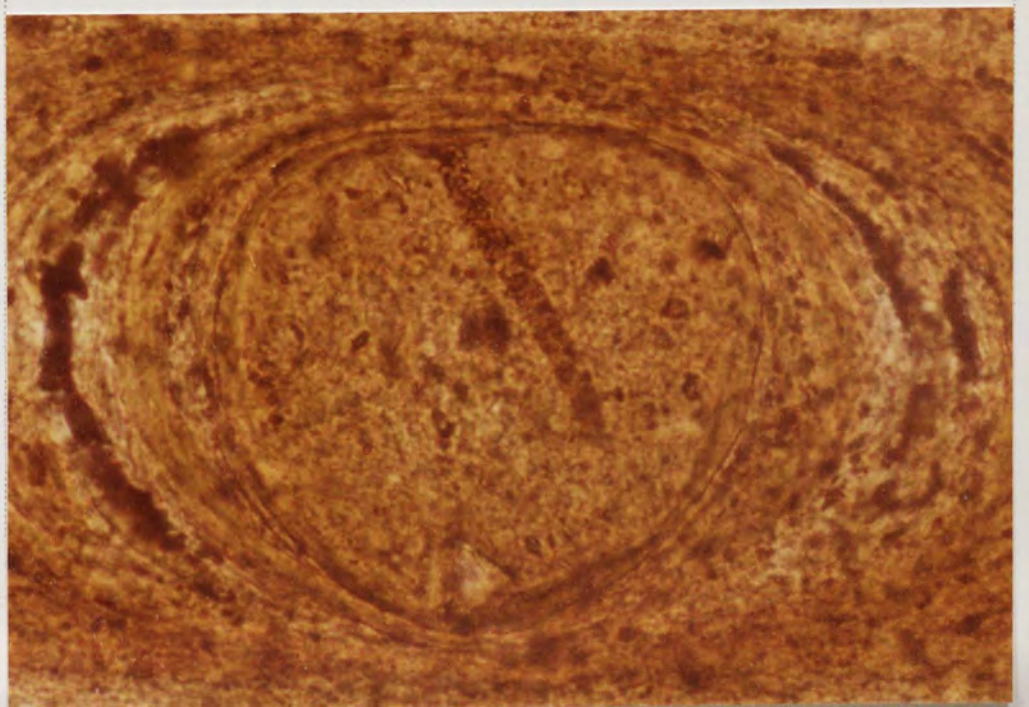
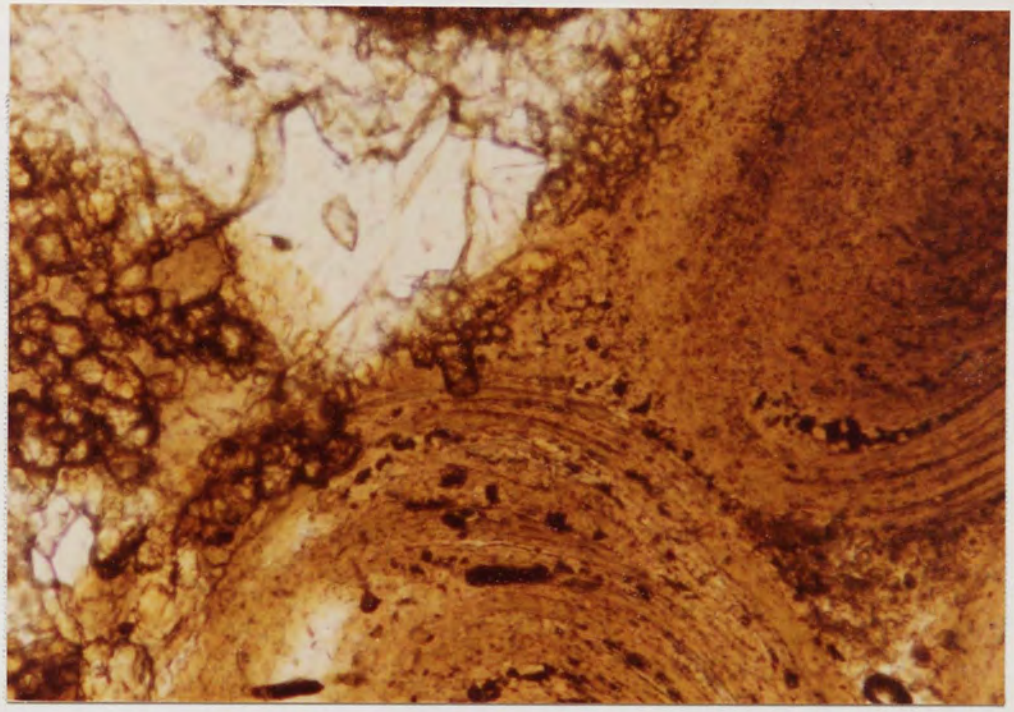


Plate 2.11a Black filamentous inclusions occur within the chamosite mud interstitial to ooids. Stained section, PPL, x200.

Plate 2.11b At low magnification there is an apparently gradational contact between chamosite ooids and chamosite mud, but at higher magnification this is not seen to be the case. Stained section, PPl, x31.25.



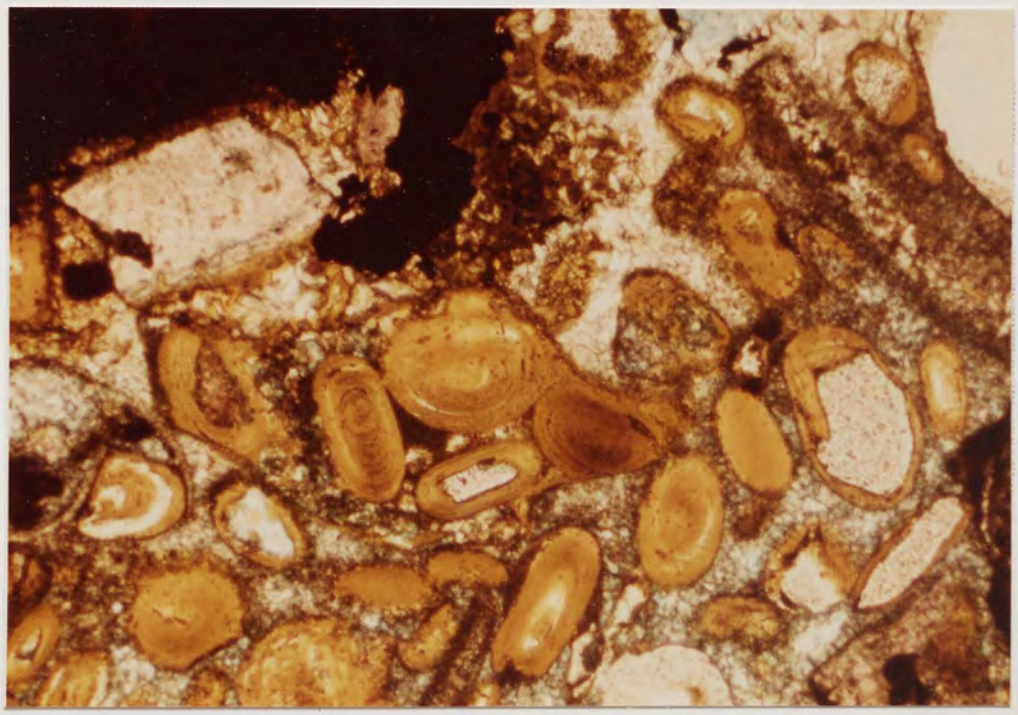
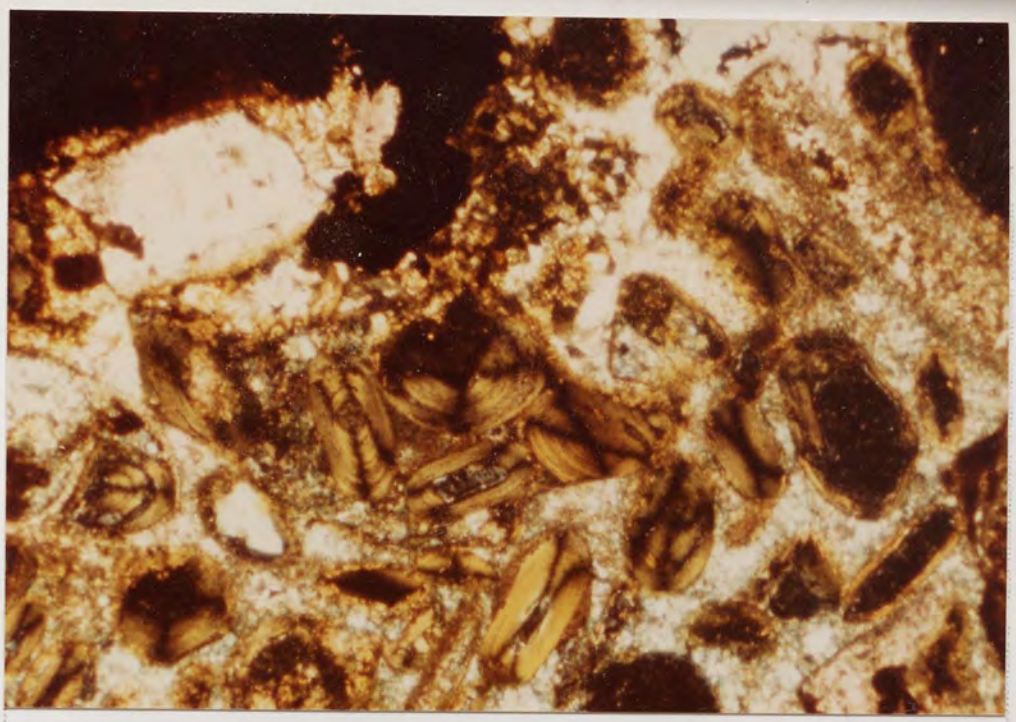
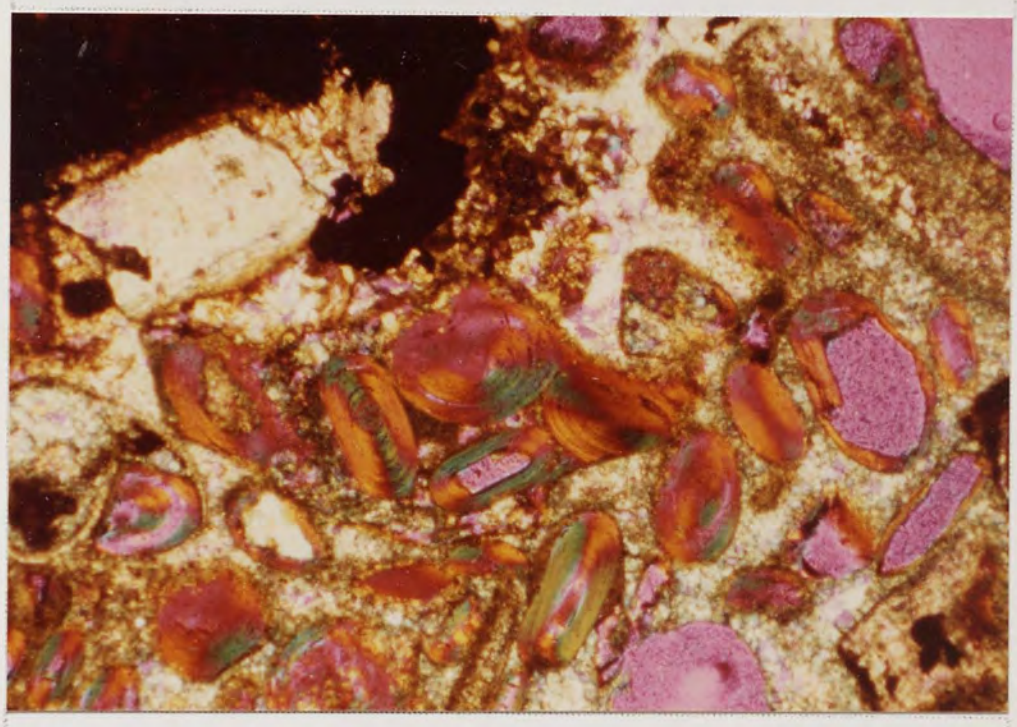


Plate 2.11c The extinction crosses of the ooids seen in Plate 2.11b extend beyond the ooid boundary and into the interstitia chamosite mud. Stained section, XP, x31.25.

Plate 2.11d With the aid of a sensitive tint plate it can be seen that some of the mud has the same optic sign as one ooid and the remainder the same sign as an adjacent ooid i.e. Plate 2.11e. Stained section, XP, mica plate, slow direction NW-SE, x31.25.

Plate 2.11e See text for discussion.





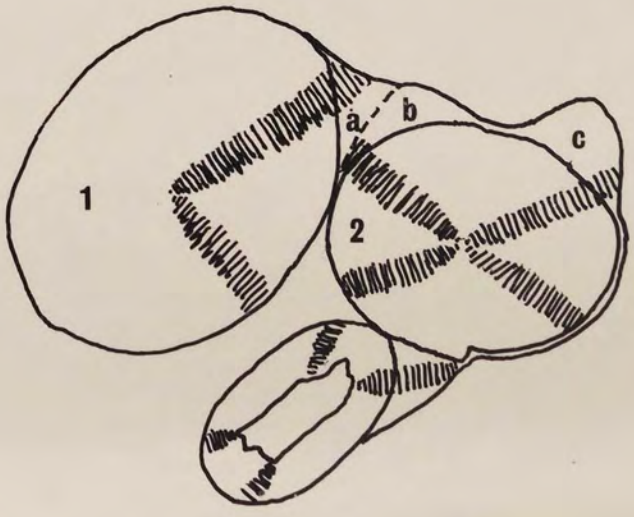
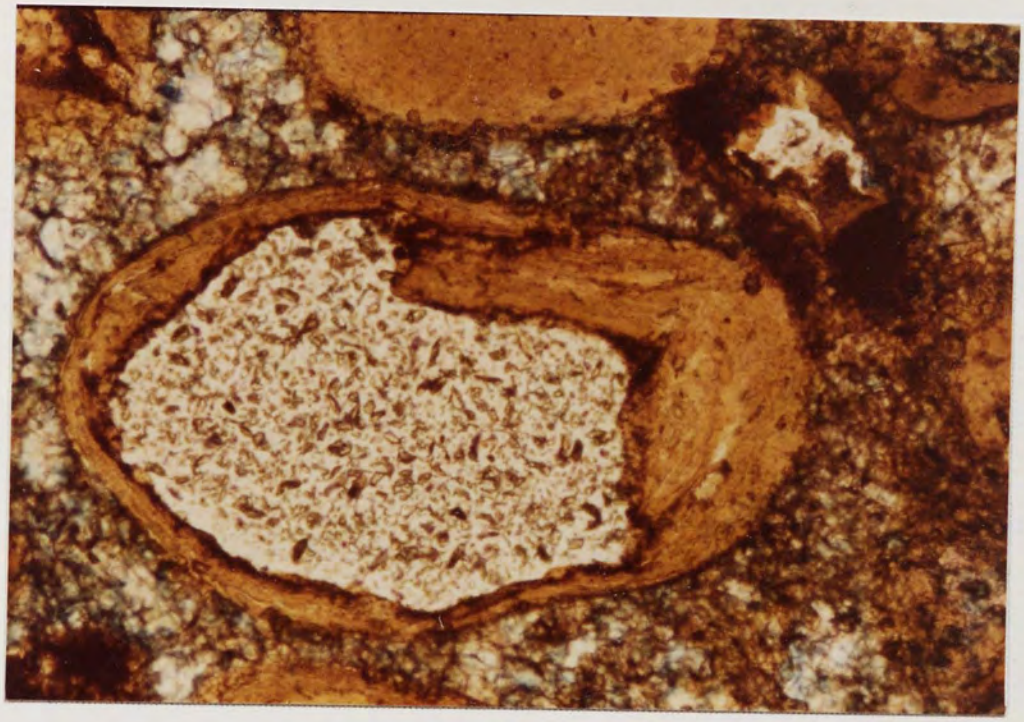

a
b
c
1
2

Plate 2.12 Ooimoulds. The majority of ooimould voids correspond to an ooid ring contact although in these examples a more irregular void-form occurs. Stained section, PPL, x125.



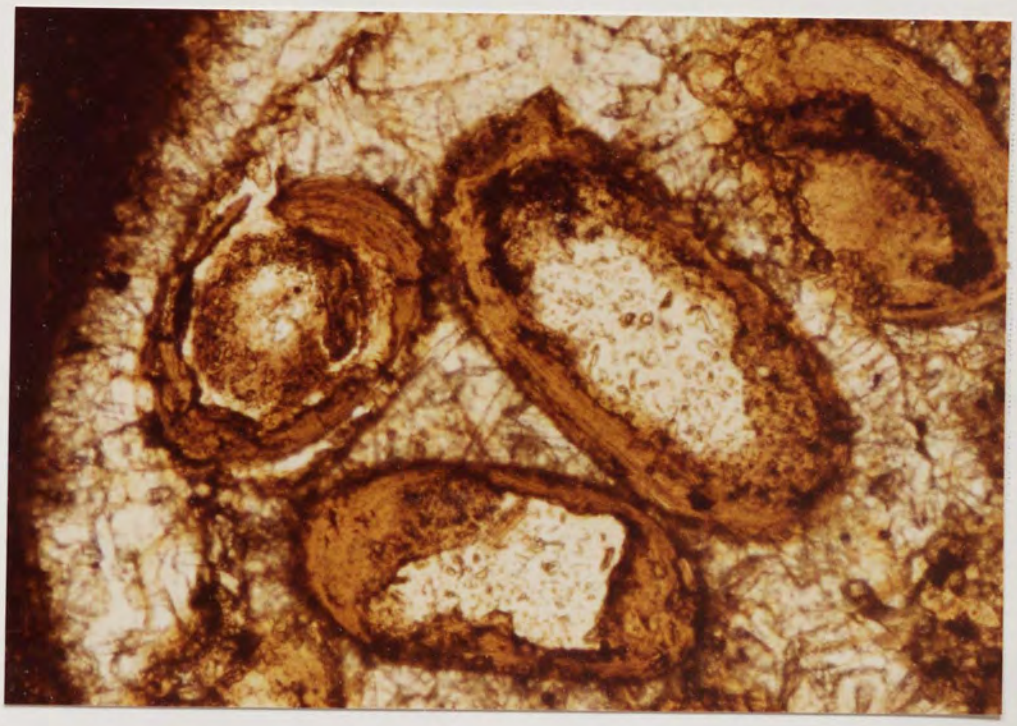
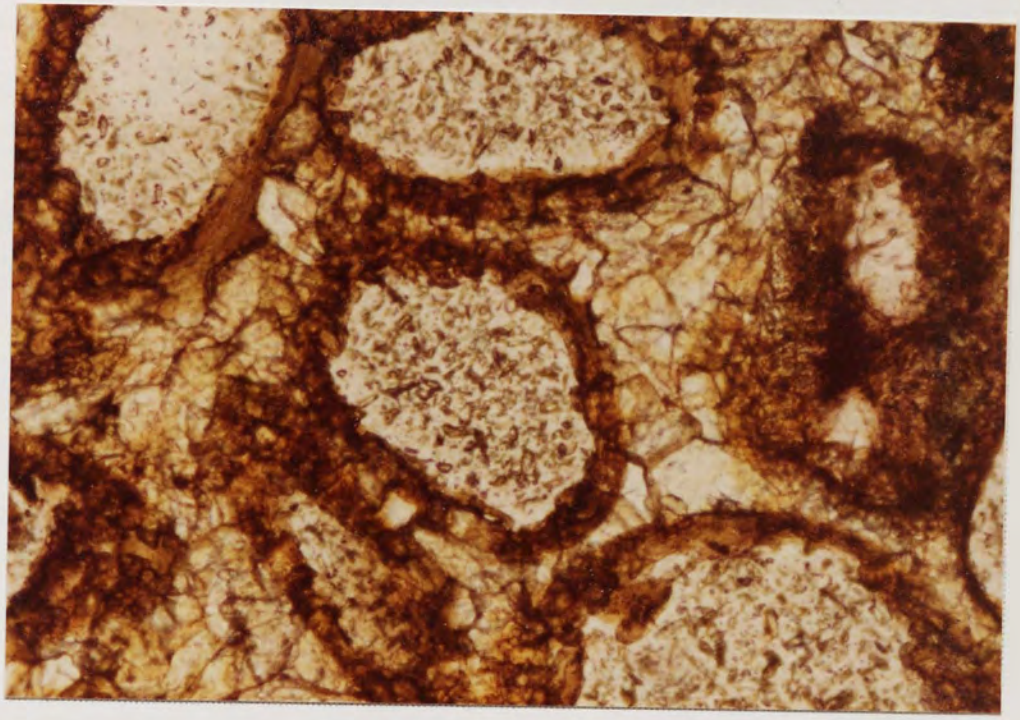


Plate 2.13a Siderite euhedra replace the outer two or three envelope rings of an ooid and show ghost ring contacts. In this example the component crystals of the siderite cement are responsible for this replacement. Stained section, PPL, x125.

Plate 2.13b As for Plate 2.13a, XP, x125.



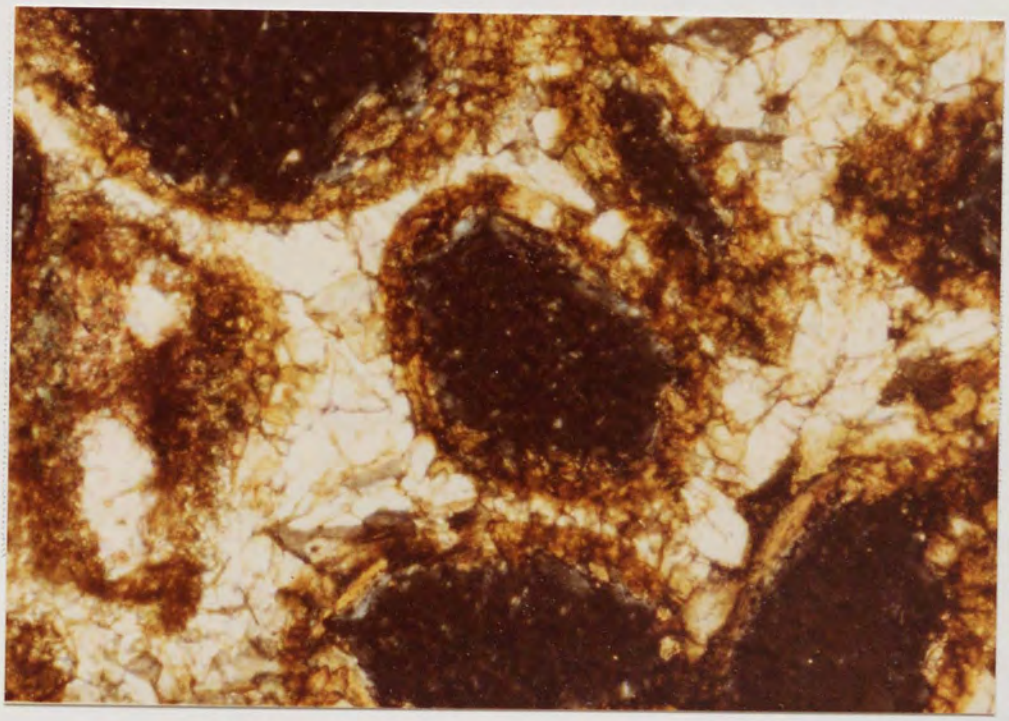
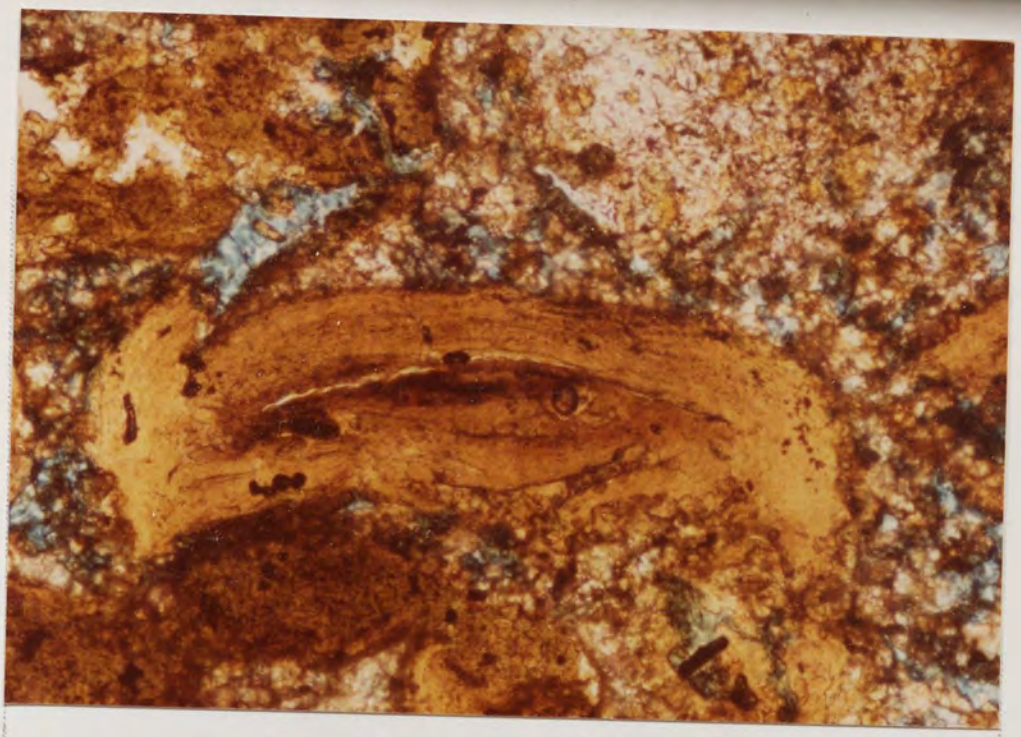


Plate 2.14 Flame ooids. The collapse of ooimoulds leads to the creation of flame-shaped hooked ooids. A central suture line corresponding to the long axis represent the boundary of the original ooimould void. Stained sections, PPL, x125.



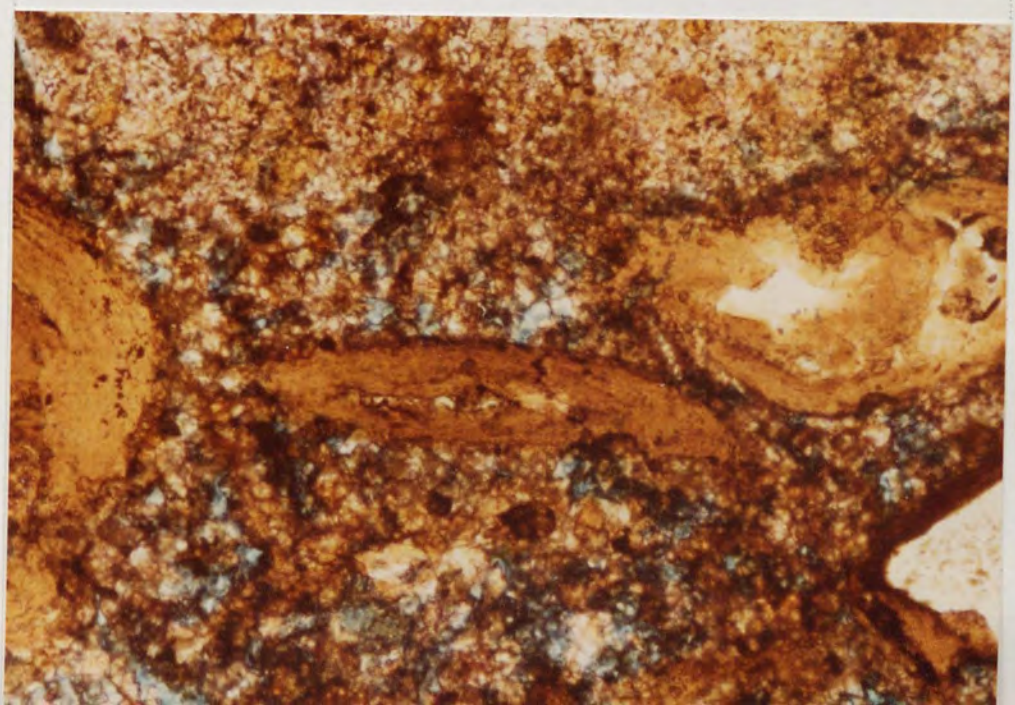
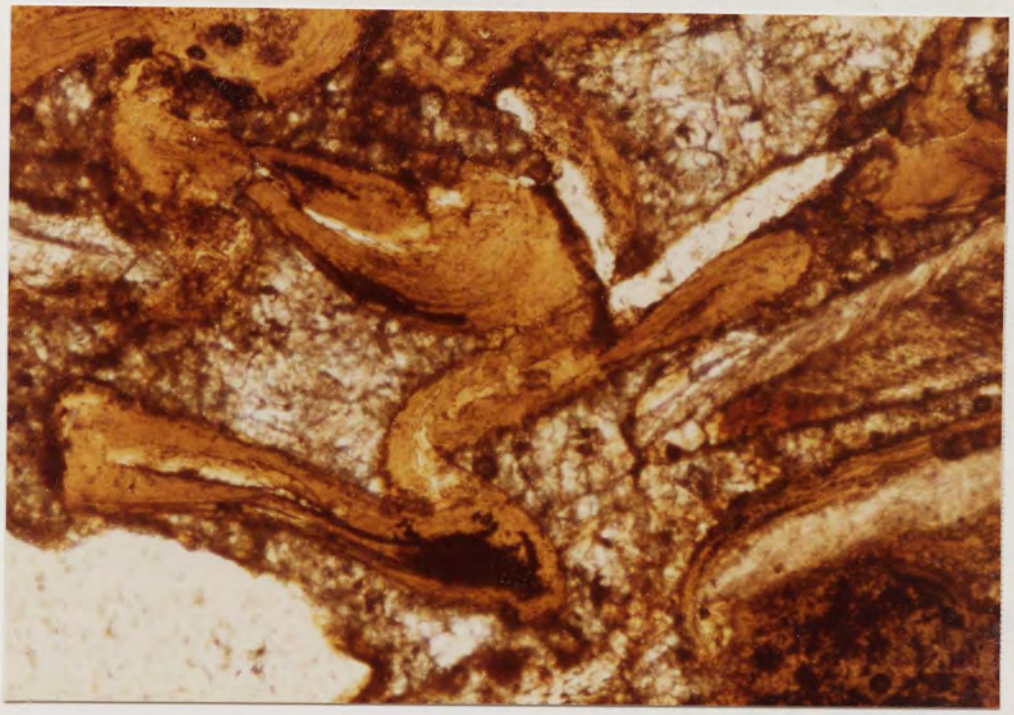


Plate 2.15 Linked flame ooids. If ooimoulds are closely situated or touching at the time of compression, linkages between the resultant flame ooids are formed. Stained sections, PPL, x125.



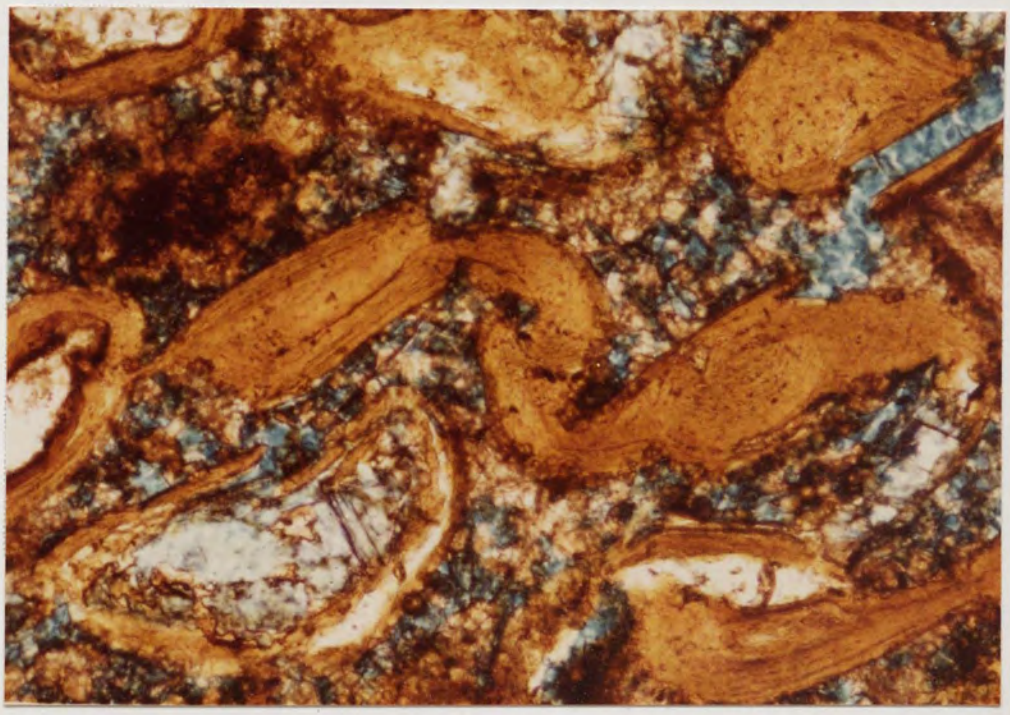
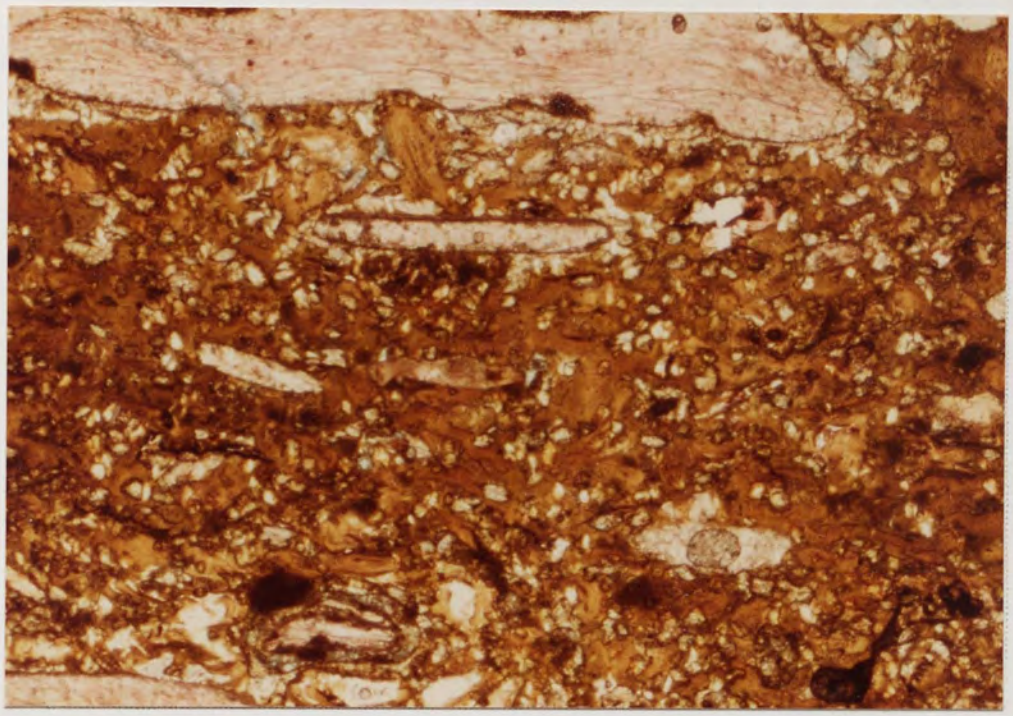


Plate 2.16 Ooid melange. The mechanical failure of a sediment comprising almost entirely ooimoulds leads to the formation of structure in which only remnants of any original ooid structure are seen. Stained sections, PPL, x31.25.



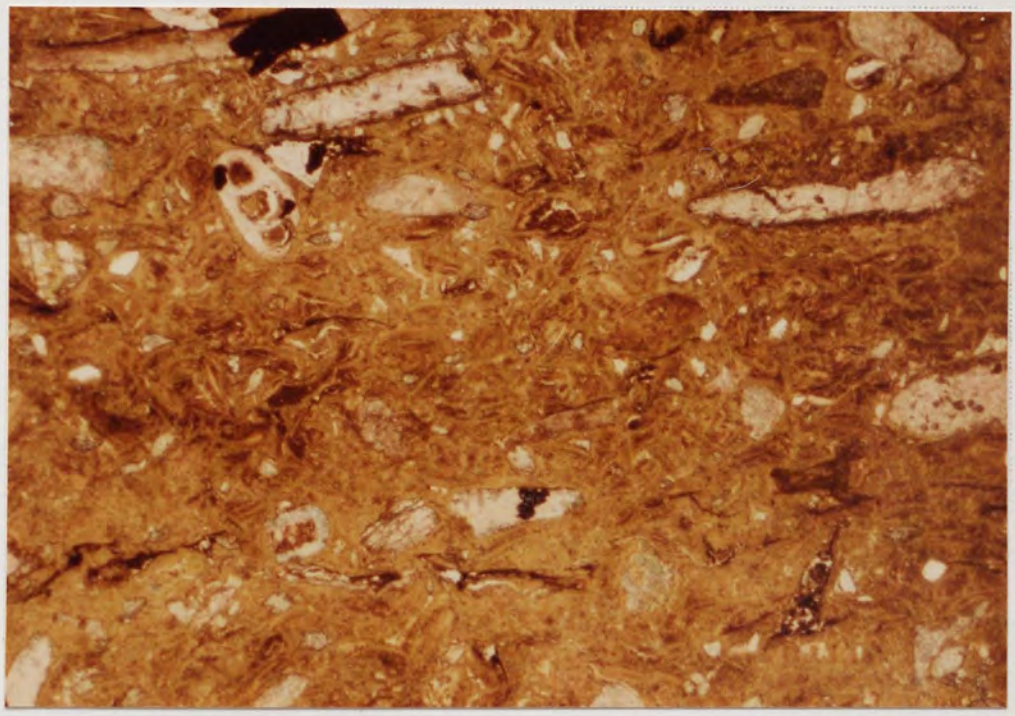
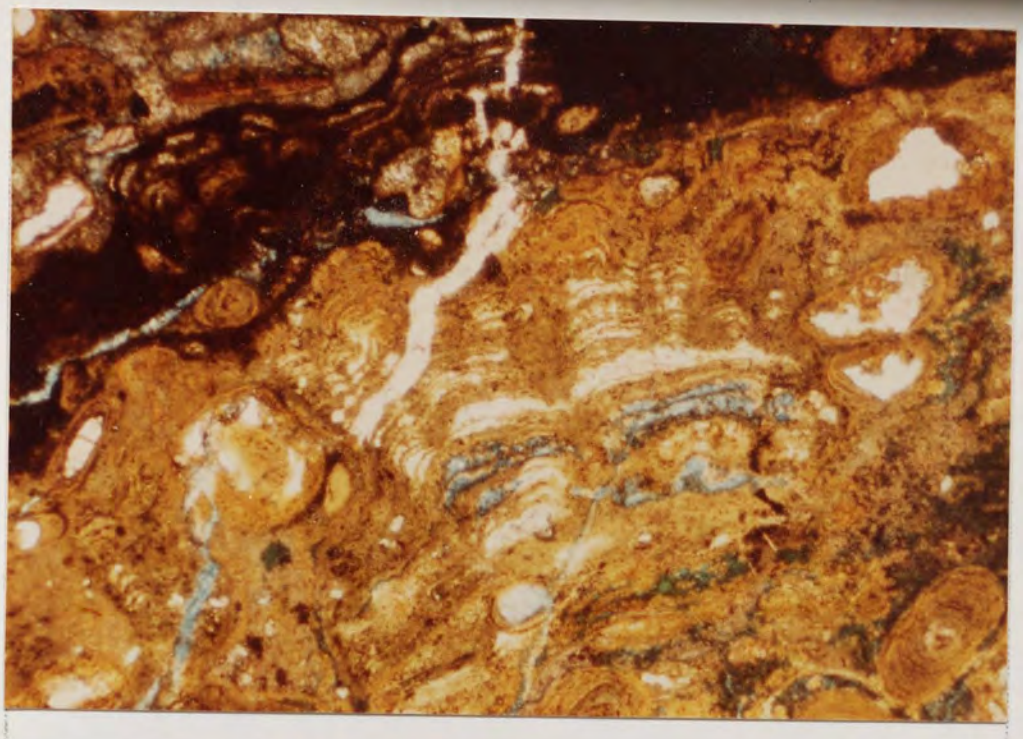
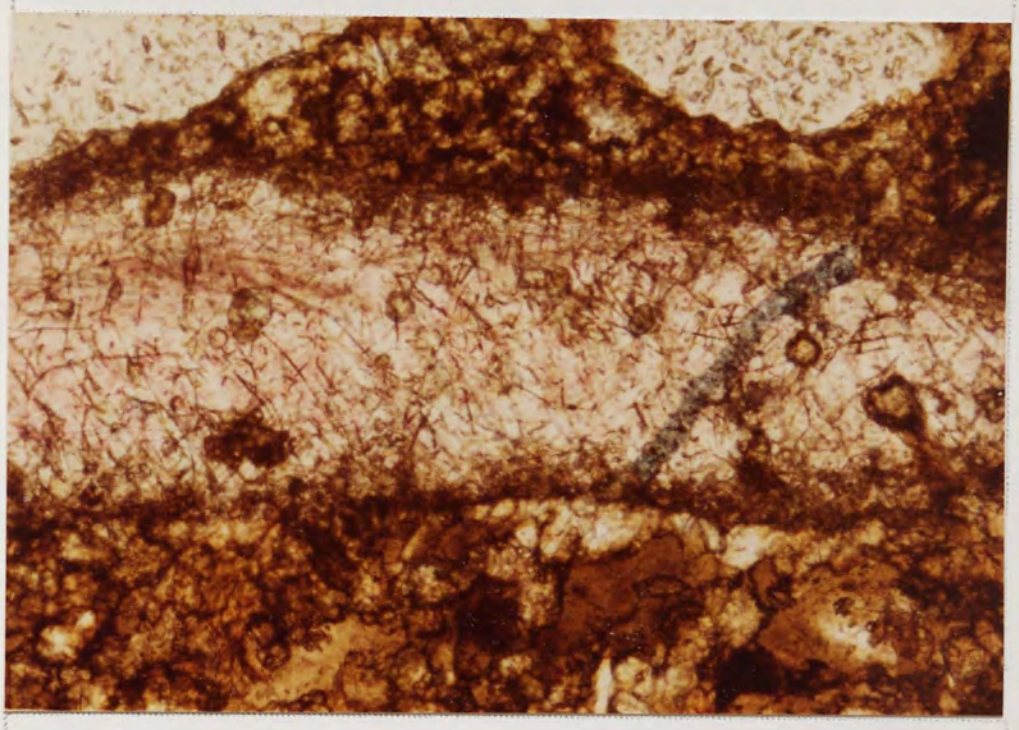


Plate 2.17 Pisoliths exhibit a hummocky structure in which ooids are oriented with their long axes tangential to the pisolith envelope. Stained section, PPL, x31.25.

Plate 2.18 Originally calcite shells exhibit thick micrite envelopes and are heavily bored. Stained section, PPL, x125.

Plate 2.19 The dissolution of originally aragonite shell fragments created secondary pore spaces which were retained by micrite envelopes. The subsequent infilling of these pore spaces by cement minerals creates a zonation corresponding to the cement paragenesis. Stained section, PPL, x125.





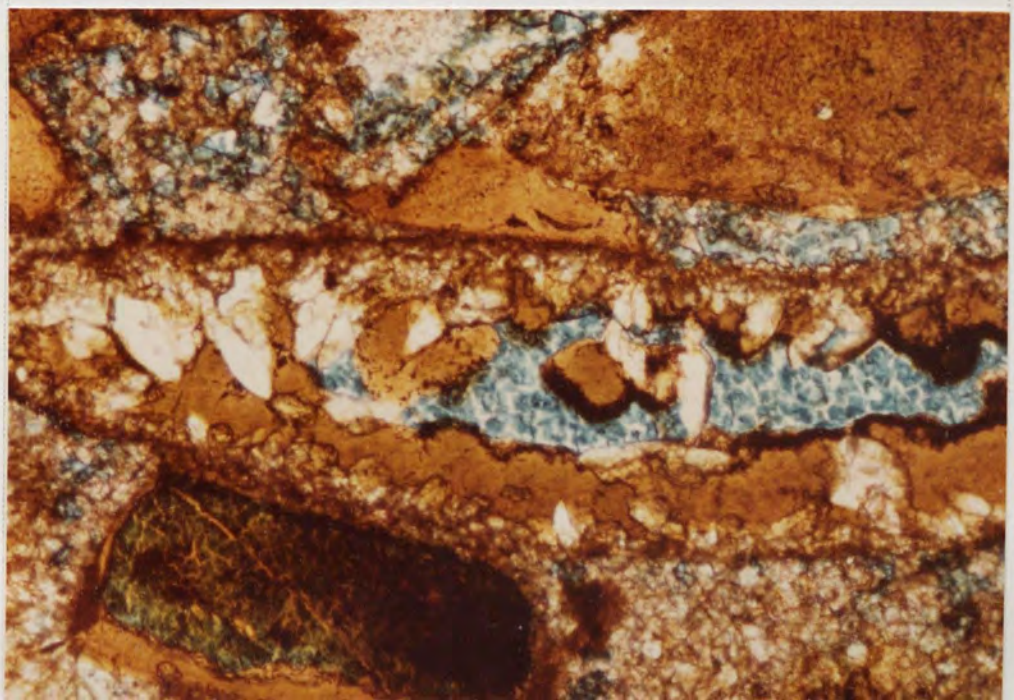
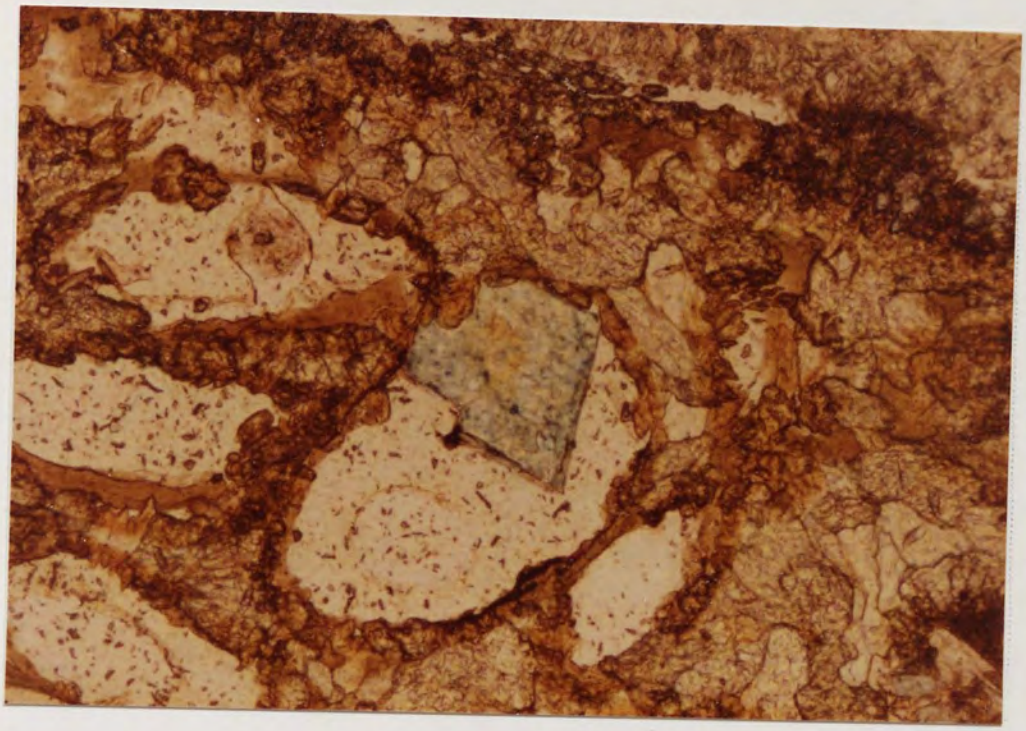


Plate 2.20 Ferroan dolomite rhombs are often found in ooimoulds. Stained section, PPL, x125.



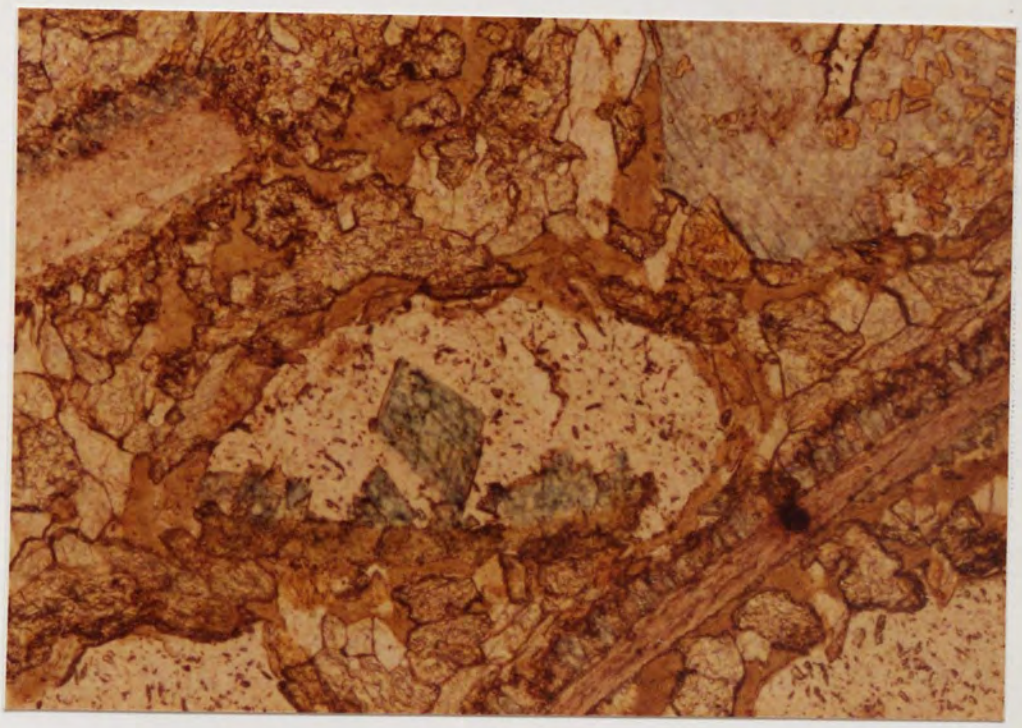
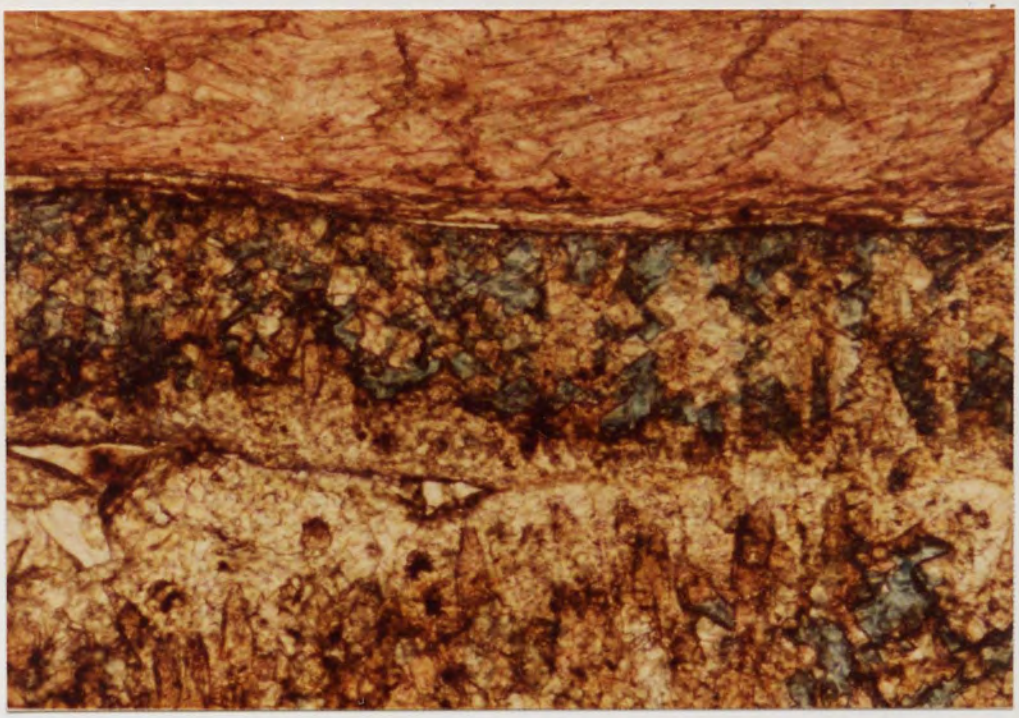


Plate 2.21 Calcite molluscan debris was initially cemented by high-magnesian calcite. The inversion of this to low-magnesian calcite was accompanied by the loss of Mg^{2+} which nucleated locally as ferroan dolomite rhombs (turquoise-bluish white) and the uptake of Fe^{2+} to form ferroan calcite (blue). Siderite precipitated contemporaneously with this, infilling the porosity and retaining ghosts of the original high-magnesian radial fibrous calcite cement. Stained section, PPL, x125.

Plate 2.22 In large pore spaces siderite precipitated as a botroidal pore lining. Ferroan calcite (light blue) crystallised as a pore-infill at a late stage. Stained section, PPL, x31.25.



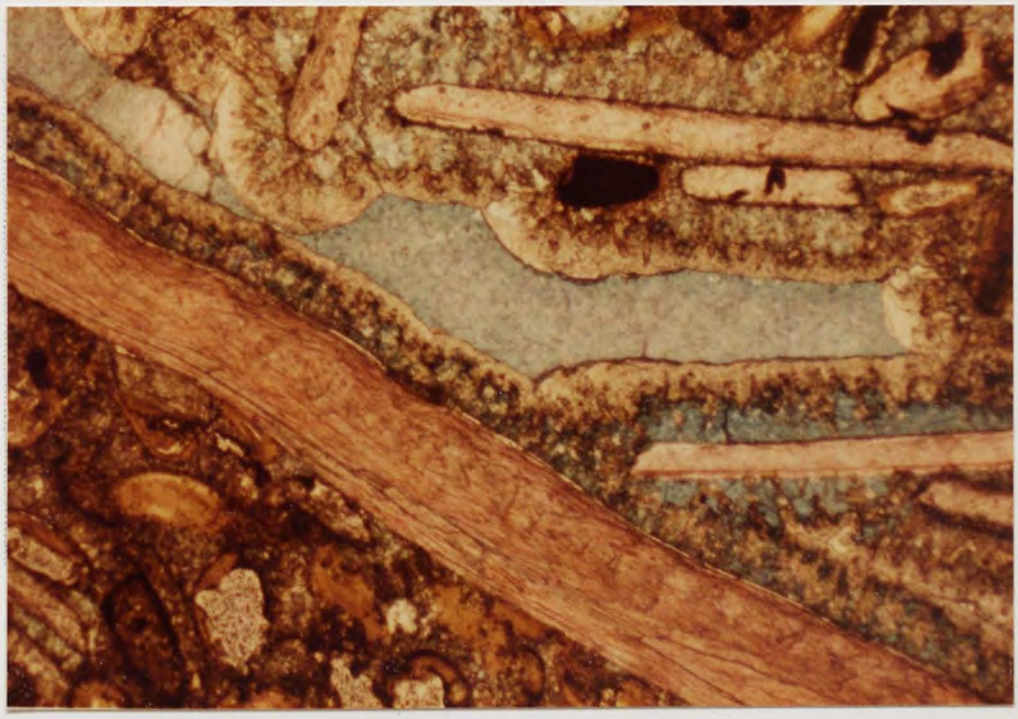
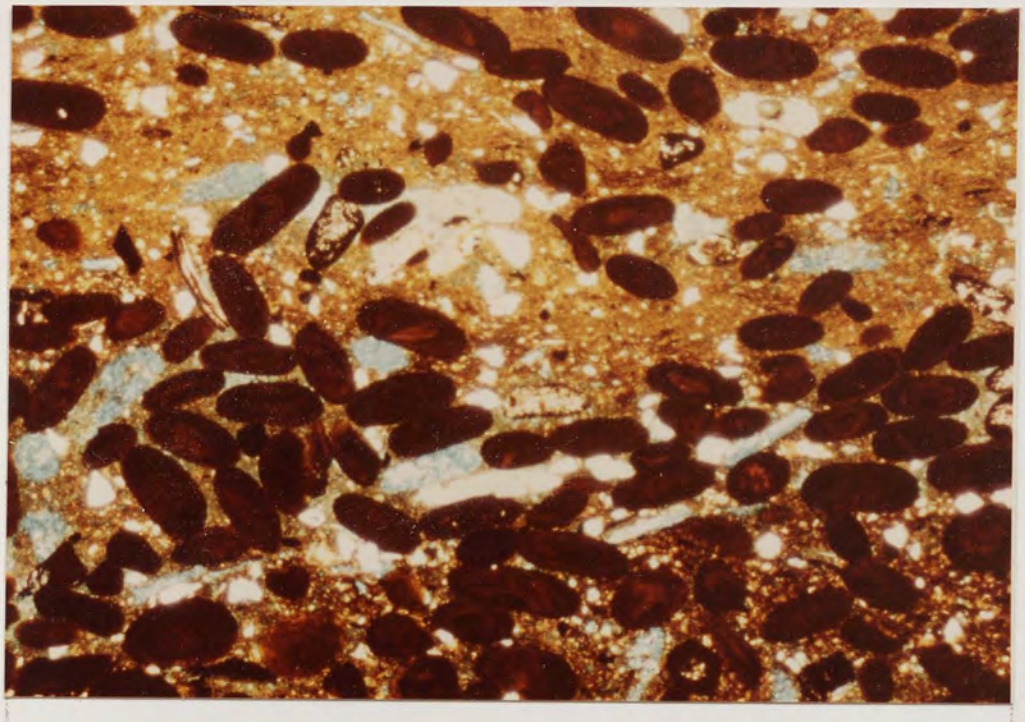
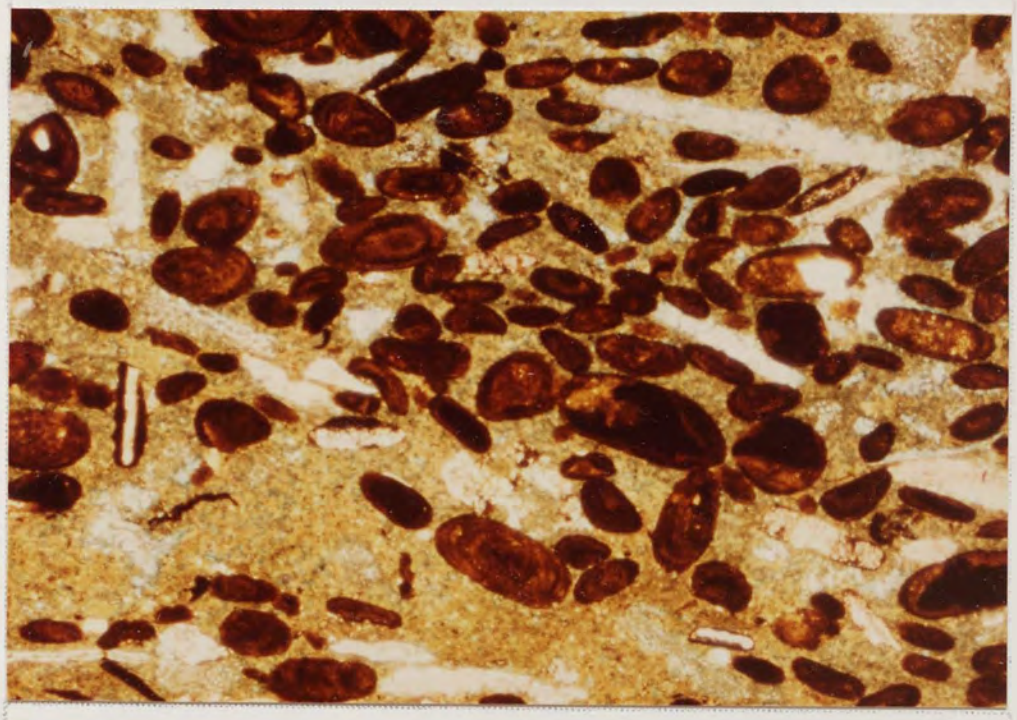


Plate 2.23 Chamositic limonite oolite sub-type (i). Dark brown goethite ooids, detrital quartz grains (white) and shell fragments are set in depositional chamosite mud and cemented with ferroan calcite. Stained section, PPL, x31.25.

Plate 2.24 Chamositic limonite oolite sub-type (ii). Allochemical grains are set in light green authigenic chamosite. Angular areas of siderite (white) and ferroan calcite are common. Quartz is absent. Stained section, PPL, x31.25.

Plate 2.25 Individual rings of chamosite (yellowish green) occur in dominantly goethite ooids. Stained section, PPL, x125.





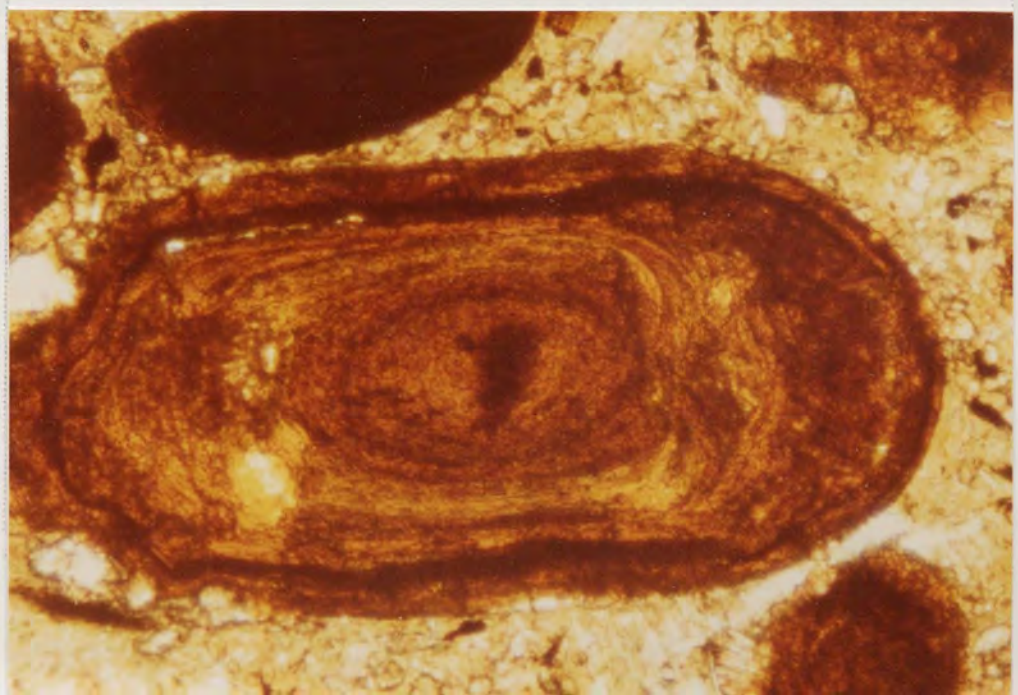
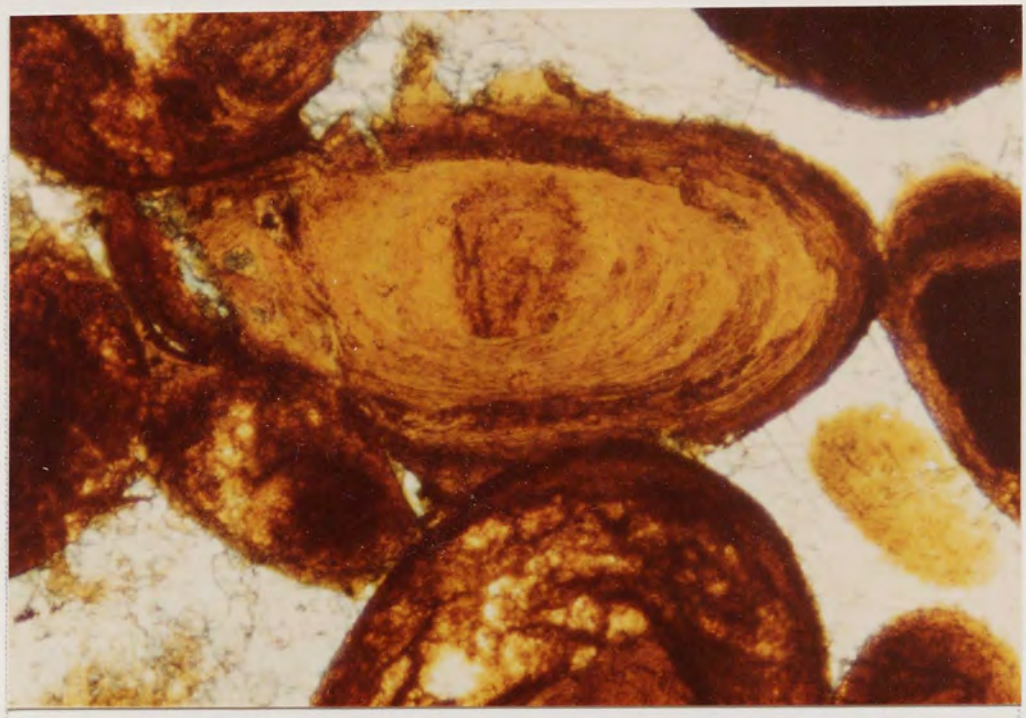
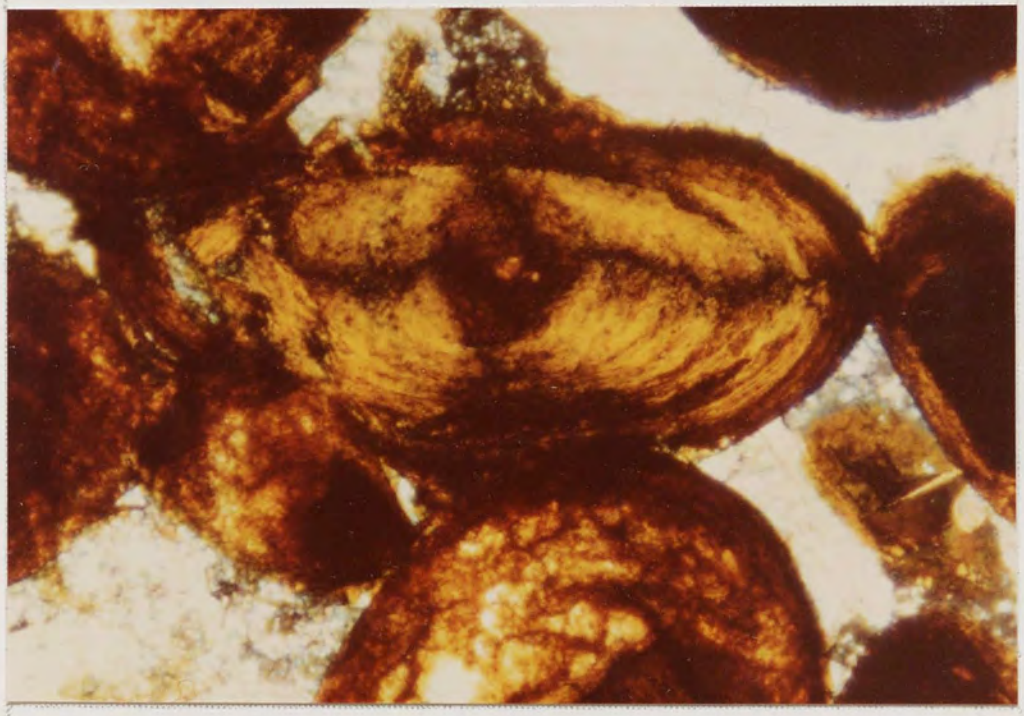


Plate 2.26a Ooids occurring in this facies are often constructed of a yellowish brown chamosite surrounded by a goethite ri or crust. Stained section, PPL, x125.

Plate 2.26b As for Plate 2.26a. XP, x125.

Plate 2.27 Ooid envelopes may consist of alternating chamosite and goethite rings. Stained section, PPL, x125.





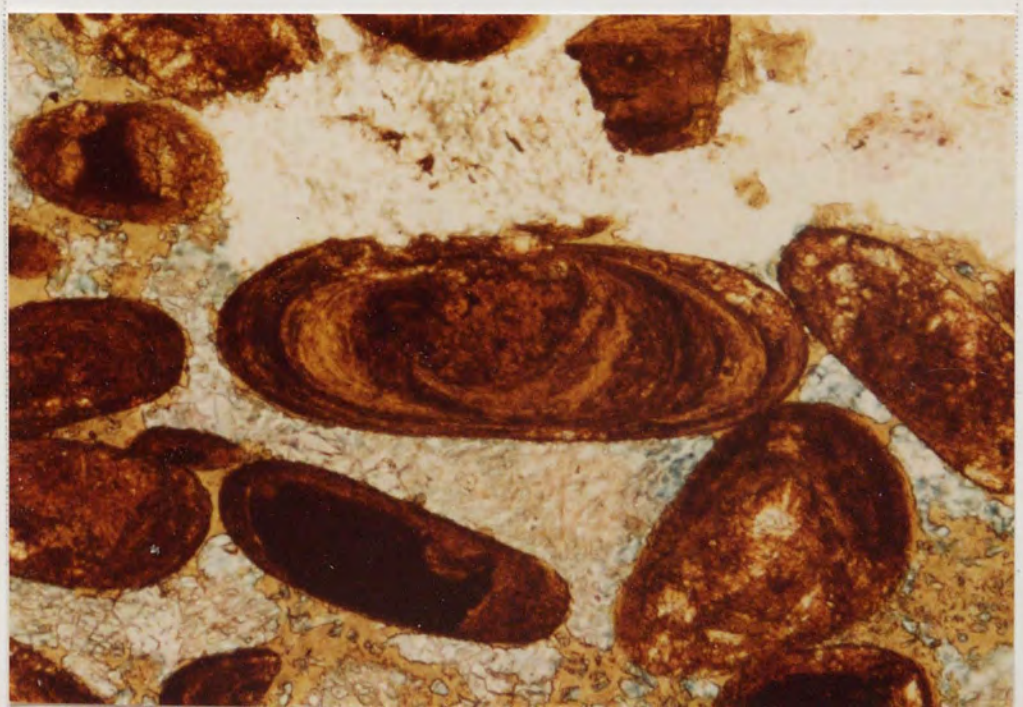
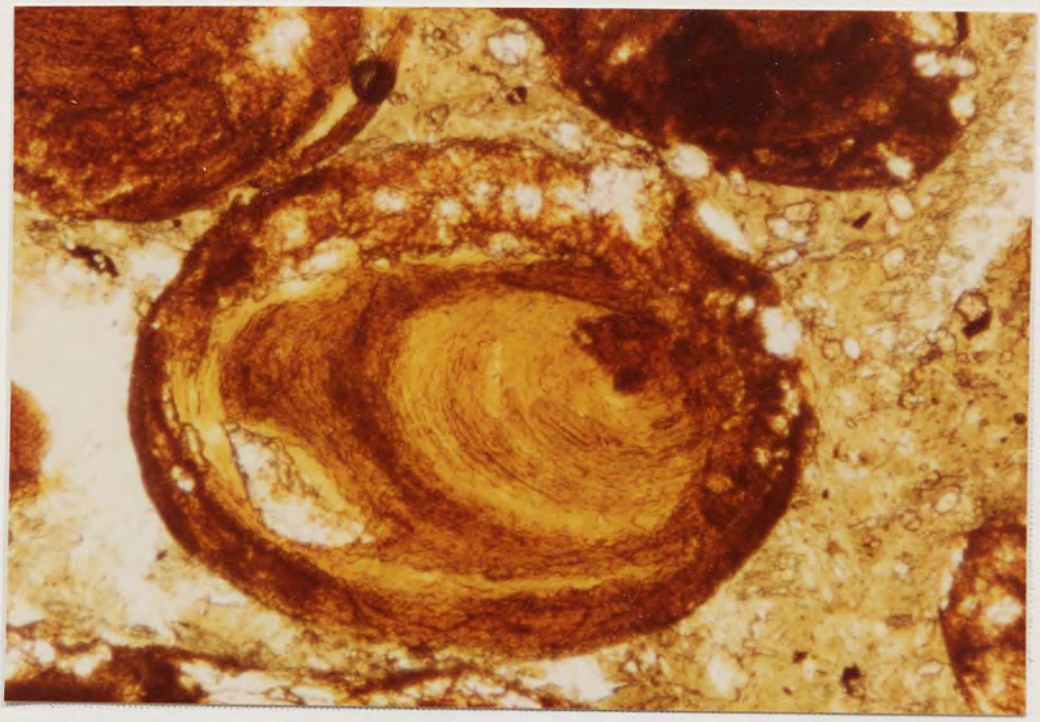


Plate 2.28a Slivers of goethite occur within the yellow-brown chamosite of ooid centres. Stained section, PPL, x125.

Plate 2.28b As for Plate 2.28a. XP, x125.



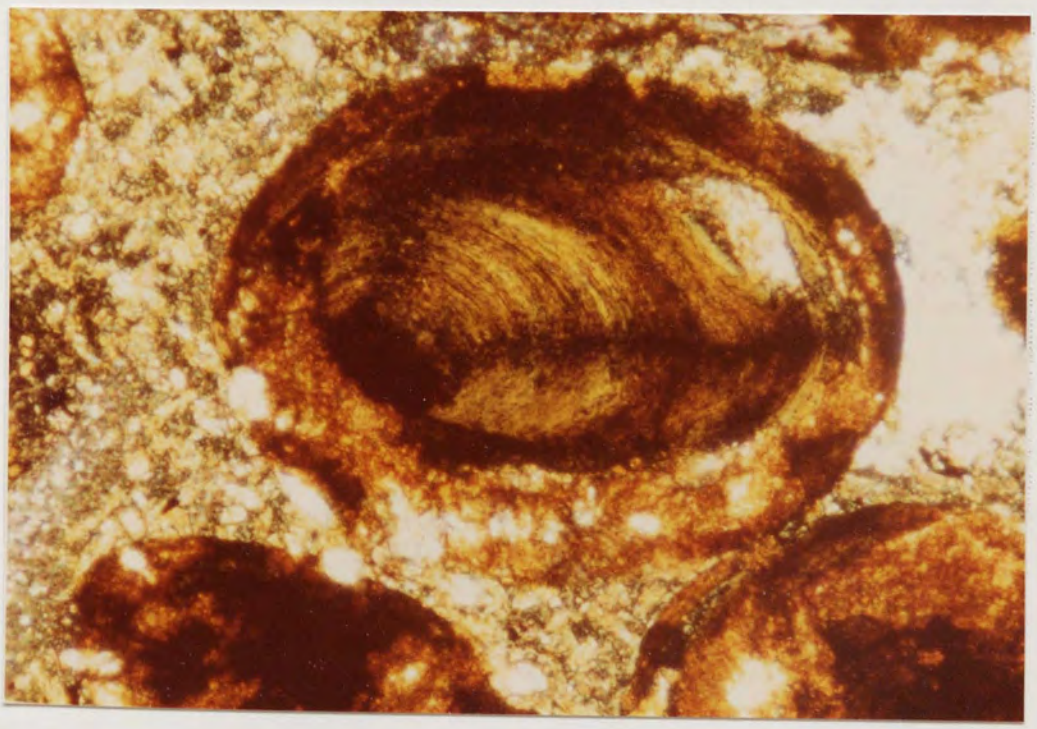
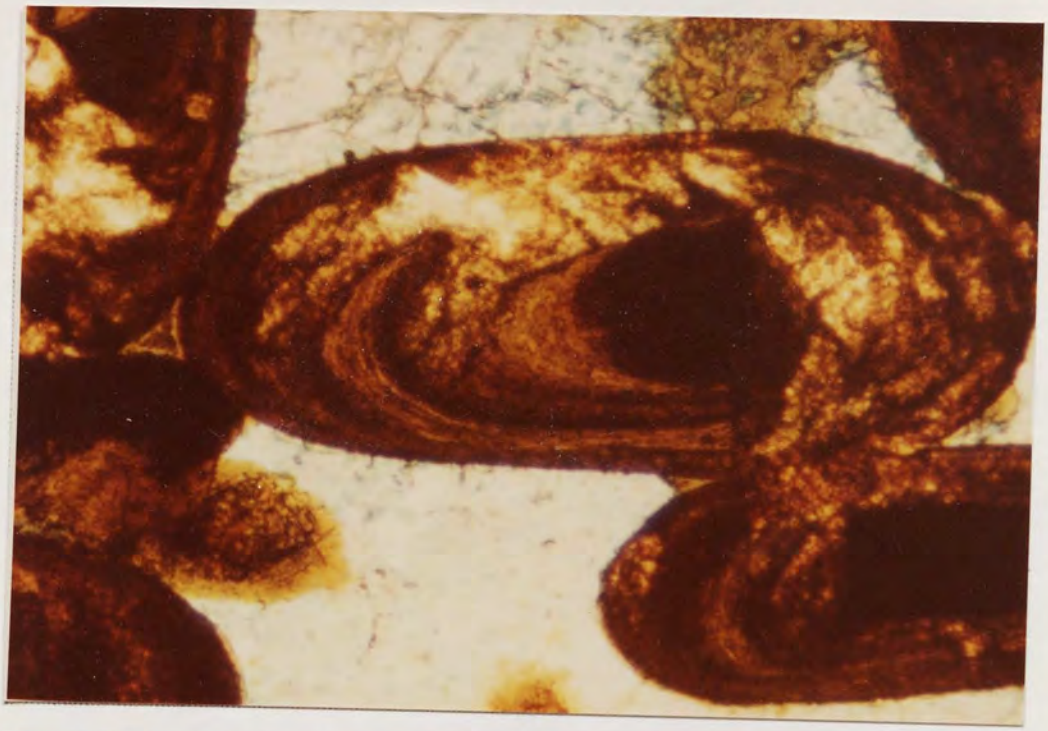
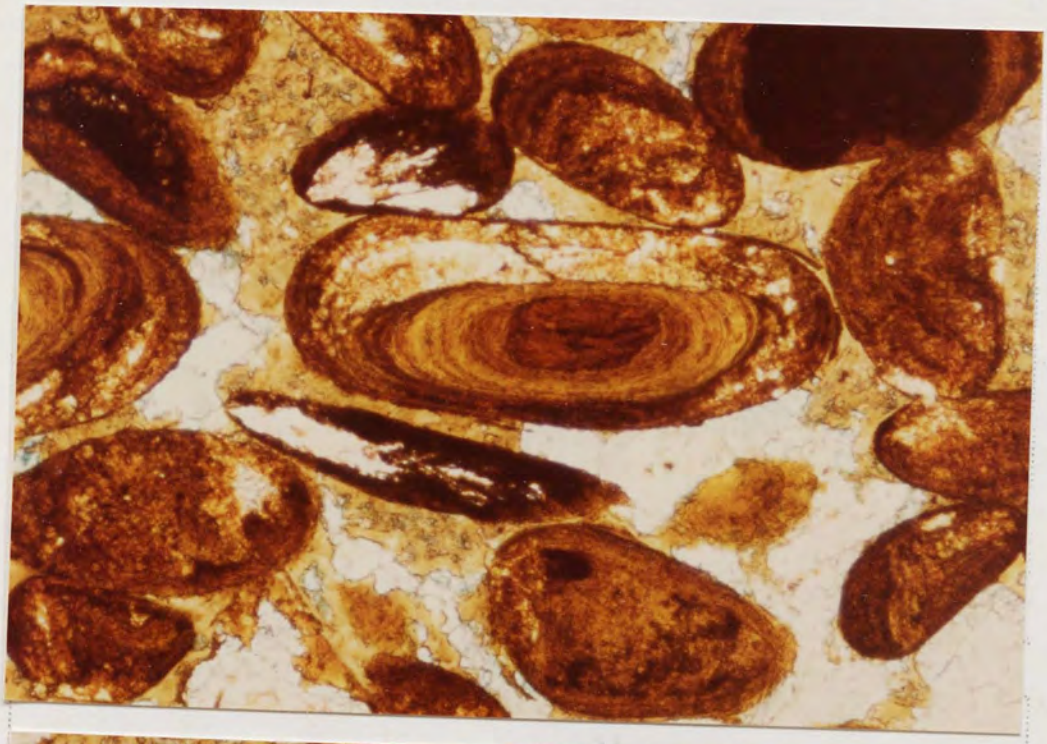


Plate 2.29 Dropped ooid cores. Partial dissolution of the interior of an ooid may result in the detachment of a central remaining portion of the grain which then drops to the bottom of the void. The void thus created is usually infilled with siderite (white, iron-stained). Stained sections, PPL, x200, x125, x125.





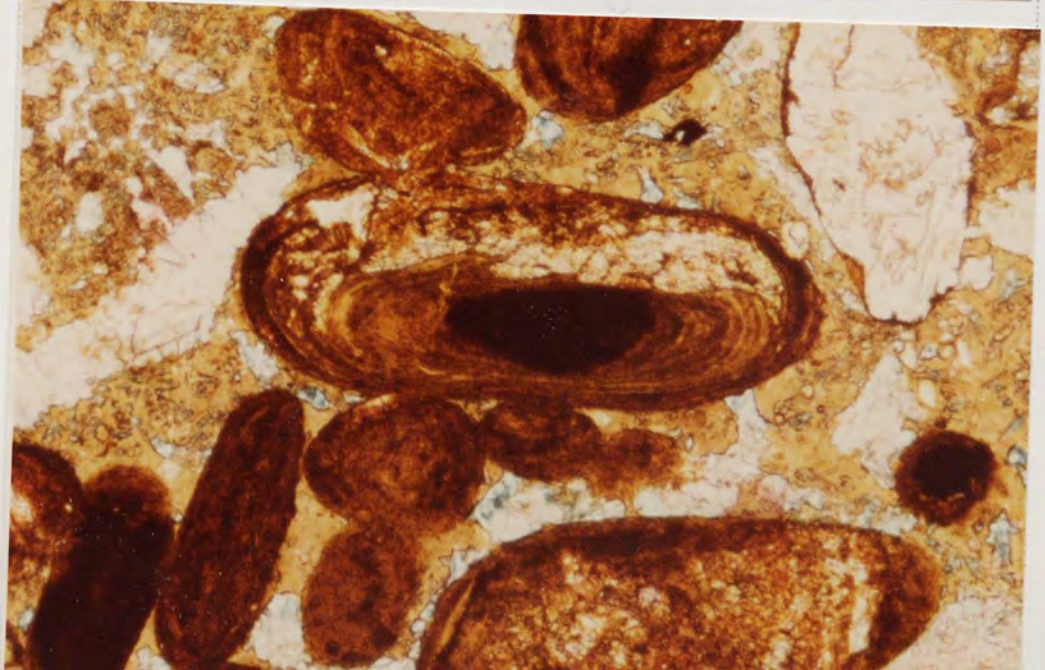
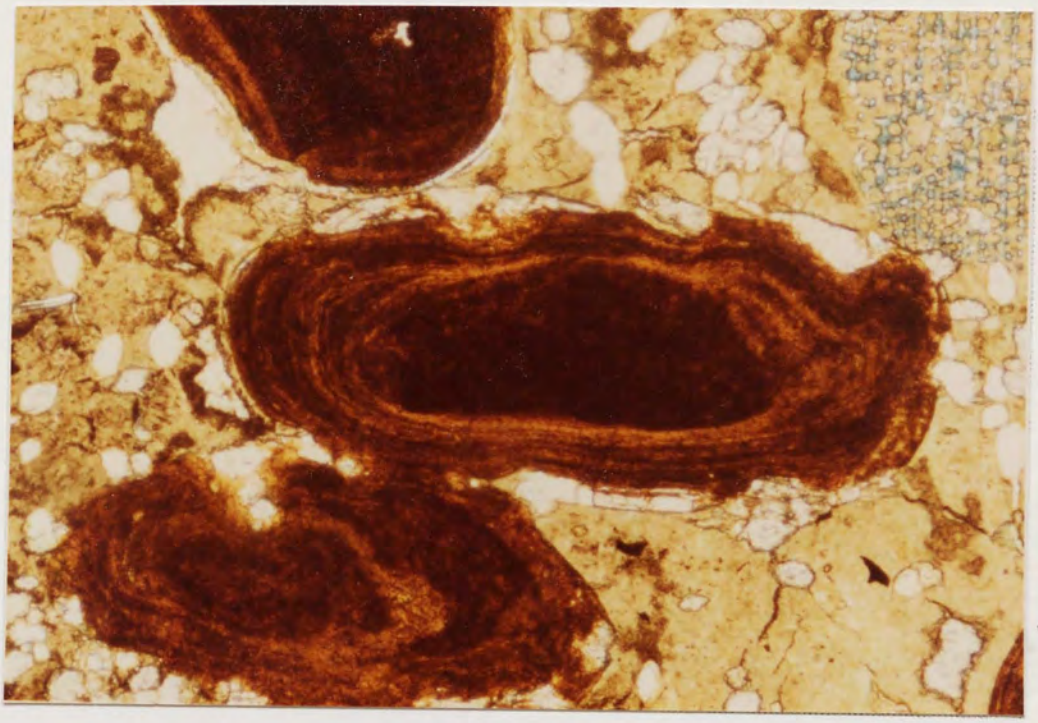


Plate 2.30 Due to the precipitation and subsequent growth of siderite (white) at the contact between goethite ooids and authigenic chamosite the ring structure of the ooid envelope is distorted. Stained section, PPL, x125.

Plate 2.31 Isopachous lining and occlusion of pore-spaces by authigenic chamosite (yellow-green) precipitated from aqueous solution. Stained section, PL, x125.



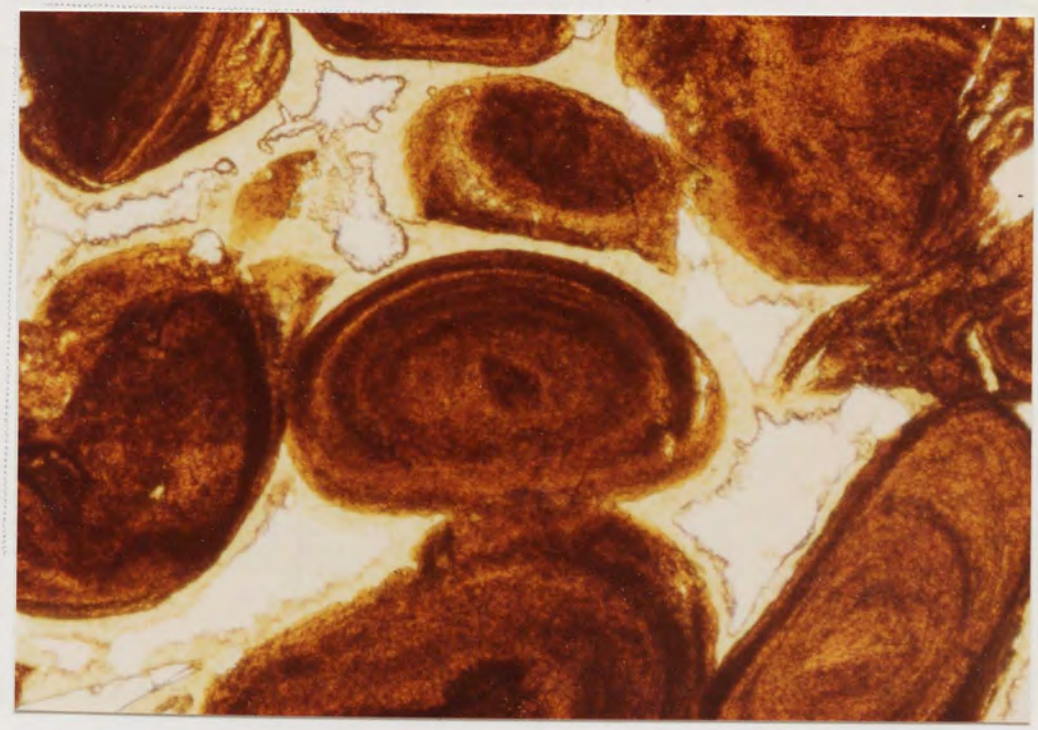
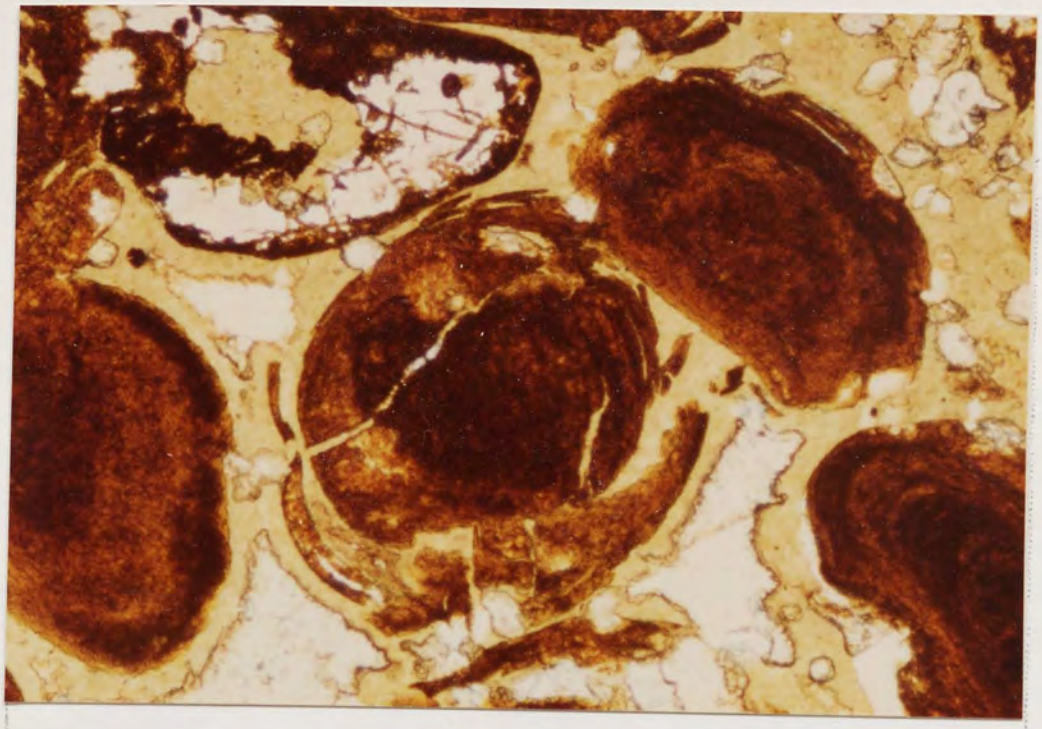
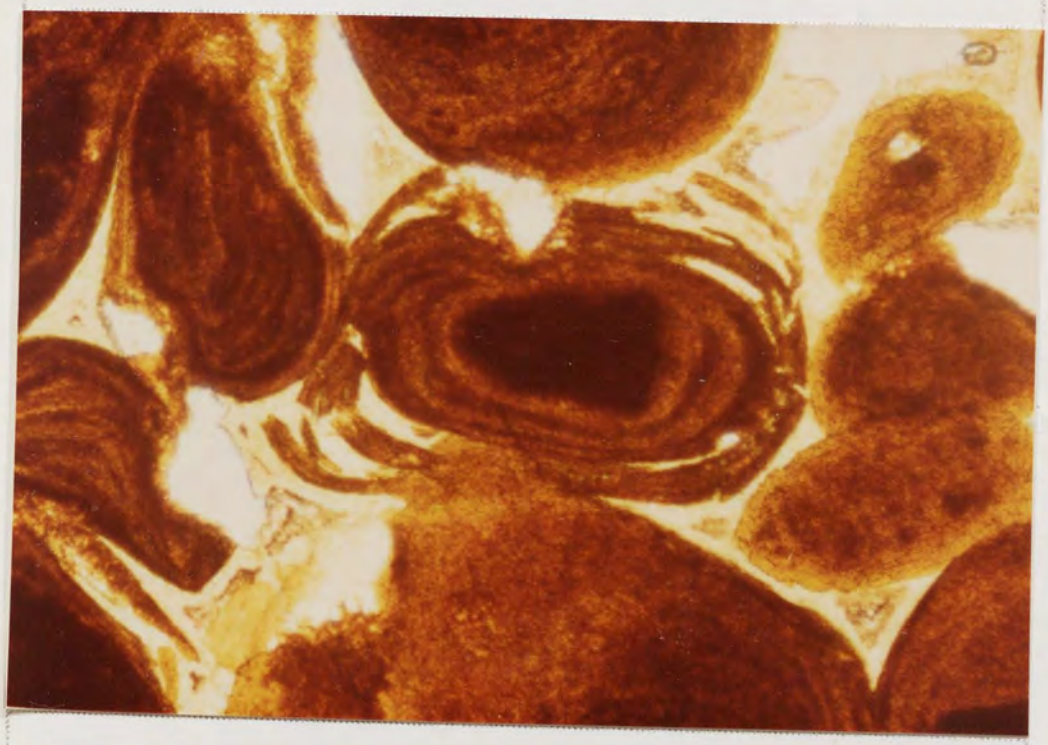


Plate 2.32 Explosion texture. Precipitating authigenic chamosite (yellow-green) exploits weaknesses such as radial fractures and ring contacts in goethite ooid envelopes and lifts portions of the envelope away from the parent ooid. Stained sections, PPL, x125.

Plate 2.33 Zoned echinoid plate. A central spot of non-ferroan calcite (pink) is surrounded by a wide zone of ferroan calcite (blue). The original stereome system is infilled by authigenic chamosite. Stained section, PPL, x125.





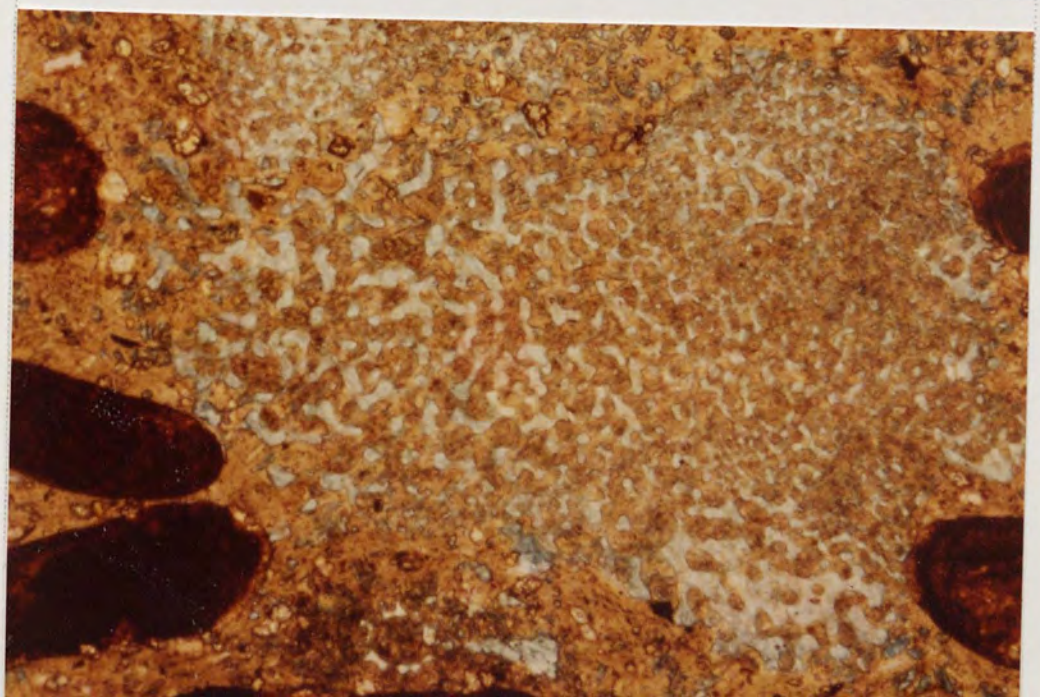
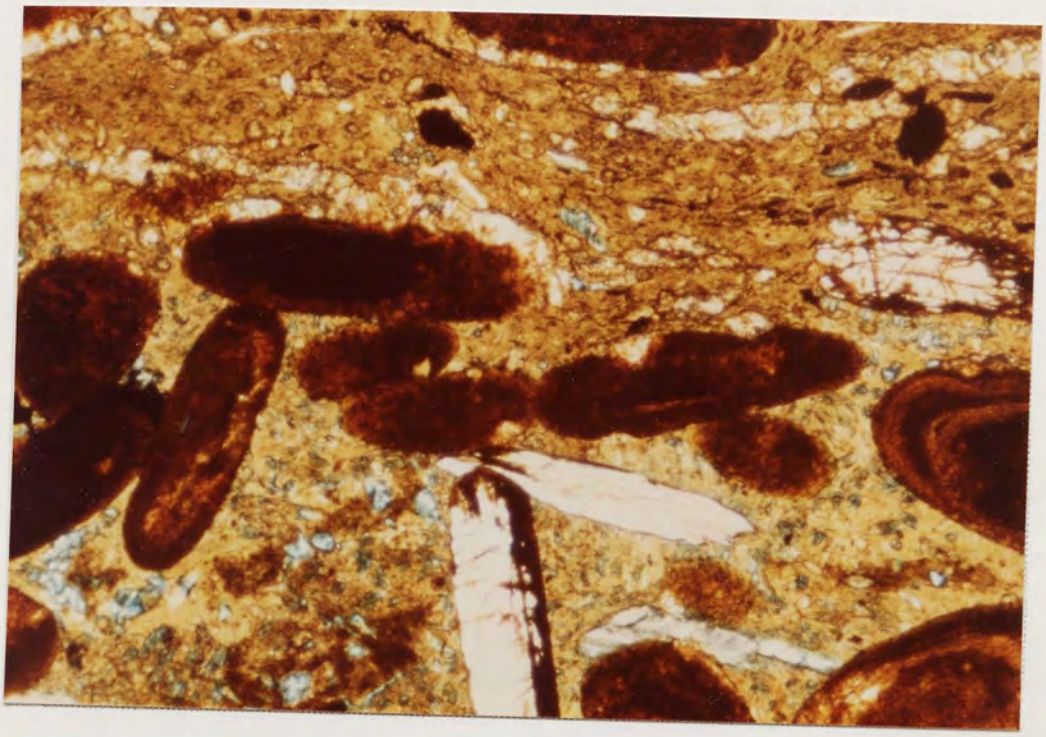


Plate 2.34a Depositional chamosite (olive-green, top) merges imperceptibly into grass green authigenic chamosite. Stained section, PPL, x125.

Plate 2.34b As for Plate 2.34b. 45° position. Note the unit extinction of the authigenic chamosite as opposed to the uniform maximum illumination of the depositional chamosite. XP, x125.



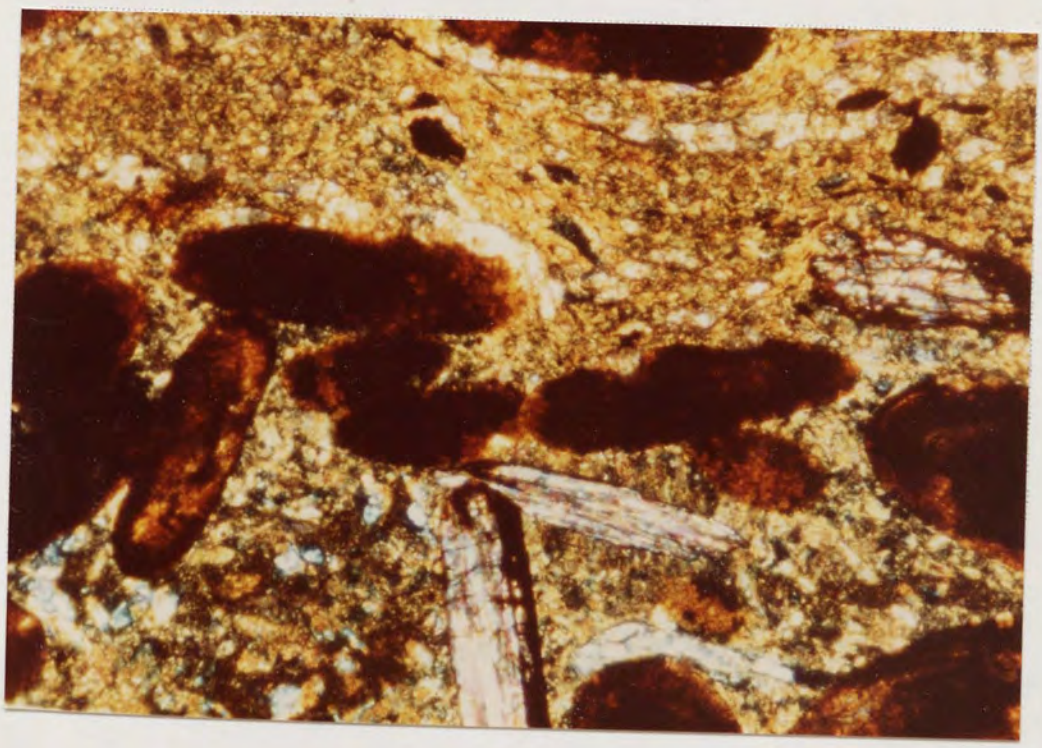
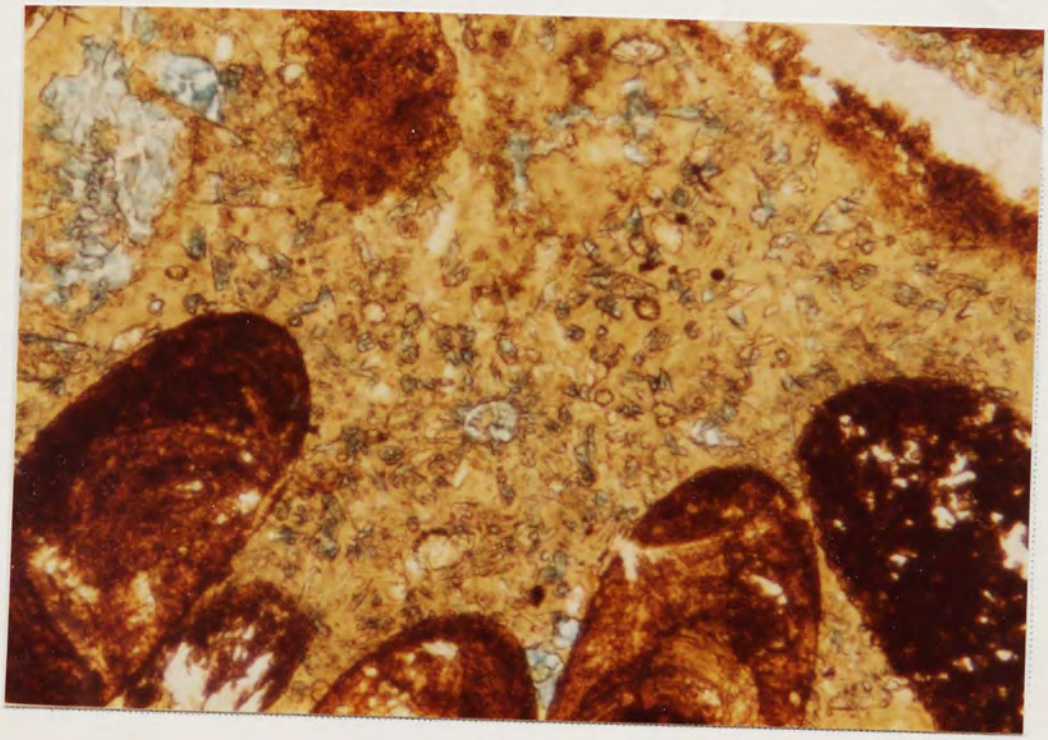


Plate 2.35 Ferroan calcite (blue) and rare siderite (white, greenish white) polygons, dominantly equilateral and isosceles triangles, set in authigenic chamosite. Stained sections, PPL, x200, x125.



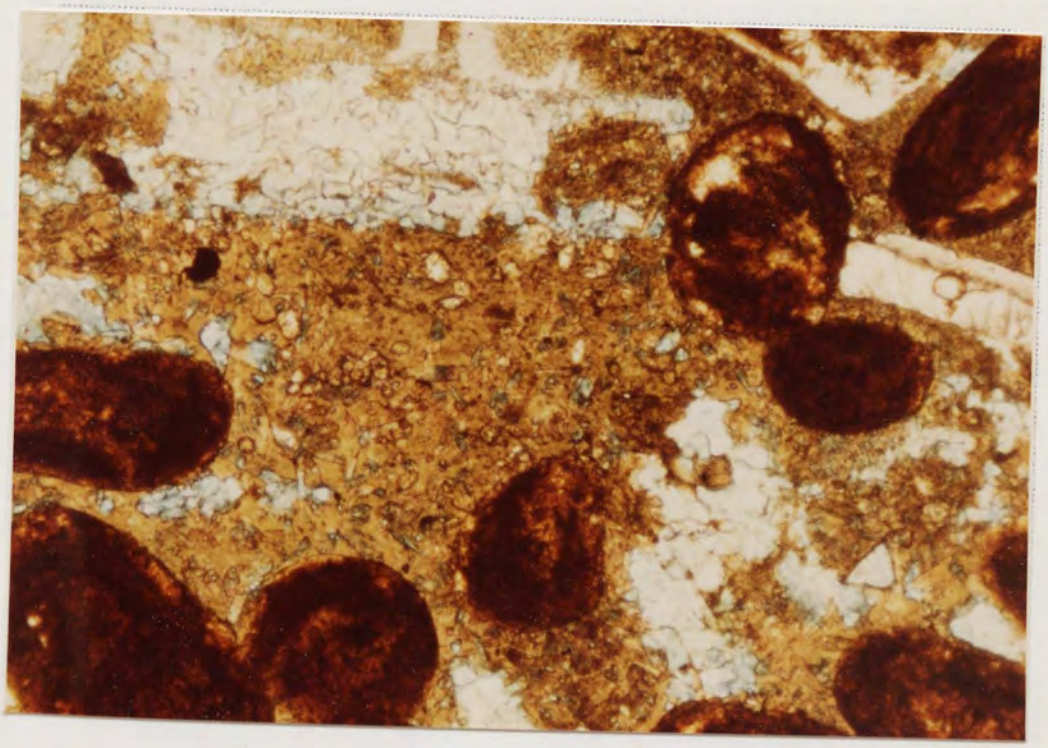
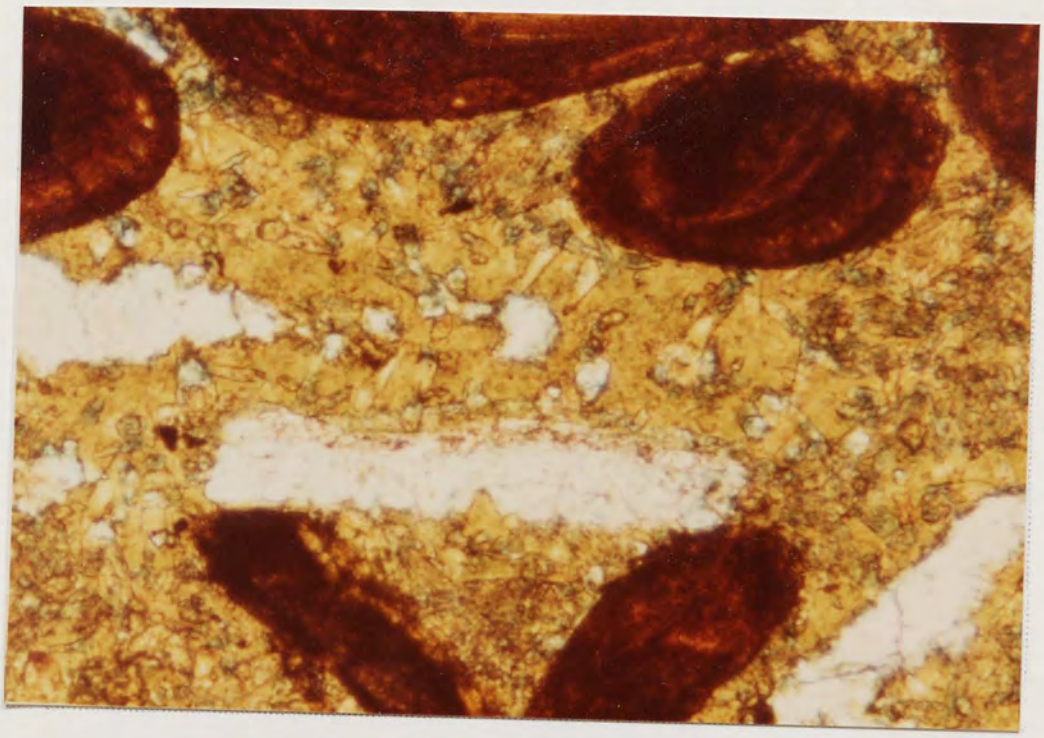


Plate 2.36a Ferroan calcite (blue) and siderite (yellowish green) polygons. Stained section, PPL, x200.

Plate 2.36b As for Plate 2.36a. Between crossed polars the yellowish green areas show a high birefringence indicative of siderite. The colour tint may therefore be due to included chamosite. XP. x200.



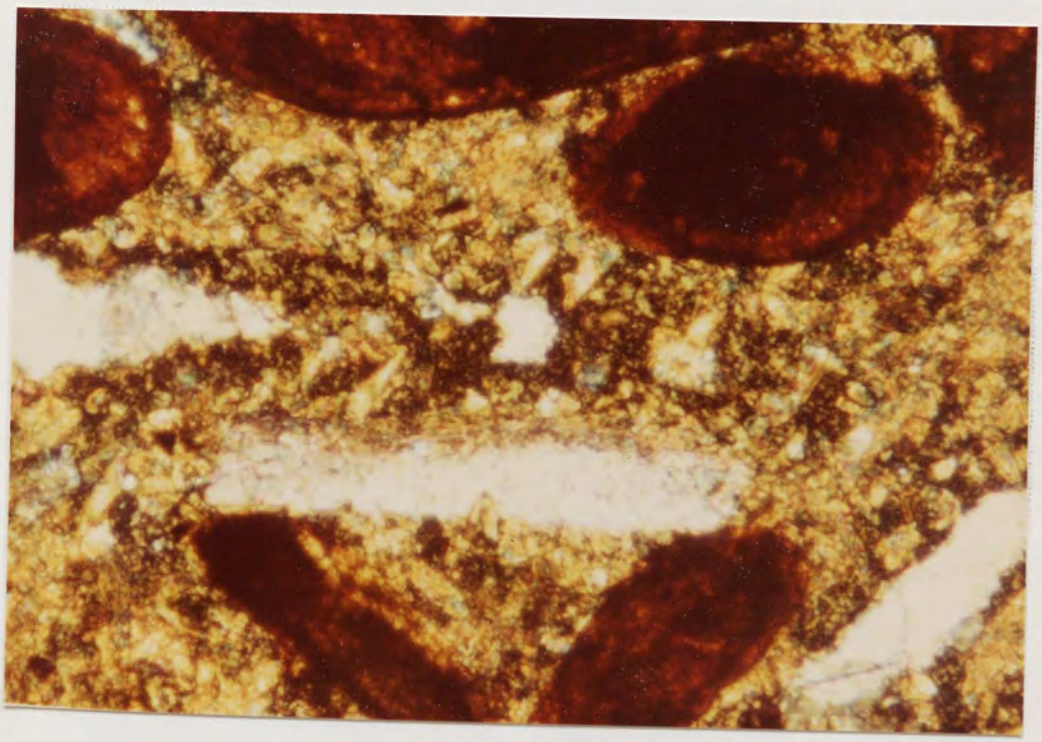
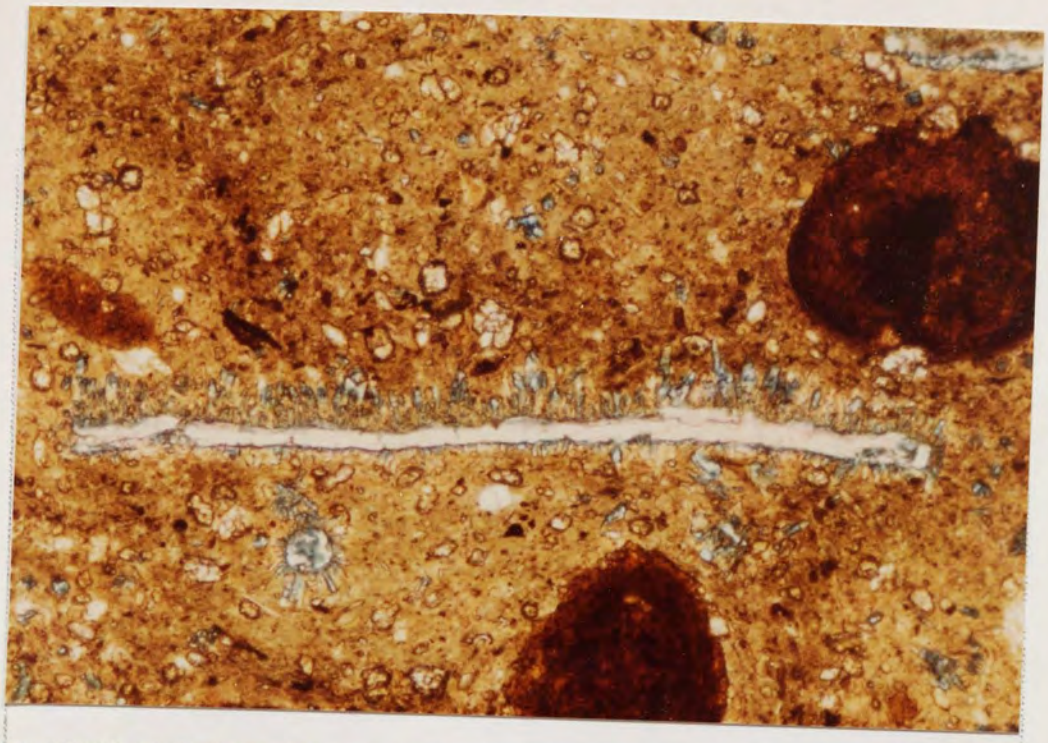
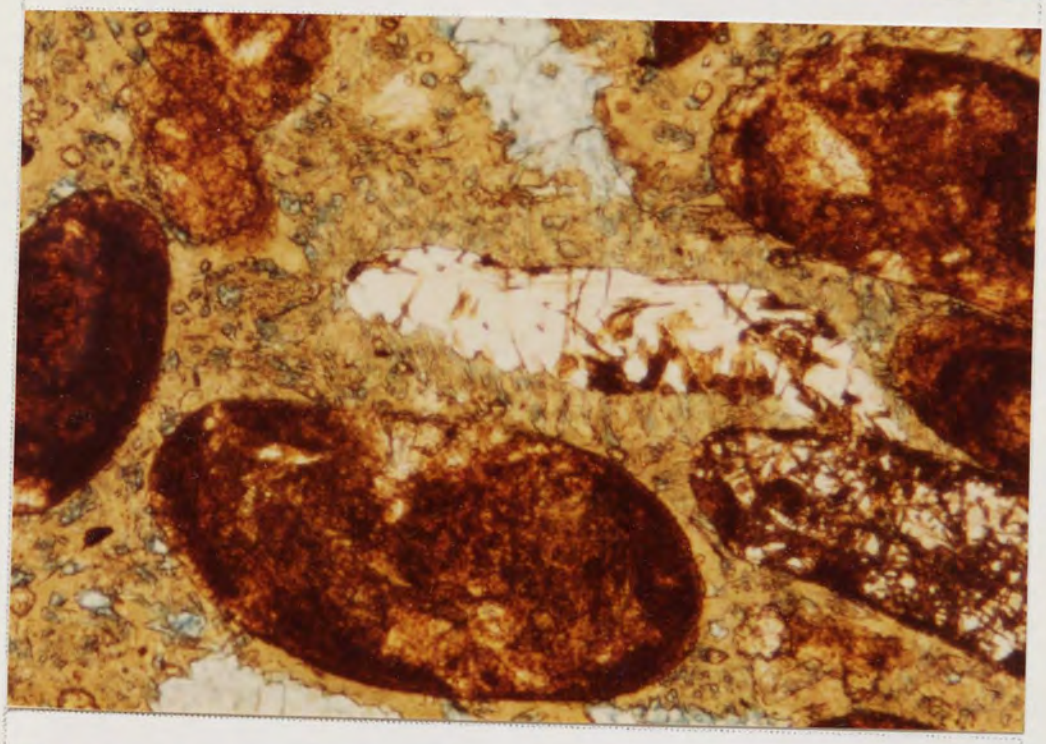


Plate 2.36c Radial fibrous fringe of ferroan calcite (blue) surrounding non-ferroan calcite (pink) mollsucan debris. Note the intervening 'filaments' of authigenic chamosite. An outer ferroan calcite layer to the shell fragment suggests the possibility that this was an originally high-magnesian calcite layer. Stained section, PPL, x125.

Plate 2.36d Radial fibrous fringe of ferroan calcite (blue), siderite (yellowish green) and intervening authigenic chamosite 'filaments' to a non-ferroan calcite (white) shell fragment. Stained section, PPL, x200.

Plate 2.36e As for Plate 2.36d. The high birefringence of the yellowish green siderite indicates that its colouration may be due to included authigenic chamosite. XP, x200.





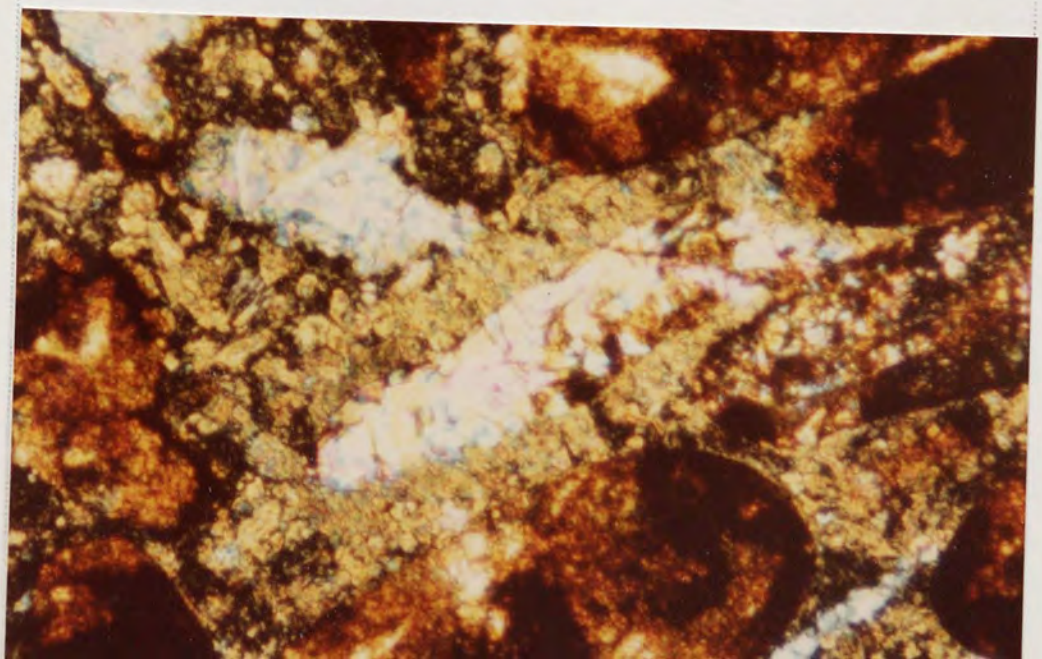
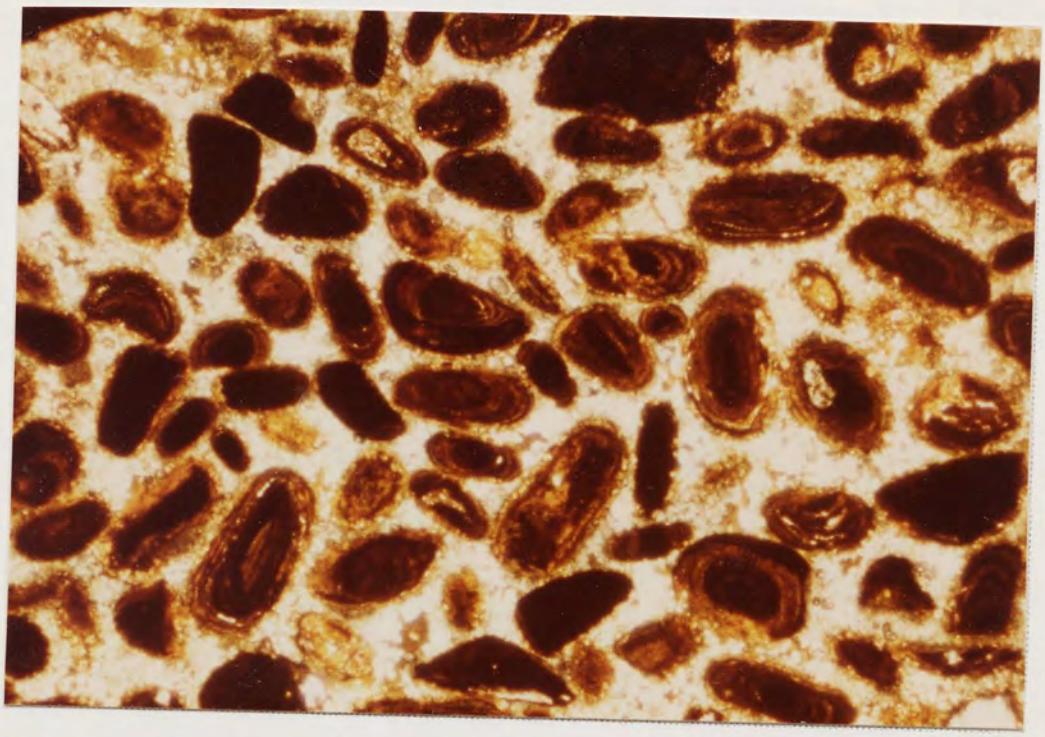


Plate 2.37 Chamositic limonite oolite sub-type (iii). Goethite ooids and intraclasts show ragged edges due to siderite precipitation. The cement consists of authigenic chamosite, ferroan calcite (blue) and siderite (white, high relief). Stained sections, PPL, x31.25, x125.



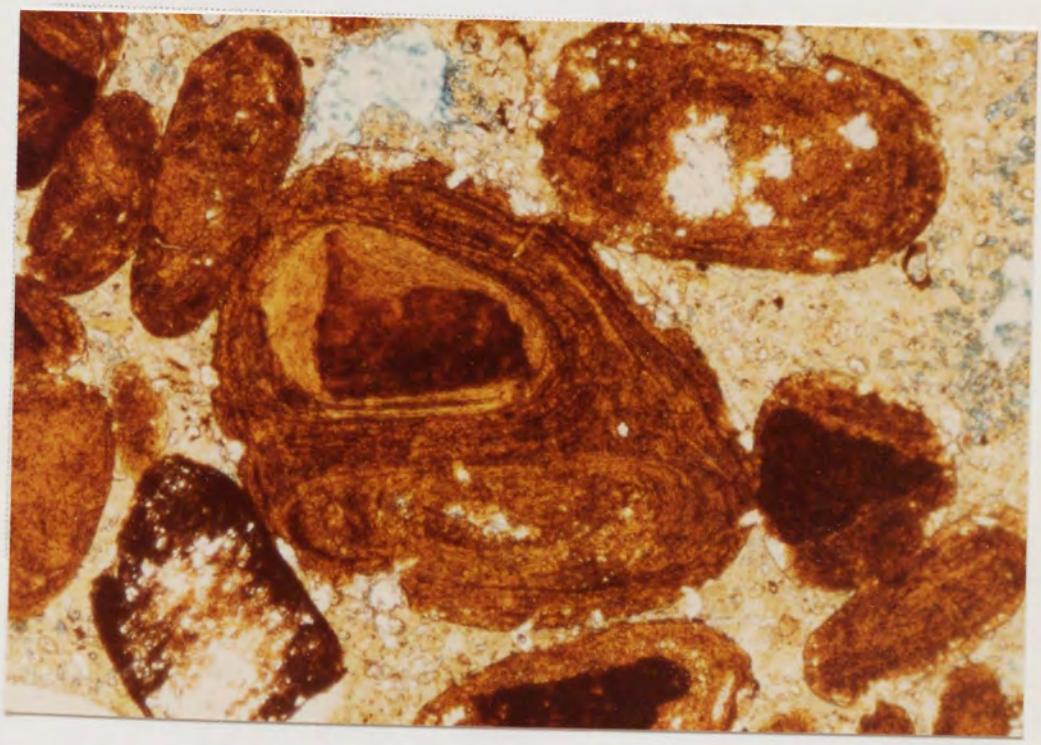


Plate 2.38 Hooked goethite ooids are common. The hooks often form the site of siderite precipitation which modifies their original form. Stained section, PPL, x125.

Plate 2.39 Occasional linkages between hooked goethite ooids result in the formation of chain ooids. Stained section, PPL, x125.

Plate 2.40 The precipitation of siderite (white) develops ragged ooid margins and further distorts chain goethite ooids. Stained section, PPL, x31.25.

Diagenesis and Mineralogy of the British Liassic Ironstones

S. J. James Ph.D. 1980 Volume II (II)

PHOTOGRAPHIC PLATES

PHOTOGRAPHIC PLATES

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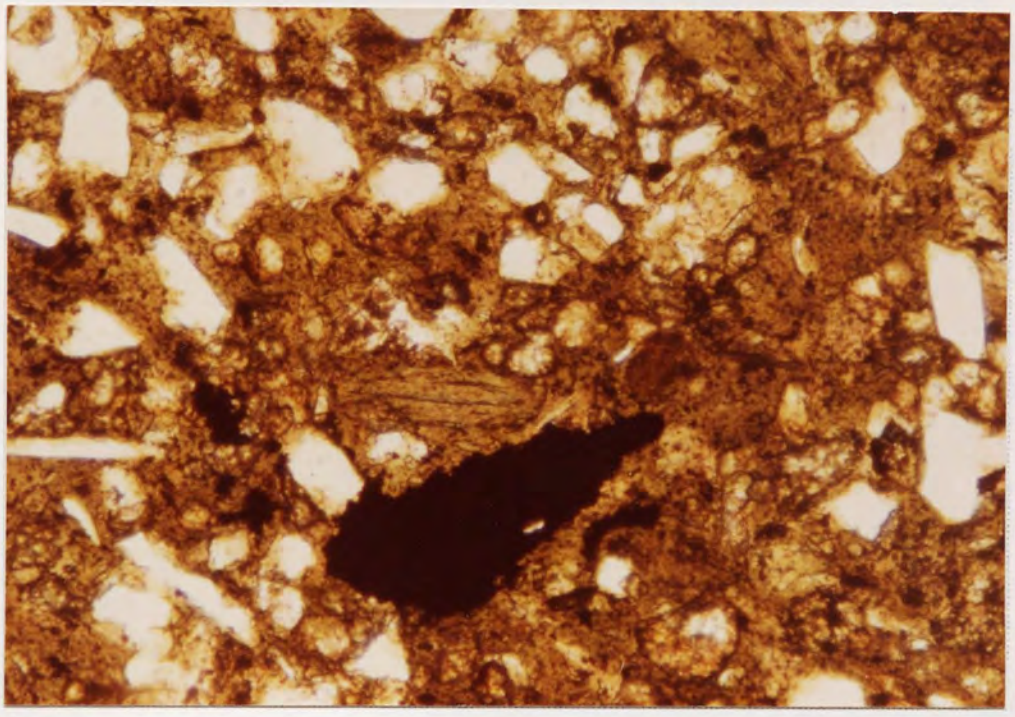
CHAPTER 2

THE FRODINGHAM IRONSTONE

Plate 2.1. Chamosite mudstone. Lamellae of depositional chamosite mud with a low proportion of detrital quartz (white) tend to alternate with more quartzose chamosite mud lamellae. Note the presence of a chamosite book with rounded and ragged ends. The opaque phase is pyrite. PPL, x200.

Plate 2.2 Chamosite mudstone intraclast armoured with quartz grains. PPL, x31.25.



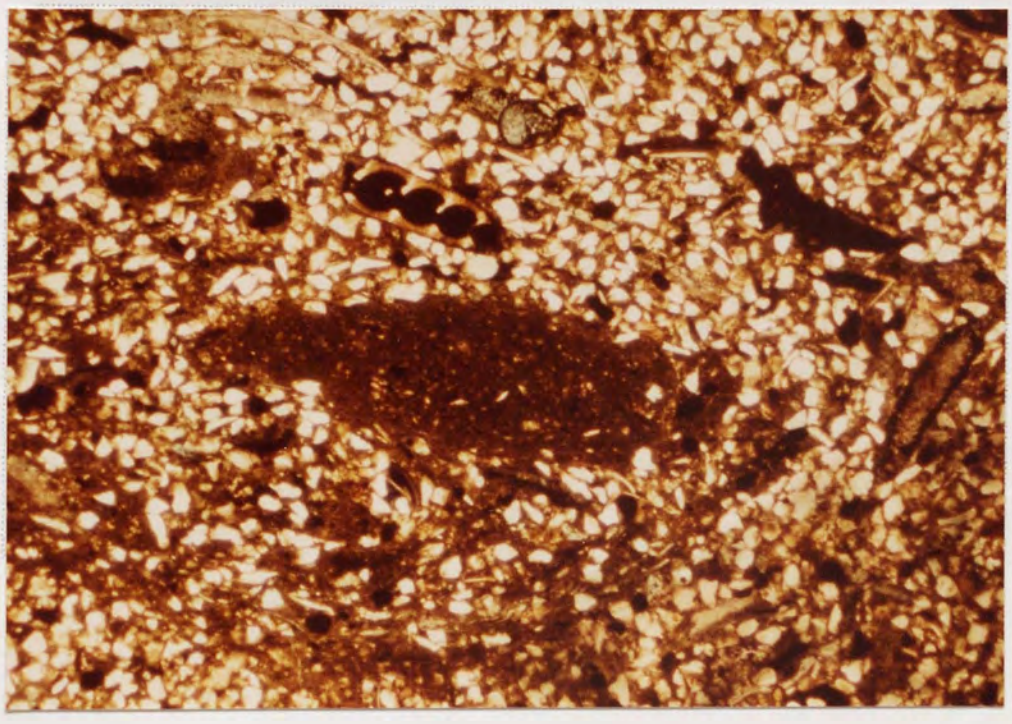
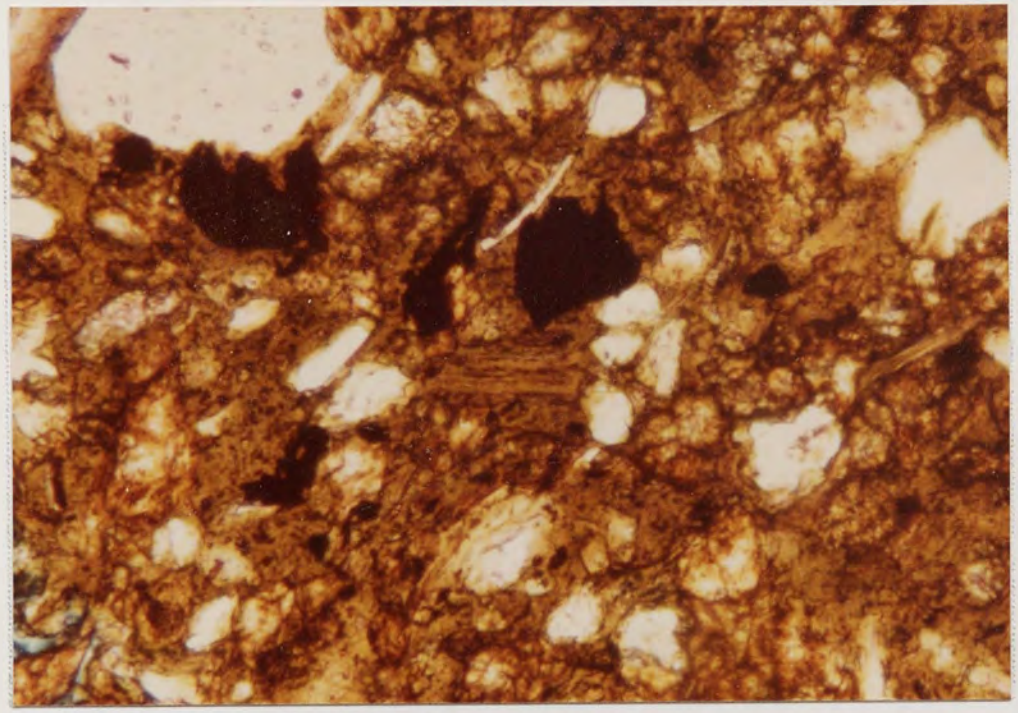
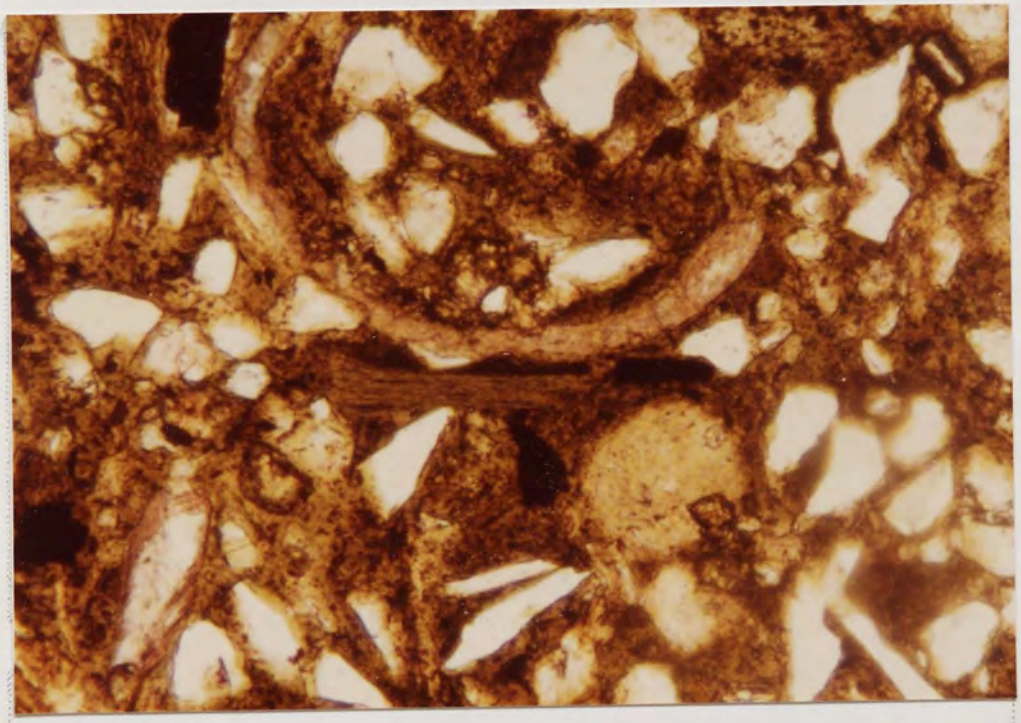


Plate 2.3a Olive green chamosite book with ragged terminations and oriented with the (001) cleavage parallel to bedding. The opaque phase is pyrite. PPL, x200.

Plate 2.3b Grass green chamosite books with terminations which are much less ragged than those of the book seen in Plate 2.3a. The opaque phase is pyrite. PPL, x200.





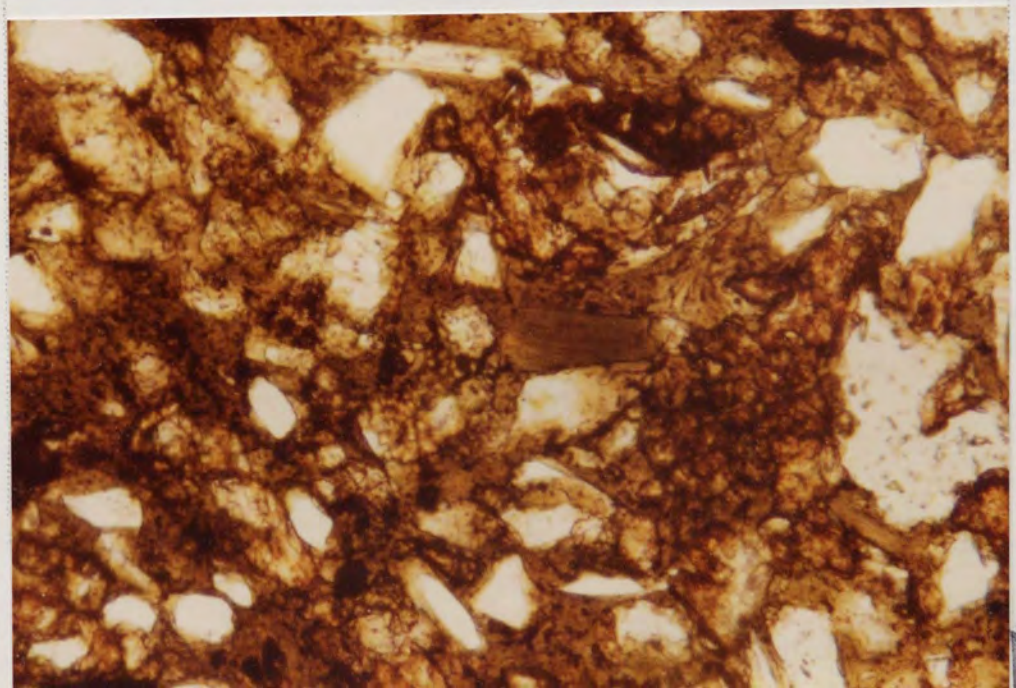
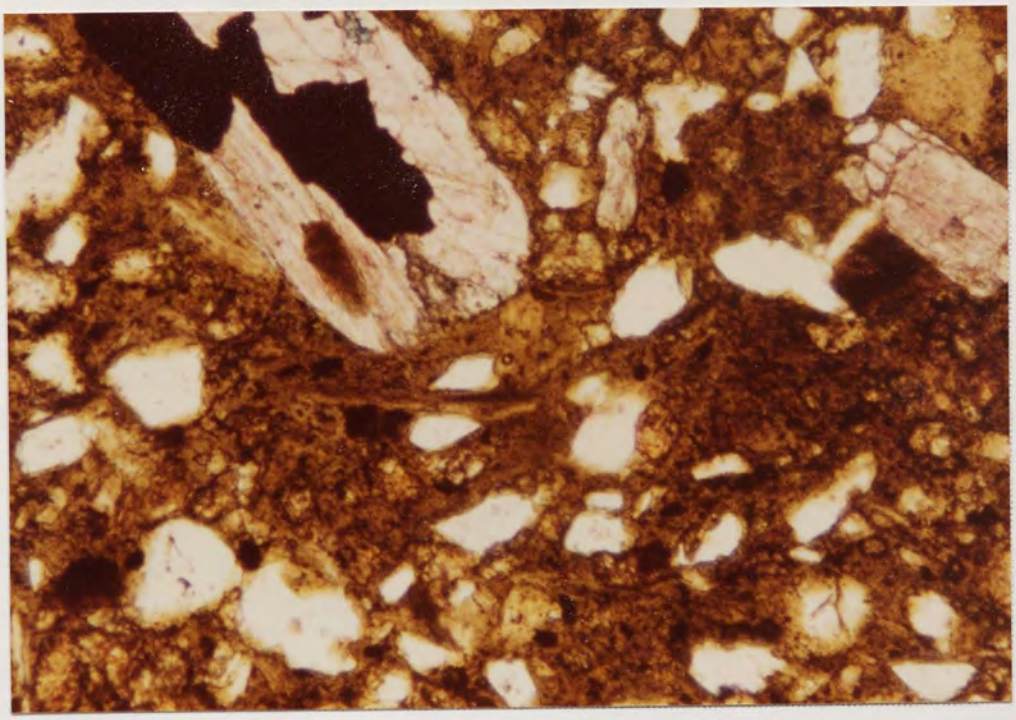


Plate 2.3b Grass green chamosite books often appear to have had their growth controlled by the presence of quartz grains (PPL) and pass with optical continuity into small patches of non-structured authigenic chamosite (XP, 45° position). The opaque phase is pyrite. x60.



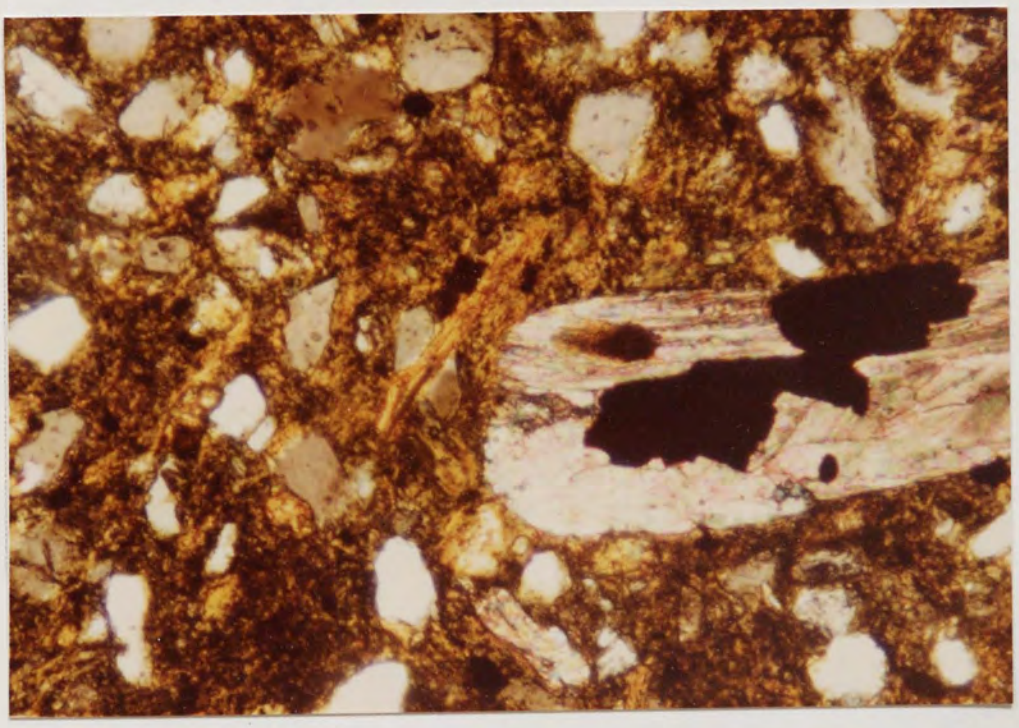
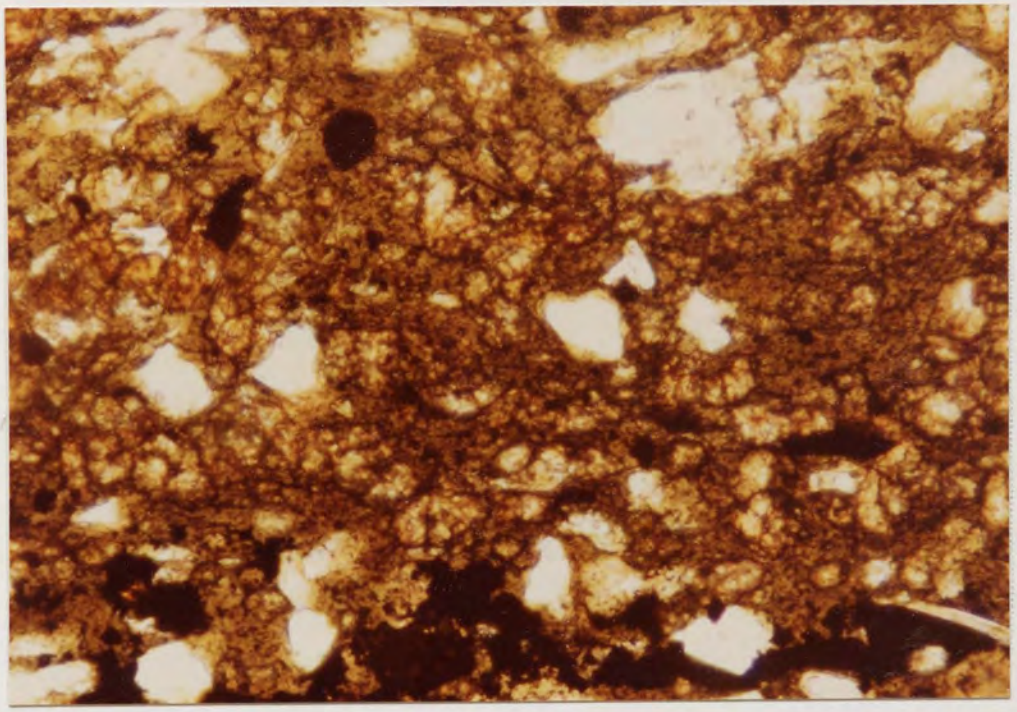


Plate 2.4 Trains of equant siderite anhedra (white, high relief, slightly iron-stained) parallel and sub-parallel to lamination. The opaque phase is pyrite. PPl, x160.

Plate 2.5 Chamosite mudstone sub-type (iii). Quartz is absent. The abundance of siderite anhedra (white, high relief) obscures any original chamosite mud fabric. PPL, x125



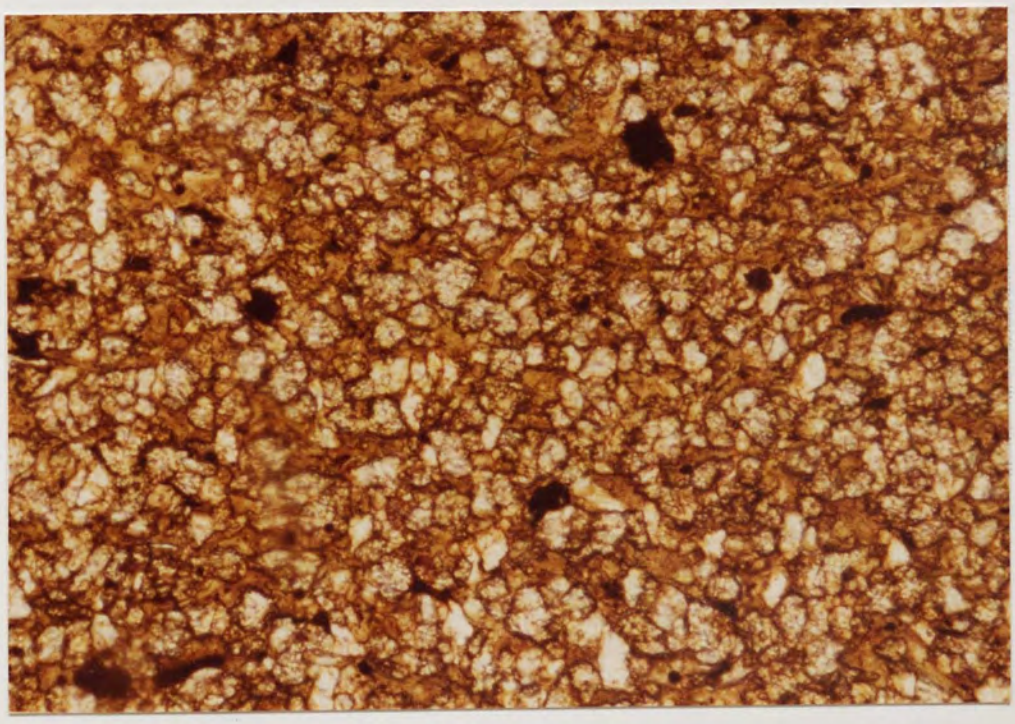
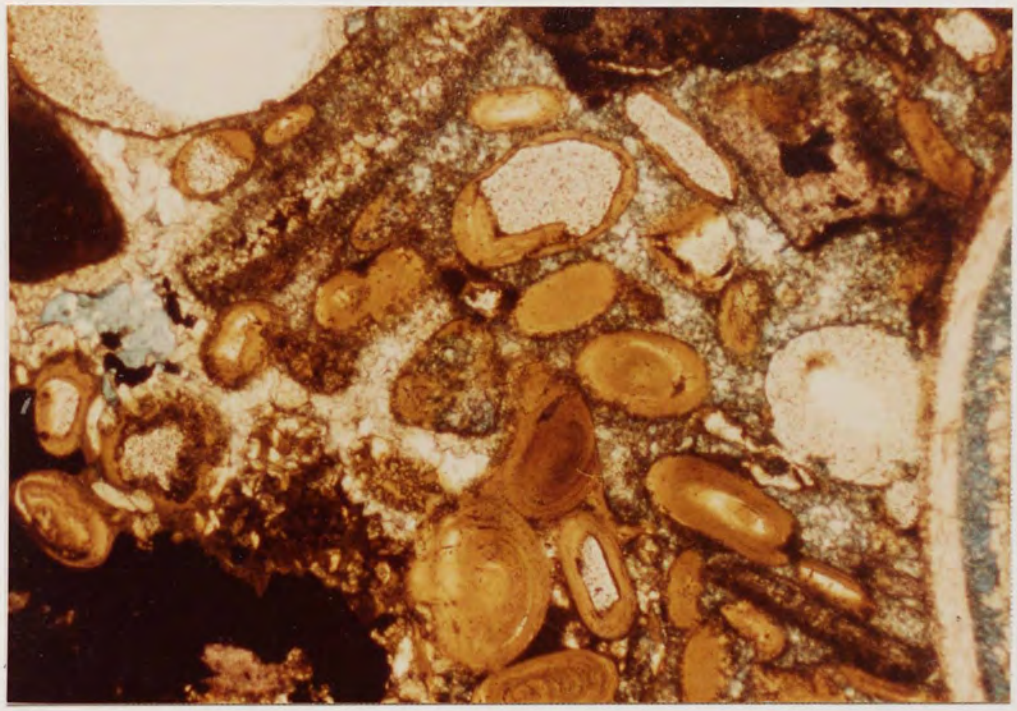


Plate 2.6 Chamositic chamosite oolite. Much of the original chamosite mud has been removed leaving remnants interstitial to chamosite ooids. Note the thick micrite envelope to an originally aragonite shell fragment (top left). Stained section, PPL, x31.25.

Plate 2.7 Chamosite ooid. Stained section, PPL, x125.



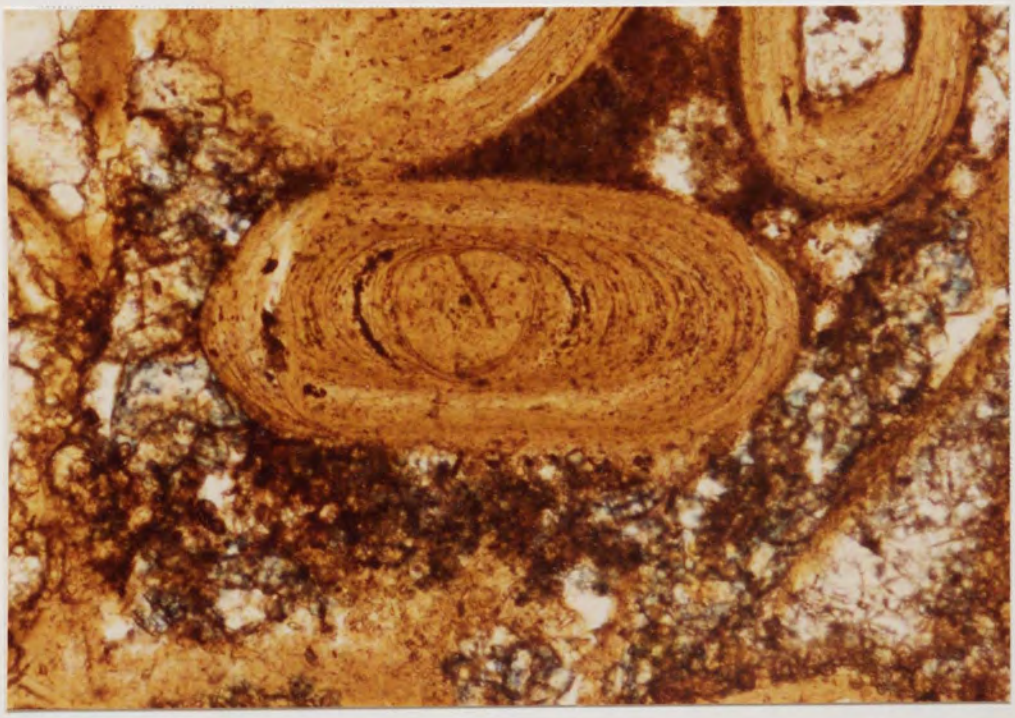


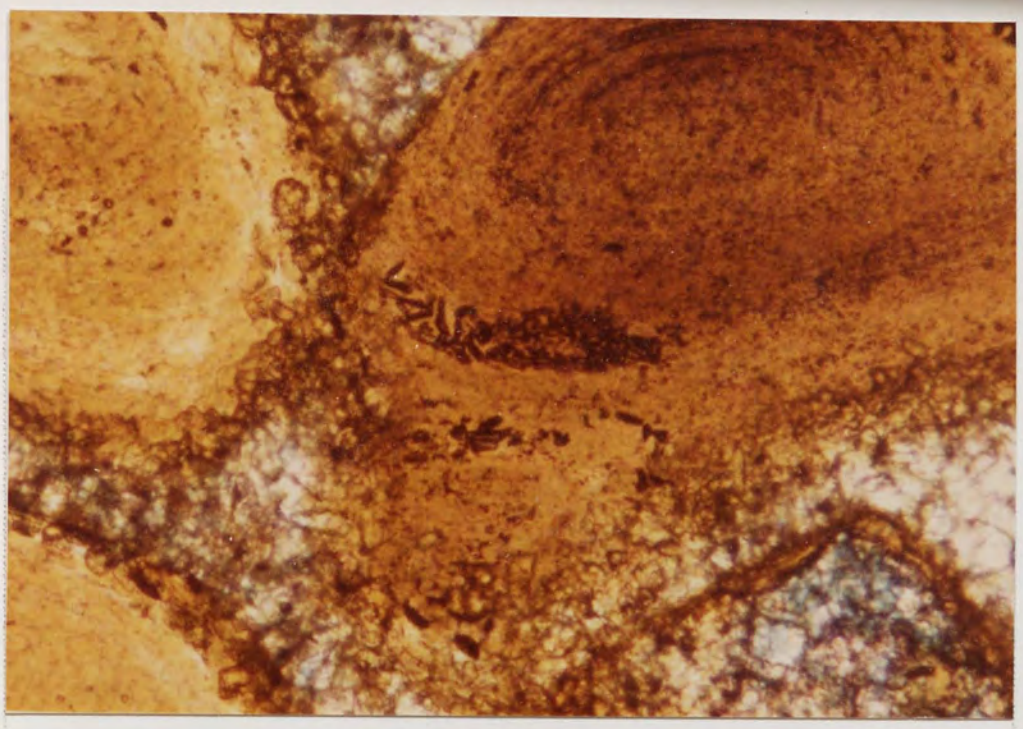
Plate 2.8a Chamosite ooid with pseudo-uniaxial extinction cross. Stained section, XP, x125.

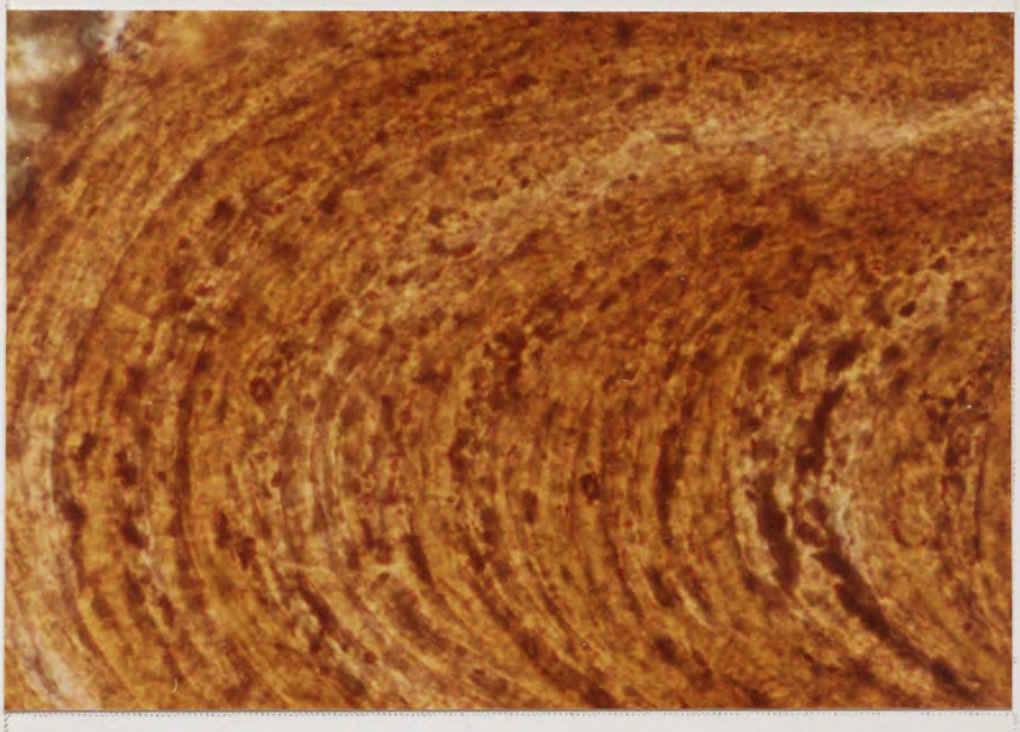
Plate 2.8b With a sensitive tint plate a positive optic sign fo chamosite ooids is obtained. Stained section, XP, mica plate, slow direction NW-SE, x125.

Plate 2.9a Concentrations of black filamentous tubular inclusions are found in ooid envelopes. They have a dominant orientation with their long axes sub-parallel to the ring structure. Stained section, PPL, x200.

Plate 2.9b Sub-parallel orientation of black filamentous inclusions at ring contacts. In some cases these are abundant and merge to form a single irregular band. Stained section, PPL, x500.

Plate 2.10 Cross-cutting burrows, thought to be algal borings, occur in ooids and are infilled with chamosite and occasional black filamentous material. PPL, x 500.





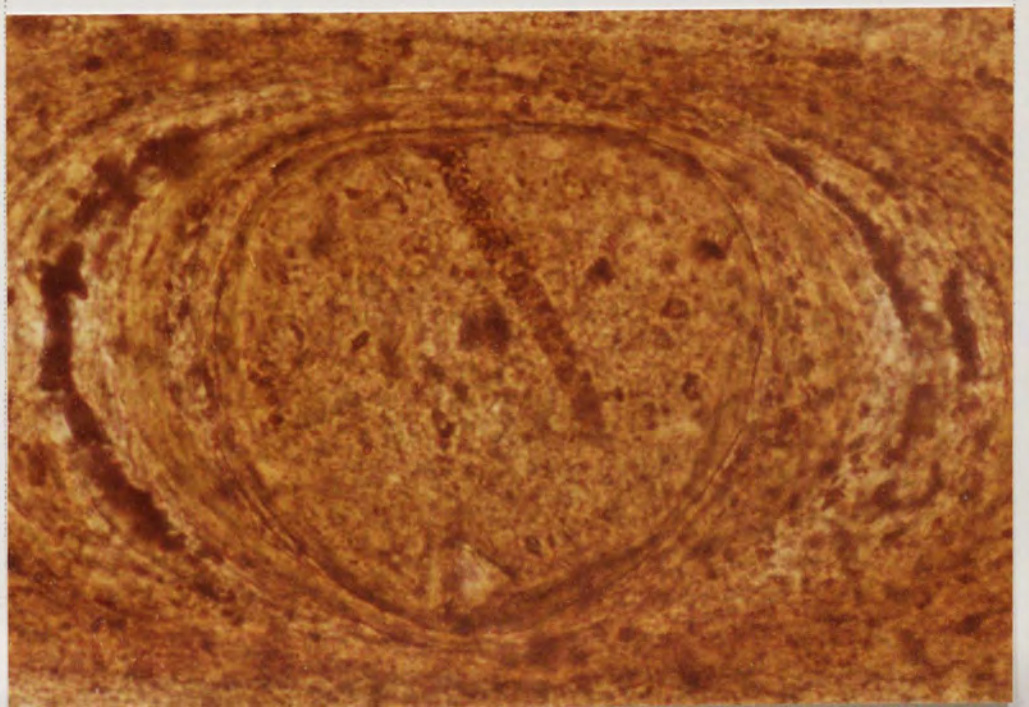
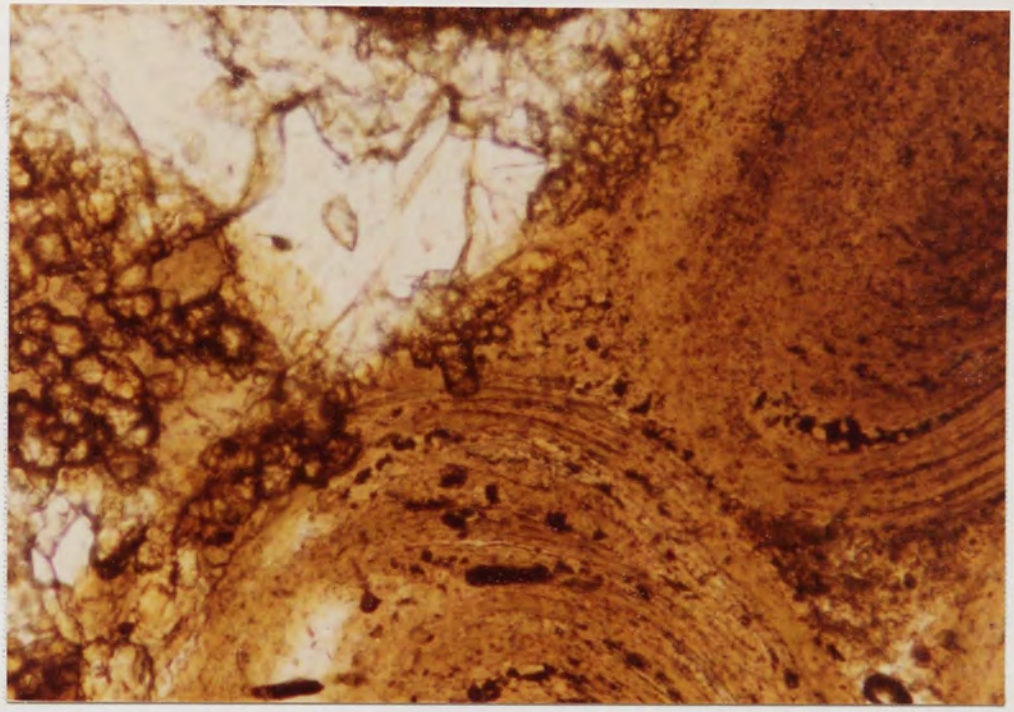


Plate 2.11a Black filamentous inclusions occur within the chamosite mud interstitial to ooids. Stained section, PPL, x200.

Plate 2.11b At low magnification there is an apparently gradational contact between chamosite ooids and chamosite mud, but at higher magnification this is not seen to be the case. Stained section, PPl, x31.25.



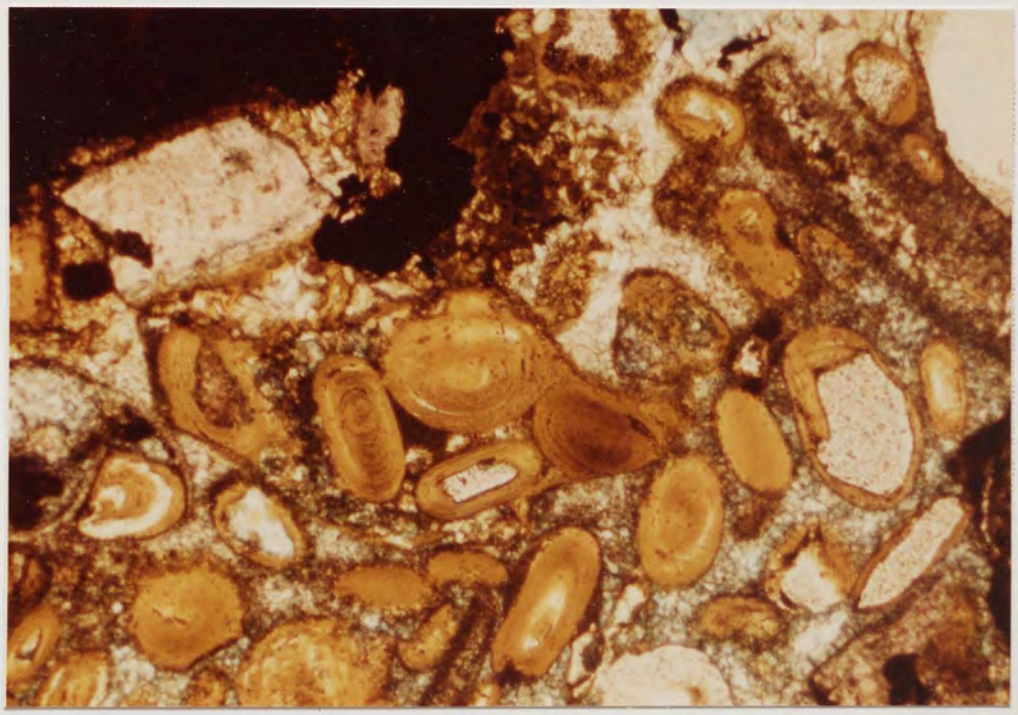
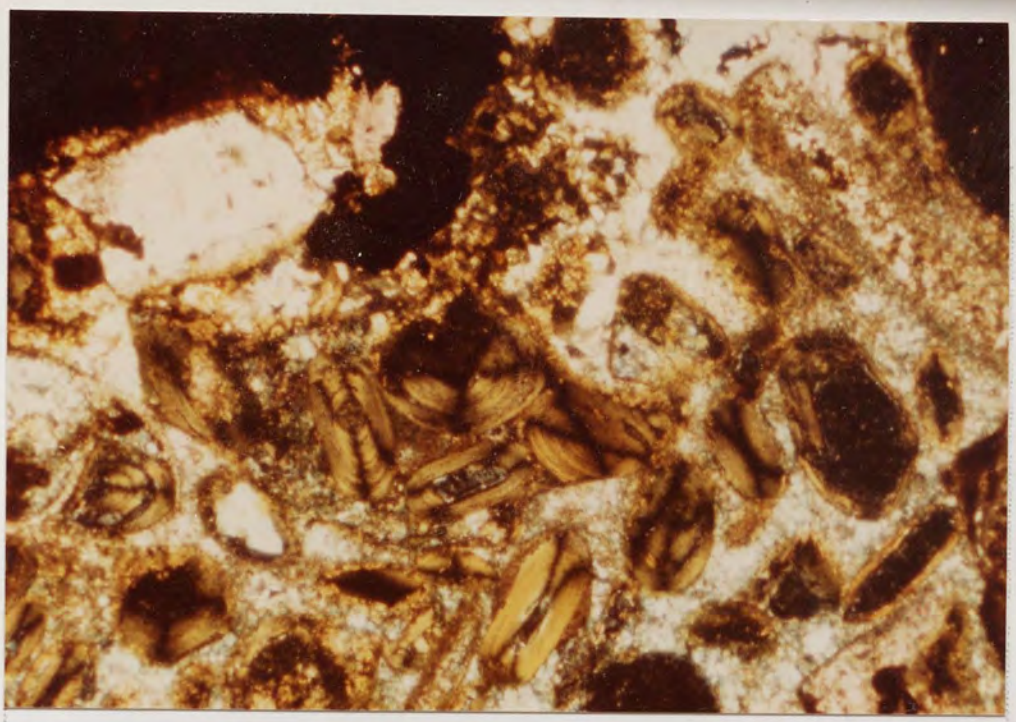
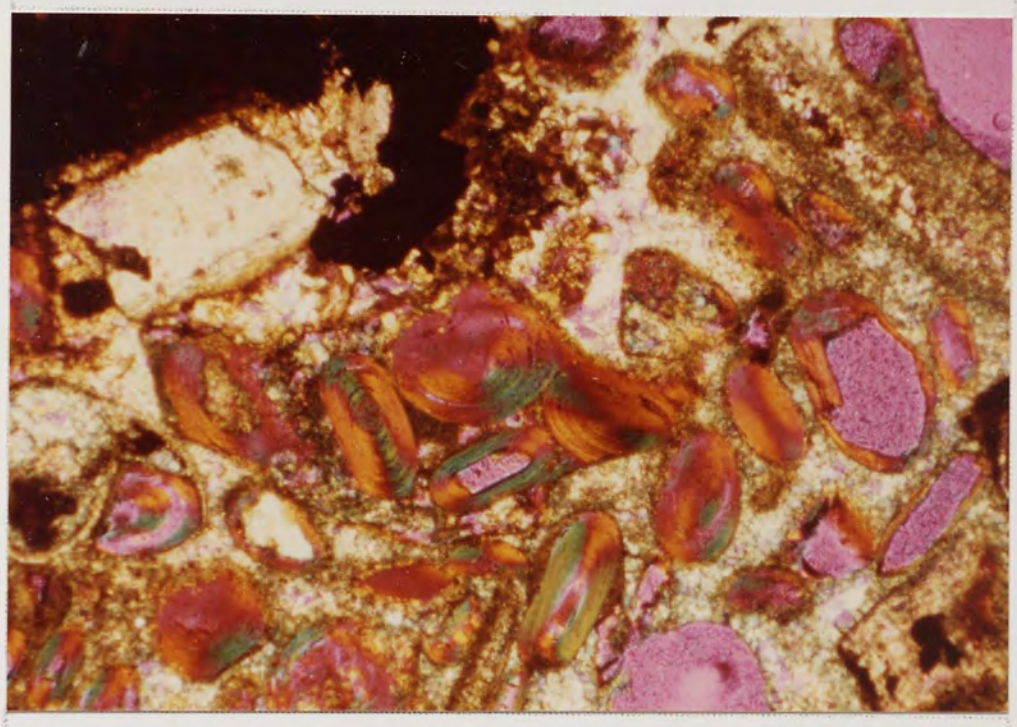


Plate 2.11c The extinction crosses of the ooids seen in Plate 2.11b extend beyond the ooid boundary and into the interstitia chamosite mud. Stained section, XP, x31.25.

Plate 2.11d With the aid of a sensitive tint plate it can be seen that some of the mud has the same optic sign as one ooid and the remainder the same sign as an adjacent ooid i.e. Plate 2.11e. Stained section, XP, mica plate, slow direction NW-SE, x31.25.

Plate 2.11e See text for discussion.





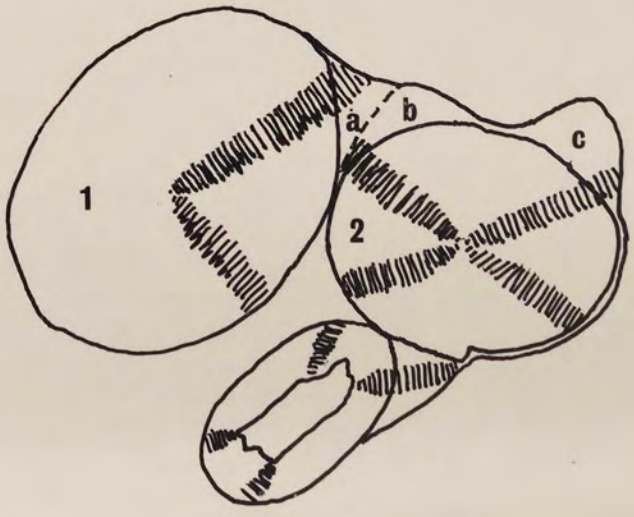
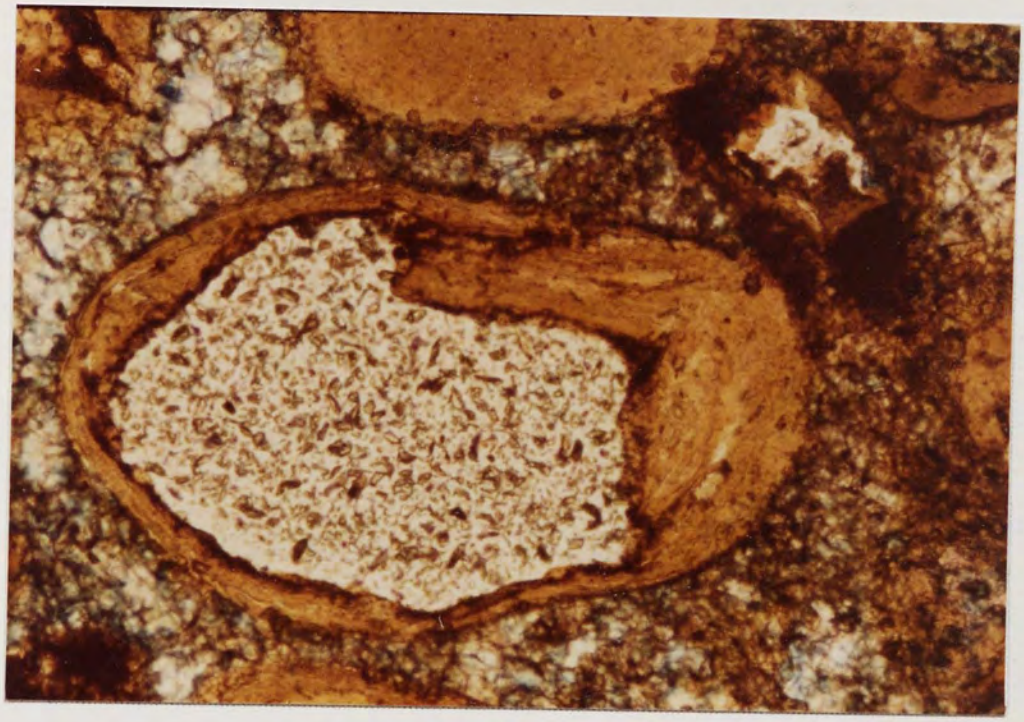

a
b
c
1
2

Plate 2.12 Ooimoulds. The majority of ooimould voids correspond to an ooid ring contact although in these examples a more irregular void-form occurs. Stained section, PPL, x125.



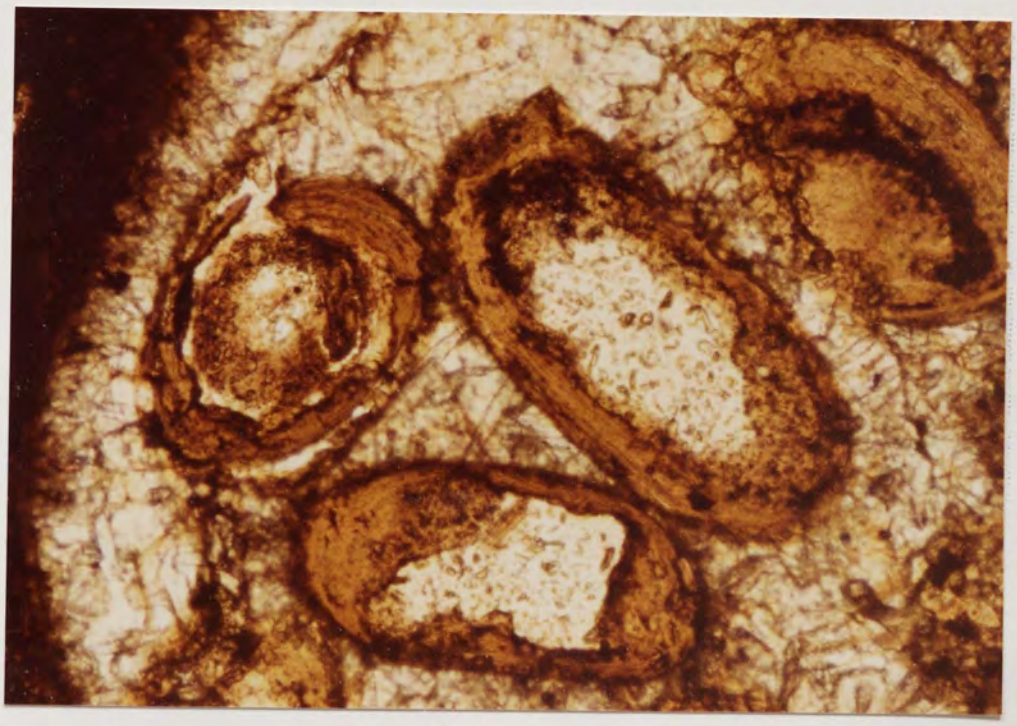
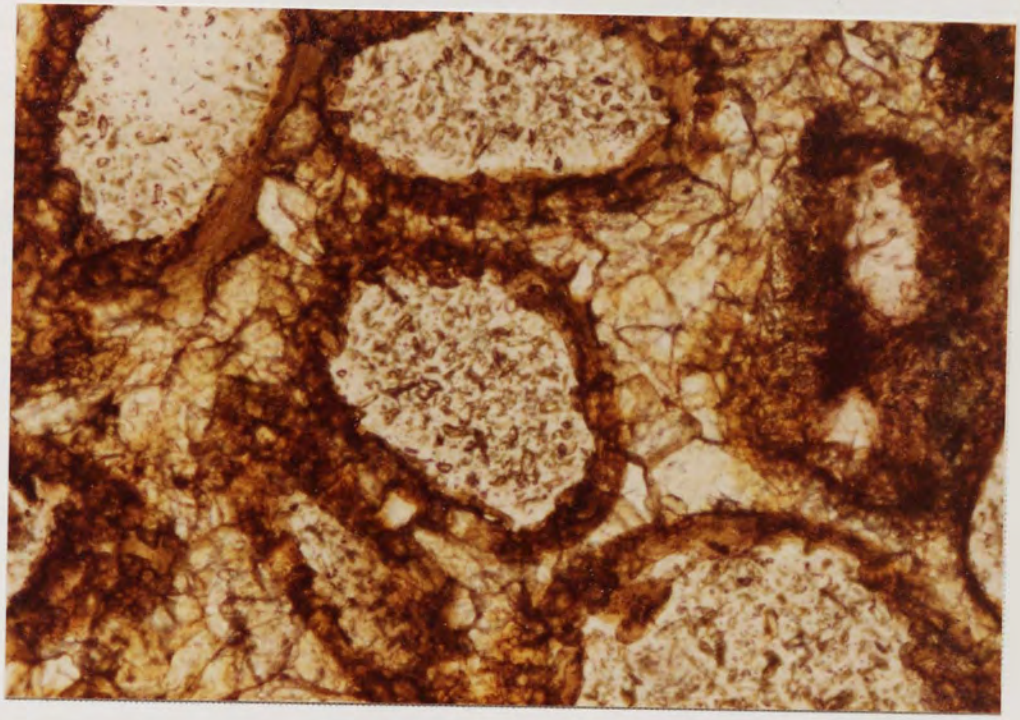


Plate 2.13a Siderite euhedra replace the outer two or three envelope rings of an ooid and show ghost ring contacts. In this example the component crystals of the siderite cement are responsible for this replacement. Stained section, PPL, x125.

Plate 2.13b As for Plate 2.13a, XP, x125.



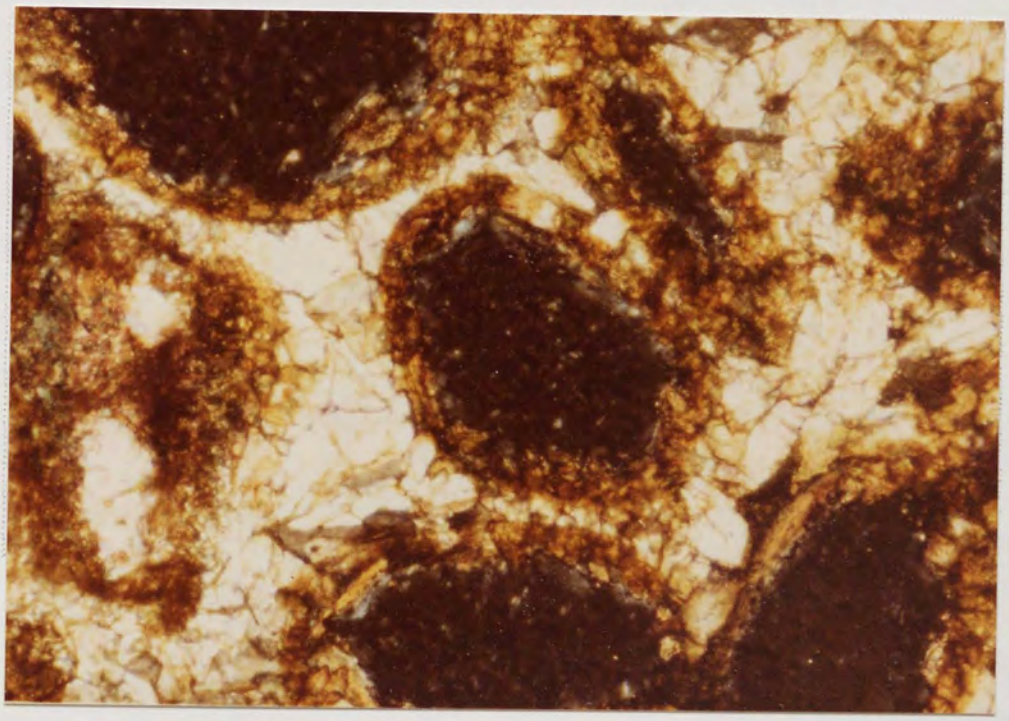
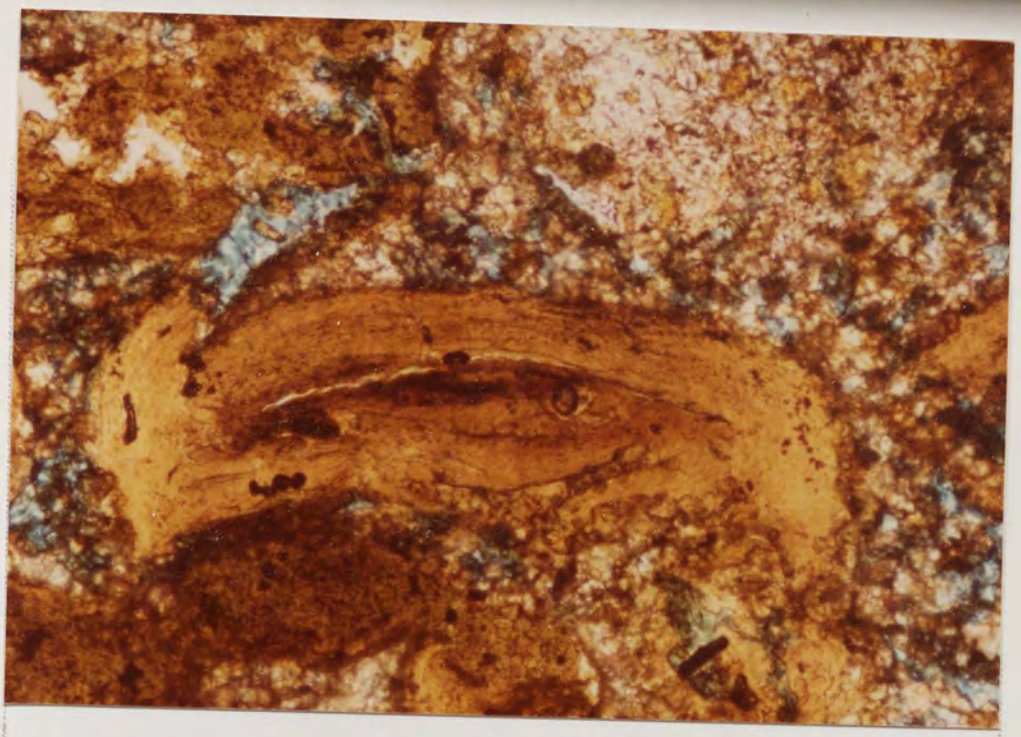


Plate 2.14 Flame ooids. The collapse of ooimoulds leads to the creation of flame-shaped hooked ooids. A central suture line corresponding to the long axis represent the boundary of the original ooimould void. Stained sections, PPL, x125.



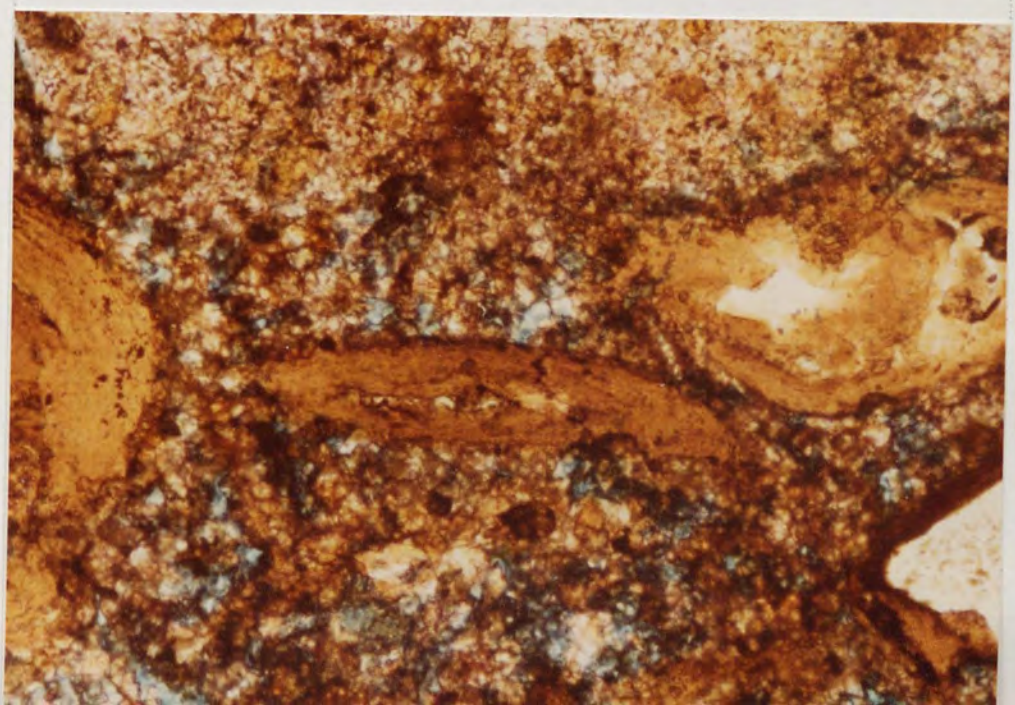
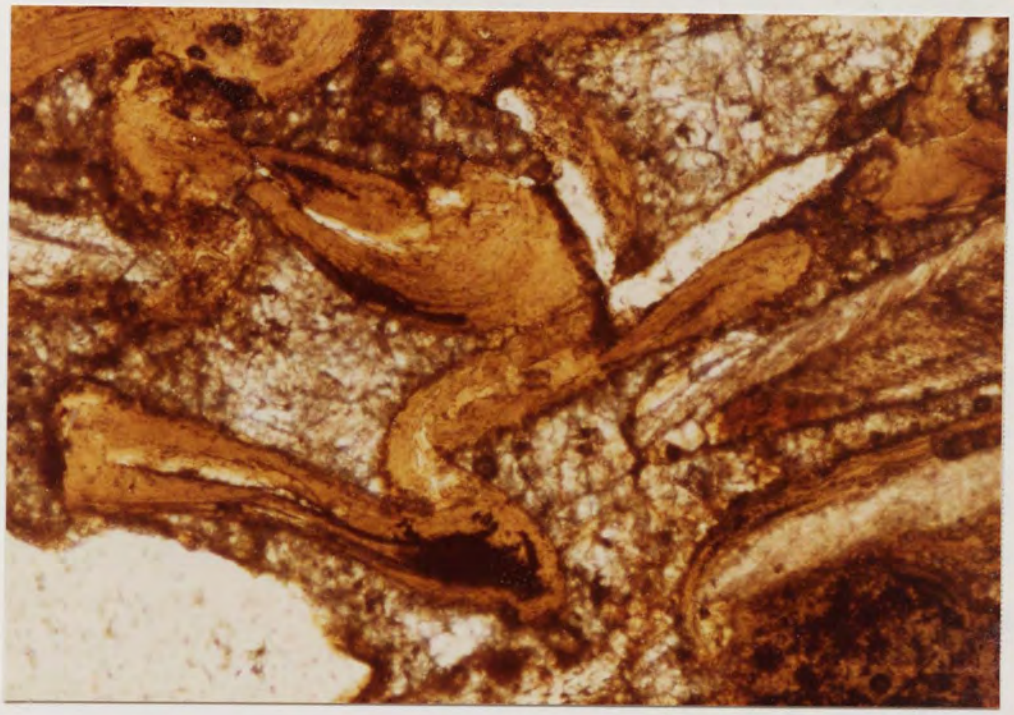


Plate 2.15 Linked flame ooids. If ooimoulds are closely situated or touching at the time of compression, linkages between the resultant flame ooids are formed. Stained sections, PPL, x125.



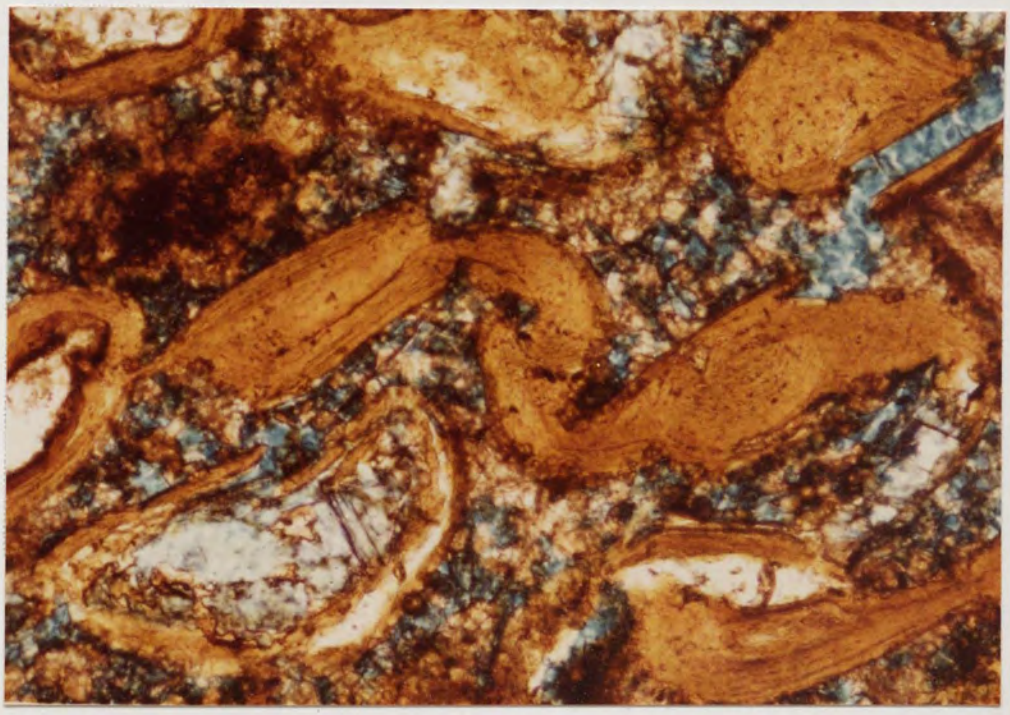
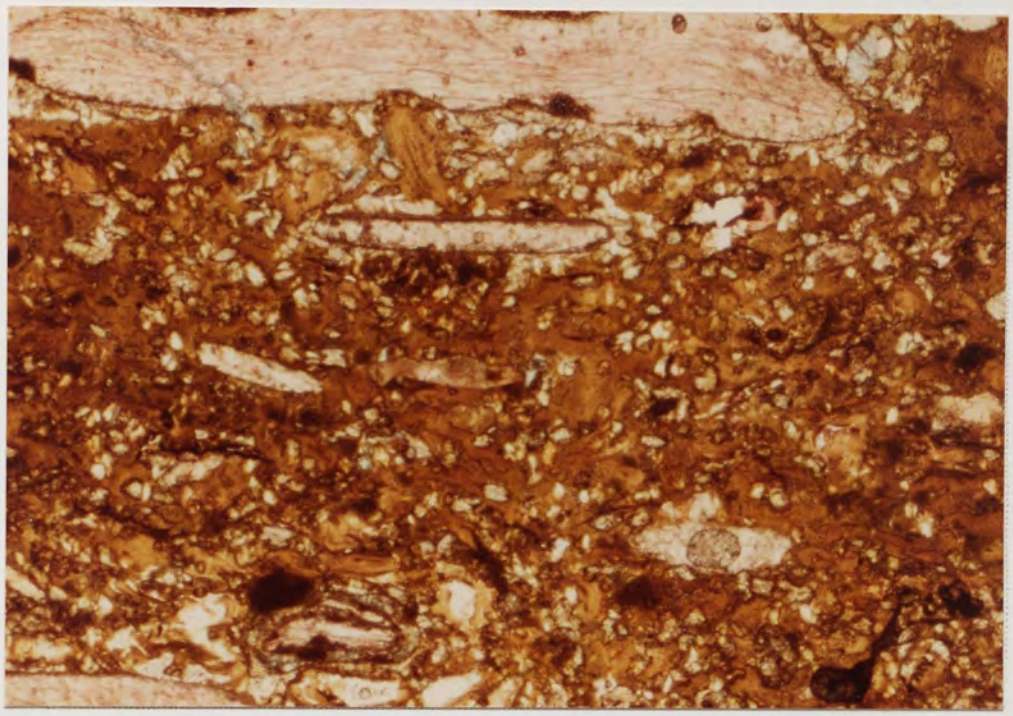


Plate 2.16 Ooid melange. The mechanical failure of a sediment comprising almost entirely ooimoulds leads to the formation of structure in which only remnants of any original ooid structure are seen. Stained sections, PPL, x31.25.



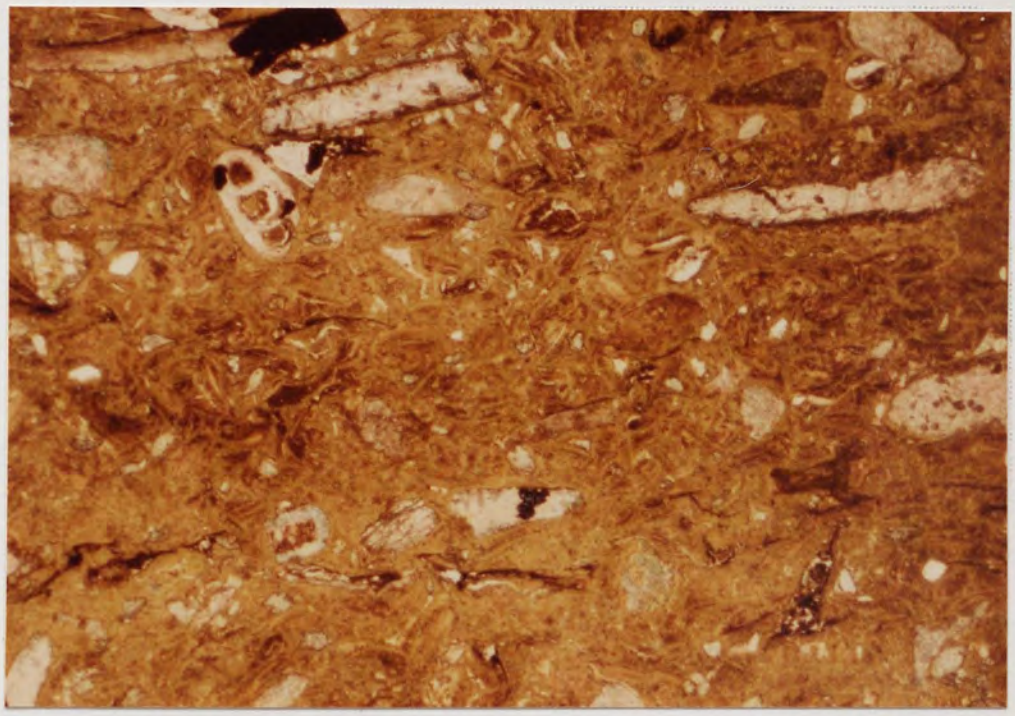
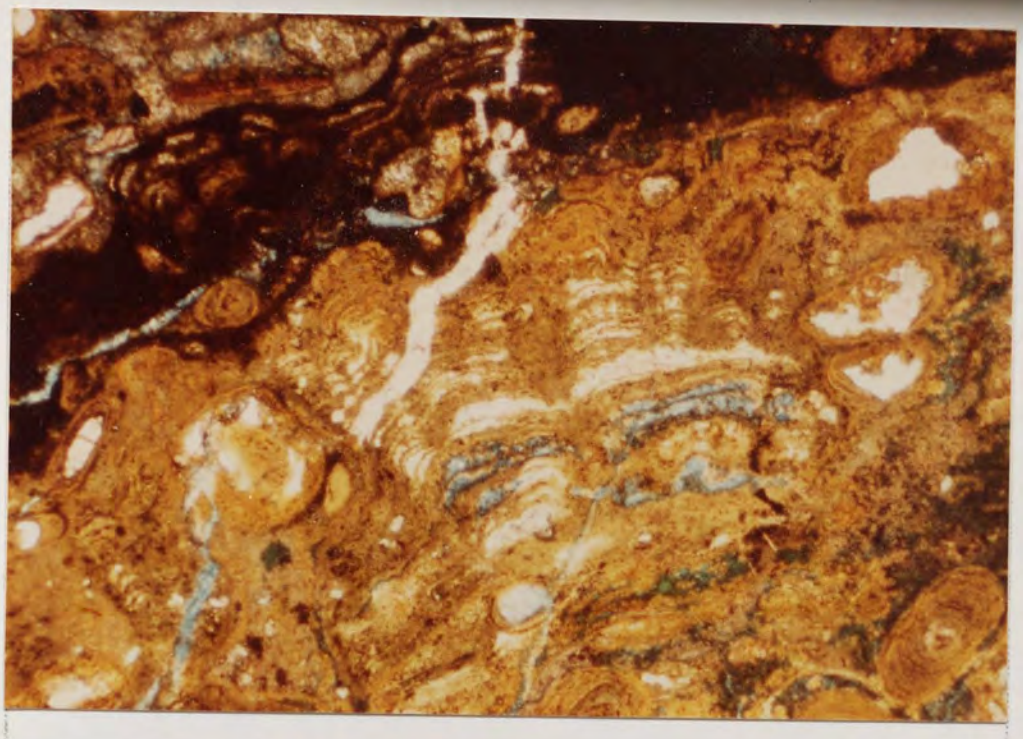
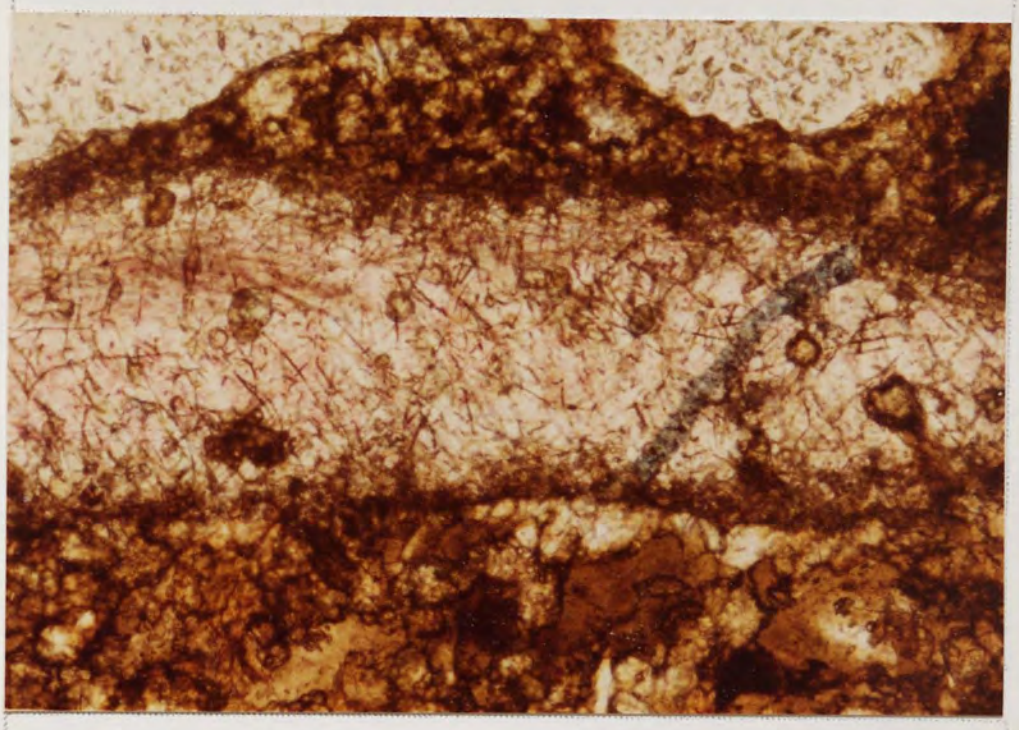


Plate 2.17 Pisoliths exhibit a hummocky structure in which ooids are oriented with their long axes tangential to the pisolith envelope. Stained section, PPL, x31.25.

Plate 2.18 Originally calcite shells exhibit thick micrite envelopes and are heavily bored. Stained section, PPL, x125.

Plate 2.19 The dissolution of originally aragonite shell fragments created secondary pore spaces which were retained by micrite envelopes. The subsequent infilling of these pore spaces by cement minerals creates a zonation corresponding to the cement paragenesis. Stained section, PPL, x125.





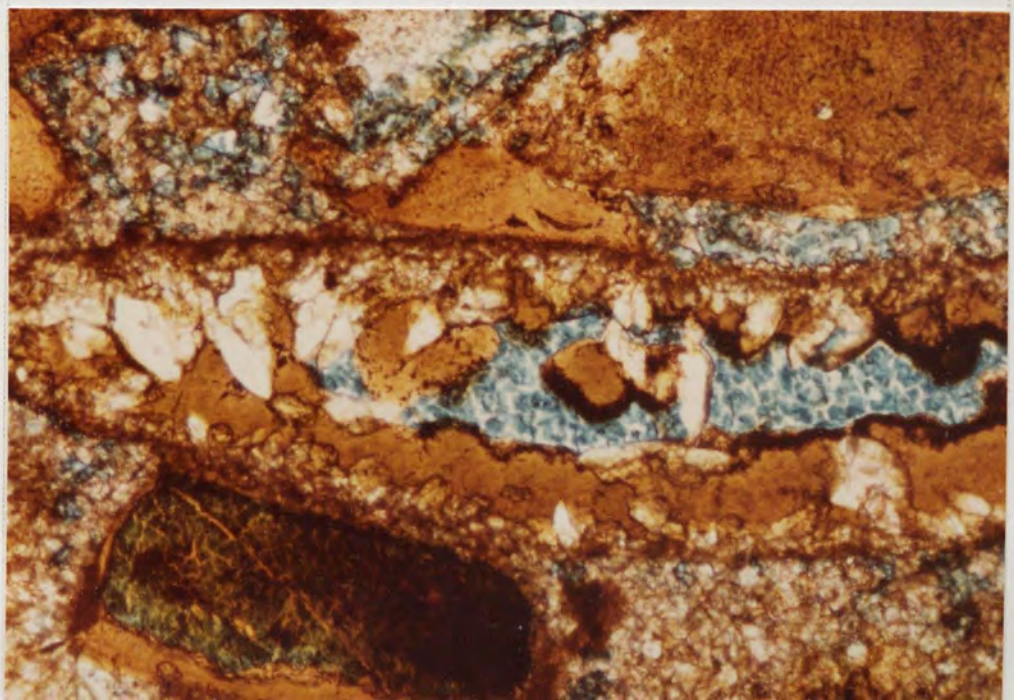
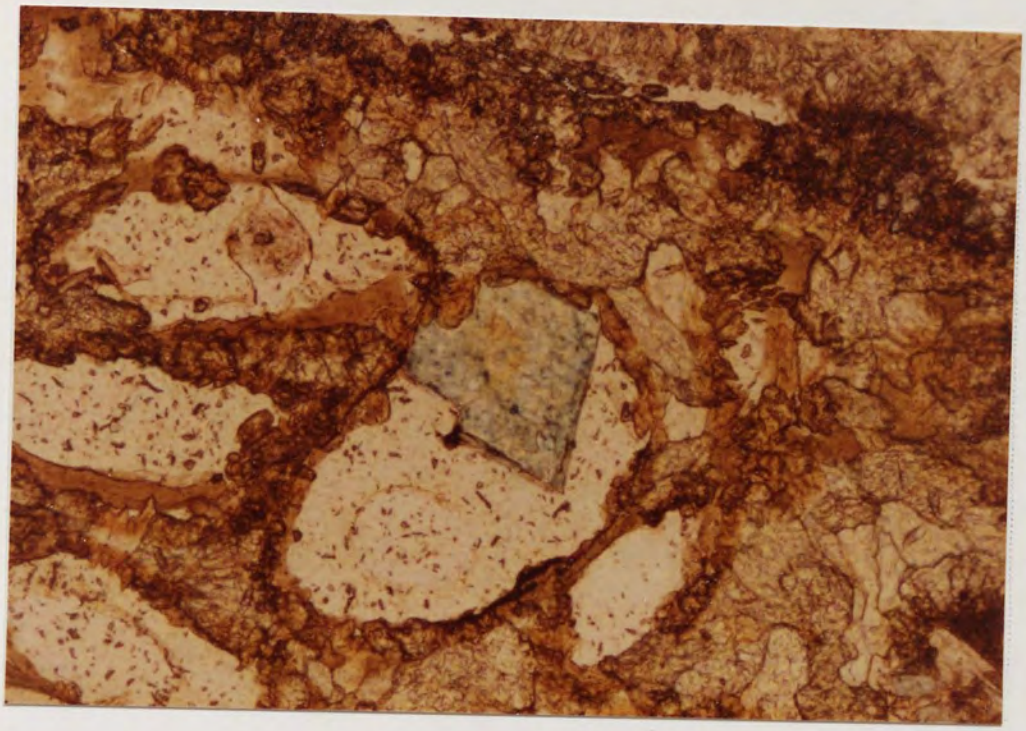


Plate 2.20 Ferroan dolomite rhombs are often found in ooimoulds. Stained section, PPL, x125.



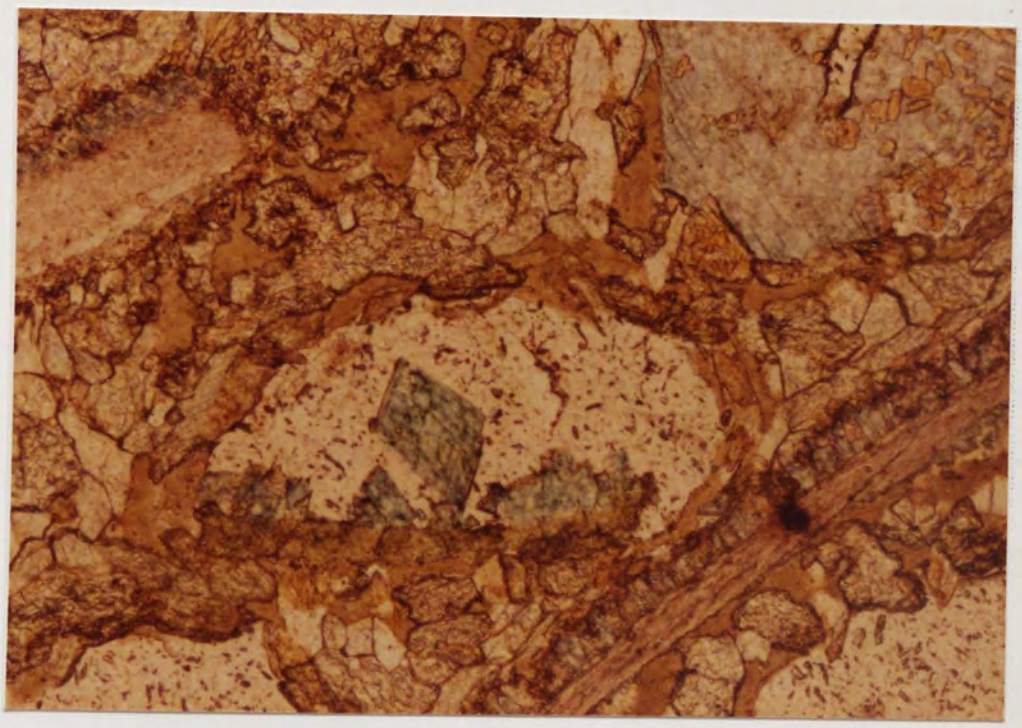
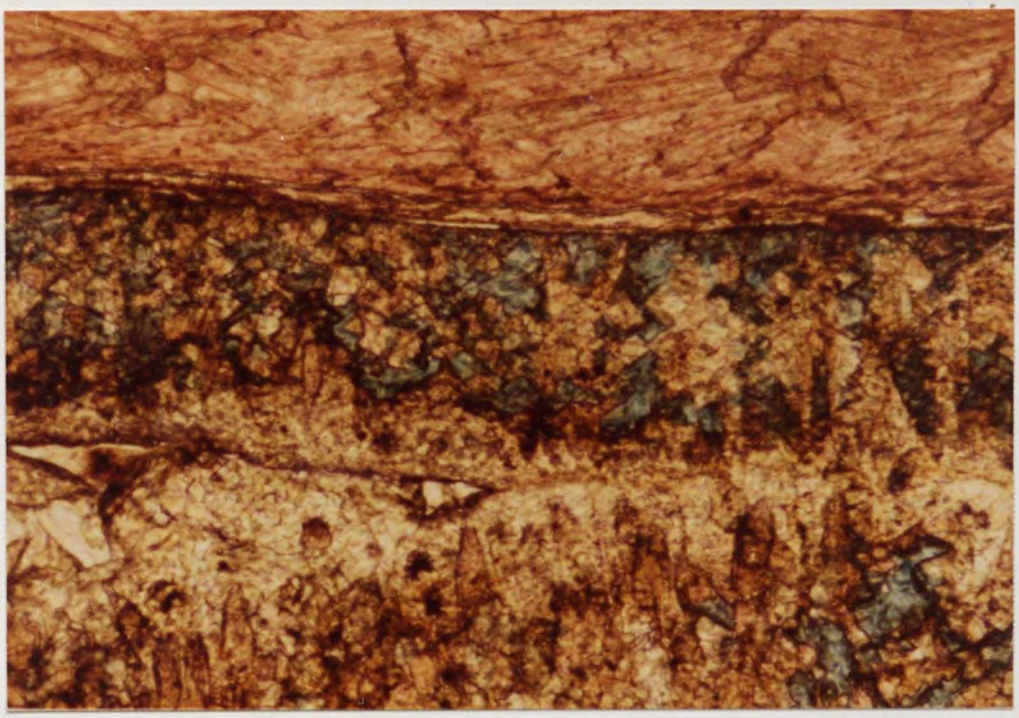


Plate 2.21 Calcite molluscan debris was initially cemented by high-magnesian calcite. The inversion of this to low-magnesian calcite was accompanied by the loss of Mg^{2+} which nucleated locally as ferroan dolomite rhombs (turquoise-bluish white) and the uptake of Fe^{2+} to form ferroan calcite (blue). Siderite precipitated contemporaneously with this, infilling the porosity and retaining ghosts of the original high-magnesian radial fibrous calcite cement. Stained section, PPL, x125.

Plate 2.22 In large pore spaces siderite precipitated as a botroidal pore lining. Ferroan calcite (light blue) crystallised as a pore-infill at a late stage. Stained section, PPL, x31.25.



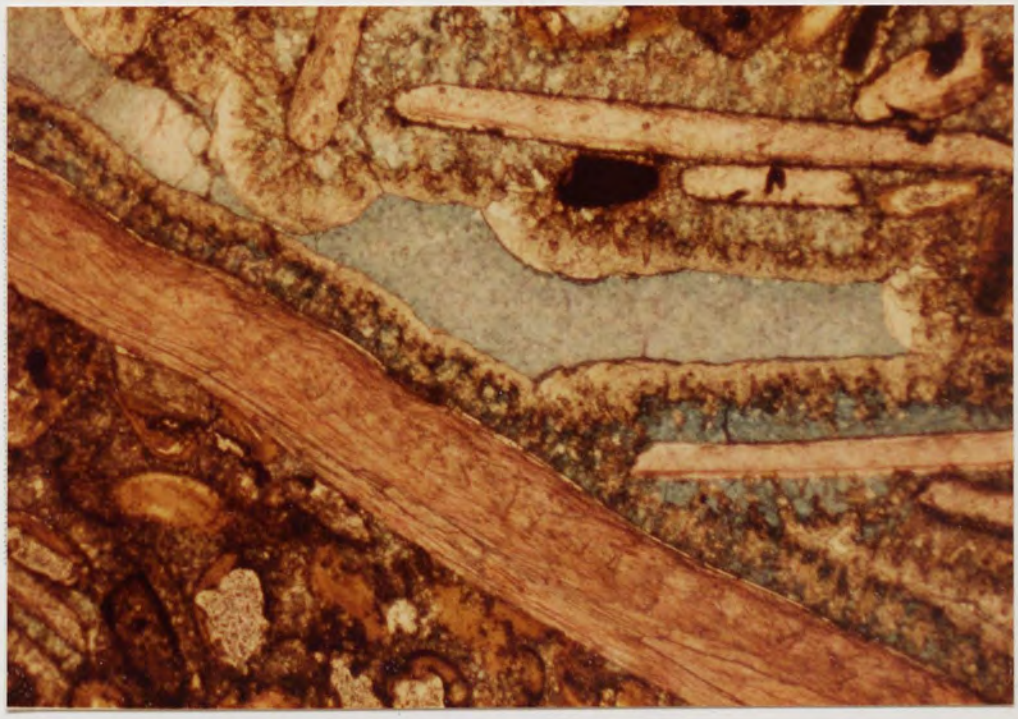
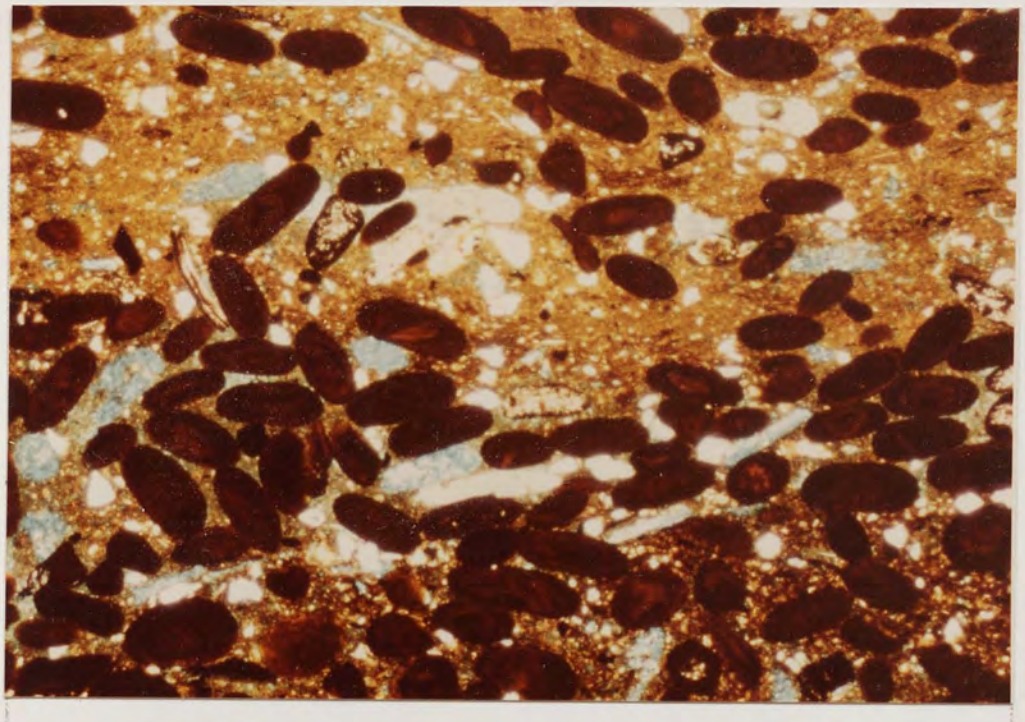
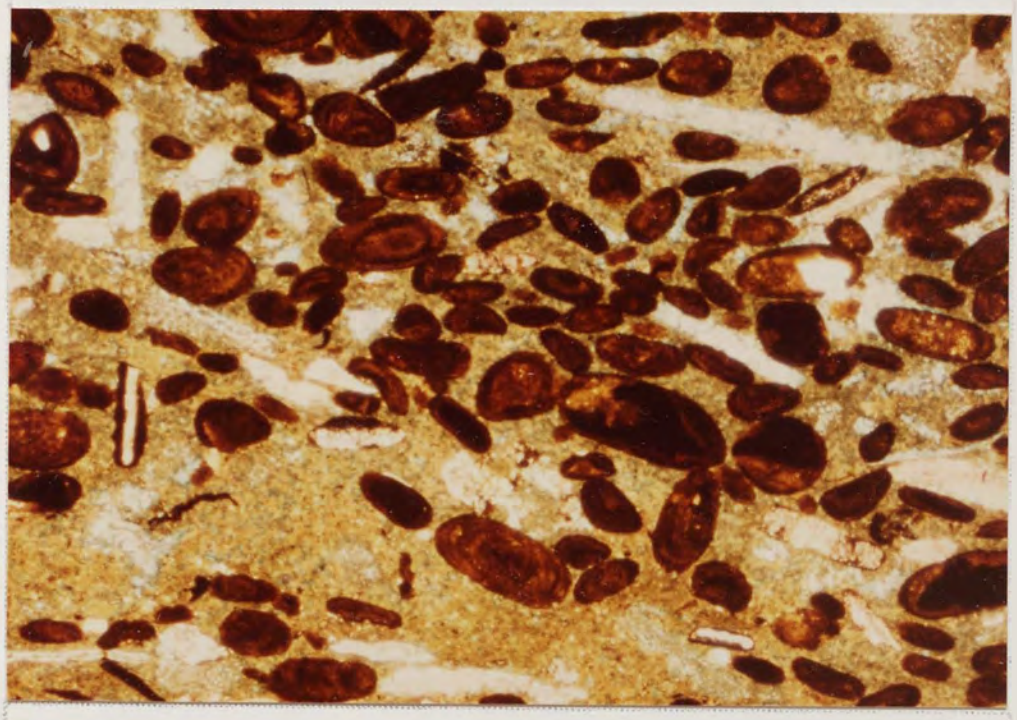


Plate 2.23 Chamositic limonite oolite sub-type (i). Dark brown goethite ooids, detrital quartz grains (white) and shell fragments are set in depositional chamosite mud and cemented with ferroan calcite. Stained section, PPL, x31.25.

Plate 2.24 Chamositic limonite oolite sub-type (ii). Allochemical grains are set in light green authigenic chamosite. Angular areas of siderite (white) and ferroan calcite are common. Quartz is absent. Stained section, PPL, x31.25.

Plate 2.25 Individual rings of chamosite (yellowish green) occur in dominantly goethite ooids. Stained section, PPL, x125.





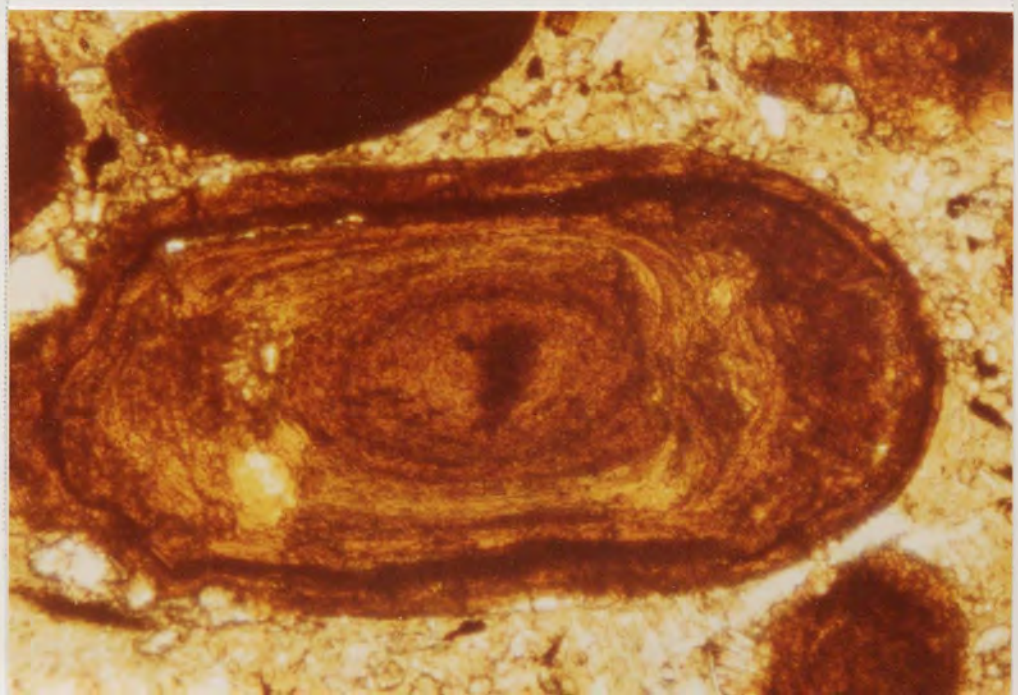
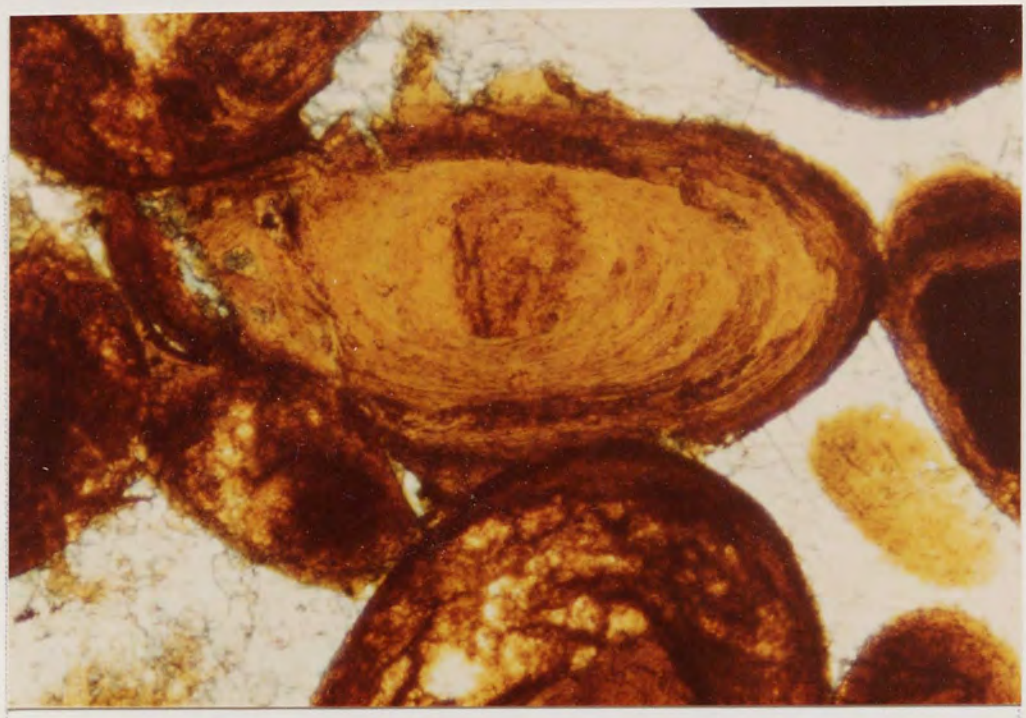
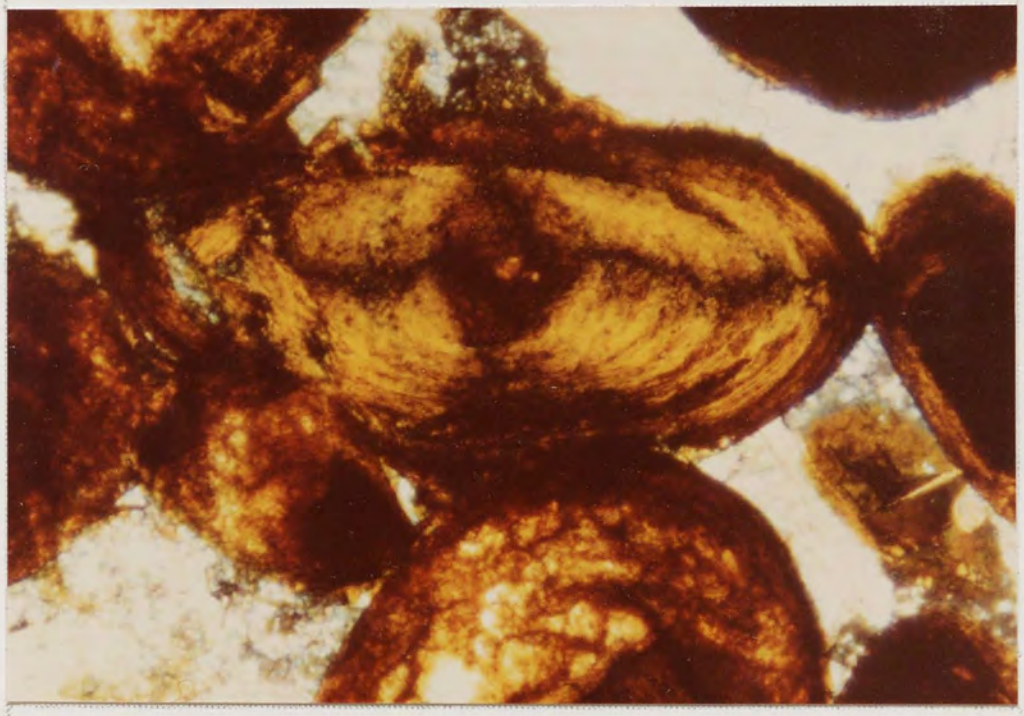


Plate 2.26a Ooids occurring in this facies are often constructed of a yellowish brown chamosite surrounded by a goethite ri or crust. Stained section, PPL, x125.

Plate 2.26b As for Plate 2.26a. XP, x125.

Plate 2.27 Ooid envelopes may consist of alternating chamosite and goethite rings. Stained section, PPL, x125.





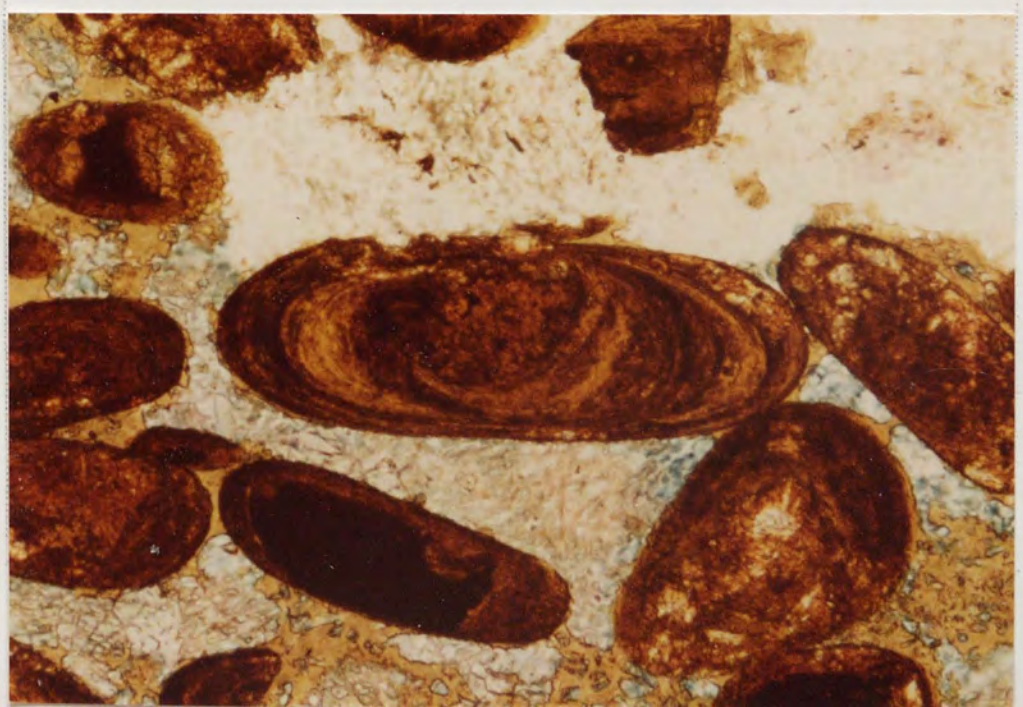
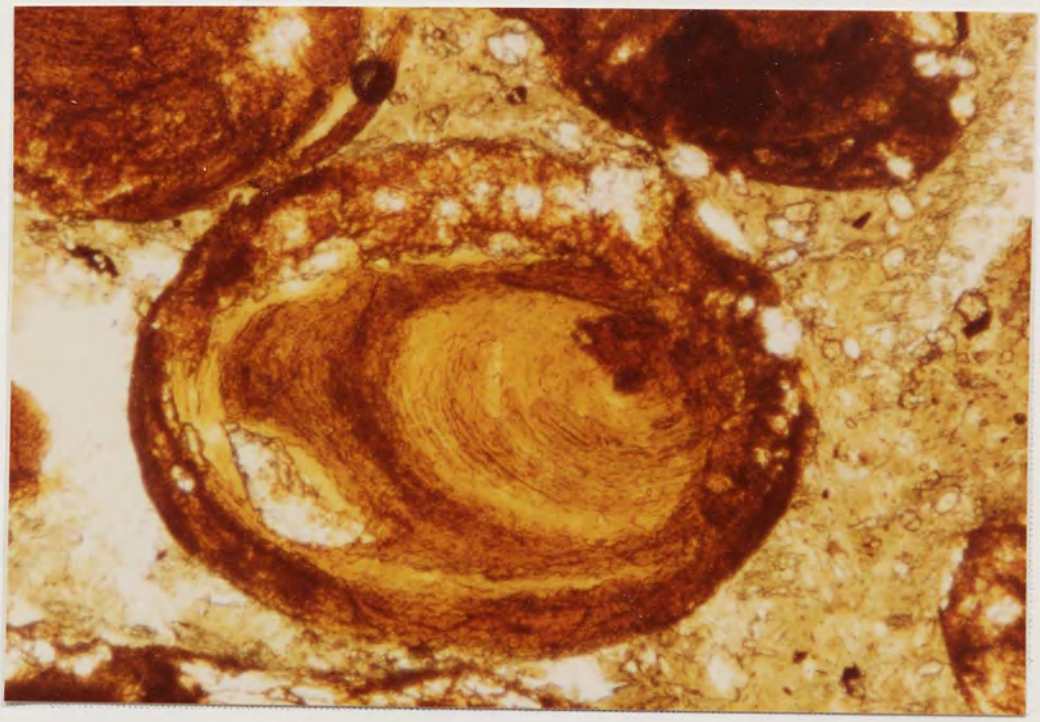


Plate 2.28a Slivers of goethite occur within the yellow-brown chamosite of ooid centres. Stained section, PPL, x125.

Plate 2.28b As for Plate 2.28a. XP, x125.



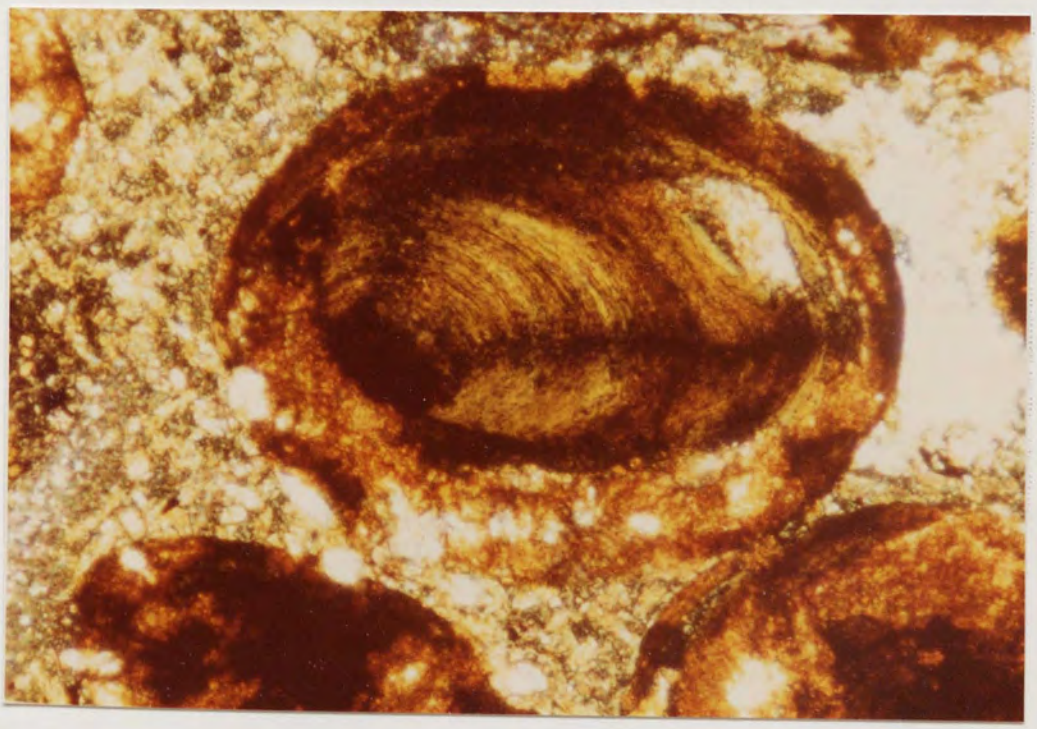
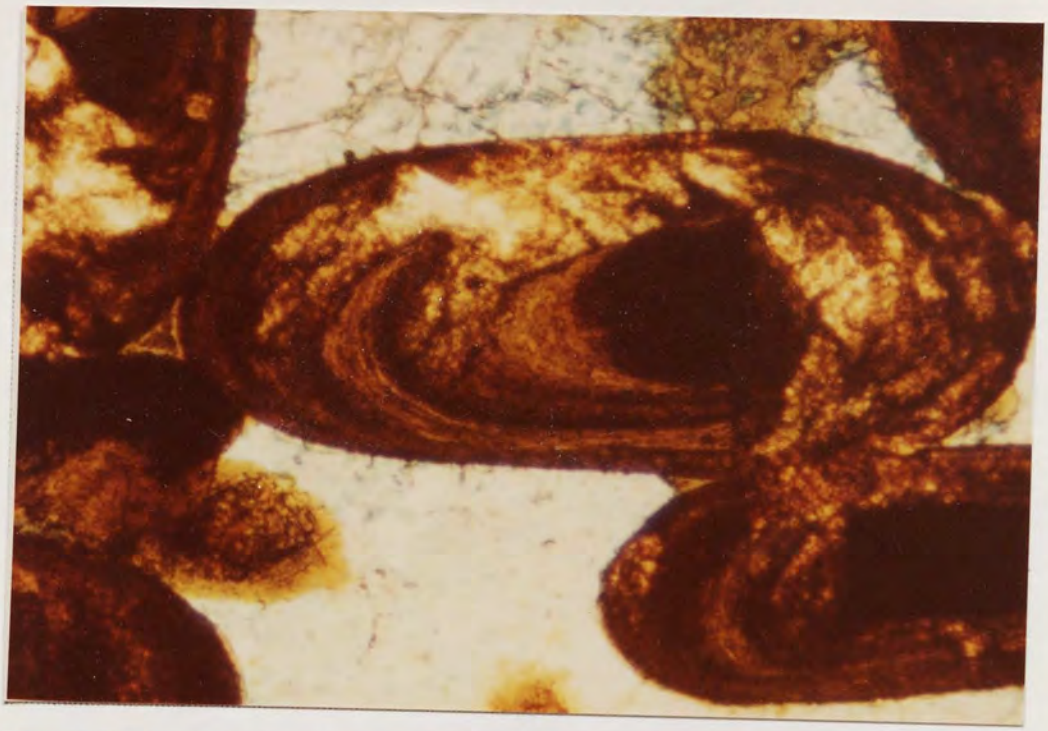
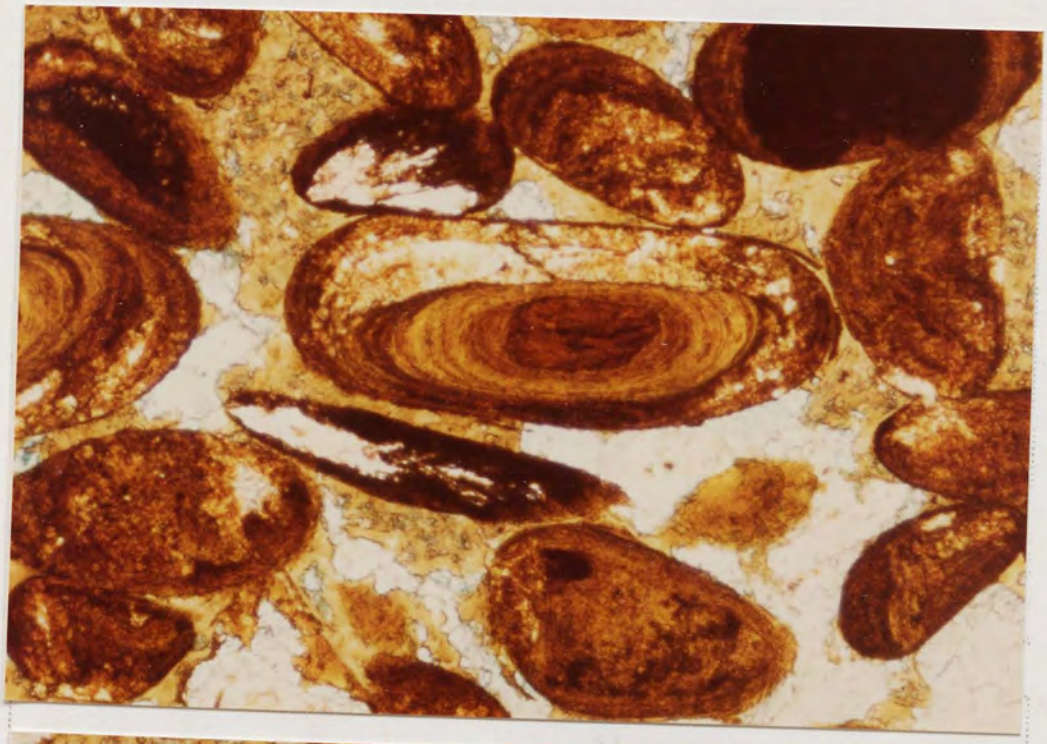


Plate 2.29 Dropped ooid cores. Partial dissolution of the interior of an ooid may result in the detachment of a central remaining portion of the grain which then drops to the bottom of the void. The void thus created is usually infilled with siderite (white, iron-stained). Stained sections, PPL, x200, x125, x125.





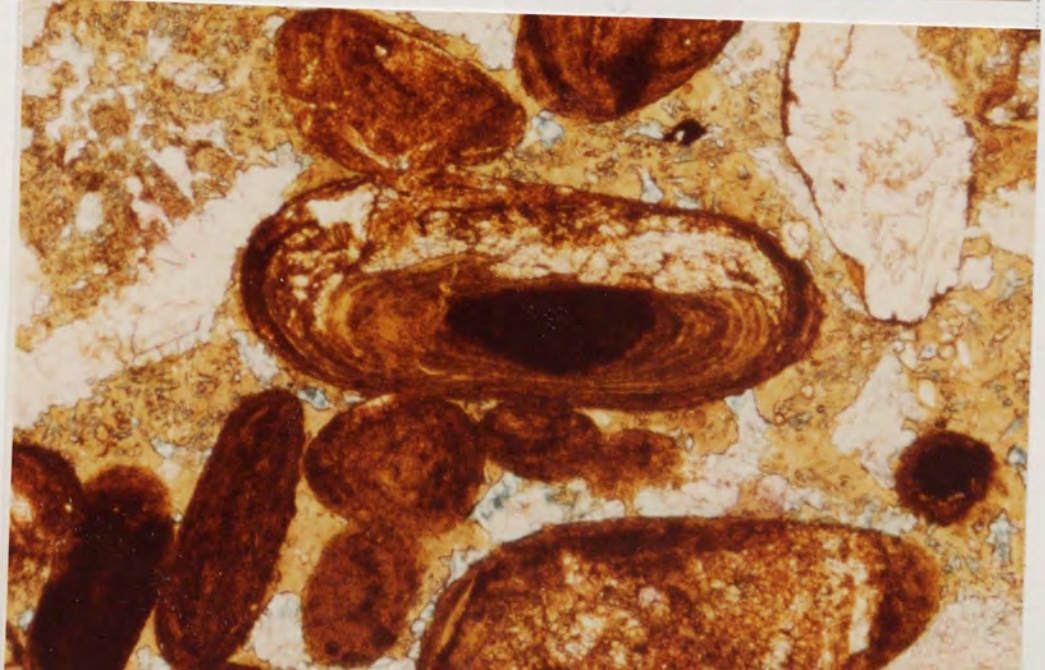
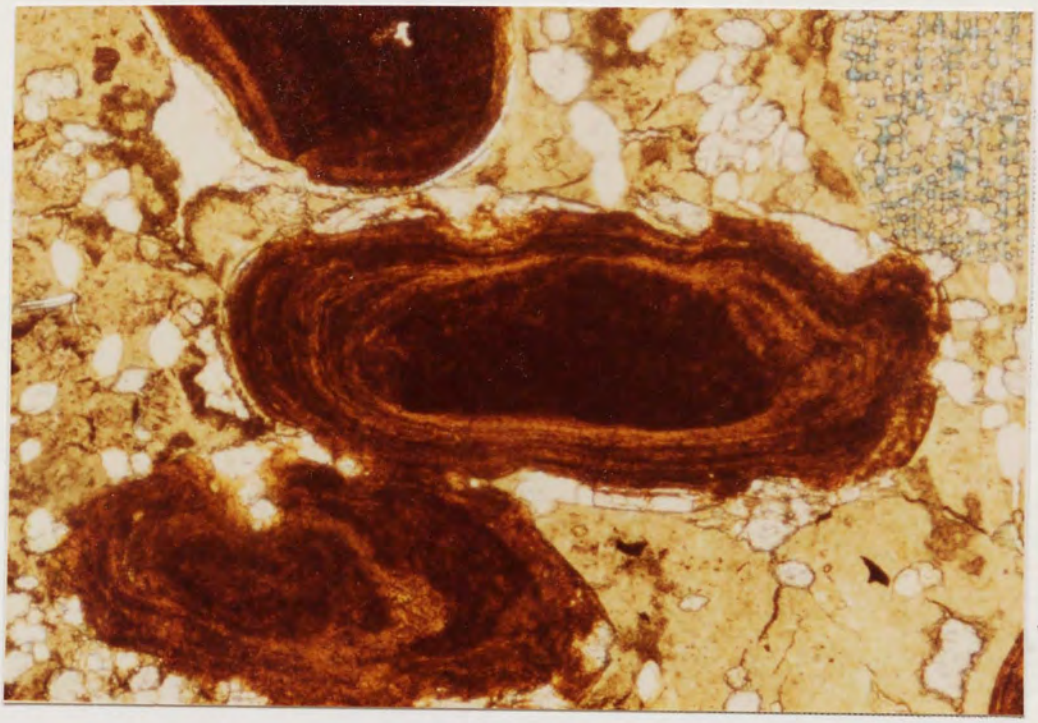


Plate 2.30 Due to the precipitation and subsequent growth of siderite (white) at the contact between goethite ooids and authigenic chamosite the ring structure of the ooid envelope is distorted. Stained section, PPL, x125.

Plate 2.31 Isopachous lining and occlusion of pore-spaces by authigenic chamosite (yellow-green) precipitated from aqueous solution. Stained section, PL, x125.



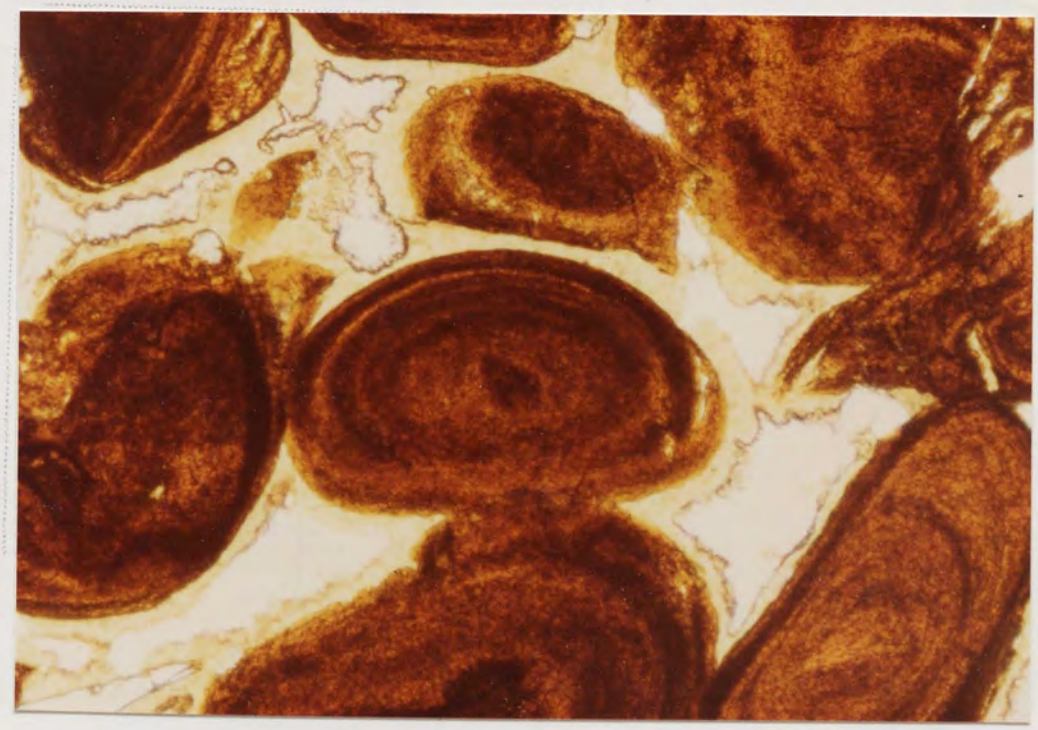
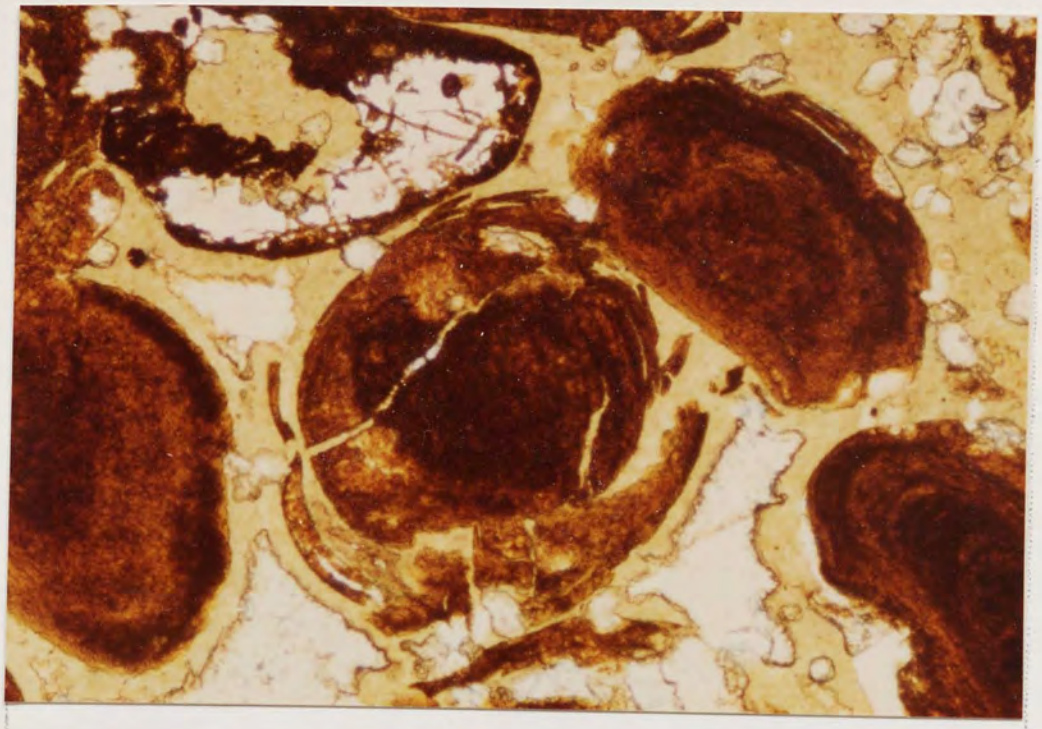
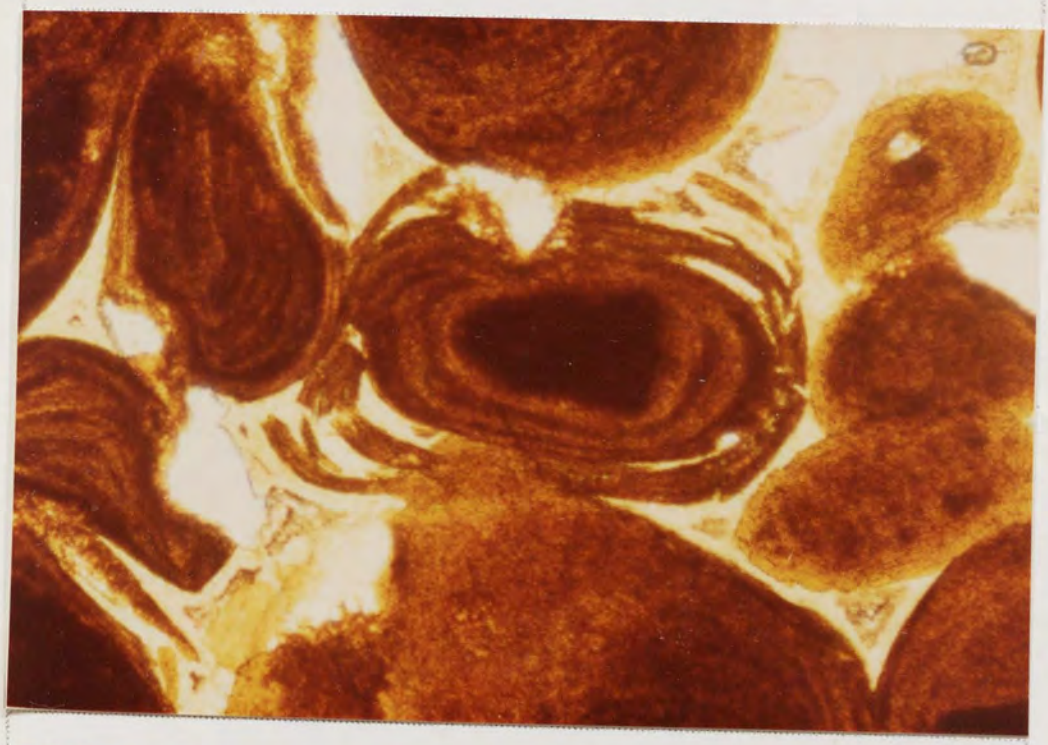


Plate 2.32 Explosion texture. Precipitating authigenic chamosite (yellow-green) exploits weaknesses such as radial fractures and ring contacts in goethite ooid envelopes and lifts portions of the envelope away from the parent ooid. Stained sections, PPL, x125.

Plate 2.33 Zoned echinoid plate. A central spot of non-ferroan calcite (pink) is surrounded by a wide zone of ferroan calcite (blue). The original stereome system is infilled by authigenic chamosite. Stained section, PPL, x125.





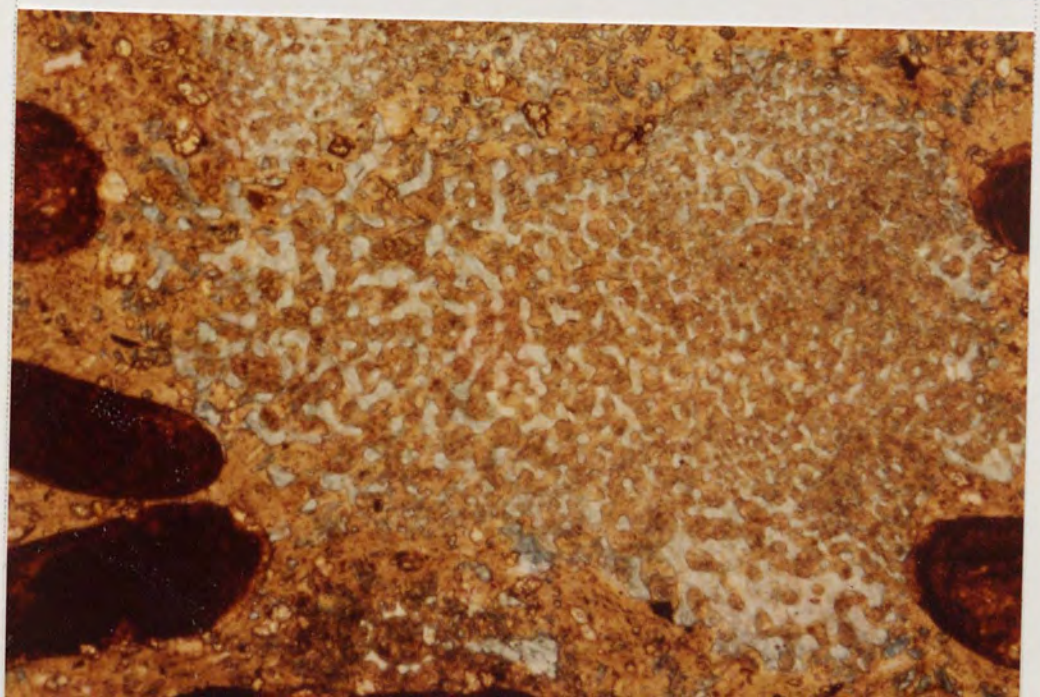
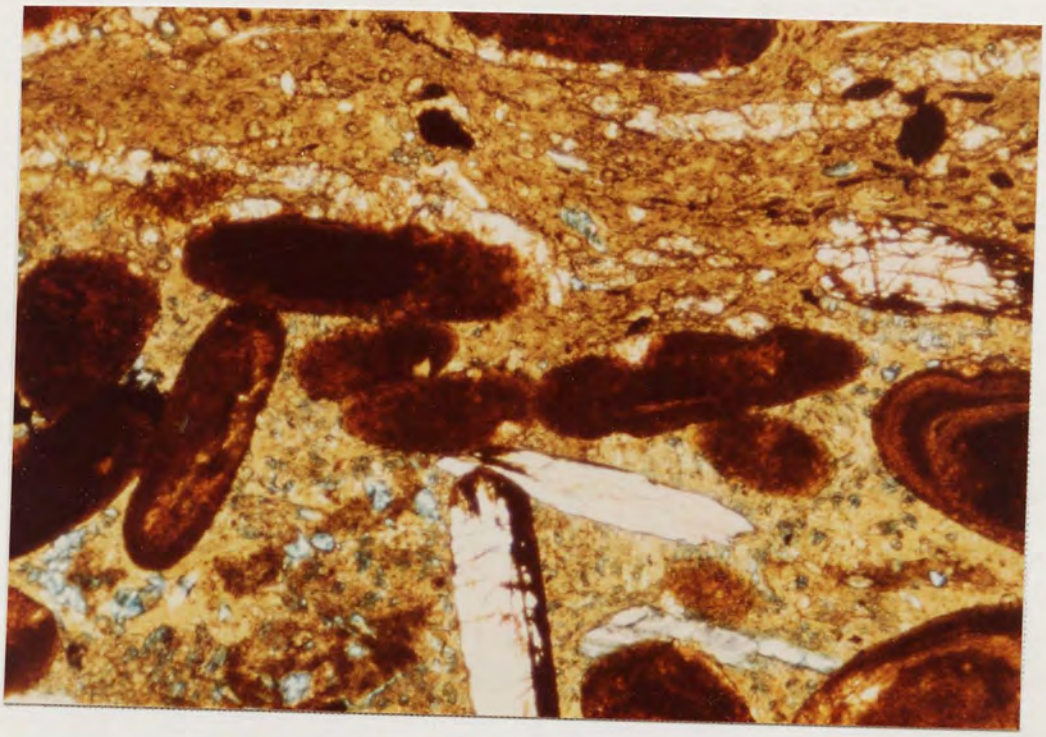


Plate 2.34a Depositional chamosite (olive-green, top) merges imperceptibly into grass green authigenic chamosite. Stained section, PPL, x125.

Plate 2.34b As for Plate 2.34b. 45° position. Note the unit extinction of the authigenic chamosite as opposed to the uniform maximum illumination of the depositional chamosite. XP, x125.



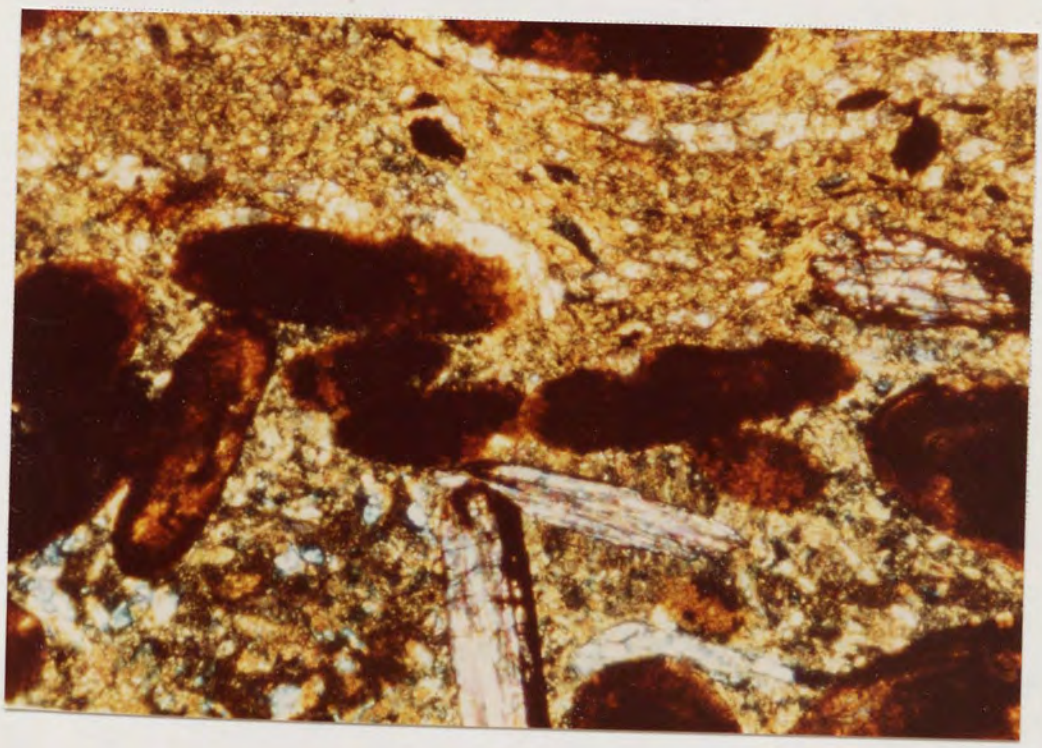
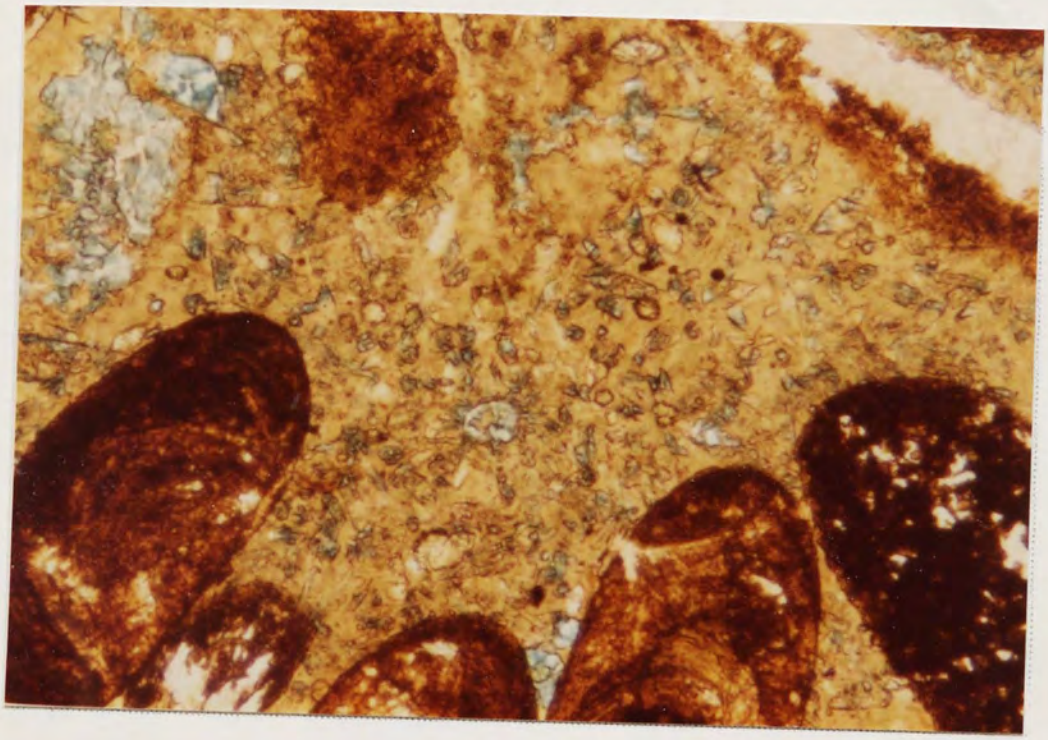


Plate 2.35 Ferroan calcite (blue) and rare siderite (white, greenish white) polygons, dominantly equilateral and isosceles triangles, set in authigenic chamosite. Stained sections, PPL, x200, x125.



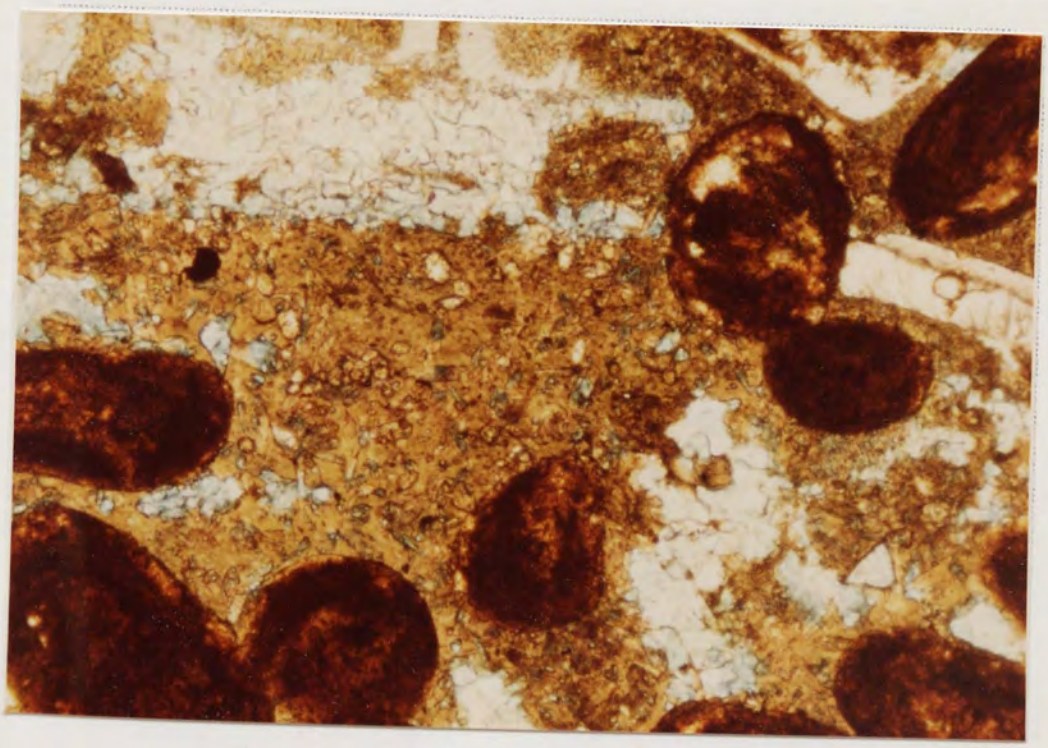
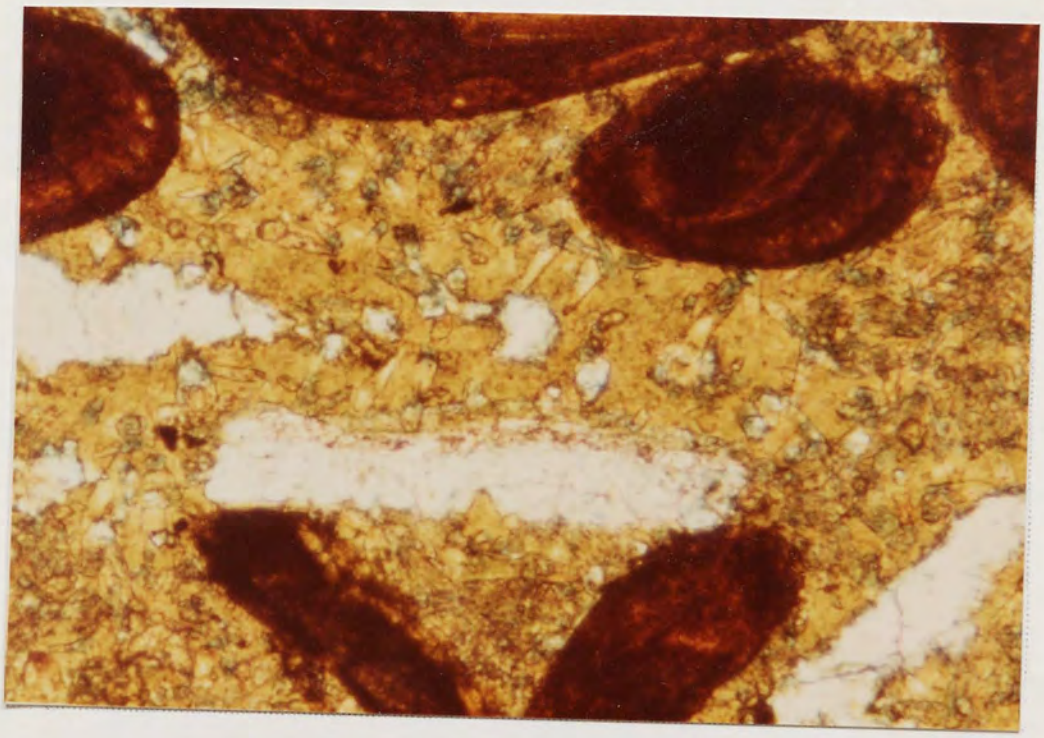


Plate 2.36a Ferroan calcite (blue) and siderite (yellowish green) polygons. Stained section, PPL, x200.

Plate 2.36b As for Plate 2.36a. Between crossed polars the yellowish green areas show a high birefringence indicative of siderite. The colour tint may therefore be due to included chamosite. XP. x200.



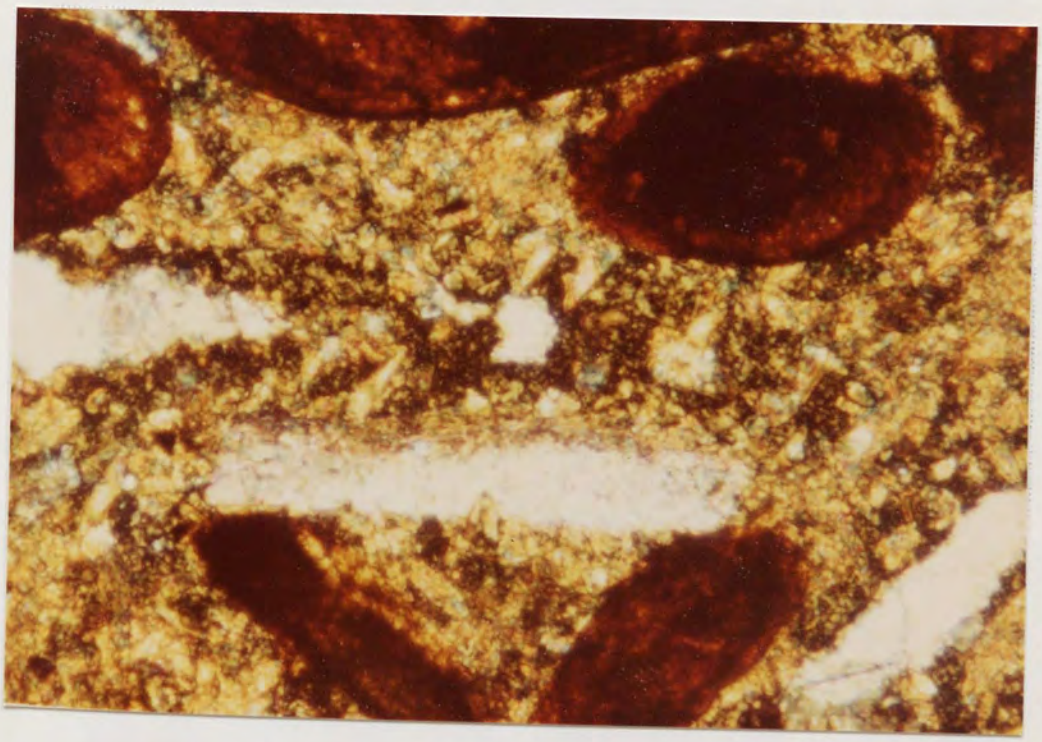
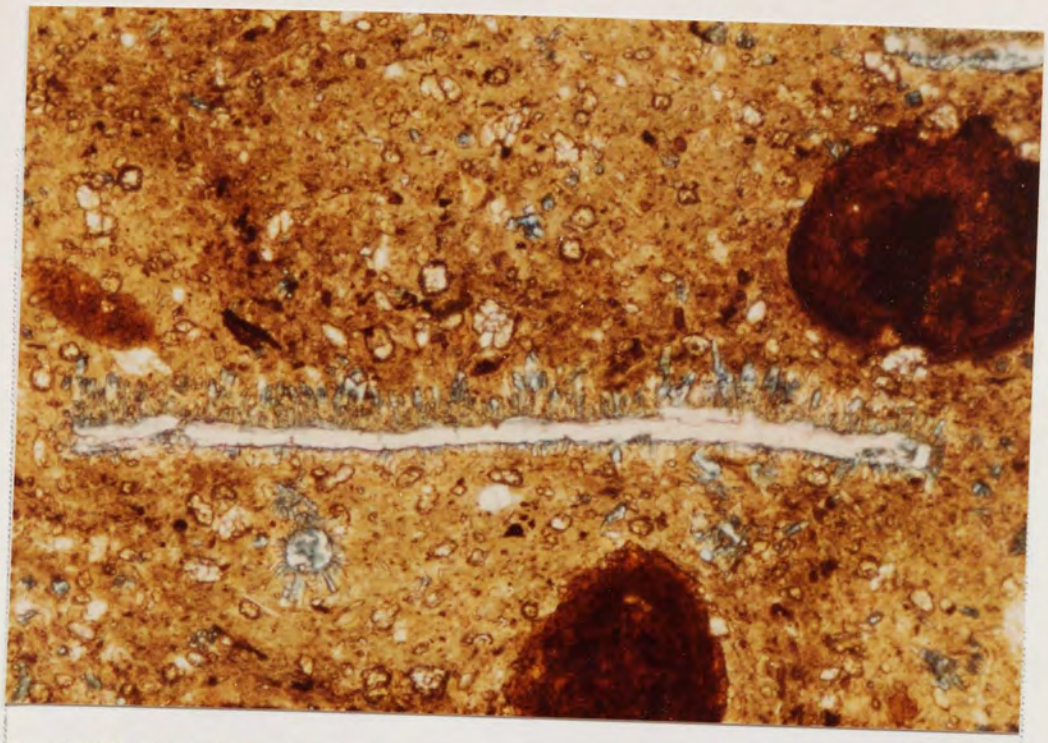
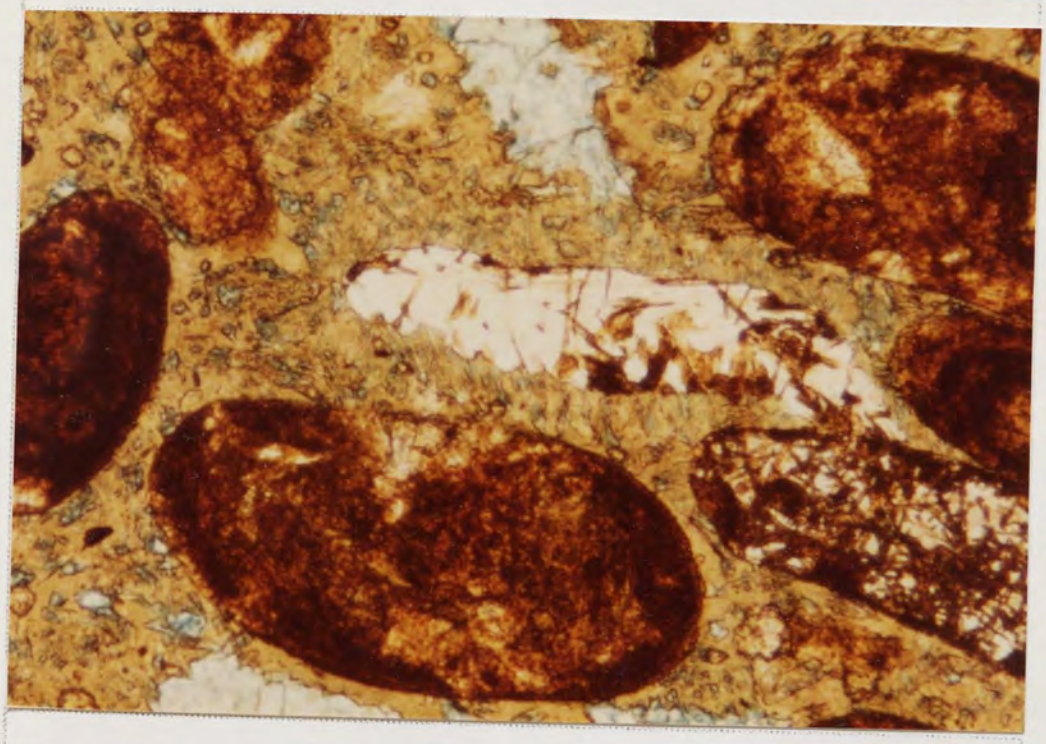


Plate 2.36c Radial fibrous fringe of ferroan calcite (blue) surrounding non-ferroan calcite (pink) mollsucan debris. Note the intervening 'filaments' of authigenic chamosite. An outer ferroan calcite layer to the shell fragment suggests the possibility that this was an originally high-magnesian calcite layer. Stained section, PPL, x125.

Plate 2.36d Radial fibrous fringe of ferroan calcite (blue), siderite (yellowish green) and intervening authigenic chamosite 'filaments' to a non-ferroan calcite (white) shell fragment. Stained section, PPL, x200.

Plate 2.36e As for Plate 2.36d. The high birefringence of the yellowish green siderite indicates that its colouration may be due to included authigenic chamosite. XP, x200.





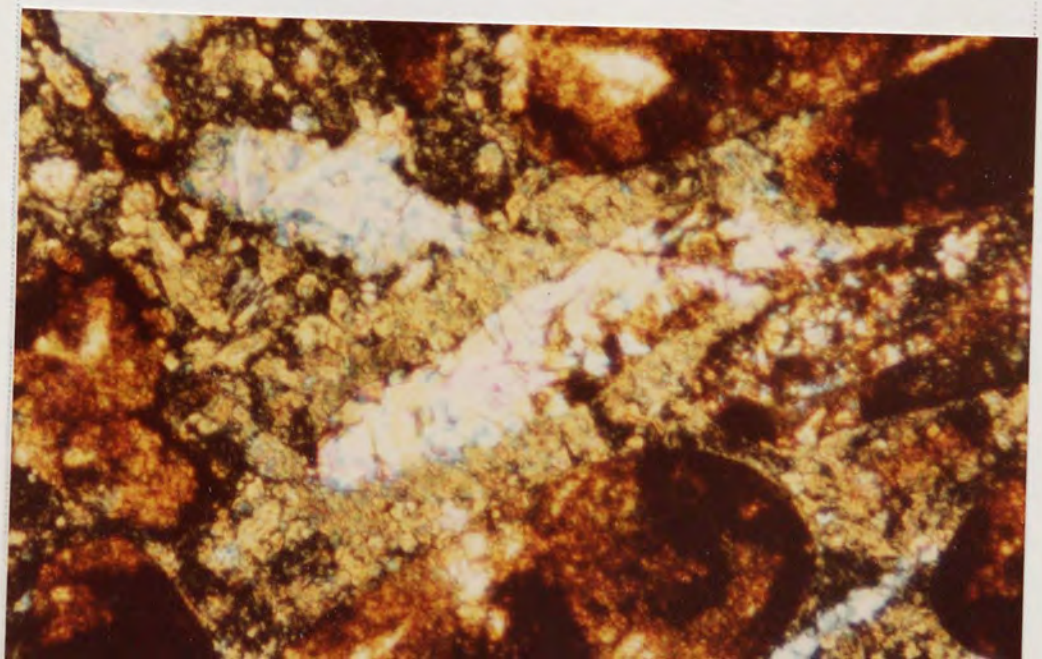


Plate 2.37 Chamositic limonite oolite sub-type (iii). Goethite ooids and intraclasts show ragged edges due to siderite precipitation. The cement consists of authigenic chamosite, ferroan calcite (blue) and siderite (white, high relief). Stained sections, PPL, x31.25, x125.