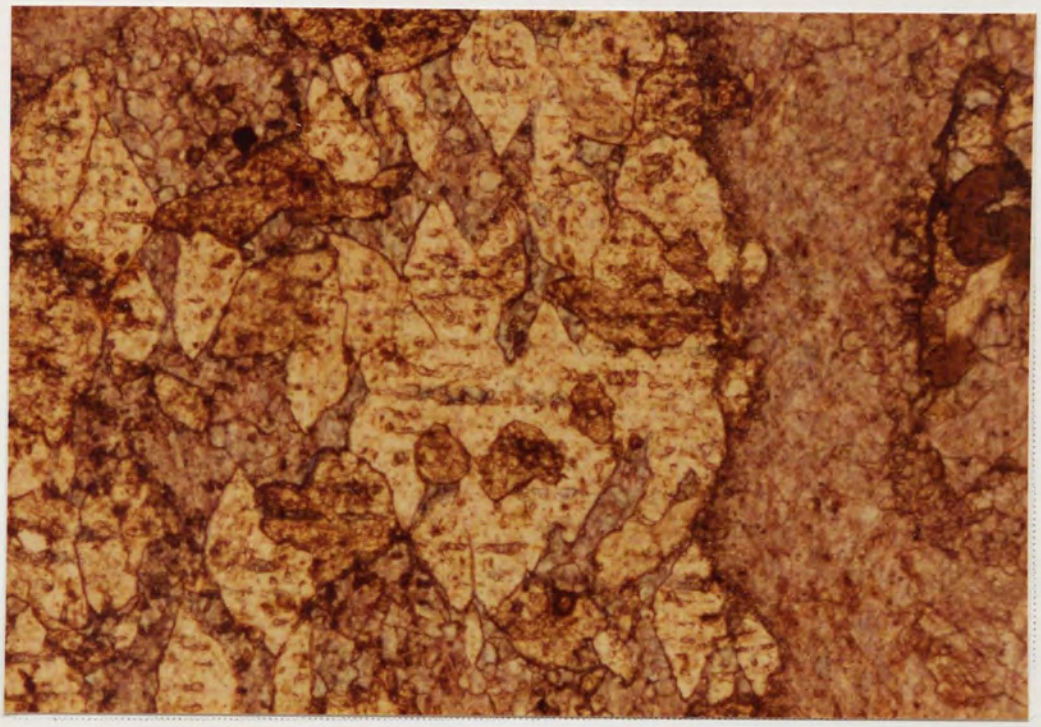
Plate 3.30a Siderite (white, high relief) overgrowth on ferroan calcite (blue) echinoid plate. Note that the siderite is poikilotopic with respect to an earlier ferroan calcite stereome system infill. Stained section, PPL, x125.

Plate 3.30b As for Plate 3.30a. Between crossed polars the optical continuity of the echinoid plate and the calcite syntaxial overgrowths can be seen. XP, x125.



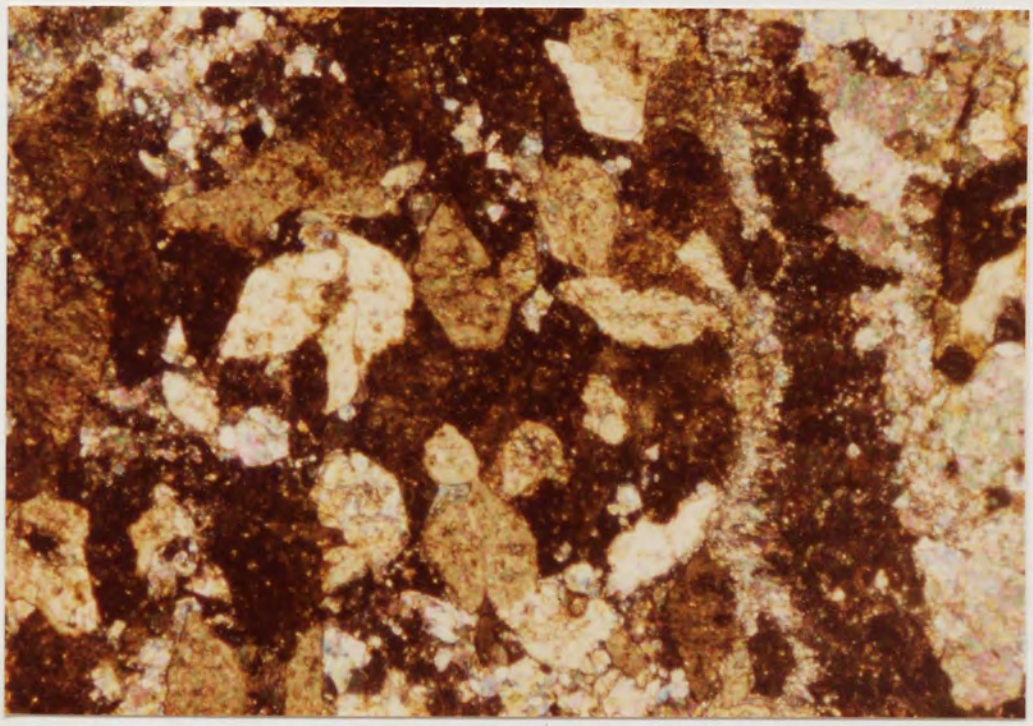
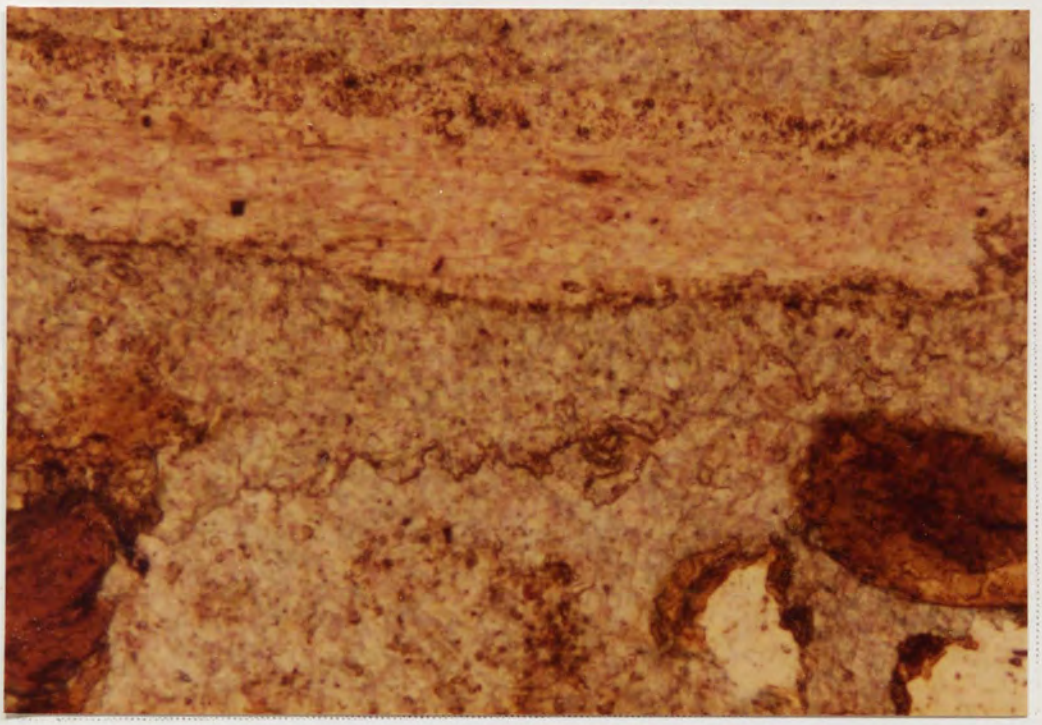
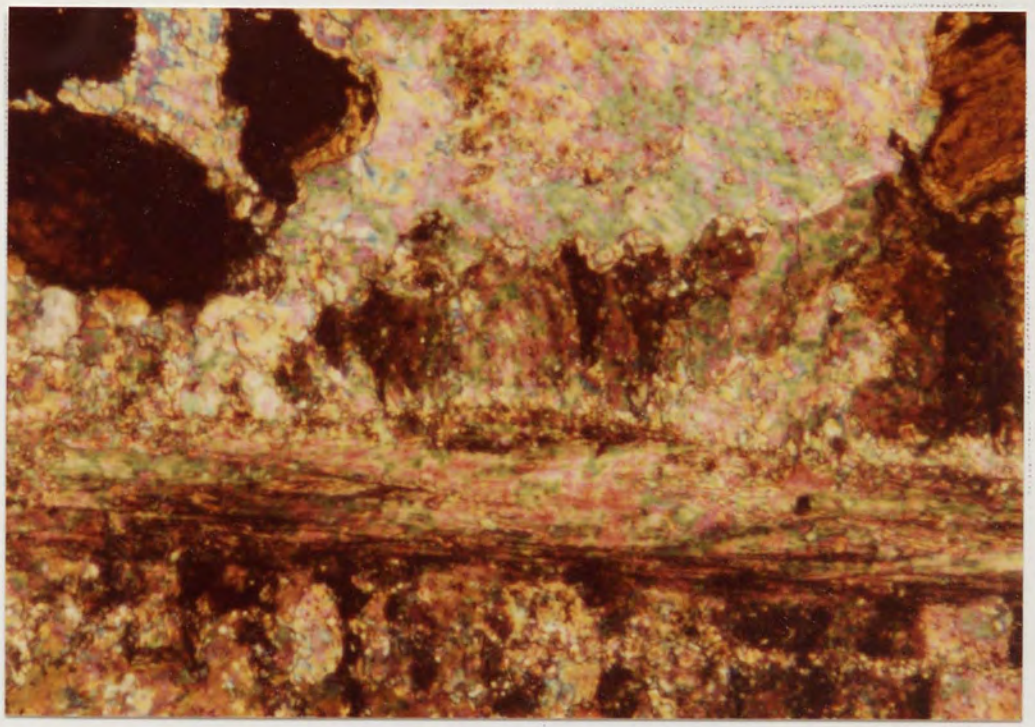


Plate 3.31a Non-ferroan calcite (pink) shell fragments are surrounded, apparently, by a single ferroan calcite (blue) grain with somewhat ragged edges. Stained section, PPL, x200.

Plate 3.31b As for Plate 3.31a. Between crossed polars the single ferroan calcite grain can be seen to be a replacement of an original radial-fibrous cement of either high-magnesian calcite or aragonite. XP, x200.



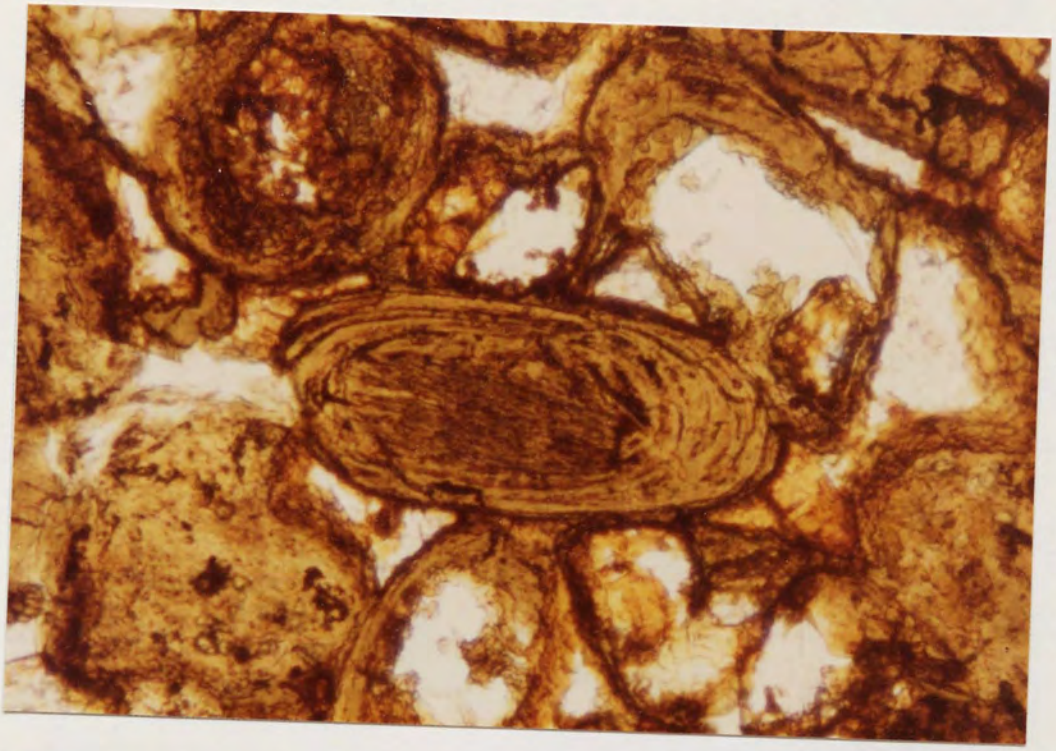


# CHAPTER 4

# THE CLEVELAND IRONSTONE FORMATION

Plate 4.1a Chamosite ooids have a uniform grass green colouration. Individual rings can be discerned by the presence of thin, black, bounding discontinuities. Stained section, PPL, x200.

Plate 4.1b As for Plate 4.1a. Between crossed polars ooids exhibit a pseudo-uniaxial extinction cross. XP, x200.



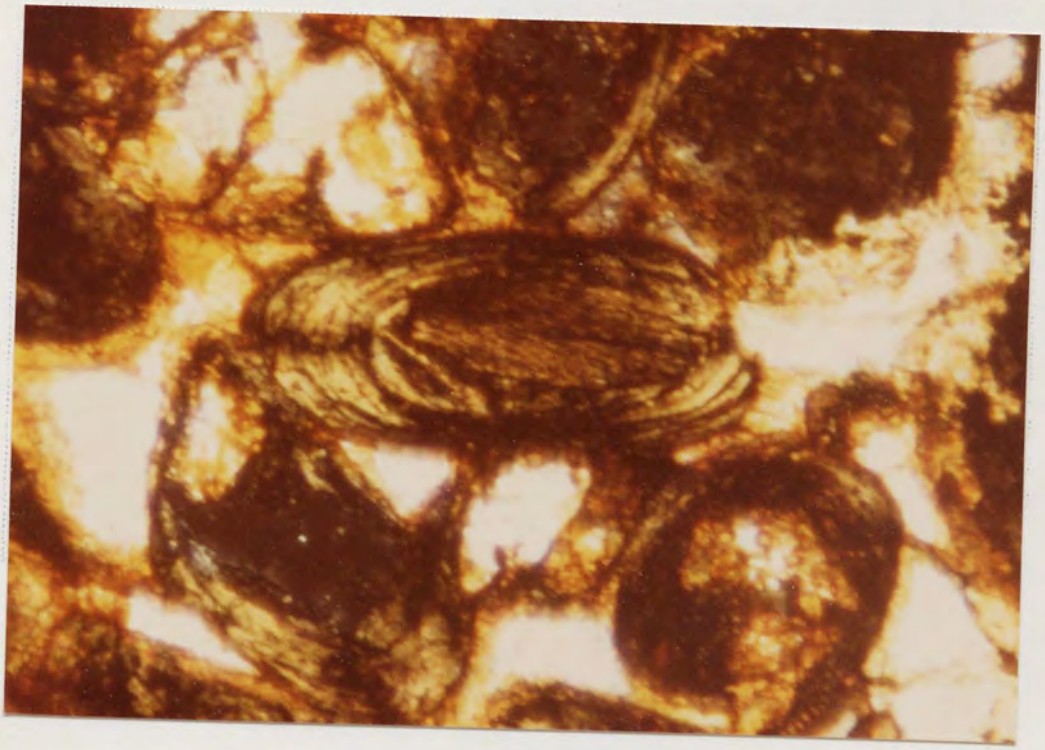
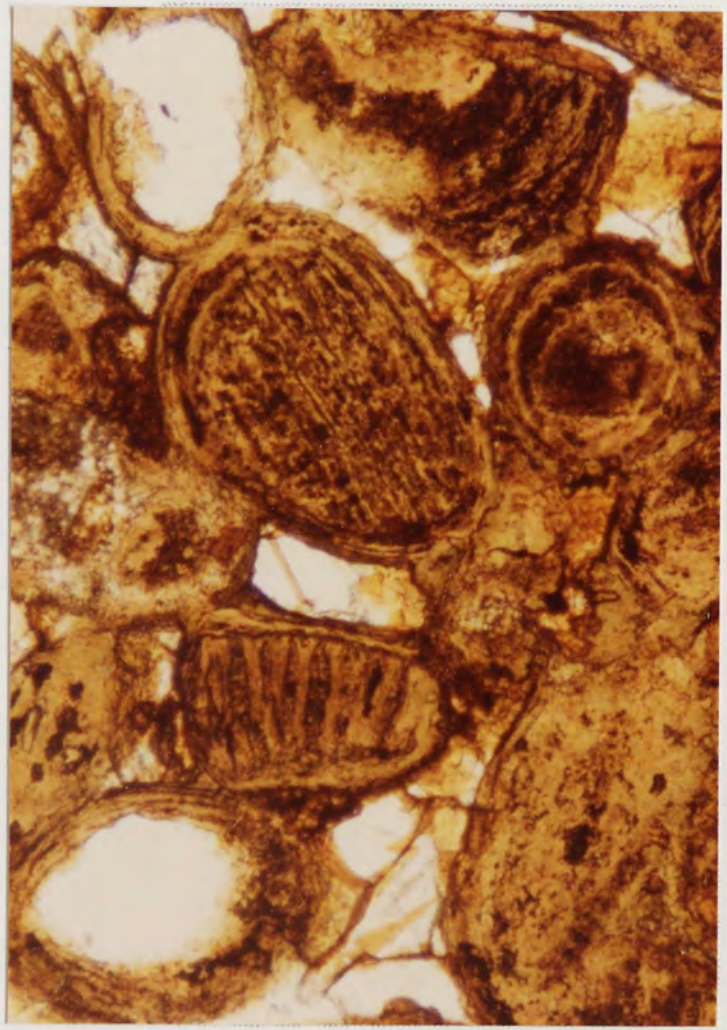


Plate 4.2 Black filamentous material is abundant in ooids and in many cases may totally obscure the core grain. Stained section, PPL, x200.

Plate 4.3 Core books are common in chamosite ooids. They are generall oriented with the (001) cleavage parallel to the ooid long axis. Occasional examples in which the (001) cleavage is perpendicular to the long axis are presnt. Black filamentou material is present along cleavage traces. Stained section, PPL, x160.



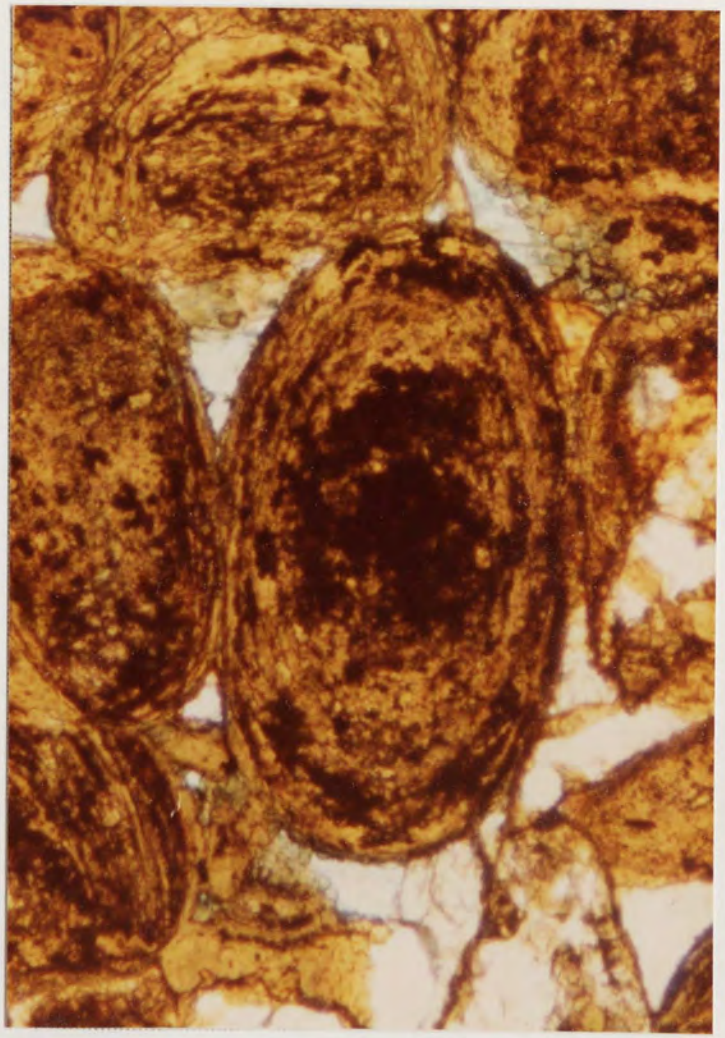
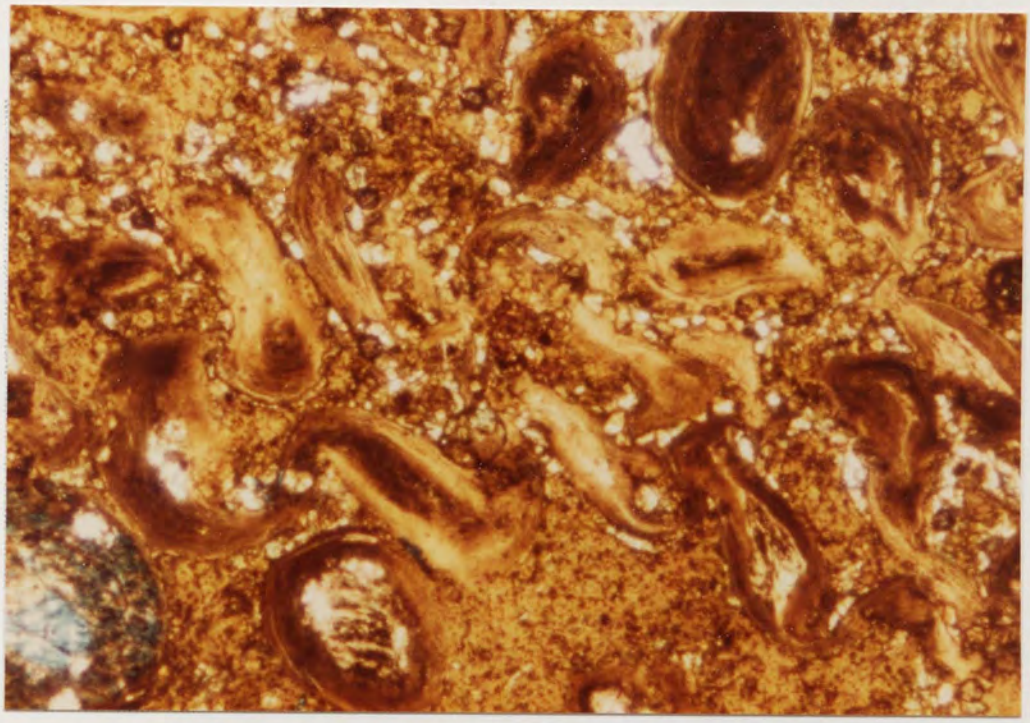


Plate 4.2 Chamositic chamosite oolite. Chain flame ooids resulting from ooimould collapse are common. Stained section, PPL, x50.

Plate 4.5 Spastoliths are often found in the chamositic chamosite oolite lithological type. They are large and irregular. Note the absence of any indication of pre-deformation ooimoulds. Stained section, PPL, x50.



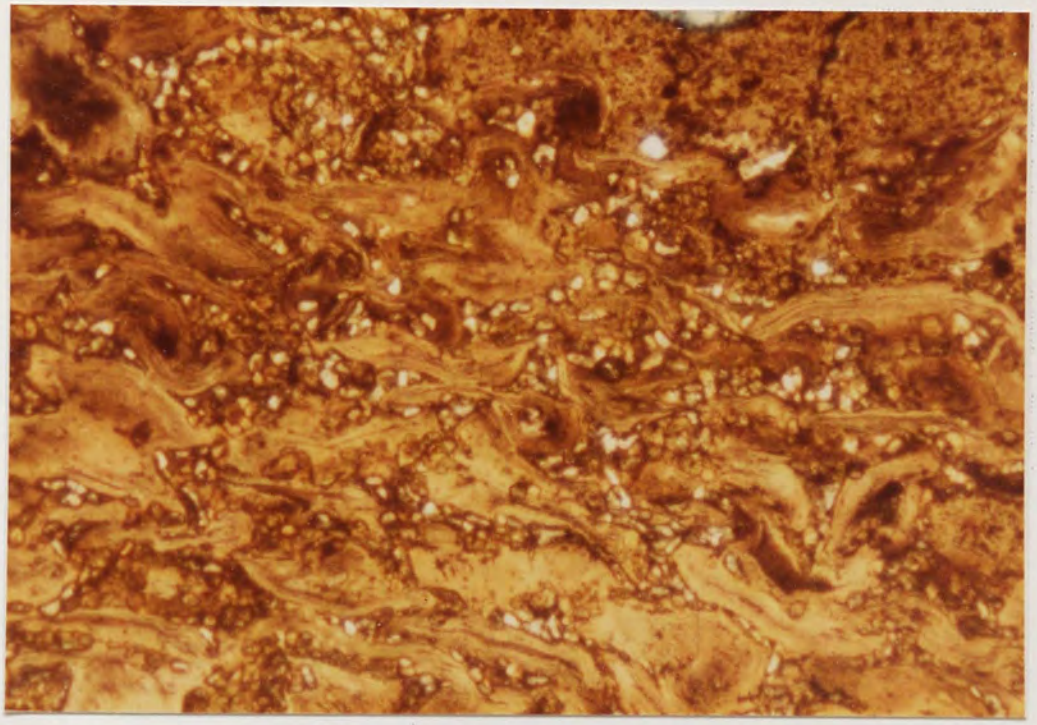
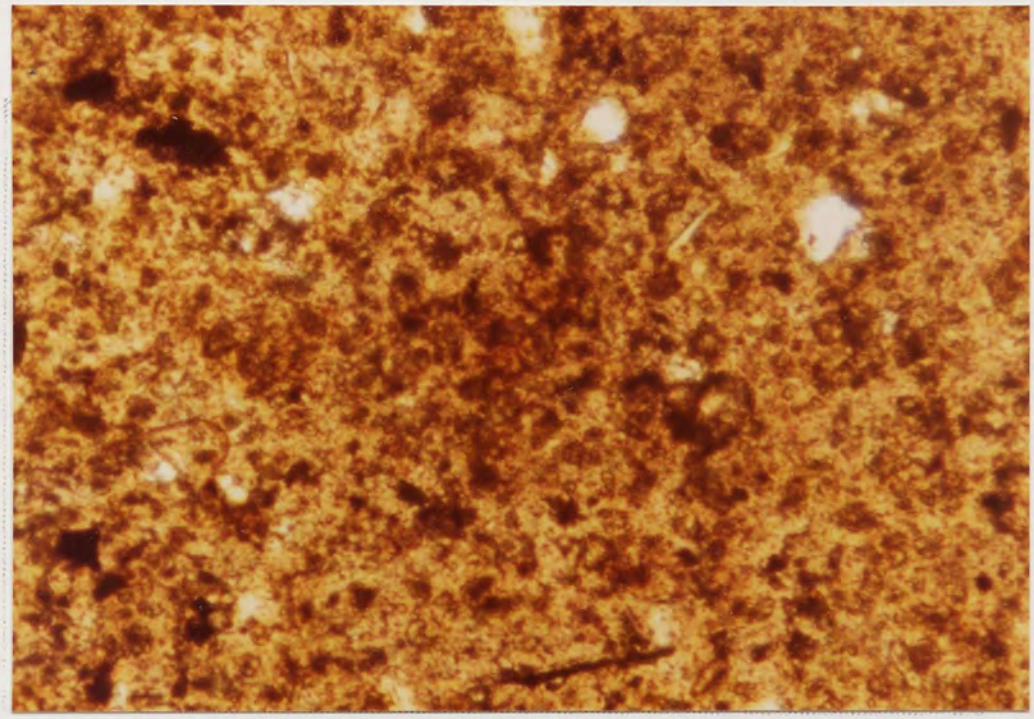


Plate 4.6a The chamosite mud lacks any indication of a depositional origin. It is characterised by the presence of many black filamentous and spot-like inclusions which may be surrounded by a small golden-brown siderite grain. These have relatively high relief. Stained section, PPL, x200.

Plate 4.6b As for Plate 4.6a. Between crossed polars the siderite grains show up as areas of high birefringence surrounding a small black inclusion. XP, x200.



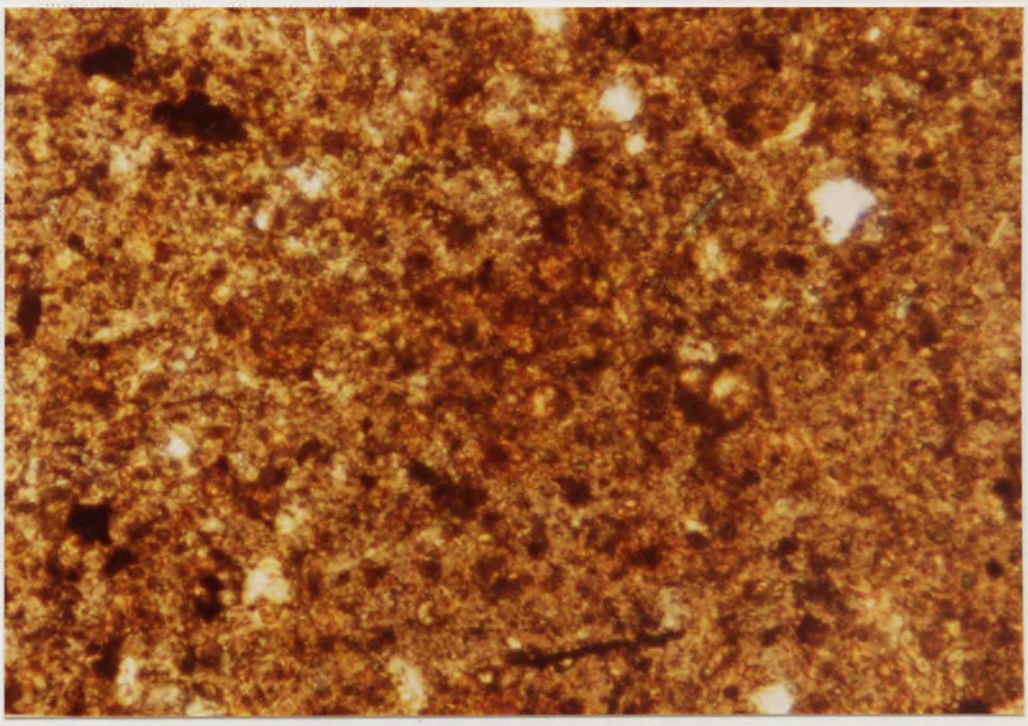
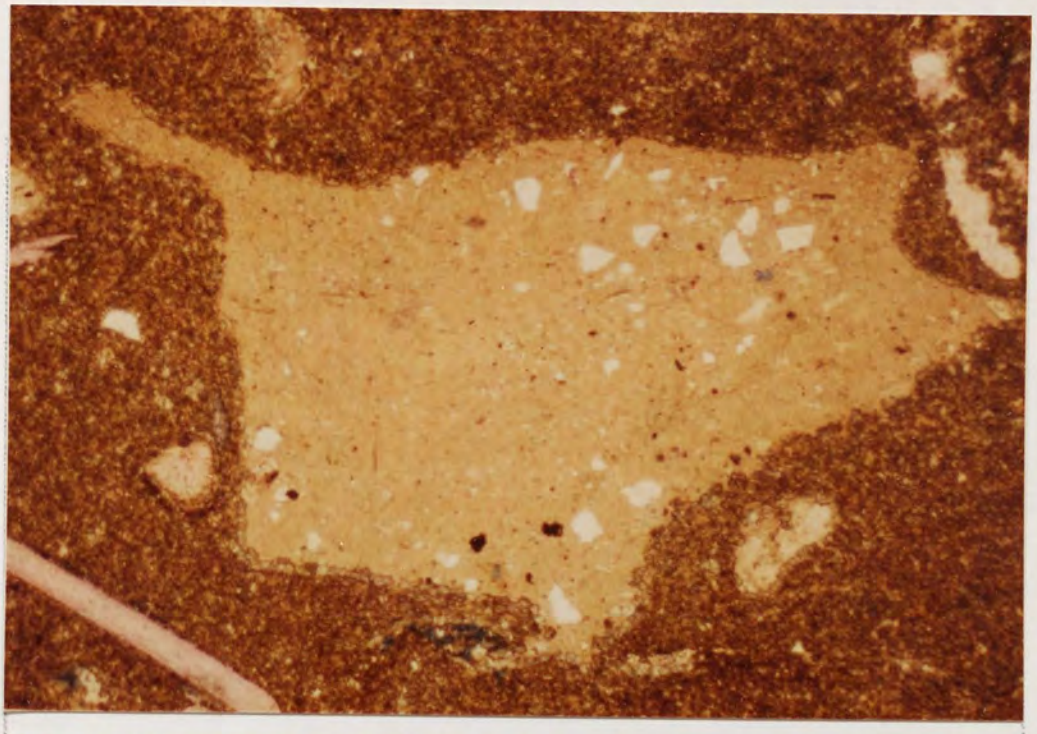
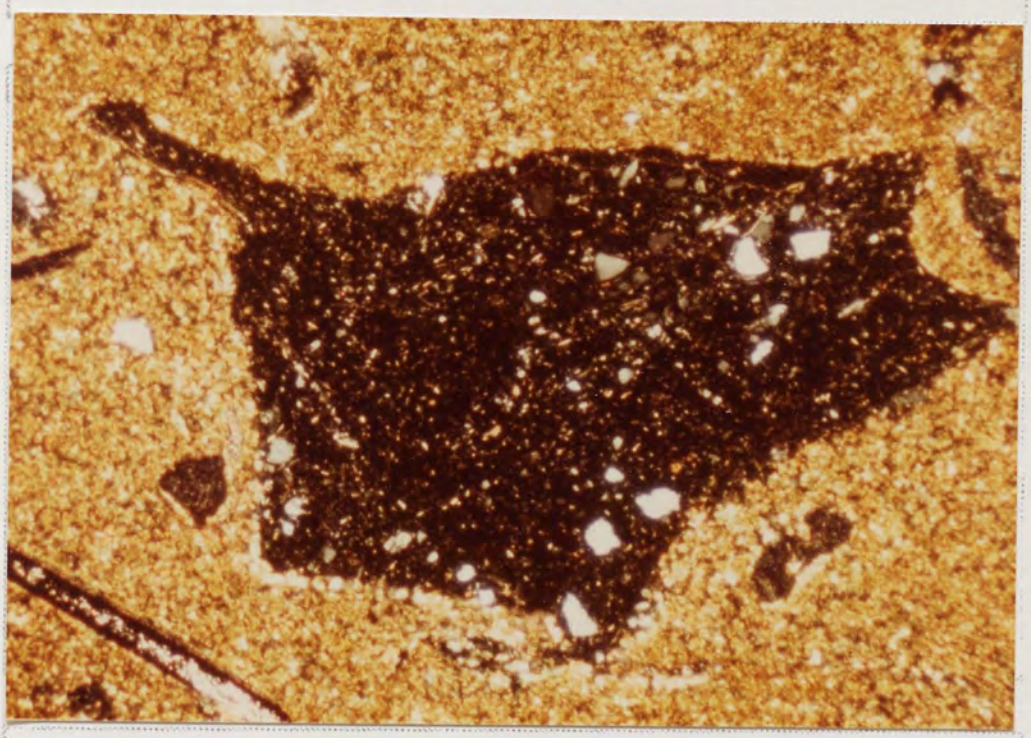


Plate 4.7a Angular lithic clasts of devitrified volcanic glass are a feature of some slides. They contain angular quartz grains (white, low relief). Not the similarity of these to those in the surrounding chamosite mud. The clast is surrounded by a rind of siderite grains. Stained section, PPL, x31.25.

Plate 4.7b As for Plate 4.7a. XP, x31.25.

Plate 4.8 Siderite trains of one anhedra thickness. Note the rind to the ferroan calcite ooid (top, right). Stained section, PPL, x160.





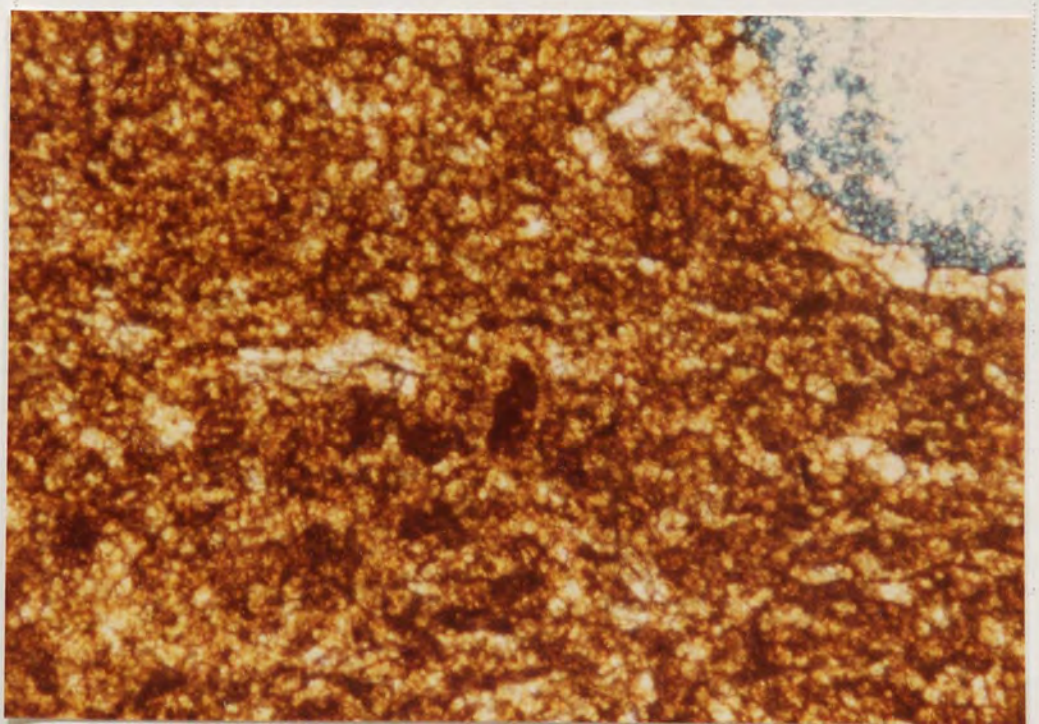
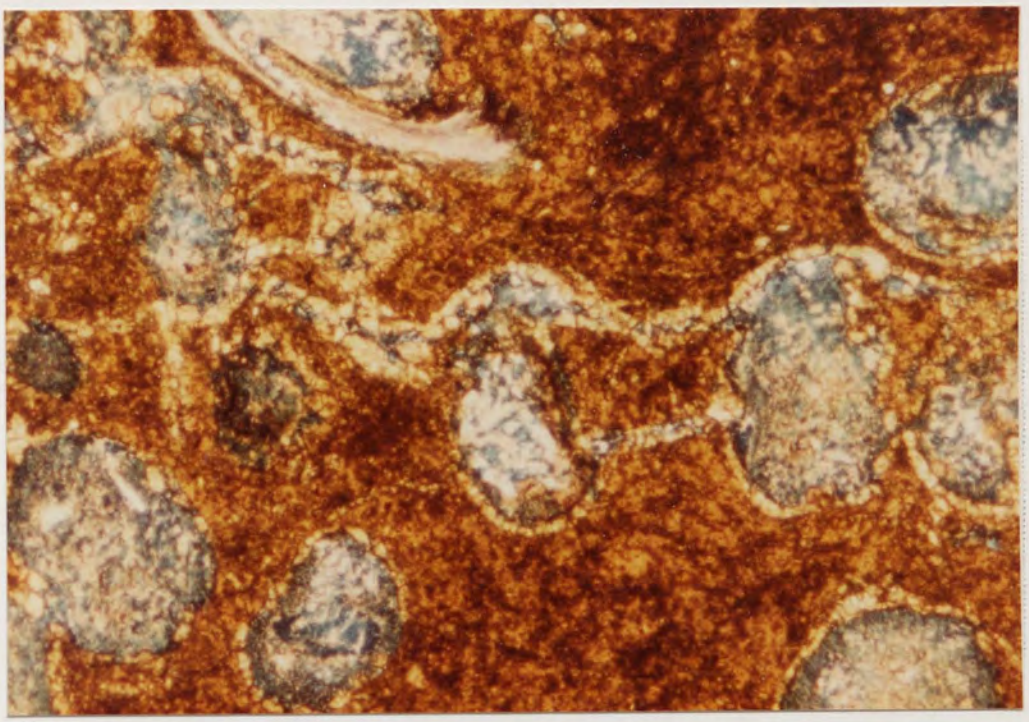


Plate 4.9 Ooids which have been replaced by ferroan calcite (blue) are surrounded by siderite rinds (cream) and connected by stylolites. These are lined by siderite rinds and infilled by ferroan calcite. Stained section, PPL, x50.

Plate 4.10 Ooimould and ferroan calcite infilled ooimould surrounded by siderite rinds. Stained section, PPL, x50.



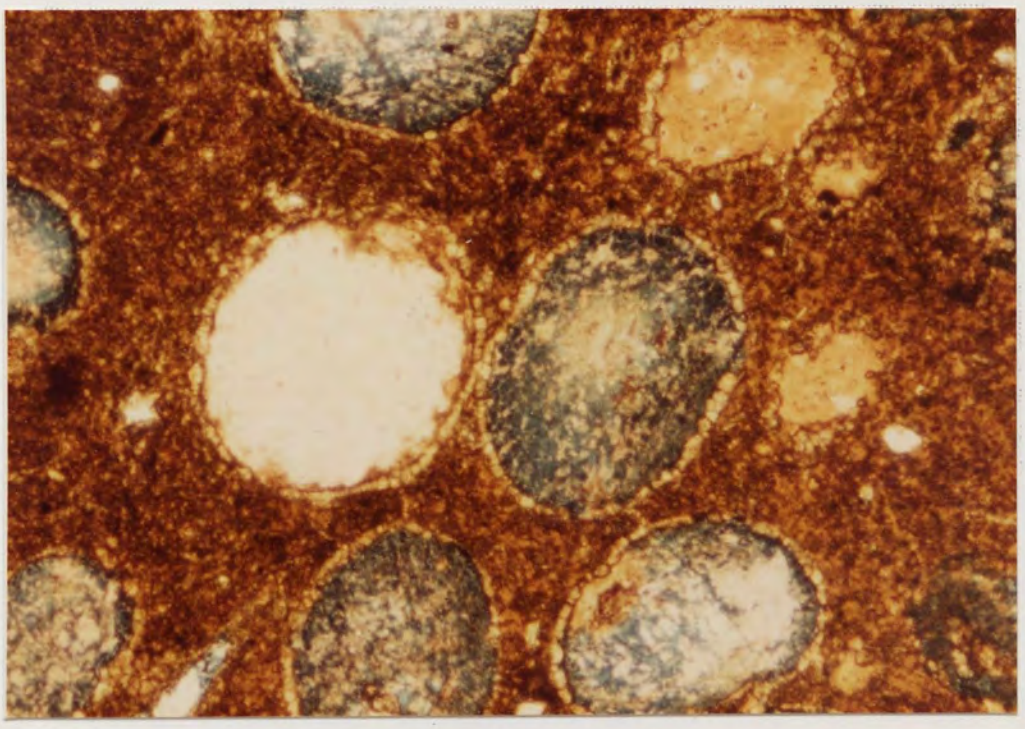
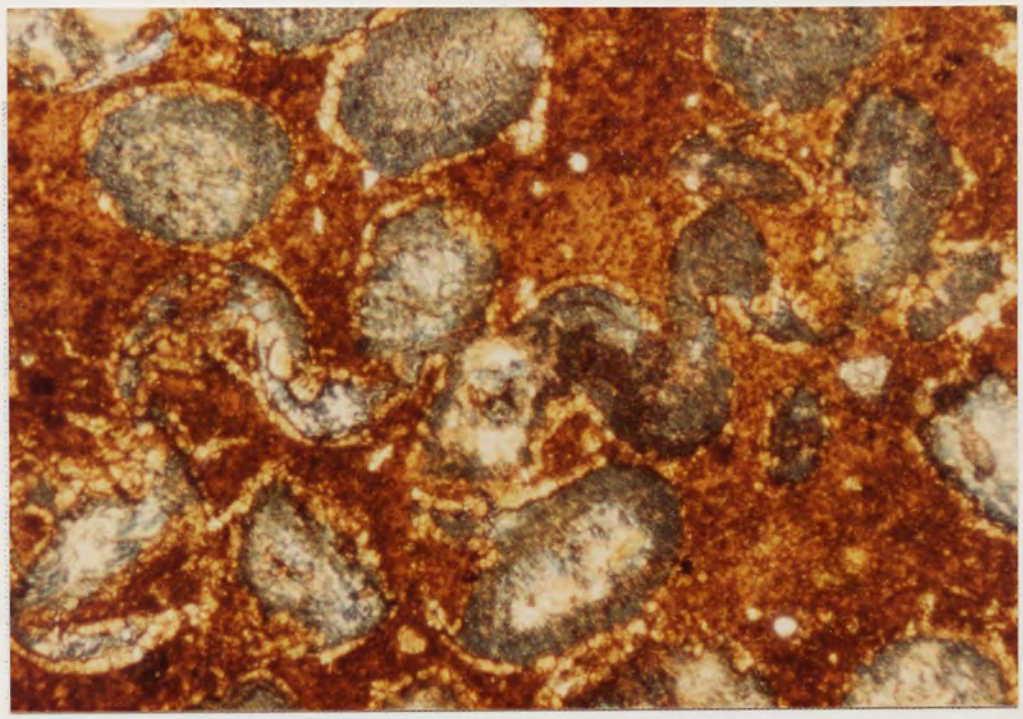


Plate 4.11 Original chain ooids of chamosite have been replaced by ferroan calcite and surrounded by a continuous siderite rind. Stained section, PPL, x50.

Plate 4.12 The replacement of chamosite ooids by ferroan calcite leaves remnants of core books lying within the calcite. Stained section, PPL, x160.



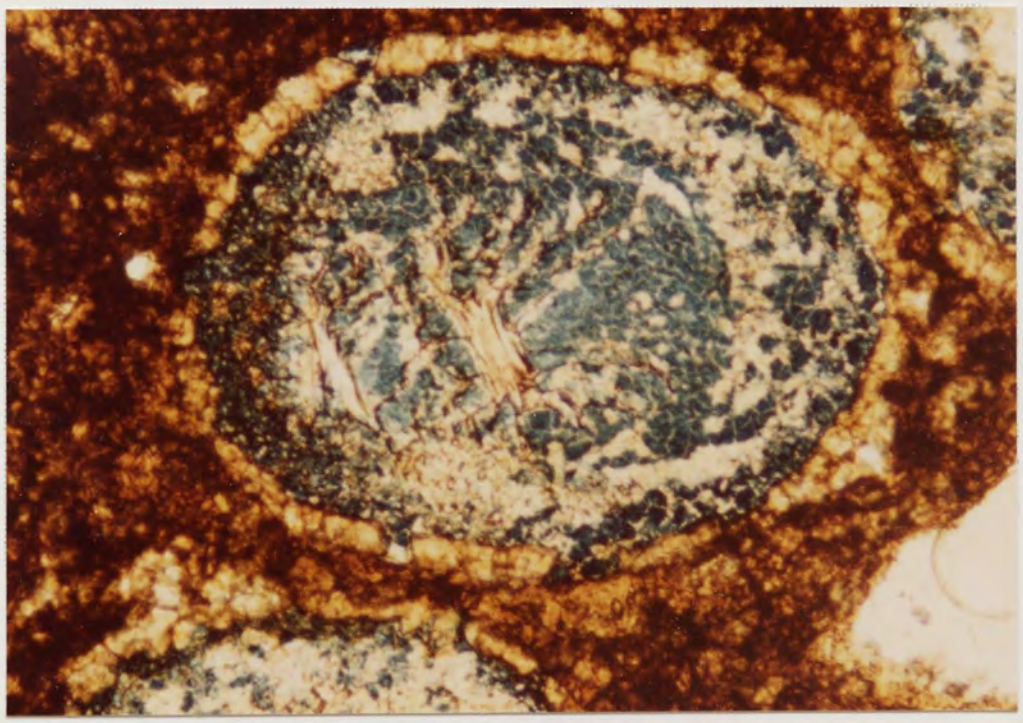
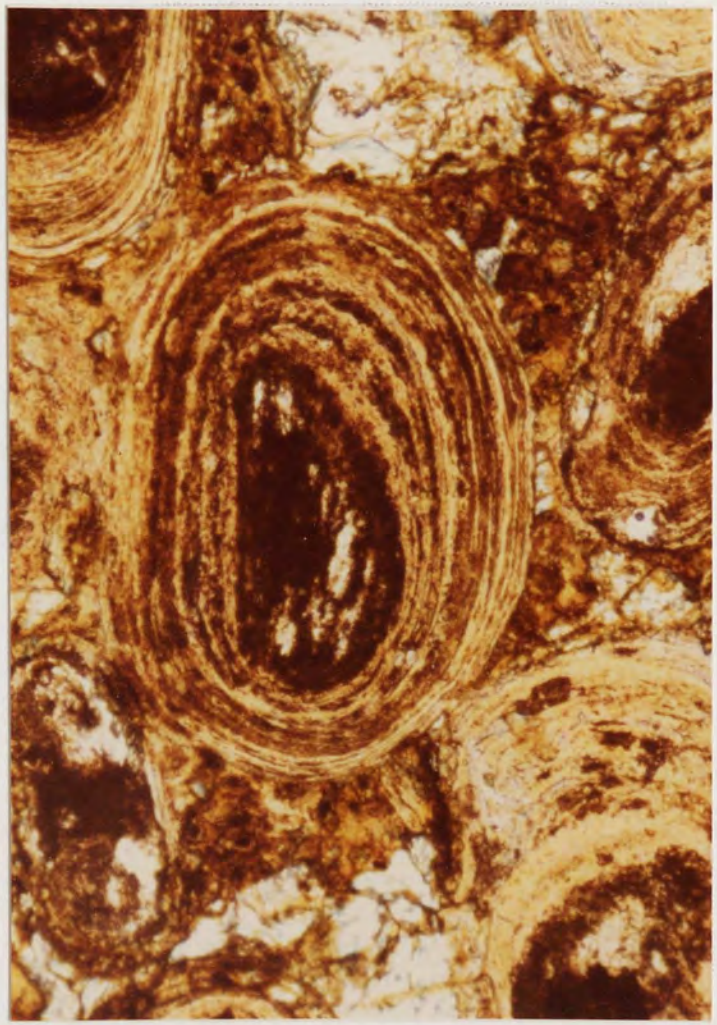


Plate 4.13 Sideritic chamosite oolite. Note the patches of remnant interstitial chamosite mud. Stained section, PPL, x31.25.

Plate 4.14 Ooids are yellowish green and contain an abundance of filamentous and band-form brown and black material. Stained section, PPL, x125.



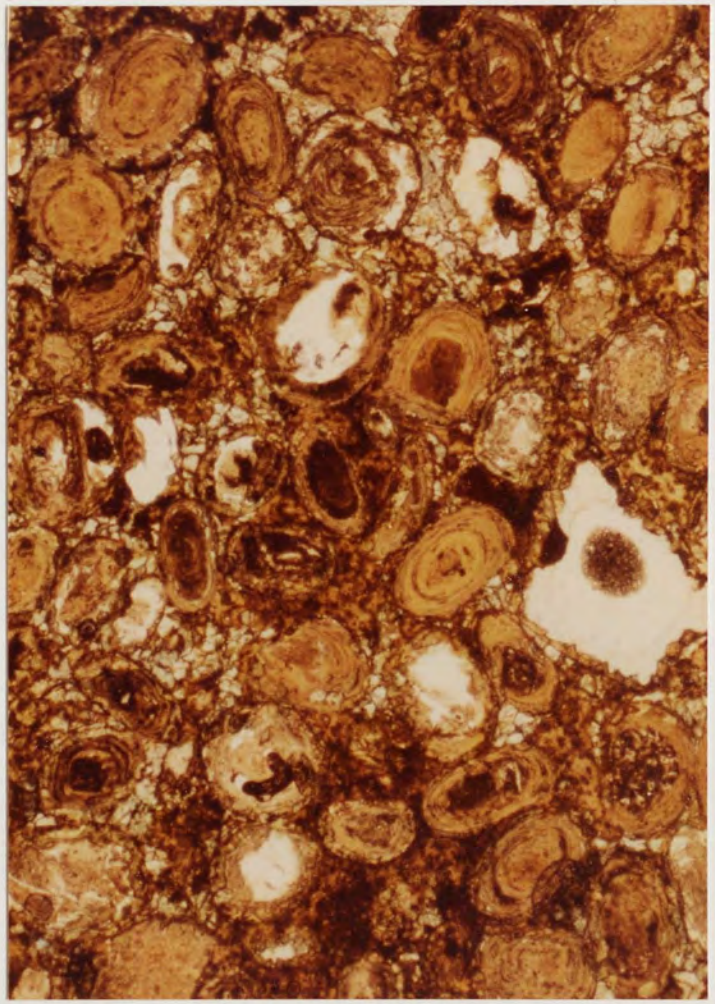
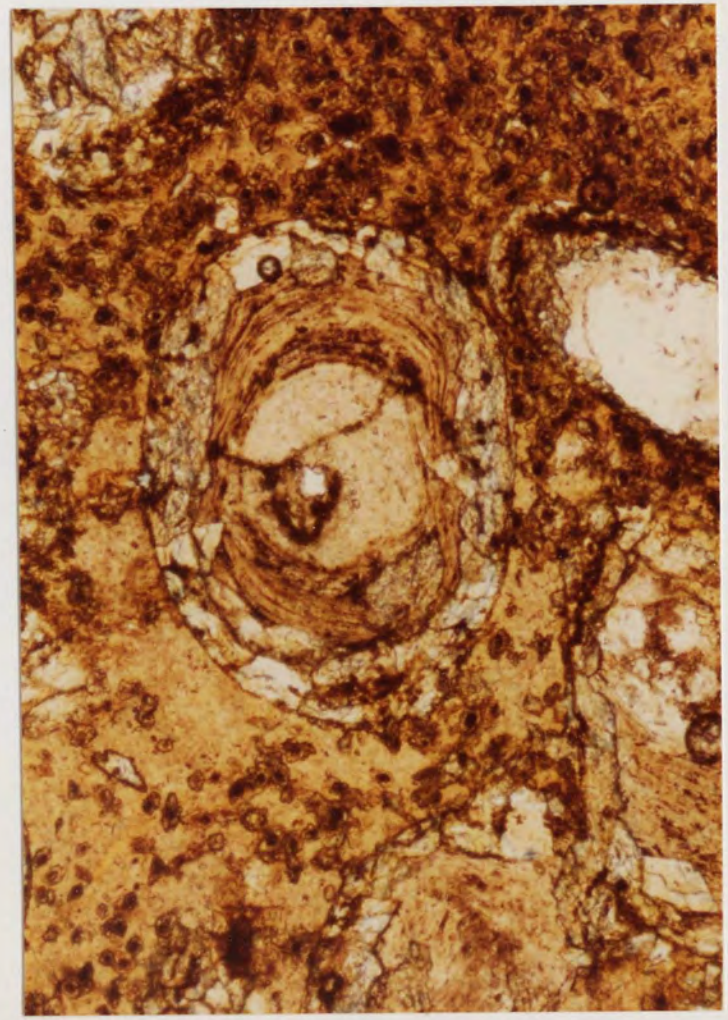


Plate 4.15a Ooid ring replacement by siderite. The ooid is surrounded by chamosite mud matrix. Note the retention of ghost ring contacts which in this case are black bands or rings. Stained section, PPL, x125.

Plate 4.15b As for Plate 4.15a, except that the replacing phase is ferroan dolomite. Stained section, PPL, x125.



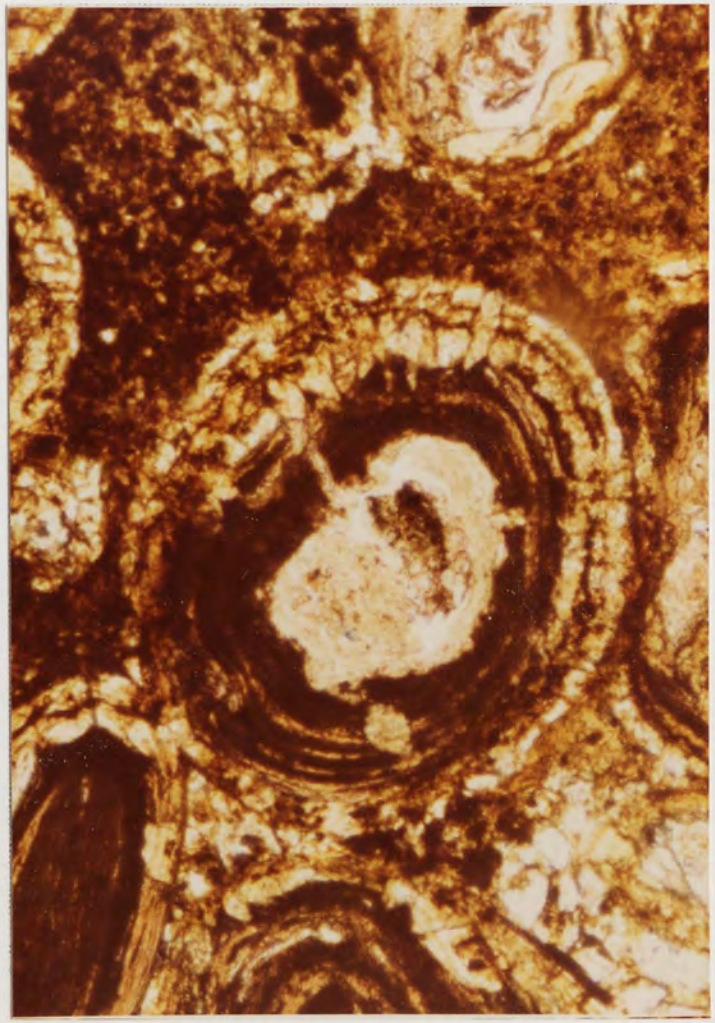
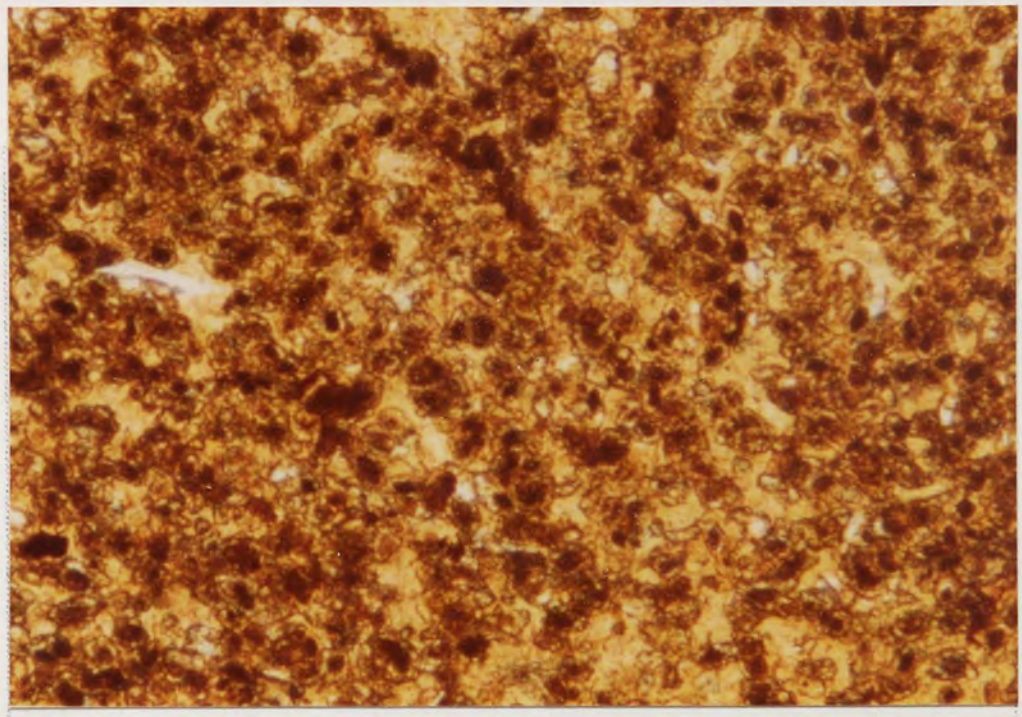
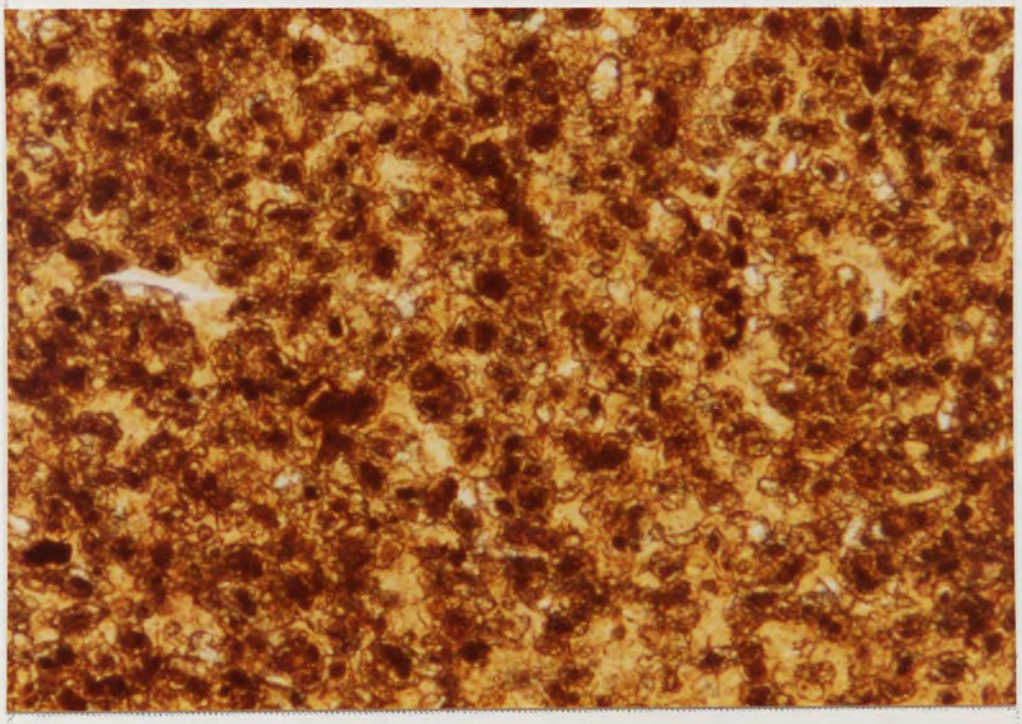


Plate 4.16a The chamosite mud matrix is characterised by abundant black inclusions set within siderite grains (golden-brown to cream). Stained section, PPl, x200.

Plate 4.16b As for Plate 4.16a. The siderite shows up as areas of high birefringence between crossed polars. XP. x200.

Plate 4.17 Ferroan dolomite cement to ooids. Stained section, PPL, x125.





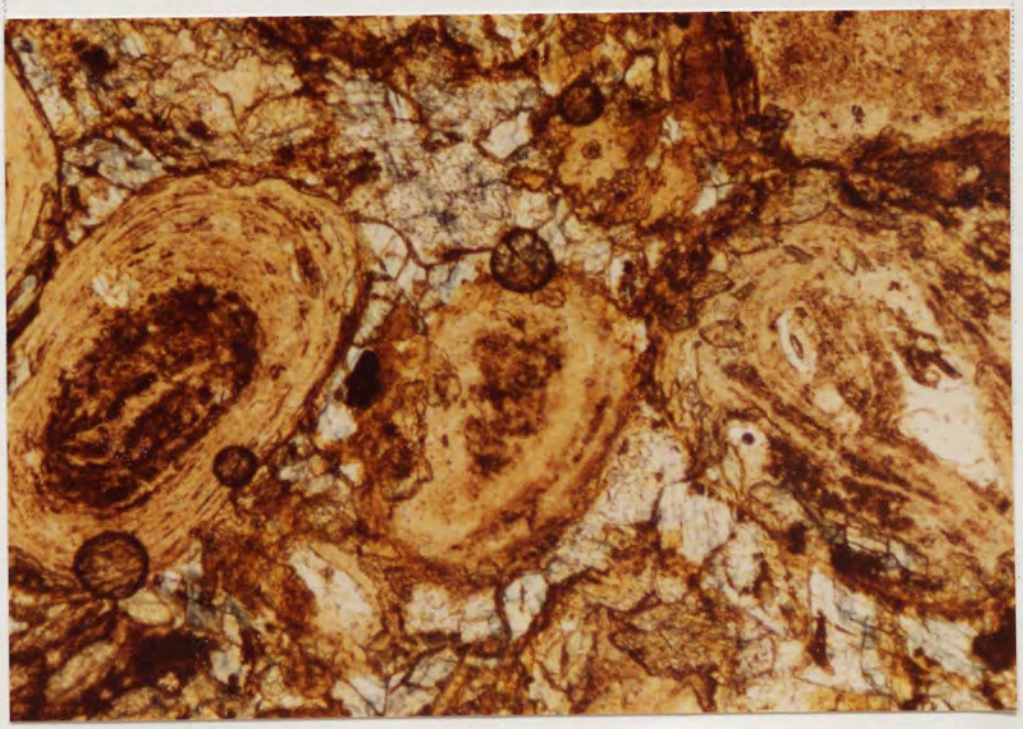
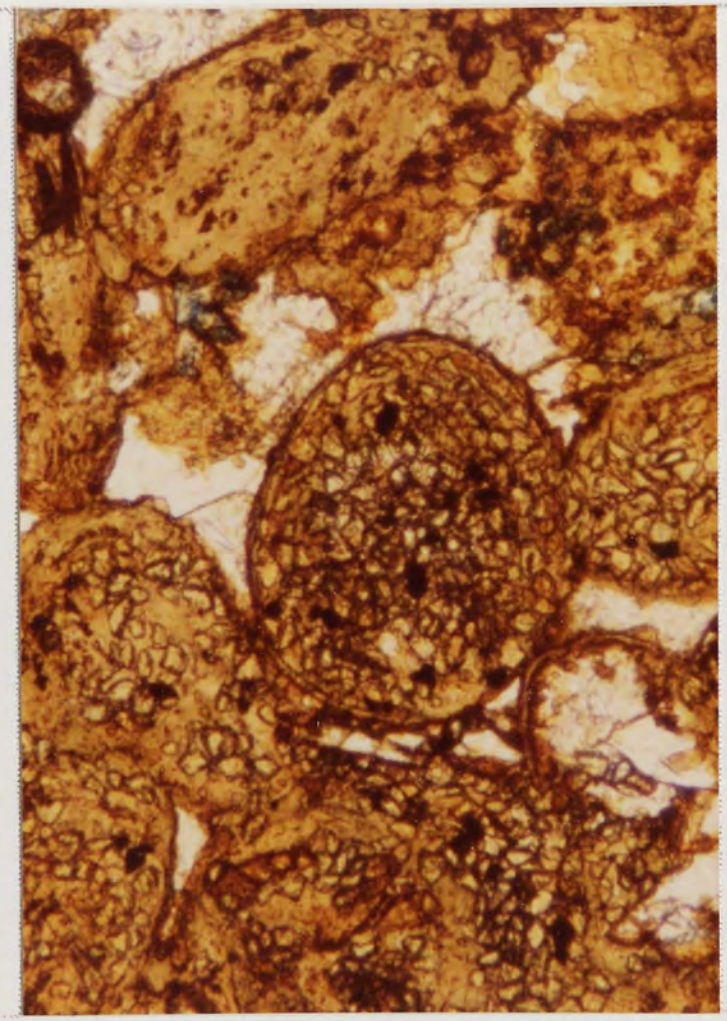


Plate 4.18 Calcitic sideritic chamosite oolite. Note the 'pressure-welded' nature of the ooid contacts. Stained section, PPL, x50.

Plate 4.19 Ooid replacement by greenish siderite anhedra. Stained section, PPL, x200.

Plate 4.20 Pore filling cement minerals. Stereome systems, brachiopod punctata, and bores in originally aragonite shell fragments are infilled by authigenic chamosite. Siderite (white) partially infills the porosity. Ferroan calcite (blue) infills the remaining pore space. Stained section, PPL, x125.



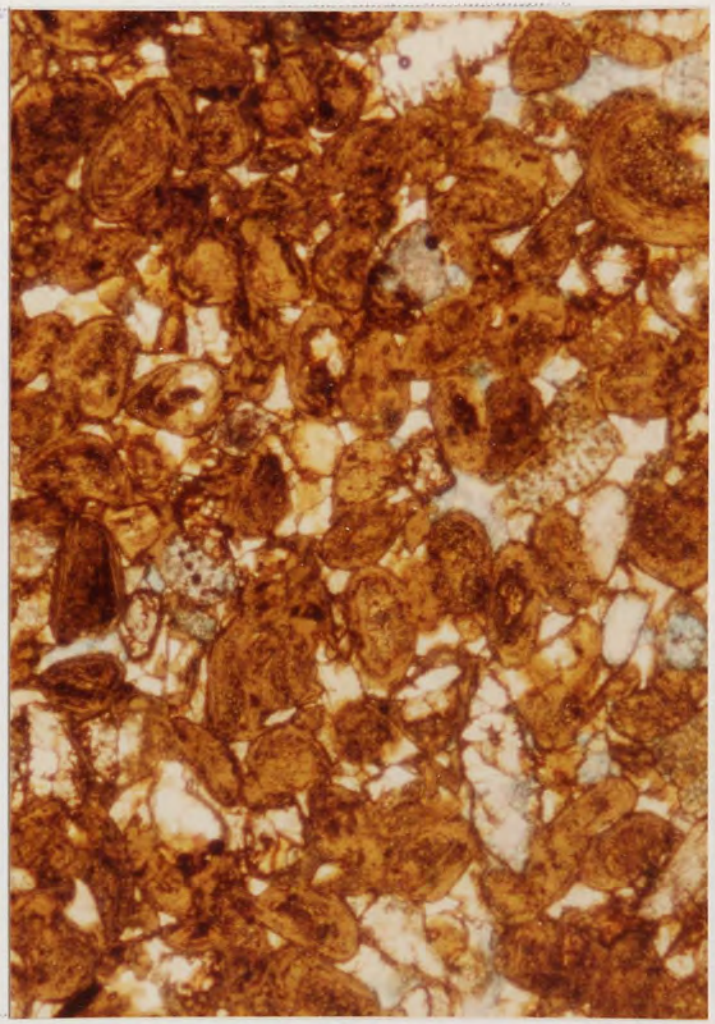
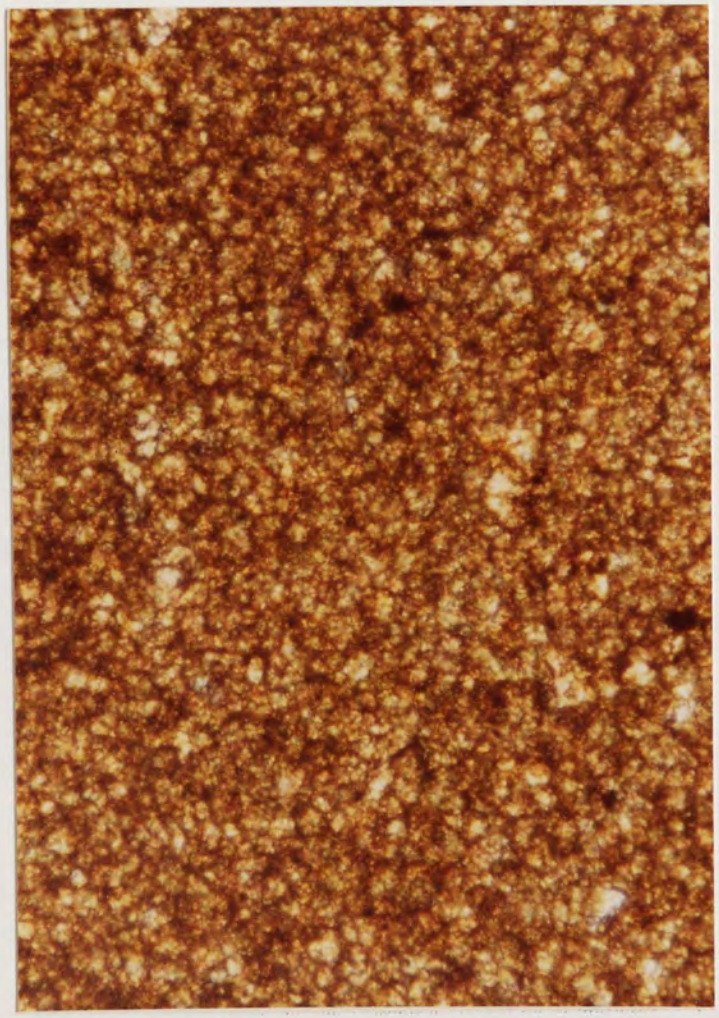
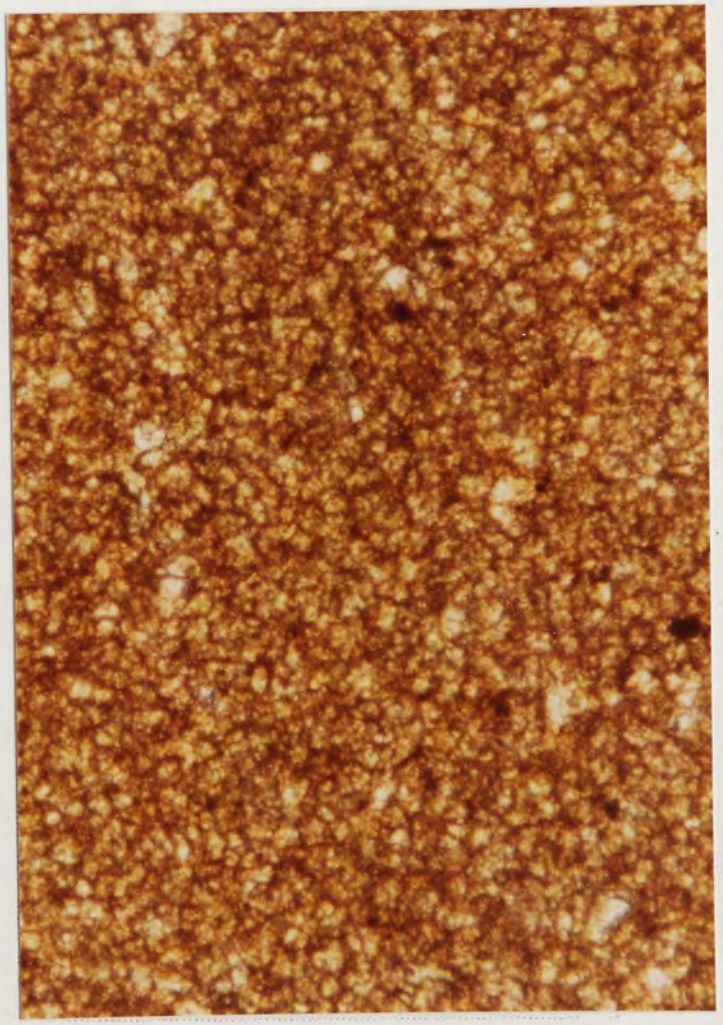


Plate 4.21a Equigranular xenotopic siderite forming siderite mudstone. Stained section, PPl, x160.

Plate 4.21b As for Plate 4.21a. XP, x160.



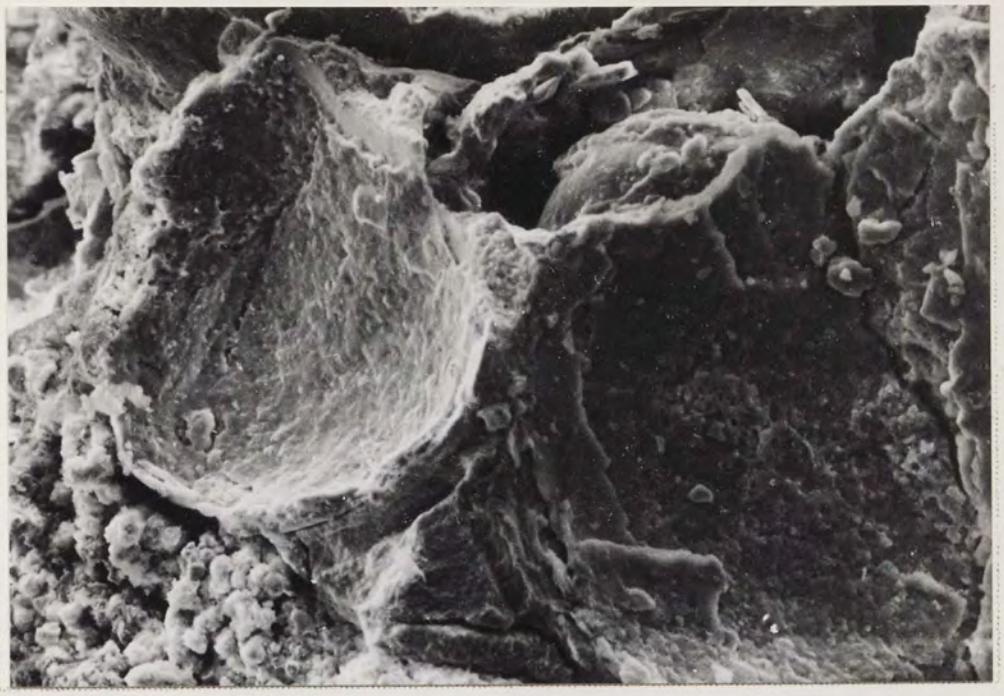


# CHAPTER 9

## THE SEDIMENTOLOGY OF THE LIASSIC IRONSTONES : CONCLUSIONS

Plate 9.1 Chamosite ooid with low surface relief. Pits are absent. Frodingham Ironstone (chamositic chamosite oolite).

Plate 9.2a Tubules of 7 μm length and 2 μm diameter. Kevex showed these to be constructed of chamosite. Marlstone Rock-bed (chamosite ooid from a burrow infill).



100 μm

10 μm

4 μm

Plate 9.2b Similar tubular structures are found on chamosite ooids from the Frodingham Ironstone (chamositic chamosite oolite).

100 μm

20 μm

Plate 9.3 Cross-sections of ooid rings show the presence of high porosity zones at ring contacts and lower porosity zones corresponding to the actual rings. Frodingham Ironstone (chamositic chamosite oolite, top) and Cleveland Ironstone (chamositic chamosite oolite, bottom two).

10 μm

20 μm

20 μm

Plate 9.4 The tubular structures have a tangential orientation with respect to the ooid. Marlstone Rock-bed (chamosite ooid from a burrow infill).

20 μm

20 μm

Plate 9.5a The majority of rough ooid surfaces have a lower relief than those seen in Plates 9.2a and b, and are heavily pitted. These correspond to smaller tubular structrues which are set in a fine-grained matrix. Frodingham Ironstone (chamositic chamosite oolite). The large tubule is an artefact.

Plate 9.5b The matrix to the smaller tubules is found to consist of many small platelets of chamosite with an orientation of the basal plane tangential to the ooid. These are mixed with even smaller tubular structures.

20 μm

4 μm

4 μm

Plate 9.6 Goethite ooids. Frodingham Ironstone (calcitic limonite oolite).

200 μm

100 μm