20 January, 2003

Esso Australia Pty Ltd
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SOUTHBANK VIC 3006

Attention: Georgina Vlassco

FINAL REPORT: 0455-01 – REMORA-1

CLIENT REFERENCE: Service Order Contract 382048

MATERIAL: Five sidewall core samples, two cuttings samples

LOCALITY: Remora-1

WORK REQUIRED: Petrology

Please direct technical enquiries regarding this work to the signatory below under whose supervision the work was carried out.

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General Manager

PETROLOGY

of

REMORA-1

for

ESSO AUSTRALIA PTY LTD

by

ACS LABORATORIES PTY LTD

PETROLOGY

of

REMORA-1 SAMPLES

A report prepared for

ESSO AUSTRALIA PTY LTD

by

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January 2003

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C O N T E N T S

1. INTRODUCTION

A petrological study was carried out on five sidewall core samples and two cuttings samples from 2284-2954m in Remora-1, Gippsland Basin. Prime aims of the study were to describe the petrology and reservoir quality of the sandstones and to determine whether samples include volcanics. Sample depths are listed in Table 1.

2. ANALYTICAL PROGRAM

Thin-sections were cut in kerosene, impregnated with blue-dyed epoxy resin to aid porosity recognition and stained with sodium cobaltinitrite to aid feldspar identification. Each cuttings thin-section includes at least 150 cuttings. Mineral composition and visible porosity of the sidewall core samples were determined by a count of 400 points, and mean grain size and sorting of the sandstones were estimated in thin-section with the aid of an eyepiece graticule. A brief point count (200 points) was carried out on several sandstone cuttings from 2695-2700m. Sandstone cuttings from 2700-2705m are too small and are insufficiently common for point counting. Photomicrographs were taken to illustrate features such as lithology, texture, composition, diagenetic effects and porosity.

3. THIN-SECTION DESCRIPTIONS

Thin-section analyses are given in Table 1, QFR ratios are plotted in Figure 1, and annotated photomicrographs are presented in Appendix 1. Samples are described individually.

SWC #43 2284m — Plate 1

Sample is a partly crushed, moderately-well or well sorted, lower medium grained sublitharenite ($Q_{83}F_1R_{16}$) in which framework grains are mainly quartz and metamorphic rock fragments. Quartz is mostly subangular to rounded and monocrystalline. Metamorphic rock fragments are low-grade metasediments (illitic meta-argillite, micaceous schist, mica-bearing quartzite) that are commonly compactionally deformed to form pseudomatrix. Other framework grains include K-feldspar (fresh to slightly altered orthoclase), chert, muscovite, biotite and accessory heavy minerals (tourmaline, bitumen-rimmed monazite).

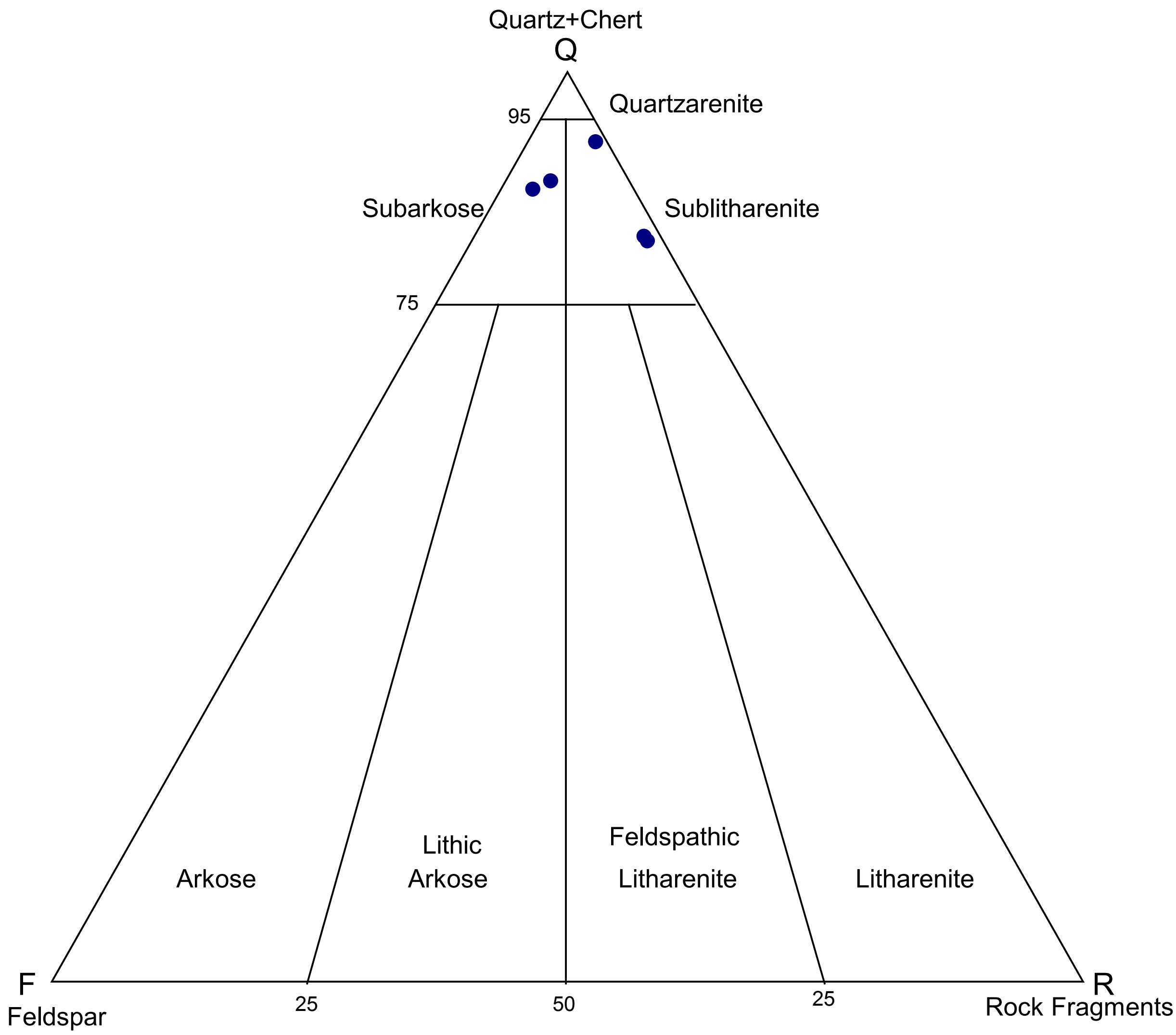
Clay is mainly illitic pseudomatrix that has formed by compactional deformation and alteration of micaceous/illitic metamorphic rock fragments and mica. Biotite grains have locally altered to kaolinite.

The sand is partly cemented by dolomite, which forms scattered, poikilotopic patches up to 2mm long. Quartz grains are enveloped by thin quartz overgrowths where adjacent pores are not filled by dolomite or compacted ductile grains.

TABLE 1. THIN-SECTION ANALYSES

SWC #	43	25	23	-	20	2
Depth (m)	2284	2622	2651	2695-2700	2738	2954
Quartz (monocrystalline)	64.1	77.9	68.0	44.5	75.4	7.0
Quartz (polycrystalline)	2.6	6.6	4.8	3.5	3.0	0.7
Quartz overgrowths	0.9	2.2	1.1	-	0.7	-
Chert	0.3	0.7	0.6	0.5	-	0.3
K-feldspar	0.9	0.7	1.1	3.9	8.4	0.6
Plagioclase	-	-	-	-	-	-
Volcanic rock fragments	0.3	0.7	1.1	-	-	-
Metamorphic rock fragments	13.4	4.8	12.3	2.1	2.3	3.3
Sedimentary rock fragments	-	0.3	1.0	-	-	0.3
Mica	2.0	0.3	-	-	-	0.6
Heavy minerals	-	-	-	-	-	-
Organics	-	-	0.3	-	-	9.9
Pyrite	-	0.7	-	-	-	-
Dolomite	7.9	-	4.5	45.5	8.7	-
Siderite	-	-	-	-	-	34.7
Authigenic clay/pseudomatrix	4.5	1.7	3.1	-	0.3	-
Detrital clay	-	-	-	-	-	42.6
Visible primary porosity	2.8	3.1	1.8	-	0.9	-
Visible secondary porosity	0.3	0.3	0.3	-	0.3	-
Q (quartz + chert)	82.3	93.2	82.8	88.9	88.0	-
F (feldspar)	1.1	0.7	1.2	7.2	9.4	-
R (rock fragments)	16.6	6.1	16.0	3.9	2.6	-
Mean grain size (mm)	0.26	0.79	0.53	-	0.63	-
Mean grain size (class)	medium	coarse	coarse	-	coarse	-
Sorting class	mod-well	mod	mod	-	mod	-

FIGURE 1. QFR COMPOSITIONS



Fine pyrite euhedra are locally associated with altered micaceous grains, and there are small (<1mm), widely scattered patches of pyrite cement.

Significant intergranular porosity reduction is the result of dolomite cementation, ductile grain compaction to form common pseudomatrix, and grain contact dissolution to form long, embayed and sutured/microstylolitic contacts between quartz grains. Microstylolitic grain contacts occur where grain contact dissolution was promoted by illitic clay films that are the altered remnants of compactionally deformed and dispersed micaceous grains.

Visible porosity could not be reliably measured due to the effects of severe impact damage. However, it is clear that large amounts of intergranular porosity have been eliminated by physical compaction, grain contact dissolution and dolomite cementation. Accordingly, it is likely that the measured visible porosity value of 3.1% is a fair indication that the sample contained only minor visible porosity prior to sidewall coring.

Visible porosity is accounted for by primary intergranular pores and subordinate secondary pores that occur where feldspar and labile rock fragments have dissolved. With many intergranular spaces being completely filled by compacted ductile grains, clay and dolomite, macropores are erratically distributed and thus would have limited connectivity. Accordingly, permeability would be low to fair.

SWC #25 2622m — Plates 2 & 3

Sample is a severely impact-damaged, moderately sorted, coarse grained sublitharenite ($Q_{90}F_1R_9$) in which framework grains are mainly quartz and also include K-feldspar, low-grade metasedimentary rock fragments (illitic meta-argillite, mica schist, mica-bearing quartzite), argillaceous sedimentary rock fragments and cherty volcanic rock fragments. Intact quartz grains are mostly subrounded to rounded.

Clay is mainly illitic pseudomatrix that has formed by compactional deformation and dispersion of micaceous/argillaceous metasedimentary rock fragments and argillaceous sedimentary rock fragments. Mica has locally altered to kaolinite.

Quartz grains are commonly thinly enveloped by quartz overgrowths, and there are widely scattered patches of coarsely-crystalline, pore-filling pyrite cement. Dolomite cement is absent.

Significant porosity reduction is the result of grain contact dissolution to form long, embayed and sutured grain contacts, ductile grain deformation to form localised pseudomatrix, and minor quartz overgrowth cementation.

Most of the sample consists of totally crushed and pulverised sandstone fragments and loose grains and grain fragments. Accordingly, visible porosity could not be reliably measured. Within the few small areas where original texture is preserved, small primary intergranular pores are locally preserved between juxtaposed quartz grains, and scattered secondary pores have formed by labile grain dissolution. Based on the coarse grain size and the likely presence of minor (?3-4%) macroporosity, permeability may be fair.

SWC #23 2651m Plates 4 & 5

Sample is a partly impact-damaged, moderately sorted, lower coarse grained sublitharenite ($Q_{83}F_1R_{16}$) in which framework grain types are the same as those in the previous samples. As at 2284m (SWC #43), micaceous/illitic metasedimentary rock fragments are common, and the sand also includes coarse organic fragments and a 2.2mm-long microcrystalline quartz granule of possible volcanic origin. Quartz is mainly subangular to subrounded and monocrystalline.

As in the previous samples, clay is mainly illitic pseudomatrix that has formed by compactional deformation of micaceous/argillaceous grains.

The sand is partly cemented by dolomite, which forms widely scattered, poikilotopic patches up to 3mm long. Quartz grains are enveloped by thin quartz overgrowths where adjacent pores are not filled by dolomite or compacted ductile grains.

Intergranular porosity has been largely eliminated by grain contact dissolution to form long, embayed and sutured/microstylolitic grain contacts, ductile grain deformation (locally to form pseudomatrix), patchy dolomite cementation and localised quartz overgrowth cementation.

Much of the sample is intact, hence original porosity characteristics are clear. Visible porosity is low (2.1%), with intergranular porosity between most grains having been eliminated by physical compaction, grain contact dissolution and dolomite/quartz overgrowth cementation. Primary intergranular pores, which account for most visible porosity, are erratically distributed and thus would have limited connectivity. Scattered secondary pores are the result of labile grain dissolution and possibly very minor dolomite dissolution. Permeability would be low.

2695-2700m (cuttings) Plates 6 & 7

Cuttings are mainly coarse/very coarse sand-sized quartz grains, dolomite-cemented sandstones, altered intermediate volcanics, mudrocks and argillaceous/carbonaceous siltstones and also include pyrite-cemented sandstones, non-dolomite cemented sandstones (similar to the previously-described sandstones), argillaceous sandstones, foraminiferal marls and organic fragments. Only the dolomite-cemented sandstones and volcanics are described below.

Dolomite-cemented sandstones are cement/grain-supported subarkoses and sublitharenites ($Q_{89}F_7R_4$ mean) that range from being well sorted and medium grained to poorly sorted and very coarse grained. Framework grains are mainly quartz, K-feldspar (fresh to slightly altered orthoclase) and low-grade micaceous/quartzose metasedimentary rock fragments and also include cherty felsic volcanic rock fragments and muscovite. Rare patches of kaolinite occur where labile grains have altered. Dolomite forms a pervasive, coarsely-crystalline/poikilotopic cement that tightly fills intergranular spaces and partly replaces some micaceous rock fragments and feldspar grains. Dolomite-cemented framework grains are generally loosely packed, but the dolomite formed at depth rather than near the depositional surface because it encapsulates compacted micaceous rock fragments as well as quartz grains that locally have long and slightly embayed grain contacts that are the result of minor grain contact dissolution. Rare secondary intragranular porosity is associated with slightly dissolved K-feldspar grains. Primary intergranular porosity is absent.

Non-dolomite-cemented sandstone cuttings lack intergranular porosity due to physical compaction, grain contact dissolution, authigenic clay formation and localised quartz overgrowth cementation.

Altered intermediate volcanics (?trachyte) account for about 20% of cuttings and consist largely of intergrown, pilotaxitically-arranged feldspar microlites up to 0.4mm long that, in most volcanic cuttings, have almost totally altered to microcrystalline kaolinite. Interstitial areas are occupied by altered mesostasis and fine opaques. Some volcanic cuttings are partly replaced by carbonate and pyrite.

<u>2700-2705m (cuttings)</u> Plate 8

Cuttings are mainly argillaceous lithologies (mudrocks, foraminiferal marls, argillaceous siltstones, argillaceous/glauconitic sandstones) and also include pyrite-cemented sandstones and dolomite-cemented sandstones (similar to those in the previous sample). Volcanics are absent.

The only sandstone cutting to lack cement and detrital clay is a well compacted, well sorted, medium grained sublitharenite in which all intergranular spaces are filled by authigenic clay (kaolinite, illite) pseudomatrix that has formed by compaction and alteration of micaceous grains (mainly biotite). The sandstone is totally microporous.

All other sandstone cuttings lack macroporosity due to physical compaction, grain contact dissolution, cementation by dolomite and pyrite, and pore filling by detrital and authigenic clay.

SWC #20 2738m Plate 9

Sample is a severely impact-damaged, moderately sorted, coarse grained subarkose ($Q_{88}F_9R_3$) in which framework grains are mainly quartz and also include K-feldspar (fresh to slightly altered orthoclase) and low-grade metasedimentary rock fragments (illitic meta-argillite, mica schist, mica-bearing quartzite). Intact quartz grains are mostly subangular to subrounded.

Rare illitic pseudomatrix has formed by compactional deformation and dispersion of micaceous/argillaceous metasedimentary rock fragments.

The sand is partly cemented by dolomite, which forms widely scattered, poikilotopic patches up to 2.5mm long. Quartz grains are enveloped by thin quartz overgrowths where adjacent pores are not filled by dolomite or compacted ductile grains.

Significant intergranular porosity reduction is the result of dolomite cementation, grain contact dissolution to form long, embayed and sutured contacts between quartz grains, and localised pore filling by compacted ductile grains.

Most of the sample consists of totally crushed and pulverised sandstone fragments and loose grains and grain fragments. Accordingly, visible porosity could not be reliably measured. Original texture is well preserved only where the sand is tightly cemented by dolomite.

Indications are that uncemented parts of the sand contained only minor (<3%) primary intergranular porosity and subordinate secondary labile grain dissolution porosity. Macropores would have been erratically distributed, hence permeability was probably low to fair.

SWC #2 2954m Plate 10

Sample is a well compacted, sideritised arenaceous mudrock in which moderately sorted, fine to medium sand-sized clastic grains (quartz, K-feldspar, metasedimentary rock fragments, chert, mica) are supported by detrital clay matrix that has been extensively replaced by microcrystalline siderite. Fine organic fragments and stringers are common. Macroporosity is absent.

4. SUMMARY AND CONCLUSIONS

- Sidewall core samples from 2284-2738m in Remora-1 are impact-damaged, medium to coarse grained sublitharenites (2284m, 2622m, 2651m) and a subarkose (2738m) in which framework grains are mainly quartz, K-feldspar and low-grade metasedimentary rock fragments.

- A sidewall core sample from 2954m is a sideritised arenaceous mudrock.

- Cuttings from 2695-2705m are mainly non-reservoir lithologies that include mudrocks, argillaceous sandstones/siltstones, marls, and tightly dolomite/pyrite-cemented sandstones.

- Cuttings from 2700-2705m lack volcanics, whereas cuttings from 2695-2700m include intermediate volcanics that have largely altered to kaolinite and are commonly partly replaced by carbonate and pyrite.

- Clay in the sandstones is mainly illitic pseudomatrix that has formed by compactional deformation and alteration of micaceous/argillaceous grains. Authigenic kaolinite occurs as an alteration product of mica.

- Diagenetic effects in the sandstones include patchy dolomite cementation, grain contact dissolution, ductile grain deformation, labile grain alteration to clay, quartz overgrowth cementation and labile grain dissolution.

- Visible porosity could not be accurately measured in some of the sidewall core samples due to the effects of severe impact damage. However, indications are that all sandstone sidewall core samples contained only minor visible porosity, reflecting significant porosity reduction by dolomite cementation, grain contact dissolution and ductile grain compaction.

- Sandstone cuttings invariably contain little or no macroporosity due to cementation, compaction and pore filling by detrital and authigenic clay.

- Visible porosity is mainly primary and intergranular and also includes secondary pores that have formed by dissolution of K-feldspar and labile rock fragments.

- Intergranular pores are generally erratically distributed and thus would have limited connectivity. Accordingly, sandstones would have only low to fair permeability.

APPENDIX 1

PHOTOMICROGRAPHS

PLATE 1 SWC #43 2284m

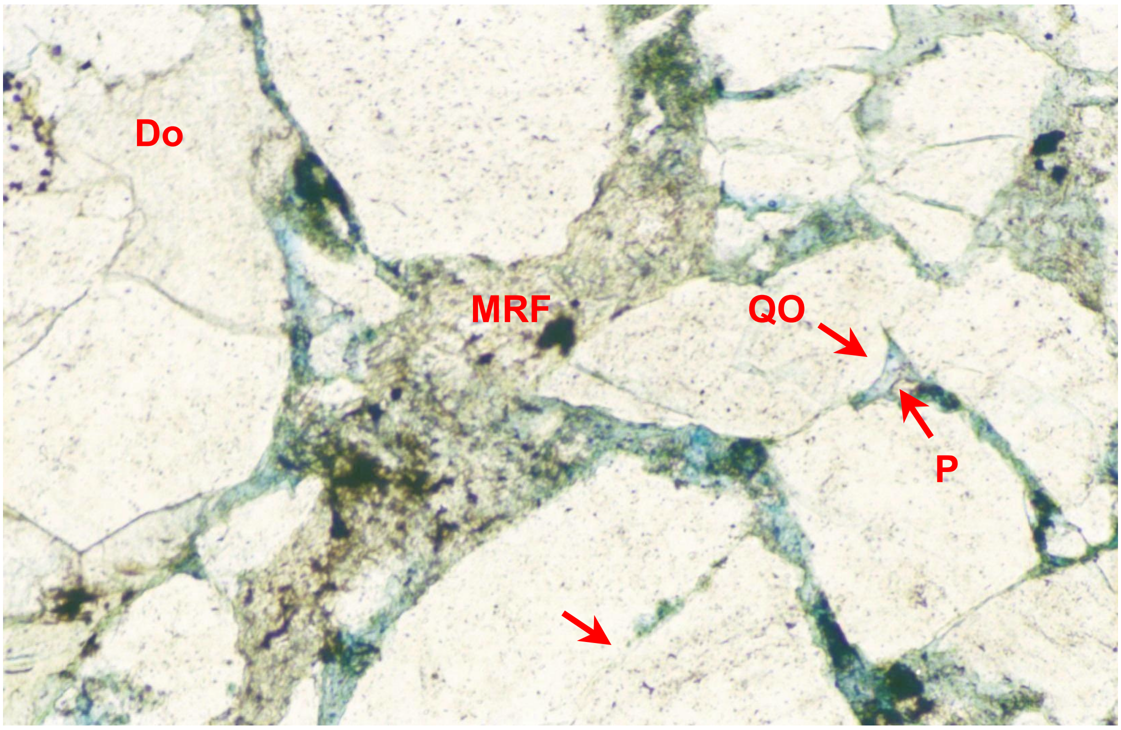
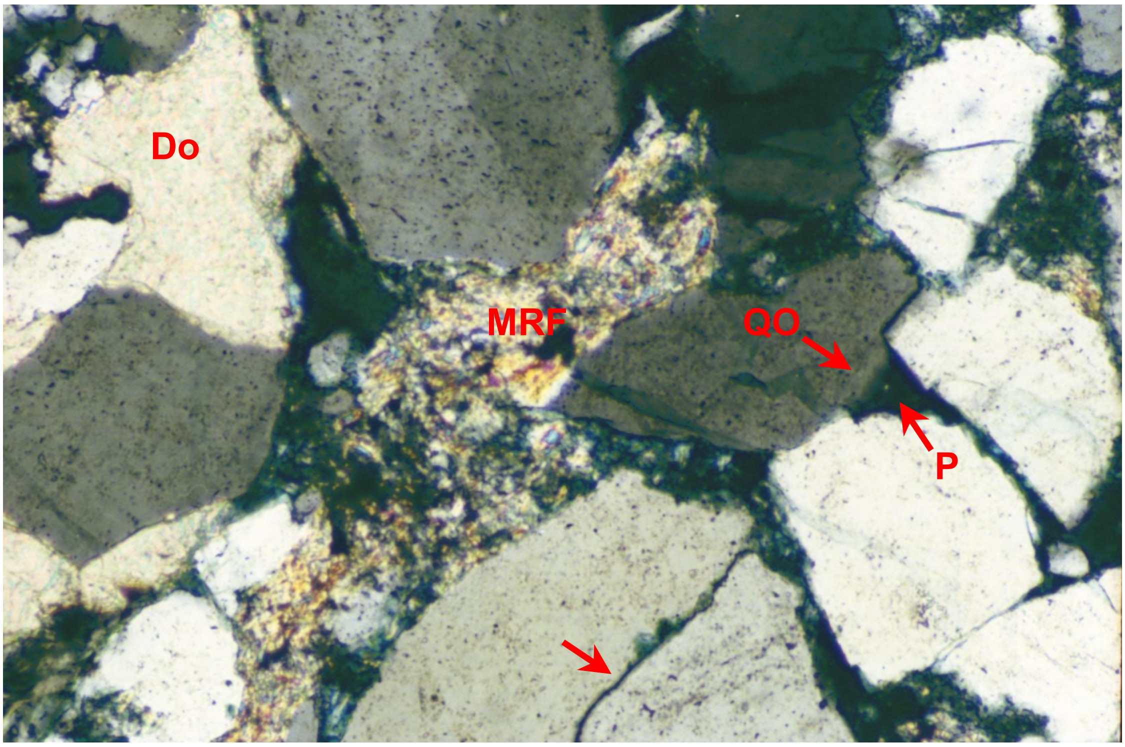


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.2 mm



Significant porosity reduction is the result of patchy dolomite (Do) cementation, compactional deformation of micaceous metamorphic rock fragments (MRF), grain contact dissolution (arrow) and localised quartz overgrowth (QO) cementation. Intergranular pores (P) are small and erratically distributed and thus would not be conducive to good permeability.

PLATE 2 SWC #25 2622m

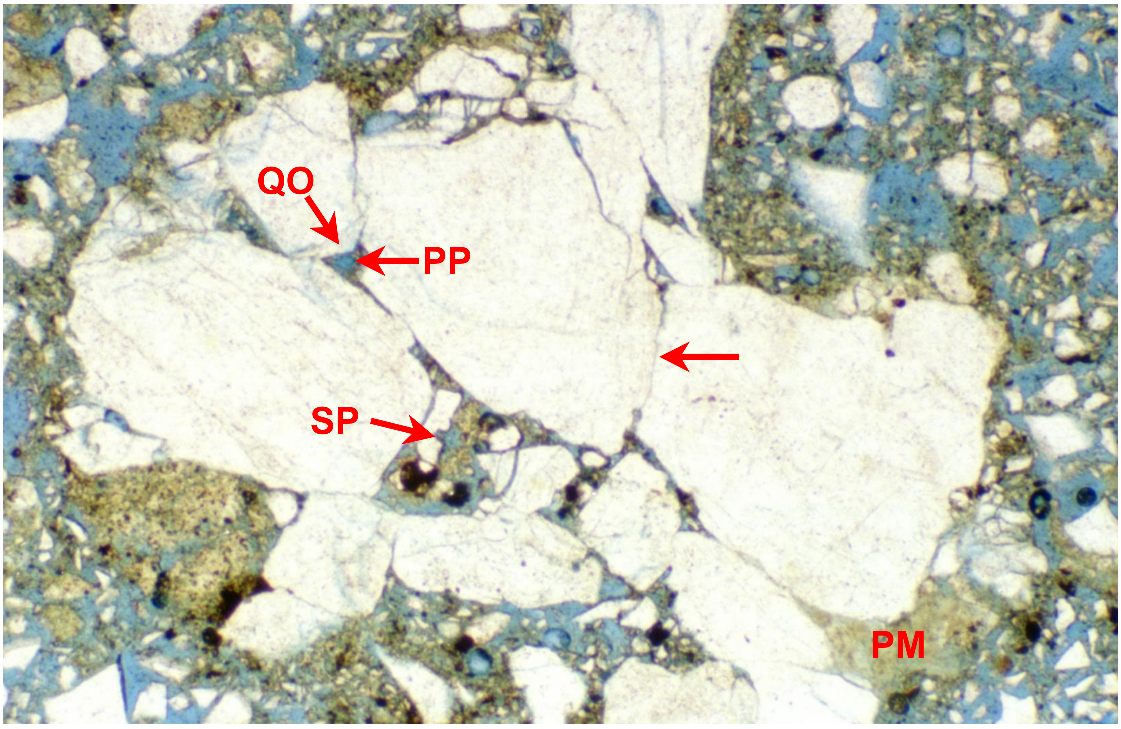
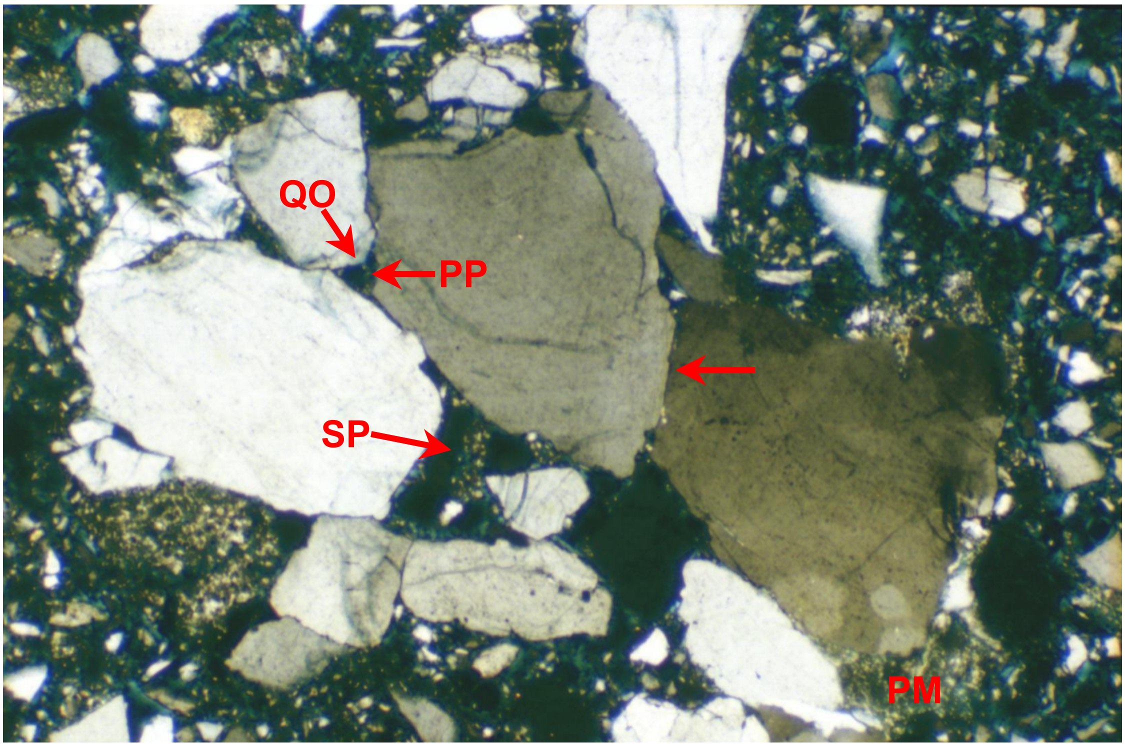


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.4 mm



A small intact sandstone fragment is preserved in a sample that is severely crushed and disaggregated as a result of sidewall coring. The fragment contains minor primary intergranular porosity (PP) and secondary labile grain dissolution porosity (SP), which, together with coarse grain size, may indicate fair permeability. Intergranular porosity reduction is the result of grain contact dissolution (arrow), ductile grain deformation to form localised pseudomatrix (PM) and minor quartz overgrowth (QO) cementation.

PLATE 3 SWC #25 2622m cont.

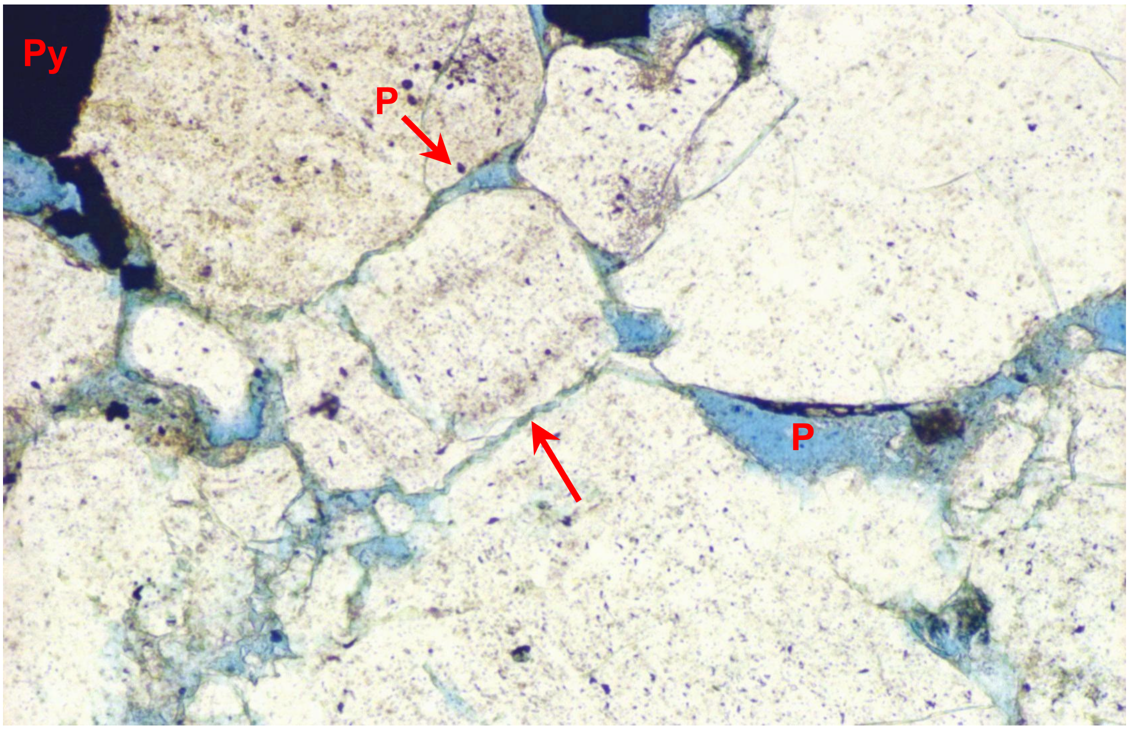
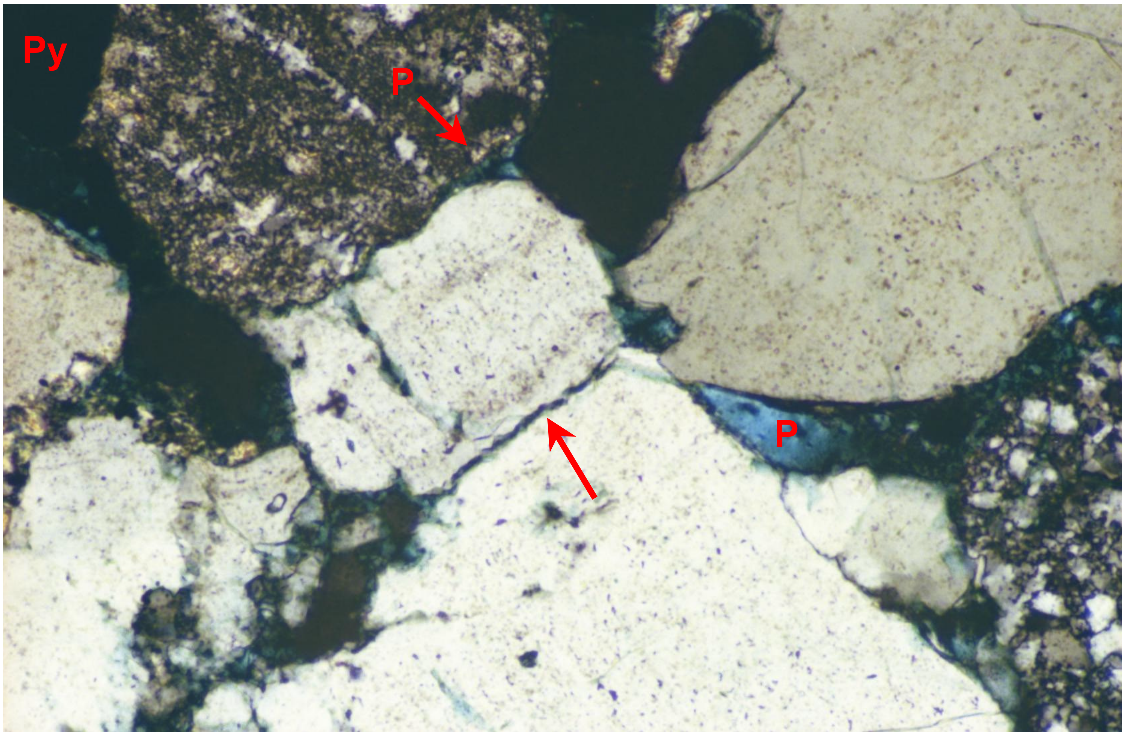


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.2 mm



Framework grain packing density has been increased by grain contact dissolution to form welded grain contacts (arrow), and further porosity reduction is the result of patchy pyrite (Py) cementation. The presence of minor intergranular porosity (P) points to fair permeability. Most of the sample is totally crushed and disaggregated.

PLATE 4 SWC #23 2651m

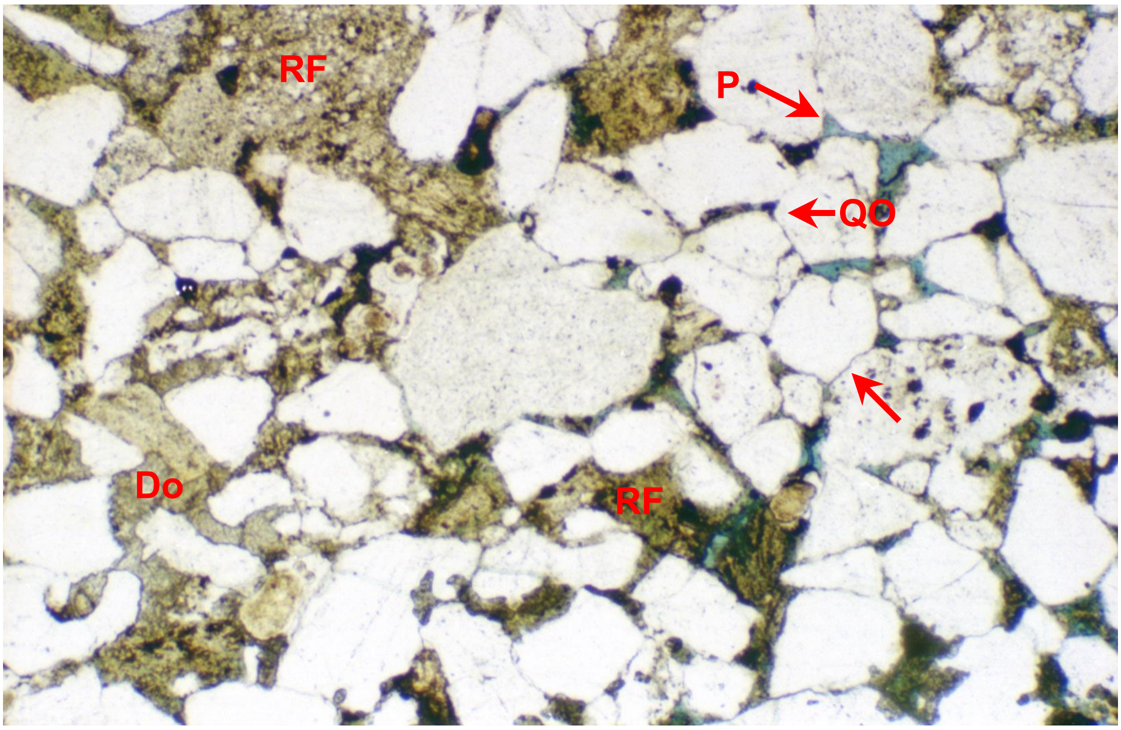
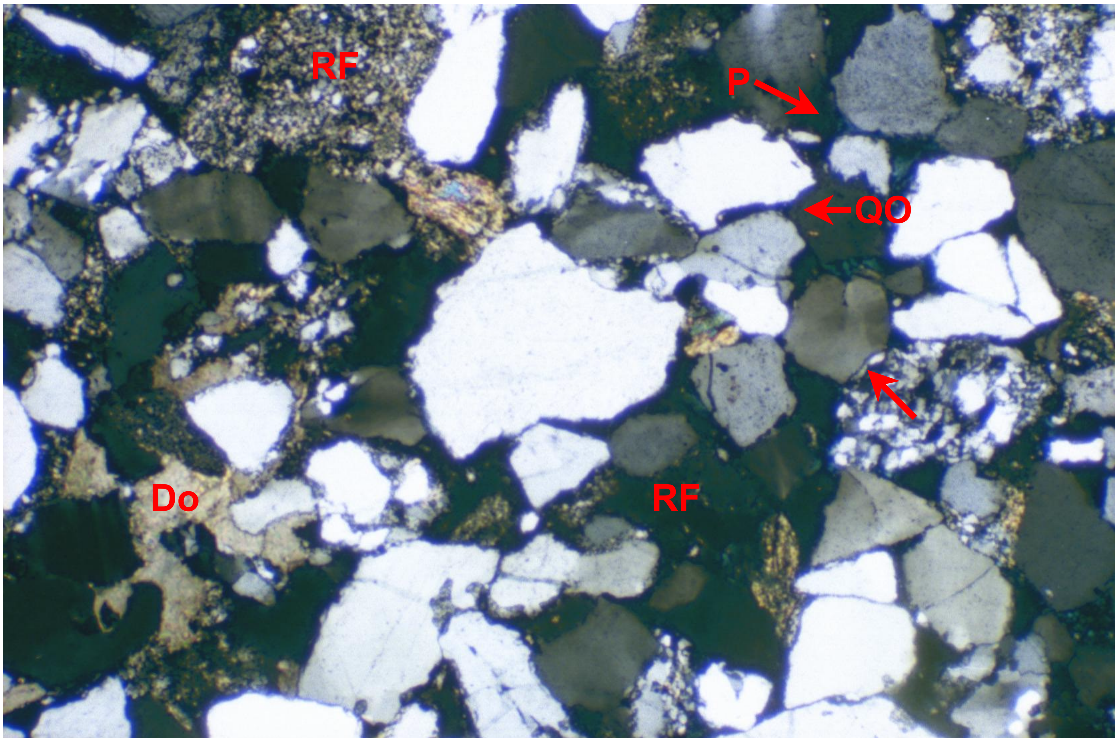


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.4 mm



Little intergranular porosity (P) remains in this intact, coarse grained sandstone due to patchy dolomite (Do) cementation, grain contact dissolution (arrow), micaceous/argillaceous rock fragment (RF) compaction, and minor quartz overgrowth (QO) cementation.

PLATE 5 SWC #23 2651m cont.

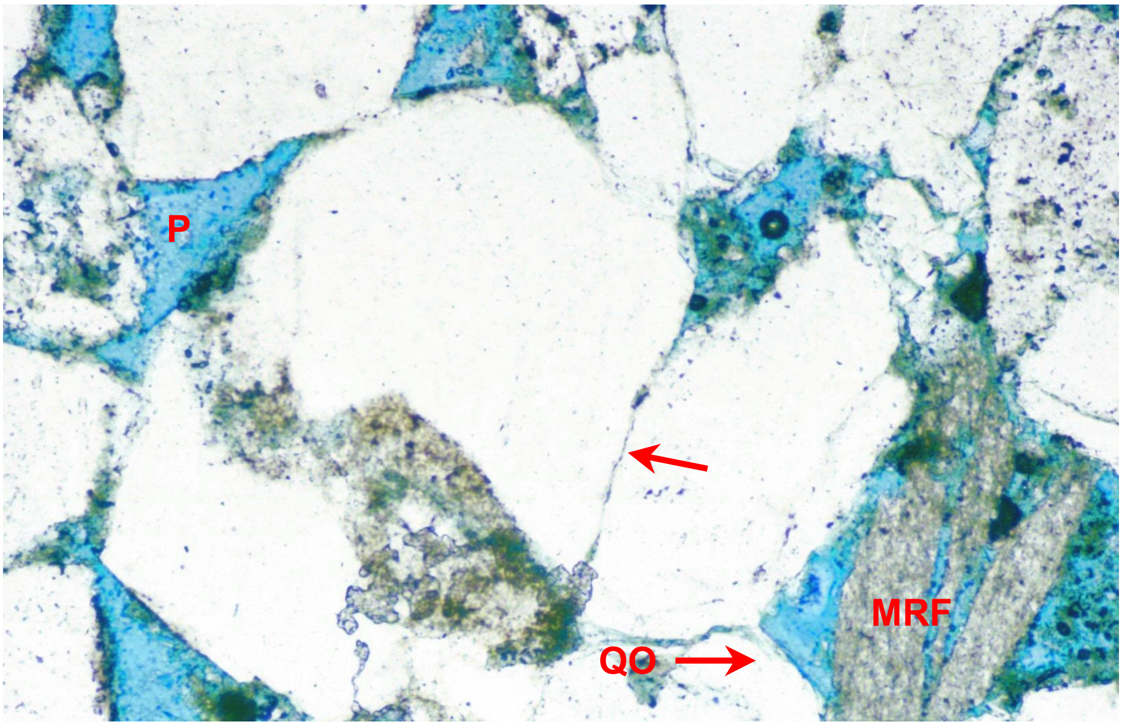
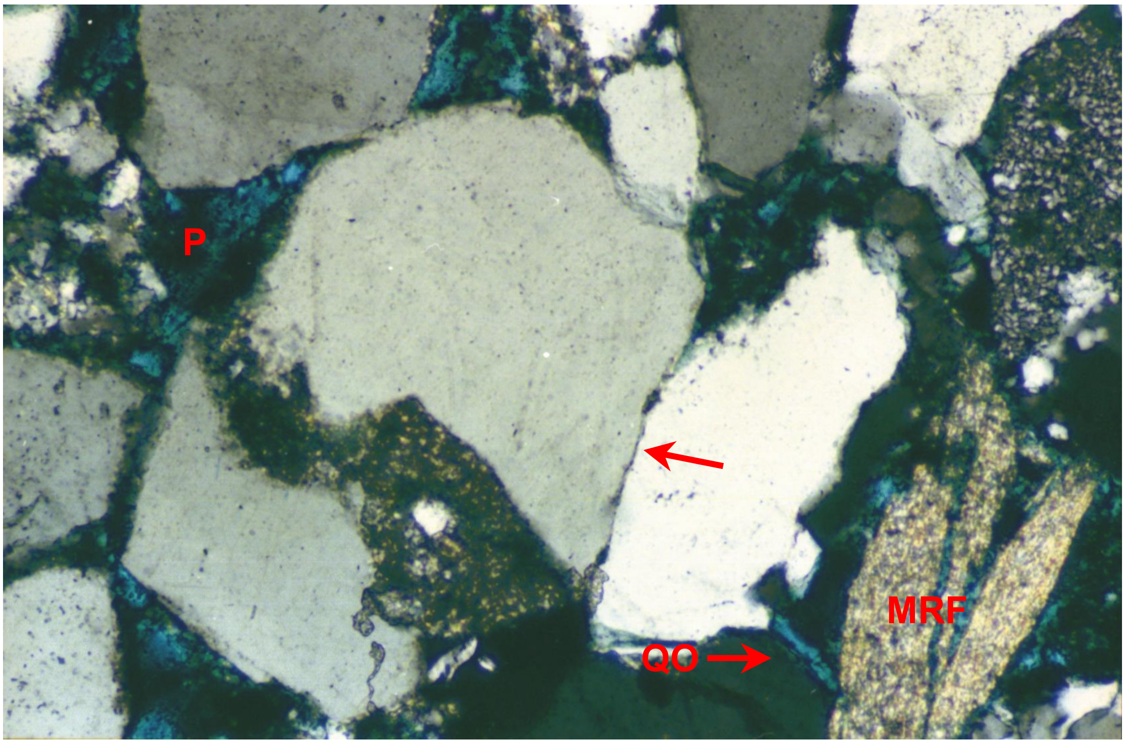


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.2 mm



A small, partly intact sandstone fragment contains good intergranular porosity (P), despite porosity reduction by grain contact dissolution (arrow) and quartz overgrowth (QO) cementation. However, such pores appear to be irregularly distributed throughout the sand, hence permeability would be low. Metasedimentary rock fragments (MRF) are common.

PLATE 6 2695-2700m (cuttings)

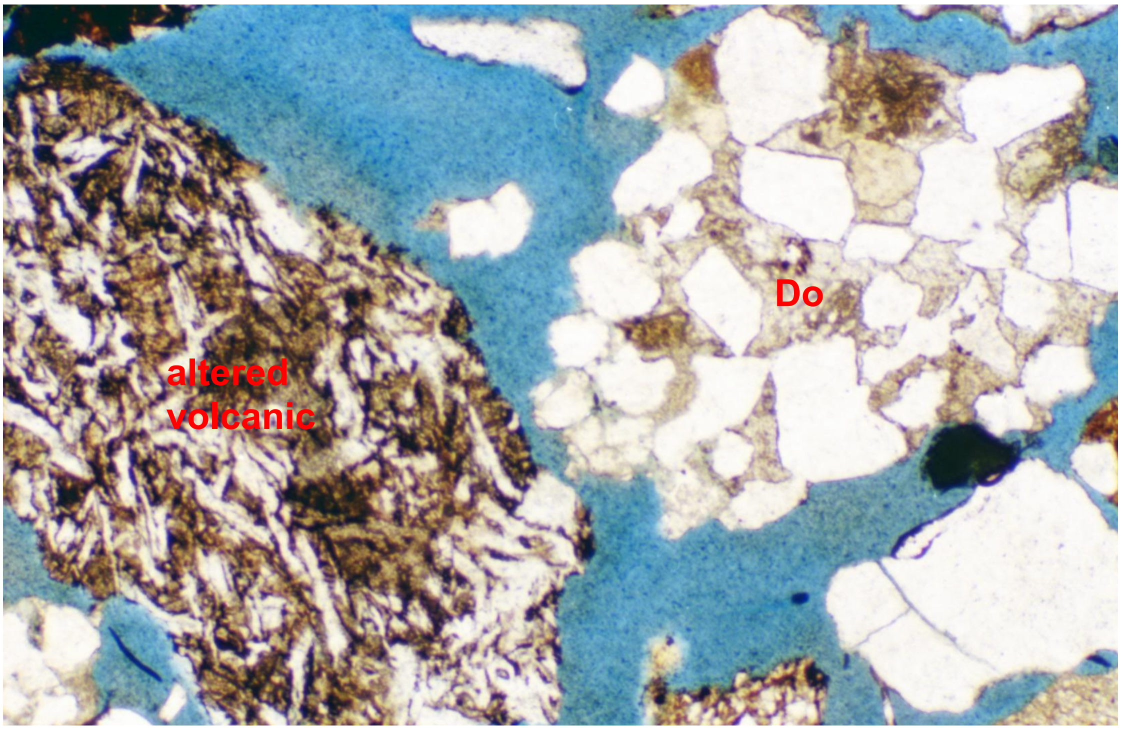
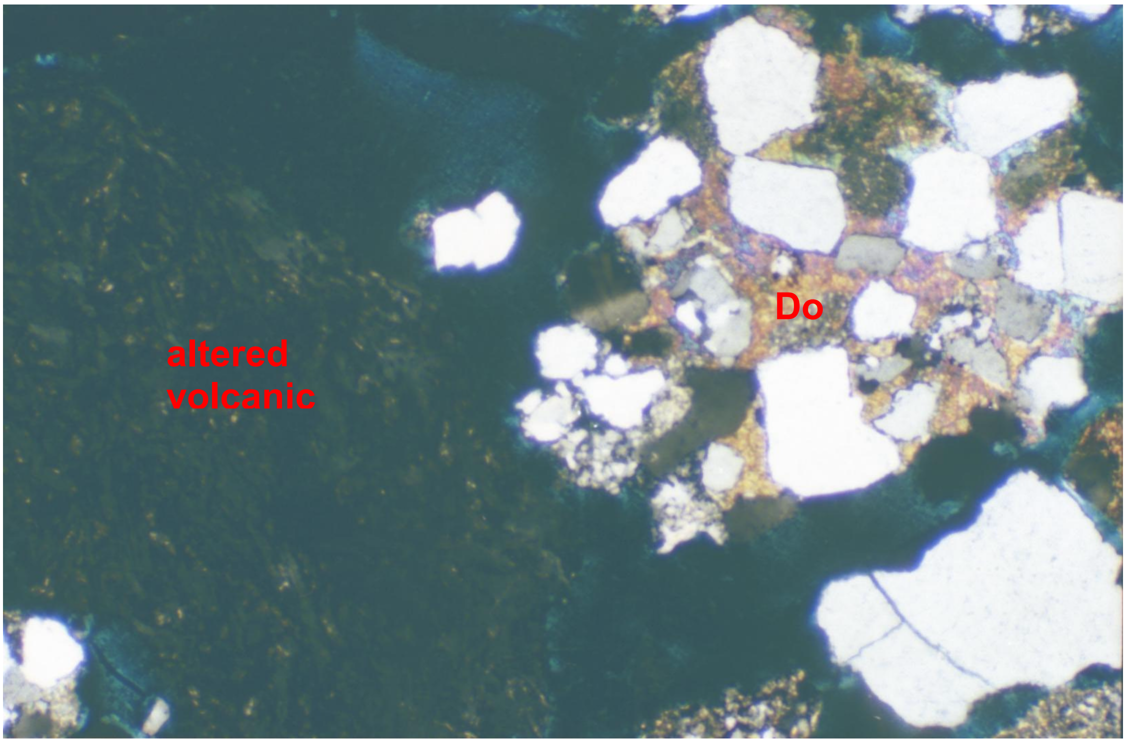


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.4 mm



Cuttings in this sample include altered intermediate volcanics and tightly dolomite (Do)-cemented sandstones.

PLATE 7 2695-2700m (cuttings) cont.

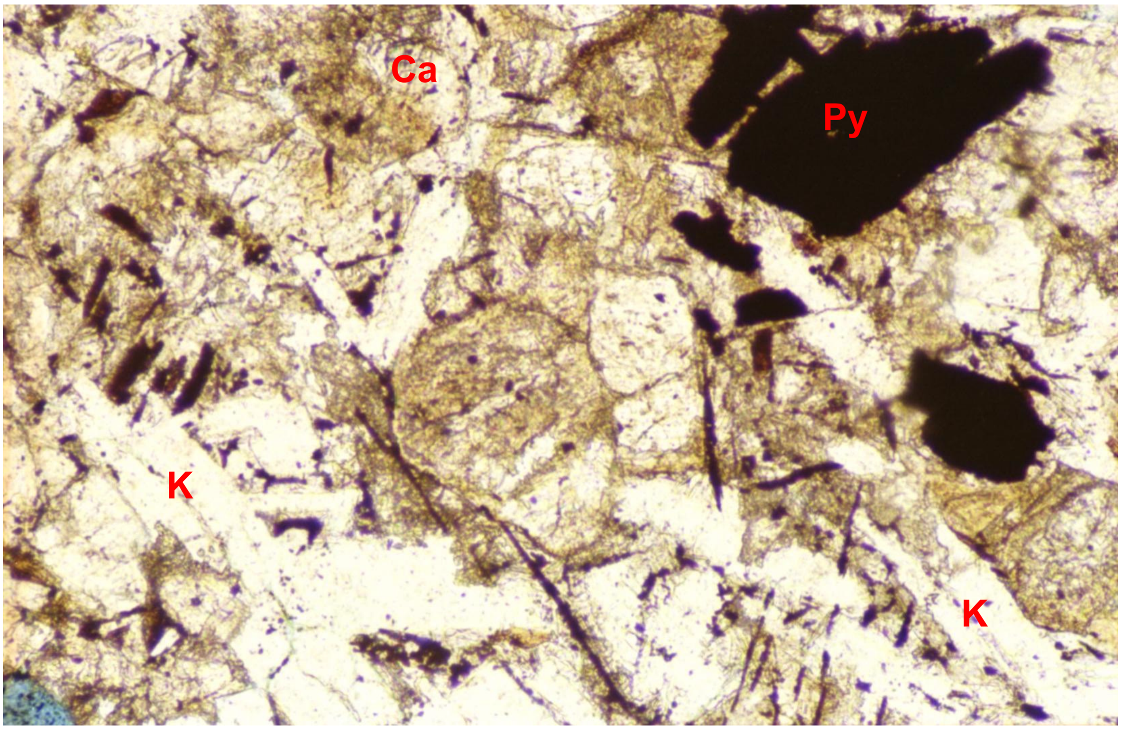
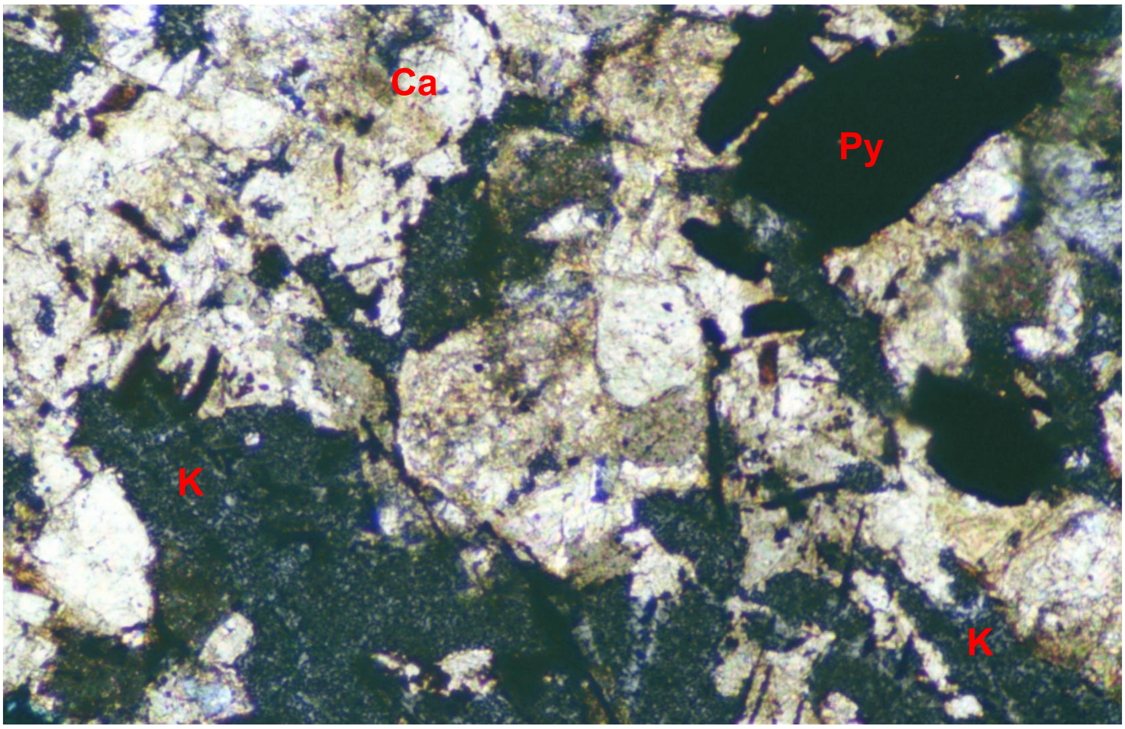


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.4 mm



An altered intermediate volcanic is largely replaced by carbonate (Ca) and pyrite (Py). Feldspar microlites have altered to microcrystalline kaolinite (K).

PLATE 8 2700-2705m (cuttings)

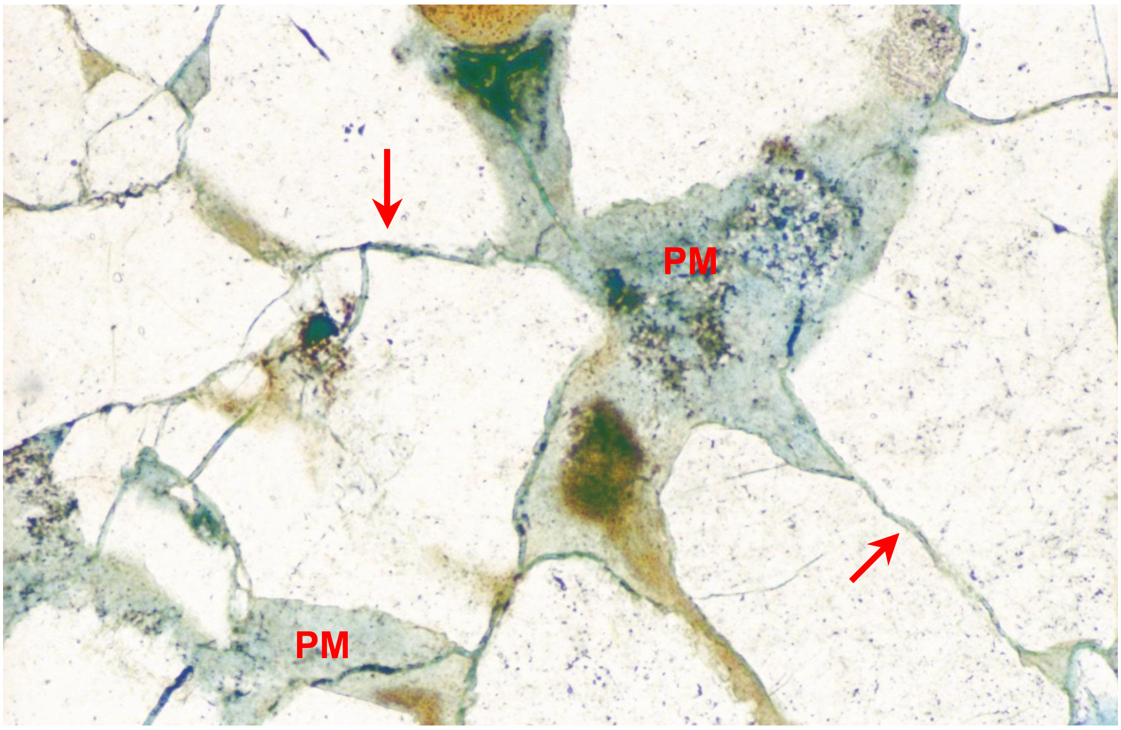
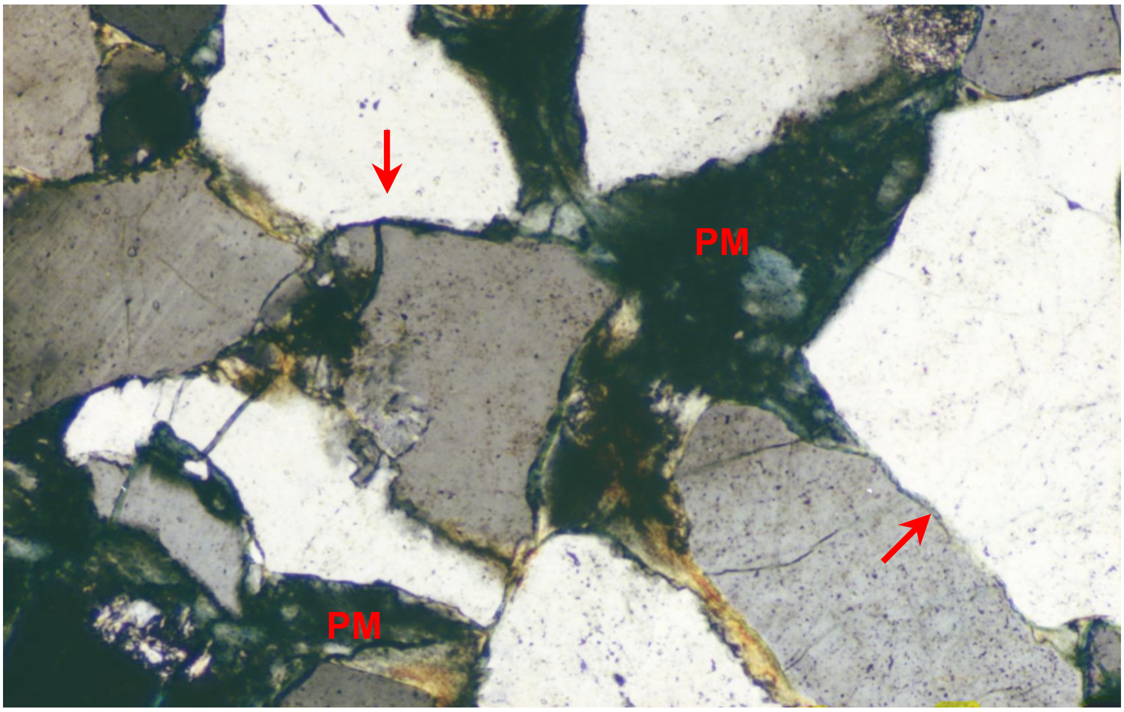


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.2 mm



This is the only sandstone cutting in the thin-section that does not contain cement and detrital clay matrix. All intergranular spaces are filled by authigenic illitic and kaolinitic pseudomatrix (PM) that has formed by micaceous grain (biotite) compaction and alteration. Welded grain contacts (arrows) are the result of grain contact dissolution.

PLATE 9 SWC #20 2738m

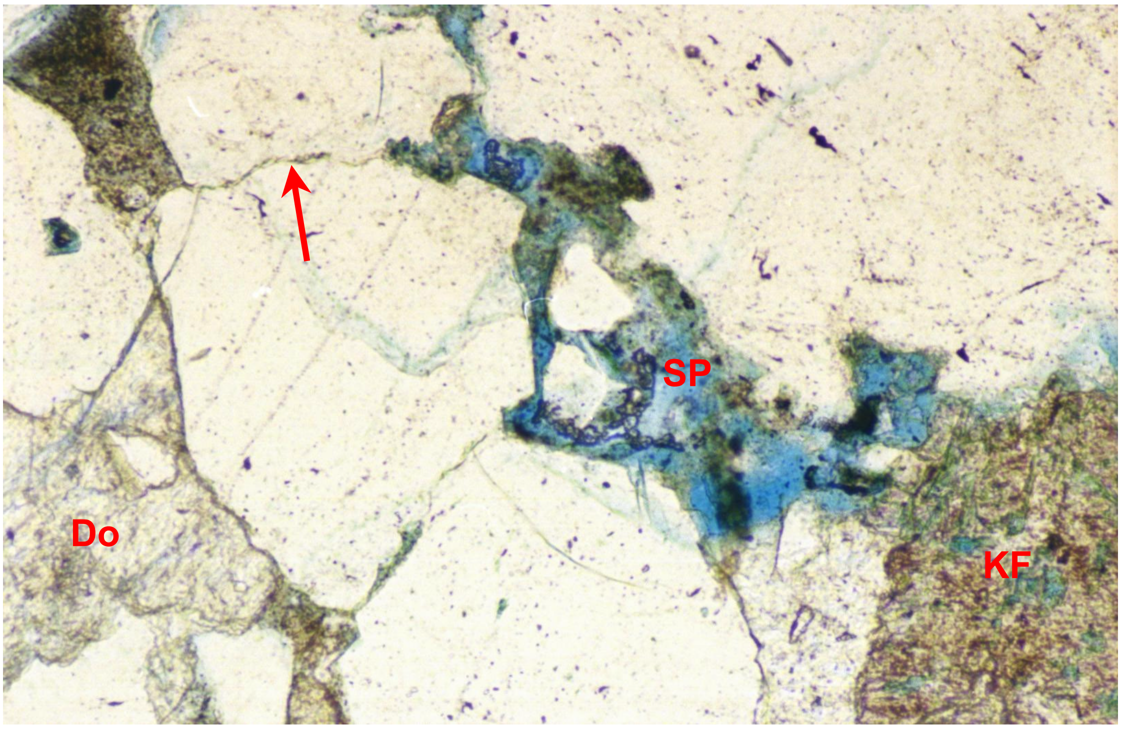
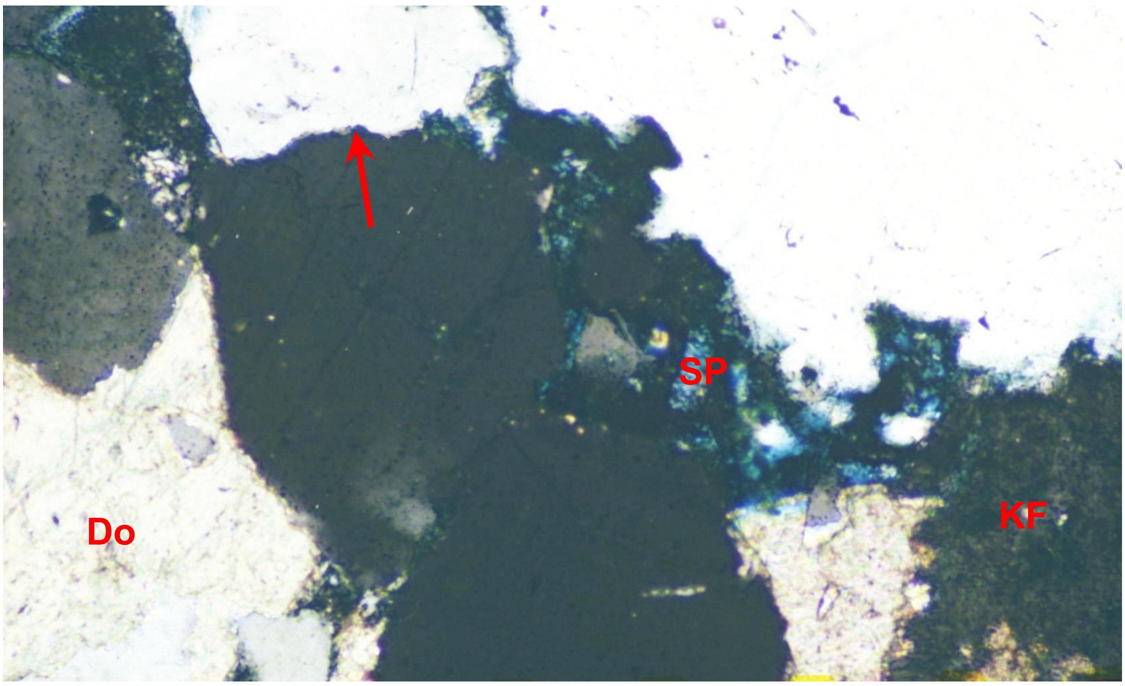


FIGURE 1 Plane polarised light

FIGURE 2 Crossed polarisers

0.4 mm



Most intact parts of this badly impact-damaged sample are tightly cemented by poikilotopic dolomite (Do), which originally formed scattered patches throughout the sand. Indications are that primary intergranular pores and secondary labile grain dissolution pores (SP) were not sufficiently common to be conducive to good permeability, with significant porosity reduction resulting from dolomite cementation, grain contact dissolution (arrow) and localised ductile grain deformation. A slightly dissolved K-feldspar grain (KF) is also marked.

PLATE 10 SWC #2 2954m

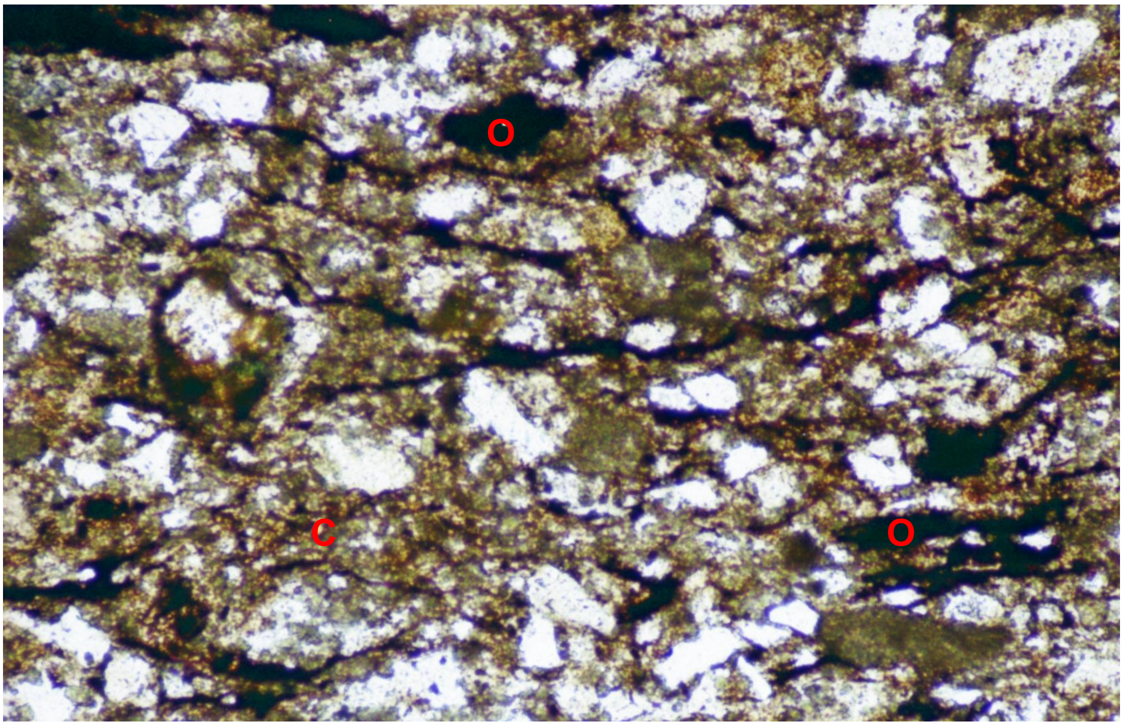
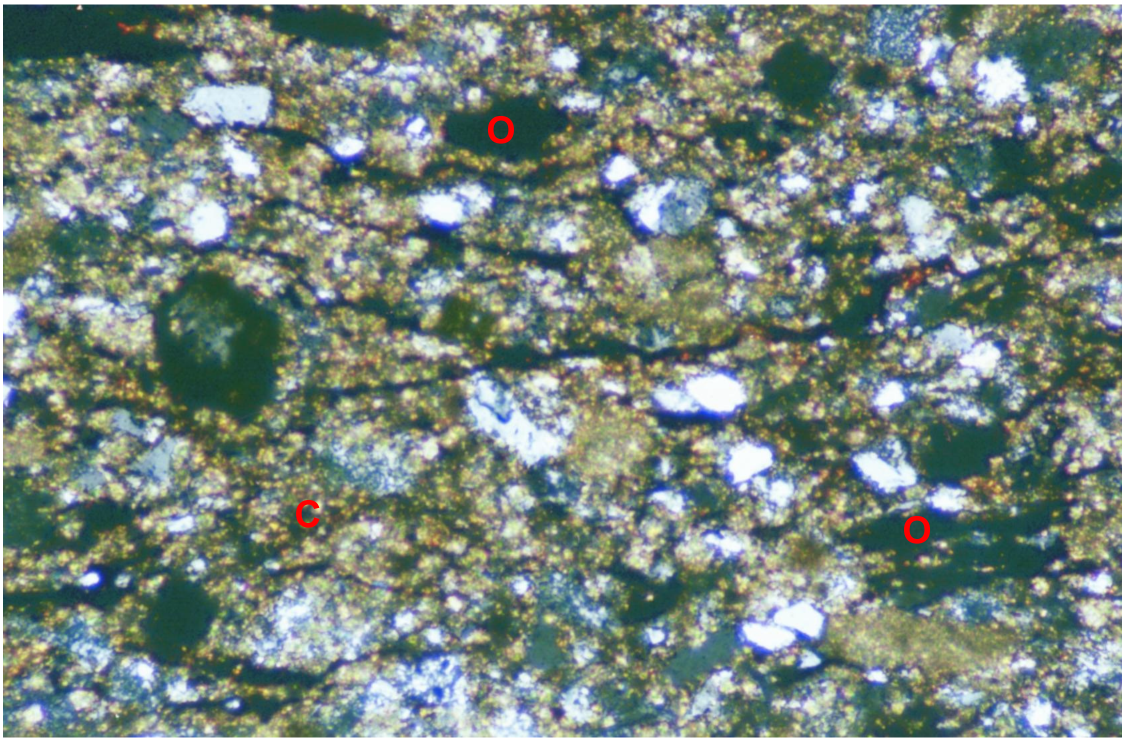


FIGURE 1 Plane polarised light
FIGURE 2 Crossed polarisers

0.4 mm



Arenaceous mudrock in which fine/medium sand-sized clastic grains and organic fragments/stringers (O) are supported by sideritised clay matrix (C).