340001

SDA 342

Petrological/diagenetic investigation of twelve core samples from Cormorant-1 Bass Basin, Australia

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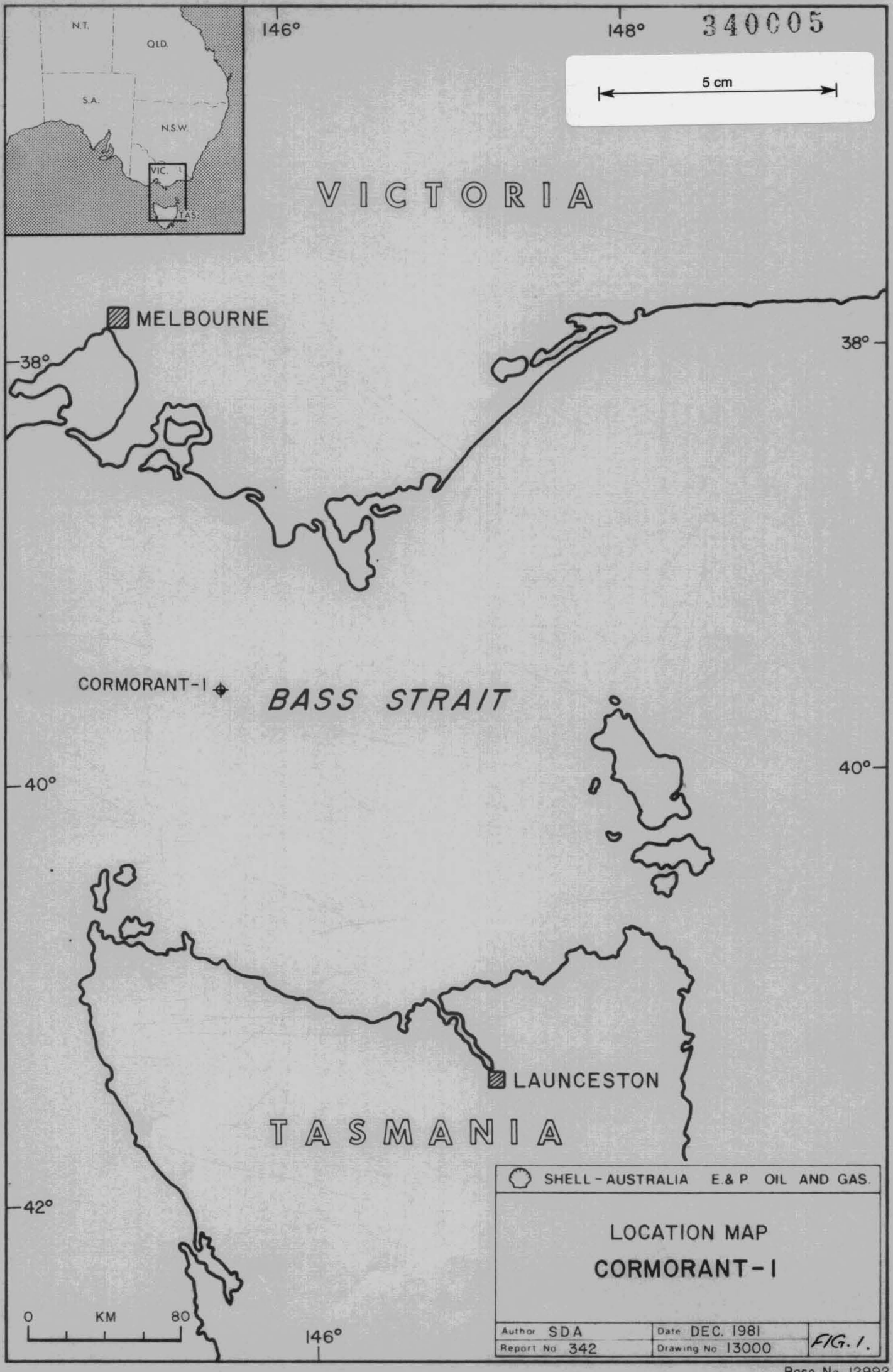
Summary

Twelve core samples from Cormorant-1 were investigated petrographically in order to assess their reservoir qualities. These samples were fine to very fine sandstones, siltstones and shales, ranging in composition from argillaceous/carbonaceous to relatively clean quartz clastics. Quartz is the dominant framework mineral, lithoclasts are also common constituents of the sandstone comprising 7 to 30% of the solid rock component.

The main porosity/permeability reducing factors in the argillaceous sandstones down to 5000' depth are compaction and the abundance of depositional argillaceous/carbonaceous matrix. In the sandstones buried at depth greater than 5500' authigenic quartz and kaolinite contribute increasingly towards porosity reduction with increasing depth of burial. Calcareous cement occurs in the form of siderite which is diagenetically early cement and in the form of dolomite/ankerite which is diagenetically late and post-dates authigenic quartz. The overall effect of calcareous cement on porosity reduction is not very significant.

The porosity of the investigated sediments ranges from 11.3 to 27.7% and the permeability from less than 1mD to 184mD. Only the sandstones with a porosity of 25% or higher retain economic permeabilities at depths greater than 7300'. This low permeability/porosity ratio is attributed to the fine grain-size of the sediments and the presence of depositional/diagenetic matrix.



Base No. 12992

1. Introduction

Twelve core samples from Cormorant-1 (depth 4292'-9114') were examined petrologically with a view to determining their composition and diagenesis. This investigation forms part of a broader study aimed at comparing the reservoir sandstones of the Bass Basin with those of the Gippsland Basin.

The Esso/BHP well Cormorant-1 was drilled in the Bass Basin (Lat 39°34'22.8", Long 145°31'35.7") in 1970. The well penetrated 2300' of calcarenite and marls of Neogene age, 960' of shale and marl of Oligocene age, 1025' of marine shale and arenites of late Eocene age and 5310' of mixed clastics with coaly horizons of Eastern View Coal Measures; 4637' of those sediments are of Eocene age and 672' of Palaeocene age. Between 8018' and 8264' depth igneous intrusive (a sill?) of olivin gabbro/syenite composition was encountered. The well terminated in Palaeocene clastics at 9845' depth bdf.

Oil and gas in non-commercial quantities was encountered in several Eocene/Palaeocene horizons.

2. Material investigated and mode of presentation

Core samples were obtained from the Department of Mines of Tasmania. Porosity/permeability plugs were cut and porosity/permeability measurements were carried out by Core Laboratories (Qld), Perth. Thin sections prepared from the porosity/permeability plugs were examined microscopically at SD(A) using polarising and reflected light microscopes. The porosity/permeability data and the petrological descriptions of individual samples are presented in Appendices 1 and 2, respectively. Twenty polaroid microphotographs are attached to illustrate some structural, textural, petrological and diagenetic features of the sediments.

3. Composition and diagenesis of sediment

3.1 Samples examined

A total of twelve samples selected from cores 4, 5, 7, 8, 10, 12 and 13 were investigated. The depth range of the samples is from 9114'5" to 4292'. The lowermost sample, from 9114'5" depth, is of Palaeocene age, the other eleven samples are of Eocene age. Nine of the samples investigated are of known porosity and eleven are of known permeability. Samples of core 4 (4292', 4294', 4276' depths) are "Boonah Sandstone" of upper Eocene age, the remaining sediments are of Eastern View Group.

3.2 Composition of sandstones

The samples investigated are arenites of very fine lithology: shale (Pl 7), siltstone (Pl 5), and very fine (Pl 6, 12, 13) to fine sandstone (Pl 4, 14, 19), well sorted, composed of subangular to subrounded grains. Only the shallowest sample (4292' depth) contains grains up to the size of a very coarse sandstone. This sandstone, however, contains a large amount of carbonaceous/argillaceous matrix (Pl 1 and 2). All the samples examined contain significant amount of carbonaceous matter, mainly disseminated among the matrix (Pl 3) or in the form of laminae (Pl 12, 17); some of the sediments are burrowed (Pl 11).

The sandstones are composed of quartz (including polycrystalline quartz and chert) which makes up 60 to 70% of the framework, lithoclasts (7-30%), feldspars (nil-8%), micas (trace to 4%) and heavy minerals (trace to 5%). Pyrite is present as a replacement mineral of carbonaceous matter and in one sample (from 5522' depth) it occurs as intergranular pore-fill (Pl 7, 8, 9).

The feldspars are of orthoclase and plagioclase composition. The lithoclasts are argillites, altered minerals, grains composed of phyllosilicates and occasionally aggregates composed of quartz and feldspar (probably derived from granites). The micas are muscovite, biotite was observed only in the sample from 4294' depth. Tourmaline, zircon and rutile are the most common heavy minerals.

The matrix is composed of micaceous flakes, carbonaceous stringers and clay minerals, mainly kaolinite but also of some unidentified argillaceous matter. The amount of matrix varies from being a minor constituent to being the major component of the rock as is the case of the shale samples from 5522' depth, where the sandstone is present only as thin laminae within a predominantly argillaceous rock (Pl 7). In the sandstones the matrix forms up to 30% of the solid rock constituent. Calcareous matter, mainly in the form of siderite, is present in samples from lower horizons.

3.3 Diagenesis

Compaction is the main postdepositional change to which the examined samples were subjected. The compaction is manifested by dense packing of the detrital grains, and by plastic deformation of the ductile lithoclasts and phyllosilicates (Pl 15). The deposition of siderite is widespread and the formation of authigenic quartz overgrowths on the detrital quartz grains is present in samples from 5537' depth downwards. Other diagenetic changes are kaolinisation of feldspars (Pl 20) and of some lithoclasts (especially in the lowermost samples, from 8685' and 9114'5") the introduction of (?) dolomite/ankerite cement (sample from 8685' depth, Pl 16 and 18) and pyritisation of carbonaceous matter.

The following paragenesis has been established:

- formation of siderite
- kaolinisation
- authigenic quartz growth
- introduction of calcareous matter (?dolomite/ankerite)

Compaction has been a continuous process from the time of deposition to the present, although compression could have been accentuated during tectonic disturbances.

3.4 Reservoir Characteristics

The porosity of nine measured samples ranges from 11.3 to 27.7% and the permeability from 0.71 to 184mD. Porosity of four shallowest

samples could not be measured on account of their friable nature, but porosities calculated from the density log are in the region of 33% at 4300'. Two permeability measurements on samples from 4294' and 4296' depth (probably carried out on loose sediment packed in a cylinder), gave values of 1262 and 547mD respectively. Taking into account the very fine grain-size of the sediment and the abundance of argillaceous/carbonaceous matrix these permeabilities seem to be on the high side. On the whole the permeabilities are rather low for sandstones with high porosities, ie. only sandstones with porosity higher than 25% have effective permeabilities of economic significance.

The low permeability/porosity ratio of the sediments investigated are attributed to fine grain-size of these sediments. The main porosity-reducing factors are: (a) compaction in samples up to 5000' depth and (b) authigenic quartz, kaolinite and calcareous cement in deeper sandstones.

The permeability is affected by the presence of a matrix, which often includes carbonaceous matter (Pl 1, 3 and 4) and unfavourable textural features, especially the very fine grain-size (Pl 10, 12 and 15); less important influences are the presence of calcareous cement such as siderite and dolomite/ankerite.

4. Concluding Remarks

1. The sediments examined are argillites and fine grained sandstones composed of quartz and lithoclasts with subordinate amounts of feldspar, micas and heavy minerals. A depositional matrix composed of clay and carbonaceous matter is common in samples above 5000' depth.

2. Measured porosities of these sandstones range from 11.3 to 27.7% and permeabilities from less than 1mD to 184mD. Two samples had permeabilities of 1262mD and 547mD but they were too friable for porosity measurements. These high permeabilities therefore cannot be taken as being reliable.

3. The permeability/porosity ratio of the sandstone is very low. This is attributed to the fine grain size of the sediments and the presence of depositional phyllosilicates and diagenetic clay.

4. The main diagenetic processes these sandstones underwent are compaction and some siderite deposition in the samples from 4292 to 4961' depth. In the samples from 5537 to 9114'5" depth authigenic quartz, and kaolinite are increasingly important diagenetic processes.

5. Calcareous cement occurs as siderite and as (?)dolomite/ankerite. The siderite is diagenetically early and the dolomite/ankerite is diagenetically late. The overall effect of the calcareous cement on porosity/permeability reduction is not significant.

6. The sediments undergo normal porosity/permeability reduction with depth; within the depth investigated the sandstones seem to lose effective permeability at 7300' depth. This reduction in permeability is brought about by compaction, authigenic quartz formation, kaolinite and calcareous cement.

7. Only coarser grained sandstones could be expected to retain commercial permeability at depths greater than 7300' at the location of Cormorant-1.

5. References

1. Cormorant-1 Wireline logs.

2. A Review of Petroleum Exploration and Prospects in the Bass Basin by Roberts C.S., Nicholas E. and Lockwood K.L., Bureau of Mineral Resources, Australia, Record 1979/5 (unpublished).

Appendix 1. Cormorant-1. Porosity and Permeability Measurements by Corelab, Perth. May 1981.

Depth	Porosity	Permeability
	%	in mD
4292	-	-
4294	-	1262
4296	-	547
4945	17.8	0.37
4961	23.9	7.3
5522	15.0	1.3
5537	26.3	184
5541	26.4	64
6015	27.7	111
7317	14.6	0.69
8685	11.3	0.97
9114	14.3	0.71

Appendix 2. Petrologic descriptions of samples from Cormorant-1.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340014

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C4	X	X	4292	1308.2	EO	100	Sst, arg, carb, vf-v crs, poorly srt, ang-rnd, argillaceous drapes, dk brn/gy; Composed of 40% Qz 10% Polyqz (Cht, recryst Qz, Vein Qz) 5% Fld (Plag, Orth) 15% Lcl (brn grains & altered grains probably Vo, Qz/Fld aggregates) tr Mica (Musc) 1% Heavy Min 15% Clay drapes 4% Opaque and dark matter (incl Py) 10% Matrix (arg, carb, ?ferrug) Intergranular matter composed of clay (Kao) and some unidentified very fine-grained matter, and occ disseminated Py; the sediment has an appearance of a "collapse breccia".	Too friable for porosity and permeability measurements; Compaction is the main diagenetic process. Compaction and the presence of matrix are the main pore-reducing factors.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340015

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C4	X	X	4294'	1308.8	EO	100	Sst, carb, vf, srt, ang-subrnd, dk brn/gy, carb Lam; composed of 60% Qz 5% Polyqz 2% Fld (Plag, Orth) 13% Lcl (altered grains, argillites, Vo glass) 1% Mica (Musc, brn Biot) 1% Heavy Min (Tourmaline, Zircon) 2% Opaque matter 4% Carbonaceous matter 7% Matrix (arg, carb, sid) Irregular carb Lam and stringers; some grains covered by arg/sid(?) coating.	Too friable for porosity measurement. Permeability 547 mD Muscovite flakes deformed by compaction in some parts of Sst; on the whole open packing of detrital grains with carb matter forming intergranular matrix; occ auth Qz overgrowth on detrital Qz. Pore-reduction is due to compaction and the presence of intergranular matrix.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340016

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C4	X	X	4296'	1309.4		100	Sst, arg, vf-f, srt, ang-subrnd, dk gy/brn; Composed of 60% Qz 8% Polyqz (Chert, vein Qz or recryst Qz) 2% Fld (Orth & some very altered Fld) 10% Lcl (Phyllosilicate grains; argillite, altered grains, ?Vo) 1% Mica (Musc kaolinised) 1% Heavy Min (Tourmaline) 12% matrix (arg/sid, carb) Abundance of dk brn, very fine intergranular matter which also forms some lithoclasts; some Qz grains seem to have auth overgrowths.	Too friable for porosity measurement. Permeability 1262 mD Good visual porosity Very friable sandstone. Open packing of detrital grains; intergranular space, occupied by dk brn very fine matrix-clay or clay/siderite. Pore-reduction is due to compaction in the presence of matrix.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340017

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C5	X	X	4945	15072	EO	100	Sltst, mic, carb, arg, gy, bioturbated; Composed of Qz, Micas (mainly Musc) Heavy Min (Tourmaline, Zircon), Py; abundance of carbonaceous matter (including (?)resin); burrows are composed of non-carb very fine Sst/Sltst.	Porosity 17.8% Permeability 0.37mD Porosity reduction is caused by compaction; low permeability is due to fine grain-size and the abundance of clay-phyllosilicates.
C5	X	X	4961	1512.1	EO	100	Sst, slt, carb, vf, srt, gy, carb Lam; Composed of 65% Qz 5% Fld (Orth, Plag) 4% Mica (Musc) 16% Lcl (Phyllosilicates, altered grains, argillites) tr Heavy & opaque Min/Zircon, Rutile Tourmaline 1% carbonaceous matter and 9% clayey intergranular matter. Some Muscovite flakes slightly deformed by compaction, very occ auth Qz overgrowths; abundance of carbonaceous stringers.	Porosity 23.9% Permeability 7.3% Porosity reduction is due to compaction; low permeability is caused by fine grain-size & carb/argillaceous matter; influence of auth Qz on porosity/ permeability is negligible.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340018

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C7	X	X	5522	1683.1	EO	100	Sh with lenses and Lam of Sst, vf, py. Sh is mic, carb with abundant yel & red bodies (probably resin or pollen) and disseminated Sid crystals; in parts variable amount of Qz & Lcl grains. Sst/Sltst is composed of Qz (60%), Fld (Orth, Plag), Lcl (mainly argillites), Musc; intergranular disseminated Py abundant in parts of Sst, Heavy Min (Zircon & bluish green Tourmaline); intergranular matrix of mica/clay/carb matter; lithified by clay/mica matrix; some sandy patches may be burrows; Sst is slt to vf, subang-subrnd, some micas are bent (compaction), some are very straight - could be diagenetic.	Porosity 15% Permeability 13mD Compaction is the main diagenetic process. Porosity reduction is caused by compaction, permeability reduction is due to the abundance of clay/mica minerals & fine grain-size of Sst.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340019

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C7	X	X	5537	1687.7	EO	100	Sst, lithic, vf-f, srt, subang-subrnd, lt brn gy, carb Lam; composed of 70% Qz (including Cht, Polyqz) 8% Fld (Orth, Plag) 7% Lcl (Argillite, altered grains Phyllosilicate grains, Sid/rock aggreg) 3% Mica (Musc) 5% Heavy Min (Tourmaline Zircon, (?)Leucoxene) & dk grain 7% shaly laminae Feldspars range from fresh to very altered; some Qz grains with auth overgrowths; some intergranular Kao & isotropic (?)clay matter; arg Lam mic, carb probably with some intergranular residual hydrocarbon; abundance of opaque grain-size matter disseminated in Sst - some resemble Zircon, some air-bubble with impurities; traces of siderite).	Porosity 26.3% Permeability 184mD High visual porosity is probably secondary or partly caused by removal of some pre-existing matter. Pore reduction is due to clay & auth Qz (mild)

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340020

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C7	X	X	5541	1688.7	EO	100	Sst, arg, mic, vf, srt, subang-subrnd, gy brn-brn, carb Lam; Composed of 75% Qz, Polyqz, Cht 4% Fld (Orth) 10% Lcl (Argillite) 3% Mica (Musc) 2% Sid tr Heavy Min & Opaque Min (Hematite, Zircon, Rutile, Tourmaline) 5% Mtx (carb/arg matter and Py) Carb matter forms irregular stringers and is associated with Sid & Py	Porosity = 26.4% Permeability - 64mD Good visual porosity, probably secondary pro-part; pore-reduction is caused by compaction, the presence of ductile lithoclasts & micas, siderite crystals and micaceous matrix; auth Qz overgrowths are present but their overall effect on porosity reduction is insignificant; siderite occurs as minute crystals and as small concretions & is often associated with carbonaceous stringers.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340021

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C8	X	X	6015	1833.4	EO	100	Sst, vf, well sorted, ang-subrnd, grains aligned, lt brn; Composed of 75% Qz, Polyqz 5% Fld (Orth) 14% Lcl (argillite, altered grains) 1% Mica (Musc) 1% Heavy Min (Tourm, Zircon, Rutile) 1% Opaque grains (Leucoxene) tr Siderite 3% intergranular clay Micas & Fld range from fresh to altered, mainly to Kao; lithified by compaction, particularly plastic deformation of ductile grains, moderately advanced authigenic quartz overgrowths; minor amount of organic matter; deep green mineral (?Glc) in trace amounts.	Porosity 27.7% Permeability 111mD Good visual porosity - some only apparent, caused by mechanical removal of clay minerals. Compaction and authigenic quartz overgrowths are the main pore reducing factors.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340022

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C10	X	X	7317	2230.2	EO	100	Sst, arg, carb, vf-f, srt, subang-subrnd, carb Lam, clay drapes, brn; composed of 50% Qz 8% Polyqz and Cht 3% Fld (Orth) 22% Lcl (argillites, altered grains) 4% Mica (Musc) and chlorite tr Heavy Min (Tourm) 5% Clay drapes 3% Carb matter 2% Calc (Sid) 3% Matrix Siderite associated with carb Lam; ductile grains & majority of mica flakes are deformed and squeezed between hard detrital grains; Fld ranges from fresh to severely altered.	Porosity 14.6% Permeability 0.69mD Low visual porosity; porosity reduction is due to compaction, particularly plastic deformation of ductile grains and micas & the presence of siderite and of organic matter

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

340023

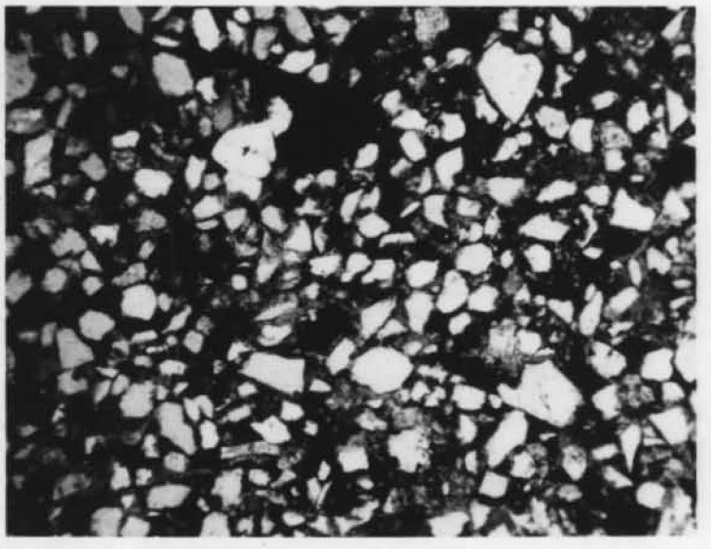
SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C12	X	X	8685	2647.2	EO	100	Sst, lithic, vf-f, srt, subang-rnd, dk brn gy, carb stringers; Composed of 75% Qz & Polyqz 18% Lcl (argillites, altered grains to Kao, altered ?Vo) tr Mica (Muscovite) tr Heavy Min (Rutile, Tourmaline, Zircon) tr Opaque Min 3% Ankerite & Dol 1% Carbonaceous matter tr siderite tr Glc 3% matrix Well compacted detrital grains; abundance of grains composed of Kao - probably products of alteration; advanced authigenic Qz overgrowths on detrital Qz, ankerite occurs as grain-size crystals, subhedral-anhedral, occ replacing Qz.	Porosity 11.3% Permeability 0.97mD Pore reduction is due to compaction (including plastic deformation of micas & ductile grains), authigenic quartz, ankerite and clay/siderite matrix.

1 Core (c) or cutting (DC)
2 Strewn sample examined
3 Thin section examined

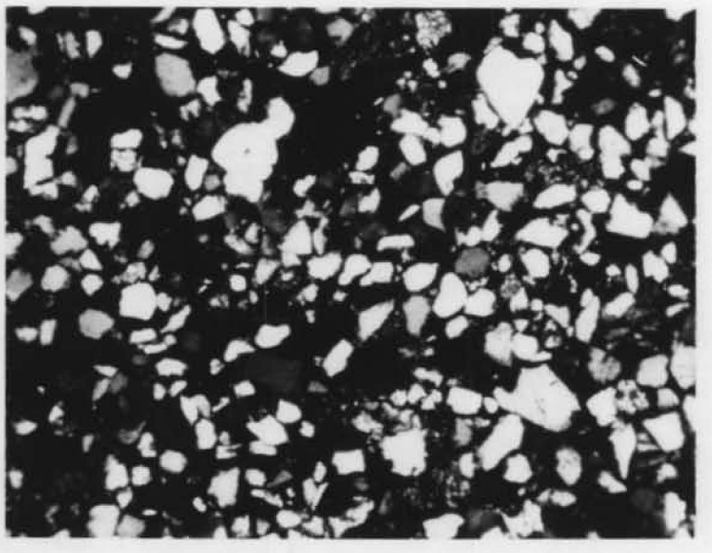
340024

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C13	X	X	9114'5"	2778.1	PC	100	Sst, sid, vf-f, mod srt, subang-subrnd, gy brn, carb partings, ripple markings; Composed of 70% Qz 15% Lcl (Kao grains, argillites, altered grains 3% Mica (Musc) 4% Heavy Min (Tourmaline, Zircon) 2% Opaque grains (carb, Fe-oxide, Py) 3% Sid tr calc (ankerite) 3% Matrix Kao occurs as pseudomorphs after detrital grains and as intergranular matrix; advanced auth Qz overgrowths on detrital quartz; Sid forms coating around detrital grains and is associated with mic/carb zones in some horizons; minor stylolites in Sid-rich zones.	Porosity 14.3% Permeability 0.71 Low visual porosity - mainly secondary Low porosity and permeability are caused by compaction, auth Qz and sid/mic matrix Kao grains form about 8% of constituents - Kao is crs & well crystalline.

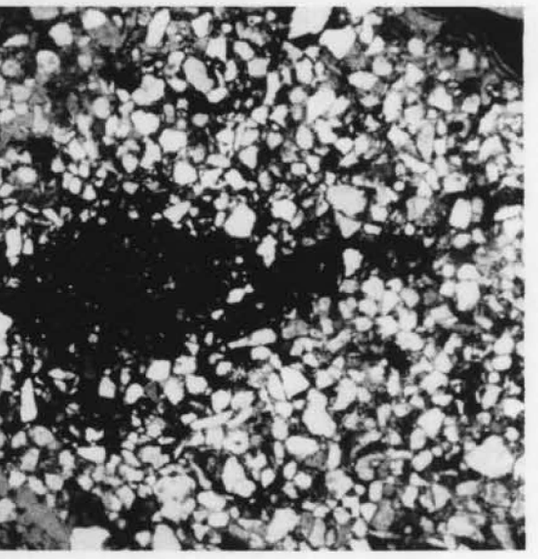
5 cm



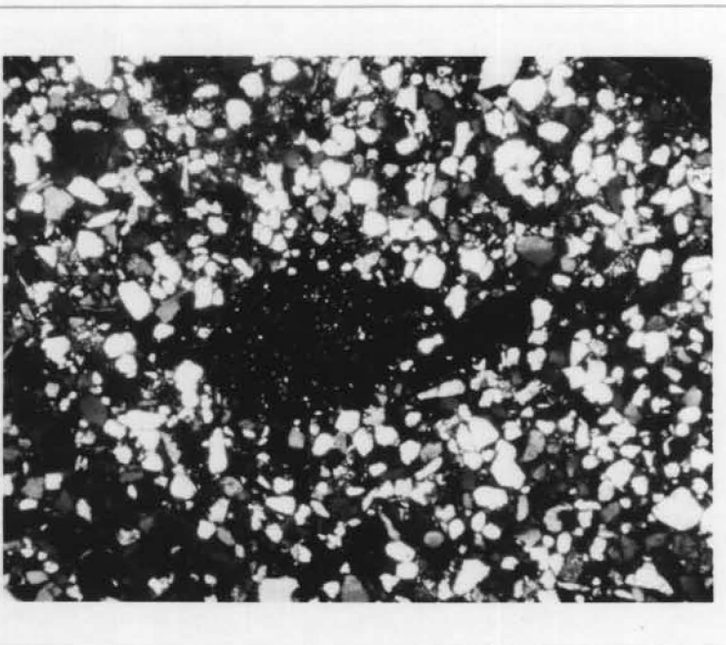
Cormorant-1 4292' depth, Eocene. Very fine argillaceous sandstone ("Boonah Sandstone") composed of quartz, lithoclasts and subordinate amounts of feldspar and mica; large proportion of the sediment consists of argillaceous/carbonaceous matrix (x 37, plane-polarised light).



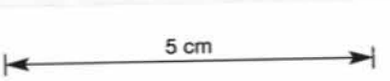
As above, crossed nicols



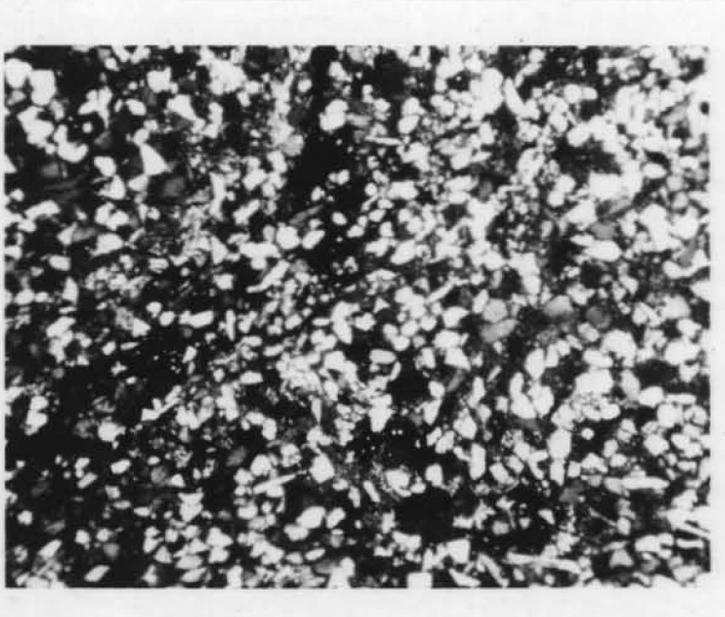
Cormorant-1 4292' depth, Eocene. Clay drape (black, centre) and siderite concretions (grey, lower left) in very fine argillaceous/ carbonaceous sandstone (x 23, plane-polarised light).



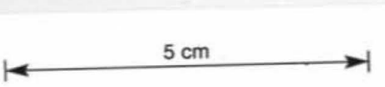
As above, crossed nicols



Cormorant-1 4294' depth, Eocene. Very fine carbonaceous sandstone("Boonah Sandstone") composed of quartz, lithoclasts, feldspars, mica and heavy minerals. Abundance of carbonaceous matter and argillaceous matrix (x 37, plane-polarised light).



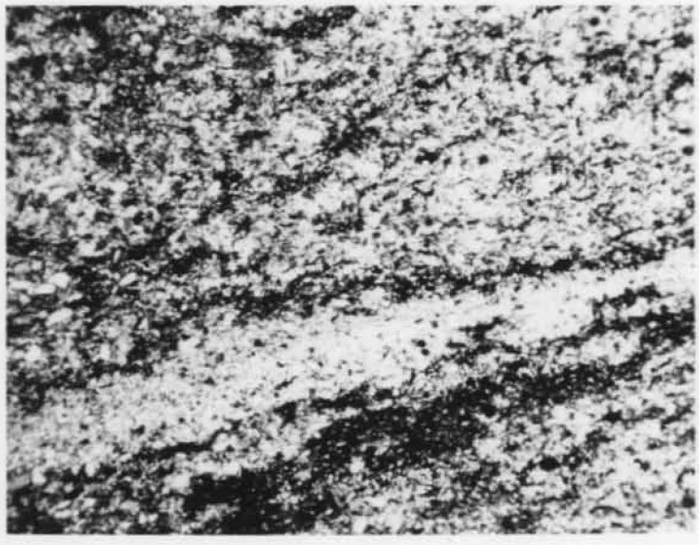
As above, crossed nicols



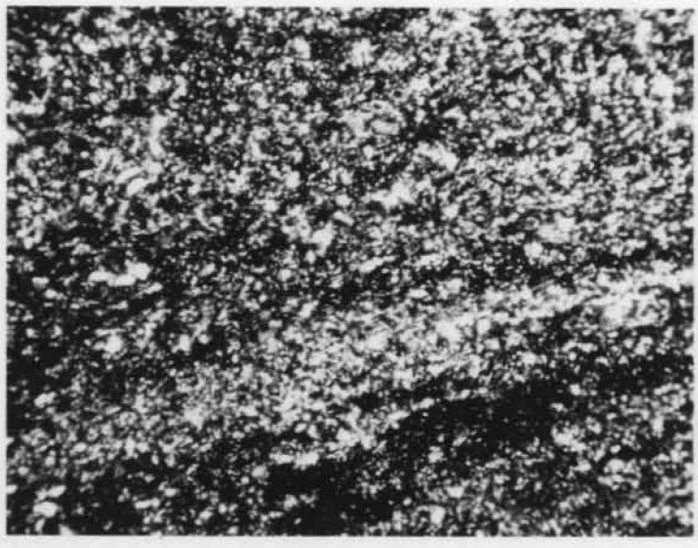
Cormorant-1 4296' depth, Eocene. Fine argillaceous sandstone ("Boonah Sandstone") composed of quartz and lithoclasts. Abundance of carbonaceous/argillaceous matrix, (x 37, plane-polarised light).

As above, ordinary light

5 cm

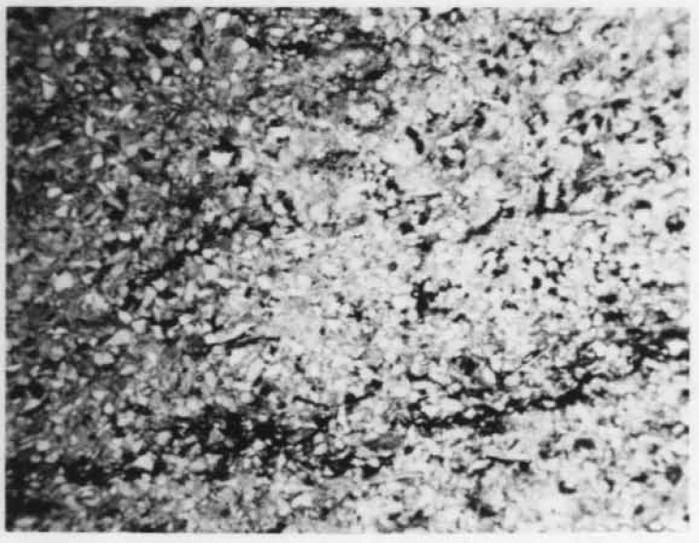


Cormorant-1, 4945' depth, Eocene. Micaceous, carbonaceous, argillaceous siltstone("Eastern View Group") composed of quartz, mica and lithoclasts. Porosity 17.8%, permeability 0.37 mD (x 37, plane-polarised light).

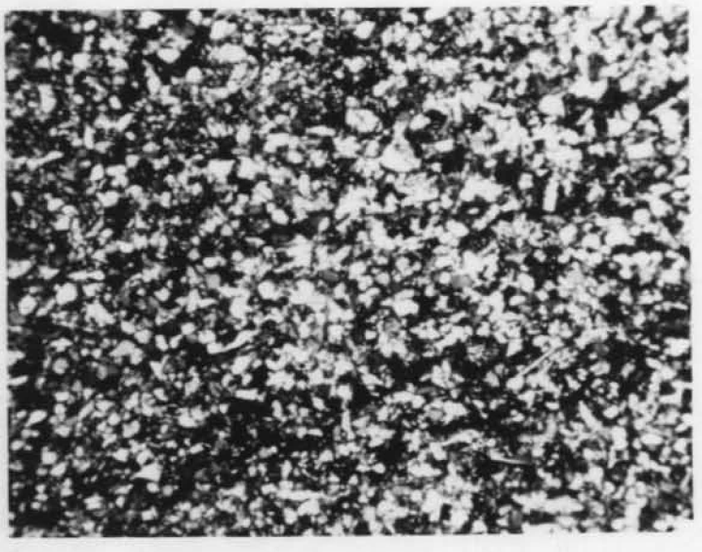


As above, crossed nicols

5 cm

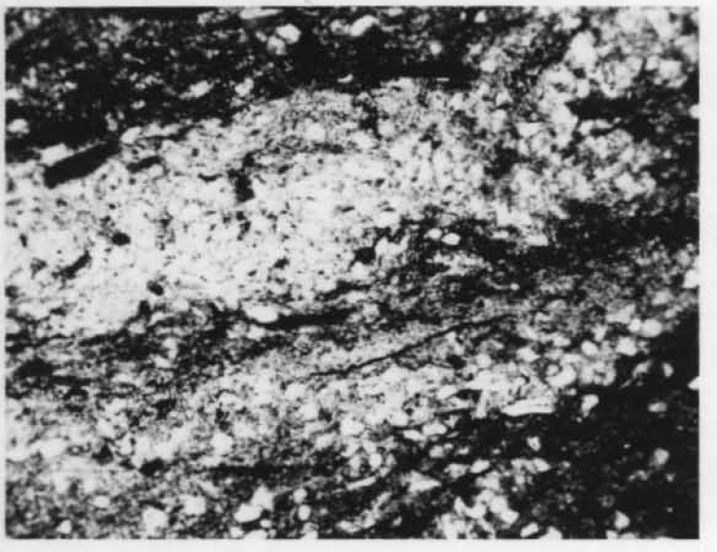


Cormorant-1 4961' depth, Eocene. Very fine silty sandstone composed of quartz, lithoclasts and feldspar; carbonaceous laminae (lower part of the microphotograph). Porosity 7.3%, permeability 23.9 mD (x 37, plane-polarised light).

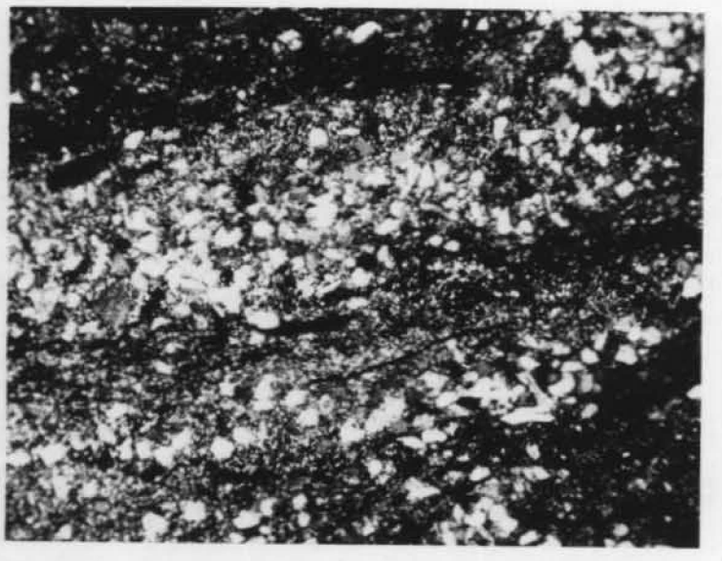


As above, crossed nicols

5 cm

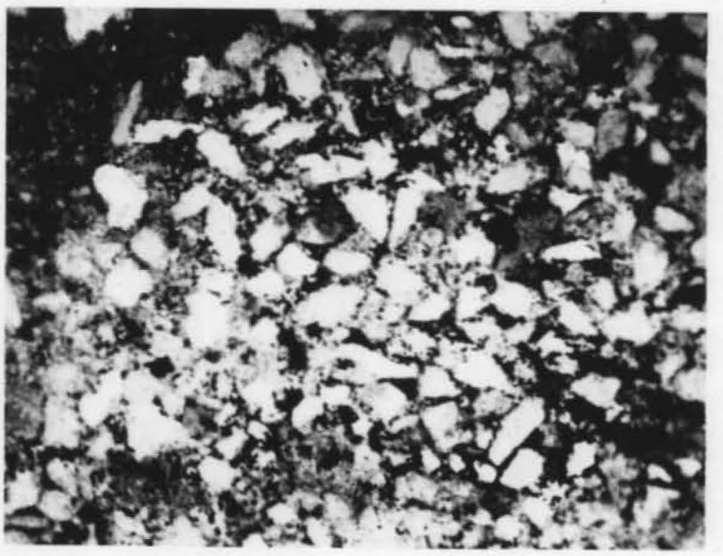


Cormorant-1 5522' depth, Eocene. Shale with lenses and laminae of very find sandstone (light). Porosity 15.0%,permeability 1.3 mD (x 37, plane-polarised light).

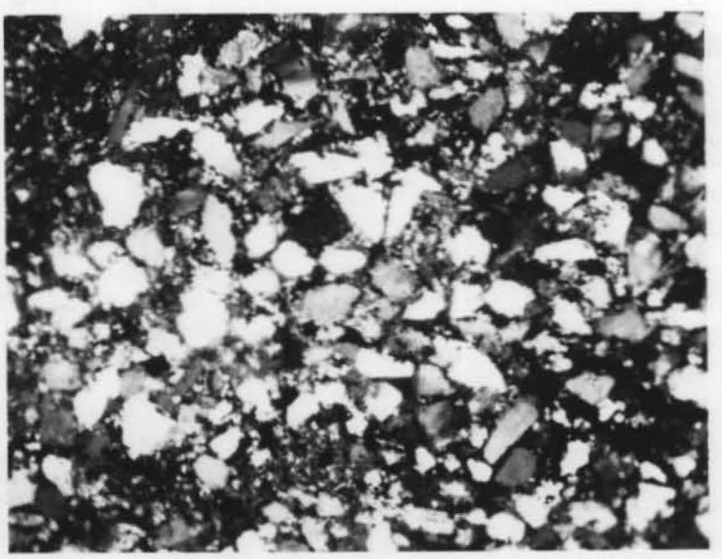


As above, crossed nicols

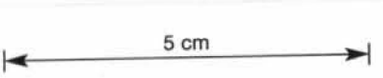
5 cm

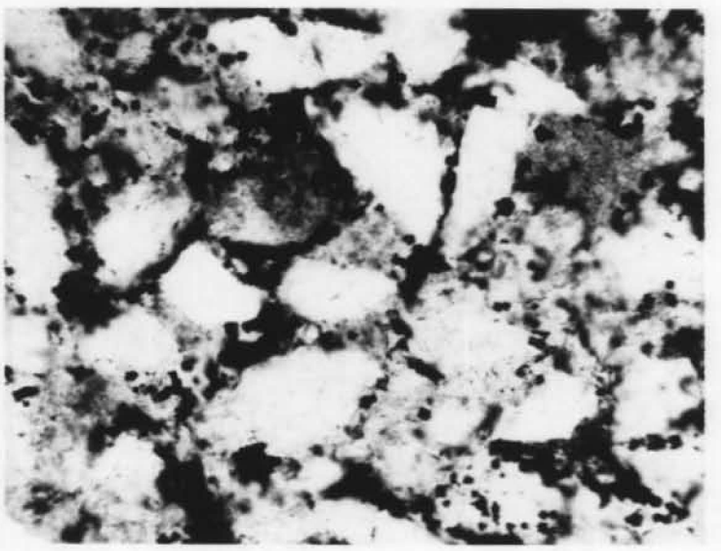


Cormorant-1 5522' depth, Eocene. Sandstone lense (light) in shale. The sandstone is cemented by pyrite(dark spots between light grains) (x 92, plane-polarised light).

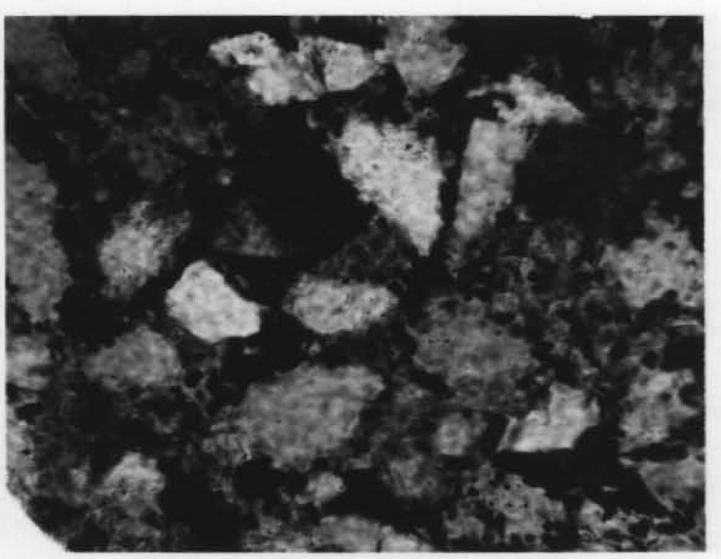


As above, crossed nicols



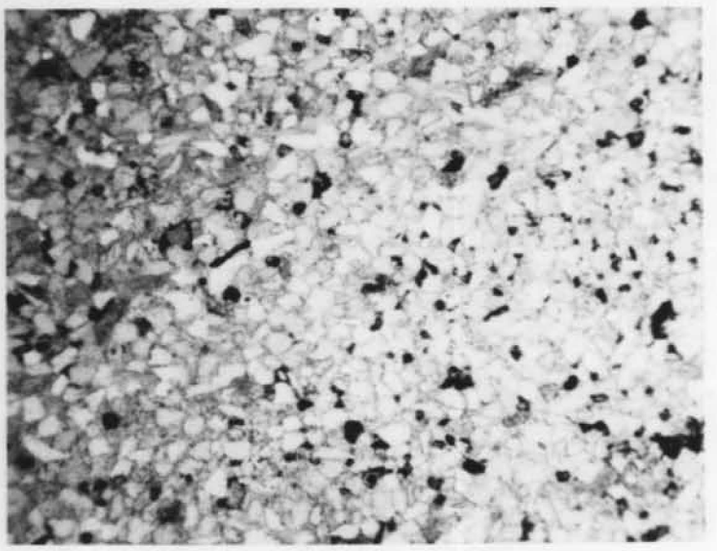


Cormorant-1 5522' depth, Eocene. Intergranular pyrite (dark) between very fine quartz grains (x 230, plane-polarised light).

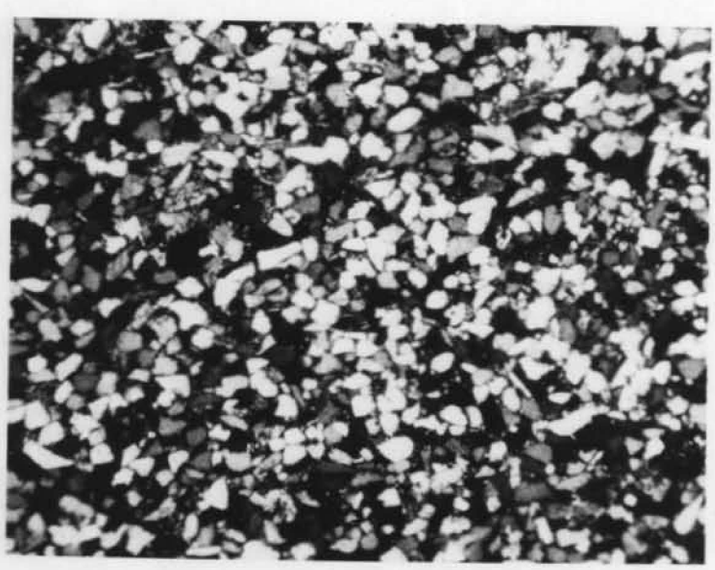


As above, crossed nicols

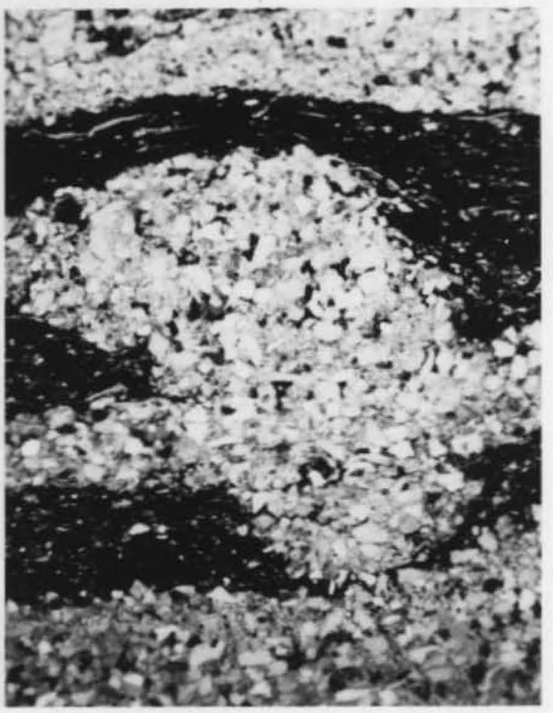
5 cm



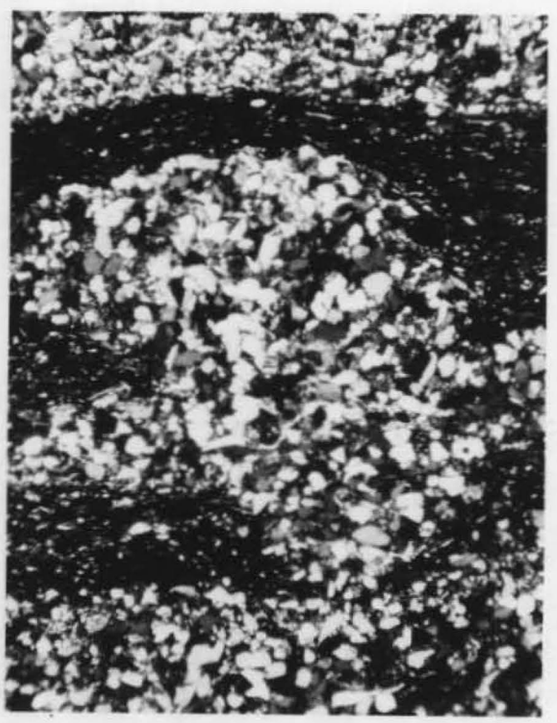
Cormorant-1 5537' depth, Eocene. Fine porous sandstone composed of quartz with subordinate amounts of feldspar and lithoclasts (pores - dark dots). Porosity 26.3%, permeability 184 mD (x 37, plane-polarised light).



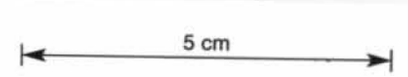
As above, crossed nicols

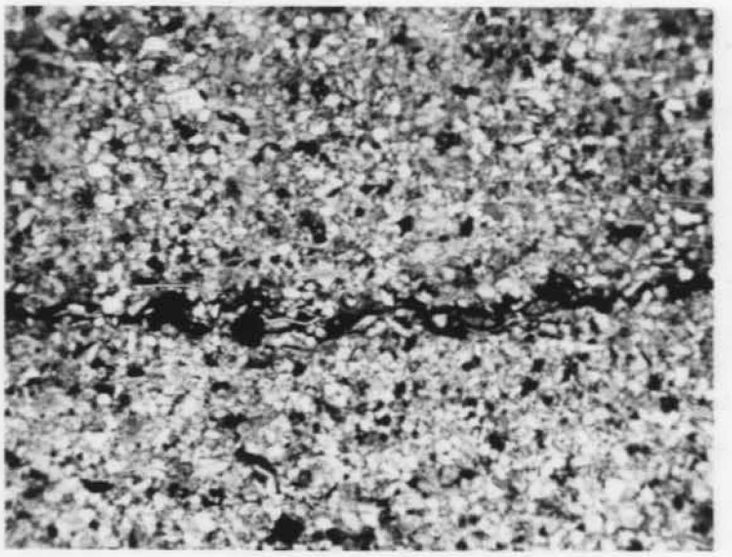


Cormorant-1 5537' depth, Eocene. Fine sandstone with carbonaceous laminae disarranged by a burrow (x 37, plane-polarised light).

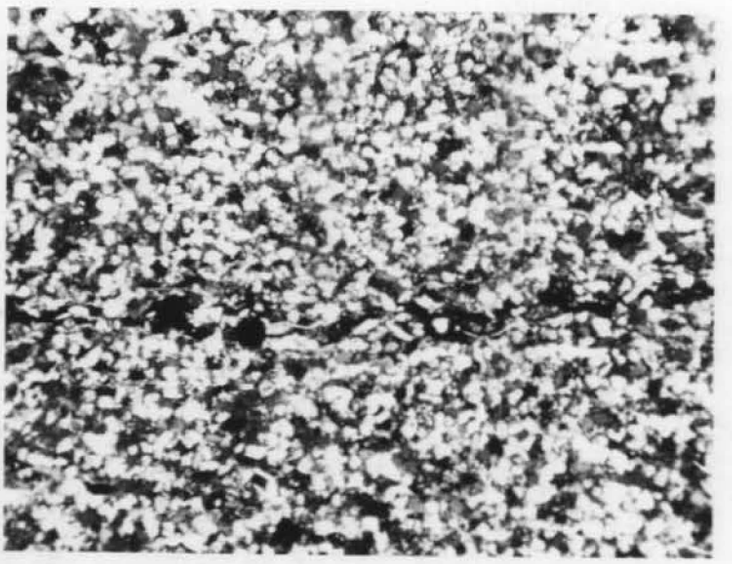


As above, crossed nicols

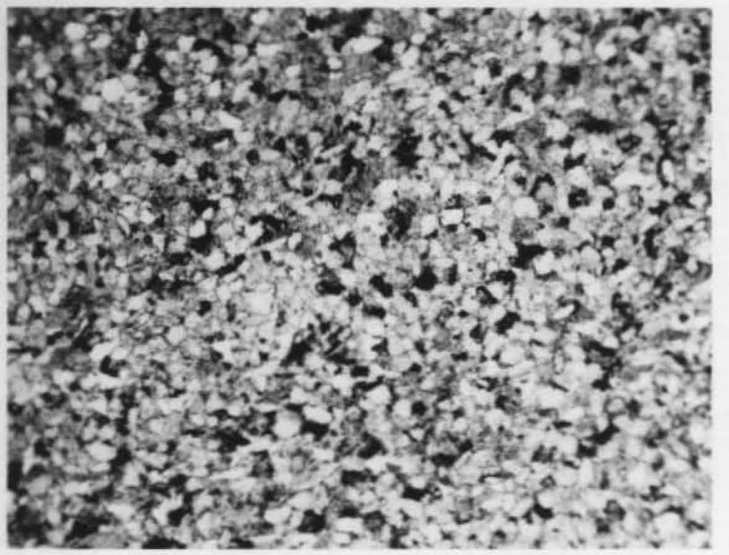




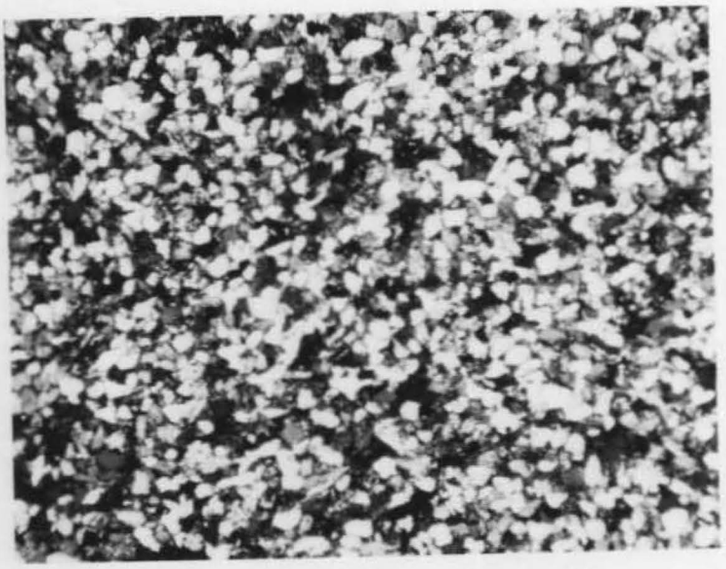
Cormorant-1 5541' depth, Eocene. Very fine, well-sorted sandstone with carbonaceous laminae (black, middle of the microphotograph). Porosity 26.4%, permeability 64 mD (x 37, plane-polarised light).



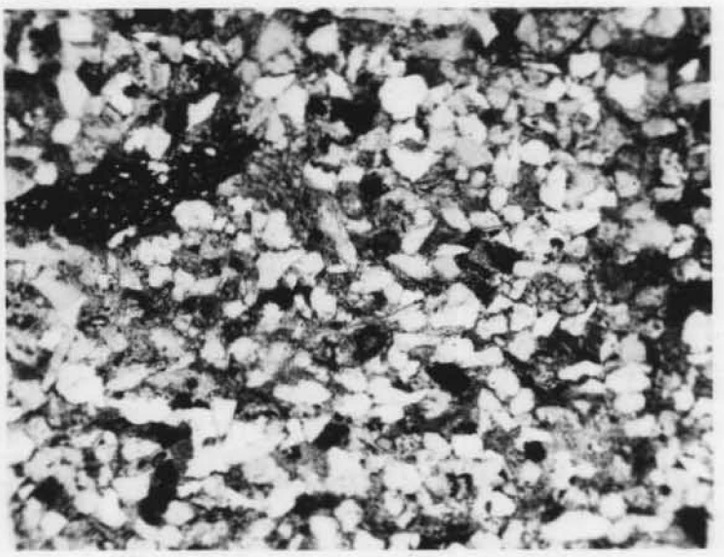
As above, crossed nicols



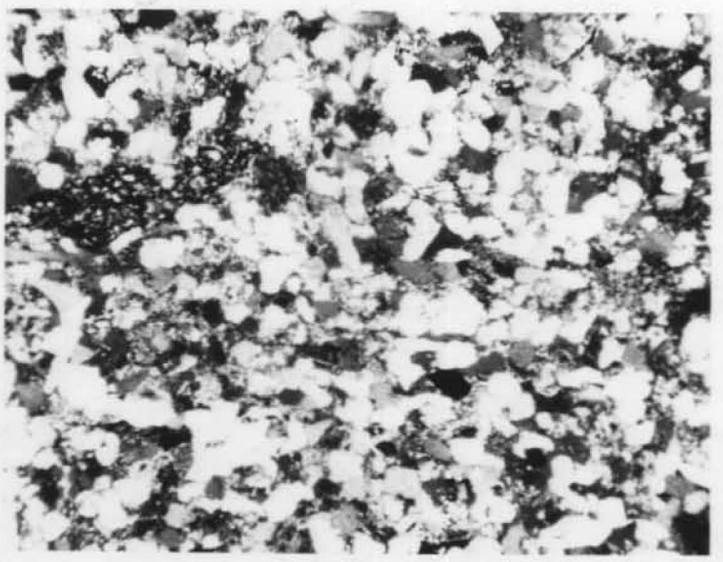
Cormorant-1 6015' depth, Eocene. Porous and permeable very fine sandstone (pores = dark spots). Porosity 27.7%, permeability 111 mD (x 37, plane-polarised light).



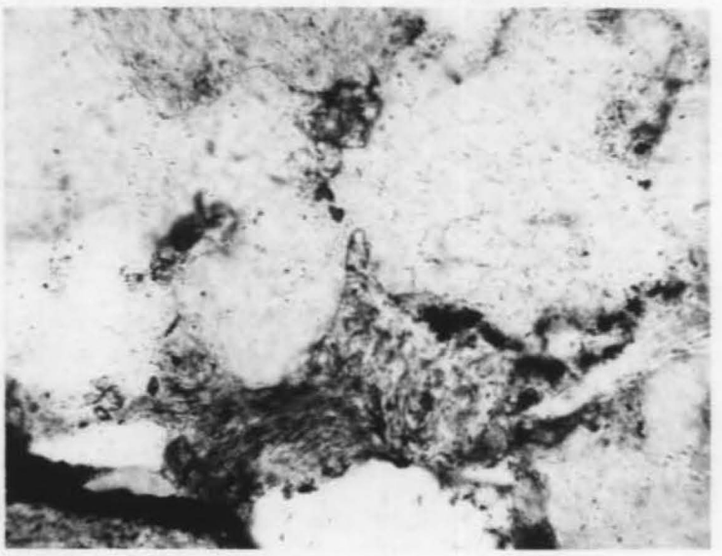
As above, crossed nicols



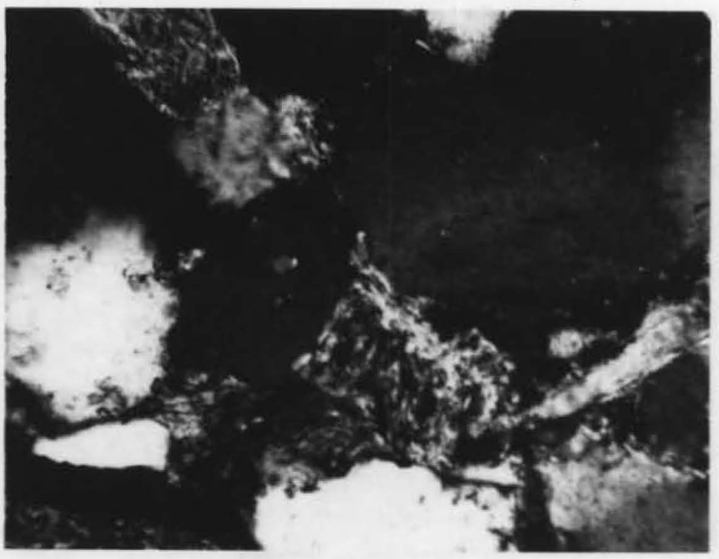
Cormorant-1 7317' depth, Eocene. Fine well sorted sandstone with carbonaceous stringers and clay drapes (upper left). Porosity 14.6%, permeability 0.69 mD (x 37, plane-polarised light).



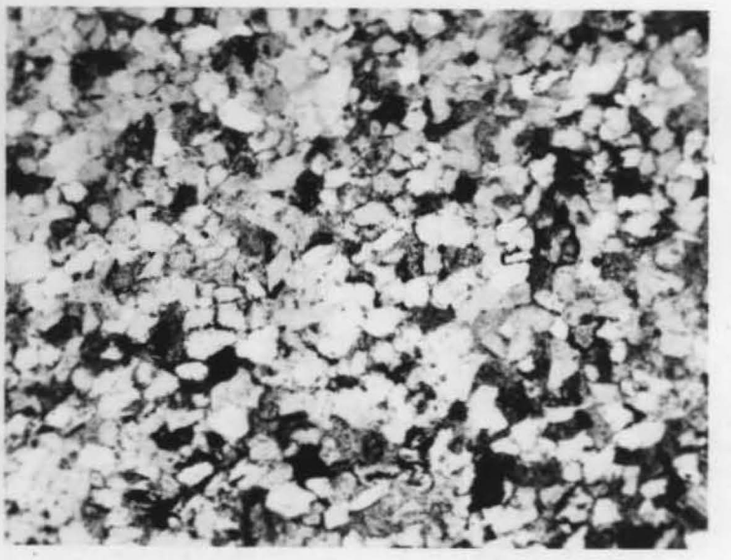
As above, crossed nicols



Cormorant-1 7317' depth, Eocene. Plastically deformed mica (grey, lower centre) squeezed between hard grains (white) (x 230, plane-polarised light).

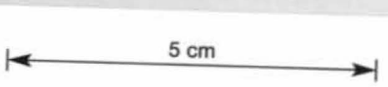


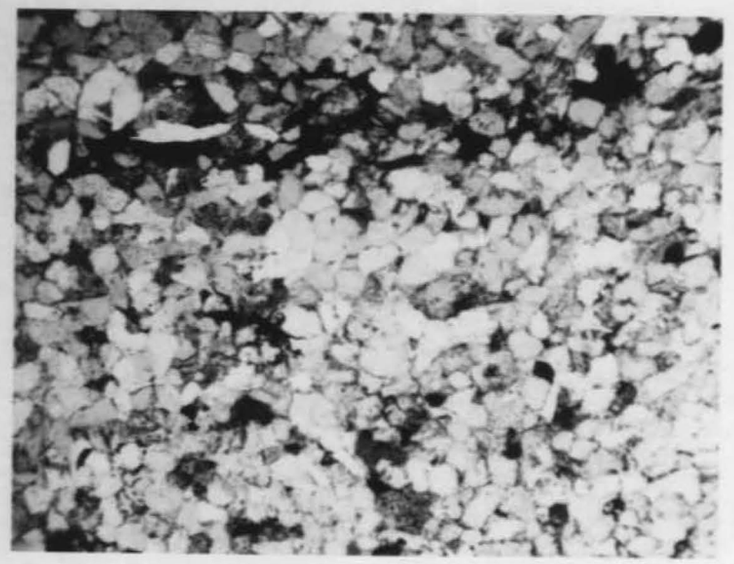
As above, crossed nicols



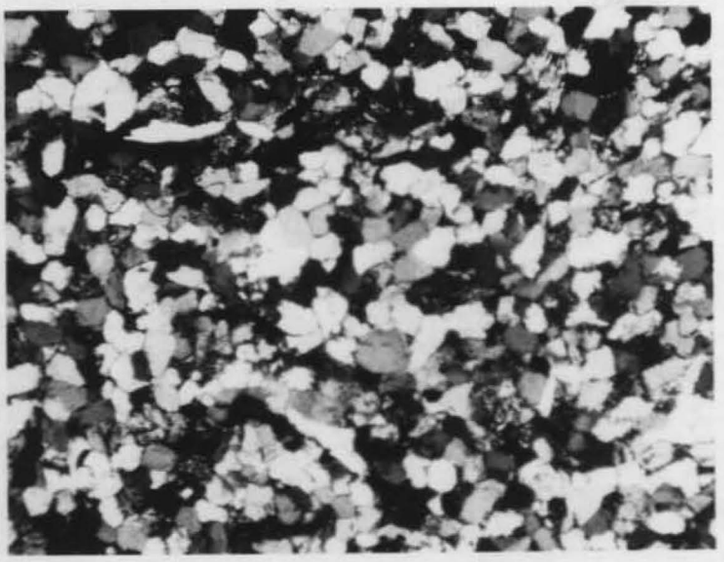
Cormorant-1 8685' depth, Eocene. Fine sandstone composed of quartz and lithoclasts; lithified by ankerite and authigenic quartz overgrowths. Porosity 11.3%, permeability 0.97 mD (x 37, plane-polarised light).

As above, crossed nicols

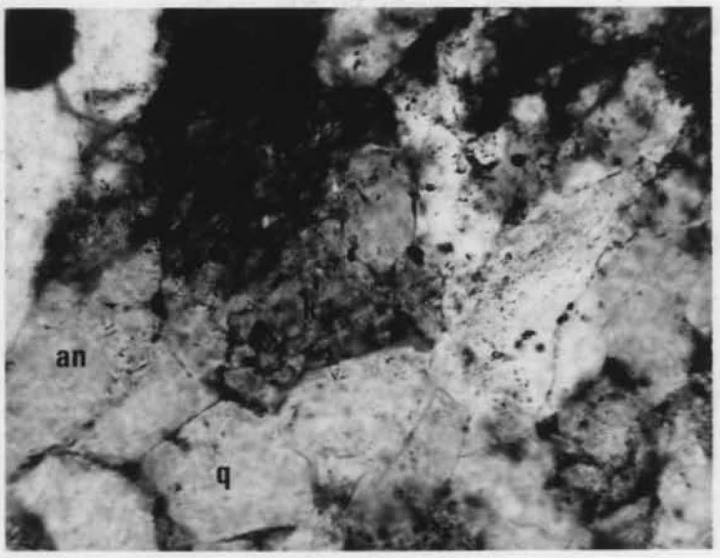




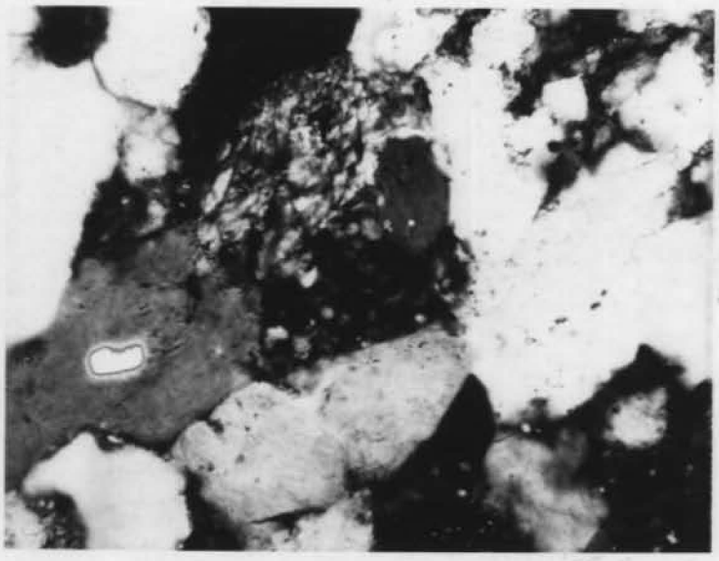
Cormorant-1 8685' depth, Eocene. Carbonaceous lamina (black, top) in fine sandstone composed of quartz and lithoclasts (x 37, plane-polarised light).



As above, crossed nicols



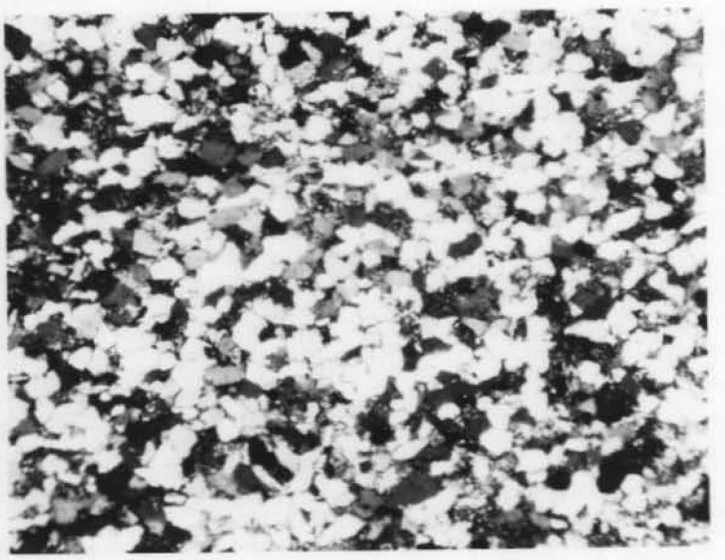
Cormorant-1 8685' depth, Eocene. Ankerite (an), quartz (q) with authigenic overgrowths and kaolinite (k) in fine sandstone composed of quartz and lithoclasts (x 230, plane-polarised light).



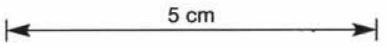
As above, crossed nicols

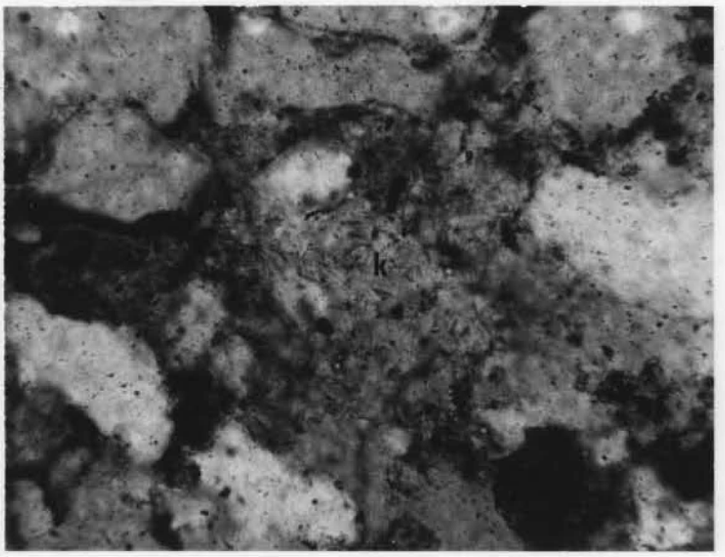
5 cm

Cormorant-1 9114.45' depth, Paleocene. Fine lithic sandstone composed of quartz, lithoclasts, micas and heavy minerals; moderately abundant grains composed of kaolinite. Porosity 14.3%, permeability 0.71 mD (x 37, plane-polarised light).

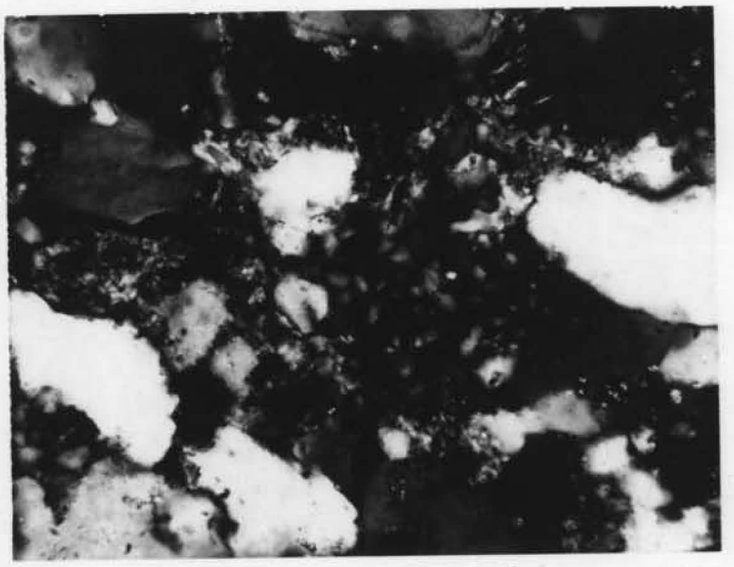


As above, crossed nicols





Cormorant-1 9114.45'depth, Paleocene. Grain of kaolinite (probably pseudomorph after feldspar) in fine grained lithic sandstone (x 230, plane-polarised light).



As above, crossed nicols