SDA 339

Petrologic/diagenetic investigation of eight core samples from Narimba-1 Bass Basin, Australia

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347002

Contents

Illustrations

347003

Plates

1	Narimba-1	9278' depth	Very fine lithic sandstone
2	"	9278' "	Siderite nodule in very fine sandstone
3	"	9278' "	Quartz grain partly covered by siderite crystals
4	"	9278' "	Feldspar partly altered to kaolinite
5	"	9286' "	Laminated very fine/fine sandstone
6	"	9286' "	Carbonaceous stringers, mica flakes and siderite in very fine sandstone
7	"	9286' "	Contorted carbonaceous matter and slightly bent muscovite
8	"	9298' "	Very fine micaceous sandstone
9	"	9302' "	Very fine micaceous sandstone
10	"	9544' "	Siderite nodules in very fine micaceous sandstone
11	"	9548' "	Fine/medium sandstone
12	"	9548' "	Chert grain surrounded by quartz grains with authigenic overgrowths
13	"	9548' "	Plastically deformed lithoclast
14	"	9548' "	Calcareous cement and authigenic quartz overgrowths
15	"	9560' "	Carbonaceous/micaceous lamina in very fine argillaceous sandstone
16	"	9560' "	Argillaceous matrix in very fine argillaceous sandstone
17	"	9560' "	Coarse sandstone
18	"	9750' "	Clay drape in coarse sandstone
19	"	9750' "	Quartz grains with authigenic overgrowths.

20	Narimba-1	9750' depth	Kaolinite in coarse sandstone
21	"	9750' "	Primary porosity in coarse sandstone
22	"	9750' "	Diagenetic kaolinite between detrital grains.

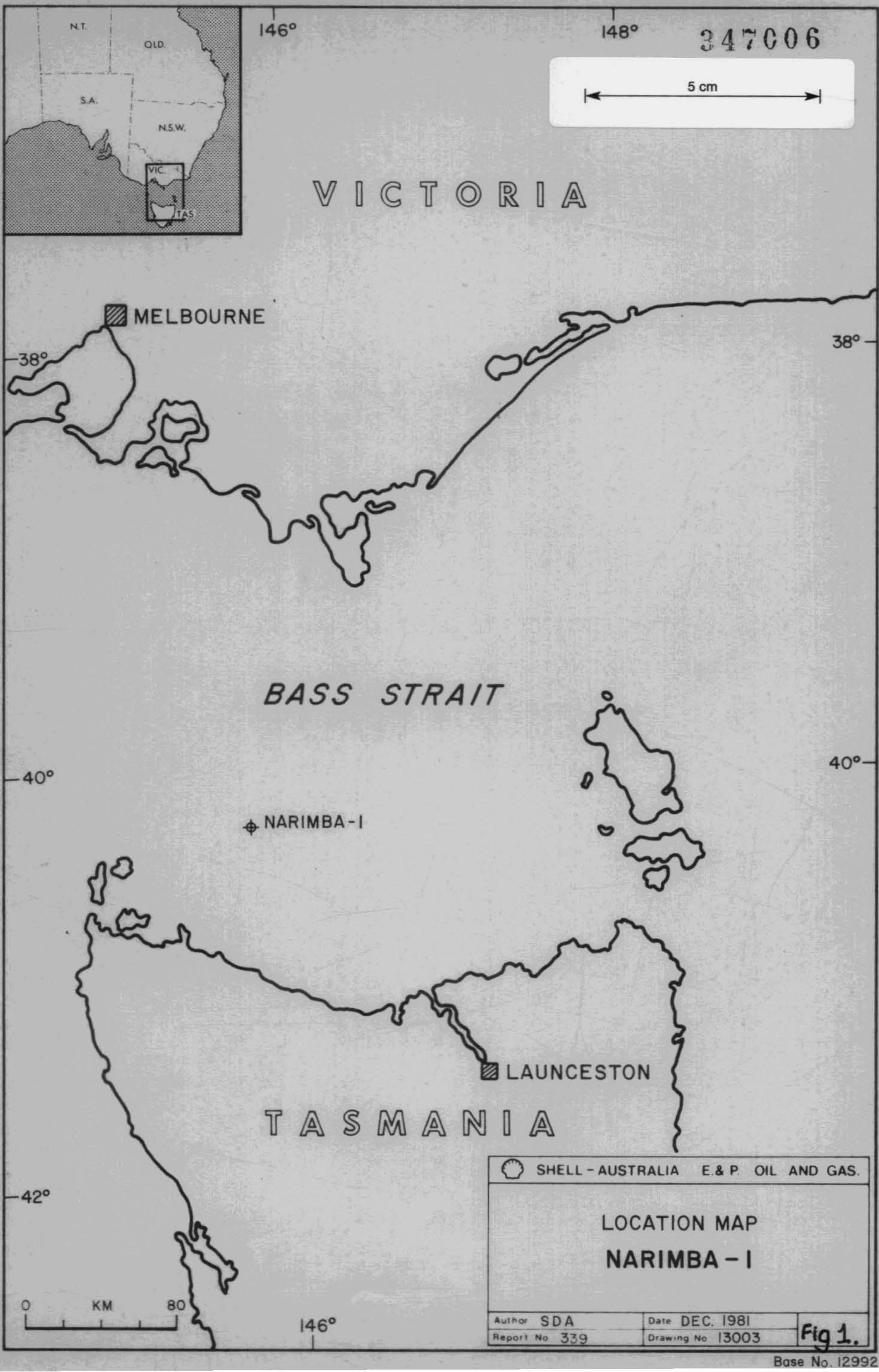
Summary

Eight core samples from Narimba-1 were investigated petrologically in order to determine their composition, diagenesis and reservoir characteristics (depth range 9278-9750'). The samples were very fine to medium/coarse sandstones ranging in composition from argillaceous/carbonaceous to relatively clean quartz clastics.

The clean sandstones (2 samples) are medium to coarse grained, composed of quartz and subordinate amounts of feldspar, lithoclasts and micas. Kaolinite is common clay mineral in these sandstones. The porosities of the two samples are 19.2% and 19.4%; permeabilities are 0.95mD and 54mD. The porosity reduction is caused by authigenic quartz overgrowths and the permeability reduction by the presence of intergranular diagenetic kaolinite.

The fine to very fine sandstones are usually micaceous and argillaceous, some with considerable amount of carbonaceous matter. The porosities of these sandstones range from 9.4 to 16.7% and permeabilities are mainly less than 1mD. The porosity reduction is caused by compaction, the presence of kaolinite, siderite and depositional matrix.

At the depth range investigated the fine argillaceous, micaceous, sandstones have virtually no effective permeability and only the clean medium-coarse sandstones have retained their primary porosity and economic permeability.



Base No. 12992

1. Introduction

As part of a study of the reservoir characteristics of sandstones from the Gippsland and Bass Basins eight samples from Narimba-1 were examined petrologically with a view to determining their composition and diagenesis (depth 9278-9750').

The Esso/BHP well Narimba-1 was drilled in the Bass Basin in 1973 (Lat 40°16'18.1"S, Long 145°43'56.6"E, see Fig. 1). The well penetrated 1650' of Miocene mudstone and calcarenite, 916' of Oligocene calcirudite and mudstone, 456' of Upper Eocene shale and 5119' of mixed clastics and coal of Middle-Lower Eocene age known as the Eastern View Coal Measures or Eastern View Group. The well terminated in Eocene clastics at 11003' (3360m) depth bdf. No commercial hydrocarbons were encountered.

2. Material Investigated and Mode of Presentation

The samples were porosity/permeability plugs cut from Cores 1, 2 and 3. From the ends of these plugs thin sections were prepared. The investigation was carried out using polarising and reflected light microscopes. The rock samples (ends of plugs) were obtained from the Bureau of Mineral Resources Core and Cutting Laboratory, on condition that the results of the investigation would be reported to the Bureau of Mineral Resources. The porosity and permeability data were also obtained from the Bureau of Mineral Resources.

The petrological descriptions of individual samples are presented in Appendix 1. Twenty-two polaroid-microphotographs are attached to illustrate some textural, petrological and diagenetic features. The microphotographs (magnification x37) are "standards" to illustrate the composition and textural/structural features of a sandstone; photographs of this magnification also serve for the comparison of grain-size between different sandstone samples. Photomicrographs of larger magnification (x92, x230 and x370) are used to illustrate some specific features of the sandstones, mainly diagenetic or petrologic.

3. Composition and Diagenesis of Sediments

3.1 Samples examined

Eight samples were investigated covering an interval from 9278 - 9750' depth. Four samples were from Core 1, three samples from Core 2 and one sample from Core 3 (Appendix 1). All the samples are from Eastern View Coal Measures and are of Eocene age.

3.2 Composition of sandstones

Six samples are very fine-fine lithic sandstones and only two medium to coarse grained sandstone samples (9548' & 9750' depth) can be considered to represent potential reservoirs.

Medium-coarse sandstones (Pl 11, 17) are composed of quartz/feldspar, lithoclasts and minor amounts of micas & heavy minerals; there is an appreciable amount of kaolinite, both intergranular and as grain-size "pods" (Pl 20) which are probably pseudomorphs after some other minerals. Quartz makes up 86-90% of the framework mineral and is predominantly of single optical orientation. Chert (Pl 12) and polycrystalline quartz, the latter mainly metaquartzite, is also present. The feldspar is orthoclase and less commonly plagioclase, the micas are mainly muscovites. Heavy minerals are mainly tourmaline and zircon. The quartz has well developed authigenic overgrowths. Clay drapes are present in the sample from 9750' depth (Pl 18).

The fine sandstones (Pl 1, 5, 8, 9) are composed of a greater proportion of lithoclasts and micas and contain appreciable amounts of siderite (Pl 2, 3, 10) and variable amounts of carbonaceous matter (Pl 6, 15). The feldspars are orthoclase, plagioclase and occasionally microcline (9544' depth). Red biotite is common as a mica mineral and is usually associated with layers rich in carbonaceous stringers (Pl 6). Tourmaline, zircon and rutile are the most common heavy minerals. The lithoclasts are argillites, altered grains (some probably altered volcanoclasts), grains composed of phyllosilicates and quartz/mica aggregates. Siderite occurs as nodules (Pl 2, 10), as individual crystals within the matrix, or intergranularly and as a coating around the detrital grain (Pl 3).

3.3 Diagenesis

Authigenic quartz is present to an advanced stage in the medium/coarse sandstones (Pl 19). Siderite formation is widespread in the very fine-fine sandstones. This siderite is a diagenetically early mineral. Alteration of feldspars (particularly orthoclase) to kaolinite (Pl 4) is very common. Compaction is advanced as evidenced by deformation of the micas and the tight packing of detrital grains, particularly of the lithoclasts (Pl 13). Some carbonate, probably dolomite, is present in samples 9544' and 9548' (Pl 14). The following paragenesis has been established for the sediments investigated:

- siderite formation,
- authigenic quartz growths,
- introduction of carbonate (dolomite).

Kaolinite formation took place prior to and post authigenic quartz formation (Pl 22). Compaction is partly post authigenic quartz.

3.4 Porosity and Permeability

Porosities of the investigated samples range from 9.4% to 19.4% and permeabilities from less than 0.1 mD to 54 mD; actually five out of the eight samples investigated had a permeability less than 0.1 mD and only the one sample of medium/coarse sandstone from 9750' depth had a fair permeability, i.e. 54 mD.

The low porosity can be attributed to four main causes which, in order of significance, are compaction, authigenic quartz formation, siderite cementation and the presence of intergranular matrix (kaolinite/carbonaceous matter). The permeability is strongly influenced by grain-size and by the abundance of phyllosilicates. All the sandstones samples of very low permeability examined are very fine and micaceous.

4. Concluding Remarks

Examination of the samples has shown that compaction and deposition of siderite are the main diagenetic processes in the fine micaceous sandstones. These combined with poor textural characteristics (very fine grain size) make these sandstones rather poor potential reservoirs.

The medium-coarse grained sandstones are principally affected by authigenic quartz cementation and diagenetic kaolinite formation. Both these diagenetic factors have reduced the porosity and permeability of the sandstone but have not eliminated it. Some relatively large primary pores could be observed microscopically in the deepest sample examined, (9750', Pl 21).

The BMR porosity/permeability data (Ref 1) shows that sandstones with better porosity/permeability than those of the samples investigated are present. Furthermore the wireline logs show that cores were not cut in the best potential reservoirs and that sandstones with better reservoir characteristics are plentiful in Narimba-1 especially at shallower horizons.

From the above it can be concluded that there is no deficiency of good potential reservoirs in Narimba-1.

5. References

1. Narimba No. 1 - Well Completion Report Tasmania (T/5P), Australia by Roberts V.A., Esso Exploration & Production Australia Inc., February 1974.

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

Appendix 1. Petrologic description of samples from Narimba-1.

NARIMBA-1

347015

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

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C1	X	X	9278	2827.9	EO(L-M)	100	Sst, lithic, vf-f, well srt, subang-subrnd; Composed of:- 55% Qz; Polyqz, Cht 5% Fld (Plag & Orth) 20% Lcl (argillites, altered grains, phyllites) 5% Micas (Musc & brn Biot) 1% Heavy & Opaque Minerals (Tourm, Zircon, Rutile) 4% Matrix (mainly Kao) 6% Calc (Sid) Siderite occurs as nodules, as disseminated crystals and as coating on detrital grains; detrital grains are tightly packed, micas and some lithoclasts are squeezed and plastically deformed between hard grains.	Porosity 13.1% Permeability less than 0.1mD Very low visual porosity. Main diagnetic processes are compaction, alteration of minerals (kaolinisation) and deposition of siderite. Low porosity is due to compaction, the presence of matrix and calcareous matter.
C1	X	X	9286	2830.4	EO(L-M)	100	Sst, mic, carb, vf-f, srt within Lam, subang-subrnd, lam, ?bioturbated, buff; Composed of:- 55% Qz 5% Polyqz 3% Fld (Orth, Plag) 20% Lcl (Argillites & yellow phyllosilicates) 4% Kao (pseudomorphs) tr Heavy Min (blue Tourm)	Porosity 9.4% Permeability less than 0.1mD Virtually no visible porosity. Main diagenetic processes, deposition of siderite, formation of kaolinite, compaction. Porosity reduction is due to compaction, pore fill by siderite, the presence of matrix minerals (mainly kaolinite), carbonaceous matter and phyllosilicates.

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

347016

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
							3% Phyllosilicates (Musc & Biot) tr Glc 3% Calc (Sid) 5% Carbonaceous matter 2% Matrix Biot red brown, up to 0.8mm long, Fld mainly altered, abundance of carbonaceous stringers particularly in slt-vf Lam.	
C1	X	X	9298	2834.0	EO(L-M)	100	Sst, mic, vf-f, occ coarser grains, srt, subang-subrnd, Lam, lt beige; Composed of:- 60% Qz 10% Polyqz (Vein Qz, Cht) 8% Fld (Orth & Plag) 12% Lcl (Argillites) 6% Phyllosilicates (Musc, Biot, Chlorite) tr Heavy Mineral (Tourm, Zircon) tr Dk Mineral (Py) 4% Carbonaceous matter Carb matter occurs as anastomosing stringers and occ as pore-fill; advanced auth Qz on some Qz grains; detrital grains are compacted; intergranular space is occupied by phyllosilicates (mainly Biot) and carbonaceous matter; some feldspars severely altered to Kao.	Porosity 12.3% Permeability less than 0.1% Very low visual porosity. Main diagenetic processes are compaction, alteration of feldspars, and formation of authigenic Qz overgrowths. Low porosity is due to compaction particularly squeezing of phyllosilicates into intergranular space, by the presence of carb matter and by auth Qz overgrowths.

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

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
C1	X	X	9302	2835.2	EO(L-M)	100	Sst, arg, mic, vf, srt, subang-subrnd, lam, beige; Composed of: 65% Qz 5% Polyqz 6% Fld (Orth, Plag) 10% Lcl (Argillite, altered grains) 5% Mica (Musc, red Biot) tr Glc 1% Heavy Min (Tourm, Zircon, Rutile, Monazite) 3% Calc (Sid) 1% Carb matter 4% Matrix Advanced auth Qz overgrowths on some Qz grains, severe corrosion of detrital Qz and Fld in Lam rich in Biot/Sid; Fld fresh to altered.	Porosity 11.4% Permeability less than 0.1mD Very low visual porosity. Main diagenetic processes are authigenic Qz formation in non-calcareous, non-micaceous parts of the sandstone, and compaction including dissolution of grains in sid/mic part of the sediment. Pore reduction is due to pore fill by auth Qz, the presence of siderite and compaction/dissolution including squeezing of micas between the hard grains.
C2	X	X	9544	2909	EO(L-M)	100	Sst, mic, sid, f, srt, subang-subrnd, lam, clay drapes, beige; Composed of:- 65% Qz 5% Polyqz (Vein Qz, Cht) 6% Fld (Plag, Mcr, Orth) 7% Lcl (Argillites, altered grains, Kao grains)	Porosity 16.7% Permeability 2.2mD Rather low visual porosity. Main diagenetic processes and deposition of siderite, formations of authigenic Qz overgrowths, formation of kaolinitic (authigenic and diagenetic) and

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

347018

SAMPLE 1	2	3	DEPTH FEET	METRES	AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
							6% Phyllosilicates (Musc, red Biot, occ chlorite) 1% Heavy & Opaque Min (Tourm, Rutile) 2% Carbonaceous matter 4% Calc (Sid, Dol) 4% Matrix (Kao) Kao occurs as grains (?pseudomorphs) and as intergranular pore fill; advanced auth Qz on some Qz grains; feldspars are fresh to altered, lamination is caused by concentration of sid nodules and mica flakes in thin laminae; most micas bent or contorted, clay drapes flattened.	compaction including plastic deformation of phyllosilicates and some lithoclasts. Pore reduction is due to authigenic quartz, compaction and the presence of intergranular kaolinite.
C2	X	X	9548	2910.2	EO(L-M)	100	Sst, qz, f-m, mod srt, subang-subrnd, lt gy; Composed of: 75% Qz 5% Polyqz (Vein Qz, Cht (ca 1%)) 7% Fld (Orth, Plag) 5% Lcl (Argillite, Vo) 2% Mica (Musc) 1% Heavy Min (Tourm, Zircon, ?Monazite) 1% Calc (sid and Dol or Calcite) 4% Kao	Porosity 19.2% Permeability 0.95mD horiz. 8.6 mD vert. Fair visual porosity - mainly secondary. Main diagenetic processes are formation of authigenic quartz overgrowths, compaction of micas and lithoclasts, kaolinite formation, deposition of siderite (diagenetically early) and introduction of Dol or calcite

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

347019

SAMPLE			DEPTH		AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
1	2	3	FEET	METRES				
							Interlocking quartz grains (when adjacent) due to authigenic overgrowths; minor amount of siderite and dolomite (or calcite); feldspars fresh to altered (kaolinised).	(diagenetically late). Pore reduction is due to authigenic quartz, intergranular kaolinite, compaction of micas/lithoclasts and calcareous cementation by calcareous cement (ca 1% of pore reduction.)
C2	X	X	9560	2913.9	EO(L-M)	100	Sst, arg, sid, vf (av 0.08mm), well srt, subang-subrnd, lam, gy; Composed of:- 55% Qz 5% Polyqz (Vein Qz) 8% Fld (Orth, Plag) 18% Lcl (Argillite, altered grains) 2% Micas (Musc, Biot) and gn? Chlorite) tr Heavy Min (Tourmaline, Zircon, Rutile) 5% Calc (sid nodules) 1% Opaque matter (mainly carb flakes) 6% Matrix (kao, Sid, carb matter, sericite) Siderite occurs as nodules, as disseminated crystals, and as pore filling mineral; authigenic Qz overgrowths on some Qz grains; tightly packed grains; Lam with stringers of carb matter.	Porosity 10% Permeability less than 0.1mD Very low visual porosity. Main diagenetic processes are introduction of siderite, growth of authigenic Qz overgrowths, compaction and formation of kaolinite. Low porosity is due to the presence of siderite and matrix, compaction or (to a lesser degree) the formation of authigenic quartz.

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

347020

SAMPLE 1	2	3	DEPTH FEET	METRES	AGE	%	DESCRIPTION	DIAGENESIS/OTHER COMMENTS
C2	X	X	9750	2971.8	EO(L-M)	100	Sst, qz, m-v crs, mod srt, subrnd, lt beige; Composed of:- 80% Qz 2% Polyqz (Vein Qz) 2% Cht 3% Fld (Orth, occ Plag) 5% Lcl (Vo, Qz/Mica aggregate) tr Mica tr Heavy & Opaque Min (Tourm, Magnetite) 2% Clay drapes 6% Matrix (Kao, well crystalline) tr carbonaceous matter. Well developed and regular authigenic Qz overgrowths on detrital Qz, occ carb matter fills pores and bordered by auth Qz; Fld variable altered, clay drapes plastically deformed.	Porosity 19.4% Permeability 54mD Visual porosity good but not representative (large cavities - human made). Some primary porosity. Main diagenetic processes are growth of authigenic quartz on detrital quartz grains, formation of kaolinite and compaction. Pore reduction is due to authigenic quartz, kaolinite matrix and compaction.

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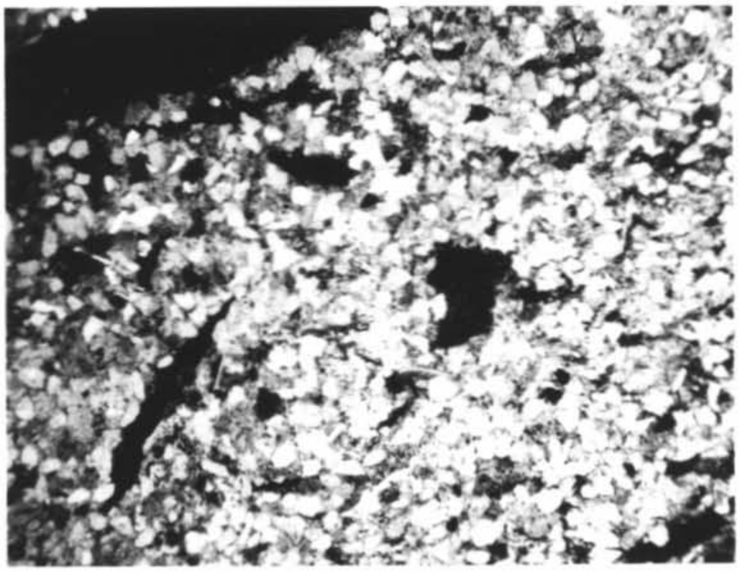
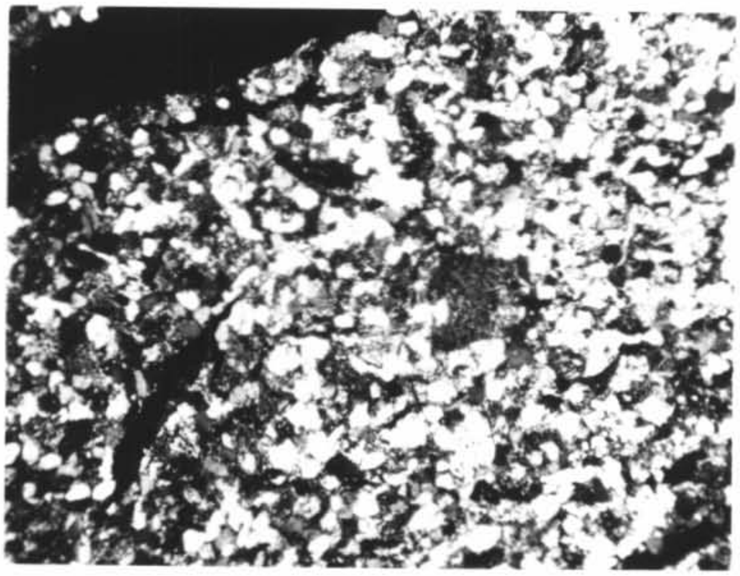


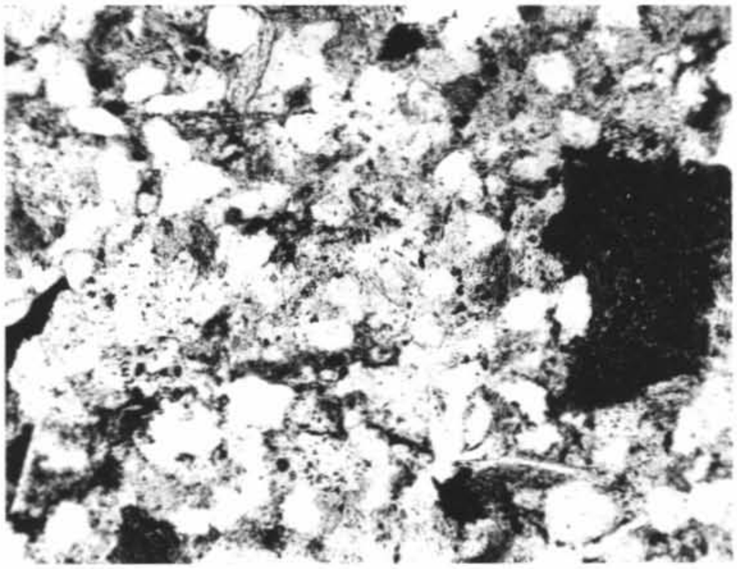
Narimba-1 9278' depth, L-M Eocene. Very fine lithic sandstone with carbonaceous stringers (top left) and siderite nodules (centre). Porosity 13.1%, permeability less than 0.1 mD (x 37, plane-polarised light).



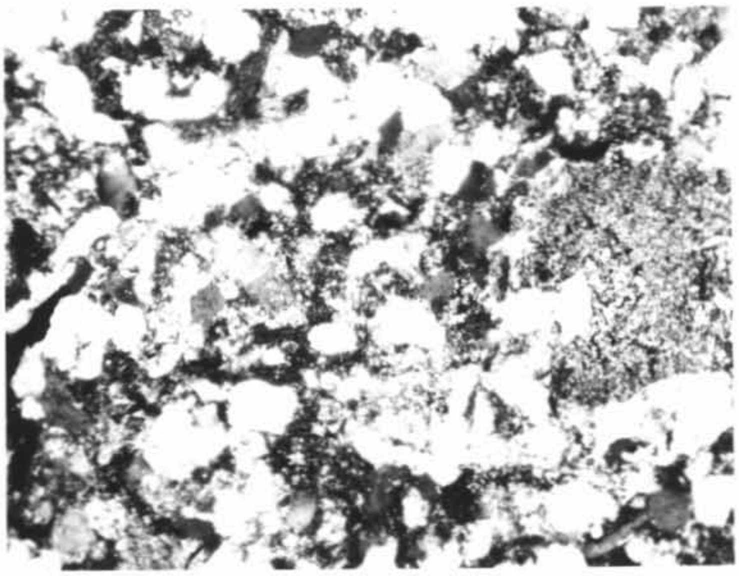
As above, crossed nicols

347022 PLATE 2

5 cm

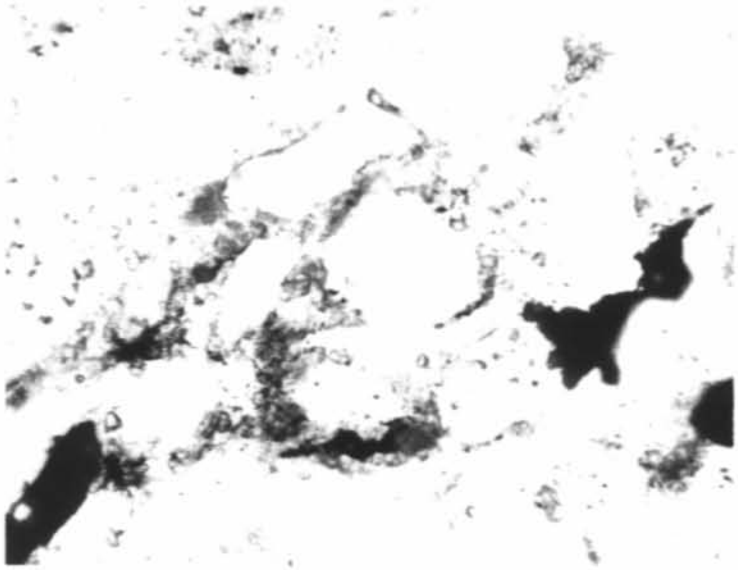


Narimba-1 9278' depth L-M Eocene. Siderite nodule in very fine lithic sandstone (x 92, plane-polarised light).

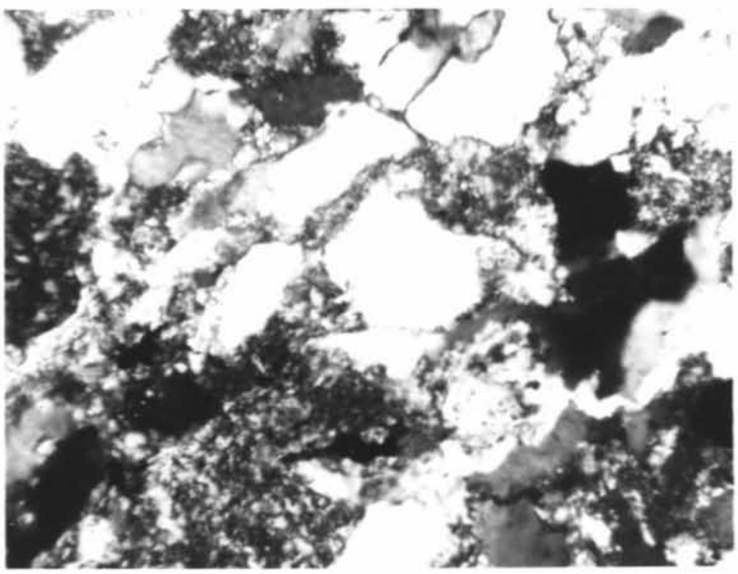


As above, crossed nicols

5 cm

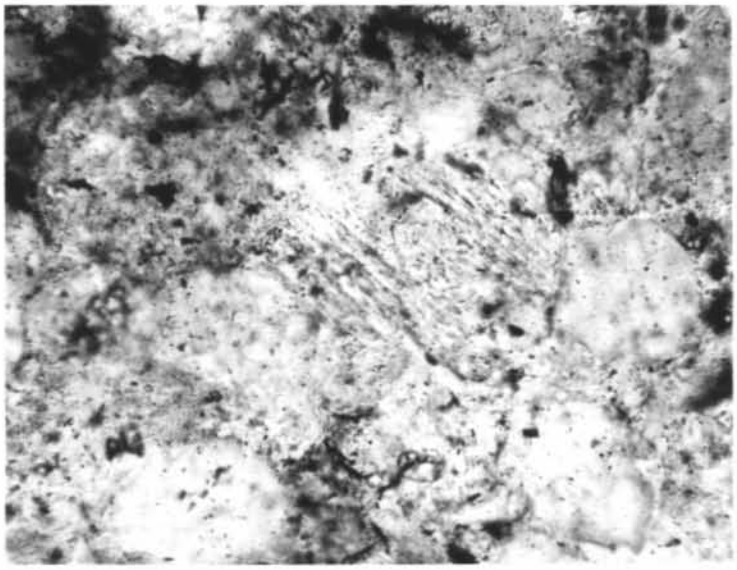


Narimba-1 9278' depth, L-M Eocene. Quartz grain (centre white) partly covered by siderite crystals (x 230, plane-polarised light).

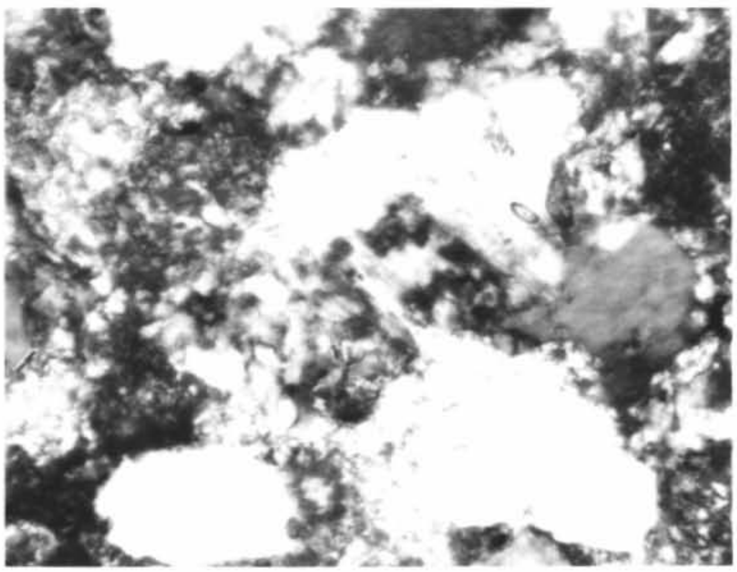


As above, crossed nicols

5 cm

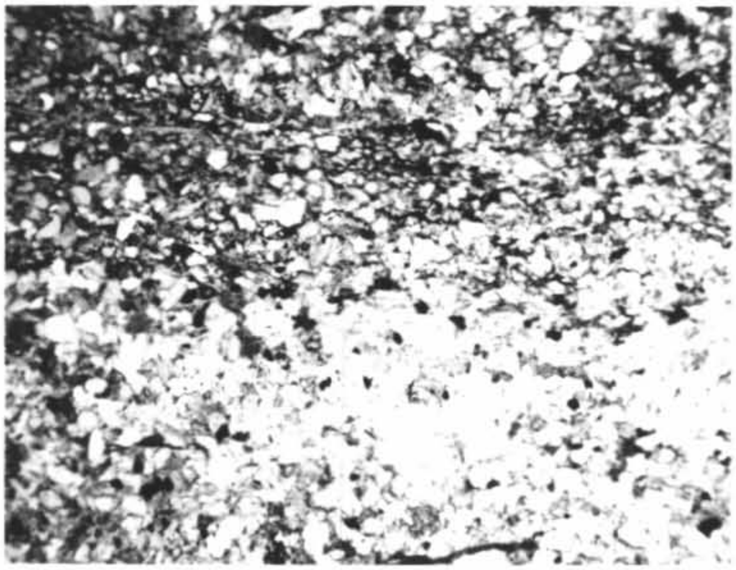


Narimba-1 9278' depth, L-M Eocene.
Feldspar grain partly altered to
kaolinite (x 370, plane-polarised light).

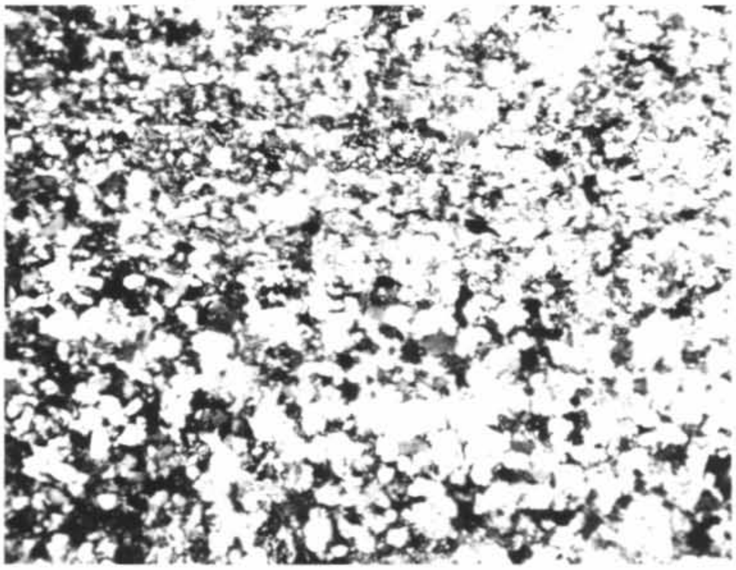


As above, crossed nicols

5 cm

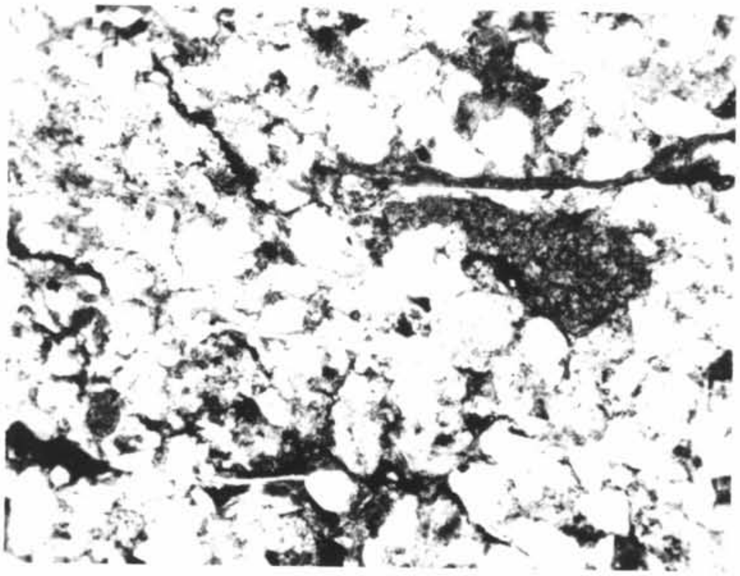


Narimba-1 9286' depth, L-M Eocene. Laminated very fine (upper half) and fine (lower half) sandstone. Porosity 9.4%, permeability less than 0.1 mD (x 37, plane-polarised light).

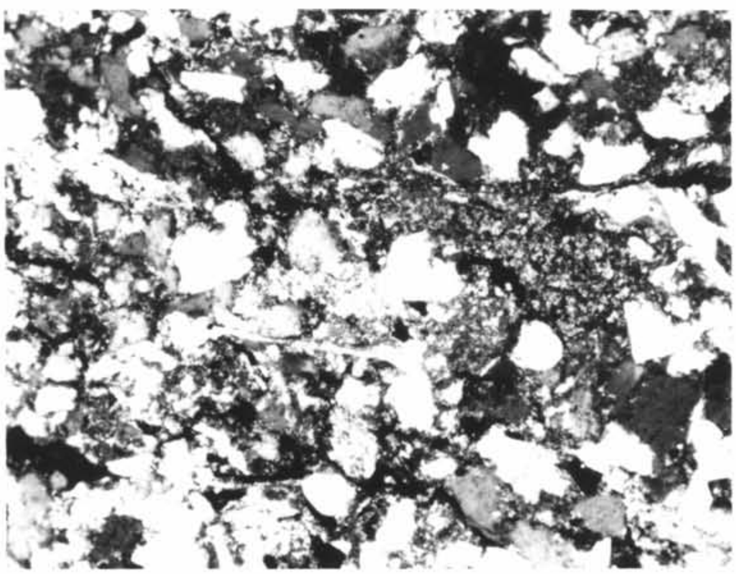


As above, crossed nicols

5 cm

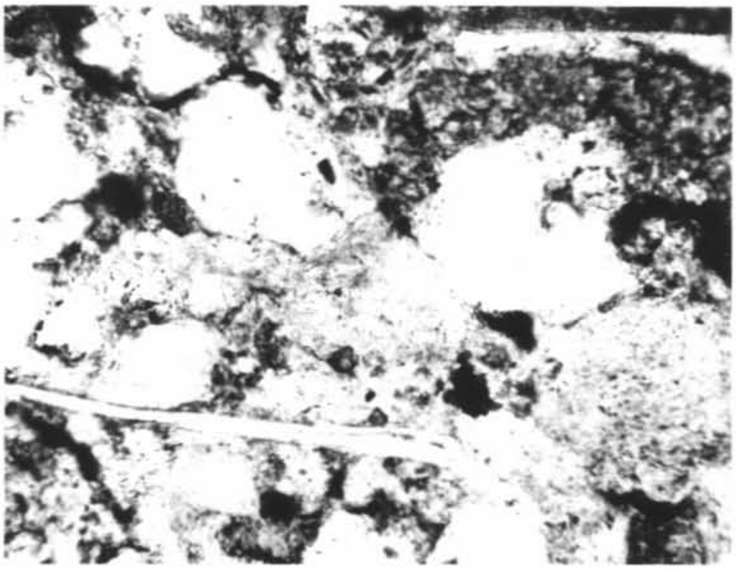


Narimba-1 9286' depth, L-M Eocene.
Carbonaceous stringers (dark), mica flakes (elongated white) and siderite (dark grey-centre right) in fine sandstone (x 92, plane-polarised light).

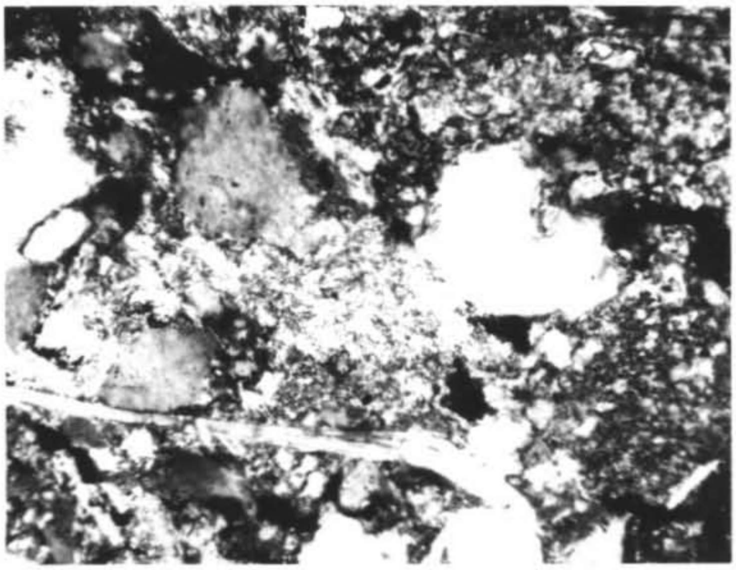


As above, crossed nicols

5 cm



Narimba-1 9286' depth, L-M Eocene.
Contorted carbonaceous matter (dark, upper left corner), slightly bent muscovite (lower left side), intergranular pyrite (black-centre right), quartz (white) and lithoclasts (grey) in fine sandstone (x 230, plane-polarised light).



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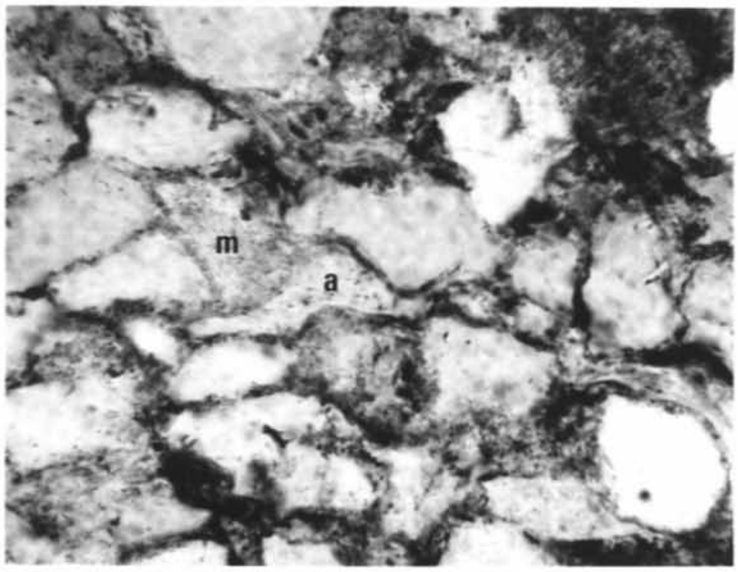
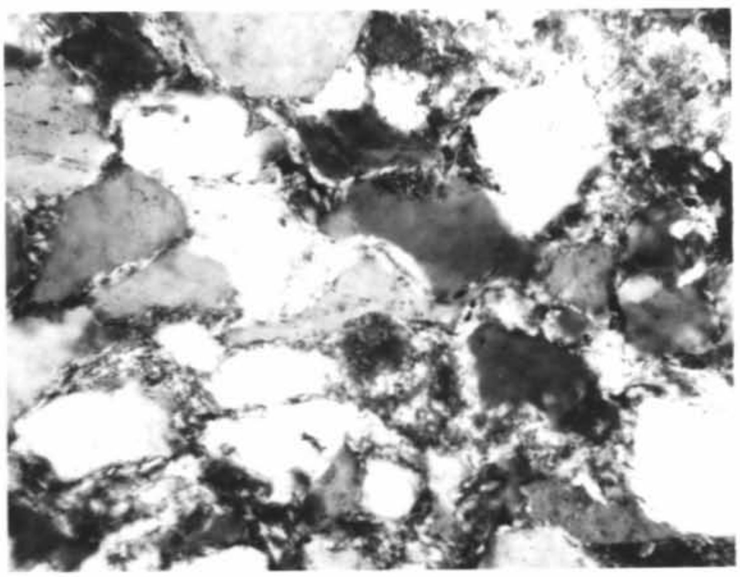
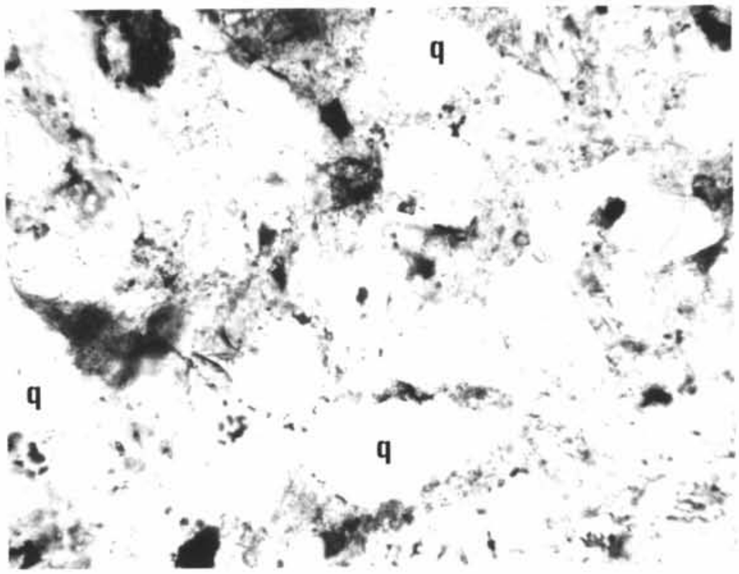


Narimba-1 9298' depth, L-M Eocene. Very fine micaceous sandstone; muscovite (m) slightly contorted and partly enclosed by authigenic quartz (a). Porosity 12.3%, permeability less than 0.1 mD (x 230, plane-polarised light).

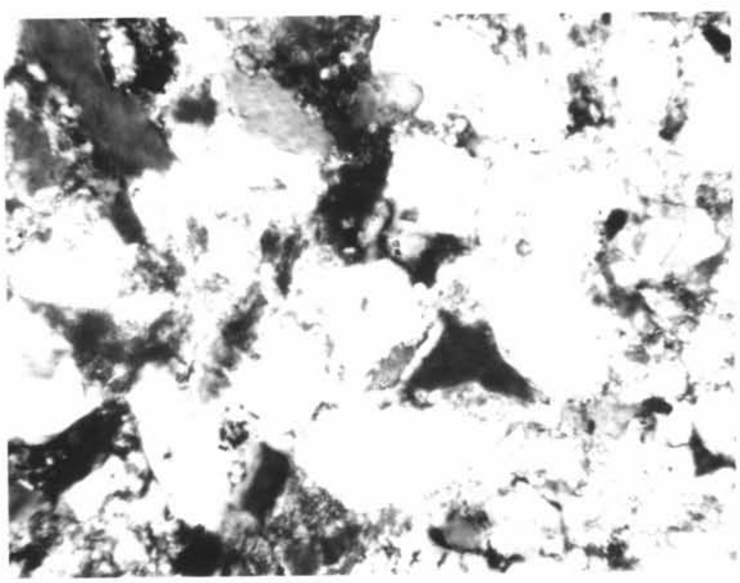


As above, crossed nicols

5 cm

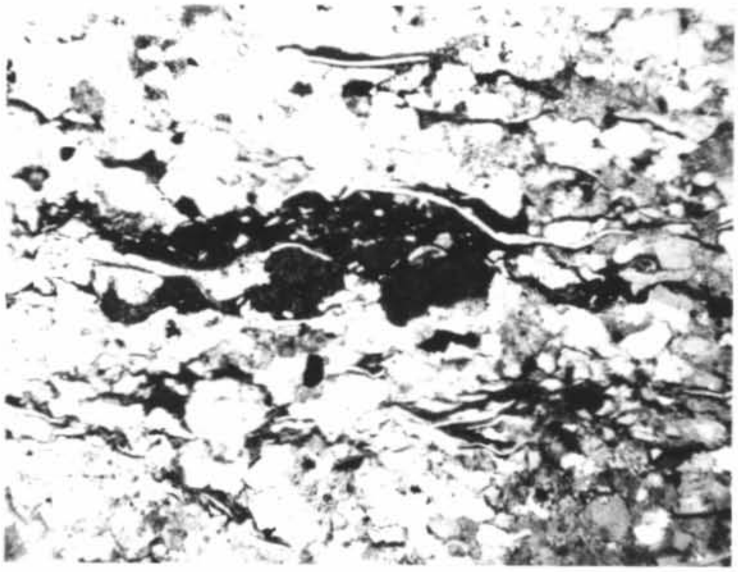


Narimba-1 9302' depth, L-M Eocene. Very fine micaceous sandstone, mica distributed between quartz grains. Some quartz grains (q) with authigenic overgrowths. Porosity 11.4%, permeability less than 0.1 mD (x 230, plane-polarised light).

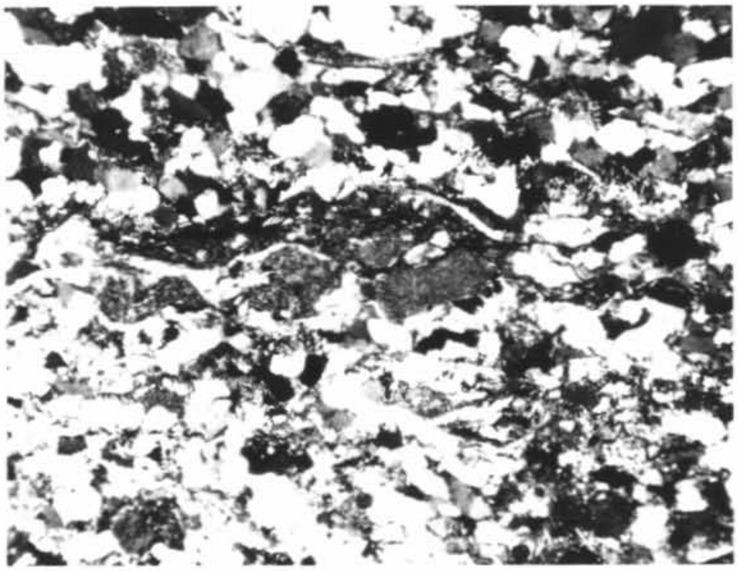


As above, crossed nicols

5 cm

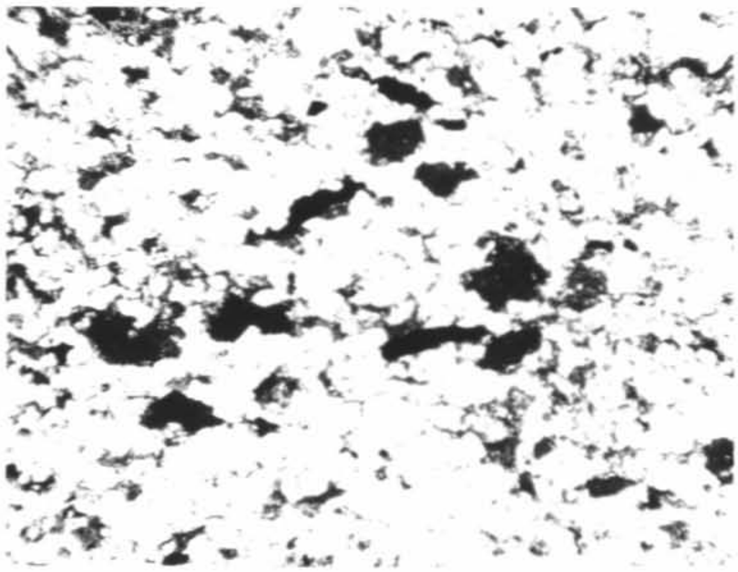


Narimba-1 9544' depth, L-M Eocene. Siderite nodules (black, centre) in very fine, micaceous sideritic sandstone. Porosity 16.7%, permeability 2.2 mD (x 37, plane-polarised light).

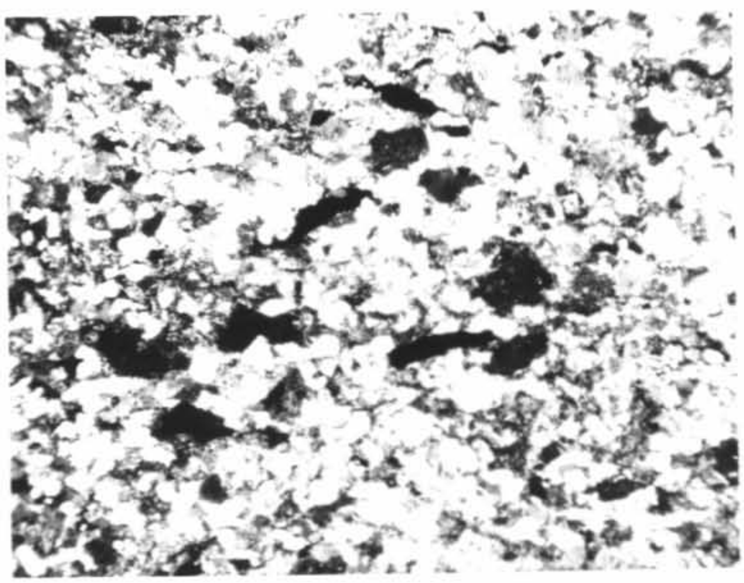


As above, crossed nicols

5 cm

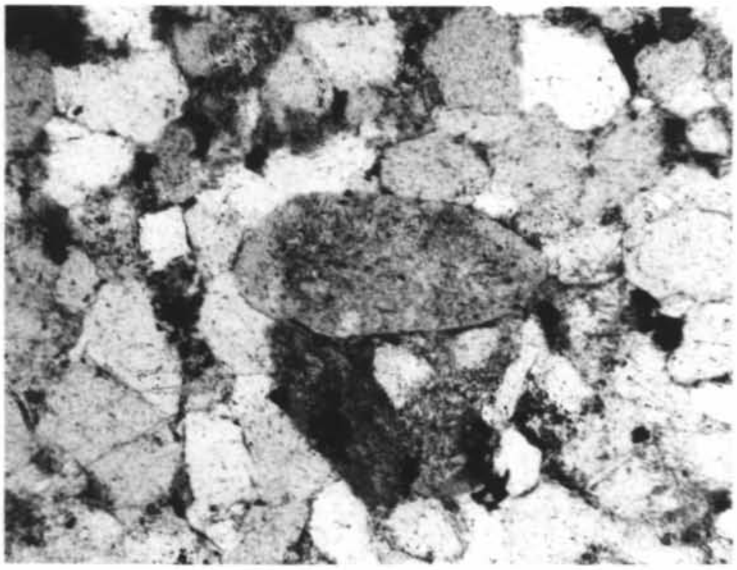


Narimba-1 9548' depth, L-M Eocene. Fine to medium sandstone composed of quartz, feldspar and lithoclasts;black angular areas in lower left are voids. Porosity 19.2%, permeability 0.95 mD (x 37, plane-polarised light).

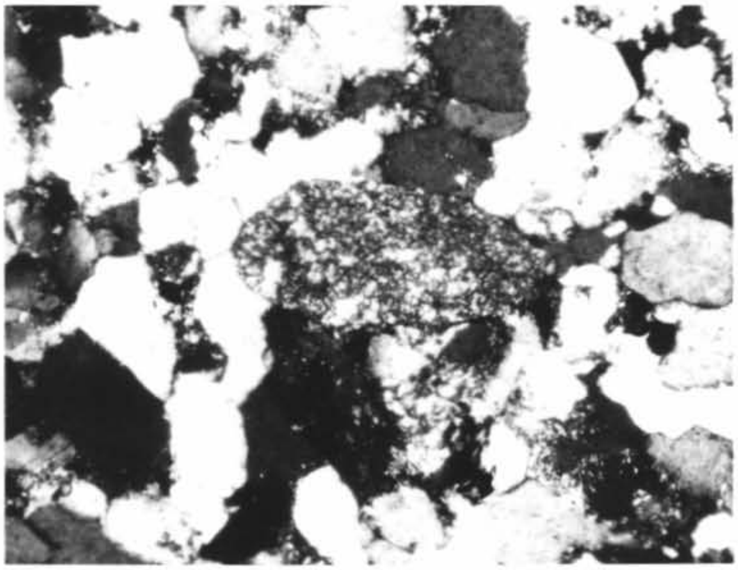


As above, crossed nicols

5 cm

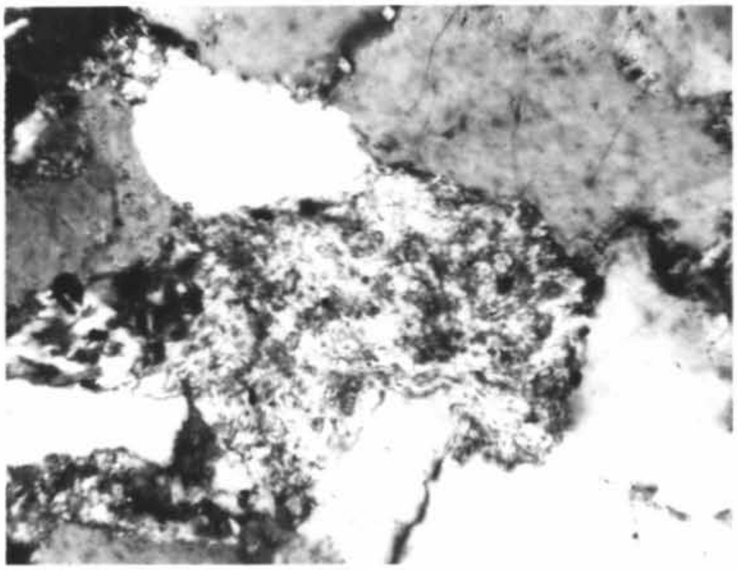


Narimba-1 9548' depth, L-M Eocene. Chert grain surrounded by quartz grains; advanced authigenic quartz overgrowths on quartz grains, but no overgrowths on the chert grain (x 92, plane-polarised light).

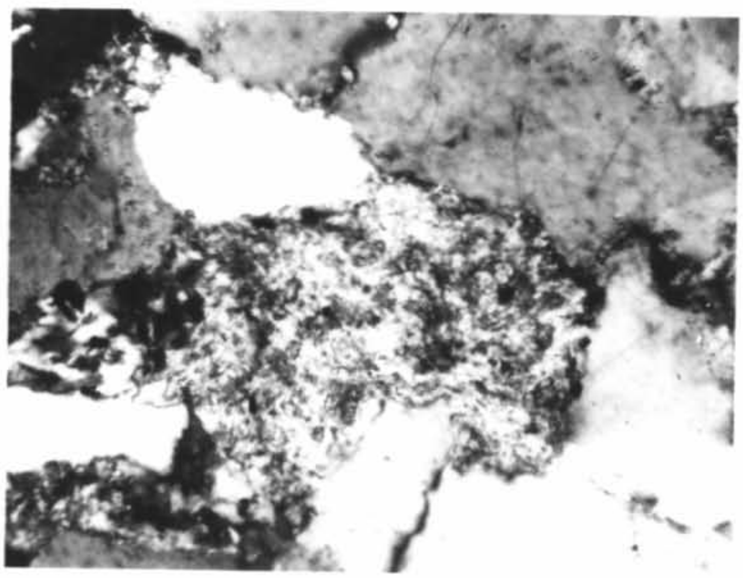


As above, crossed nicols

5 cm

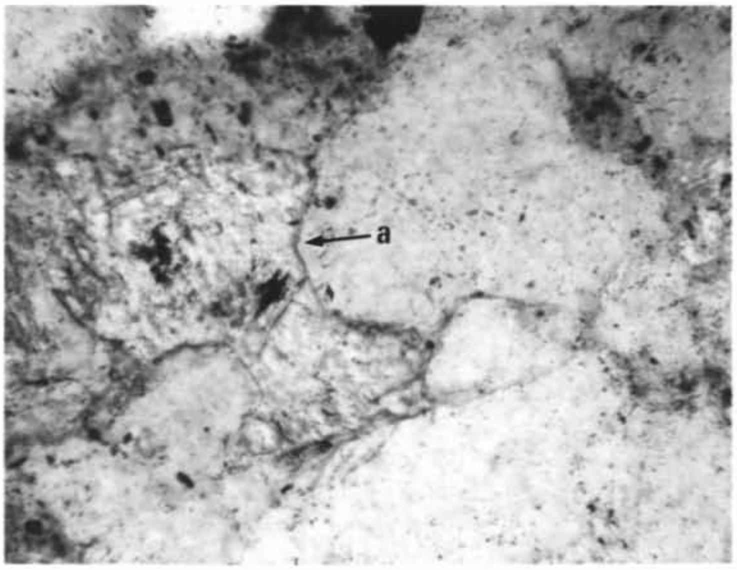


Narimba-1 9548' depth, L-M Eocene.
Plastically deformed lithoclast as a result of compaction (x 230, plane-polarised light).

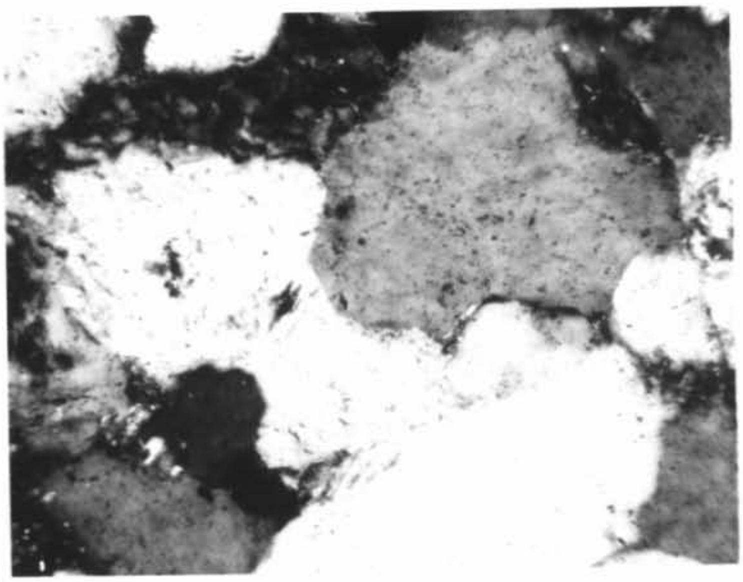


As above, crossed nicols

5 cm

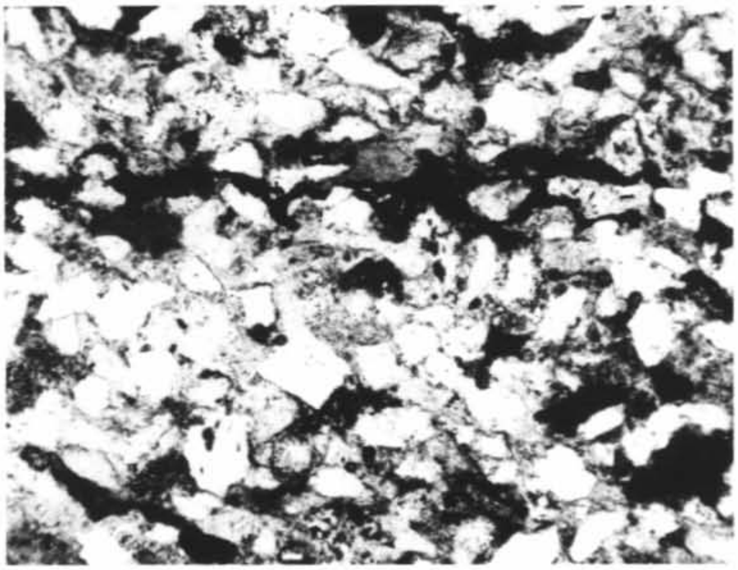


Narimba-1 9548' depth, L-M Eocene.
Calcareous cement (centre left) adjoins authigenic quartz overgrowth (a) (x 230, plane-polarised light).

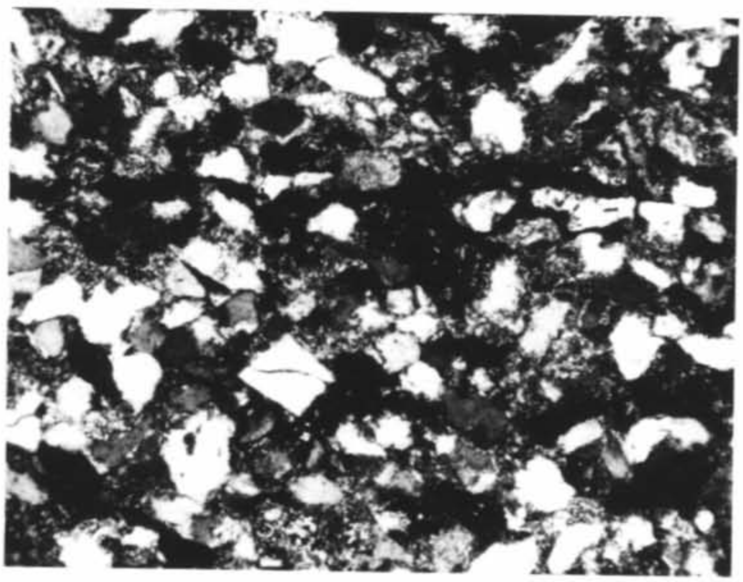


As above, crossed nicols

5 cm

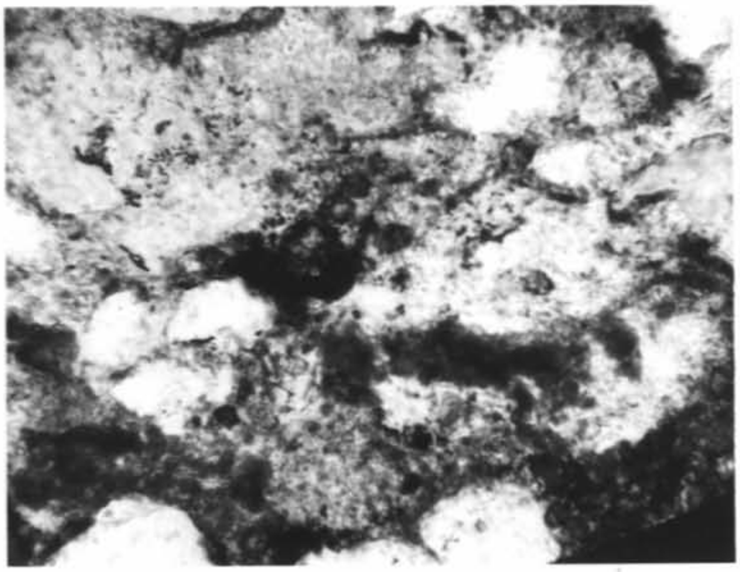


Narimba-1 9560' depth, L-M Eocene.
Carbonaceous, micaceous (mainly red biotite) laminae in very fine, argillaceous sandstone. Porosity 10%, permeability less than 1 mD (x 92, plane-polarised light).

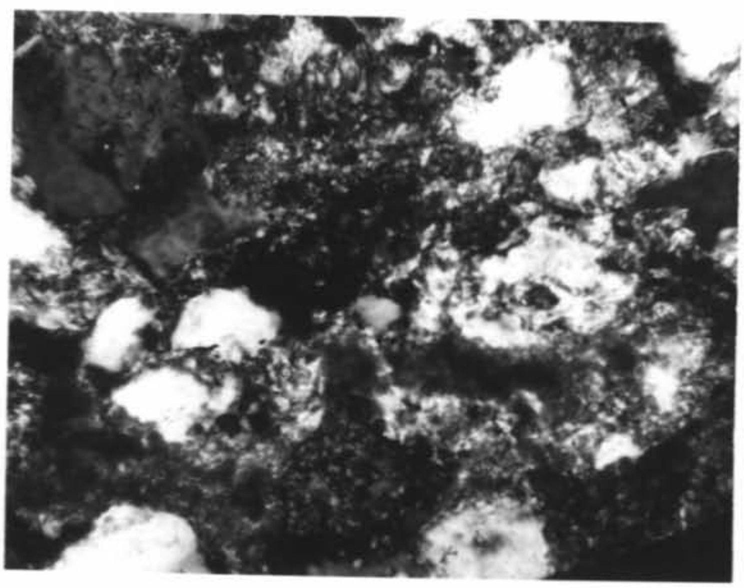


As above, crossed nicols

5 cm

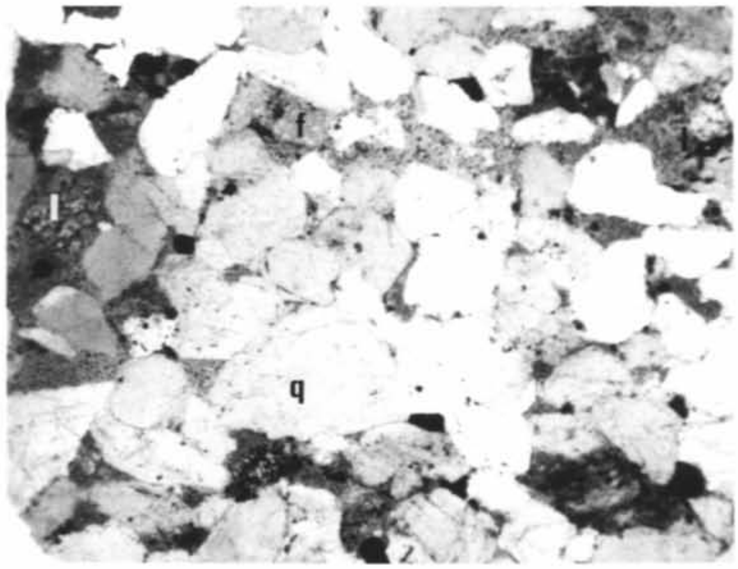


Narimba-1 9560' depth, L-M Eocene.
Argillaceous matrix between detrital quartz and lithoclasts in very fine argillaceous sandstone (x 230, plane-polarised light).

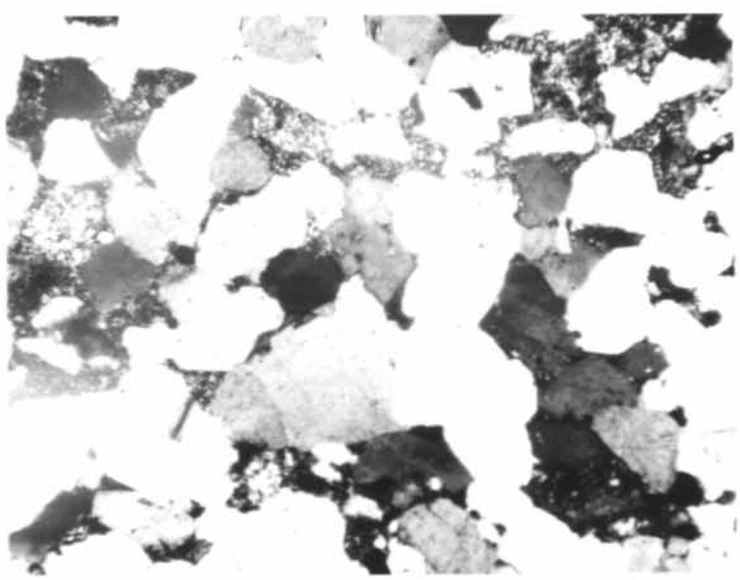


As above, crossed nicols

5 cm

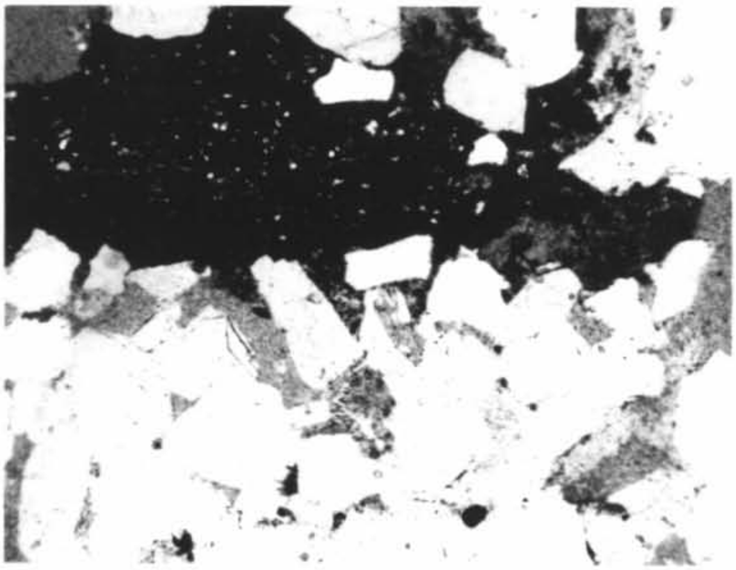


Narimba-1 9750' depth, L-M Eocene. Coarse sandstone composed of quartz (q), lithoclasts (l) and feldspar (f); cemented by authigenic quartz overgrowths. Porosity 19.4%, permeability 54 mD (x 37, plane-polarised light).

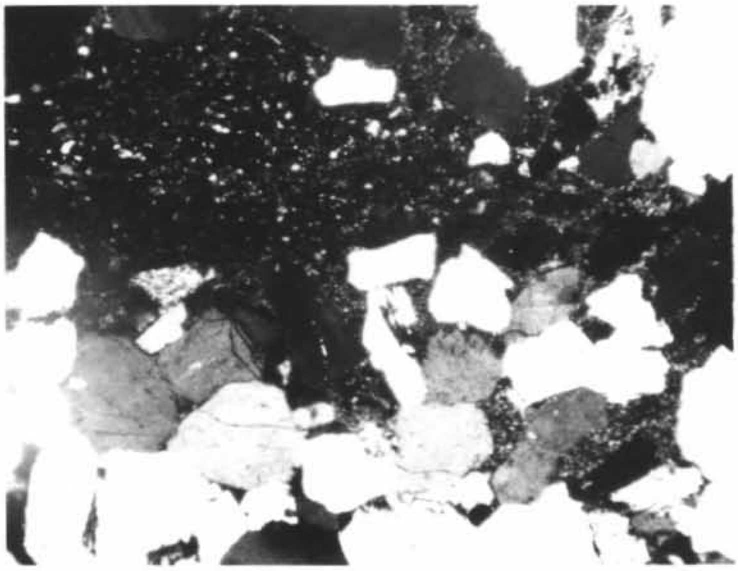


As above, crossed nicols

5 cm

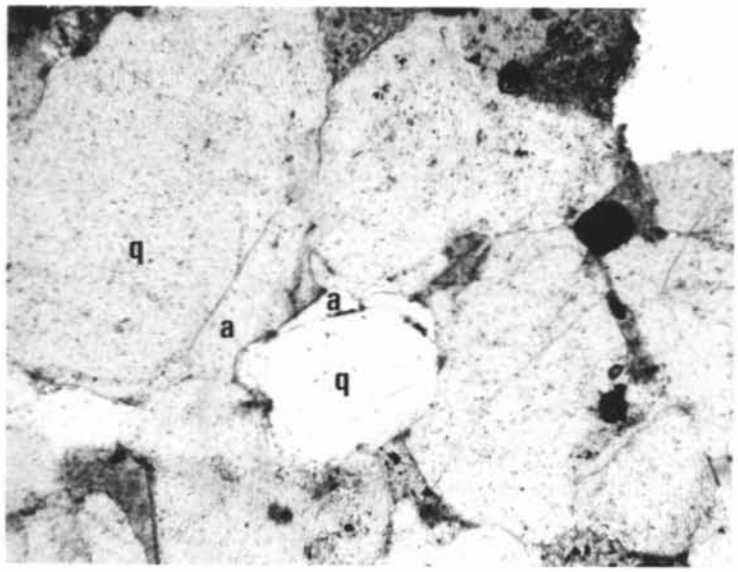


Narimba-1 9750' depth, L-M Eocene. Clay drape (black) in coarse quartz sandstone (x 37, plane-polarised light).

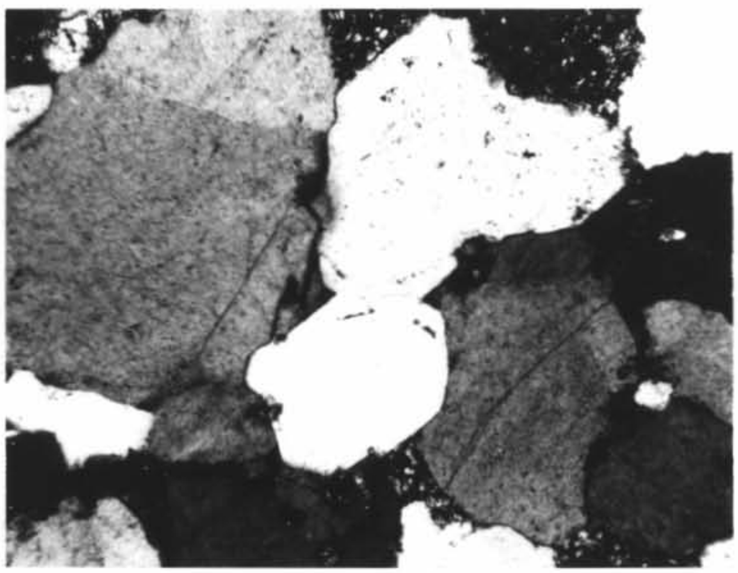


As above, crossed nicols

5 cm

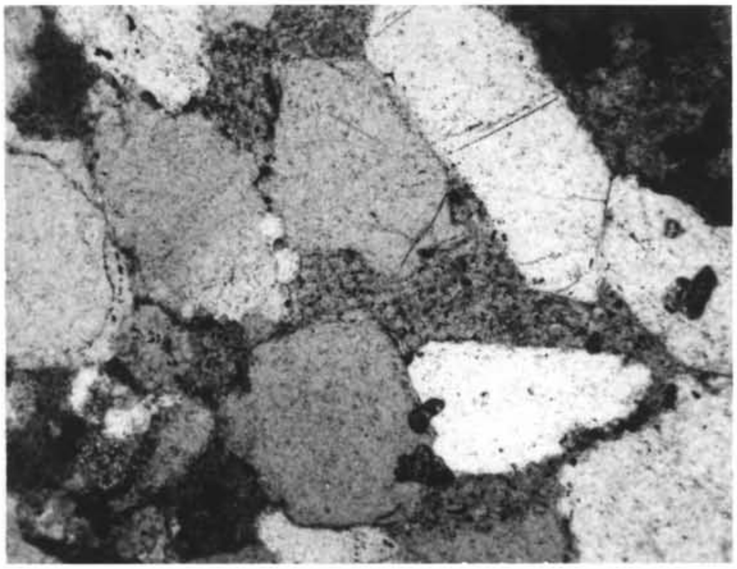


Narimba-1 9750' depth, L-M Eocene. Coarse sandstone; authigenic quartz overgrowths (a) on detrital quartz (q) grains (x 92, plane-polarised light).

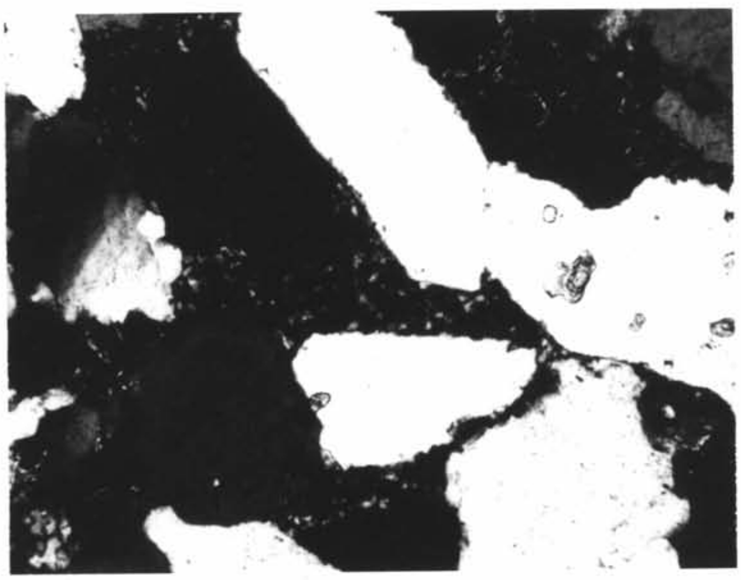


As above, crossed nicols

5 cm

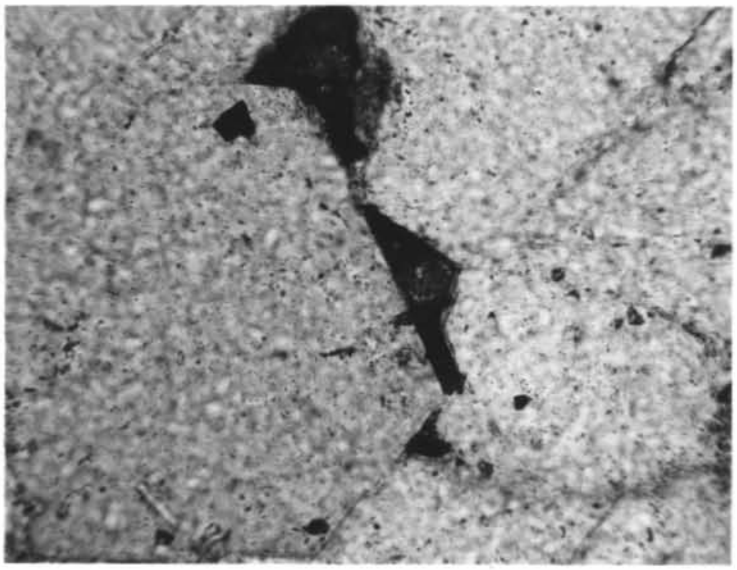


Narimba-1 9750', L-M Eocene. Large kaolinite patch (grey, centre right) is probably kaolinised feldspar or volcano-clast (x 92, plane-polarised light).

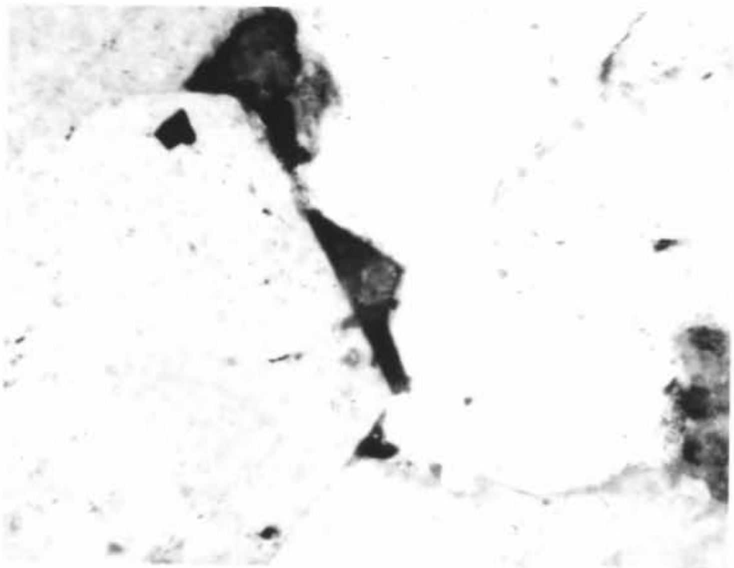


As above, crossed nicols

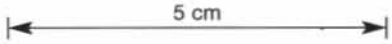
5 cm

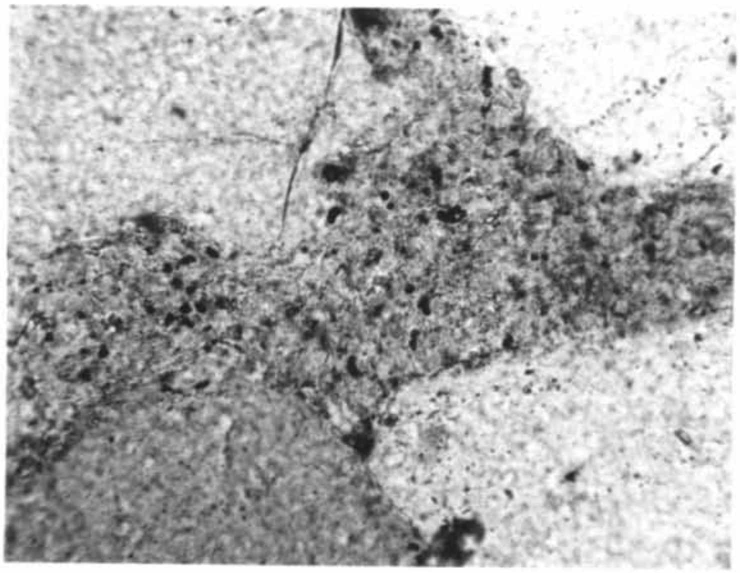


Narimba-1 9750' depth, L-M Eocene. Primary porosity (black, centre) walled by authigenic quartz overgrowths (x 230, plane-polarised light).

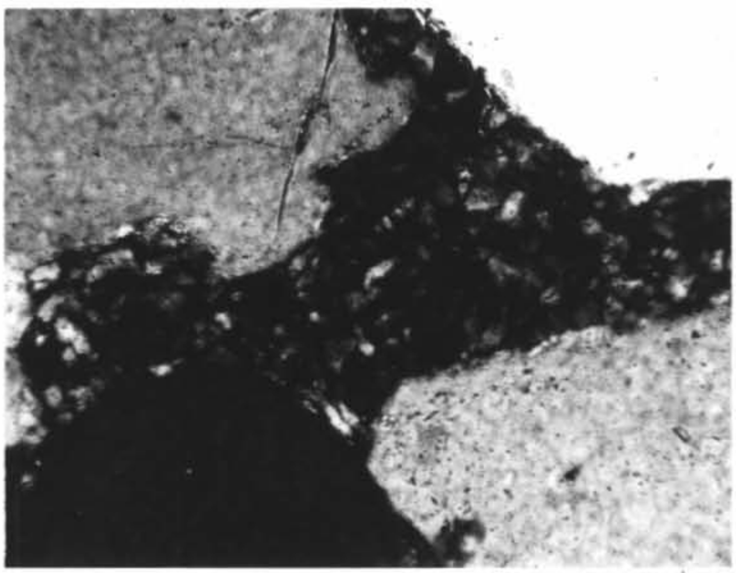


As above, crossed nicols





Narimba-1 9750' depth, L-M Eocene.
Diagenetic kaolinite occupies an intergranular pore (x 230, plane-polarised light).



As above, crossed nicols