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THIN SECTION STUDY NAHANNI FORMATION KOTANEELEE AREA

Ian G. Hunter, Ph.D., P. Geol.
Ian Hunter Consulting Ltd.

January, 2001

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INTRODUCTION

This report is a summary of a thin section study of the Kotaneelee, Pointed Mountain, and Beaver River fields of southeast Yukon Territory and southwest Northwest Territories. Numerous thin sections from the Nahanni Formation and Manetoe facies were examined to provide a comparison of producing and non-producing zones in the Liard area.

METHODS

A total of 76 thin sections (see attached list) were either borrowed from the Head, Core and Sample Repository, Geological Survey of Canada Calgary, or prepared by Calgary Petrographics Ltd. These were examined by Ian G. Hunter, Ph.D., P. Geol. using a standard petrographic microscope. Photographs are enclosed with this report.

LITHOLOGY

The Nahanni Formation in the Kotaneelee Area consists of a dark grey lime mudstone to wackestone with scattered fossil material, probably deposited in a medial carbonate ramp with scattered patch reefs. There appears to be little variation in the Nahanni Formation throughout the Liard Area.

The Nahanni is commonly dolomitized where the original limestone is replaced by a very fine crystalline dolostone with abundant bitumen in the intercrystalline porosity. A later coarse crystalline dolomitization (Manetoe diagenetic event) leaves vuggy porosity lined with saddle dolomite and occasional white crystalline calcite and quartz crystals. This vuggy porosity commonly occurs after dissolution of macrofauna (including colonial corals, brachiopods, and stromatoporoids). The porosity is lined or occluded by white sparry, vug lining saddle dolomite and occasionally with pore filling, late stage coarse crystalline calcite and quartz.

FRACTURES

Overall, large-scale vertical and subvertical brittle fractures are not common at Kotaneelee. Microfractures are common throughout the area. Some of the microfractures are lined with calcite or quartz crystals.

DIAGENESIS

There is a distinct paragenetic sequence that can be identified from the thin sections in the Kotaneelee Area.

- Early pervasive very fine crystalline dolomitization.
- Emplacement of disseminated bitumen in intercrystalline porosity in very fine crystalline dolomite.
- Early formation of fractures through zones of weakness.
- Leaching and replacement with coarse crystalline saddle dolomite (Manetoe Facies).
- Quartz filling or lining fractures and vugs, associated with sphalerite and galena. Some quartz replacement associated with quartz cementation.
- Late stage bitumen.
- Calcite lining and filling pores and fractures.

*Stylolitization occurs throughout and may conduct fluids.

Well Name	UWI	FDD	Thin Section Depth
Columbia Gas et al Kotaneelee YT	E37-6010-12400	1978	12805 ft.
			12864 ft.
			12875 ft.
			12892 ft.
			12945 ft.
			13132 ft.
			13146 ft.
Columbia Gas et al Kotaneelee YT	B38-6010-12400	1977	11693 ft.
			11706 ft.
			11722 ft.
			11734 ft.
			12050 ft.
			12284.5 ft.
			12457.75 ft.
			12509 ft.
			12735.5 ft.
			12748 ft.
Columbia Gas et al Kotaneelee YT	I48-6010-12400	1980	3666.5 m
			3669.4 m
			3724.0 m
			3730.0 m
			3737.8 m
			3742.2 m
			3747.3 m
			3755.7 m
			3764.0 m
			4035.3 m
Canada South et al N. Beaver R. YT	I27-6010-12400	1964	12594 ft.
			12609 ft.
			12612 ft.
Pan Am Kotaneelee	O67-6030-12400	1969	8543 ft.
			8567 ft.
Chevron et al Liard M-25	M25-6030-12330	2000	3452.4 m
			3454.0 m
			3455.2 m
Amoco A-4 Pointed Mountain	A55-6030-12345	1974	10298.5 ft.
			10308 ft.
			10322 ft.
			10355 ft.
			10364 ft.
			10600.25 ft.
			10612 ft.
			10624.25 ft
			10863 ft.
			10868 ft.
			11205.5 ft.

			11223 ft.
			12160.5 ft.
Pan Am Pointed Mountain	P53-6030-12345	1967	12848 ft.
			12855 ft.
			12925 ft.
			13061 ft.
			13066 ft.
			13135 ft.
			13324 ft.
			13685 ft.
Pan Am Beaver River YT	G01-6010-12415	1969	13536 ft.
			13552 ft.
			13561 ft.
			13677.25 ft.
			13759 ft.
			13940.5 ft.
			14184 ft.
			14203 ft.
			14414.5 ft.
			14429 ft.
Pan Am Shell Merril YT	L60-6020-12415	1969	5254 ft.
			5275 ft.
			5300 ft.
CPOG et al LaBiche	F08-6040-12430	1970	6525 ft.
			6526 ft.
			6527 ft.
			6527.5 ft.
			6538 ft.
			6707 ft.
Bluemount et al Beavercrow YT	B16-6010-12515	1969	7350 ft.

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			6526 ft.
			6527 ft.
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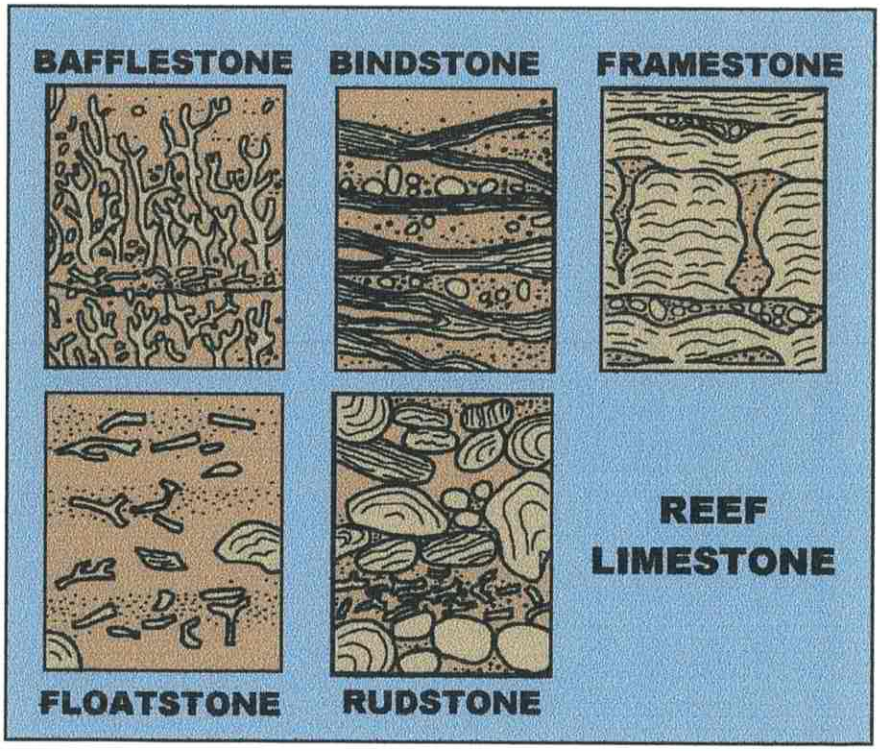
			6538 ft.
			6707 ft.
Bluemount et al Beavercrow YT	B16-6010-12515	1969	7350 ft.

<table>
<tr><th colspan="8">CARBONATE CLASSIFICATION</th></tr>
<tr><th colspan="7">DEPOSITIONAL TEXTURE RECOGNIZABLE</th><th rowspan="2">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE</th></tr>
<tr><td colspan="3">Less than 10% > 2 mm Components</td><td colspan="2">Greater than 10% > 2 mm Components</td><td rowspan="2">Consists of Organisms Which Build a Rigid Framework

(Does not Include Organisms that Encrust, Bind, or Baffle)</td></tr>
<tr><td colspan="2">Contains Mud (Particles of Clay and Fine Silt Size)</td><td>Lacks Mud</td><td rowspan="3">Matrix Supported</td><td rowspan="3">> 2 mm Component Supported</td></tr>
<tr><td colspan="2">Mud Supported</td><td colspan="2" rowspan="2">Grain Supported</td></tr>
<tr><td>Less than 10% Grains (>0.03 mm <2 mm)</td><td>Greater than 10% Grains</td></tr>
<tr><td>MUDSTONE</td><td>WACKESTONE</td><td>PACKSTONE</td><td>GRAINSTONE</td><td>FLOATSTONE</td><td>RUDSTONE</td><td>FRAMESTONE</td><td>CRYSTALLINE CARBONATE</td></tr>
</table>

Textural carbonate rock classification. (Modified from Dunham, 1962 and Embry and Klovan, 1971). An important part of this classification as used by Embry and Klovan (1971) is to use various modifiers for the matrix associated with a floatstone, rudstone, or framestone.



Textural classfication of reef limestones as used by Embry and Klovan (1971).

BASIC POROSITY TYPES

FABRIC SELECTIVE


INTERPARTICLE BP


INTRAPARTICLE WP


INTERCRYSTAL BC


MOLDIC MO


FENESTRAL FE


SHELTER SH


FRAMEWORK GF

NOT FABRIC SELECTIVE


FRACTURE FR


CHANNEL CH


VUG VUG


CAVERN CV

FABRIC SELECTIVE OR NOT


BRECCIA BR


BORING BO


BURROW BW


SHRINKAGE SH

MODIFYING TERMS

GENETIC MODIFIERS

PROCESS		DIRECTION OR STAGE	
SOLUTION	s	ENLARGED	x
CEMENTATION	c	REDUCED	r
INTERNAL SEDIMENT	i	FILLED	f

TIME OF FORMATION

PRIMARY	p
pre-depositional	pp
depositional	pd
SECONDARY	S
eogenetic	Se
mesogenetic	Sm
telogenetic	St

SIZE* MODIFIERS

CLASSES				mm[1]
				256
MEGAPORE	mg	large	lmg	
		small	smg	32
				4
MESOPORE	ms	large	lms	1/2
		small	sms	
				1/16
MICROPORE	mc			

Use size prefixes with basic porosity types:

mesovug	msVUG
small mesomold	smsMO
microinter particle	mcBP

* For regular-shaped pores smaller than cavern size.

[1] Measures refer to average pore diameter of a single pore assemblage in size of a pore assemblage. For tubular pores use average cross-section. For platy pores use width and hole shape.

Genetic modifiers are combined as follows:

PROCESS + DIRECTION + TIME

EXAMPLES:

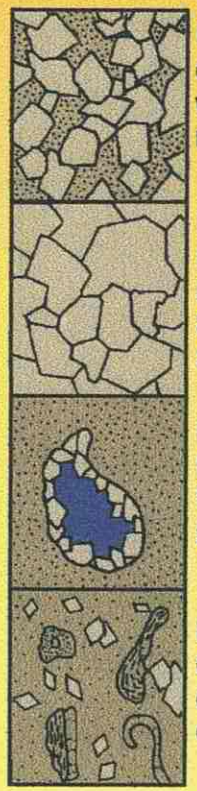
solution- enlarged	sx
cement-reduced primary	crP
sediment-filled eogenetic	if Se

ABUNDUNCE MODIFIERS

percent porosity (15%)
or
ratio of porosity types (1:2)
or
ratio and percent (1:2) (15%)

Geologic classification of pores and pore systems in carbonate rocks (modified after Choquette and Pray, 1970).

Idiotopic Dolomite - Rhombic shaped euhedral to subhedral crystals.



Idiotopic-E (Euhedral), almost all dolomite crystals are euhedral rhombs; crystal-supported with intercrystalline area filled by another mineral or porous (as in sucrosic texture).

Idiotopic-S (Subhedral), subhedral to anhedral dolomite crystals with low porosity and/or low, intercrystalline matrix; straight, compromise boundaries are common and many of the crystals have preserved crystal-face junctions.

Idiotopic-C (Cement), euhedral dolomite crystals lining large pores and vugs or surrounding patches of another mineral such as gypsum or calcite.

Idiotopic-P (Porphyrotopic), euhedral dolomite crystals floating in a limestone matrix. The crystals are matrix-supported rather than crystal-supported.

Xenotopic Dolomite - Nonrhombic, usually anhedral crystals.

Xenotopic-A (Anhedral), tightly packed anhedral dolomite crystals with mostly curved, lobate serrated, indistinct or otherwise irregular intercrystalline boundaries. Preserved crystal-faced junctions often have undulatory extinction in cross-polarized light.

Xenotopic-C (Cement), pore lining saddle-shaped or baroque dolomite crystals characterized by scimitarlike terminations, when observed in thin section, and sweeping extinction in cross-polarized light.

Xenotopic-P (Porphyrotopic), single anhedral dolomite crystals or patches of anhedral dolomite crystals floating in a limestone matrix. The dolomite crystals usually have undulatory extinction in cross-polarized light.

Dolomite textural classification system, modified from Gregg and Sibley, 1984.

I27-6010-12400

Plate 1

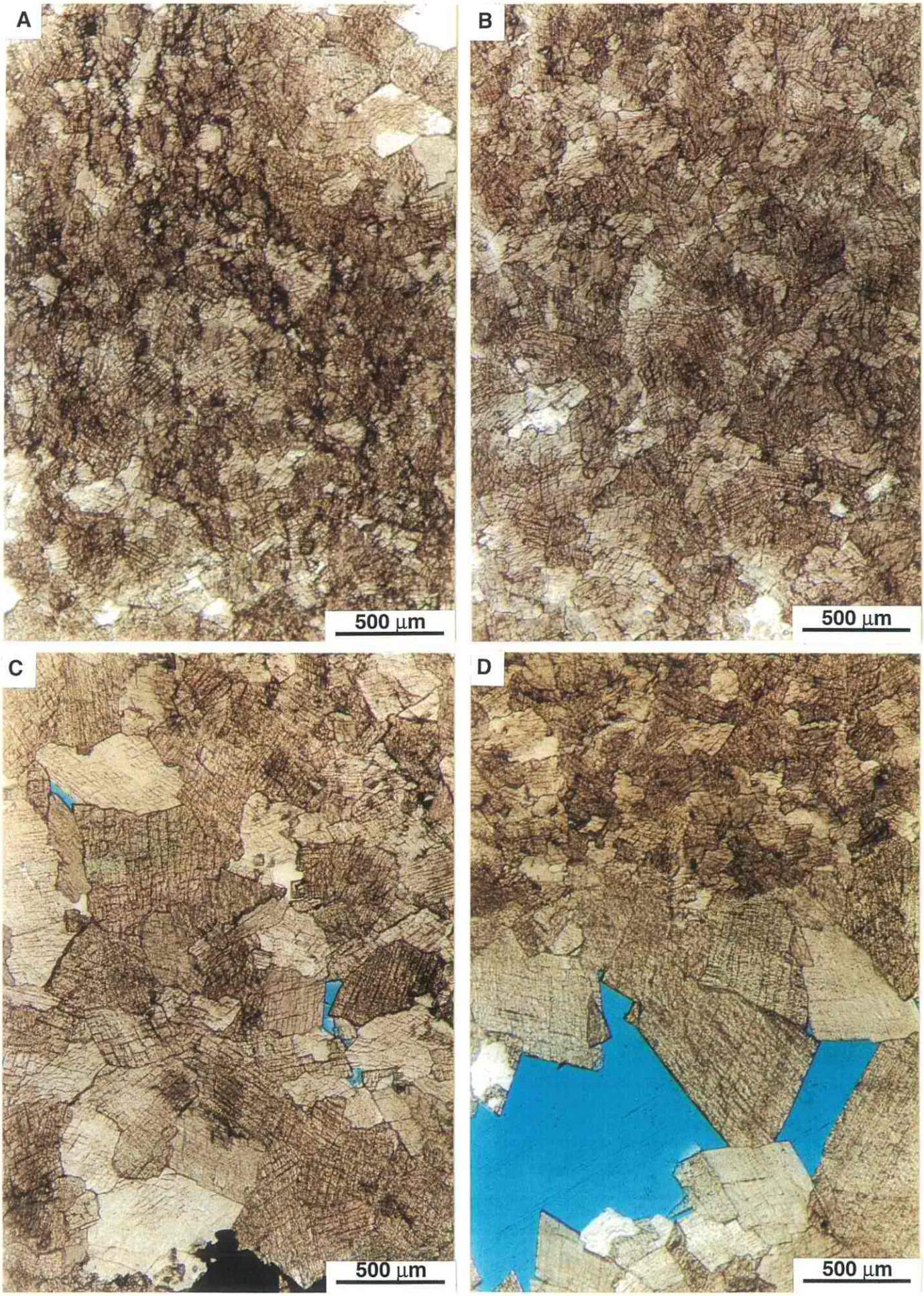
A) 12594 ft. Dolomite, very fine to fine crystalline, wackestone, recrystallized.

B) 12594 ft. Dolomite, fine crystalline, minor bitumen.

C) 12594 ft. Dolomite, medium crystalline dolomite in vug, bitumen in center of vug.

D) 12594 ft. Dolomite, very fine crystalline dolomite, very coarse crystalline saddle dolomite filling vug, good porosity in center of vug.

Plate 1



I27-6010-12400

Plate 2

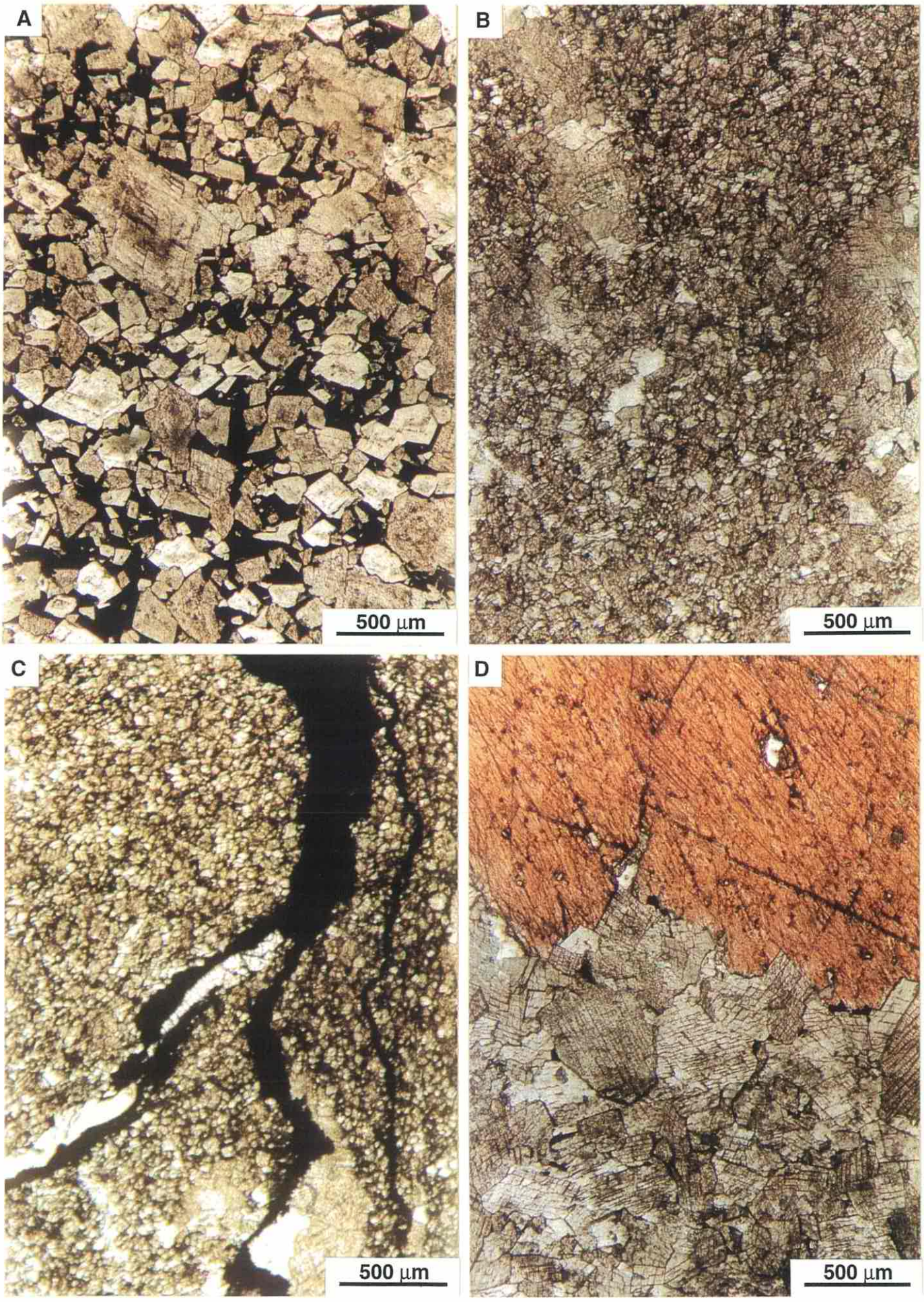
A) 12609 ft. Recrystallized fine crystalline dolomite, abundant bitumen between dolomite crystals.

B) 12612 ft. Dolomite, very fine crystalline, wackestone. Note the individual skeletal fragments as shown by the coarser crystalline dolomite.

C) 12612 ft. Dolomite, microcrystalline, associated with stylolites. Note the abundant bitumen associated with the stylolites.

D) 12612 ft. Dolomite, very fine to fine crystalline, wackestone, vugs lined with medium crystalline dolomite and filled with calcite.

Plate 2



E37-6010-12400

Plate 1

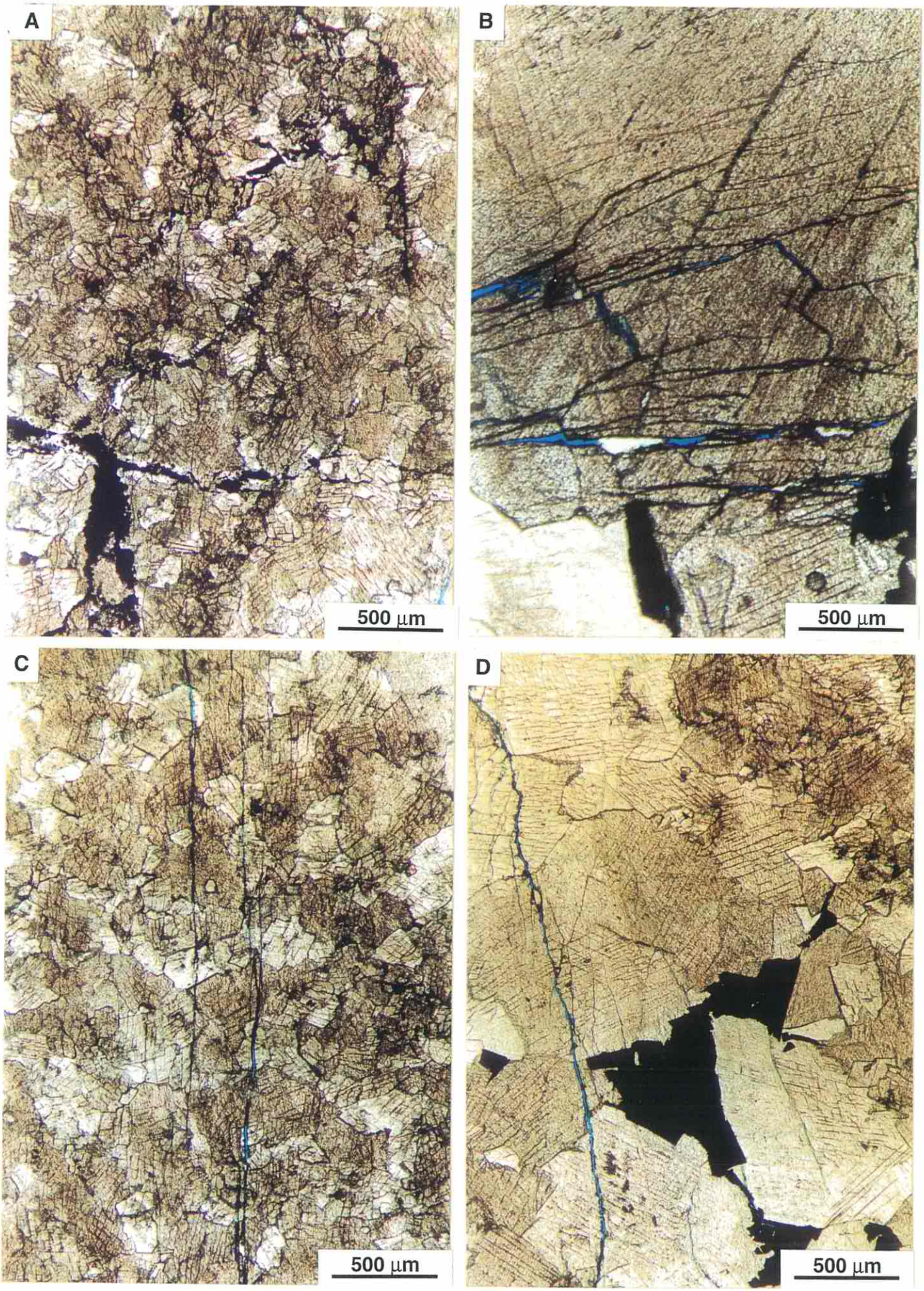
A) 12805 ft. Fine crystalline dolomite recrystallized from an earlier very fine crystalline dolomite, minor bitumen in intercrystalline porosity. Some bitumen in later fractures.

B) 12805 ft. Saddle dolomite in large vug, some bitumen in vug after saddle dolomite. Note the numerous microfractures.

C) 12864 ft. Breccia fragment consisting of very fine crystalline dolomite, recrystallized. Note the microfractures.

D) 12864 ft. Saddle dolomite cement between breccia fragments. Original breccia fragment in upper right of photo. Some bitumen after the saddle dolomite. Note the microfractures.

Plate 1



E37-6010-12400

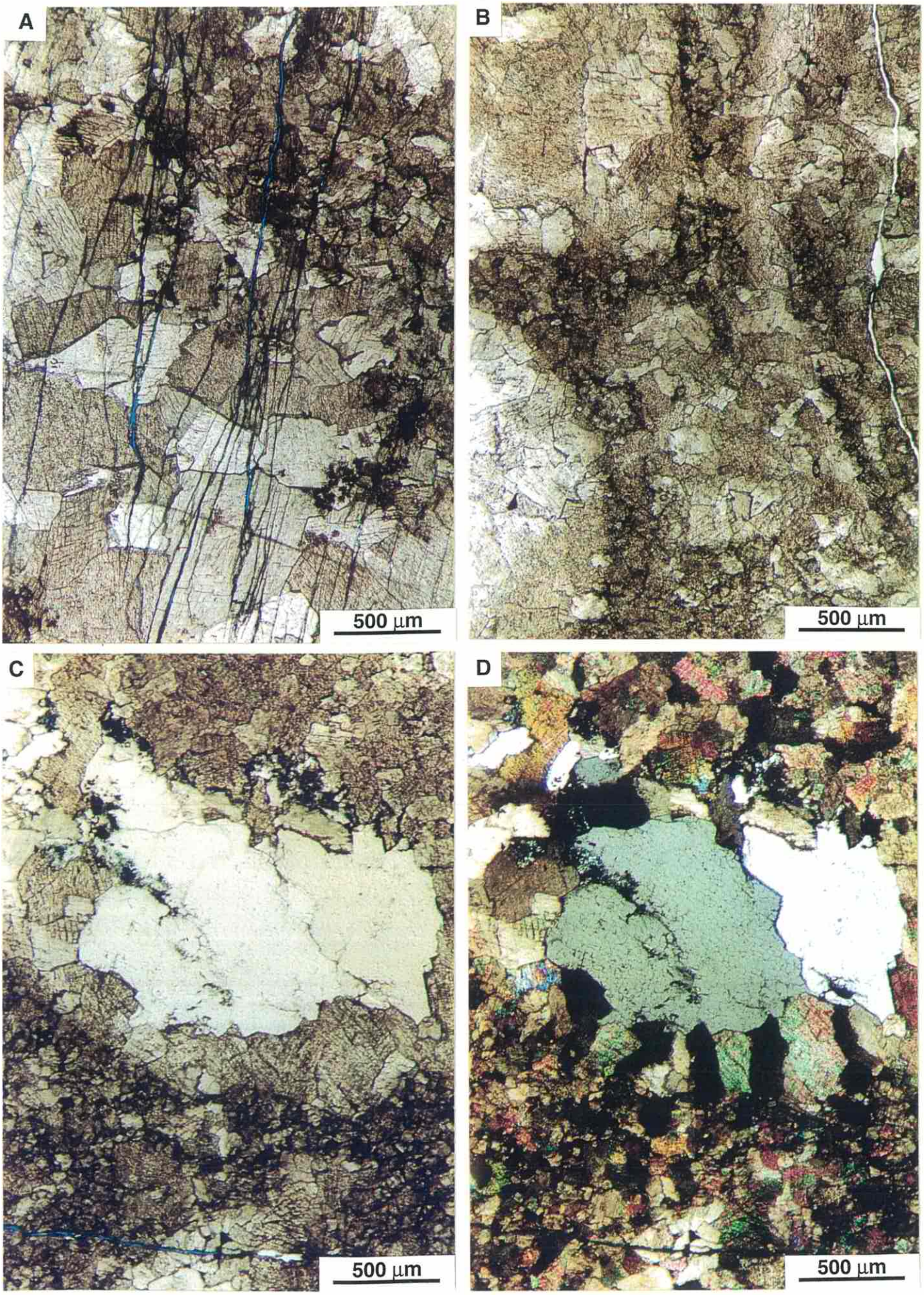
Plate 2

A) 12864 ft. Recrystallized fine crystalline dolomite in upper right of photo. Late saddle dolomite in lower left of photo. Note the swarm of microfractures crossing the saddle dolomite and earlier matrix dolomite.

B) 12875 ft. Floatstone with numerous shell fragments, wackestone matrix, late saddle dolomite infilling shelter porosity in gastropods.

C & D) Very fine crystalline dolomite (at base of photo), early bitumen in intercrystalline porosity. Large vug lined with saddle dolomite and filled with quartz and bitumen. 12875 ft. C - plain light, D - crossed nicols.

Plate 2



E37-6010-12400

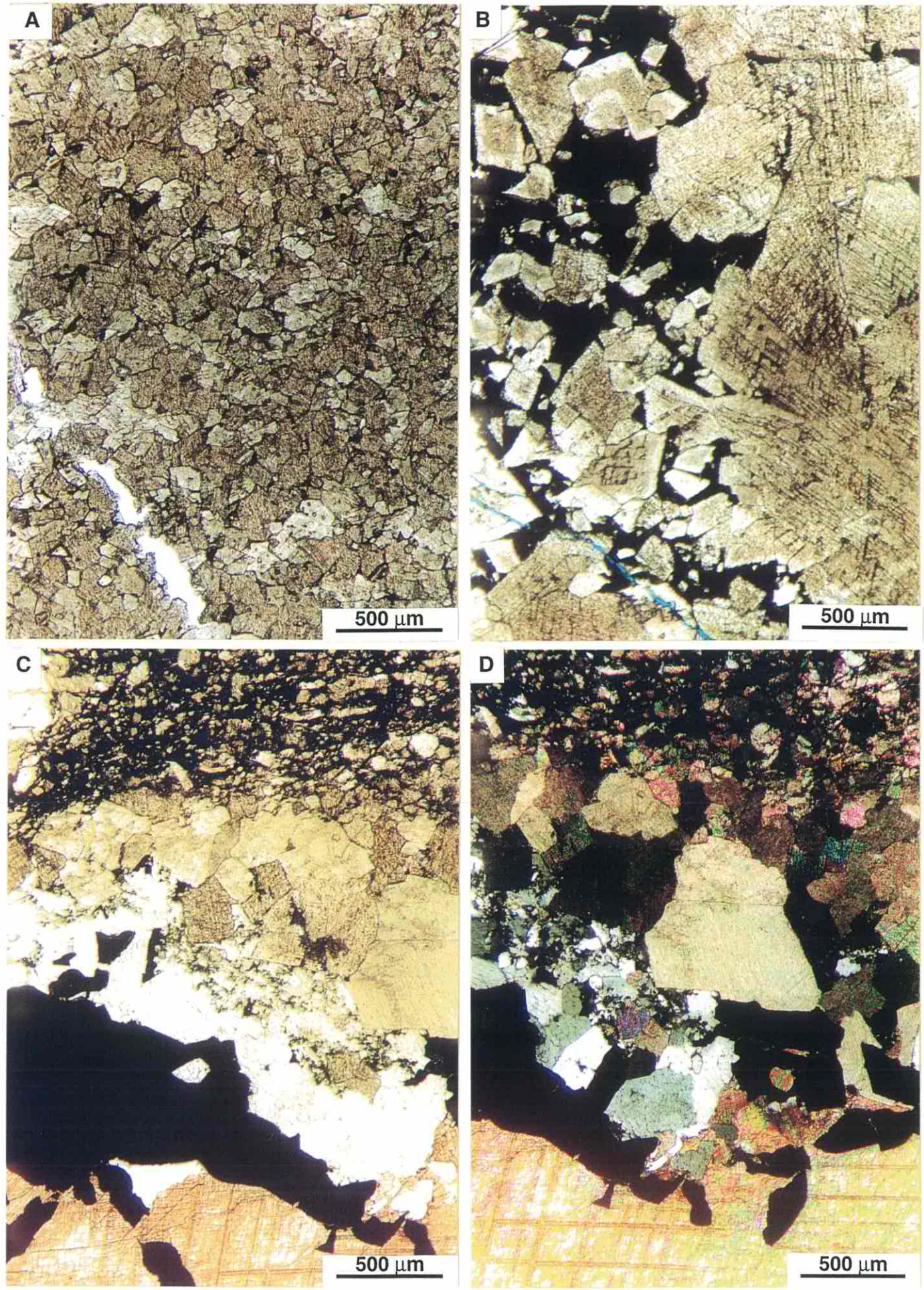
Plate 3

A) 12892 ft. Very fine crystalline dolomite matrix, originally a mudstone, bitumen in intercrystalline porosity. Note small fracture at bottom of photo filled with quartz.

B) 12892 ft. Saddle dolomite in vug. Note the large amount of bitumen between the dolomite crystals.

C & D) 12945 ft. A large cavity filled with a succession of minerals. The matrix consists of very fine crystalline dolomite with abundant bitumen in the intercrystalline porosity. The vug is lined with saddle dolomite, then quartz, then late bitumen, and finally filled with very coarse crystalline calcite. C - plain light, D - crossed nicols, slightly different fields of view.

Plate 3



E37-6010-12400

Plate 4

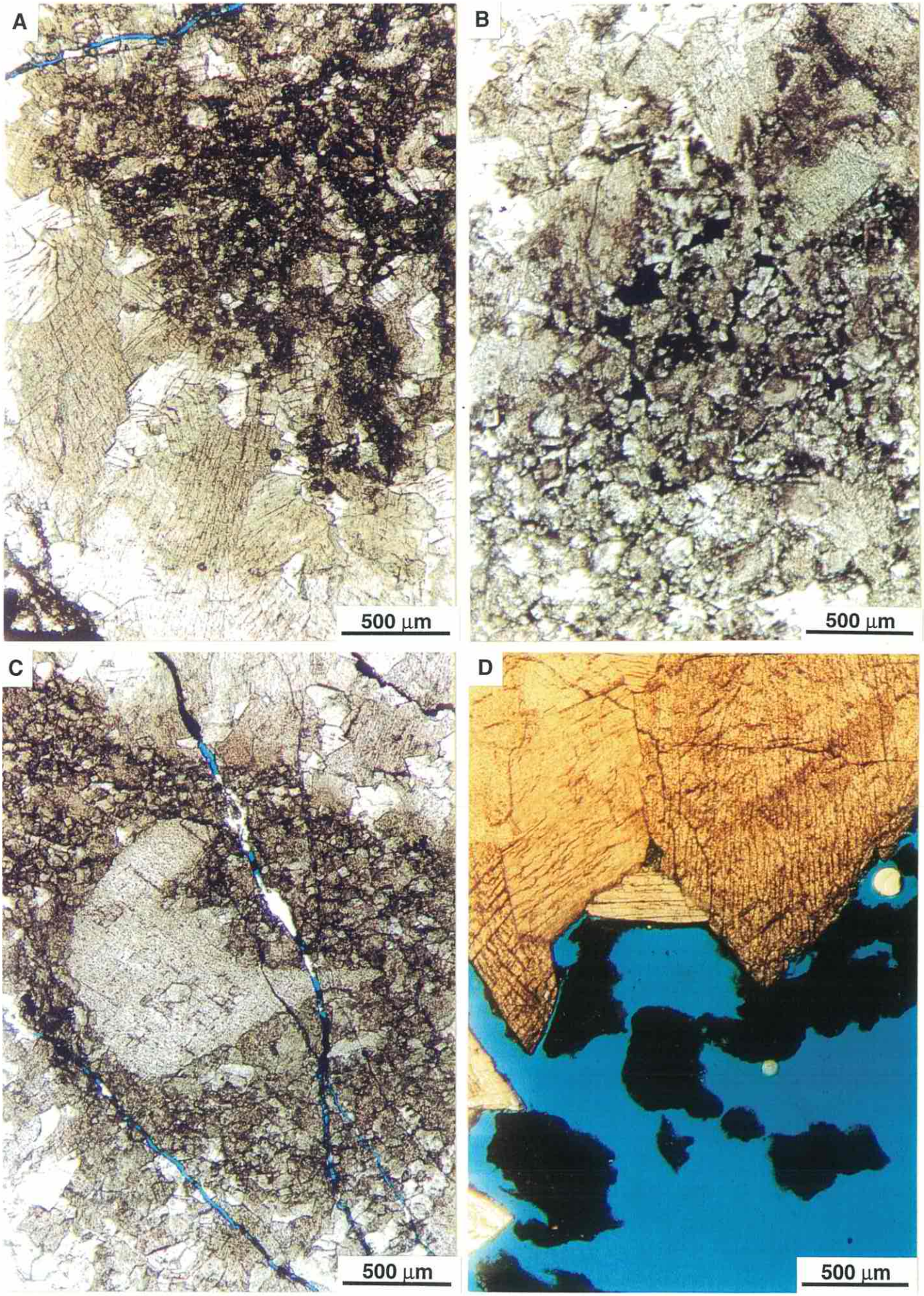
A) 13132 ft. Breccia fragment consisting of very fine crystalline dolomite with interstitial bitumen. Saddle dolomite cement between breccia fragments, microfractures.

B) 13132 ft. Recrystallized very fine crystalline dolomite, bitumen.

C) 13132 ft. Breccia fragment consisting of very fine crystalline dolomite (wackestone with crinoid fragments). Saddle dolomite cement between breccia fragments, microfractures.

D) 13132 ft. Saddle dolomite lining vug, late bitumen in centre of vug, good vuggy porosity remaining.

Plate 4



E37-6010-12400

Plate 5

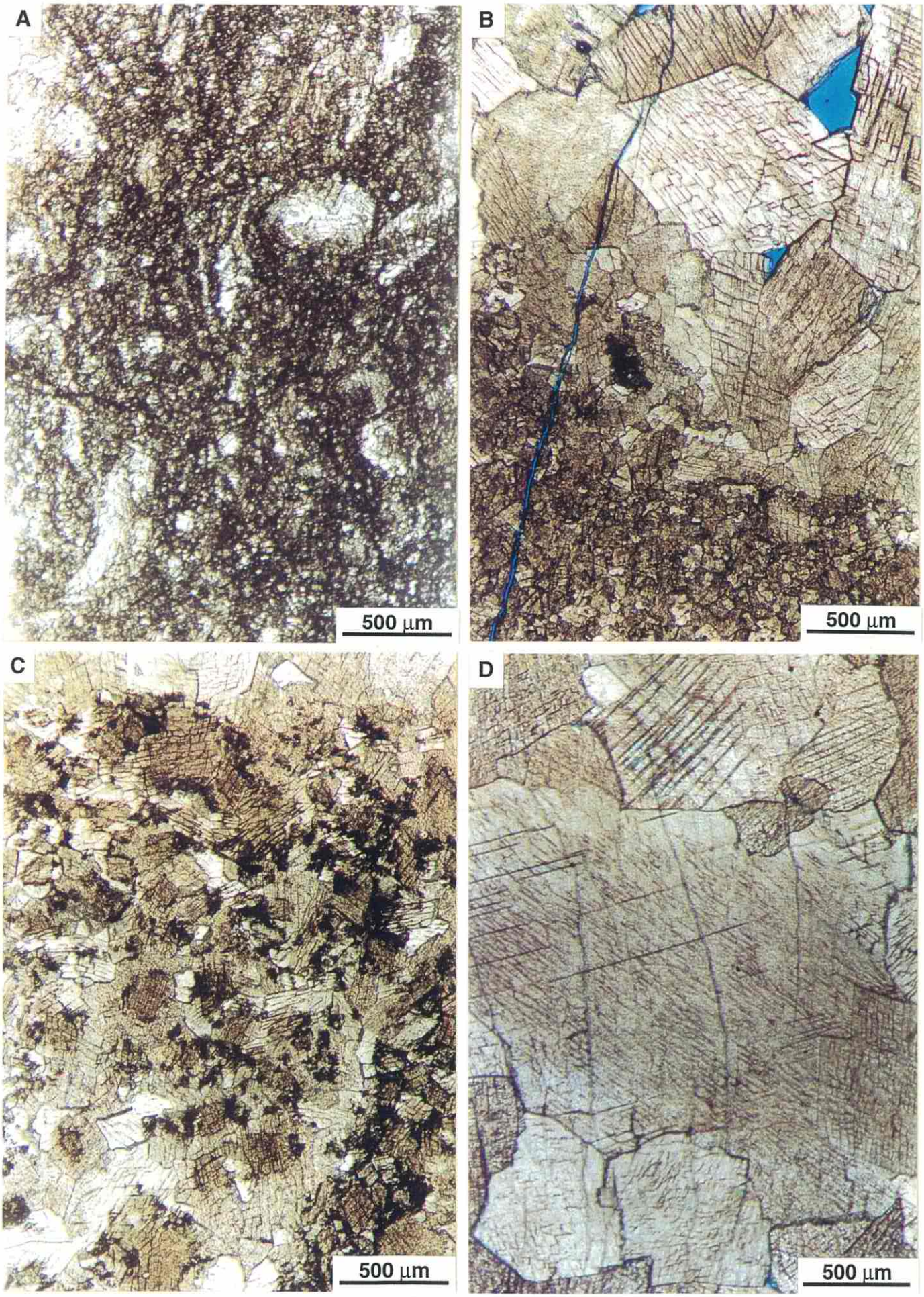
A) 13140 ft. Dolomite, microcrystalline, wackestone.

B) 13140 ft. Breccia fragment consisting of very fine crystalline dolomite, saddle dolomite cement between breccia fragments. Note microfractures crossing both phases of dolomite.

C) 13140 ft. Dolomite, medium crystalline, recrystallized.

D) 13140 ft. Saddle dolomite filling large vug. Note microfractures through the dolomite crystals.

Plate 5



B38-6010-12400

Plate 1

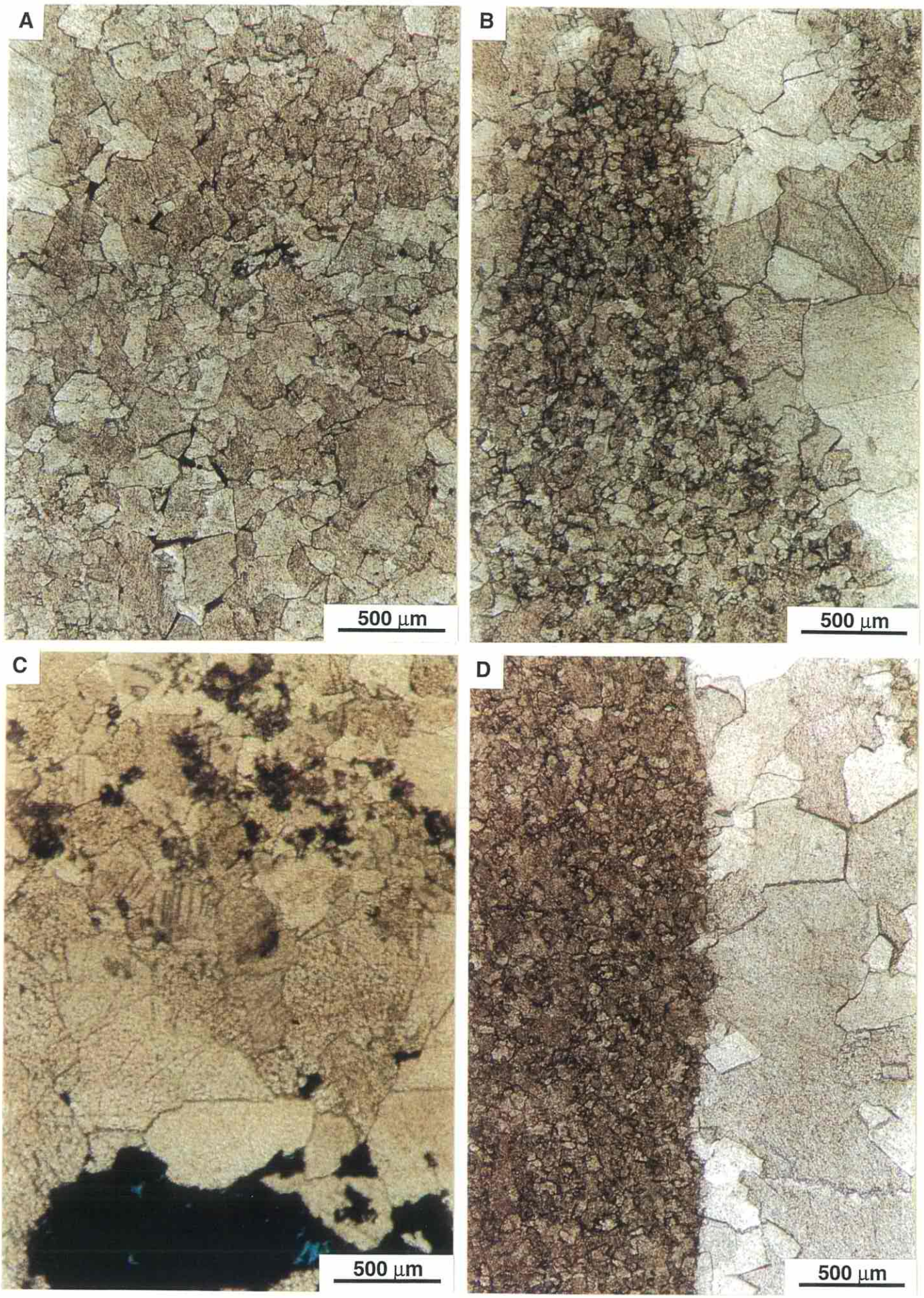
A) 12284.5 ft. Dolomite, very fine crystalline dolomite, mudstone, minor bitumen in intercrystalline porosity.

B) 12457.75 ft. Dolomite, breccia fragment of microcrystalline dolomite cemented by medium to coarse crystalline saddle dolomite.

C) 12457.75 ft. Very fine crystalline dolomite being replaced by medium crystalline dolomite, vug lined with very coarse crystalline dolomite, late bitumen in centre of vug.

D) 12509 ft. Dolomite, breccia fragment of microcrystalline dolomite, cemented by medium to coarse crystalline dolomite.

Plate 1



B38-6010-12400

Plate 2

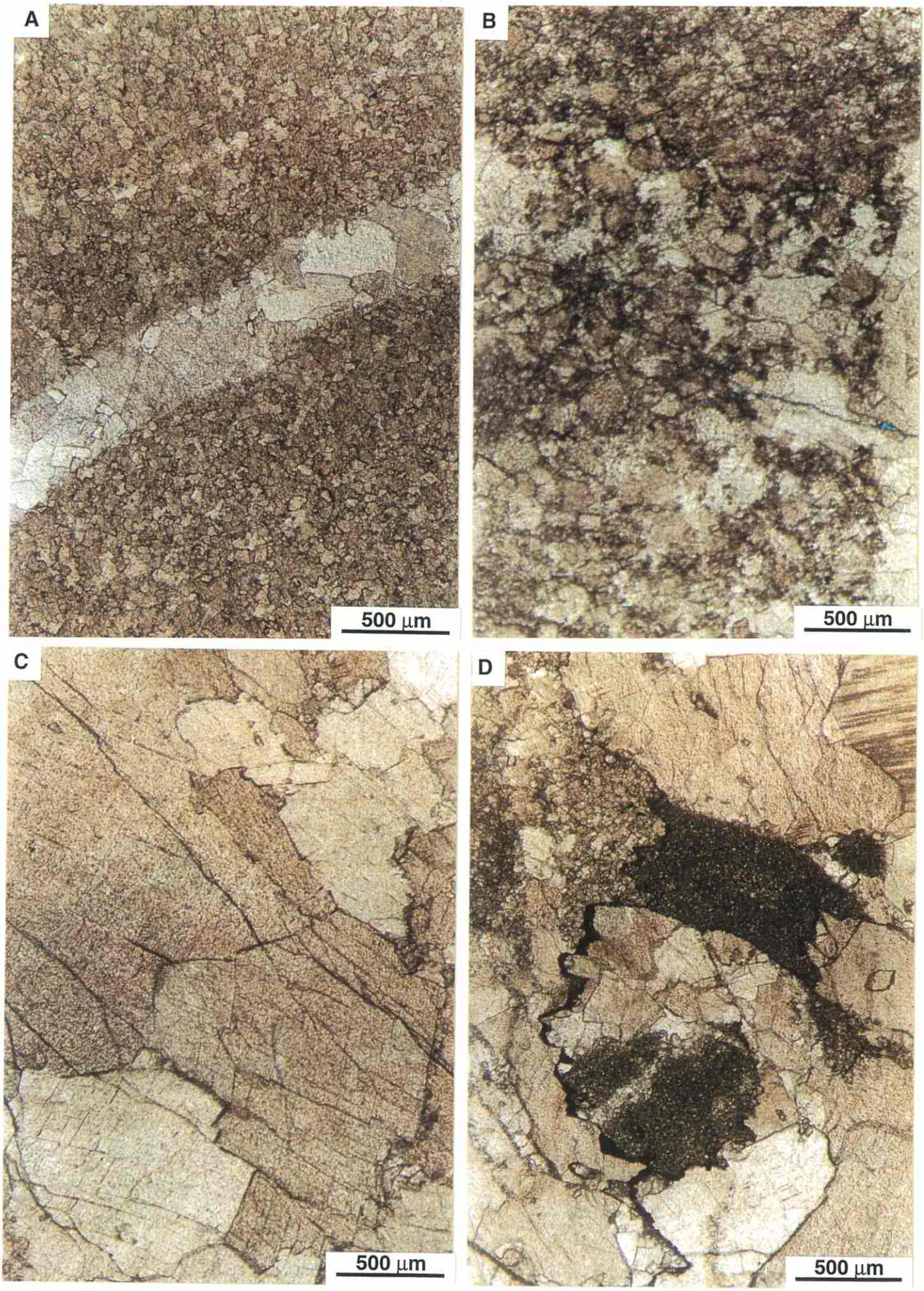
A) 12509 ft. Dolomite, microcrystalline, mudstone, fracture filled with medium crystalline dolomite.

B) 12509 ft. Dolomite, very fine to fine crystalline dolomite, recrystallized, microfractures.

C) 12735.5 ft. Very coarse crystalline saddle dolomite filling vug, microfractures.

D) 12735.5 ft. Dolomite, microcrystalline, mudstone along stylolites, very coarse crystalline dolomite cement.

Plate 2



B38-6010-12400

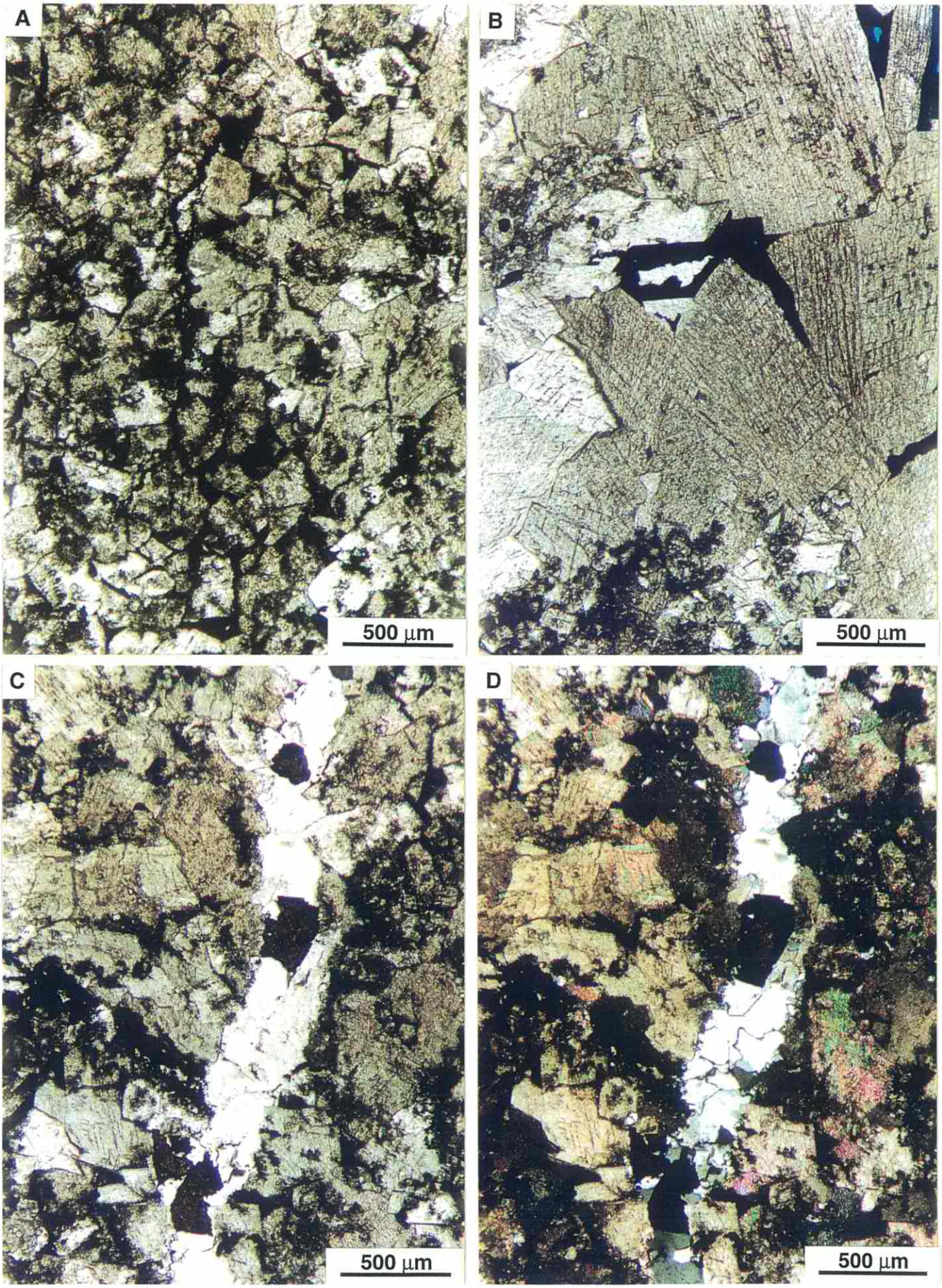
Plate 3

A) 11693 ft. Recrystallized very fine crystalline dolomite with abundant early bitumen in intercrystalline porosity.

B) 11693 ft. Saddle dolomite filling large vug, minor late bitumen in centre of vug.

C & D) 11693 ft. Recrystallized fine crystalline dolomite with early bitumen in intercrystalline porosity. Note fracture filled with quartz and sphalerite. C - plain light, D - crossed nicols.

Plate 3



B38-6010-12400

Plate 4

A & B) 11706 ft. Recrystallized very fine crystalline dolomite. Note minor quartz replacement. A - plain light, B - crossed nicols.

C) 11706 ft. Fine to medium crystalline saddle dolomite. Note small fracture held open with quartz and dolomite crystals.

D) 11706 ft. Vugs filled with saddle dolomite, quartz, and late bitumen. Note the zones of bitumen in the quartz crystals. This confirms the timing of the bitumen and quartz cementation. They must have occurred at the same time. The bitumen occurs during and after the quartz cement.

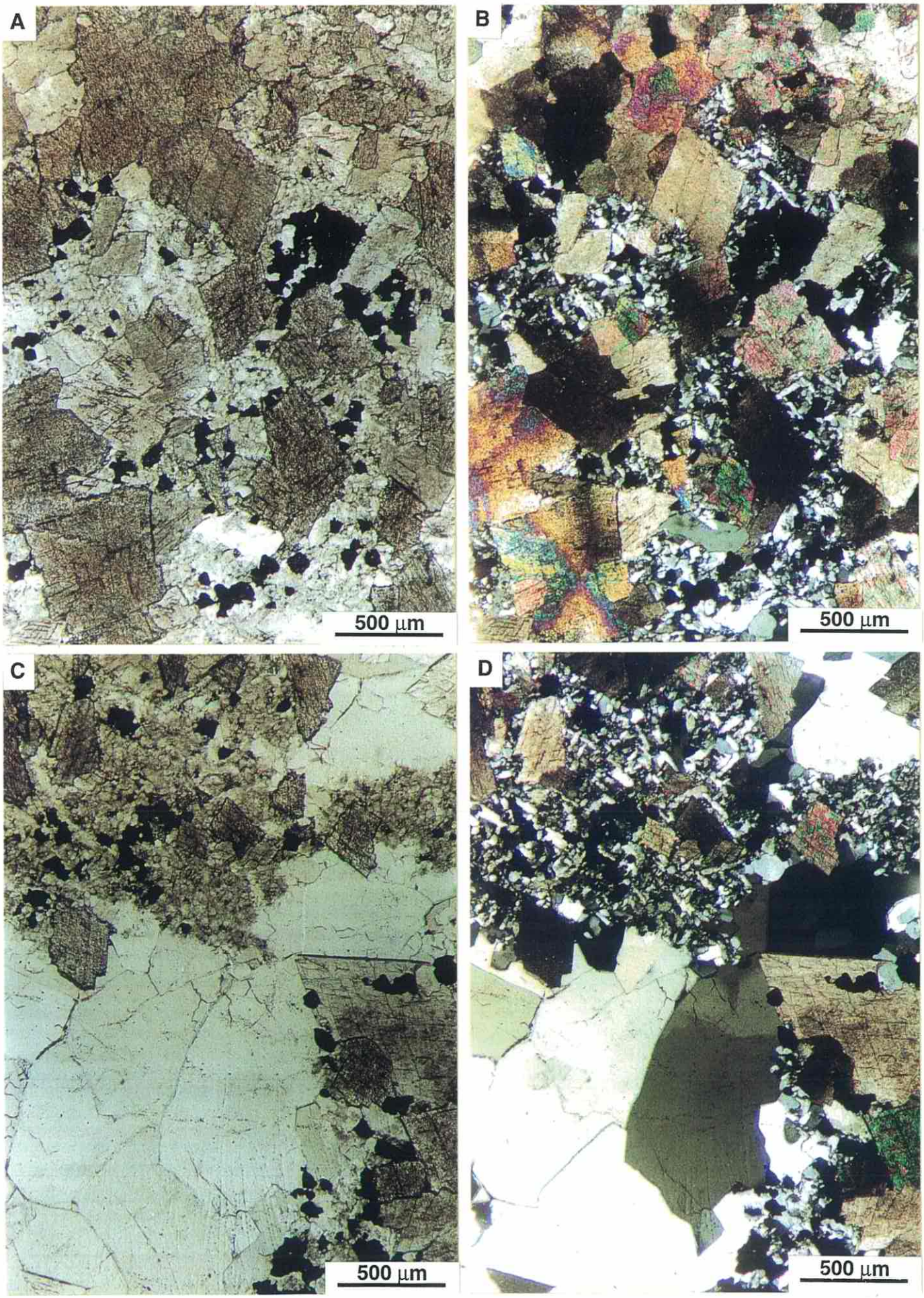
B38-6010-12400

Plate 5

A & B) 11722 ft. Medium crystalline saddle dolomite, abundant quartz replacement. Some sphalerite as cement between quartz crystals. A - plain light, B - crossed nicols.

C & D) 11722 ft. Medium crystalline saddle dolomite, abundant quartz replacement, some sphalerite. Vug filled with saddle dolomite, then quartz, then sphalerite. C - plain light, D - crossed nicols.

Plate 5



B38-6010-12400

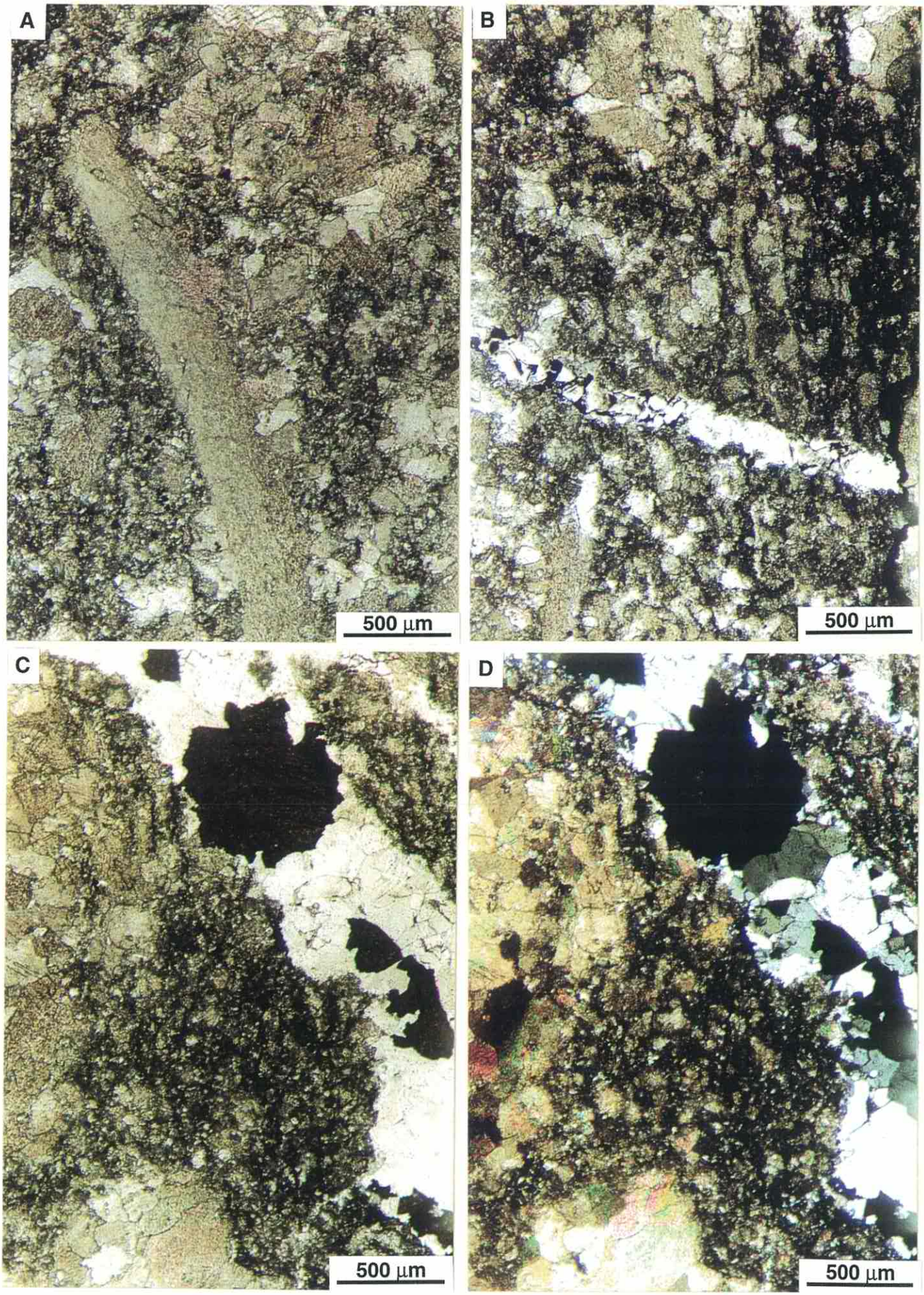
Plate 6

A) 11734 ft. Microcrystalline dolomite, originally a wackestone.

B) 11734 ft. Recrystallized very fine crystalline dolomite, originally a mudstone to wackestone, abundant bitumen in intercrystalline porosity. Note fracture filled with quartz and late bitumen.

C & D) 11734 ft. Very fine crystalline dolomite with abundant early bitumen in intercrystalline porosity, originally a mudstone matrix. Note fracture filled with quartz and sphalerite. C - plain light, D - crossed nicols.

Plate 6



B38-6010-12400

Plate 7

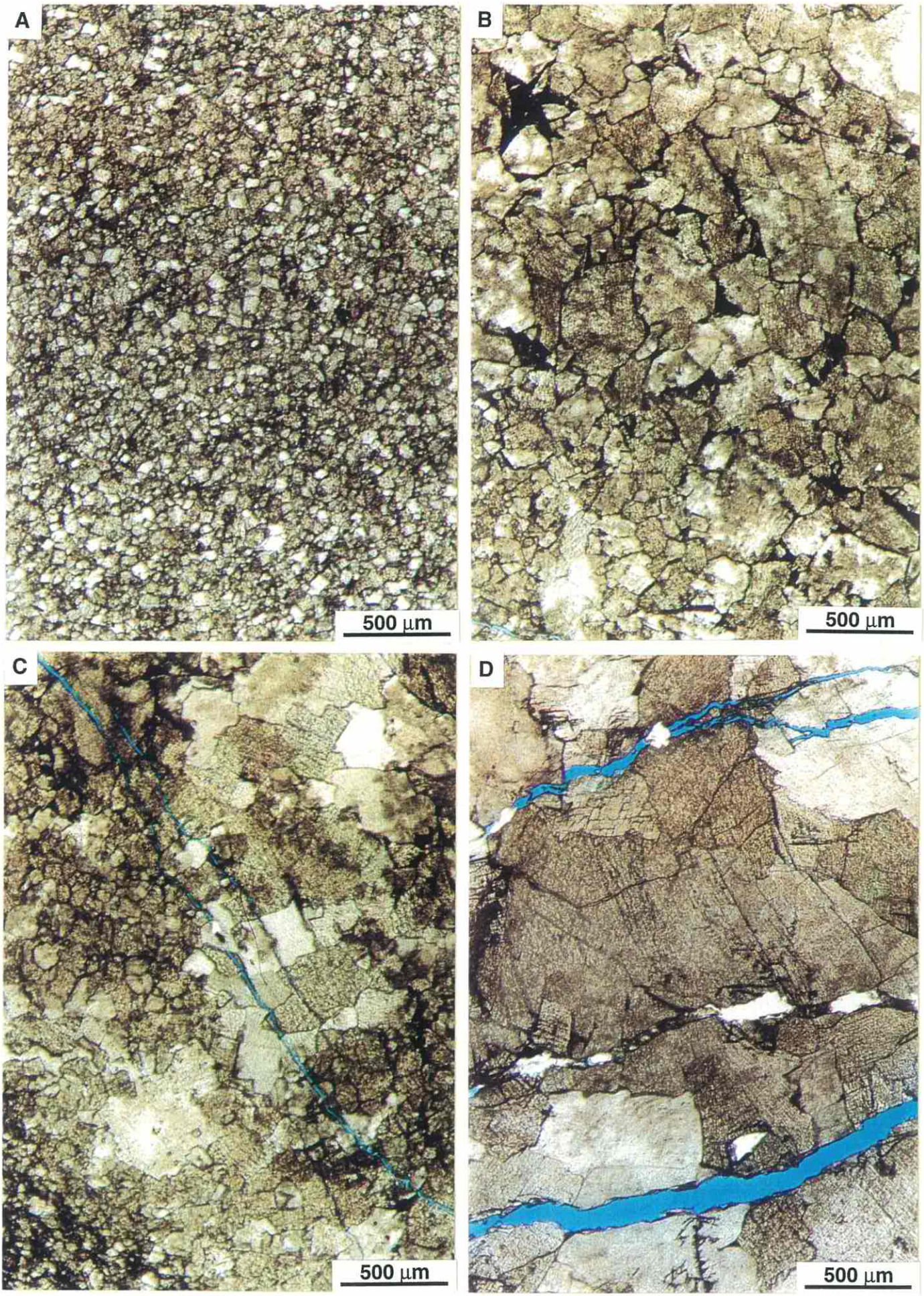
A) 12050 ft. Breccia fragment consisting of very fine crystalline dolomite with early bitumen in intercrystalline porosity.

B) 12050 ft. Recrystallized fine crystalline dolomite with bitumen in intercrystalline porosity.

C) 12050 ft. Recrystallized dolomite with saddle dolomite in vug. Note open microfractures.

D) 12748 ft. Saddle dolomite in vug. Note open microfractures.

Plate 7



I48-6010-12400

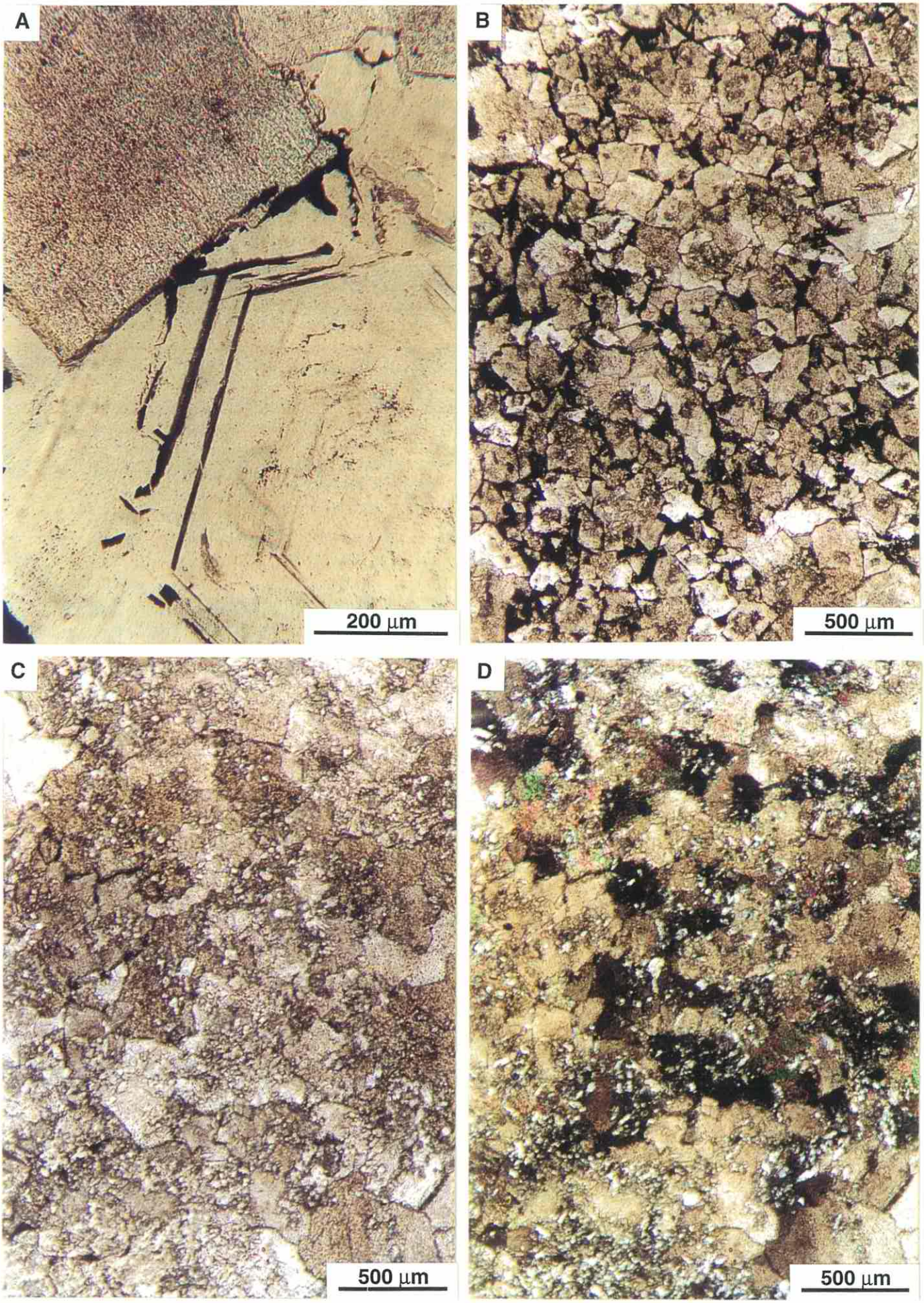
Plate 1

A) 3666.5 m. Dolomite, very coarse crystalline saddle dolomite in centre of vug (top right). The dolomite is followed by very coarse crystalline quartz. During the deposition of the quartz, there was deposition of bitumen on the quartz crystal faces. This indicates that the bitumen was deposited at the same time and after the deposition of the quartz. Note smaller scale.

B) 3666.5 m. Dolomite, very fine crystalline, mudstone, early bitumen in intercrystalline porosity.

C & D) 3666.5 m. Dolomite, fine crystalline, minor quartz replacement. C - plain light, D - crossed nicols.

Plate 1



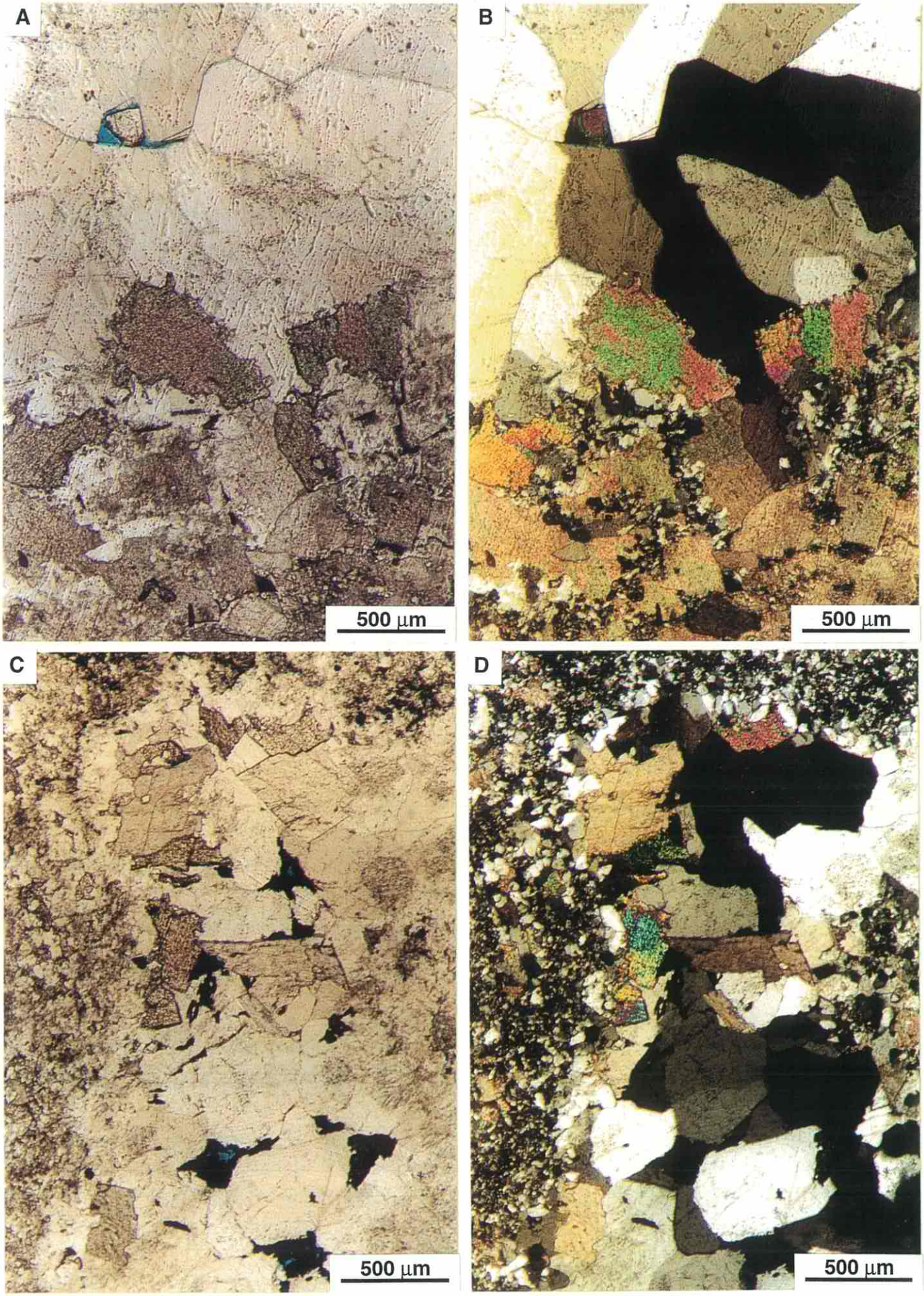
I48-6010-12400

Plate 2

A & B) 3666.5 m. Dolomite, fine crystalline. Note the coarse crystalline quartz filling the vug at top of photo. There is also quartz replacement in the dolomite. A - plain light, B - crossed nicols.

C & D) 3669.4 m. Dolomite, fine crystalline. Note the coarse crystalline quartz filling the vug in centre of photo. There is also abundant quartz replacement in the dolomite. Bitumen is also present in the centre of the vug. The relationship of the quartz cement and bitumen suggests that the quartz was precipitated prior to the emplacement of the bitumen. C - plain light, D - crossed nicols.

Plate 2



I48-6010-12400

Plate 3

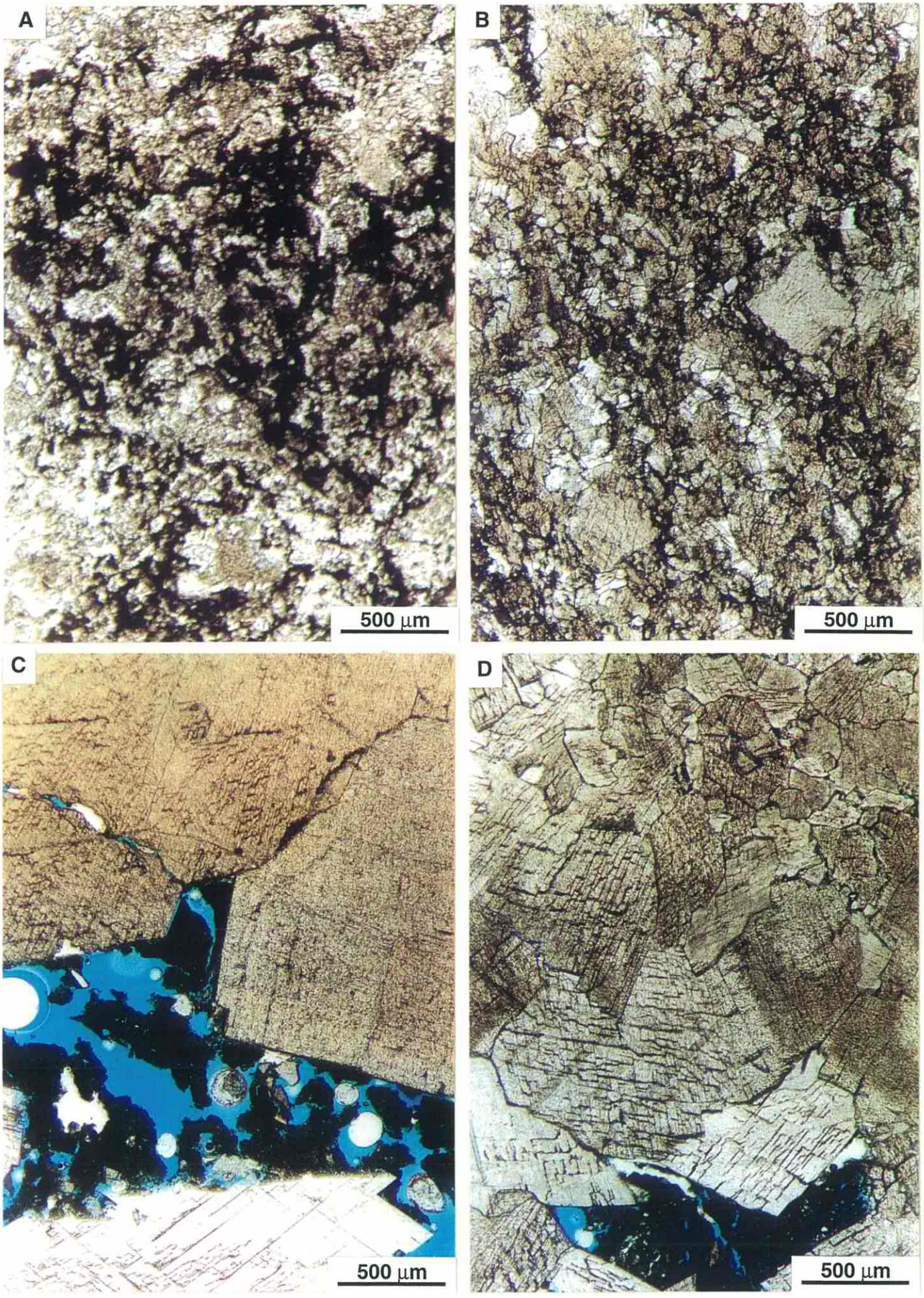
A) 3669.4 m. Very fine to fine crystalline dolomite, abundant bitumen in intercrystalline porosity.

B) 3724.0 m. Very fine crystalline dolomite, originally a skeletal wackestone, abundant bitumen in intercrystalline porosity.

C) 3724.0 m. Saddle dolomite lining large vug, late bitumen in centre of vug.

D) 3730.0 m. Coarse to very coarse crystalline saddle dolomite lining large vug, late bitumen filling vug.

Plate 3



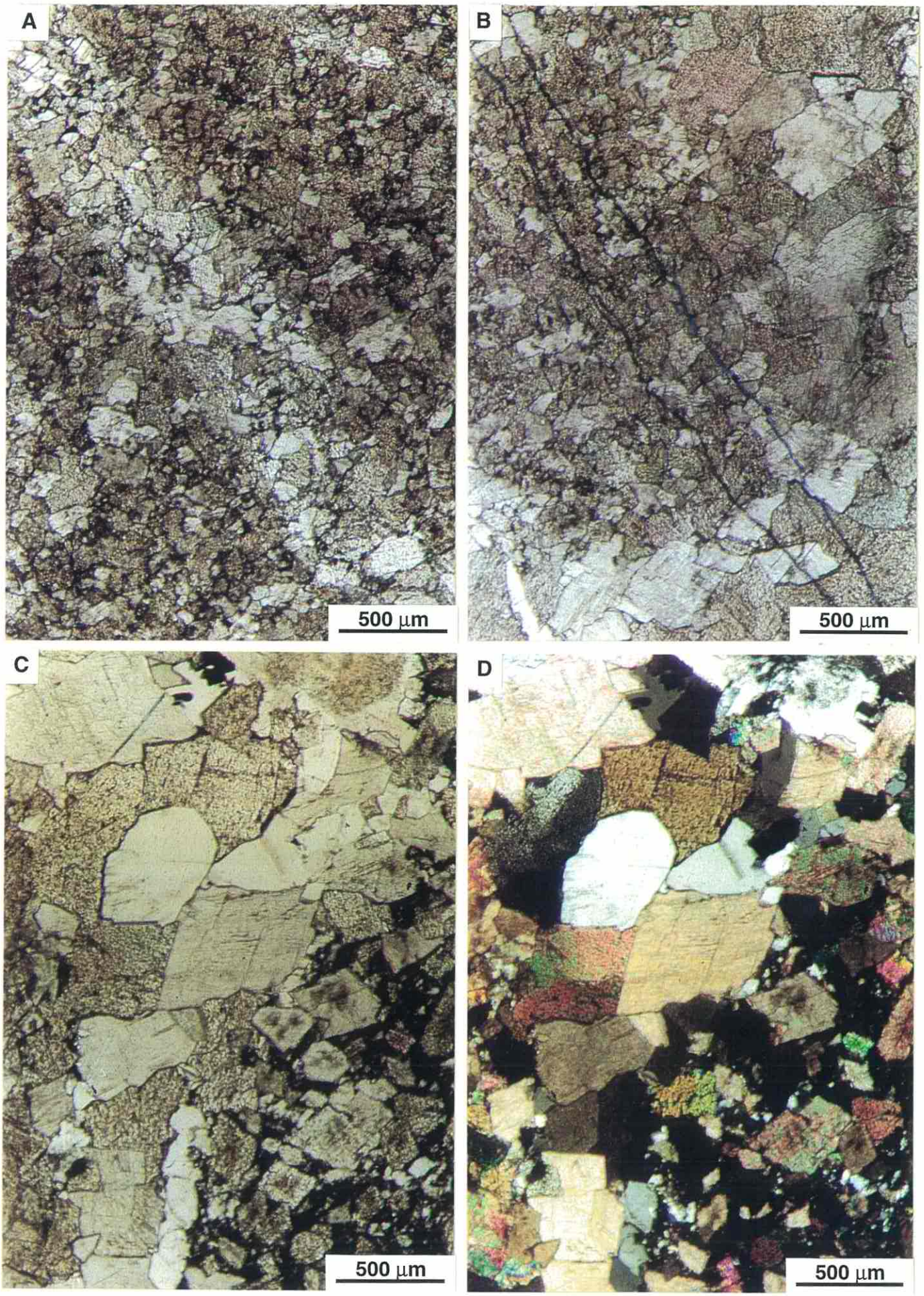
I48-6010-12400

Plate 4

A) 3737.8 m. Very fine crystalline dolomite, originally a mudstone to wackestone. Note early fracture filled with very fine crystalline dolomite.

B) 3737.8 m. Very fine crystalline dolomite, originally a mudstone to wackestone. Vug filling saddle dolomite, at right and bottom of photo. Note late open microfractures crossing both matrix and later saddle dolomite.

C & D) 3737.8 m. Fine crystalline dolomite plugged with early bitumen (lower right of photo). The vuggy porosity is filled with saddle dolomite and quartz. C - plain light, D - crossed nicols.


A
500 µm
B
500 µm
C
500 µm
D
500 µm

I48-6010-12400

Plate 5

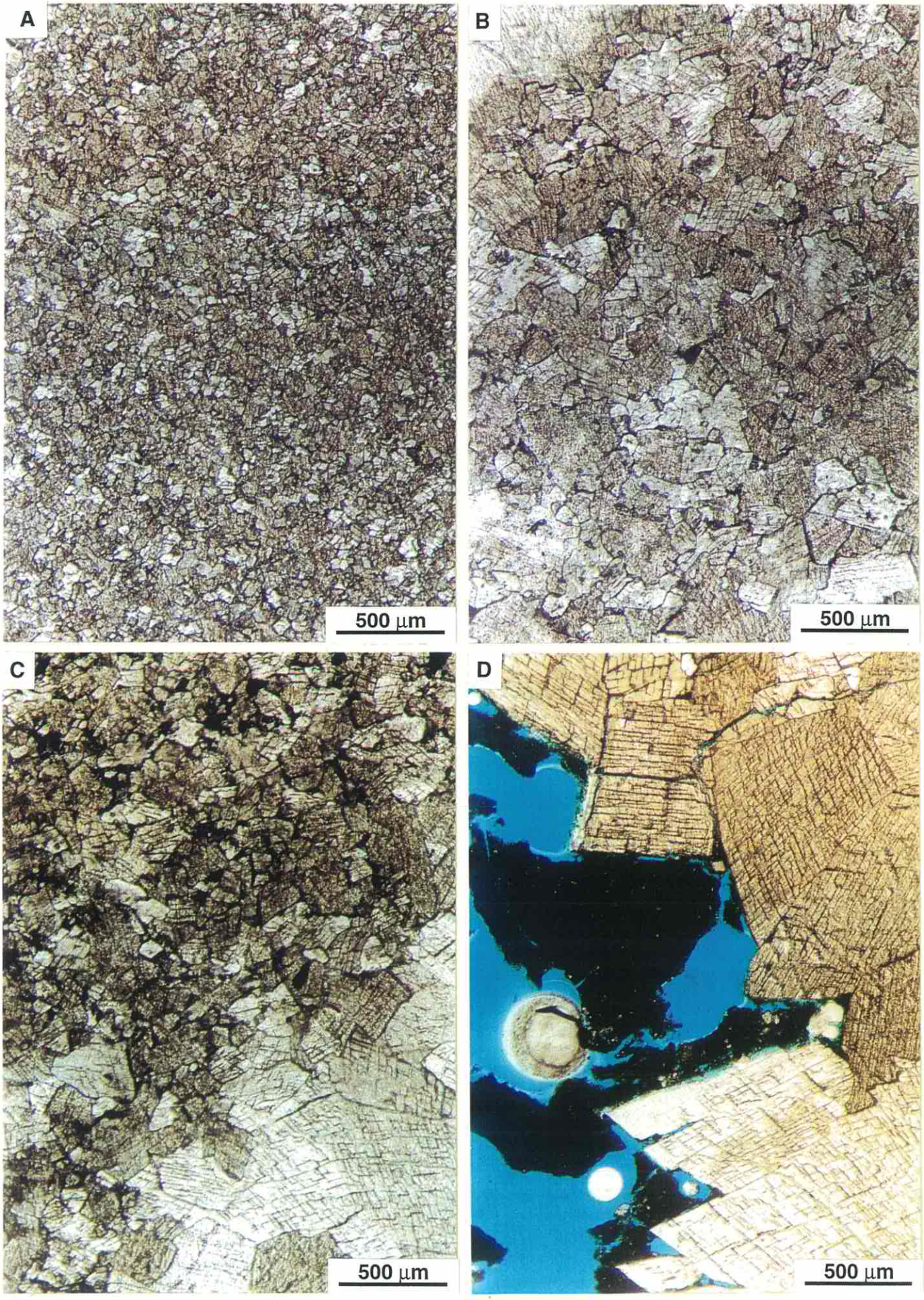
A) 3742.2 m. Microcrystalline dolomite, originally a mudstone.

B) 3742.2 m. Fine crystalline replacement dolomite, early bitumen in intercrystalline porosity.

C) 3747.3 m. Very fine to fine crystalline dolomite, originally a mudstone, bitumen in intercrystalline porosity, saddle dolomite filling vuggy porosity.

D) 3747.3 m. Saddle dolomite lining large vug, late bitumen in centre of vug.

Plate 5



I48-6010-12400

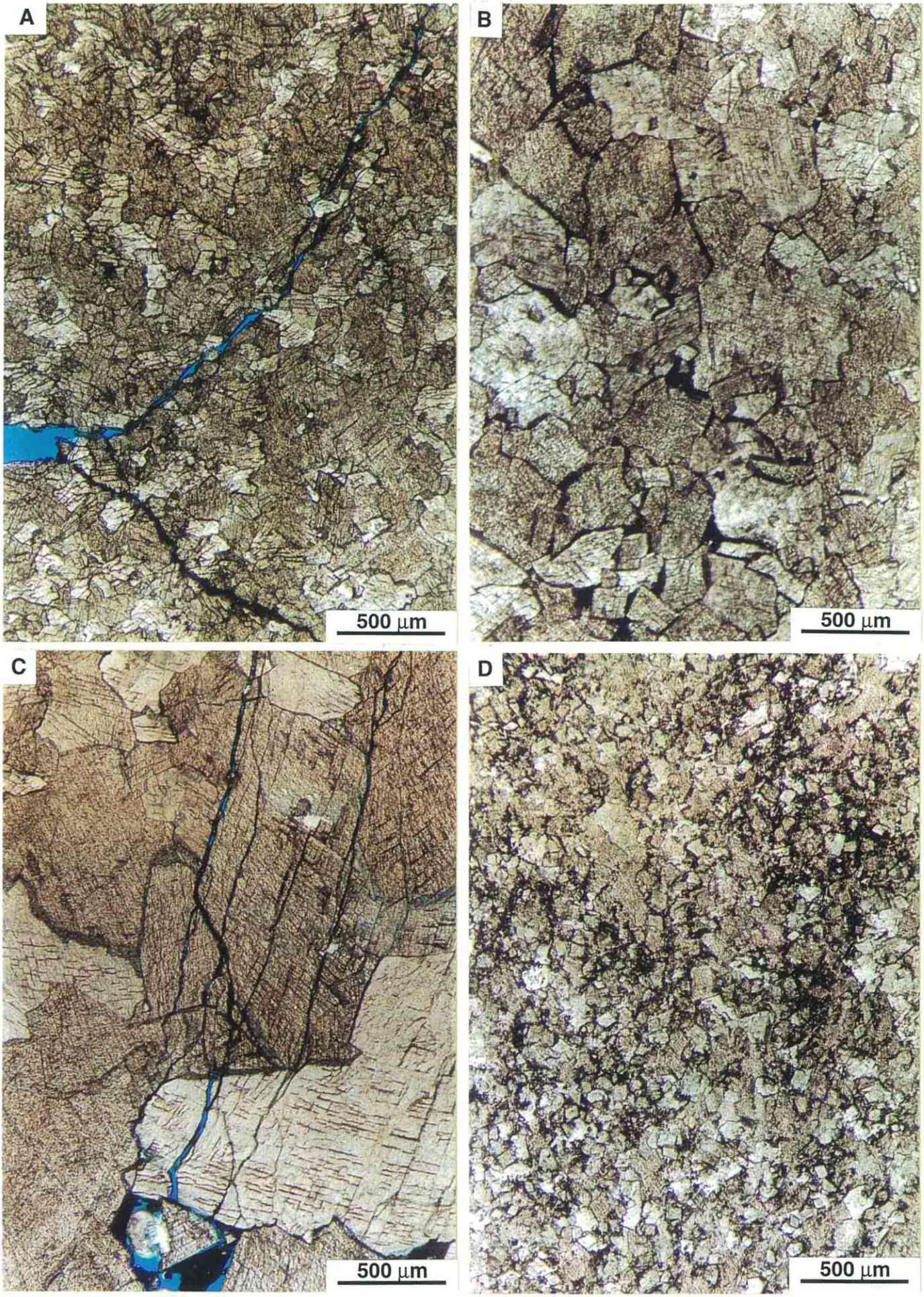
Plate 6

A) 3755.7 m. Very fine crystalline dolomite, mudstone. Note late open fractures.

B) 3755.7 m. Fine crystalline replacement dolomite, early bitumen in intercrystalline porosity.

C) 3755.7 m. Saddle dolomite in large vug, late bitumen in centre of vug. Note the numerous microfractures.

D) 3764.0 m. Very fine crystalline dolomite, wackestone, early bitumen in intercrystalline porosity.


A
500 µm
B
500 µm
C
500 µm
D
500 µm

I48-6010-12400

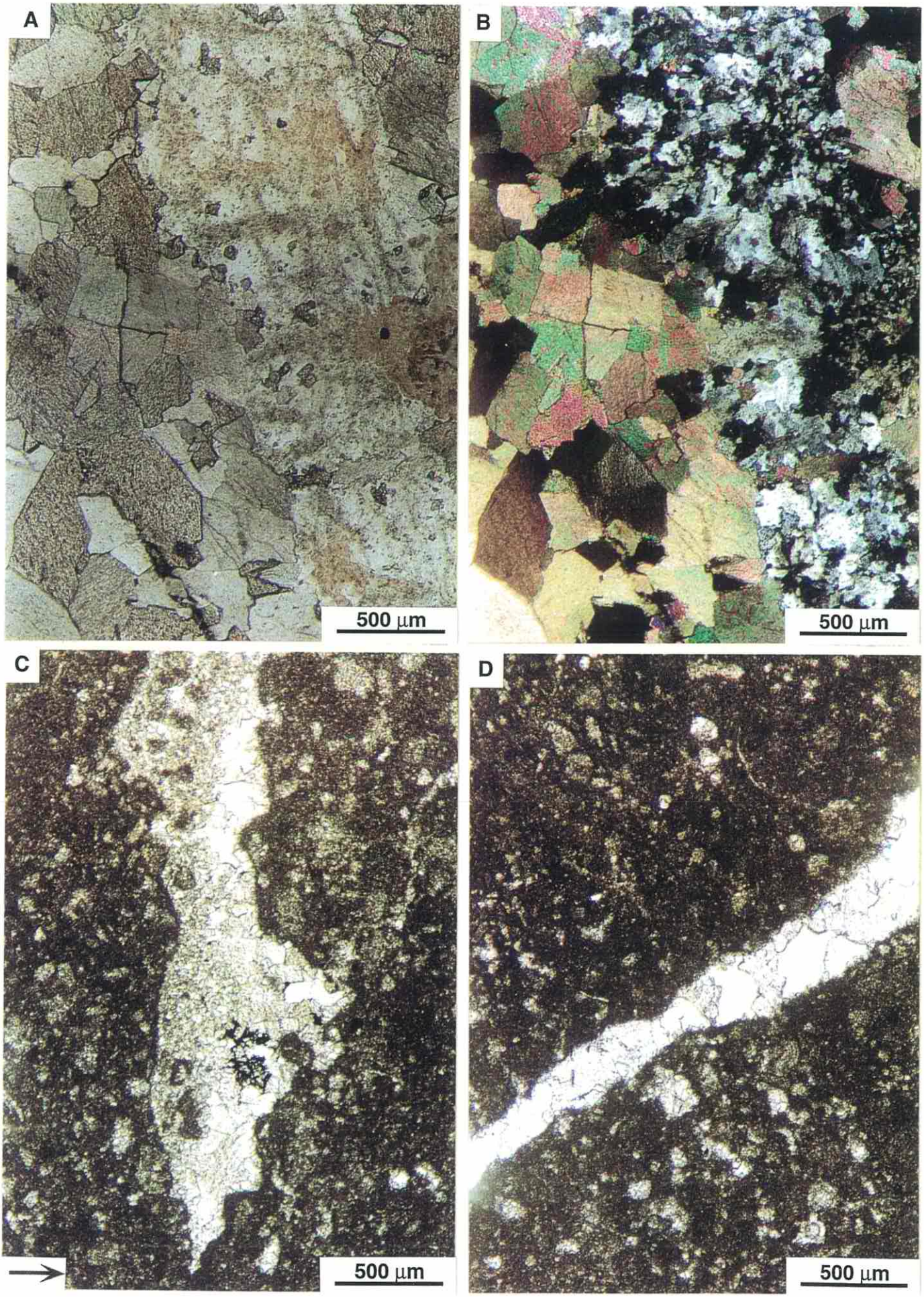
Plate 7

A & B) 3764.0 m. Medium to coarse crystalline saddle dolomite replacing original very fine crystalline dolomite. Note abundant quartz replacement. A - plain light, B - crossed nicols.

C) 4035.3 m. Dolomite, microcrystalline, wackestone, fenestral fabric.

D) 4035.3 m. Dolomite, microcrystalline, wackestone, fracture filled with fine crystalline dolomite.

I48-6010-12400
Plate 7



G01-6010-12415

Plate 1

A) 13677.25 ft. Dolomite, breccia fragments of wackestone at top of photo, medium crystalline dolomite in large fracture at base of photo.

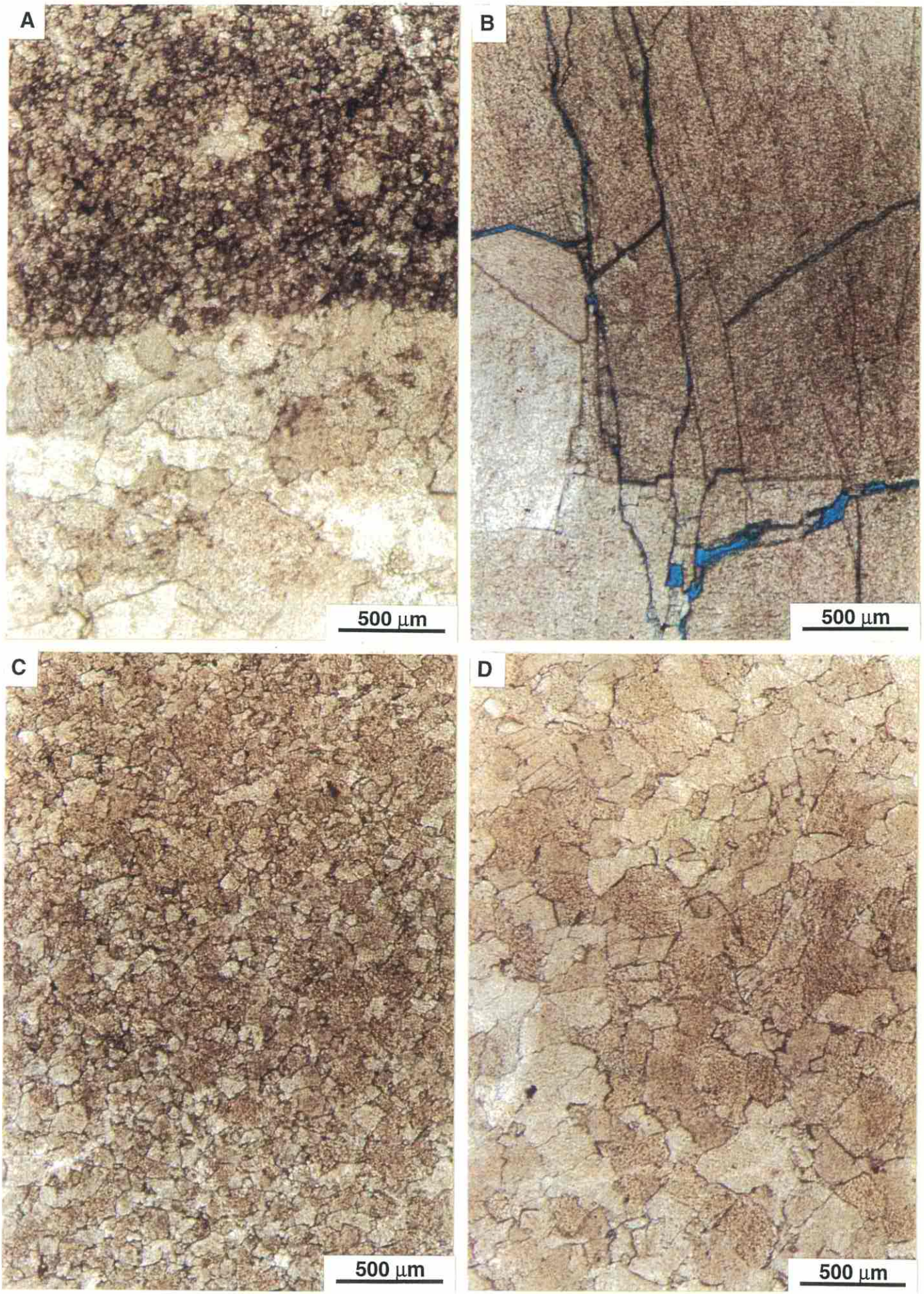
B) 13677.25 ft. Very coarse crystalline saddle dolomite in cavity filling cement. Note numerous microfractures.

C) 13940.5 ft. Dolomite, very fine crystalline, originally a mudstone. Little bitumen in intercrystalline porosity.

D) 13940.5 ft. Dolomite, fine to medium crystalline, recrystallized from very fine crystalline dolomite.

G01-6010-12415

Plate 1



G01-6010-12415

Plate 2

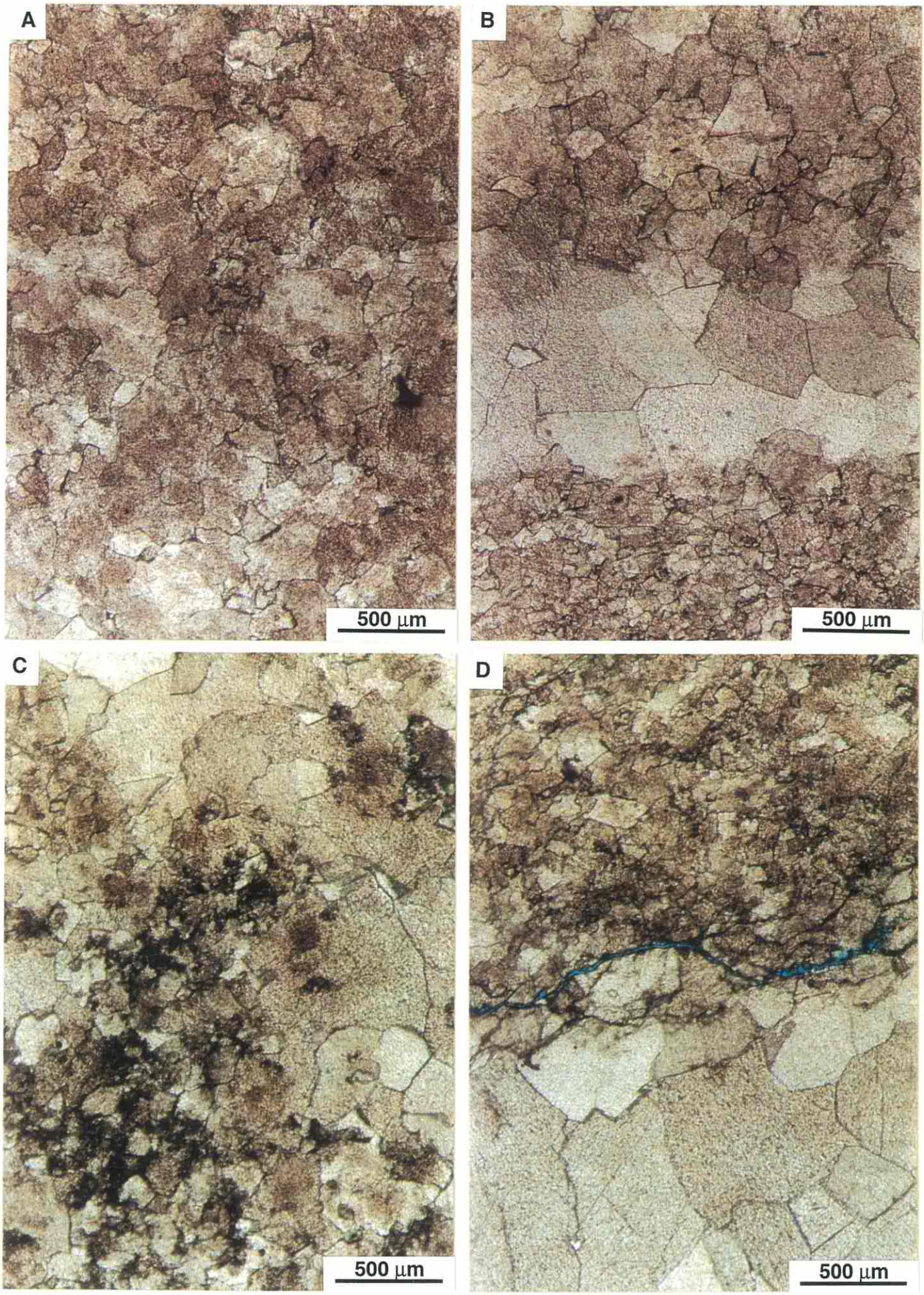
A) 14414.5 ft. Dolomite, very fine crystalline, being recrystallized by medium crystalline dolomite.

B) 14414.5 ft. Dolomite, very fine crystalline, originally a mudstone, fracture filled with coarse crystalline saddle dolomite.

C) 14429 ft. Dolomite, replacement of very fine crystalline dolomite with medium crystalline dolomite.

D) 14429 ft. Dolomite, very fine crystalline, originally a wackestone to mudstone, vug filled with very coarse crystalline saddle dolomite, microfractures.

Plate 2



G01-6010-12415

Plate 3

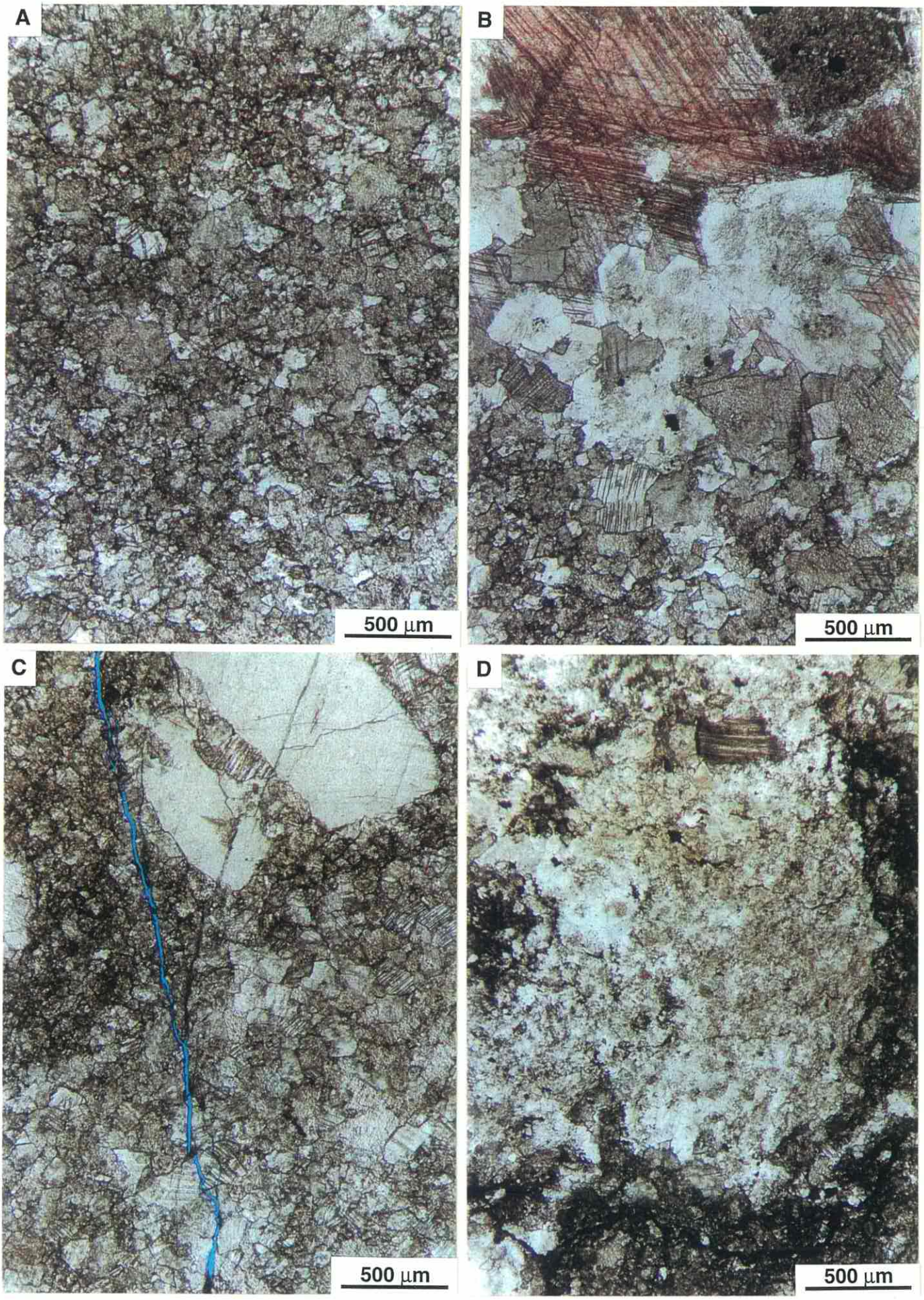
A) 13536 ft. Dolomite, very fine crystalline, wackestone, bitumen.

B) 13536 ft. Recrystallized dolomite at base of photo, quartz replacement, calcite as last phase of cavity fill.

C) 13552 ft. Dolomite, very fine crystalline, wackestone, crinoid fragments, microfractures.

D) 13552 ft. Massive quartz replacement.

Plate 3



G01-6010-12415

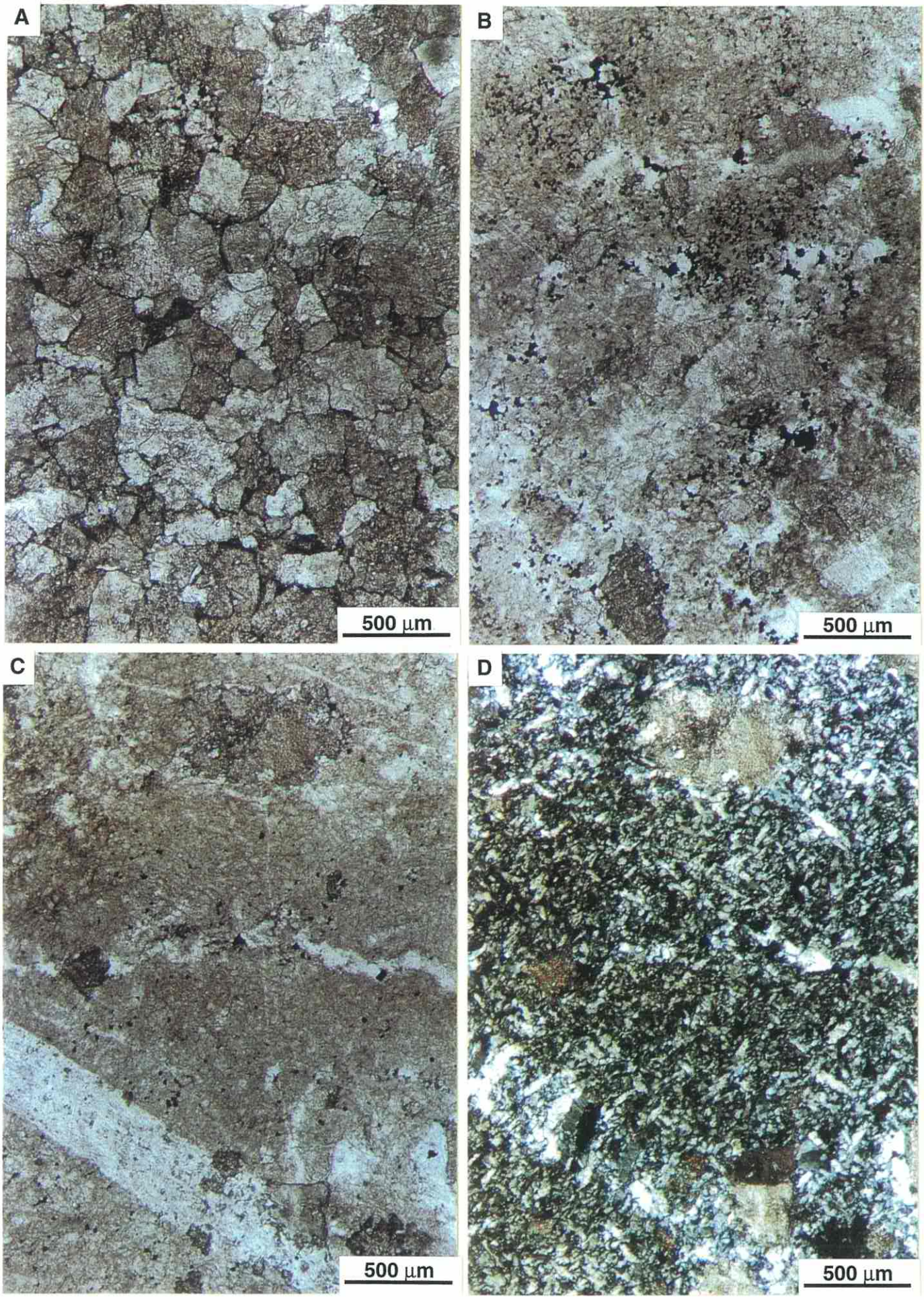
Plate 4

A) 13561 ft. Recrystallized fine crystalline dolomite, minor quartz replacement

B) 13561 ft. Massive quartz replacement, minor sphalerite associated with the quartz replacement.

C & D) 13561 ft. Massive quartz replacement. C - plain light, D - crossed nicols.

Plate 4



G01-6010-12415

Plate 5

A) 13759 ft. Recrystallized dolomite, saddle dolomite in cavity fill at base of photo, microfractures.

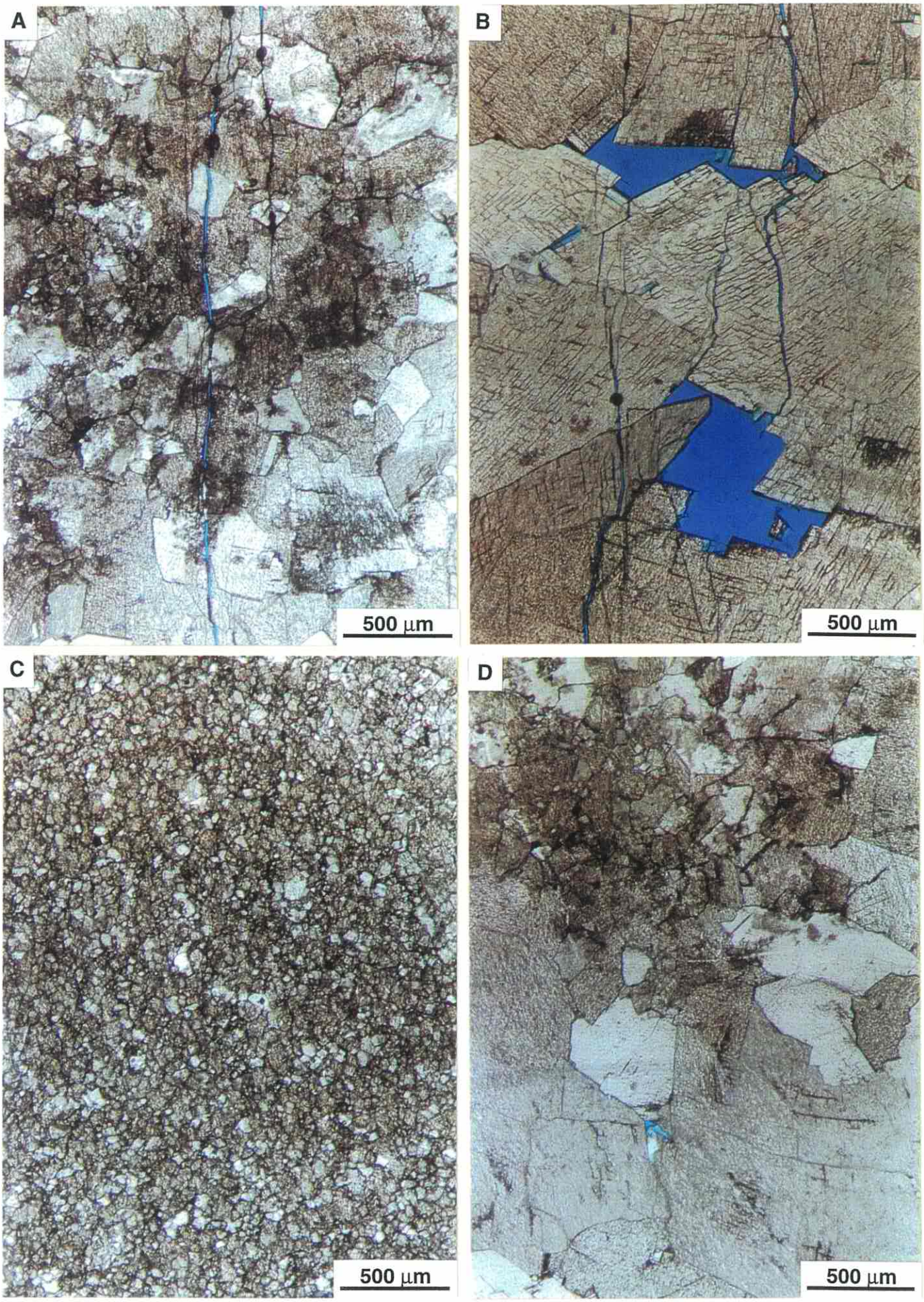
B) 13759 ft. Saddle dolomite lining vug, some vuggy porosity remaining, microfractures.

C) 14203 ft. Breccia fragment consisting of microcrystalline dolomite with bitumen between dolomite crystals.

D) 14203 ft. Recrystallized dolomite at top of photo, large vugs filled with very coarse crystalline saddle dolomite.

G01-6010-12415

Plate 5



B16-6010-12515

Plate 1

A & B) 7350 ft. Dolomite, crinoid grainstone. Very fine crystalline dolomite replacing the matrix. A - plain light, B - crossed nicols.

C) 7350 ft. Dolomite, crinoid grainstone. Very fine crystalline dolomite replacing the matrix.

B16-6010-12515

Plate 1

L60-6020-12415

Plate 1

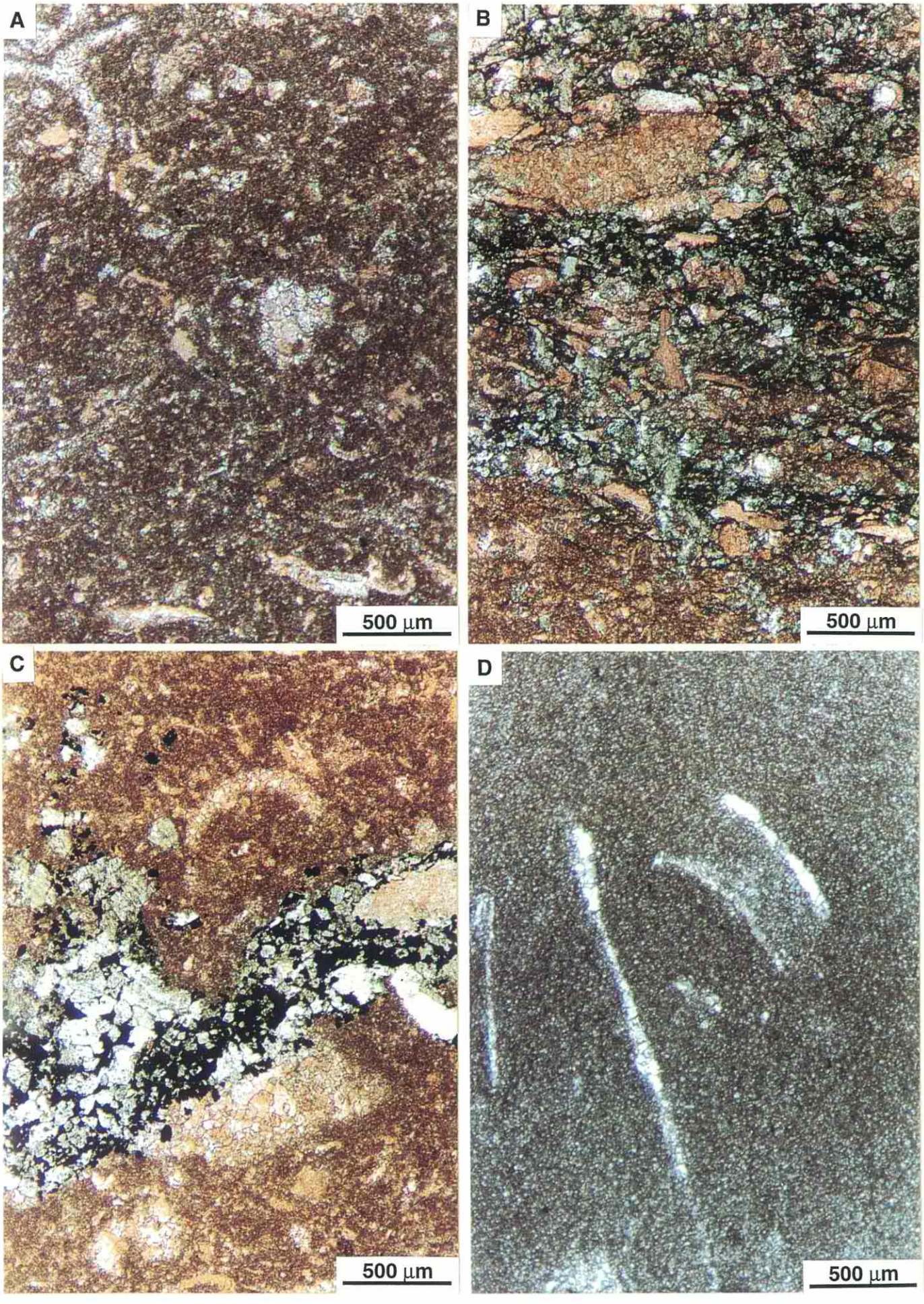
A) 5254 ft. Limestone, skeletal wackestone.

B) 5254 ft. Dolomitic limestone, wackestone, matrix dolomitized, early bitumen associated with dolomite.

C) 5254 ft. Limestone, skeletal wackestone, dolomitization along stylolites, bitumen along stylolites associated with dolomitization.

D) 5275 ft. Dolomite, microcrystalline, wackestone, scattered skeletal fragments.

Plate 1



L60-6020-12415

Plate 2

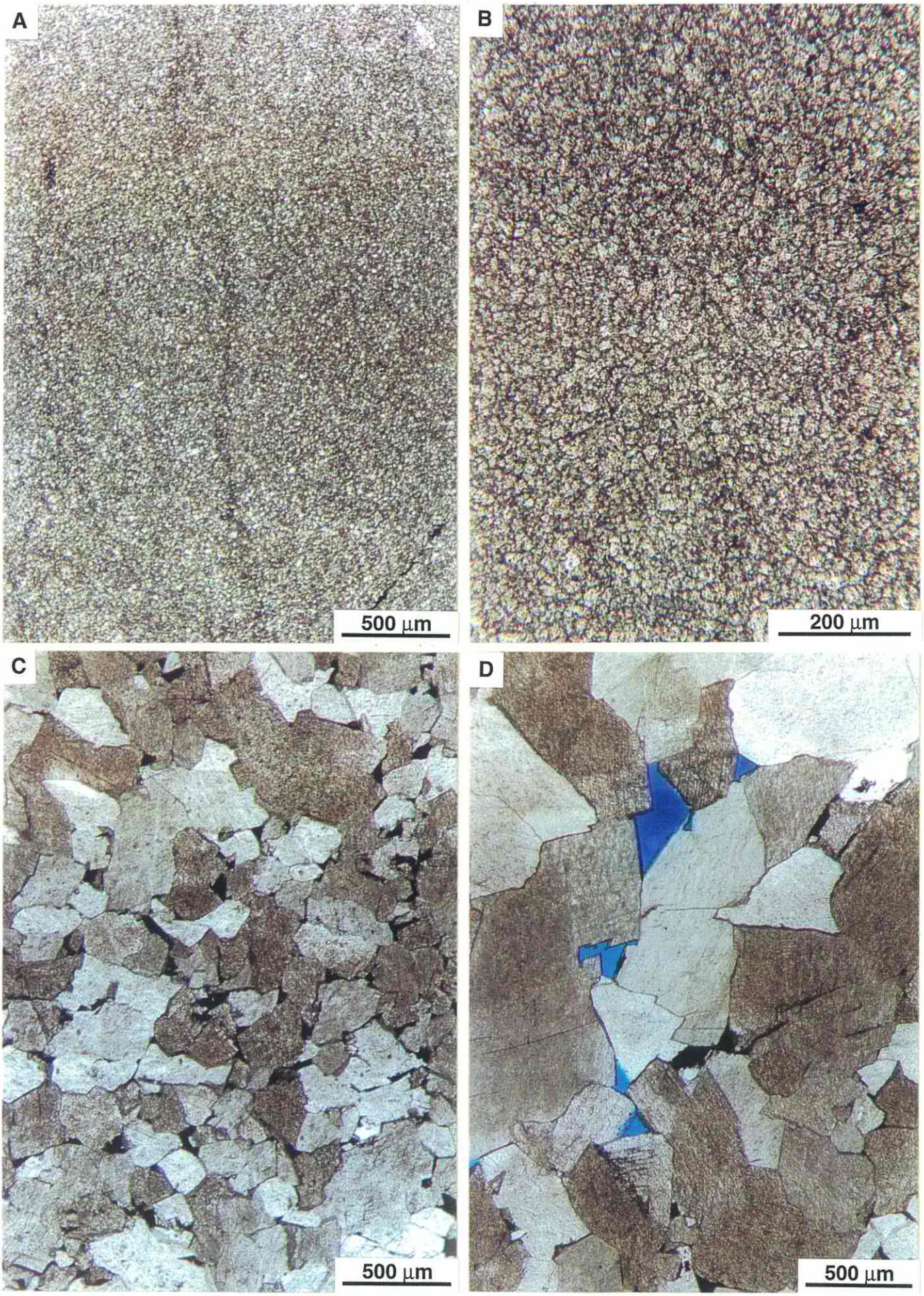
A) 5275 ft. Dolomite, microcrystalline, mudstone to wackestone.

B) 5275 ft. Dolomite, microcrystalline, mudstone to wackestone. Note different scale.

C) 5300 ft. Dolomite, fine to medium crystalline, recrystallized, bitumen between dolomite crystals.

D) 5300 ft. Dolomite, medium to coarse crystalline, bitumen, some remnant vuggy porosity.

Plate 2



M25-6030-12330

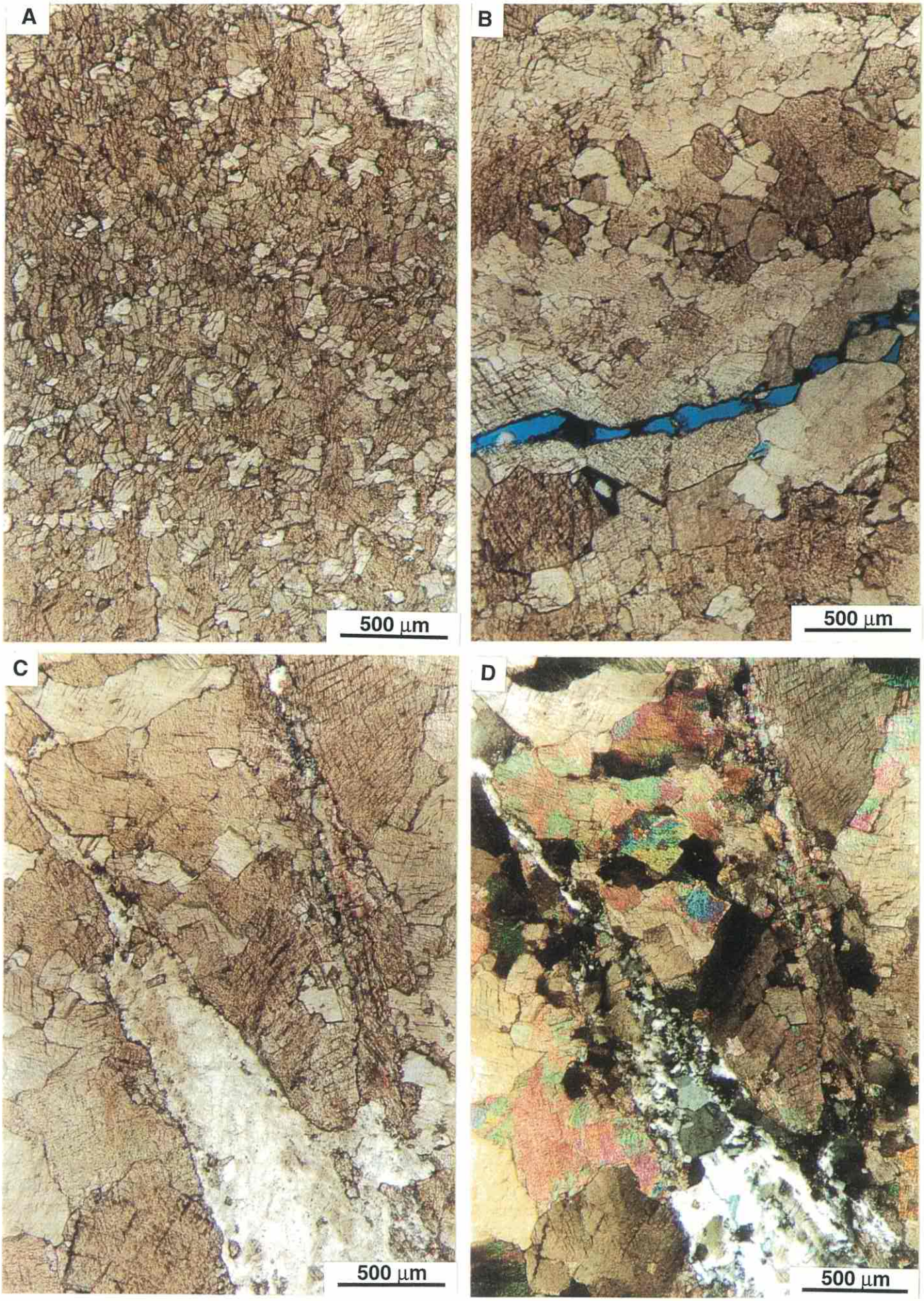
Plate 1

A) 3452.4 m. Dolomite, very fine crystalline, mudstone.

B) 3452.4 m. Dolomite, very fine to fine crystalline, mudstone to wackestone. Note open fracture. This must be an open fracture because of the bitumen along the fracture.

C & D) 3452.4 m. Dolomite, medium crystalline, recrystallized, late fracture filled with quartz and calcite. C - plain light, D - crossed nicols.

Plate 1



M25-6030-12330

Plate 2

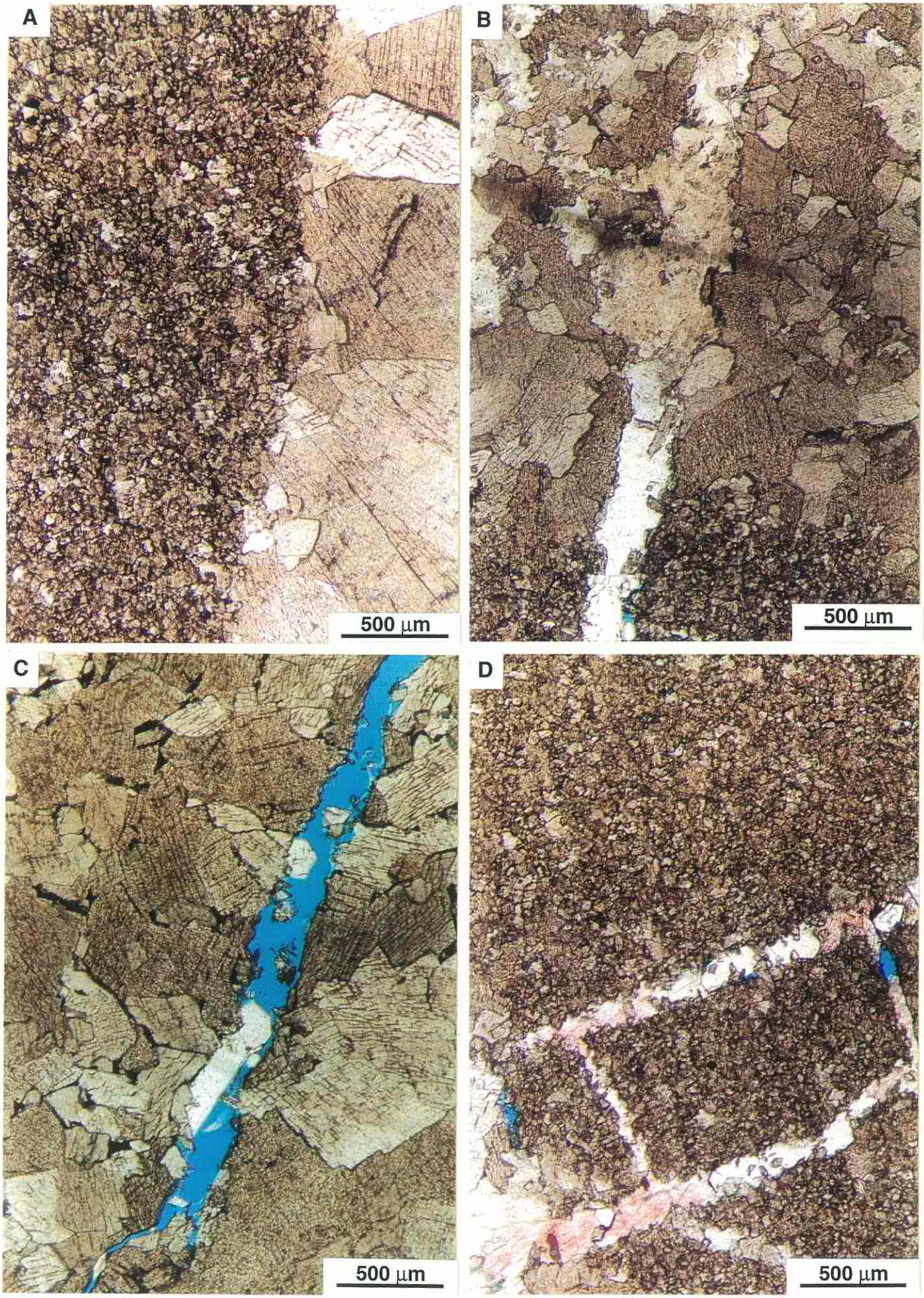
A) 3454 m. Dolomite, very fine crystalline breccia fragment (mudstone), cemented with very coarse crystalline saddle dolomite (right).

B) 3454 m. Dolomite, fine to medium crystalline. Note fracture in center of photo filled with quartz. Quartz is also replacing dolomite along this fracture.

C) 3454 m. Dolomite, medium crystalline dolomite, recrystallized. Note the late fracture with isolated quartz crystals along the fracture.

D) 3454 m. Dolomite, microcrystalline, mudstone. A few fractures filled with quartz and calcite. The calcite definitely postdates the quartz cement.

M25-6030-12330
Plate 2



M25-6030-12330

Plate 3

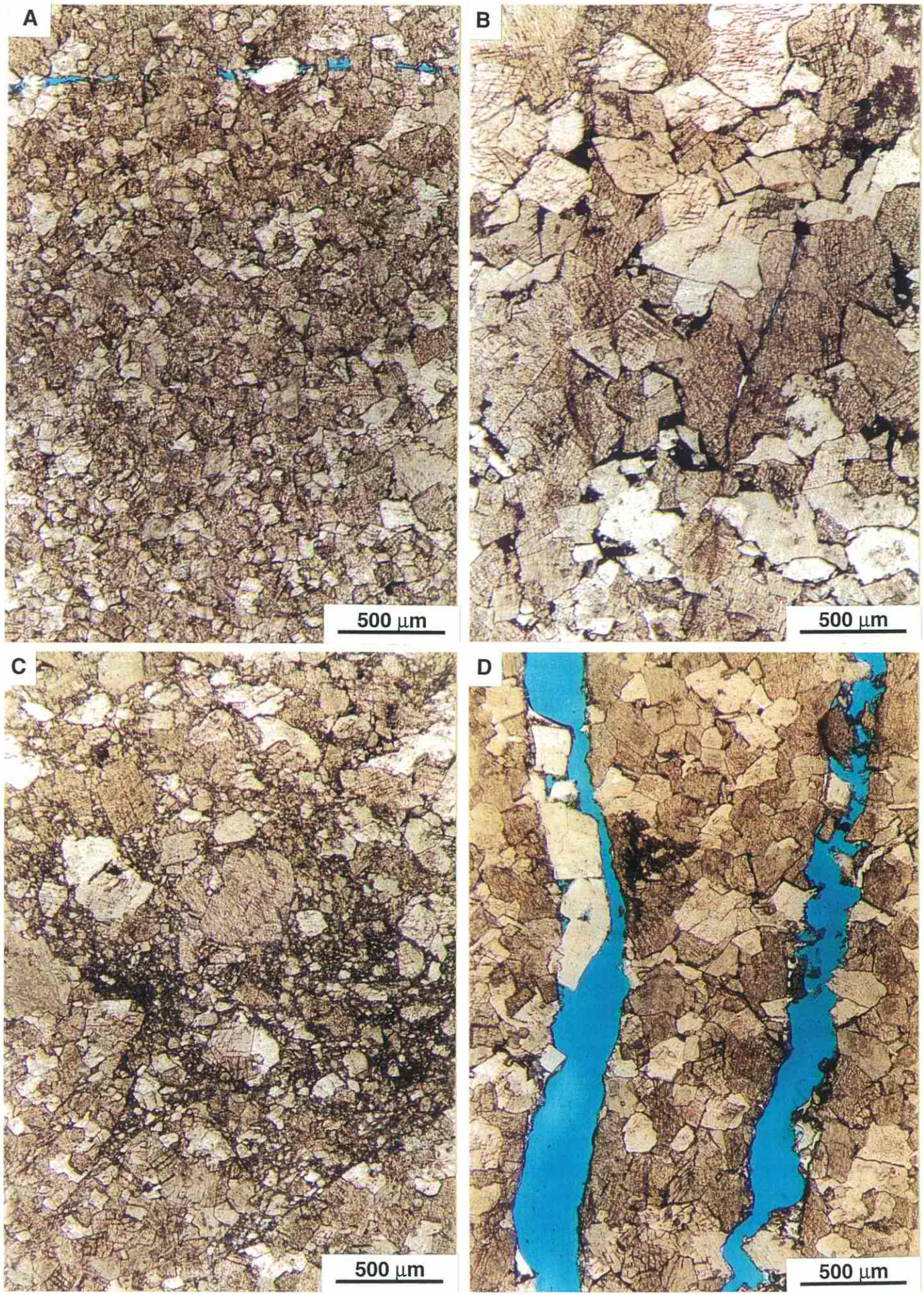
A) 3455.2 m. Dolomite, very fine crystalline, mudstone. Note the open fracture at the top of the photo with dolomite and quartz crystals along the fracture.

B) 3455.2 m. Dolomite, fine crystalline, early bitumen in intercrystalline porosity.

C) 3455.2 m. Dolomite, early breccia, porosity between breccia fragments filled with microcrystalline dolomite.

D) 3455.2 m. Dolomite, fine crystalline. Note isolated quartz crystals along open fractures.

Plate 3



P53-6030-12345

Plate 1

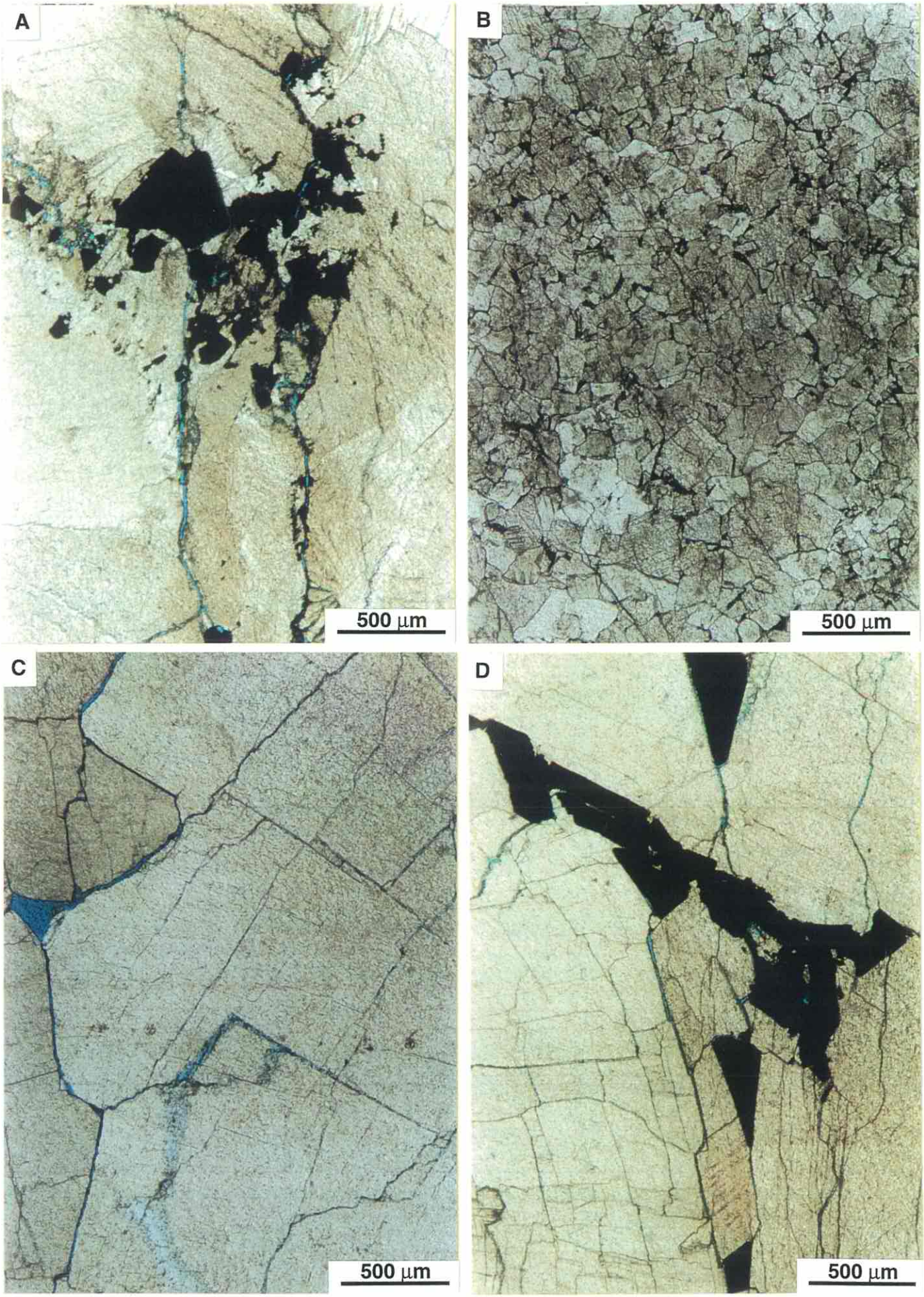
A) 12855 ft. Dolomite, wackestone, abundant bitumen in the intercrystalline porosity in the matrix dolomite, some replacement of the matrix dolomite by saddle dolomite.

B) 13066 ft. Dolomite, very coarse crystalline saddle dolomite filling vuggy porosity, some late bitumen in the vuggy porosity, some microfractures after the deposition of the bitumen.

C) 13066 ft. Dolomite, very coarse crystalline saddle dolomite filling vuggy porosity, some microfractures in the saddle dolomite.

D) 13066 ft. Dolomite, very coarse crystalline saddle dolomite filling vuggy porosity, some late bitumen in the vuggy porosity.

Plate 1



P53-6030-12345

Plate 2

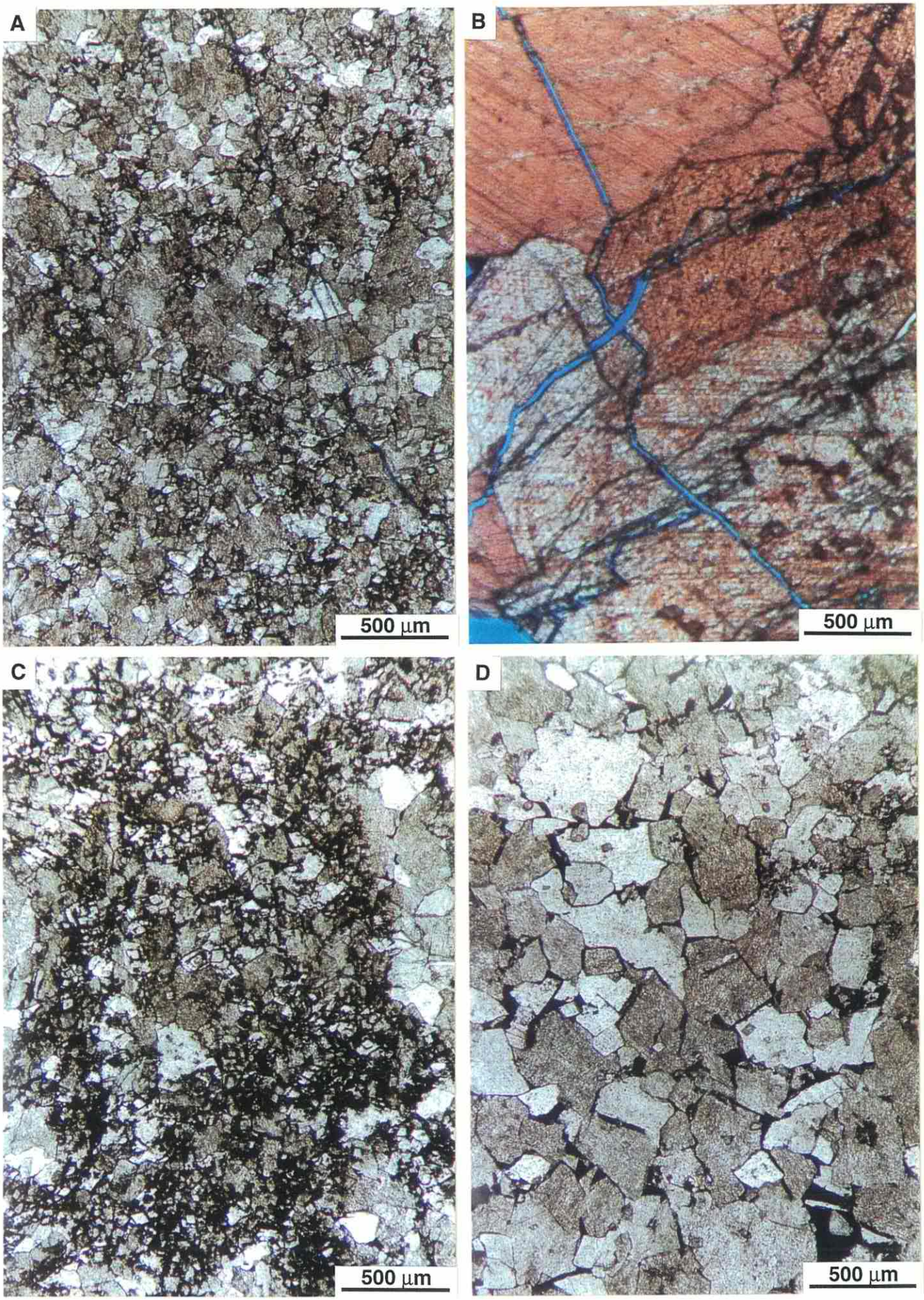
A) 12848 ft. Dolomite, very fine crystalline, wackestone, early bitumen.

B) 12848 ft. Large cavities are filled with saddle dolomite and bitumen. This photograph shows the calcite that is the final stage of vug fill. Note the numerous microfractures in the calcite.

C) 13061 ft. Dolomite, very fine crystalline, wackestone, abundant early bitumen.

D) 13061 ft. Recrystallized medium crystalline dolomite, abundant late bitumen between saddle dolomite crystals.

Plate 2



A55-6030-12345

Plate 1

A) 10298.5 ft. Dolomite, very fine crystalline, originally a wackestone, intercrystalline porosity filled with bitumen.

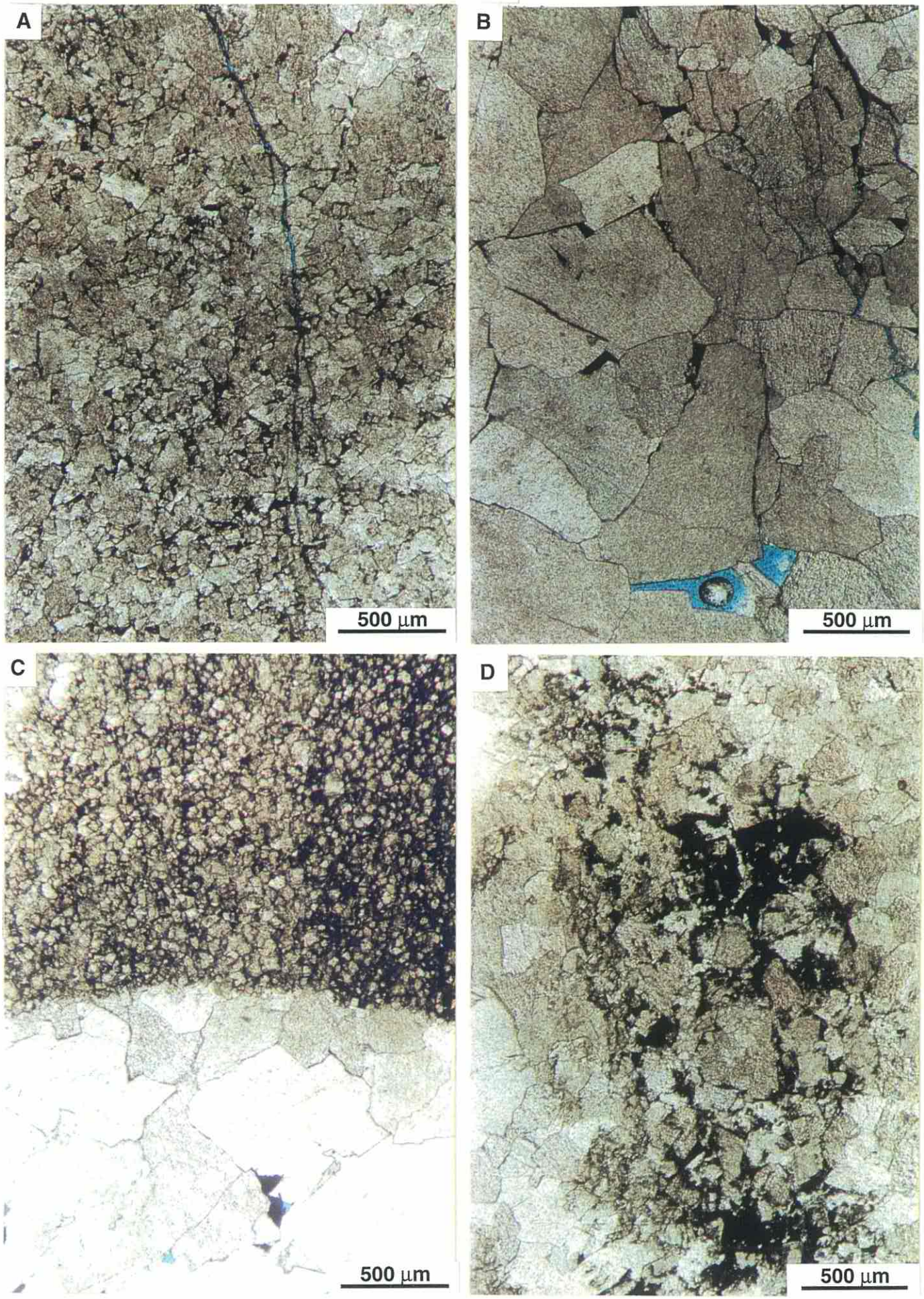
B) 10298.5 ft. Dolomite, very coarse crystalline saddle dolomite filling vug, minor bitumen between saddle dolomite crystals, minor vuggy porosity remaining.

C) 10308 ft. Dolomite, a fracture filled with very coarse crystalline saddle dolomite (base of photo), minor bitumen in saddle dolomite. Matrix (upper part of photo) consists of very fine crystalline dolomite with abundant bitumen in intercrystalline porosity, originally a wackestone. There is a sharp edge between the two phases indicating that the saddler dolomite in the fracture fill is a later phase than the matrix dolomite.

D) 10308 ft. Dolomite, coarse crystalline dolomite, with abundant bitumen in intercrystalline porosity.

A55-6030-12345

Plate 1



A55-6030-12345

Plate 2

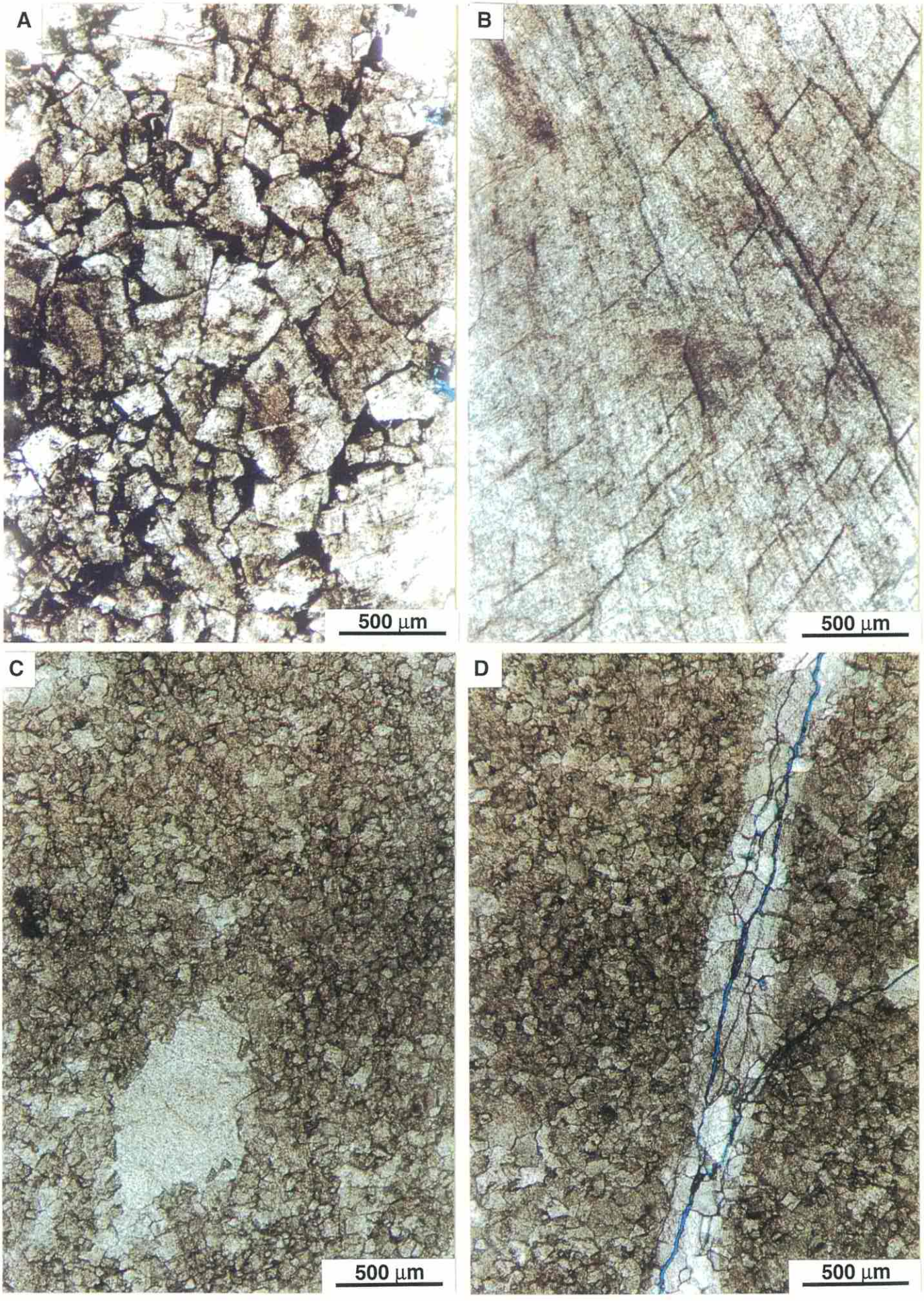
A) 10600.25 ft. Dolomite, fine crystalline, abundant bitumen in intercrystalline porosity.

B) 10600.25 ft. Dolomite, very coarse crystalline saddle dolomite through most of the thin section.

C) 10612 ft. Dolomite, very fine crystalline, wackestone. Note crinoid fragments at base of photo. Note bitumen in intercrystalline porosity in matrix.

D) 10612 ft. Dolomite, very fine crystalline, wackestone. Note the fracture filled with late medium crystalline dolomite. This fracture is also the site of later microfractures.

Plate 2



A55-6030-12345

Plate 3

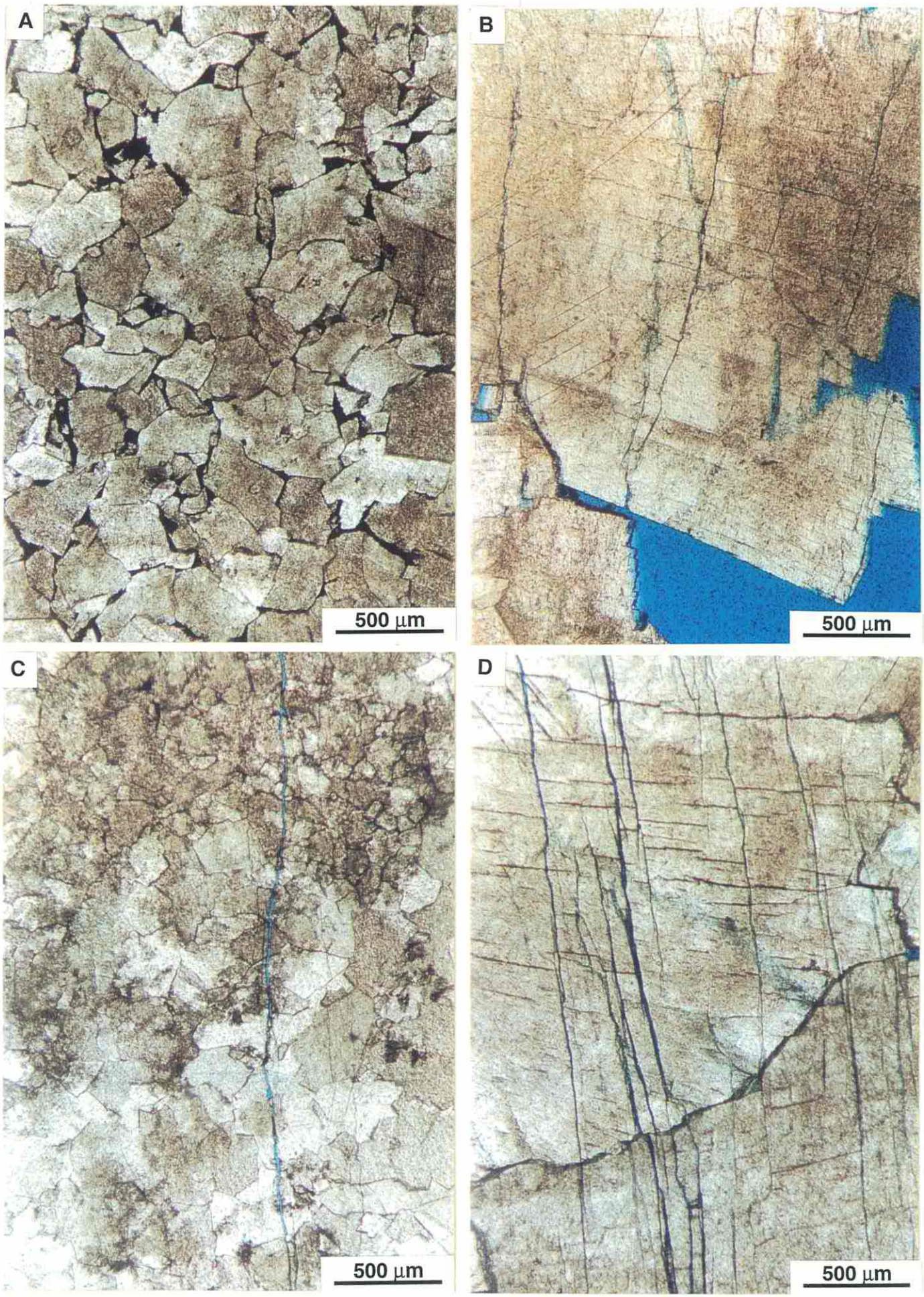
A) 10624.5 ft. Dolomite, medium crystalline dolomite, probably recrystallized wackestone. Note abundant bitumen in intercrystalline porosity.

B) 10624.5 ft. Dolomite, very coarse crystalline saddle dolomite, with remnant porosity in centre of vug.

C) 10863 ft. Dolomite, very fine crystalline dolomite (at top of photo) is being replaced by medium crystalline dolomite (at base of photo). This indicated that there are at least two stages of dolomitization. The first stage of dolomitization results in the very fine crystalline dolomite in the matrix. The second stage of dolomitization is the medium crystalline dolomite that replaces the very fine crystalline dolomite. The third stage of dolomitization is the saddle dolomite that fills the vuggy porosity.

D) 10863 ft. Dolomite, very coarse crystalline saddle dolomite filling vugs. Note the abundant microfractures in the saddle dolomite crystals.

Plate 3



A55-6030-12345

Plate 4

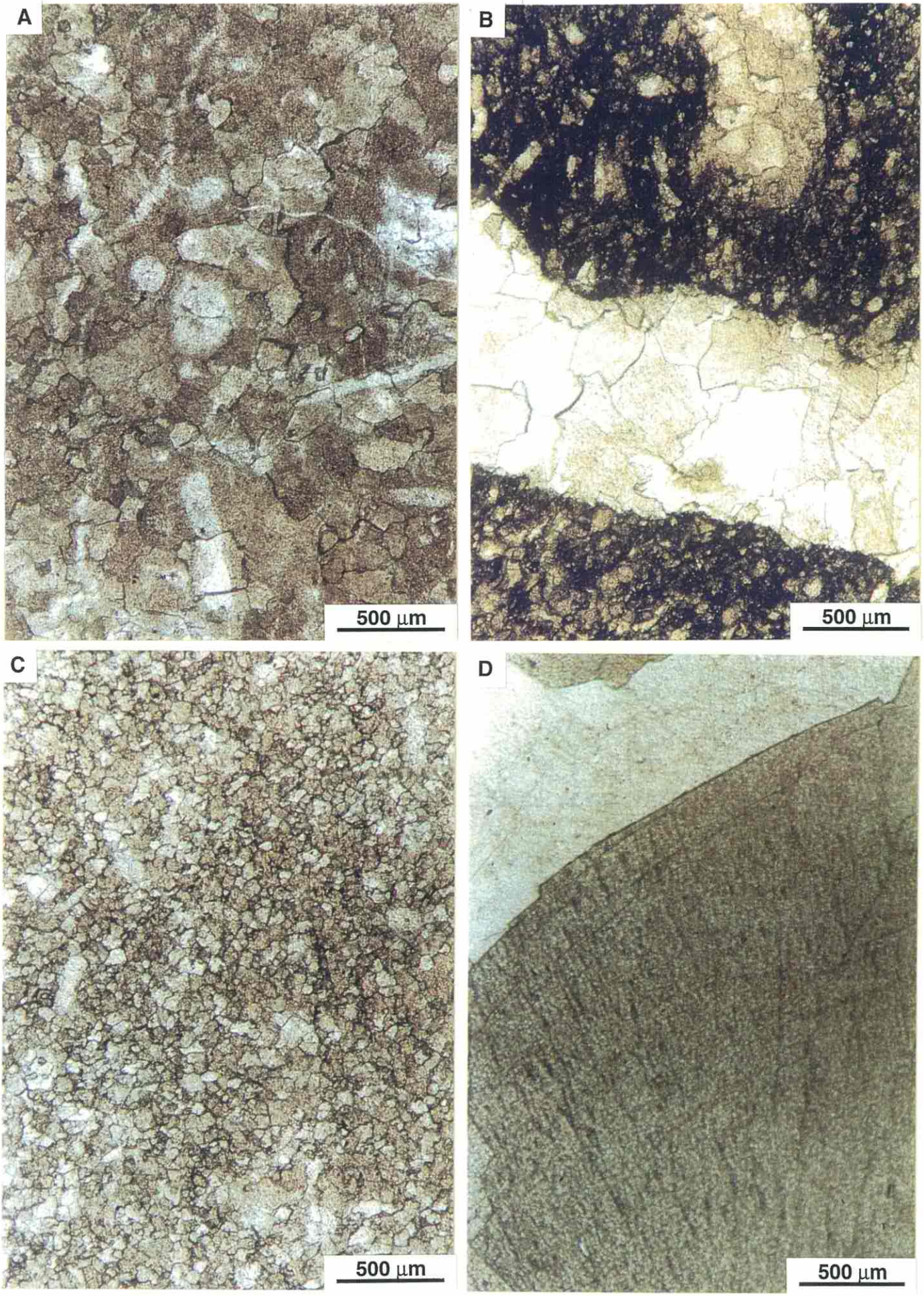
A) 11205.5 ft. Dolomite, very fine to fine crystalline, packstone. Note the numerous skeletal fragments that can be seen in thin section.

B) 11205.5 ft. Dolomite, very fine crystalline, wackestone. Note the numerous skeletal fragments. The matrix is cut by a fracture that is filled with coarse crystalline saddle dolomite.

C) 12160.5 ft. Dolomite, very fine crystalline dolomite, originally a wackestone, abundant bitumen in intercrystalline porosity

D) 12160.5 ft. Dolomite, very coarse crystalline saddle dolomite filling vugs. Note the curvature of the crystals.

Plate 4



A55-6030-12345

Plate 5

A) 10322 ft. Dolomite, very fine crystalline, wackestone, early bitumen between dolomite crystals.

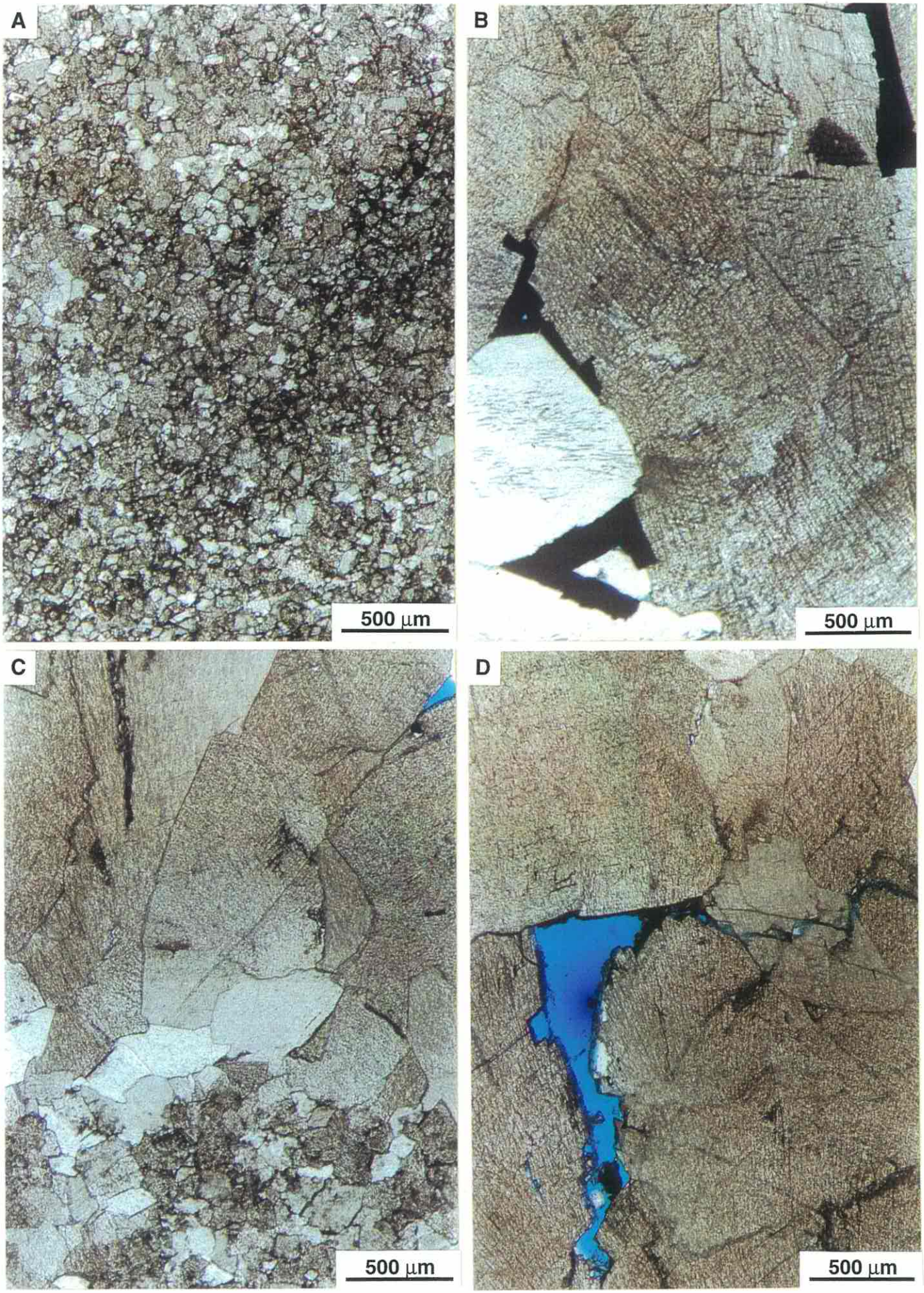
B) 10322 ft. Large vug filled with saddle dolomite and late bitumen.

C) 10355 ft. Recrystallized matrix at base of photo, saddle dolomite filling vug.

D) 10355 ft. Saddle dolomite filling vug, some bitumen, some remnant vuggy porosity, microfractures.

A55-6030-12345

Plate 5



A55-6030-12345

Plate 6

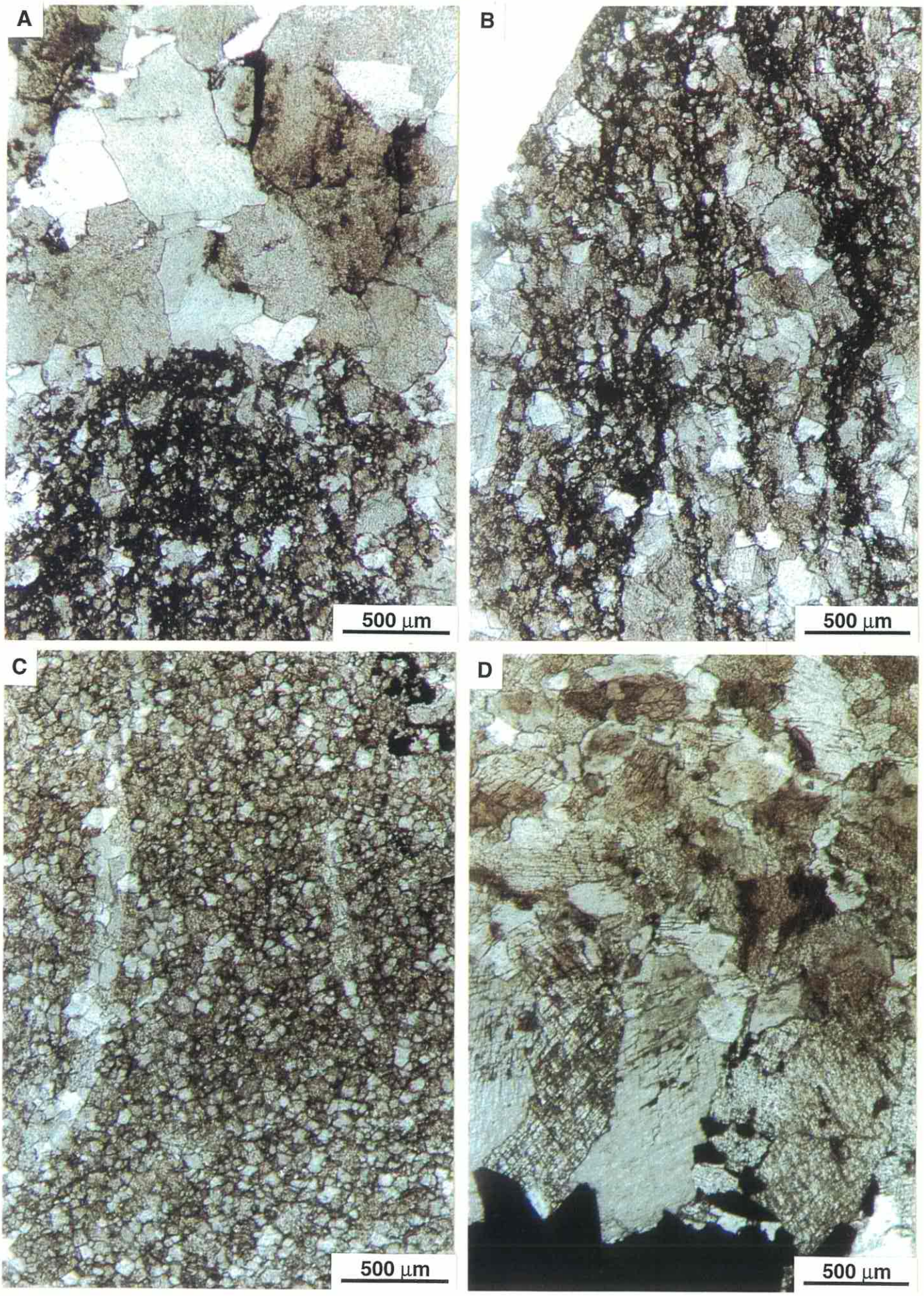
A) 10364 ft. Breccia fragment consisting of very fine crystalline dolomite with early bitumen, cemented with saddle dolomite.

B) 10364 ft. Abundant bitumen along stylolites.

C) 10868 ft. Dolomite, very fine crystalline, wackestone, little bitumen.

D) 11233 ft. Recrystallized dolomite at top of photo, vug lined with saddle dolomite and filled with late bitumen at base of photo.

Plate 6



O67-6030-12400

Plate 1

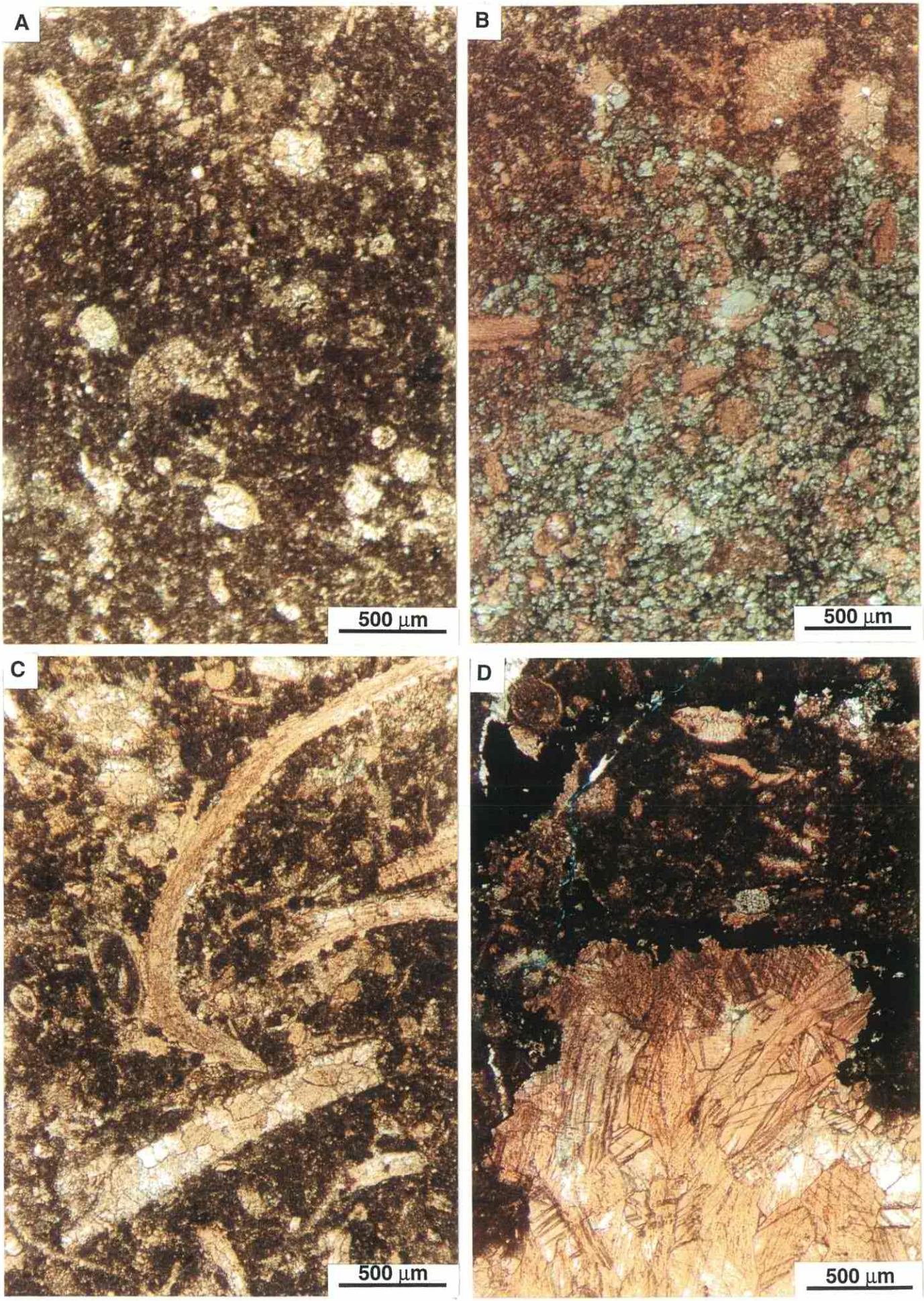
A) 8543 ft. Limestone, wackestone, scattered skeletal fragments, tight.

B) 8543 ft. Limestone, wackestone, scattered skeletal fragments, minor dolomitization, tight.

C) 8543 ft. Limestone, wackestone, numerous brachiopod and bivalve fragments, tight. Note the internal structure of the brachiopods and the recrystallized structure of the bivalve fragments.

D) 8567 ft. Limestone, wackestone at top of photo. The base of the photo is filled with coarse crystalline calcite in a fracture.

Plate 1



F08-6040-12430

Plate 1

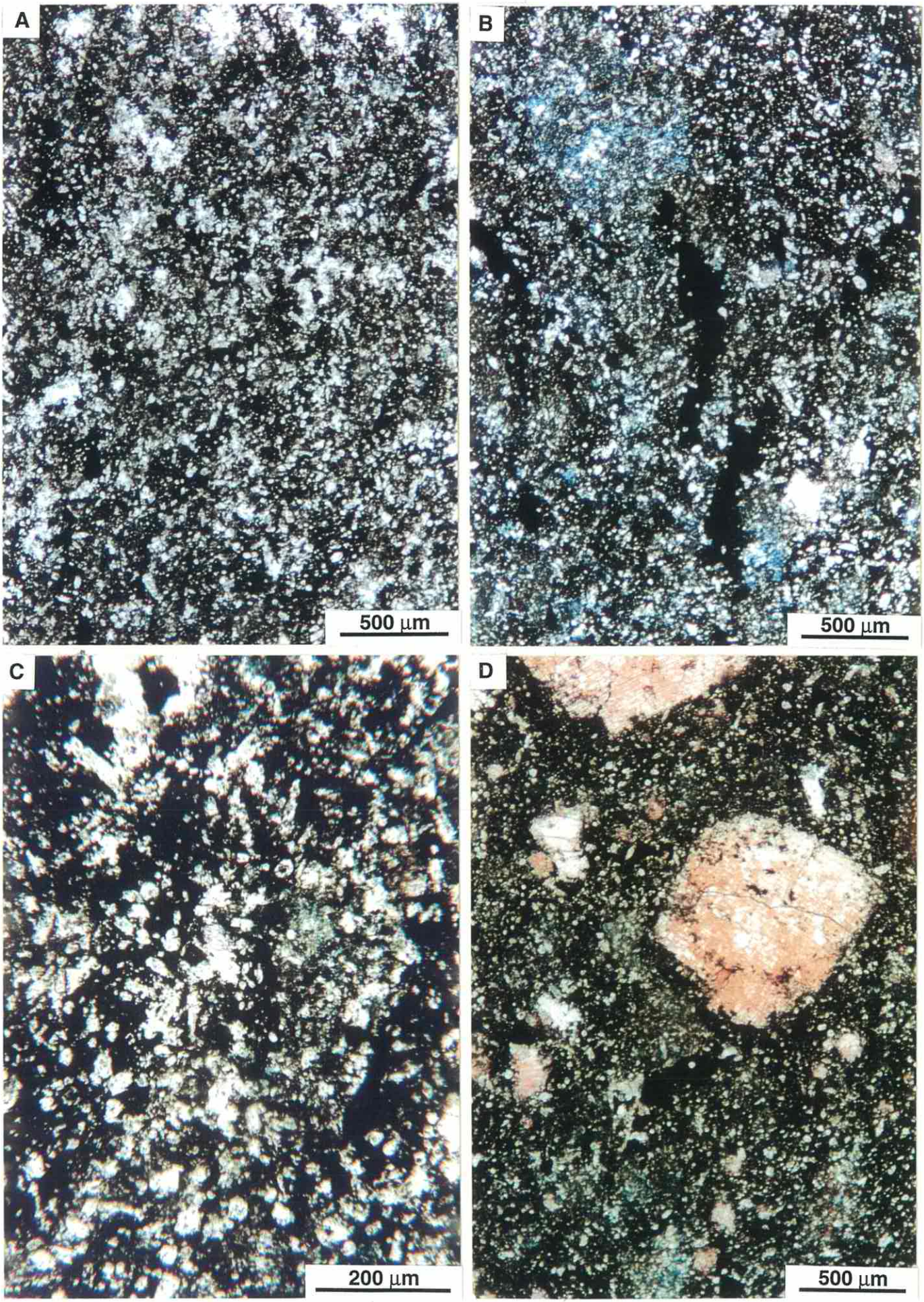
A) 6525 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity.

B) 6525 ft. Dolomite, very fine crystalline to microcrystalline, some leached shells and other fossil fragments filled with bitumen, abundant bitumen in intercrystalline porosity, some remnant intercrystalline porosity.

C) 6525 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity. Note: smaller scale than other photos.

D) 6525 ft. Dolomite, very fine crystalline to microcrystalline, some remaining crinoid (lime) fragments, abundant bitumen in intercrystalline porosity.

Plate 1



F08-6040-12430

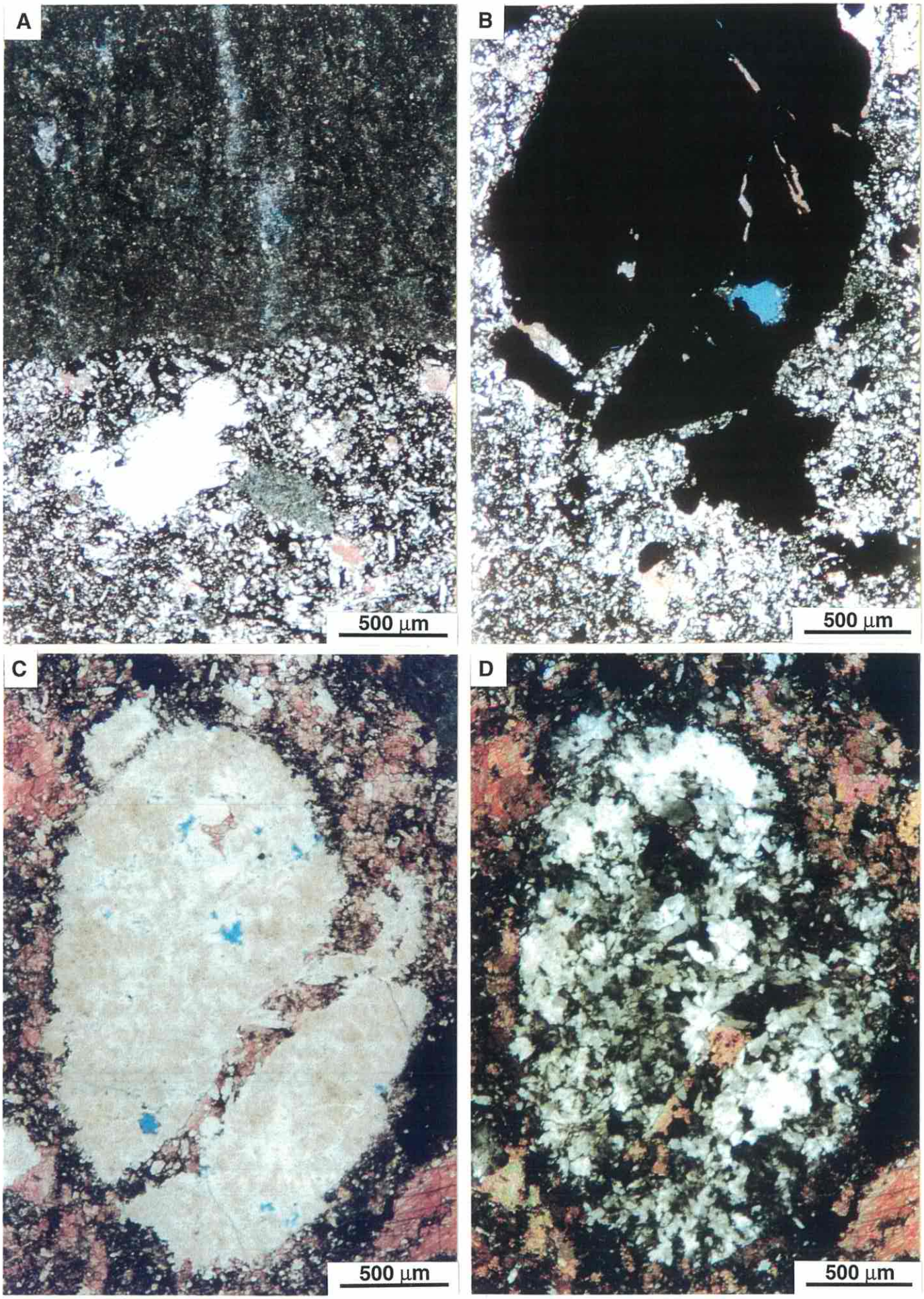
Plate 2

A) 6526 ft. Dolomite, very fine crystalline to microcrystalline, breccia fragments, wackestone, some skeletal fragments in base of photo, abundant bitumen in intercrystalline porosity.

B) 6526 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, some large pores from leached fossil fragments filled with bitumen.

C & D) 6526 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, abundant silicification of some skeletal fragments, some calcite cement. C - plain light, D - crossed nicols.

Plate 2



F08-6040-12430

Plate 3

A & B) 6527 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, good remnant porosity. A - plain light, B - crossed nicols.

C & D) 6527 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, abundant silicification. C - plain light, D - crossed nicols.

Plate 3

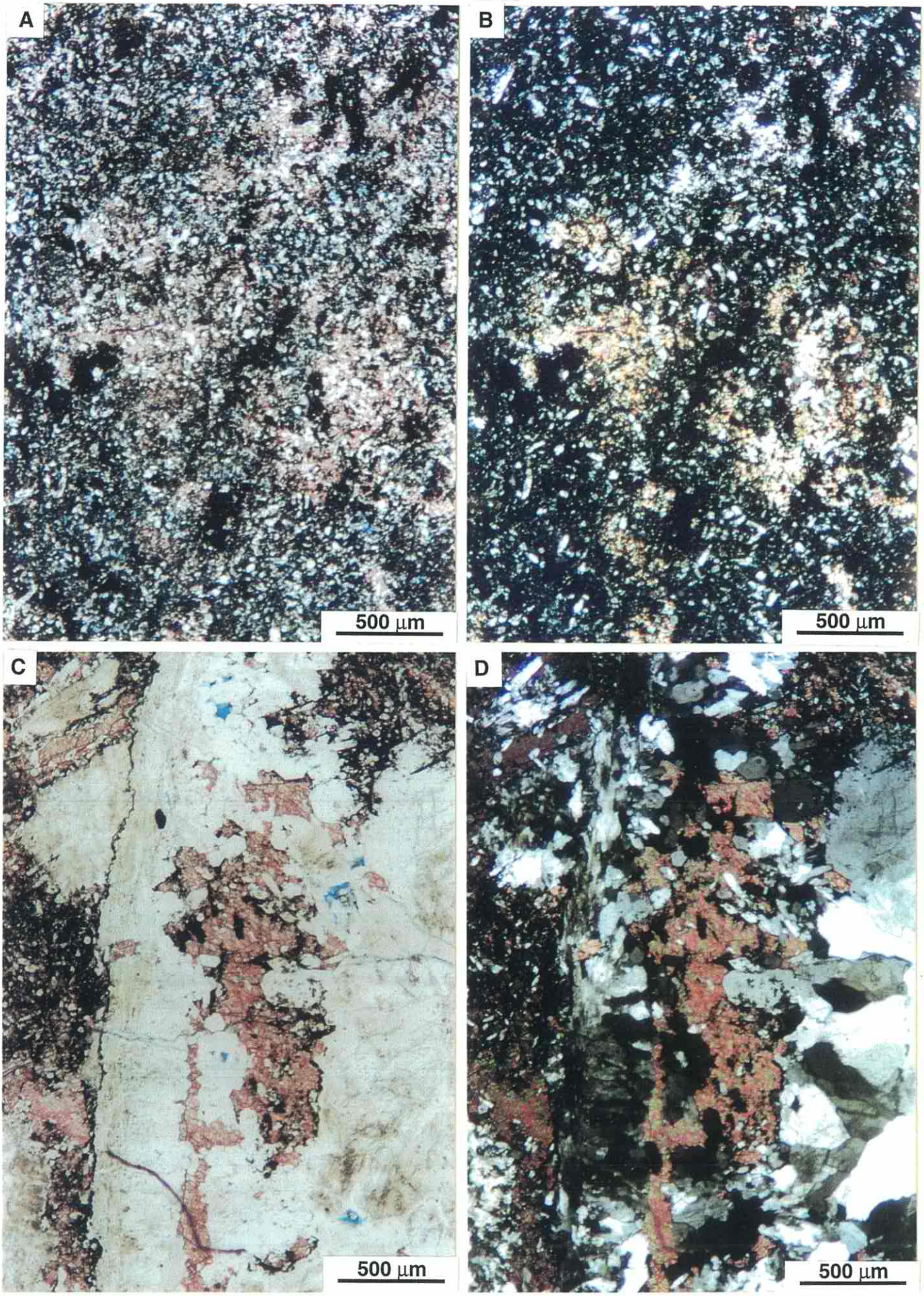


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Plate 4

A & B) 6527 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, abundant silicification. Note fossil fragments in the chert. A - plain light, B - crossed nicols.

C & D) 6527.5 ft. Dolomite, very fine crystalline to microcrystalline, abundant bitumen in intercrystalline porosity, abundant silicification. C - plain light, D - crossed nicols.

Plate 4

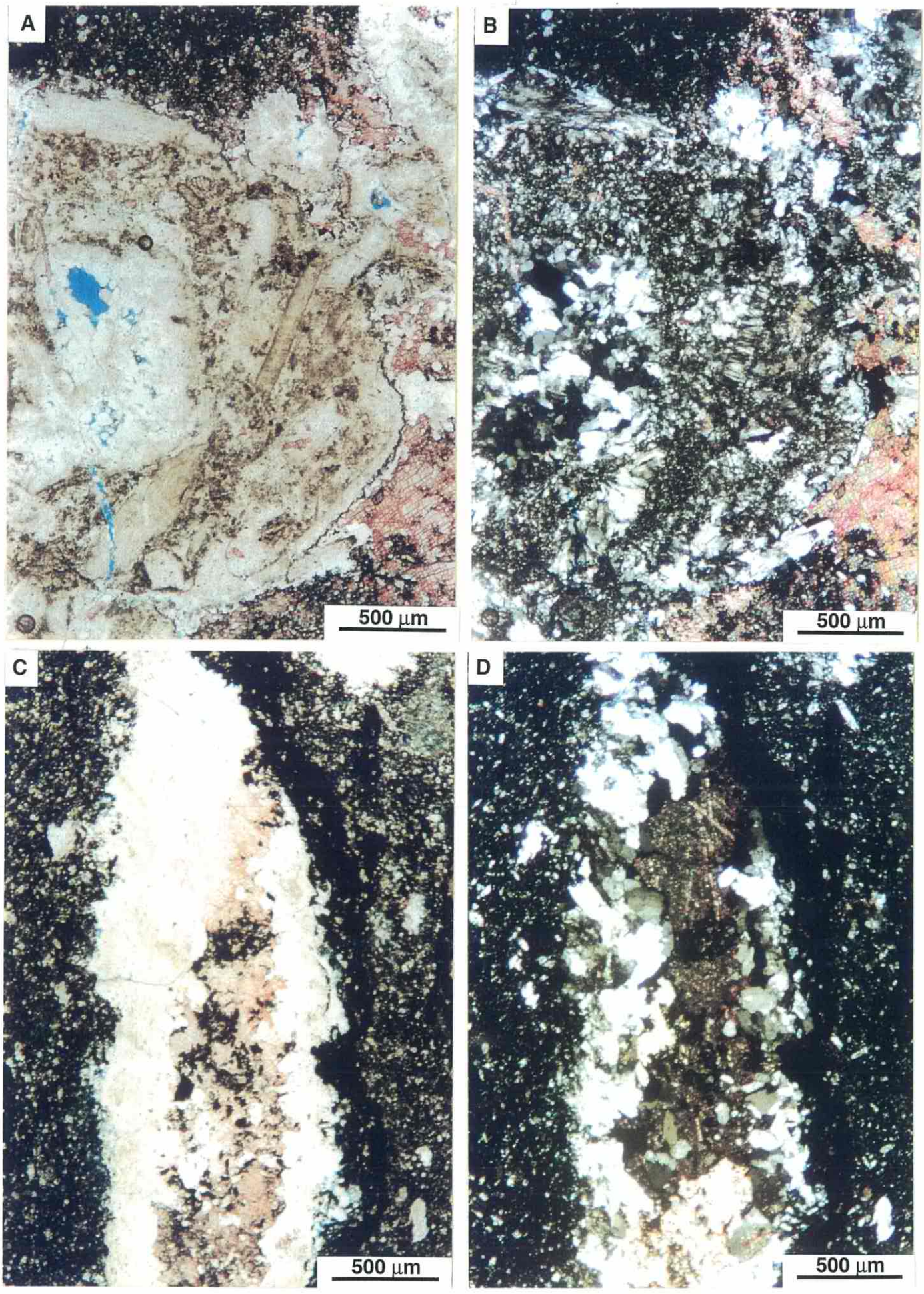

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Plate 5

A) 6538 ft. Limestone, skeletal wackestone. Note the brachiopod and crinoid fragments.

B) 6538 ft. Limestone, skeletal wackestone, minor quartz replacement in centre of photograph. Note the large brachiopod fragments.

C) 6538 ft. Limestone, skeletal wackestone. Note the dolomitization associated with the stylolite.

D) 6538 ft. Limestone, skeletal wackestone, replacement of fossil by quartz.

Plate 5

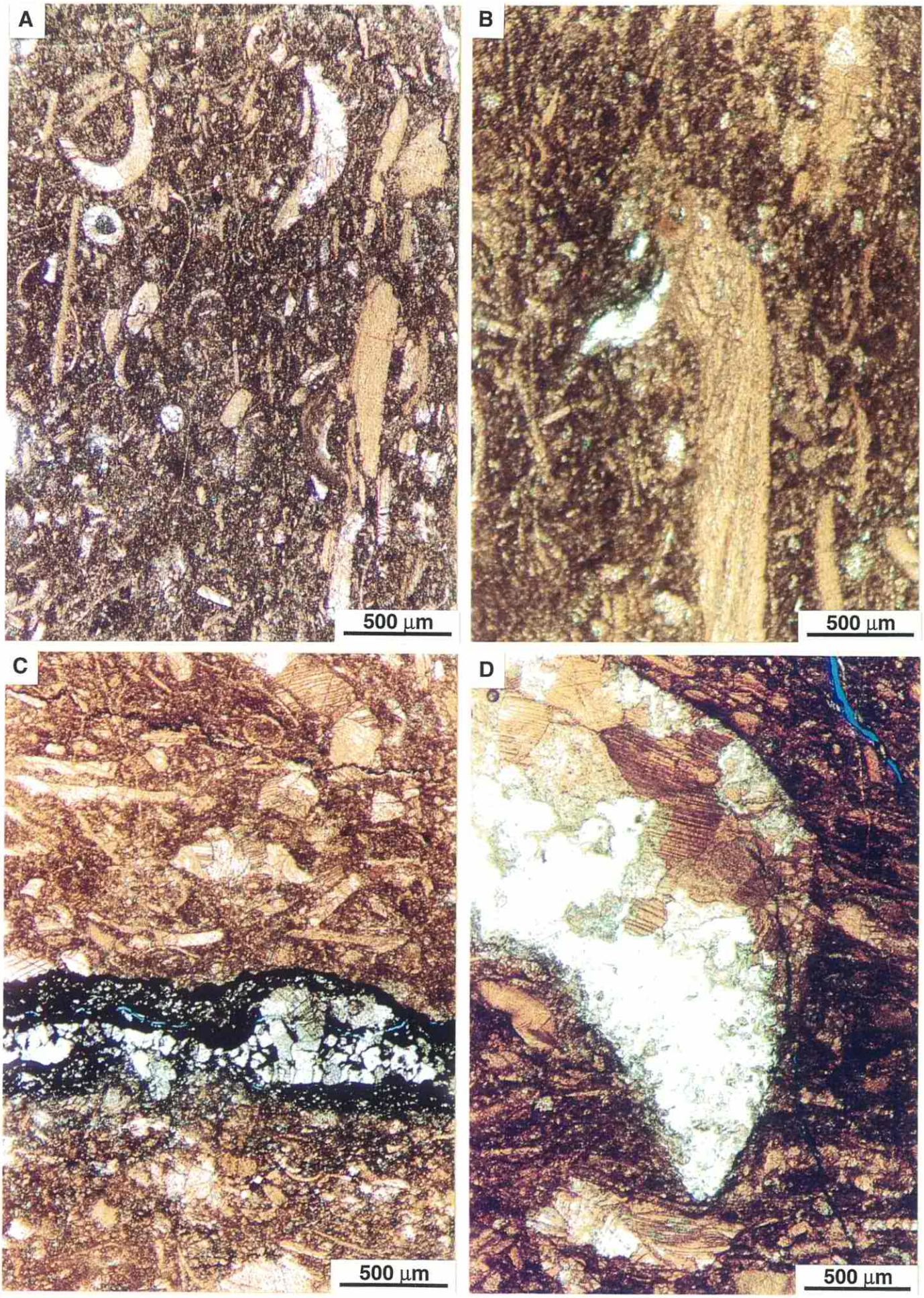

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Plate 6

A) 6707 ft. Early dolomite replaced by medium to coarse crystalline saddle dolomite. Late bitumen between saddle dolomite crystals.

B) 6707 ft. Early dolomite replaced by medium to coarse crystalline saddle dolomite. Late bitumen between saddle dolomite crystals. Fracture filled with quartz offset by fracture filled with calcite. This indicates that the calcite must have precipitated after the quartz.

C & D) 6707 ft. Coarse crystalline saddle dolomite, abundant quartz replacement, bitumen associated with the quartz crystals. C - plain light, D - crossed nicols.

Plate 6