

13-32-38W  
E-18-20579

FILE COPY

# SERVICE REPORT

GEOLOGIC AND RESERVOIR CHARACTERIZATION  
OF THE PERMIAN CHASE GROUP, ANADARKO WALTERS A#1 WELL  
STEVENS COUNTY, KANSAS



Prepared for  
Anadarko Production Company  
Englewood, Colorado

CONFIDENTIAL  
August 1982

1827 GRANT STREET • DENVER, COLORADO 80203 • (303) 830-1986

COMPANY PROPRIETARY

RMD 399

GEOLOGIC AND RESERVOIR CHARACTERIZATION  
OF THE PERMIAN CHASE GROUP, ANADARKO WALTERS A#1 WELL  
STEVENS COUNTY, KANSAS

INTRODUCTION

The purposes of this study are to:

1. Characterize lithologies, porosities, and factors controlling porosity of the Permian Chase Group, from the Anadarko Walters A#1 Well, Stevens County, Kansas.
2. Infer the environment(s) of deposition in the subject well.
3. Interpret the major diagenetic events and their effect on the pore system.
4. Characterize the reservoir potential of each formation in the subject well.

Samples were selected from conventional slabbed core and are considered representative of the Permian Chase Group in the subject well. This study integrates data obtained through the following techniques:

1. Detailed core description.
2. Thin section petrology.
3. Scanning electron microscopy (SEM).
4. Energy dispersive spectrometry (EDS).
5. X-ray diffraction (XRD).
6. Petrophysical data.

Reservoirs, Inc. has assigned job number RMD399 to this study of the Permian Chase Group cored in the Anadarko Walters A#1 Well, Sec. 13, T.32S., R.38W., Gentzler Field, Stevens County, Kansas. Three copies of RMD399 have been delivered to Mr. Brent Miyazaki of Anadarko Production Company, Englewood, Colorado. One copy of this report, all data generated, and original samples are retained by Reservoirs, Inc. for future reference and discussion with the client company.

Matters relating to RMD399 are considered highly confidential and the sole property of Anadarko Production Company and Reservoirs, Inc. Discussion of this information with persons other than those of Anadarko Production Company is not permitted without approval of the client company.

---

Thomas G. Powell  
Staff Geologist  
RESERVOIRS, INC.

---

Jack B. Thomas  
Vice President-Manager  
RESERVOIRS, INC.

## SUMMARY

### Well and Location:

Anadarko Production Company Walters A#1, Sec. 13, T.32S., R.38W., Gentzler Field, Stevens County, Kansas.

### Formations: 314 feet of Permian Chase Group, including:

1. Herrington Formation (2540.0-2572.0 feet).
2. Krider Formation (2572.0-2616.0 feet).
3. Odell Formation (2616.0-2640.0 feet).
4. Winfield Formation (2640.0-2664.0 feet).
5. Gage Formation (2664.0-2687.0 feet).
6. Towanda Formation (2687.0-2731.0 feet).
7. Fort Riley Formation (2744.0-2774.0 feet).
8. Florence Formation (2774.0-2807.5 feet).
9. Wreford Formation (2834.0-2860.0 feet).

### Production History:

In Gentzler Field, Stevens County, Kansas, the Krider and Winfield Formations are typically good gas producers, whereas the Herrington and Towanda Formations are moderate gas producers. The rest of the formations are typically non-productive (Brent Miyazaki, personal communication, 1982).

### Dominant Lithologies of Each Formation (based on core description and thin section petrology):

1. Herrington Formation:
  - a. Red and green, silty shale.
  - b. Anhydrite: massive and "chicken wire" types.
  - c. Fine- to medium-grained, quartzose sandstone.
2. Krider Formation:
  - a. Dolomitic shale.
  - b. Fine to medium crystalline, vuggy dolomite.
3. Odell Formation:
  - a. Red and dark gray, dolomitic shale.
  - b. Fine- to medium-grained, quartzose sandstone.
4. Winfield Formation: Partially dolomitized, bioclastic wackestone/packstone.
5. Gage Formation:
  - a. Wavy laminated, shaly dolomite.
  - b. Red and grayish-green, dolomitic shale.

6. Towanda Formation:
  - a. Fine-grained, quartzose sandstone.
  - b. Partially dolomitized, bioclastic wackestone.
  - c. Dolomitic anhydrite.
7. Fort Riley Formation: Partially dolomitized, bioclastic wackestone/packstone.
8. Florence Formation:
  - a. Algal dolomite.
  - b. Black, bioclastic mudstone/wackestone.
  - c. Bioclastic wackestone/packstone.
  - d. Oolitic limestone.
9. Wreford Formation:
  - a. Fine crystalline, bioclastic wackestone.
  - b. Algal-bryozoan mudstone/wackestone.
  - c. Bioclastic wackestone/packstone.

Inferred Environments of Deposition (based on sedimentary structures and diagenesis):

The entire Chase Group interval from the Anadarko Walters A#1 Well is interpreted to be cyclic carbonate shelf deposits. It is also interpreted that five cycles of deposition from subtidal to supratidal environments are present in the core.

1. Herrington Formation: Intertidal, shallow marine to supratidal.
2. Krider Formation: Marine subtidal.
3. Odell Formation: Shallow marine, intertidal to supratidal (paleosol).
4. Winfield Formation: Marine subtidal.
5. Gage Formation: Intertidal to supratidal (paleosol).
6. Towanda Formation: Marine subtidal to supratidal (anhydrite).
7. Fort Riley Formation: Shallow marine subtidal to intertidal.
8. Florence Formation: Algal bank (?), marine subtidal and possibly an ooid shoal.
9. Wreford Formation: Marine subtidal to intertidal.

## Porosity Development and Controls:

Five types of porosity are evident in the nine formations cored:

1. Intergranular: between framework components.
2. Intragranular: within framework components.
3. Moldic or Vuggy: within framework, matrix, or cement components.
4. Microporosity: pores with aperture radii less than 0.5 microns.
5. Fracture.

Porosity types (in decreasing abundance by formation) include:

1. Herrington Formation:

- a. Intergranular.
- b. Microporosity.
- c. Intragranular.

2. Krider Formation:

- a. Vuggy (dissolution-enhanced molds).
- b. Intercrystalline.
- c. Moldic (selective leaching of bioclastic grains).
- d. Fracture (not abundant in core).

3. Odell Formation:

- a. Intragranular (not abundant).
- b. Microporosity (not abundant).
- c. Fracture (not abundant).

4. Winfield Formation:

- a. Intercrystalline.
- b. Vuggy.
- c. Moldic.
- d. Intraparticle (within bioclastic particles).
- e. Microporosity (in clay-rich areas).

5. Gage Formation: Fracture (not abundant).

6. Towanda Formation:

- a. Intergranular (in upper sandstone unit).
- b. Intercrystalline (not abundant).
- c. Intraparticle.
- d. Interparticle (between bioclastic particles).
- e. Microporosity (in micrite-rich areas).

7. Fort Riley Formation:

- a. Interparticle.
- b. Intraparticle.

- c. Intercrystalline.
- d. Microporosity (in micrite-rich areas).

8. Florence Formation:

- a. Intraparticle.
- b. Oomoldic (rare dissolution of ooids).
- c. Microporosity (in micrite- and clay-rich areas).

9. Wreford Formation:

- a. Intraparticle (not abundant).
- b. Interparticle (not abundant).
- c. Microporosity (in micrite- and clay-rich areas).

The best reservoir rock observed in the cored interval is the Krider Formation. The abundance of well connected porosity is documented. The two sandstone units (Herrington and upper Towanda Formations) exhibit significant amounts of intergranular porosity.

Porosity Controls:

1. Original sediment or particle size and composition.
2. Amount of dolomite vs. calcite. Typically more dolomite, more porosity.
3. Anhydrite replacement: generally rare.
4. Leaching of unstable material (calcite, dolomite, anhydrite, feldspar, lithic fragments).
5. Stylolitization.
6. Silica replacement or silica infilling of intraparticle porosity.
7. Abundance and thickness of interbedded shale and anhydrite.

Diagenesis:

Petrographic evidence indicates that parts or all of the cored sequence reflect diagenesis occurring under normal marine, fresh water, and some hypersaline conditions. Subaerial exposure, oxidation, and reduction also affected portions of the interval. Major diagenetic alterations included:

1. Dolomitization: more complete at the top of the cored interval.
2. Cementation.
3. Recrystallization.
4. Silica replacement.
5. Anhydrite replacement.

TABLE 1  
Sample List

<u>Core Depth (ft)</u>	<u>Formation</u>	<u>Thin Section</u>	<u>SEM</u>	<u>XRD</u>
2551.3	Herrington	X		
2554.5	Herrington	X		
2561.5	Herrington	X	X	X
2580.7	Krider	X		
2586.6	Krider	X		
2593.2	Krider	X	X	X
2597.5	Krider	X		
2605.2	Krider	X		
2631.5	Odell	X		
2640.5	Winfield	X		
2644.5	Winfield	X		
2649.5	Winfield	X	X	X
2654.3	Winfield	X		
2658.8	Winfield	X		
2660.6	Winfield	X		
2662.0	Winfield	X		
2665.2	Gage	X		
2692.5	Towanda	X		
2703.4	Towanda	X		
2716.5	Towanda	X	X	X
2720.6	Towanda	X		
2730.4	Towanda	X		
2749.5	Fort Riley	X		
2755.5	Fort Riley	X		
2759.5	Fort Riley	X		
2764.5	Fort Riley	X	X	X
2771.3	Fort Riley	X		
2780.7	Florence	X		
2792.6	Florence	X		
2803.0	Florence	X	X	X
2806.2	Florence	X		
2810.5	Florence	X		
2835.5	Wreford	X		
2839.5	Wreford	X		
2843.5	Wreford	X		
2852.5	Wreford	X	X	X
2859.5	Wreford	X		

## RESULTS AND INTERPRETATIONS

Each formation is discussed separately in this section.

### Lithologies and Thin Section Petrology

(Refer to Figure 1, Detailed Core Description.)

#### Herrington Formation:

Three separate lithologies were observed in the core of the Herrington Formation. The upper lithology is a red and green silty shale. The unit is commonly wavy laminated and slightly dolomitic. More fissility was observed at the top than at the base. The next lower lithology is a translucent gray and white, dolomitic anhydrite. This unit commonly exhibits "chicken wire" texture. The lowermost lithology of the Herrington Formation is a light brown, fine- to medium-grained, quartzose sandstone. This unit exhibits ripple laminations, and portions that are massive. Traces of burrowing are evident. Scattered anhydrite nodules increase in size downward through the unit. Thin sections of this sandstone reveal relatively abundant intergranular porosity decreasing downward. The unit is cemented by dolomite and anhydrite. Portions of the dolomite may have been deposited as part of the matrix and later recrystallized. Some "secondary" dolomite rhombs are present, which may be evidence of recrystallized dolomite mud.

The overall reservoir quality of the sandstone unit is moderately good at the top and poor at the base, due to increasing cement and decreasing porosity downward.

#### Krider Formation:

The Krider Formation is composed of one lithology, a light brown and light gray, fine to medium crystalline dolomite. Crystal size decreases at the top and base of this unit. The upper portion contains wispy, laminated pyrite. Only traces of calcite are present in this unit. Thin sections of the Krider exhibit numerous open vugs and molds, as well as abundant, well interconnected, intercrystalline pores. Some "ghosts" of particles were observed, which are interpreted to be bioclastic particles, now completely dolomitized. Scattered areas of anhydrite are present, but are not abundant.

The overall reservoir quality of the Krider Formation in the Walters A#1 Well is considered excellent because of the interconnected pore space.

#### Odell Formation:

Two lithologies are evident in the Odell Formation in the subject well. The upper lithology is a red shale, which turns gray towards the top of the unit. This unit appears to be mottled overall, and more dolomitic in the upper portions. The lower lithology in the Odell is a light brown to dark gray, fine- to medium-grained, quartzose sandstone. Wavy and ripple laminations are dominant; however, some have been disrupted by bioturbation. Framework grains are quartz, feldspar, and minor micas. This unit is cemented by sparry calcite, anhydrite, and isolated dolomite rhombs. Thin sections

reveal very little intergranular porosity. Some detrital clay matrix was observed, however, which may contain abundant microporosity.

Overall reservoir quality of the Odell "sandstone" is poor due to its lack of intergranular porosity, and relatively tight nature. The overlying shale unit should act as a permeability barrier, producing very little communication with the Krider Formation "reservoir" above.

#### Winfield Formation:

One lithology dominates the Winfield Formation in the subject well. This unit is a light brown and light gray, partially dolomitized, bioclastic wackestone/packstone, which is commonly massive to wavy laminated. Minor stylolites and anhydrite nodules are present. This unit becomes more argillaceous towards the base. Identifiable bioclasts in thin section include echinoderms (crinoids and echinoids), bryozoans, brachiopods, foraminifera, and possibly ostracods. Overall, more dolomite and less calcite are observed at the top, with more calcite present at the base. In the upper portions of the unit, many bioclasts have been dolomitized; in the middle, most bioclasts are partially dolomitized; and at the base, most bioclasts are still calcite. Scattered silty to upper fine-grained quartz and feldspar are present throughout. Higher porosities and permeabilities were observed in the upper portions of the unit. Open molds and vugs occur in the upper portions, with fine intercrystalline pores between dolomite crystals. Decreasing porosities and permeabilities downward are interpreted to be a function of the amount of undolomitized material (calcite). In general, those thin sections containing more dolomite (more complete dolomitization) contain more porosity.

The overall reservoir quality of the Winfield Formation is considered fair at the top and decreases to moderately poor towards the base, again interpreted to be a function of the amount of dolomitization.

#### Gage Formation:

The Gage Formation is a red and grayish-green, mottled shale, which grades upward into a finely crystalline, sandy and silty dolomite. A thin section of the upper dolomite exhibits moderately good intercrystalline porosity. Scattered pyrite and anhydrite nodules were noted.

Due to the abundance of shale (except for the upper two feet) in the Gage Formation, overall reservoir quality is poor. Communication with the Winfield Formation above will be good for the upper two feet of the Gage, but due to its gradation into a tight shale, overall communication of the Winfield above and Towanda below is interpreted to be poor.

#### Towanda Formation:

Five lithologies are evident in the Towanda Formation portion of the core. The uppermost lithology is a fine- to upper fine-grained sandstone. This unit appears to be dolomite-cemented at the top, and calcite-cemented at the base. It is commonly parallel laminated to massive and contains a few shaly streaks. These shale seams may act as vertical permeability barriers. Scattered anhydrite nodules and rare shell fragments were observed. A thin section of this sandstone unit exhibits excellent intergranular porosity.

Traces of dolomite mud matrix are present, along with scattered rhombic dolomite cement. It appears that much of the original dolomite matrix has been partially leached, producing abundant secondary intergranular porosity. Minor leaching of unstable mineral phases such as feldspar has also occurred, increasing porosity. Underlying this sandstone unit by an unconformable contact is a light gray, partially dolomitized, fossiliferous wackestone. Scattered chalky calcite nodules are interpreted to represent caliche formed by leaching associated with subaerial exposure of the Gage "shale" above. Fossil particles include abundant crinoids and solitary corals. Many of the corals have been replaced by anhydrite, but many of them still retain their original coralline structure. Fossil material increases downward, and is more poorly sorted, possibly indicating reworking of the top of the unit. The wavy, unconformable contact with the overlying sandstone also supports this interpretation. The next lower lithology is a tight, light brown dolomite containing abundant massive and nodular anhydrite. Elongate, sometimes radiating anhydrite crystals may represent pseudomorphs after gypsum "rosettes." This anhydritic dolomite unit will act as a vertical barrier and block communication between the upper and lower Towanda Formation. It is not known, however, how laterally extensive this unit is, but it is interpreted that it should be present in the same vertical location along the "paleostrand." The lowermost lithology in the Towanda Formation is a light brown and light gray, partially dolomitized, fossiliferous wackestone/packstone. Dolomite content decreases downward; very little dolomite is present at the base of the unit. The lower portion also exhibits bioturbation and contains anhydrite-filled burrows. Bioclasts observed in thin section include echinoderms (crinoids and echinoids), bryozoans, brachiopods, forams, and possibly ostracods. Many of these fossil fragments are coated with algae, which is observed to be a relatively thick coating of micrite on fossil particles (see thin section photos 2716.5 and 2720.6). Very little porosity was observed in this unit. Some intercrystalline porosity exists in the dolomite-dominated portion (upper). Inter- and intraparticle pores were observed in the lower limestone-dominant portion.

The best reservoir rock in the Towanda Formation appears to be the upper sandstone unit. Abundant intergranular pores and good permeabilities exist. Below the anhydritic dolomite, the reservoir quality is fair. Porosities and permeabilities decrease downward, which is interpreted to be a function of the amount of dolomite (more porosity). Communication between the upper and lower Towanda is interpreted to be low, due to the tight, anhydritic dolomite unit between the two.

Separating the Towanda Formation from the Fort Riley Formation is a green and partially red, mottled shale. This unit is wavy laminated, and generally lacks fissility. Anhydrite occurs in traces. Vertical burrows are rare, but were observed in the core. This unit will act to decrease communication with the Towanda Formation above, and the Fort Riley Formation below.

#### Fort Riley Formation:

One lithology was observed in the Fort Riley Formation. This unit is a light brown and light gray, partially dolomitized, bioclastic wackestone/packstone. The upper portions are shaly, and the unit becomes "cleaner" towards the base. Portions of this interval appear to be replaced by anhydrite. Petrographic analyses support this interpretation. Fossils observed in thin

section include echinoderms (crinoids and echinoids), bryozoans, brachiopods, forams, and fusulinids. Fusulinids are abundant between 2765 and 2769 feet. Encrusting algae, similar to that found in the lower Towanda Formation, was noted at 2758 feet. Encrusting foraminifera are associated with this grain-coating algae. Interparticle porosity is moderately abundant at the top and decreases toward the base. Portions of the interval are partially dolomitized. Calcite remnants appear to reduce porosity and permeability.

Overall reservoir quality of the Fort Riley Formation is good at the top, and fair to poor toward the base.

#### Florence Formation:

The Florence Formation consists of two main lithologies. The majority of the Florence is a dark brown and gray, algal dolomite, which grades downward into a dark gray to black, fossiliferous mudstone/wackestone. Abundant brachiopods are associated with the black mudstone. The upper algal dolomite consists of scattered, relatively large (up to three inches), nodular algae. Some of this algae appears to have been replaced by anhydrite. Spicules, possibly from sponges, were also found in association with the algal dolomite. Thin section analysis indicates that much of the upper portion of the Florence has been replaced by chalcedonic and microcrystalline quartz. No visible porosity is evident in thin sections of the upper Florence. The lower Florence is a light gray, fossiliferous wackestone which contains abundant grain-coating algae. The algae coats fossil particles, which include brachiopods, bryozoans, and echinoderms. This unit grades downward into an oolitic packstone. Recrystallized ooids are cemented by isopachous and mosaic calcite spar. A portion of the unit has been replaced by anhydrite. Numerous ooid "ghosts" can be observed in the anhydrite (see thin section photo 2806.2). Some oomoldic porosity from the leaching of ooids and interparticle porosity between ooids were observed.

Overall reservoir quality of the Florence is considered poor, due to the tight mudstone unit and a general lack of porosity throughout. The best porosity was observed in the basal oolitic packstone.

Separating the Florence Formation from the Wreford Formation is a gray and brown siltstone, which grades downward into a massive and mottled, red shale. The shale becomes greenish-gray toward the base. Scattered anhydrite nodules and caliche (?) are present. A thin section of the upper siltstone shows framework grains of quartz, feldspar, micas, and rare lithic fragments. Detrital clay matrix is abundant. No porosity was observed in this unit.

Wreford Formation: Three lithologies are evident in the Wreford Formation portion of the cored interval. The uppermost lithology is a light gray, very fine crystalline limestone. This unit contains scattered bioclasts, mainly crinoids. Shaly laminations occur at the top of the interval, where it grades into the green and red shale above. Thin section analysis reveals a tight, fossiliferous limestone with anhydrite and sparry calcite cement. Minor amounts of intra- and interparticle porosity were observed. Overall, this unit is tight. The middle lithologic unit is a light gray and dark gray, algal-bryozoan mudstone/wackestone. Abundant nodular algae is present, similar to that found in the Upper Florence Formation. Dark clay seams are

scattered throughout this unit. Thin sections show minor amounts of quartz sand. Portions of the unit have been partially silicified. Silica replacement is interpreted to have rendered this rock tight. No porosity was found. The lowermost lithology in the Wreford Formation is a light brown and gray, fossiliferous wackestone/packstone. Abundant grain-coating algae coats crinoids, bryozoans, brachiopods, and foraminifera. A small amount of anhydrite replacement appears to have occurred. Traces of intra- and inter-particle porosity were observed.

This lower unit is the best reservoir rock in the Wreford Formation. An overall lack of porosity throughout the Wreford gives it fair to poor reservoir quality.

TABLE 2

Porosity Types, Abundances and Interpreted Effectiveness

Anadarko Walters A#1

<u>Formation</u>	<u>Porosity Types</u>	<u>Abundance</u>	<u>Effectiveness</u>	<u>Reservoir Quality</u>
Herrington	Intergranular	A	E	Moderate
	Microporosity	MA	I	
	Intragranular	NA	I without connection to intergranular system	
Krider	Vuggy	A	E due to good intercrystalline system	Excellent
	Intercrystalline	A	E	
	Moldic	A	E due to good intercrystalline system	
	Fracture	NA	?	
Odell	Intragranular	NA	I	Poor
	Microporosity	NA	E possibly, if no fluid retention	
	Fracture	NA	E	
Winfield	Intercrystalline	A in upper portions	E	Moderate
	Vuggy	MA in upper portions	E when connected by intercrystalline system	
	Moldic	MA in upper portions	E when connected by intercrystalline system	
	Intraparticle	NA	I	
	Microporosity	MA	I	
Gage	Fracture	NA	E in part	Poor
Towanda	Intergranular	MA in sandstone	E	Good/moderate
	Intercrystalline	NA in carbonates	E	
	Intraparticle	NA in carbonates	I	
	Interparticle	MA in carbonates	E	
	Microporosity	MA in carbonates	I	

TABLE 2 (continued)

<u>Formation</u>	<u>Porosity Types</u>	<u>Abundance</u>	<u>Effectiveness</u>	<u>Reservoir Quality</u>
Fort Riley	Interparticle	MA	E	Moderate/poor
	Intraparticle	NA	I	
	Intercrystalline	NA	E	
	Microporosity	MA	I	
Florence	Intraparticle	MA	I	Moderate/poor
	Oomoldic	NA	I	
	Microporosity	NA	I	
	Interparticle	MA	E	
Wreford	Intraparticle	NA	I	Moderate/poor
	Interparticle	NA	E	
	Microporosity	MA	I	

KEY:

Abundance

A - abundant  
 MA - moderately abundant  
 NA - not abundant

Effectiveness

E - effective  
 I - ineffective

## Inferred Environments of Deposition

(Refer to Figure 1, Detailed Core Description.)

The entire Permian-Chase Group core from the Anadarko Walters A#1 Well is interpreted to have been deposited in cyclic sequences on a shallow carbonate shelf. The cored interval contains five shoaling upward cycles. The sequence of environments in each cycle commonly changes from marine subtidal at the base, to supratidal (generally represented by a shale unit) at the top.

### Cycle 1 (2860.0-2807.5 feet):

The lowermost cycle extends from the base of the core (2860.0 feet, Wreford Formation) to 2807.5 feet (base of the Florence Formation). The Wreford Formation (2834.0-2860.0 feet) is interpreted to represent the subtidal portion of the cycle. The uppermost Wreford may be intertidal, or the intertidal portion of this cycle may be missing. An assemblage of normal marine fossils, crinoids, brachiopods, bryozoans, and forams, were observed. The interval 2845.0-2850.0 feet may represent a small algal-bryozoan bank on the shallow shelf. Overlying the subtidal portion is a mottled, green and red shale. This unit (2834.0-2807.5 feet) is interpreted to represent a paleosol. The red portions are oxidized (above the water table) and the lower green portions are reduced (below the water table). The silty portion of the shale interval may represent a lagoonal stage, as the marine waters were beginning to transgress.

### Cycle 2 (2807.5-2731.0 feet):

The next cycle begins at 2807.5 feet at the base of the Florence Formation, and ends at 2731.0 feet (base of the Towanda Formation). The Florence and Fort Riley Formations comprise the subtidal portion of this cycle. The "deepest" rocks are interpreted to be the black and dark gray brachiopod mudstone of the Florence Formation. A small ooid shoal, which is interpreted to be migrating with the transgressions and regressions of the sea, is present at the base. Another small algal bank may be represented by the upper Florence Formation. An intertidal zone may be reflected in the shaly portions at the top of the Fort Riley Formation. This unit is overlain by a green and partially red, mottled shale. It is interpreted that weathering of the shale unit mostly took place beneath the water table; hence the dominant green color. Small strands above the water table (vadose zones) are represented by the interspersed red shales.

### Cycle 3 (2731.0-2664.0 feet, overall):

The next cycle begins at the base of the Towanda Formation (2731.0 feet), and ends at the base of the Winfield Formation (2664.0 feet). Two cycles were actually observed here. These are separated by the anhydritic dolomite in the middle of the Towanda. This unit indicates the development of a supratidal flat, but the thinness of the unit suggests it was not well developed. Subtidal rocks are located in the basal Towanda and the upper Towanda. The intertidal portion of the cycle is interpreted to be present in the sandstone unit at the top of the Towanda Formation. No well developed beach is present, which may be a function of generally low energies. (Note: Lack of sorting may represent a very low wave energy and a tidal-dominated system.) The Gage

Formation represents the top of the cycle. This red shale is again interpreted to be a paleosol, weathered and formed above the water table. Intermittent greenish shale suggests a higher water table for short periods of time.

#### Cycle 4 (2664.0-2616.0 feet):

The next cycle begins at the base of the Winfield Formation (2664.0 feet) and ends at the top of the Odell Formation (2616.0 feet). Subtidal deposition is represented by Winfield rocks. Though normal marine fossils are present, some clastic material is intermixed (though not in abundance), and may represent a minor clastic source. The sandstone unit at the base of the Odell may represent a continuation of clastic input to the cycle, and is also interpreted to depict the intertidal portion of the cycle. This unit is again interpreted to represent a tidal-dominated system, with a general lack of wave energy, as indicated by extensive burrowing and ripple laminations. The paleosol for this cycle directly overlies this sandstone unit (upper Gage). Its mottled red and green coloration again indicates weathering related to a fluctuating water table.

#### Cycle 5 (2616.0-2540.0 feet):

The uppermost cycle begins at the base of the Krider (2616.0 feet) and ends at the top of the cored interval (2540.0 feet). The Krider Formation is interpreted to be subtidal. Although dolomitization has obliterated many original textures and particles, "ghosts" of bioclasts were observed in thin section. These are interpreted to be similar to other subtidal units in the core, but this is the most completely dolomitized unit. The intertidal zone is again represented by a sandstone unit in the lower portions of the Herrington Formation. Burrowing and ripple laminations again suggest low turbulence, shallow marine deposition. The upper Herrington represents the supratidal and paleosol portion of this cycle. A thin "chicken wire" anhydrite unit indicates a minor tidal flat development with hypersaline waters. Continued evaporation and regression of the sea resulted in paleosol development reflected by the shale at the top of the cored interval.

#### Environmental Generalizations

1. Relatively low energy: lack of sand beaches, no "storm deposits," extensive bioturbation.
2. Predominantly normal marine salinities: suggested by normal marine fauna throughout core.
3. Shallow water: presence and abundance (in some zones) of algae.
4. Cyclic sedimentation: reflected in the five shoaling-upward sequences, each capped by a paleosol.
5. Fluctuating water table at the top of each cycle (probably in response to rising and lowering sea level): reflected in red-green color variations of paleosols.
6. Relative proximal clastic source: reflected in "intertidal" sandstone units, and dispersed sand and silt throughout much of the core.

## Diagenetic Events

Petrographic evidence indicates that the cored interval was subjected to diagenesis involving normal marine, fresh, and some hypersaline waters. Subaerial exposure also affected the uppermost unit in each depositional cycle (see "Depositional Environment").

Major diagenetic events (in inferred sequence) and their effect on the pore system are as follows:

1. Recrystallization: In the carbonates, recrystallization of fine carbonate material to sparry calcite has reduced porosity. Primary porosity in carbonates at the time of deposition is generally high (e.g., 30-50% and possibly higher). Recrystallization has reduced this significantly. Because faunal constituents present were assumed to have been originally composed of aragonite and high magnesium calcite, and the carbonate mud was probably low magnesium calcite, recrystallization most likely occurred at different rates (see 4, below).
2. Cementation: Marine and fresh water carbonate cements, as well as anhydrite, have reduced porosity in ~~all~~ <sup>some</sup> carbonate rocks. Cementation has also reduced some porosity in the ~~sandstone units~~ <sup>siltstone</sup> (see SEM photo 2561.5 - ~~Herrington Formation~~).
3. Dolomitization: This has increased porosity in completely dolomitized intervals (i.e., Krider Formation). In partially dolomitized intervals, remnant calcite still occludes ~~much~~ <sup>some</sup> pore space. Again, original particle size probably has affected rates of dolomitization. Finer-grained material (micrite) may have been dolomitized more slowly.
4. Leaching: Leaching of bioclastic material has formed molds and vugs in most carbonate units. Leaching of dolomite "matrix," and calcite and dolomite cements, as well as a few unstable framework grains, has increased porosity in ~~the Herrington and upper Towanda sandstones~~ <sup>some of the siltstone units,</sup>
5. Anhydrite Replacement: This has generally had little effect; ~~however, in the anhydrite replacement of the ooid packstone (Florence Formation) has decreased interparticle porosity.~~ <sup>and is only minor in the Keenan core</sup>
6. Silica Replacement: This is not very abundant; therefore, its effect on porosity is minimal. ~~Silica replacement has occluded porosity in the Florence Formation (see thin section photos 2780.7 and 2806.2).~~

## Appendices

1. Figure 1 - Detailed Core Description and Remarks
2. Core Description Legend
3. Close-up Core Photos and Remarks
4. Table 3 - X-ray Diffraction Data
5. Thin Section Photomicrographs and Annotations
6. SEM Photomicrographs and Annotations
7. Porosity-Permeability Cross Plots

I. Red and green, silty shale: This zone is typically wavy laminated and slightly dolomitic. More dolomite appears to be abundant at the bottom than at the top. This unit is generally more fissile at the top.

II. Translucent gray and white anhydrite: This zone exhibits "chicken wire" structure in part.

III. Light brown, fine- to medium-grained sandstone: This unit is dolomite- and anhydrite-cemented. Commonly parallel and wavy laminated; however, portions are massive. A few scattered, interbedded shales are also present. Portions appear to be ripple laminated and burrowed, in part. Small (less than 1 cm), round and oblong anhydrite nodules are present at the top of the unit, and increase in size (3 cm) in the shaly portions and at the bottom of the unit.

IV. Dark gray, dolomitic shale grading downward into dolomite: Scattered anhydrite nodules and burrows are present.

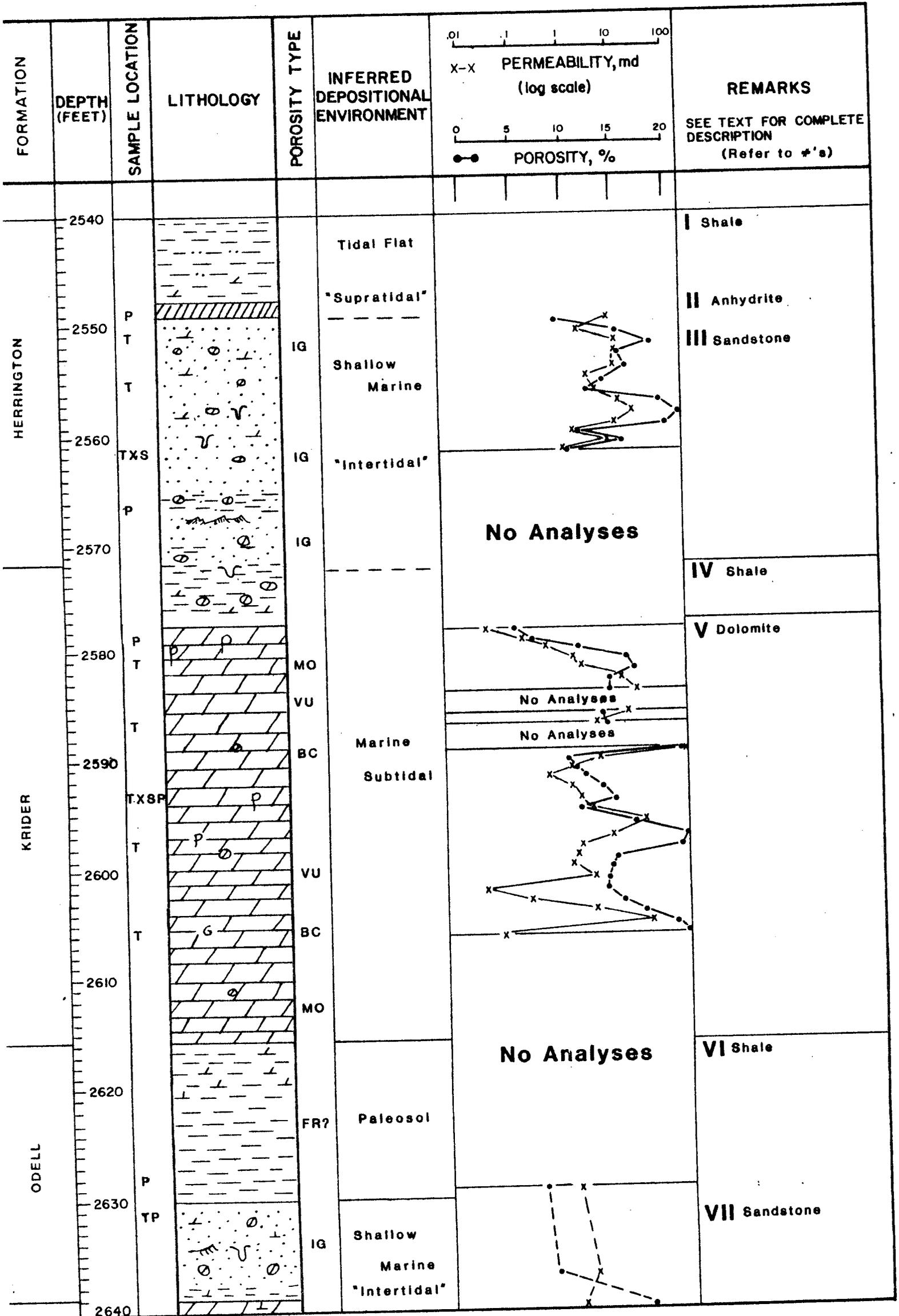
V. Light brown and light gray, fine to medium crystalline dolomite: Many molds and vugs are present, and are well interconnected by intercrystalline pores. The top of this unit is wispy laminated with pyrite. A few scattered anhydrite nodules are present, and some anhydrite replacement of carbonate appears to have occurred at 2589.7 and 2600.2 feet. Commonly, a finer particle size is found at the bottom of this unit than at the top. Dolomite has obliterated much original texture; however, molds and vugs are presumed to be selectively leached bioclasts.

VI. Red shale, turning dark gray at the top: This unit has a mottled appearance, and greenish areas are also present. The top portion is dolomitic, whereas a lack of dolomite appears to be common at the bottom of this unit.

VII. Light brown to dark gray, fine- to medium-grained sandstone: This sandstone is wavy laminated, and ripple laminated in part. Scattered anhydrite nodules and burrows are present. One large burrow, filled with anhydrite nodules and internal sediment, was noted.

**FIGURE 1 DETAILED CORE DESCRIPTION**  
**ANADARKO WALTERS A#1,**  
**STEVENS COUNTY, KANSAS**

pg. 1/4  
**RESERVOIRS**  
**INC.**



VIII. Light brown and light gray, partially dolomitized, bioclastic wackestone/packstone: There appears to be less dolomite at the bottom, and the lower portions are also shaly. This unit is commonly massive to wavy laminated and contains scattered anhydrite nodules and traces of burrowing. Minor amounts of quartz and feldspar sand are present. Stylolites are poorly developed and rare. Bioclasts include echinoderms (crinoids and echinoids), bryozoans, brachiopods, and foraminifera.

IX. Wavy laminated, gray, shaly dolomite: This unit is burrowed, in part.

X. Red and grayish-green shale: This unit is dolomitic at the top and bottom, whereas the middle portions appear to lack carbonate. A trace of pyrite was observed, as were scattered anhydrite nodules. The overall appearance of this unit is mottled.

XI. Fine-grained sandstone: This unit is dolomite-cemented at the top and calcite-cemented at the bottom. Shaly streaks are present. This unit is typically parallel laminated to massive. Scattered anhydrite nodules and rare shell fragments were observed.

XII. Light gray, fossiliferous, partially dolomitized wackestone: This unit appears to have better sorting than the unit directly below. It also contains a smaller overall particle size and fewer crinoids. Scattered, nodular, chalky calcite is present at the top of the unit. This is interpreted to be caliche associated with subaerial exposure during the development of the paleosol directly above the sands.

XIII. Light brown and light gray, fossiliferous, partially dolomitized wackestone: Scattered crinoids are abundant. A few solitary corals are present, some of which have been replaced by anhydrite, but the original structure is still preserved in most.

XIV. Light brown dolomite with abundant massive and nodular anhydrite: Numerous elongate anhydrite crystals are present, and are presumed to be pseudomorphs after gypsum.

XV. Light brown and light gray, partially dolomitized wackestone/packstone: This unit is very fossiliferous, and most of the bioclasts are still calcite. The majority of the matrix appears to be partially dolomitized. There seems to be less dolomite at the bottom of this unit than at the top. Identifiable bioclasts include crinoids, echinoids, bryozoans, brachiopods, and forams. Anhydrite laths are present at 2722.2 and 2723.8 feet. These are interpreted to be replacing calcite. An anhydrite-filled burrow was observed at 2728.0 feet.

XVI. Green and partially red, mottled shale: This unit is wavy laminated in part and contains traces of burrows and anhydrite. Some of this wavy lamination is interpreted to possibly be algae. The upper portions of this unit are very silty.



Walters A#1

FORMATION	DEPTH (FEET)	SAMPLE LOCATION	LITHOLOGY	POROSITY TYPE	INFERRED DEPOSITIONAL ENVIRONMENT	PERMEABILITY, md (log scale)		REMARKS	
						X-X	●		
WINFIELD	2640	T	[Lithology: Diagonal lines]	MO	Marine Subtidal		SEE TEXT FOR COMPLETE DESCRIPTION	VIII Dol. wackestone/ packstone	
		T	[Lithology: Diagonal lines]	VU					
		P	[Lithology: Diagonal lines]						
	2650	TXS	[Lithology: Diagonal lines]	BC					
		T	[Lithology: Diagonal lines]						
	2660	T	[Lithology: Diagonal lines]						
		T	[Lithology: Diagonal lines]	BC					
		T	[Lithology: Diagonal lines]						
		P	[Lithology: Diagonal lines]						
		T	[Lithology: Diagonal lines]						
GAGE	2670	P	[Lithology: Horizontal lines]	FR?	Intertidal	No Analyses	IX Shaley dol. X Shale		
		P	[Lithology: Horizontal lines]		Paleosol	No Analyses			
	2680	P	[Lithology: Horizontal lines]		Supratidal	No Analyses			
		P	[Lithology: Horizontal lines]			No Analyses			
		P	[Lithology: Horizontal lines]			No Analyses			
TOWANDA	2690	TP	[Lithology: Stippled]	IG	Shallow Marine		SEE TEXT FOR COMPLETE DESCRIPTION	XI Sandstone XII Dol. wackestone XIII Dol. wackestone XIV Anhydritic dol. XV Wackestone/ packstone	
		P	[Lithology: Stippled]		Subtidal Reworked?				
	2700	P	[Lithology: Stippled]	BP	Subtidal				
		T	[Lithology: Stippled]						No Analyses
		P	[Lithology: Stippled]		Supratidal				No Analyses
	2710	P	[Lithology: Stippled]						No Analyses
		TXSP	[Lithology: Stippled]	FR	Shallow subtidal				
	2720	T	[Lithology: Stippled]	BP					
		P	[Lithology: Stippled]	WP					
		P	[Lithology: Stippled]	BC					
2730	T	[Lithology: Stippled]							
				FR?	Paleosol?	No Analyses	XVI Shale		
	2740	P	[Lithology: Stippled]						

XVII. Light brown and light gray, partially dolomitized, fossiliferous wackestone/packstone: This unit is shaly at the top. Identifiable bioclasts include crinoids, echinoids, bryozoans, brachiopods, and forams. Abundant, large fusulinids are present from 2765.0 to 2769.0 feet. Some encrusting algae was noted at 2758.0 feet. Parts of this unit appear to be partially replaced by anhydrite. Some fossil material has also been replaced by anhydrite.

XVIII. Dark brown and dark gray, algal dolomite at the top, grading into a dark, fossiliferous mudstone/wackestone: Brachiopods are abundant in the lower portion of this interval in the dark mudstone unit. Much of the upper part of the unit is silicified. Much of the lower portion is calcareous and partially dolomitic. Spicules may occur at the top, which possibly are from sponges.

XIX. Light gray, fossiliferous wackestone/packstone containing abundant grain-coating algae and scattered clay seams, grading downward into an oolitic limestone: Scattered foraminifera and some anhydrite replacement were noted.

XX. Gray and brown siltstone, grading down into massive and mottled, red shale: This unit becomes greenish and gray towards the bottom. Dark, shaly laminations were observed at the top. Scattered anhydrite nodules and chalky calcite (caliche) may be present.

XXI. Light gray, very fine limestone with scattered bioclasts: The majority of the bioclasts are echinoderms, probably crinoids. Shaly laminations are present in the upper portions of this unit. Traces of stylolites were also found.

Valters A#1

FORMATION	DEPTH (FEET)	SAMPLE LOCATION	LITHOLOGY	POROSITY TYPE	INFERRED DEPOSITIONAL ENVIRONMENT	PERMEABILITY, md (log scale)		REMARKS	
						X-X	●-●		
	2740				Paleosol?			Shale	
FORT RILEY	2750	P			Shallow Subtidal/ Intertidal			XVII Wackestone/ packstone No Analyses	
		TP		BP					
		T		WP					
		2760	TP						BC
			TXS						
		2770	T						BP
FLORENCE	2780	P			Algal Bank?			XVIII Algal dol. No Analyses	
		T		WP					
				FR					
		2790	T		BC				
			P						
		2800	TXS						
		TP			Subtidal			XIX Oolitic limestone	
	2810	T		Low Energy Lagoonal?					
	2820	P			Paleosol			XX Siltstone No Analyses	
	2830								
WREFORD		TP			Intertidal/ Subtidal			XXI Limestone	
	2840	T							

XXII. Light gray and dark gray, algal-bryozoan mudstone/wackestone: Abundant nodular algae and relatively large, well preserved bryozoans are present. Traces of quartz sand were observed in thin sections of this unit. Dark gray and dark green clay seams are scattered throughout. This unit is commonly wavy laminated, partially dolomitized, and contains some silica replacement.

XXIII. Light brown and gray, fossiliferous wackestone/packstone: Abundant grain-coating algae was observed in thin sections of this unit. Bioclasts include crinoids, bryozoans, brachiopods, and forams. Minor amounts of anhydrite replacement were also observed.



Walters A#1

FORMATION	DEPTH (FEET)	SAMPLE LOCATION	LITHOLOGY	POROSITY TYPE	INFERRED DEPOSITIONAL ENVIRONMENT	<p>X-X PERMEABILITY, md (log scale)</p> <p>●-● POROSITY, %</p>	REMARKS
WREFORD	2840	TP		WP	Shallow Subtidal		Limestone
	2850	P TXS		BP	Shallow Subtidal	<p style="text-align: center;"><b>No Analyses</b></p>	XXII Mudstone/ wackestone
	2860	TP					XXIII Wackestone/ packstone

# LEGEND

## LITHOLOGIES, SEDIMENTARY STRUCTURES, FOSSILS

	SHALE		BURROWS
	SANDSTONE		ANHYDRITIC
	SILTSTONE		FRACTURES
	LIMESTONE		STYLOLITES
	DOLOMITE		OIDS
	ANHYDRITE		CRINOIDS
	CALCAREOUS		BRYOZOANS
	DOLOMITIC		FORAMINIFERA
	PYRITE		BRACHIOPODS
	GLAUCONITE		CORALS
	ANHYDRITE NODULES		OOTOID ALGAE
	ANHYDRITE CRYSTALS		GASTROPODS
	SILICEOUS		SHELL FRAGMENTS
	RIPPLES		INFERRED

## SAMPLE LOCATIONS

	THIN SECTION		SEM
	X-RAY DIFFRACTION		CLOSE-UP PHOTOGRAPHY

## POROSITY TYPES

	INTERGRANULAR		FRACTURE
	MOLDIC		INTERPARTICLE
	VUGS		INTRAPARTICLE
	INTERCRYSTALLINE		

PLATE 1

- A. 2549 feet: Herrington Formation  
Translucent gray and white anhydrite. This sample exhibits "chicken wire" structure, in part, and is partially dolomitic (darker areas). "Supratidal."
- B. 2566-2567 feet: Herrington Formation  
Light brown, fine- to medium-grained sandstone. Note the "ripple" laminations, and the small anhydrite nodules at the base. "Intertidal."
- C. 2578-2579 feet: Krider Formation (?)  
Dark gray, shaly dolomite. Note the wavy shale laminations, and the white anhydrite nodules. "Intertidal/Subtidal."
- D. 2592-2593 feet: Krider Formation  
Light brown, medium crystalline dolomite. Note the numerous vugs and molds, and the fracture at upper left. "Subtidal."

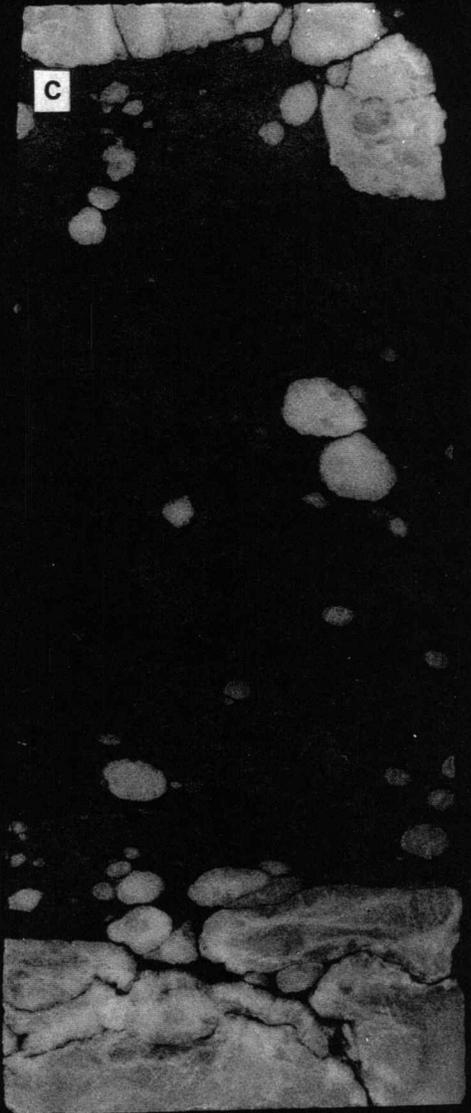
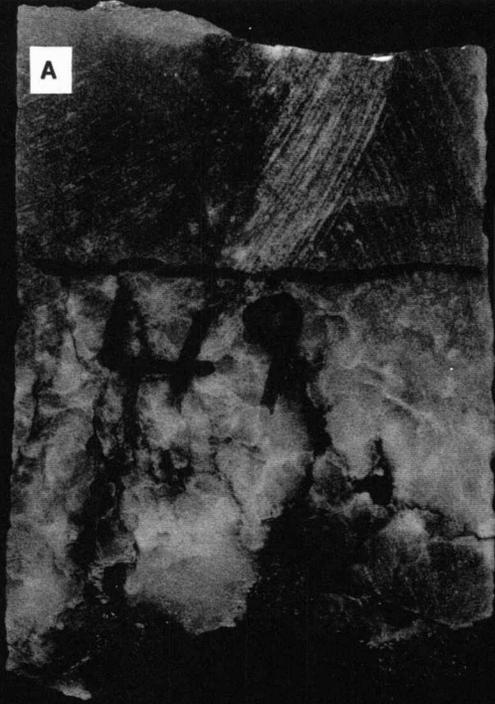
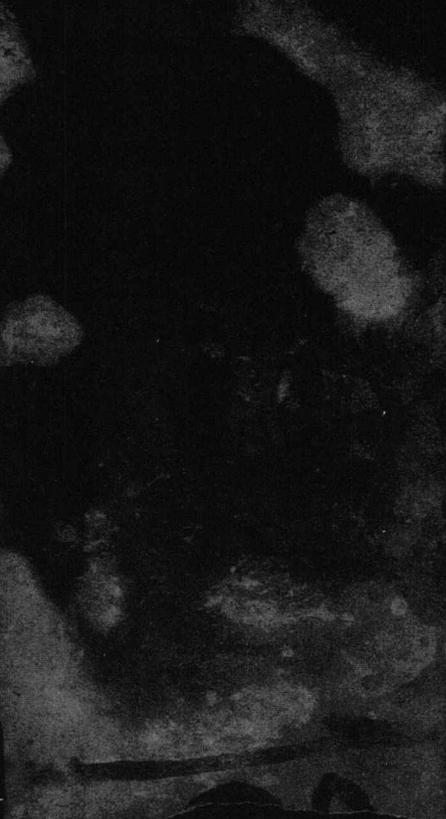


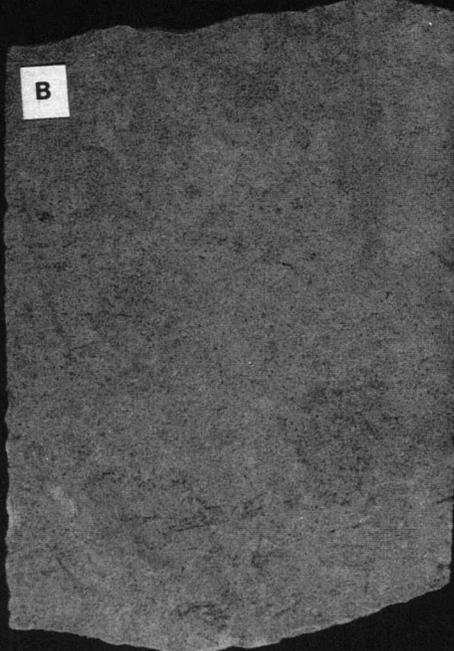
PLATE 2

- A. 2627-2628 feet: Odell Formation  
Dark gray and red, mottled shale. Note the massive nature (lack of fissility). "Paleosol."
- B. 2631-2632 feet: Odell Formation  
Light brown, fine- to medium-grained sandstone. Note the "homogeneous" nature, possibly due to bioturbation. "Intertidal."
- C. 2645-2646 feet: Winfield Formation  
Light brown and light gray, partially dolomitized, bioclastic wackestone/packstone. Note the large bryozoan about 3 cm down from the top. "Subtidal."
- D. 2664-2665 feet: Winfield Formation (base)  
Gray, wavy laminated, shaly dolomite. Note the large burrow at bottom right. "Intertidal."

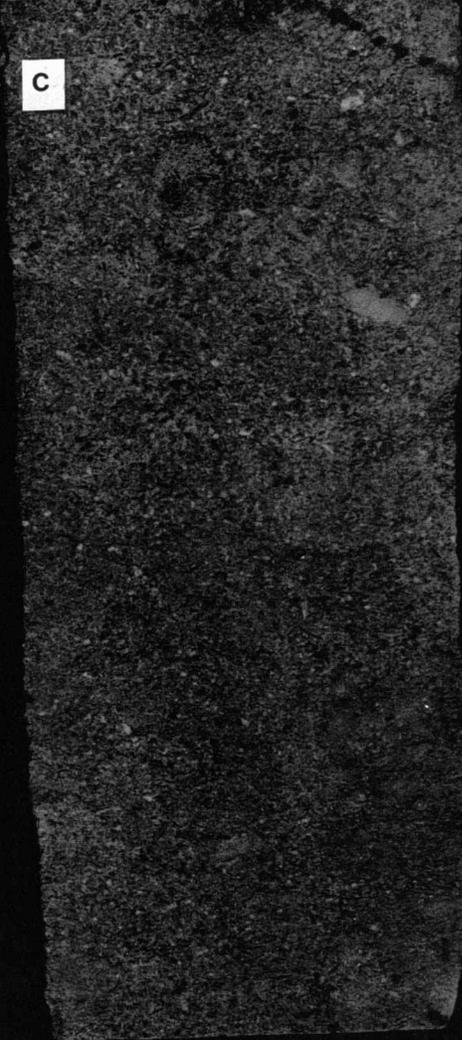
A



B



C



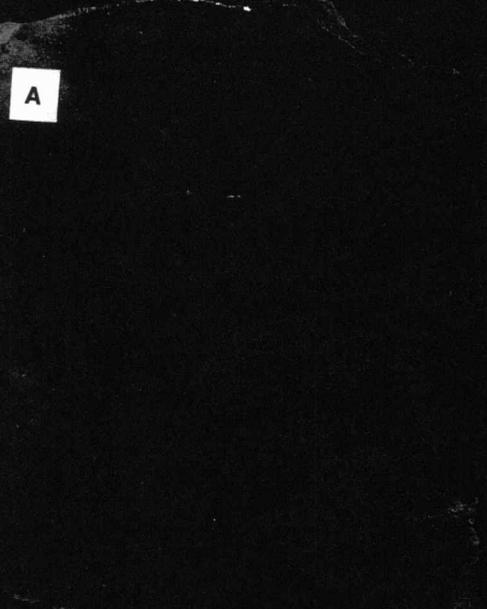
D



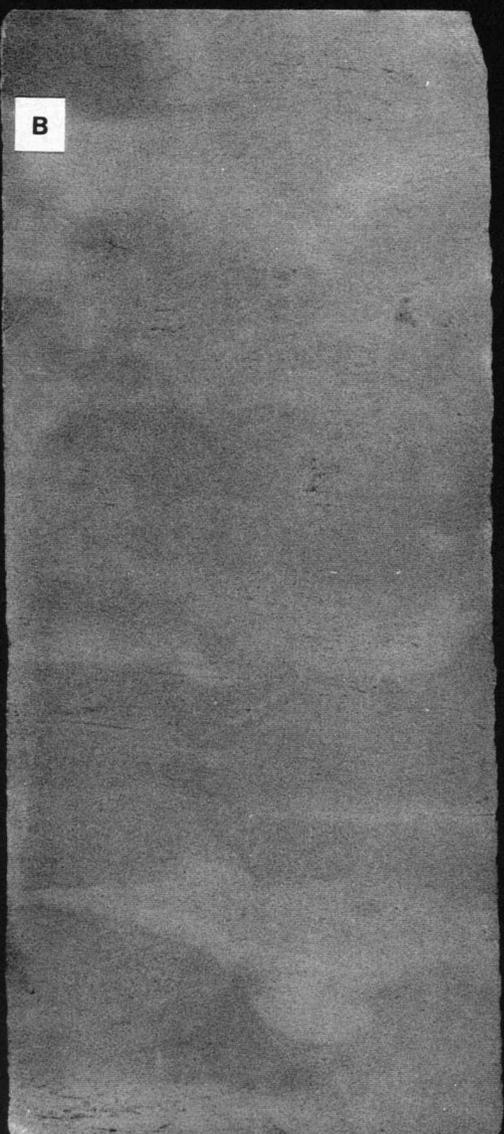
PLATE 3

- A. 2677-2678 feet: Gage Formation  
Red, partially dolomitic shale. Note the lack of fissility. "Paleosol."
- B. 2692-2693 feet: Towanda Formation  
Light gray, fine- to medium-grained sandstone. Note the mottled appearance and "faint" laminations. "Shallow Marine."
- C. 2695-2696 feet: Towanda Formation  
Light gray, dolomitized wackestone. Lighter areas are "chalky" calcite, interpreted to be caliche. "Reworked (?) Subtidal."
- D. 2701-2702 feet: Towanda Formation  
Light gray and light brown, bioclastic, partially dolomitized wackestone. Note the abundant crinoids. "Subtidal."

A



B



C



D



PLATE 4

- A. 2703-2704 feet: Towanda Formation  
Light brown, fossiliferous, partially dolomitized wackestone. Note the solitary corals, some of which (darker ones) have been replaced by anhydrite. "Subtidal."
- B. 2709-2710 feet: Towanda Formation  
Light brown dolomite containing massive and nodular anhydrite. Note the anhydrite pseudomorphs after gypsum. "Supratidal."
- C. 2727-2728 feet: Towanda Formation  
Dark and light gray, partially dolomitized wackestone. Note the large burrow which has been infilled with anhydrite nodules and sediment. "Subtidal."
- D. 2716-2717 feet: Towanda Formation  
Light gray and light brown, fossiliferous, partially dolomitized wackestone/packstone. Note the abundant fossil debris. "Subtidal."

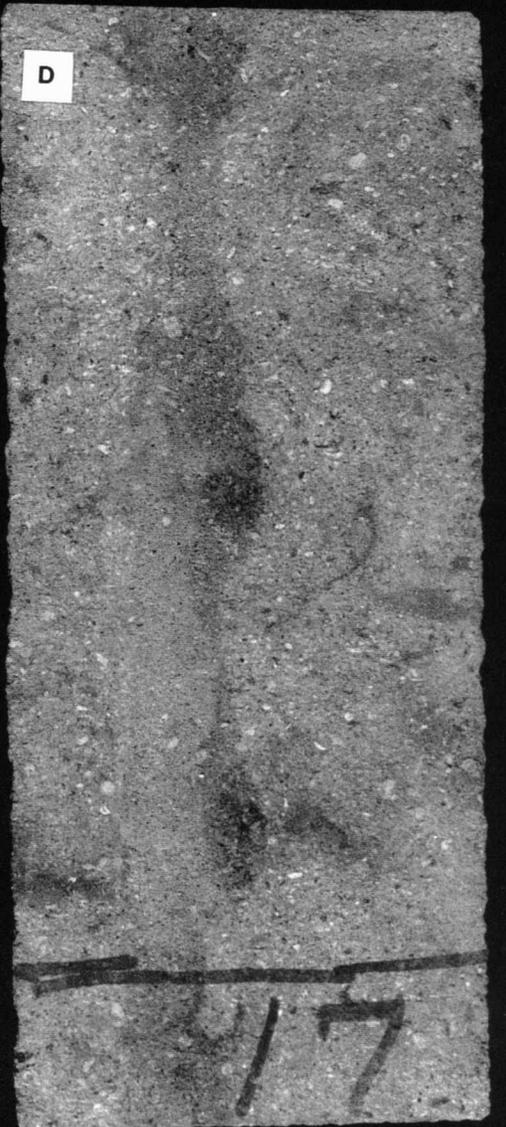
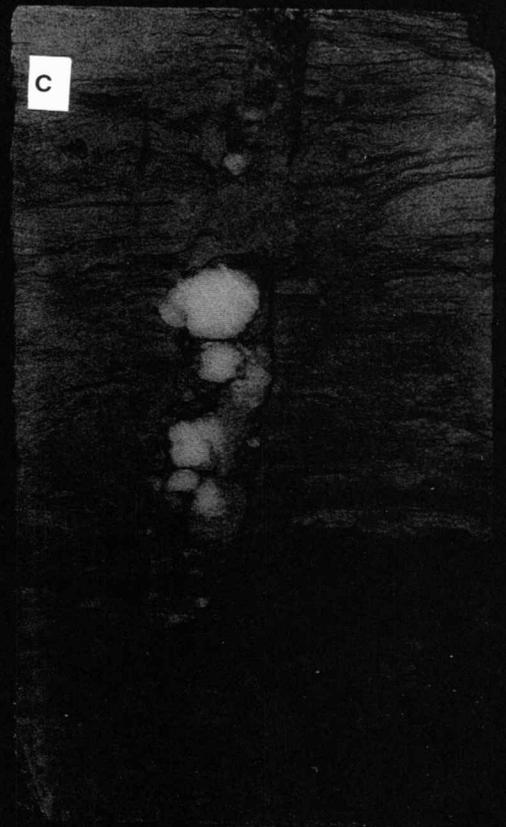
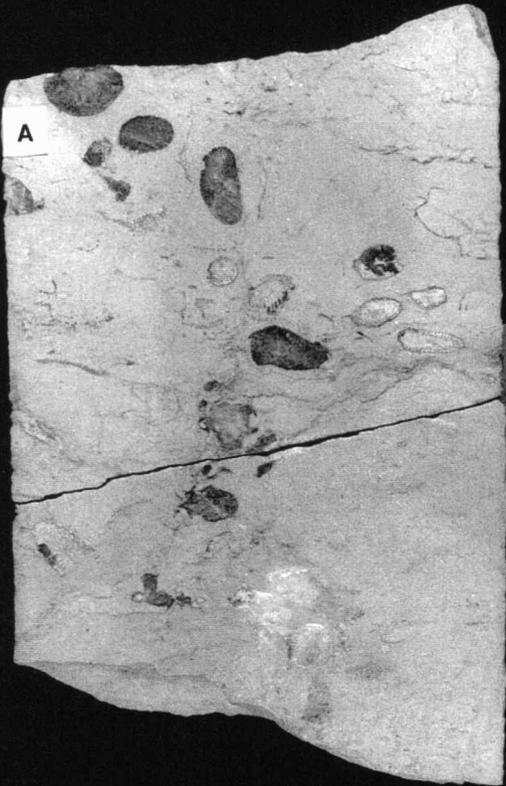


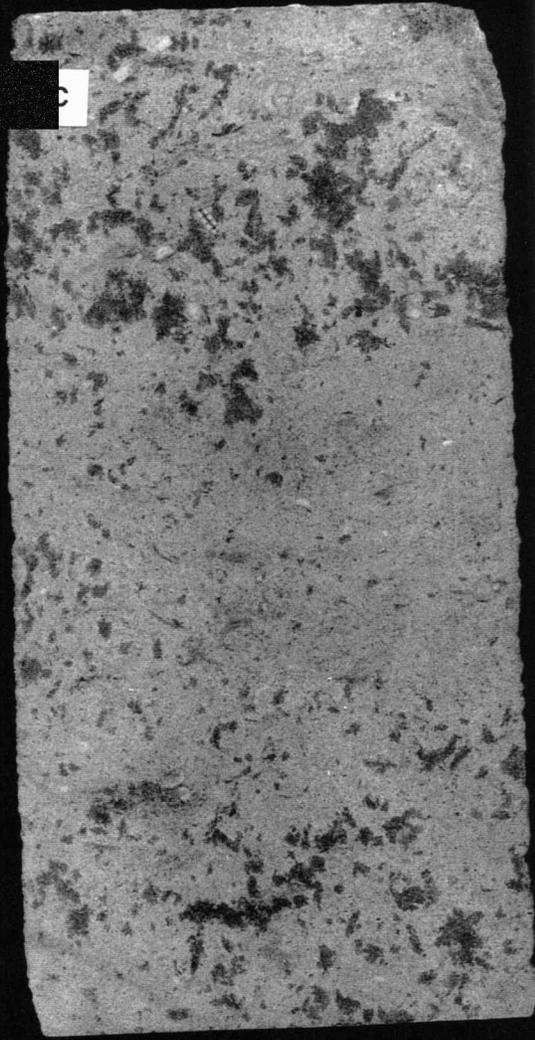
PLATE 5

- A. 2739-2740 feet  
Green and partially red, mottled shale. Note the wavy laminations.  
"Poorly Developed Paleosol."
- B. 2744-2745 feet: Fort Riley Formation  
Light gray, partially dolomitized, fossiliferous wackestone.  
"Intertidal/Subtidal."
- C. 2749-2750 feet: Fort Riley Formation  
Light gray, partially dolomitized, fossiliferous wackestone/packstone.  
Note the anhydrite replacement (darker areas). "Subtidal."
- D. 2757-2758 feet: Fort Riley Formation  
Light brown, partially dolomitized, fossiliferous wackestone. "Subtidal."

A



C



B



D



PLATE 6

- A. 2779-2780 feet: Florence Formation  
Dark brown and gray, algal dolomite. Note the nodular algae (top) and anhydrite nodules (bottom). "Algal Bank, Subtidal."
- B. 2797-2798 feet: Florence Formation  
Dark gray and black, fossiliferous mudstone. Note the scattered shell fragments. "Subtidal."
- C. 2805-2806 feet: Florence Formation  
Light gray, oolitic limestone. Note the stylolites, and anhydrite replacement (dark areas). "Subtidal Ooid Shoal (?)."
- D. 2823-2824 feet  
Mottled, red shale. Note the lack of fissility. "Paleosol."

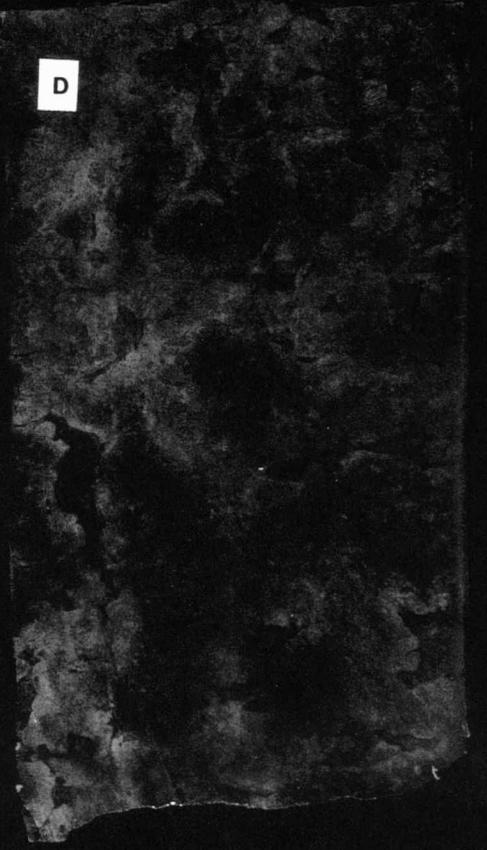
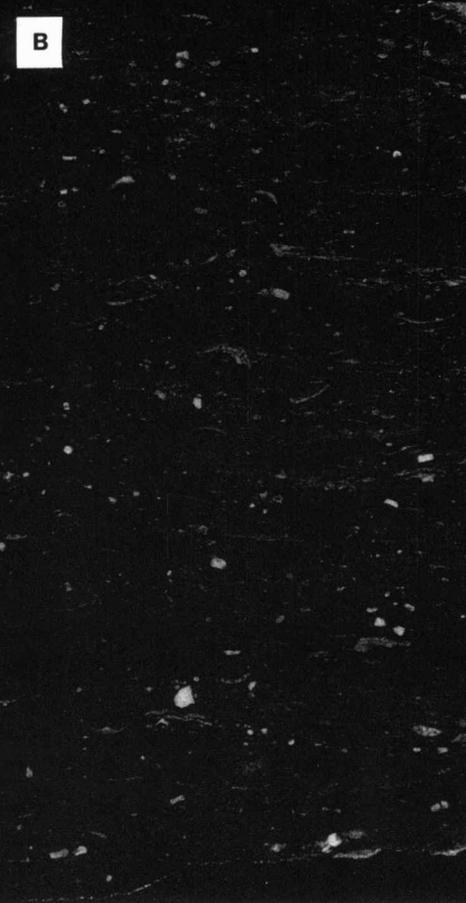
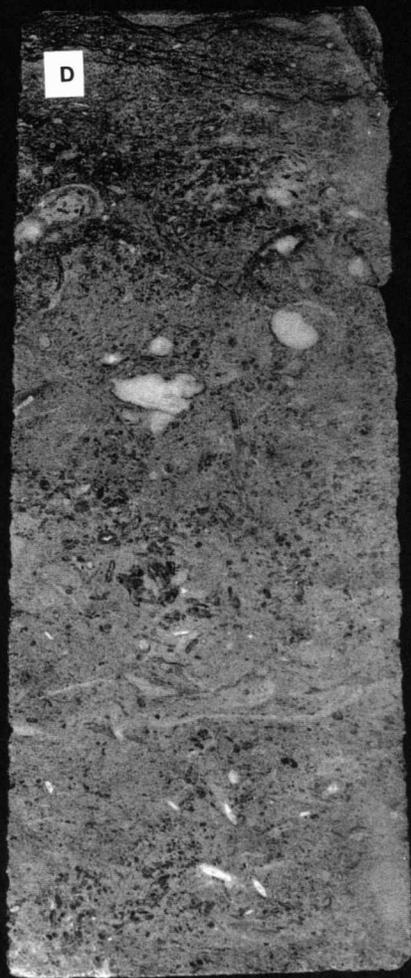


PLATE 7

- A. 2835-2836 feet: Wreford Formation  
Light gray, fossiliferous limestone. Note the scattered bioclasts and fine crystalline nature. "Intertidal/Subtidal."
- B. 2844-2845 feet: Wreford Formation  
Light to dark gray, algal mudstone/wackestone. Note the nodular algae, and wavy laminations. "Subtidal."
- C. 2850-2851 feet: Wreford Formation  
Light gray, fossiliferous wackestone. Note the scattered bioclasts, and shale lamination at top. "Subtidal."
- D. 2859-2860 feet: Wreford Formation  
Light brown and gray, fossiliferous wackestone/packstone. Note the dark rims around particles; they are algae and encrusting forams. "Subtidal."



Sample Designation: 2551.3 feet    Herrington Formation

View A, 80X, Plane Light. Intergranular porosity (blue) can be seen between individual quartz and feldspar grains. Sparse dolomite cement (arrows) fills some intergranular porosity. Note the shaly lamination at the top of the photo.

View B, 135X, Crossed Nicols. This crossed nicol photo shows relatively high birefringent clay between quartz and feldspar grains. This higher magnification view is of a shaly lamination similar to that at the top of View A.

Sample Designation: 2554.5 feet    Herrington Formation

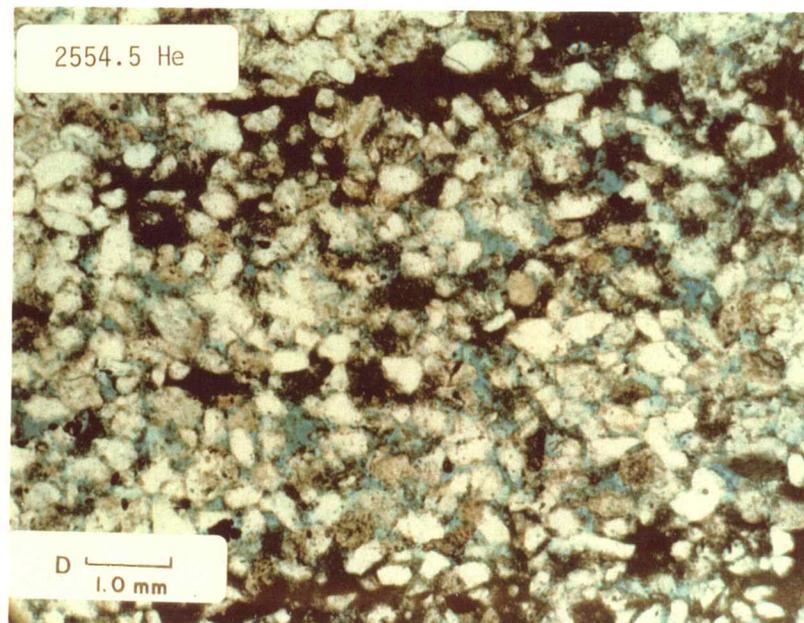
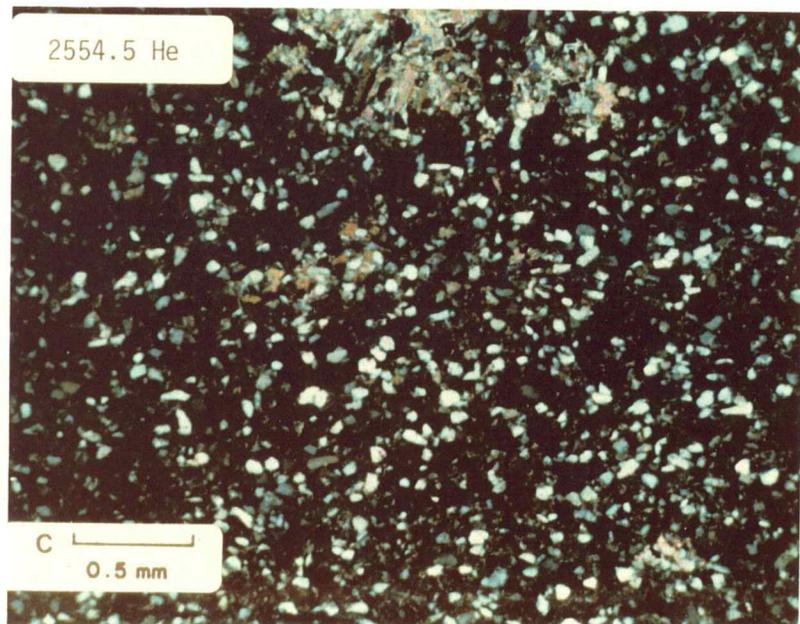
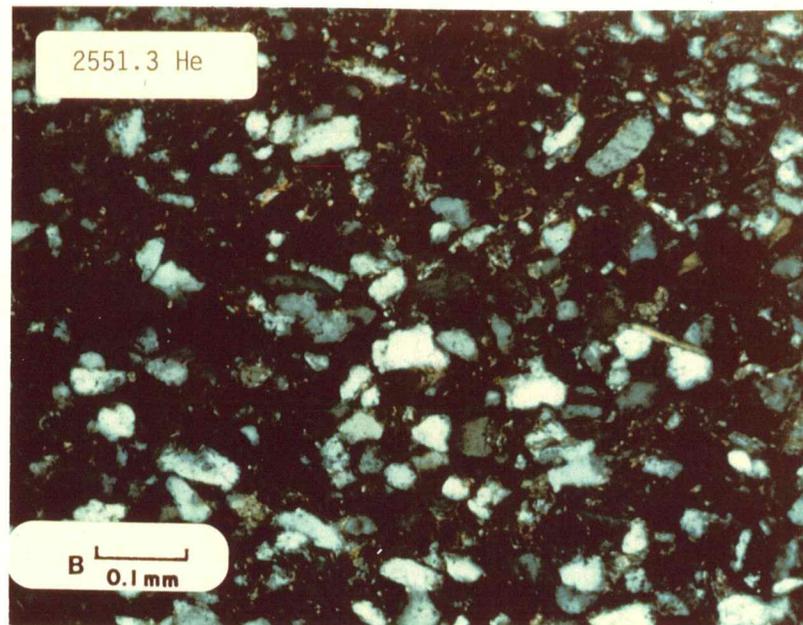
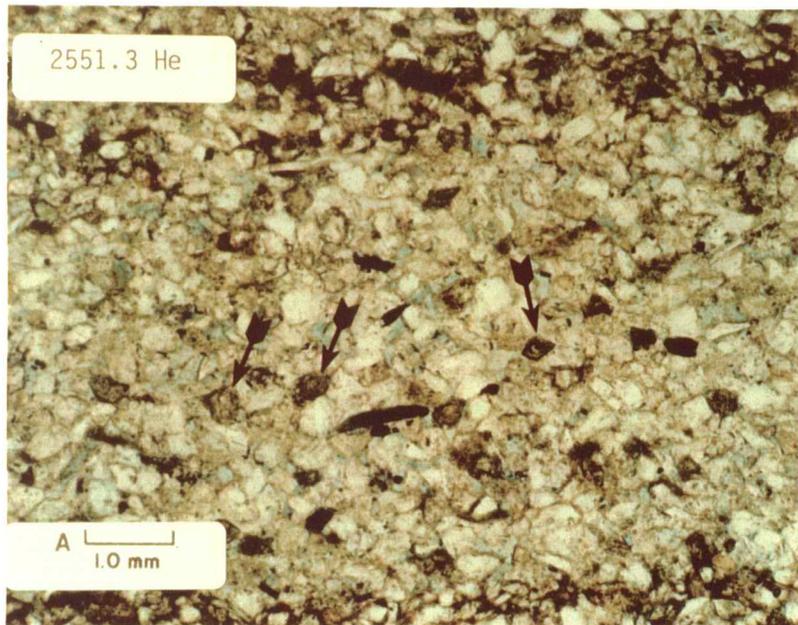
View C, 35X, Crossed Nicols. This fine-grained sandstone is cemented by anhydrite (top) and dolomite (lower portions of photo). Dolomite and anhydrite have reduced porosity and hence permeability at this depth.

View D, 80X, Plane Light. Higher magnification reveals what appears to be porosity (blue) generated by the leaching of some fine-grained dolomite (dark). Note that some intergranular pores are still completely filled with this fine dolomite.

TABLE 3

Summary of "Bulk" X-ray Diffraction Data

<u>Sample Depth</u>	<u>Formation</u>	<u>Calcite</u>	<u>Dolomite</u>	<u>Anhydrite</u>	<u>K-feldspar</u>	<u>Plagioclase</u>	<u>Quartz</u>	<u>% Total Clay</u>	<u>Rock Type</u>
2561.5	Herrington	--	20	23	10	14	28	5	Sandstone
2593.2	Krider	1	95	3	--	--	1	--	Dolomite
2649.5	Winfield	4	63	30	--	1	2	--	Dolomite
2716.5	Towanda	55	41	1	--	--	3	--	Dolomitic Limestone
2764.5	Fort Riley	35	29	32	--	--	4	--	Dolomitic Limestone
2803.0	Florence	88	--	7	--	--	5	--	Limestone
2852.5	Wreford	90	2	5	--	--	3	--	Limestone



Sample Designation: 2561.5 feet Herrington Formation

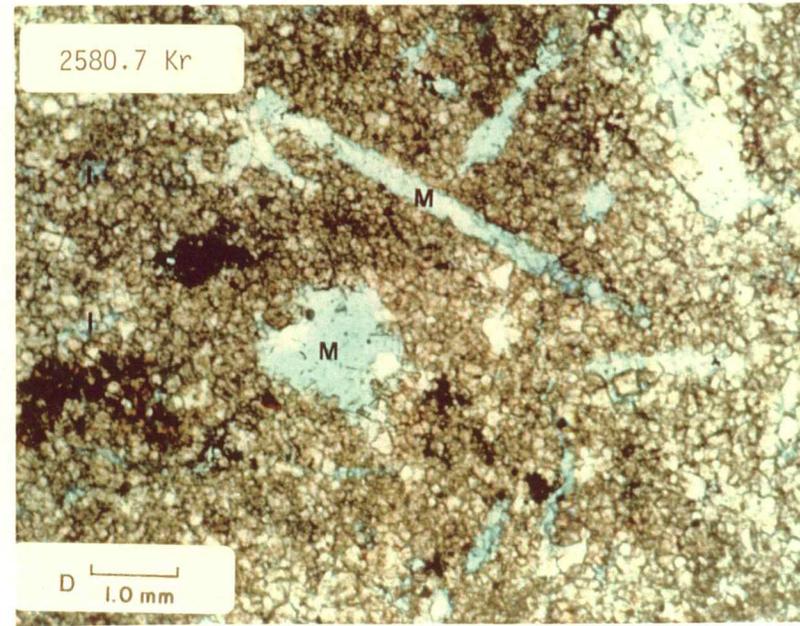
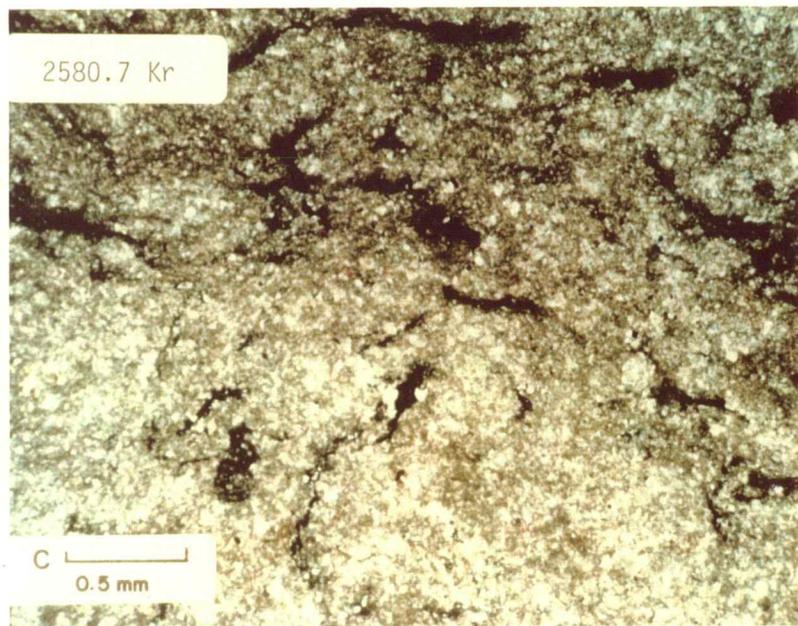
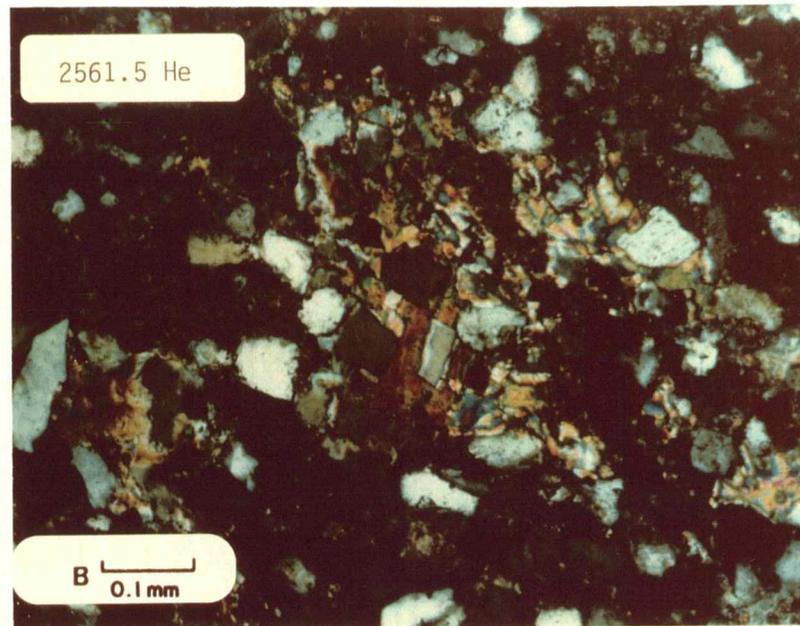
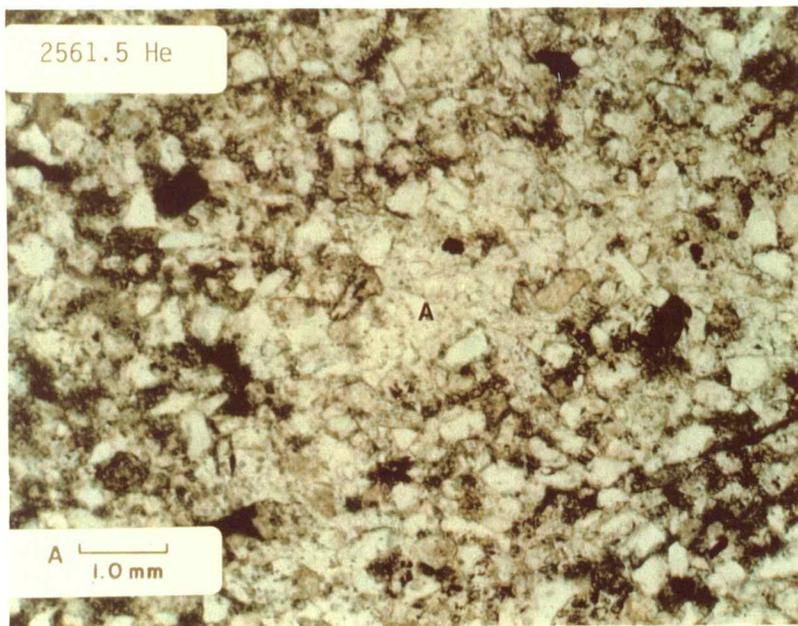
View A, 80X, Plane Light. This is a dolomite- and anhydrite-cemented sandstone. Anhydrite (A) appears to have precipitated early and is reflected in the lack of grain-to-grain contacts in heavily anhydrite-cemented areas. Very fine dolomite (dark) may have been a "detrital matrix" deposited with the sand grains.

View B, 135X, Crossed Nicols. High birefringent anhydrite is visible at center. Note the lack of grain-to-grain quartz contacts. The anhydrite is interpreted to have precipitated as a cement early in the diagenetic history of this rock.

Sample Designation: 2580.7 feet Krider Formation

View C, 35X, Plane Light. Abundant wispy laminations of pyrite are evident in this very fine crystalline dolomite. Note the lack of porosity in this view.

View D, 80X, Plane Light. In another area of the same sample, moldic pores are visible (M). These molds are interpreted to have formed from the dissolution of calcareous material, probably bioclasts. Scattered intercrystalline porosity (I, left) has formed between individual dolomite crystals. The opaque material is pyrite.



Sample Designation: 2586.6 feet Krider Formation

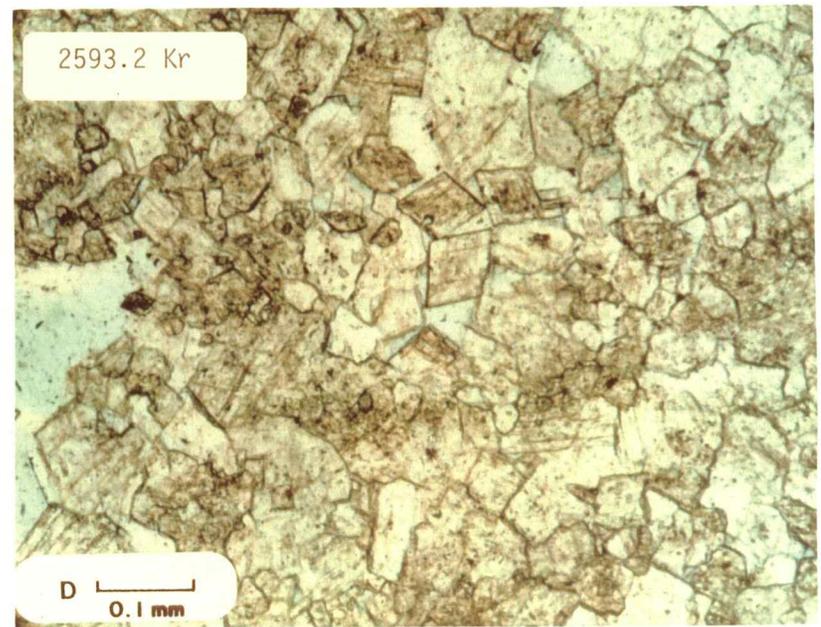
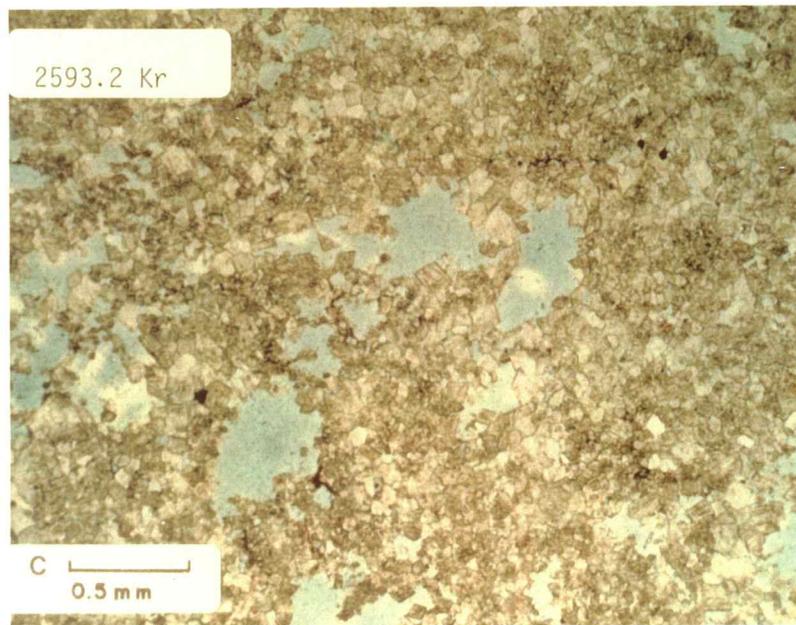
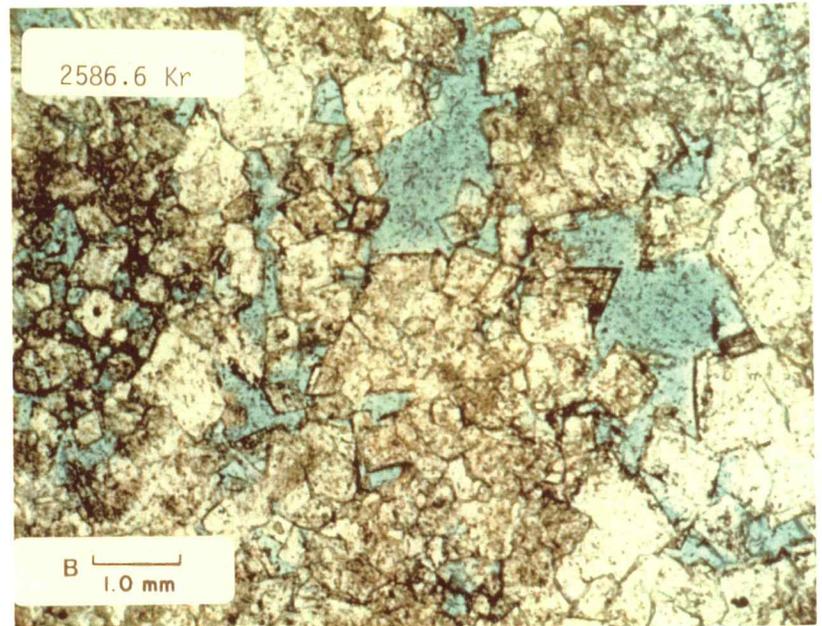
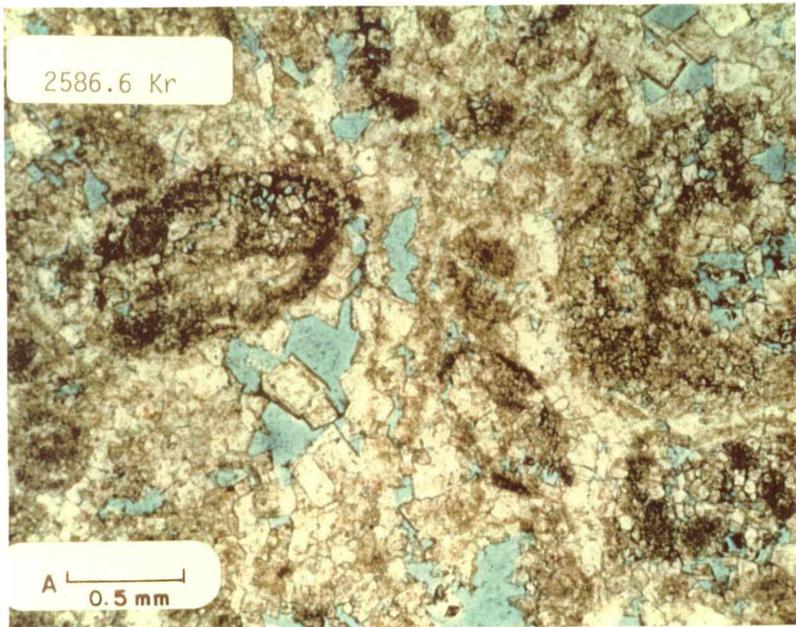
View A, 35X, Plane Light. Abundant dolomite ("ghosts") is present in this sample. These "ghosts" are considered to represent original particle material. Note the excellent vuggy and intercrystalline porosities (blue) scattered throughout the view.

View B, 80X, Plane Light. Higher magnification reveals the rhombic nature of the dolomite, and the abundant porosity associated with this rock.

Sample Designation: 2593.2 feet Krider Formation

View C, 35X, Plane Light. Abundant molds and vugs are present in this sample. These vugs give this rock a high porosity. Some areas of this sample (right) have been rendered relatively tight due to the interlocking nature of some of the dolomite.

View D, 135X, Plane Light. Intercrystalline porosity is visible at center. Some tightly interlocking dolomite is present; however, this sample is considered to have excellent reservoir properties.



Sample Designation: 2597.5 feet Krider Formation

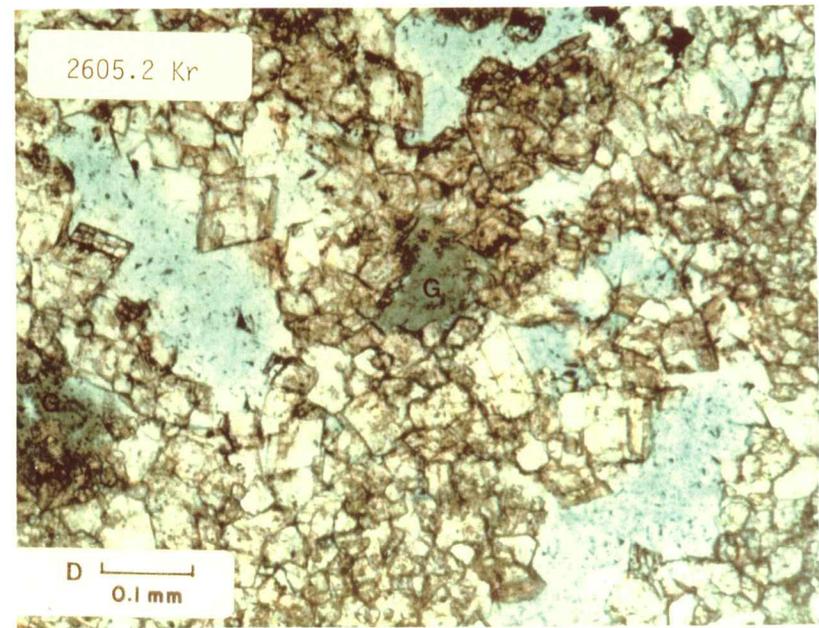
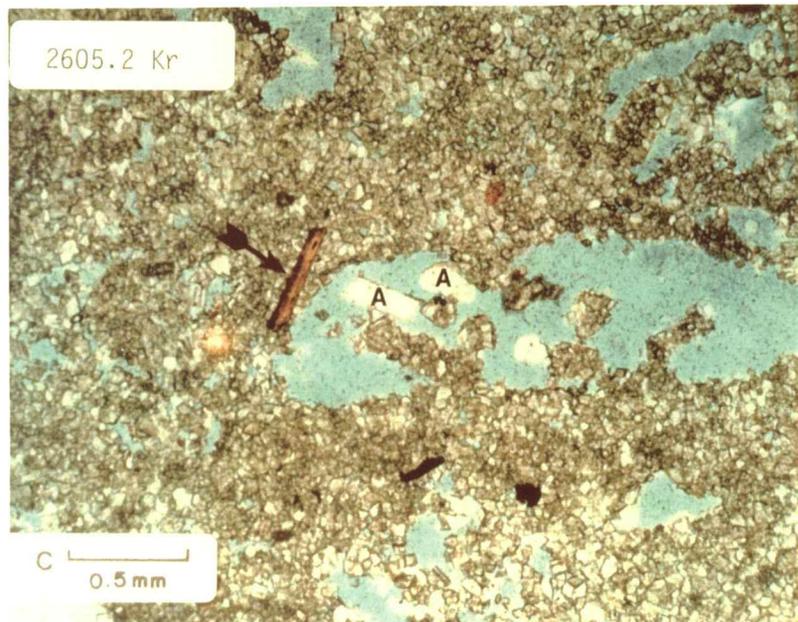
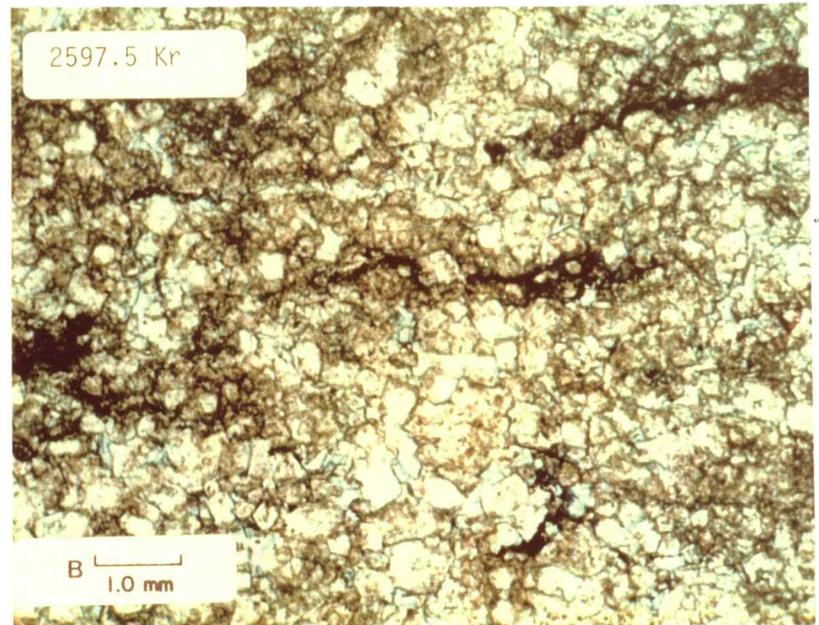
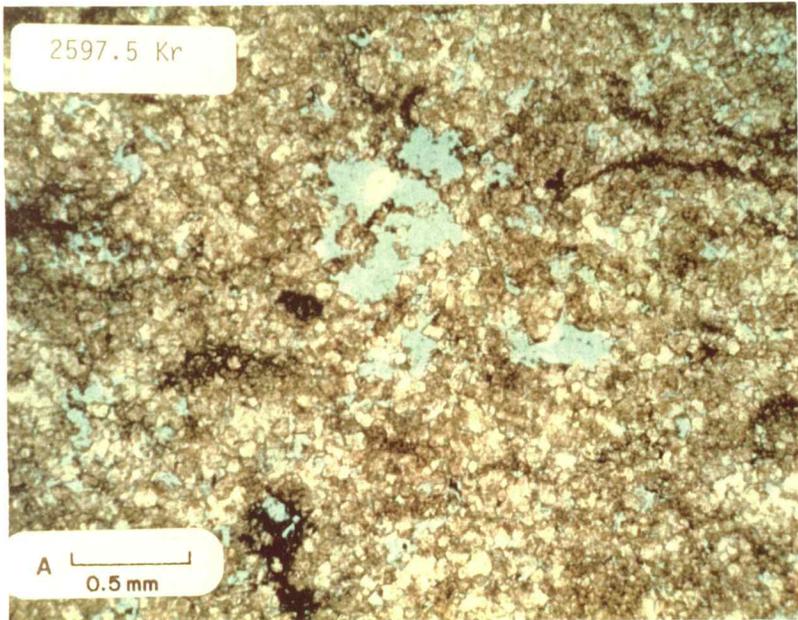
View A, 35X, Plane Light. Some open vugs can be seen in this sample. The majority of the porosity is intercrystalline between individual dolomite crystals. Pyrite and organic material (opaques) are scattered throughout the view. It is interpreted that intercrystalline pores act as permeable pathways connecting large vugs.

View B, 80X, Plane Light. Higher magnification illustrates intercrystalline porosity (blue). Wispy laminations of pyrite (opaque) can act as very small local permeability barriers throughout this sample. Tightly interlocking dolomite is evident in some areas throughout the photo.

Sample Designation: 2605.2 feet Krider Formation

View C, 35X, Plane Light. Moldic and vuggy porosity dominates this sample. Anhydrite (A) can be seen at center, and may mean that these molds at one time were filled with anhydrite. Subsequent leaching of the anhydrite has produced abundant porosity. The arrow at left center points to a phosphatic shell fragment, which is rare throughout this interval.

View D, 135X, Plane Light. Vuggy and intercrystalline porosity can be seen throughout the view. Glauconite (G) has filled some intercrystalline porosity, but is interpreted not to significantly reduce reservoir porosity and permeability.



Sample Designation: 2631.5 feet Odell Formation

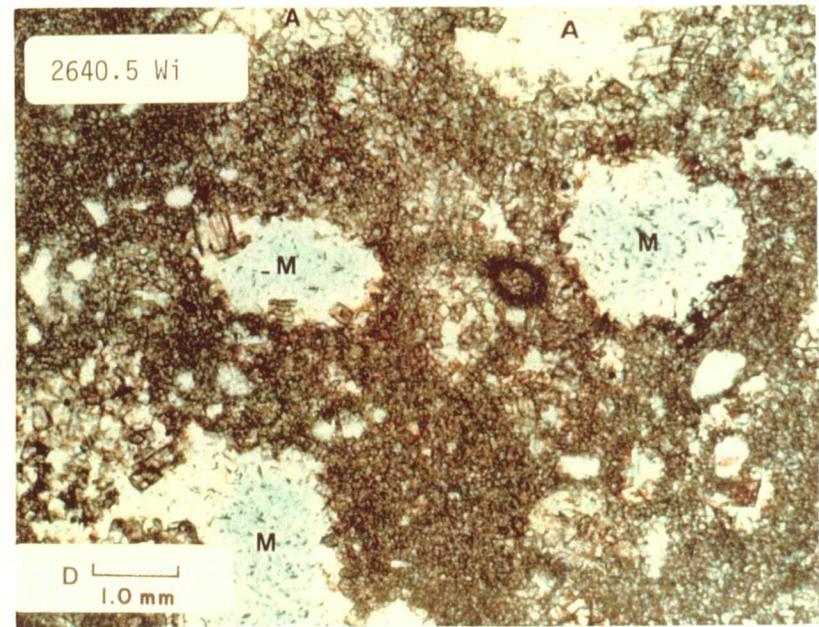
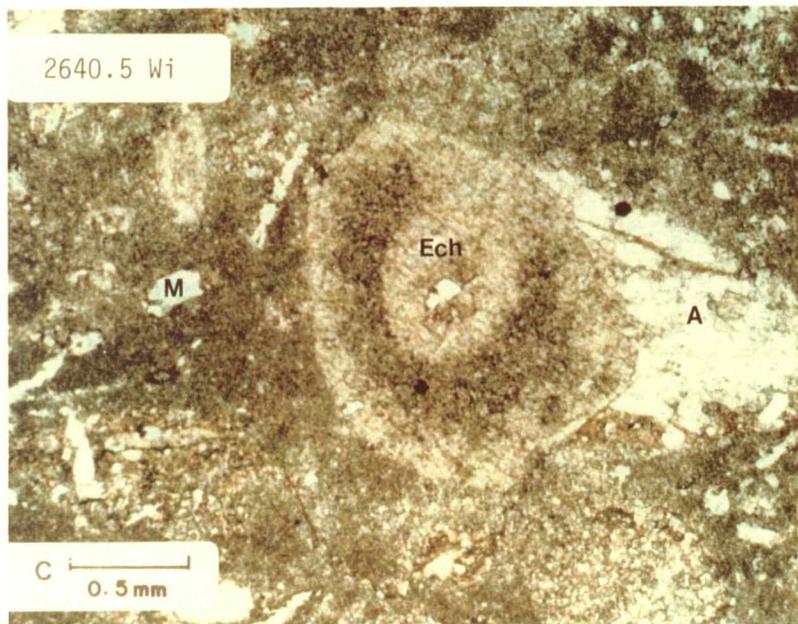
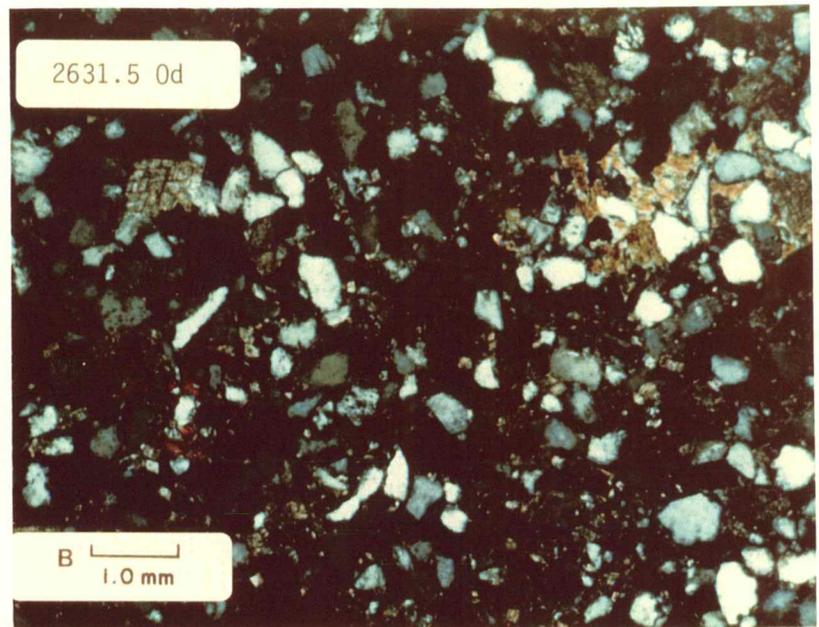
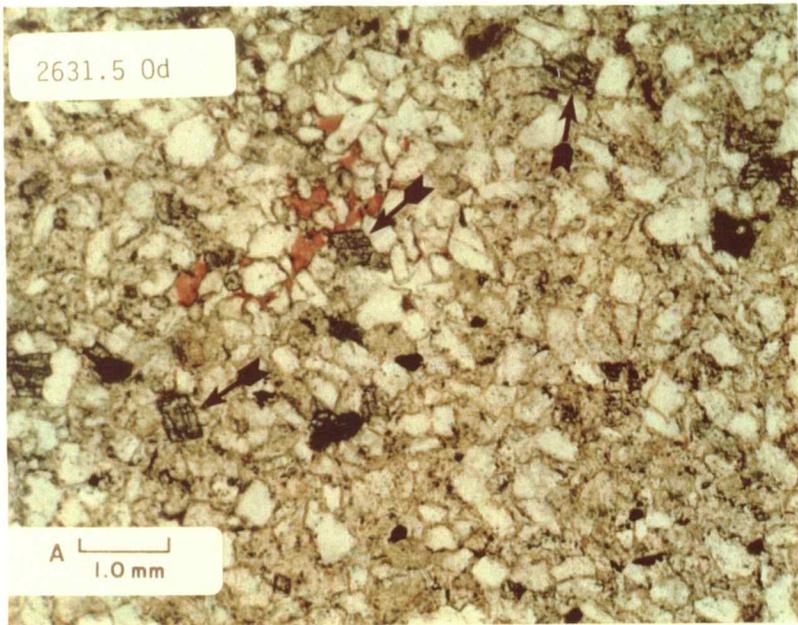
View A, 80X, Plane Light. This upper fine- to medium-grained sandstone is cemented by calcite (red) and dolomite (arrows). Abundant detrital clay matrix can also be seen between individual quartz and feldspar grains. Note the lack of porosity throughout this view.

View B, 80X, Plane Light. This sample exhibits anhydrite cement (upper right) as well as dolomite (upper left) and calcite (lower left). Very fine, high birefringent clay is found between quartz and feldspar grains.

Sample Designation: 2640.5 feet Winfield Formation

View C, 35X, Plane Light. A large, dolomitized echinoderm fragment (ECH) can be seen at center. This echinoderm fragment has retained much of the original texture associated with this fragment. A moldic pore (M) is isolated due to the very tight nature of the fine dolomite. Anhydrite (A) fills a vug at far right and reduces porosity and permeability.

View D, 80X, Plane Light. Isolated molds (M) and anhydrite-filled molds (A, at top) are evident in this view. Note the tight nature of the matrix, and the very fine habit of the majority of the dolomite in this sample. Some molds have larger, more rhombic dolomite rhombs protruding into them. Quartz grains are scattered in the lower right portion of the view. Note the circular "ghost" just right of center. This may represent a bioclastic fragment which has retained some of its original texture.



Sample Designation: 2644.5 feet Winfield Formation

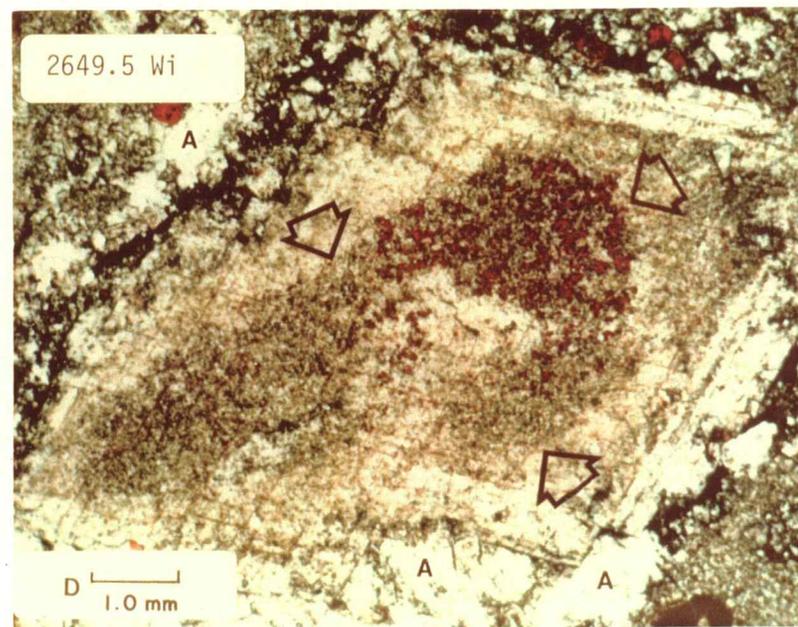
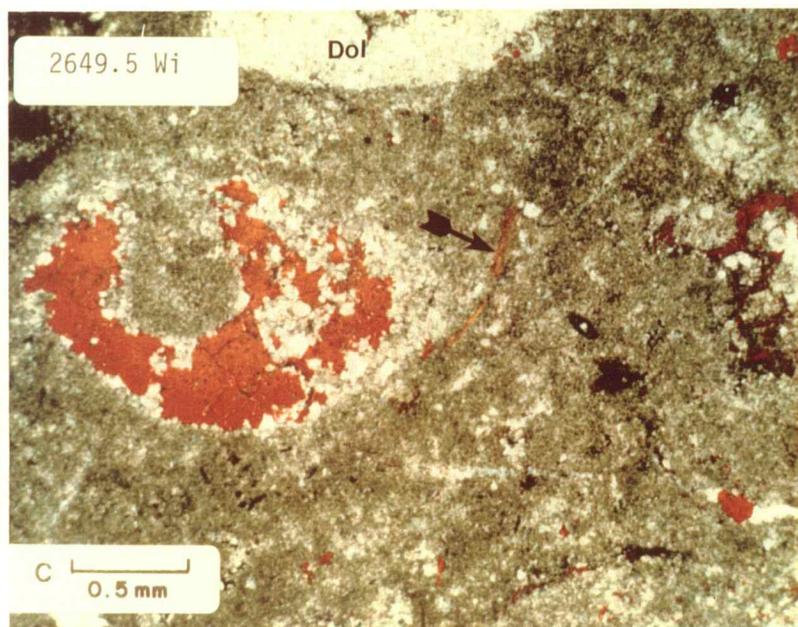
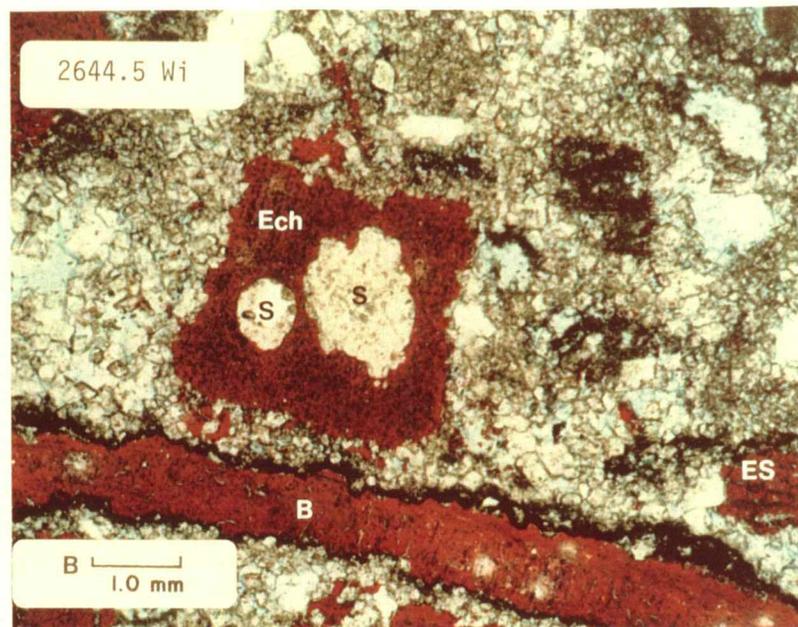
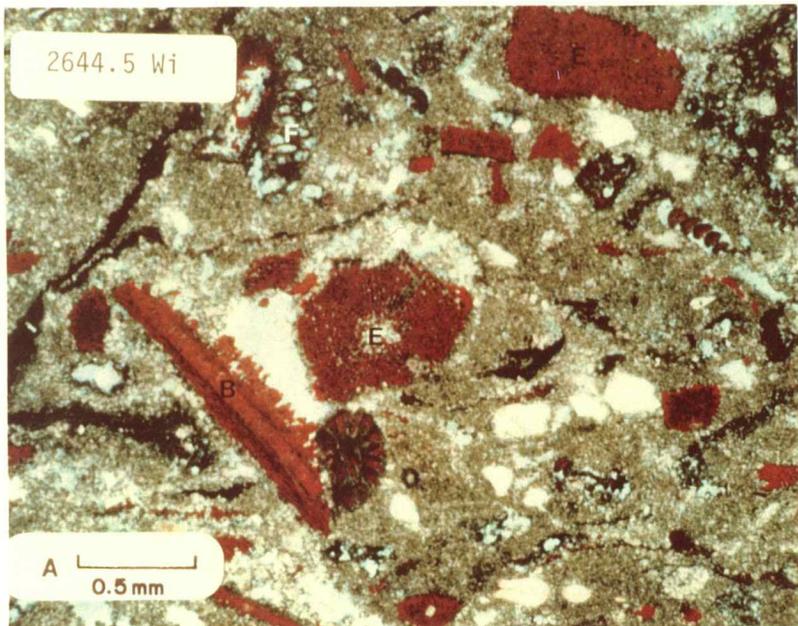
View A, 35X, Plane Light. Scattered bioclasts (red) are undolomitized in this sample. The majority of the matrix is very fine and fine crystalline dolomite. Scattered echinoderm fragments (E), foraminifera (F), and a brachiopod shell fragment constitute some of the bioclasts in this sample. Note the vuggy porosity between the brachiopod and echinoderm fragments towards the center of this photo. Also note the intraparticle porosity developed within a foraminifer at upper left. Scattered white grains are quartz. Opaque material throughout the view is pyrite.

View B, 80X, Plane Light. Higher magnification reveals that there is some intercrystalline porosity in the dolomite matrix. These intercrystalline pores (blue) will act as permeable pathways to connect vugs and molds. An echinoderm fragment (ECH) has been partially replaced by silica (S). This silica is chalcedonic, and has only partially replaced some bioclasts in this sample. A brachiopod shell fragment (B) is visible at bottom, and is lined with opaque pyrite. An echinoid spine (ES) can be observed at lower right.

Sample Designation: 2649.5 feet Winfield Formation

View C, 35X, Plane Light. A partially dolomitized bioclast can be seen at left in this photo. The calcite (red) has been stained with Alizarin Red-S to highlight partially dolomitized areas. Note the tight matrix and lack of porosity in this sample. Also note the phosphatic shell fragment (arrow). A bioclast, presumably similar to the one at left of center, can be seen at top. It has been completely dolomitized (DOL).

View D, 80X, Plane Light. This view highlights a large dolomite rhomb which has replaced a single echinoderm fragment. The large arrows point to the outer edges of the original echinoderm fragment. Note that portions of this fragment are still calcite. Anhydrite (A) is scattered around the outer portions of this dolomite rhomb. Opaque pyrite is scattered throughout the view.



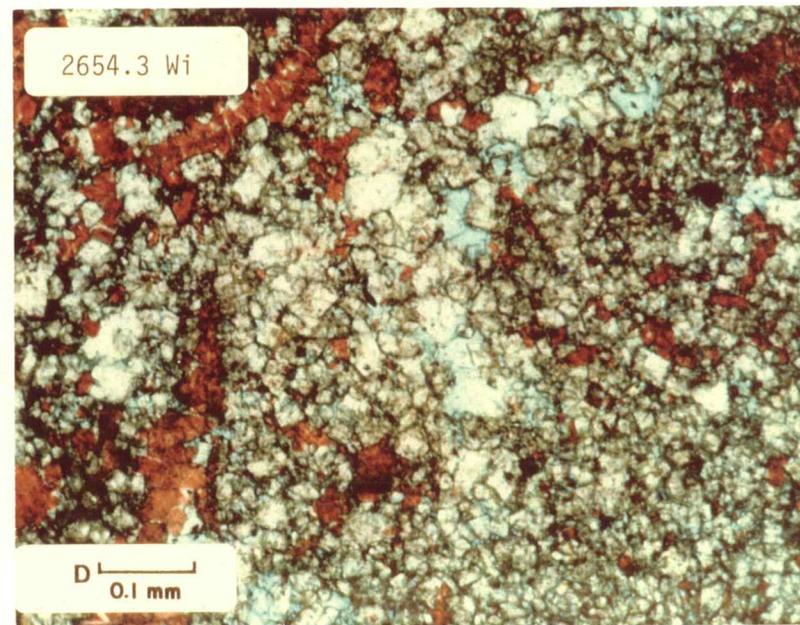
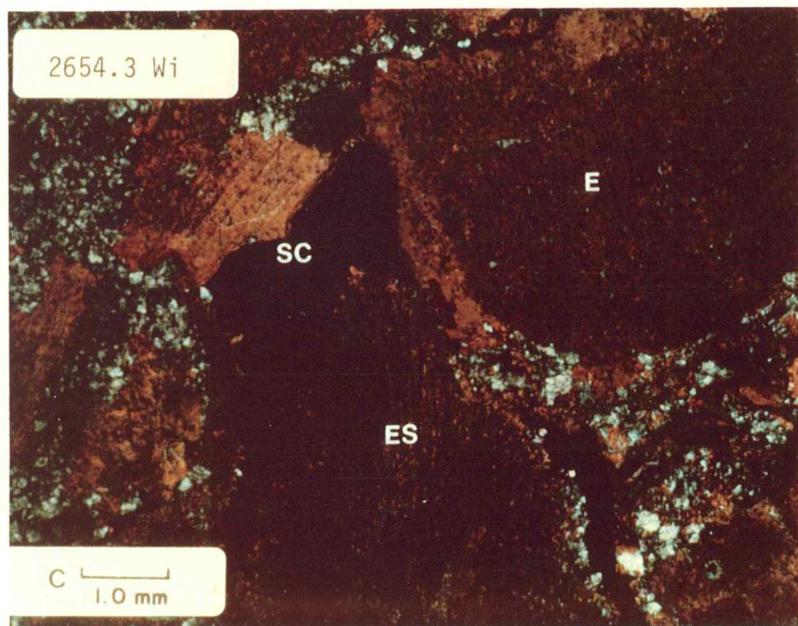
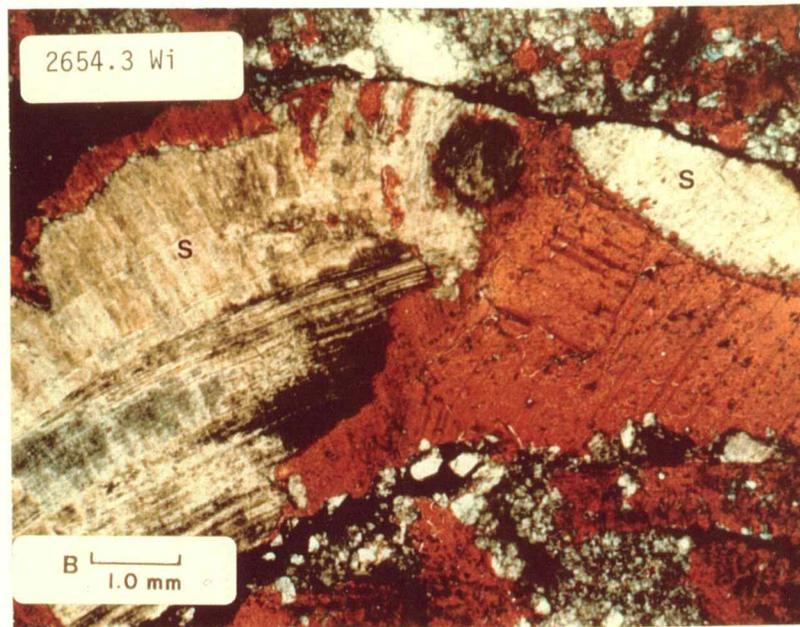
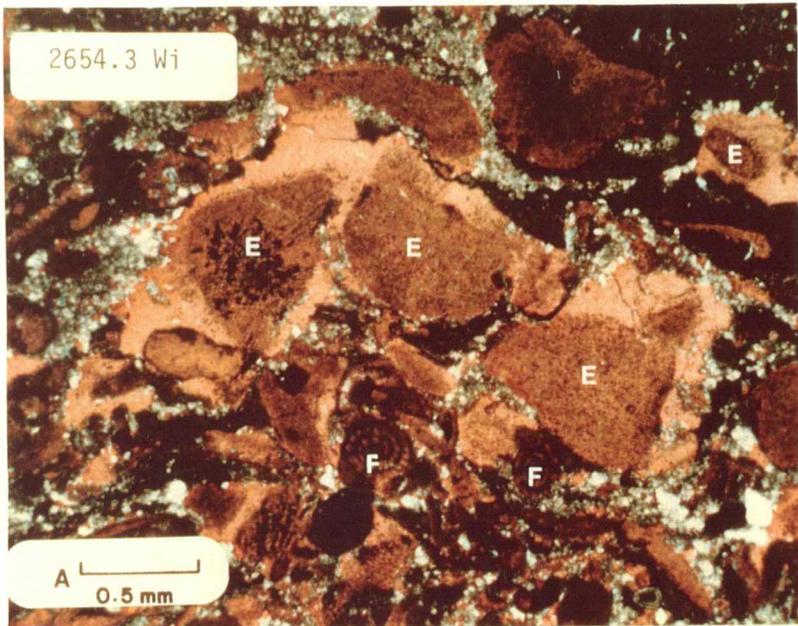
Sample Designation: 2654.3 feet Winfield Formation

View A, 35X, Plane Light. Many bioclasts in this sample remain undolomitized, whereas the majority of the matrix consists of very fine dolomite crystals. Scattered echinoderm fragments (E) are coated with syntaxial cement. This cement is in optical continuity with the individual echinoderm fragment it coats. Scattered foraminifera (F) are also visible in this view. Note the lack of porosity.

View B, 80X, Plane Light. In this view, a fossil fragment has been partially replaced by silica. It also appears that the calcite which is left over has been recrystallized. This is noted by the laminated structure preserved in the silica-replaced portion (left) and the lack of laminated structure in the calcitic portion of the fragment (right). Opaque material is pyrite, and scattered white grains (bottom) are quartz. Note that some very fine intercrystalline and interparticle porosity exists in the upper right. Partial leaching has produced some intraparticle porosity in a fossil fragment at lower right.

View C, 80X, Crossed Nicols. Higher magnification illustrates the optical continuity of the syntaxial cement (SC) which coats an echinoid spine (ES). Another echinoderm fragment, also coated with syntaxial rim cement, is visible at upper right (E). Note the partially dolomitized matrix, and the relatively poor sorting of this sample.

View D, 135X, Crossed Nicols. The partially dolomitized matrix of this sample contains scattered intercrystalline porosity. Much of the calcite remaining due to partial dolomitization will occlude much pore space. It is interpreted that if this rock had been more completely dolomitized, it would contain more porosity and hence higher permeability.



Sample Designation: 2658.8 feet Winfield Formation

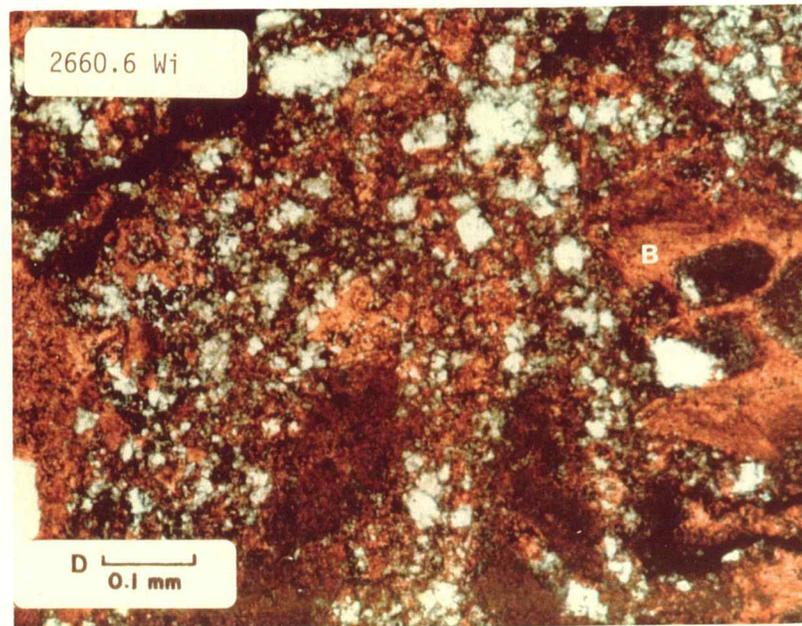
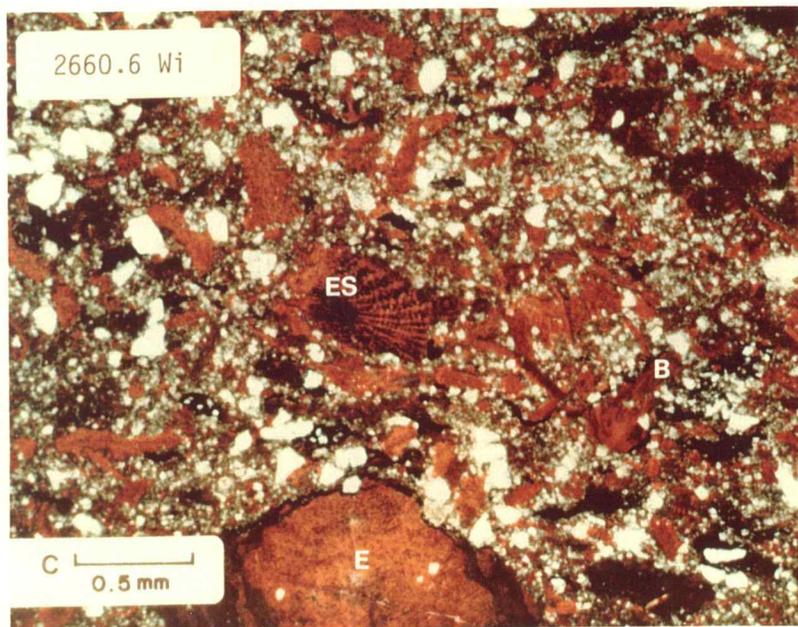
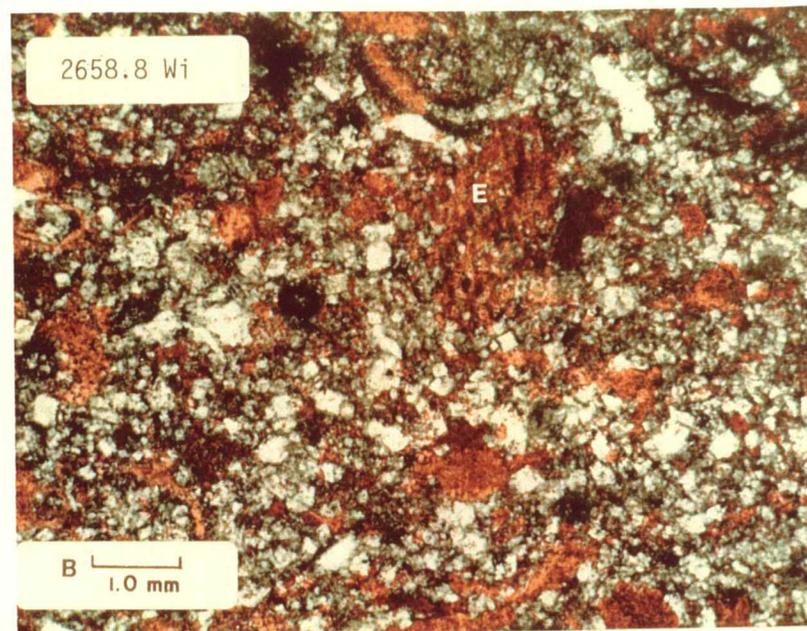
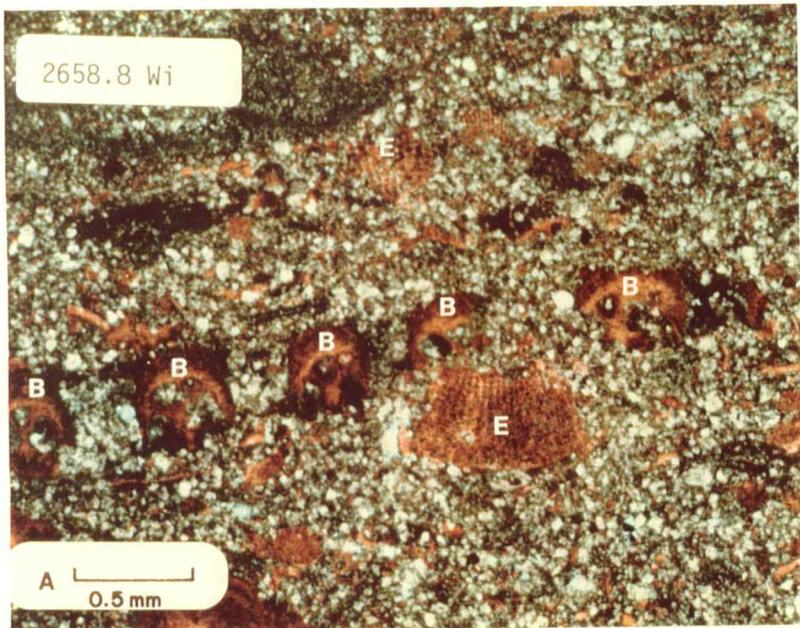
View A, 35X, Plane Light. A large bryozoan fragment has been partially dolomitized along with the majority of the matrix in this sample. This bryozoan crosses the photo; it is labeled "B." Scattered partially dolomitized echinoderm fragments are also present. Note that some very fine intercrystalline porosity is scattered throughout this view; however, it is not abundant in this sample.

View B, 80X, Plane Light. This view highlights the partially dolomitized nature of the matrix and bioclasts in this sample. Note that abundant calcite (red) exists throughout the matrix. An echinoderm fragment (E) has retained some of its original structure, but also is partially dolomitized. A few scattered grains of quartz sand can also be observed.

Sample Designation: 2660.6 feet Winfield Formation

View C, 35X, Plane Light. Scattered bioclasts are partially dolomitized in this sample. An echinoid spine (ES), an echinoderm fragment (E), and a bryozoan fragment (B) are visible. Note the scattered upper fine- to medium-grained quartz sand (white) throughout the view. Also note the partially dolomitized matrix, and the lack of porosity in this sample.

View D, 135X, Plane Light. This higher magnification view illustrates the partially dolomitized nature of the matrix in this sample. It is interpreted that the lack of porosity in this sample is due to the abundance of calcite remaining undolomitized. A large bryozoan fragment which contains internal dolomite sediment can be seen at far right (B). Organic material and pyrite are visible at upper left and lower right.



Sample Designation: 2662.0 feet Winfield Formation

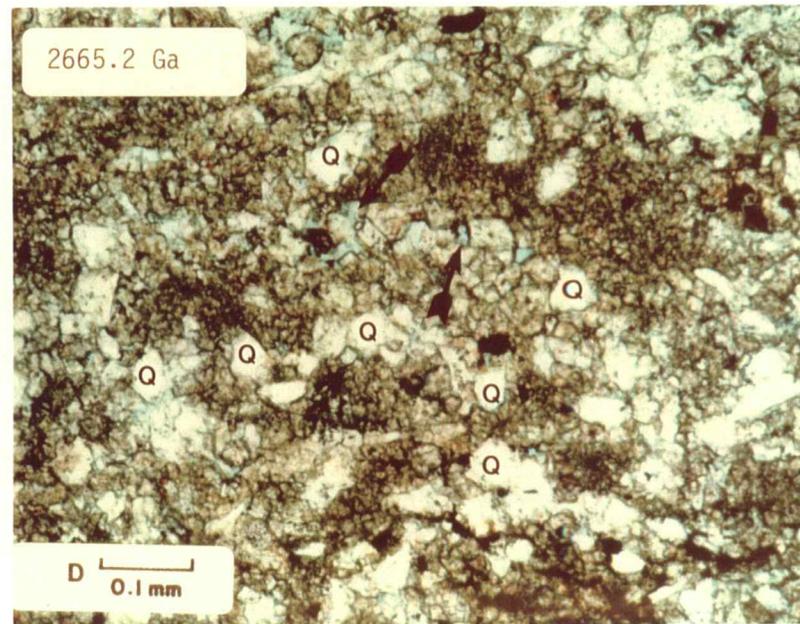
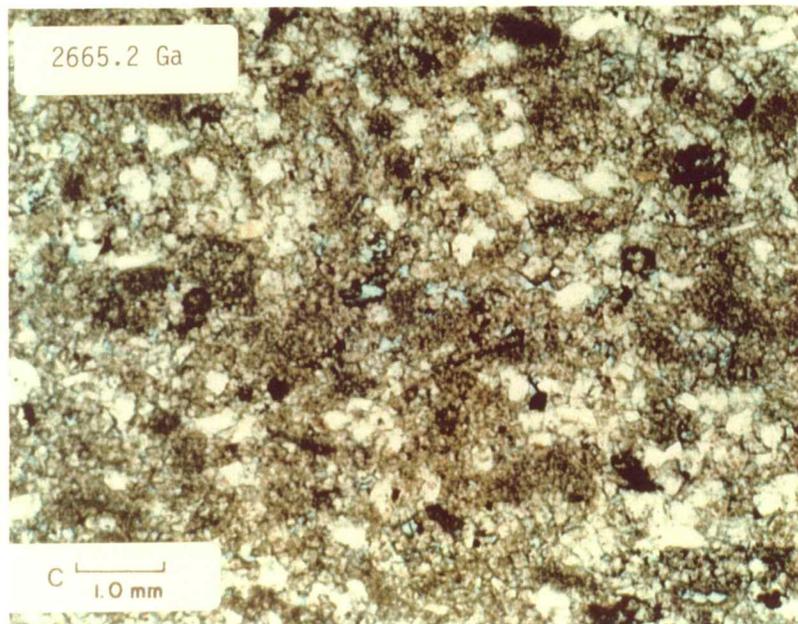
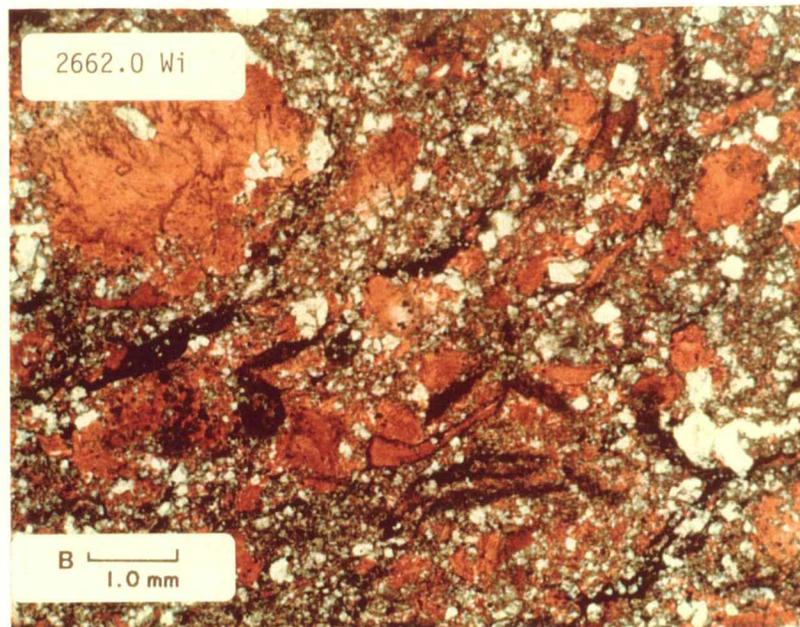
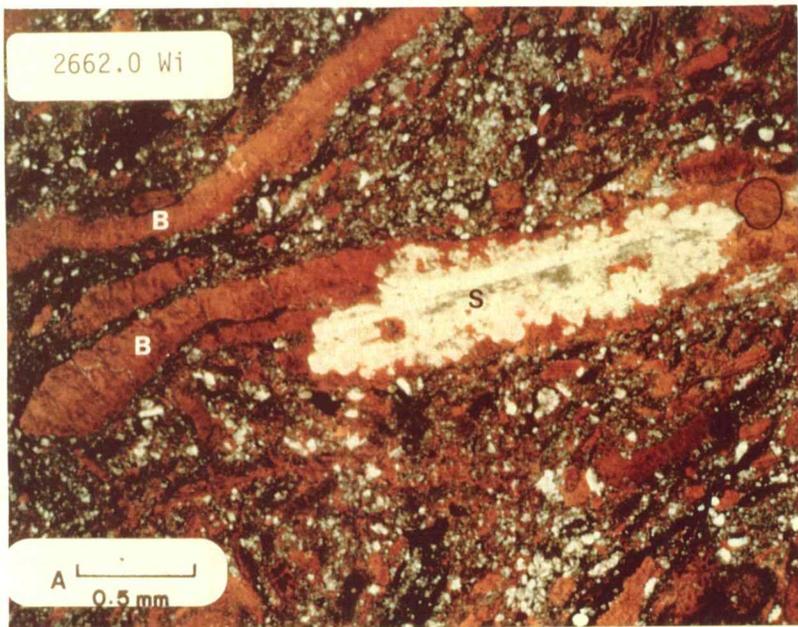
View A, 35X, Plane Light. Brachiopod shell fragments (B) are relatively abundant in this sample. Note that silica (S) has partially replaced one of these brachiopod fragments. The silica is observed as chalcedonic; closer inspection shows that some of the original structure of the brachiopod has been preserved within the silica. Note the partially dolomitized matrix, and the lack of porosity throughout this view.

View B, 80X, Plane Light. Scattered quartz sand (white) visible throughout the view. The matrix of this sample has been only partially replaced by dolomite, and contains very little porosity. Abundant micro-porosity may be present within extremely fine crystalline areas of the sample.

Sample Designation: 2665.2 feet Gage Formation

View C, 80X, Plane Light. This sample consists of a mixture of quartz (white) and relatively tightly interlocking dolomite. Note the "clotted" nature of this sample, which is due to the different sizes of dolomite. The very fine crystalline dolomite is darker than the coarser, more rhombic dolomite crystals. Intercrystalline pores are scattered throughout the view.

View D, 135X, Plane Light. Scattered quartz grains (Q) are observed in this view. Note the intercrystalline porosity (arrows) which may be partially isolated due to the tightly interlocking, finely crystalline areas of dolomite and the scattered clastic sand material.



Sample Designation: 2692.5 feet    Towanda Formation

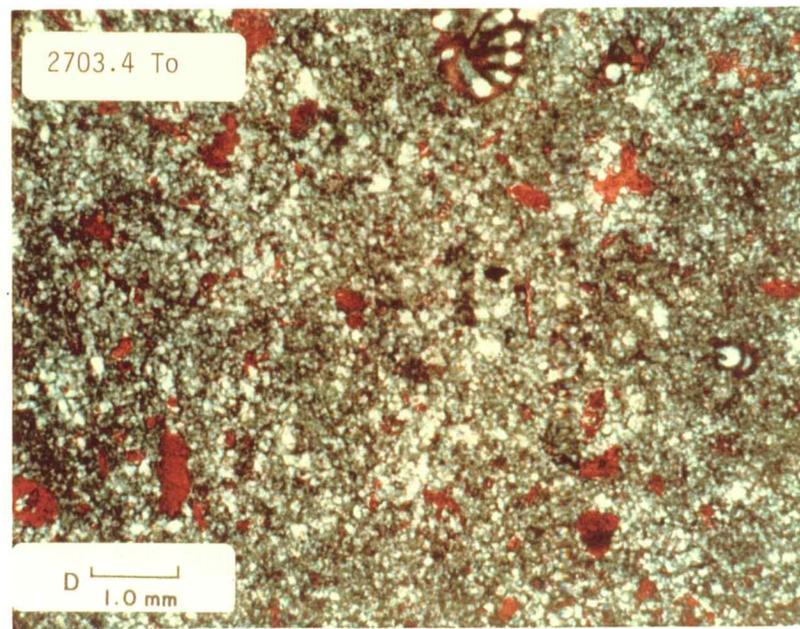
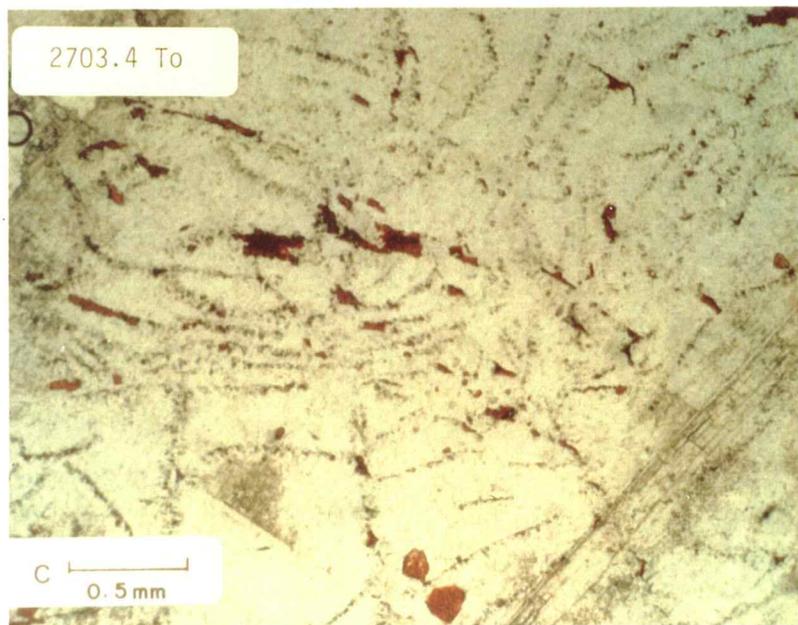
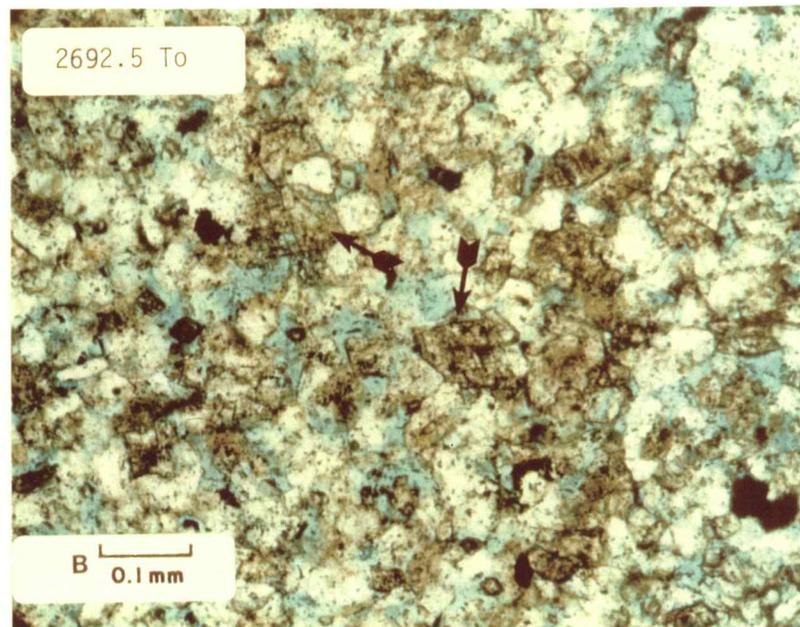
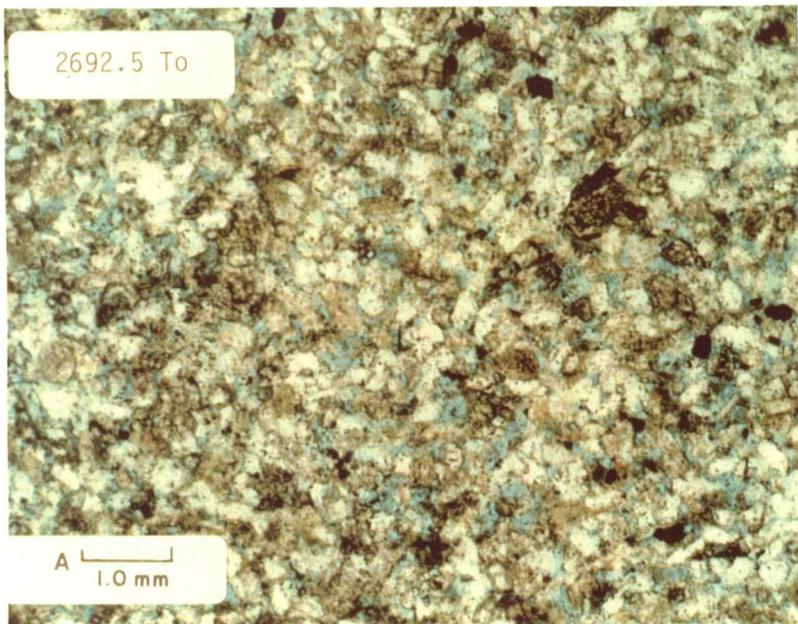
View A, 80X, Plane Light. This fine- to upper fine-grained sandstone contains abundant intergranular porosity. Scattered dolomite cement (high relief) is visible in a few areas. The majority of the porosity is interpreted to have formed from the leaching of cement (probably dolomite).

View B, 135X, Plane Light. Higher magnification highlights the partially leached nature of some of the dolomite (arrows). Opaque material is pyrite. Due to the abundance of intergranular porosity, this sample is interpreted to have good reservoir potential.

Sample Designation: 2703.4 feet    Towanda Formation

View C, 35X, Plane Light. This view shows a large coral which has been replaced by anhydrite. Note that some calcite remains. Also note the original septa, which are observed as dolomite stringers radiating out from the center of this photo.

View D, 80X, Plane Light. This view highlights the partially dolomitized nature of this sample. Very few scattered intercrystalline pores are present, which is due in part to the remaining calcite. Note the foram at upper center, and the white intraparticle pores associated with it. It is interpreted that further dolomitization of this rock may produce larger amounts of porosity and hence, higher permeability.



Sample Designation: 2716.5 feet Towanda Formation

View A, 35X, Plane Light. Bioclasts are abundant in this view. Echinoderm fragments (E) and bryozoan fragments (B) dominate. Many particles are coated with algae (A). These algal coatings consist of micritic calcite. Note the partially dolomitized nature of the matrix, and the lack of porosity in this view.

View B, 135X, Plane Light. This is a higher magnification view of an algal coating on a bioclastic grain. Partial leaching of this coating has produced some intraparticle porosity. Note the micritic nature of the algae, and its relative resistance to dolomitization.

View C, 135X, Plane Light. Higher magnification illustrates the partially dolomitized nature of this matrix. Most of the remaining calcite is interpreted to have been partially recrystallized (neomorphosed). Note the scattered anhydrite (white areas), which is interpreted to be replacing calcite, in part. Also note the lack of porosity in this view, due to the partially dolomitized nature of the matrix.

View D, 135X, Plane Light. This is a close-up of an echinoderm fragment which has been partially replaced by silica (S). Note that some leaching of dolomite has occurred in the upper portions of this photo, producing minor amounts of intragranular porosity. Some syntaxial rim cement remains on this echinoderm fragment, visible at upper right and lower left.



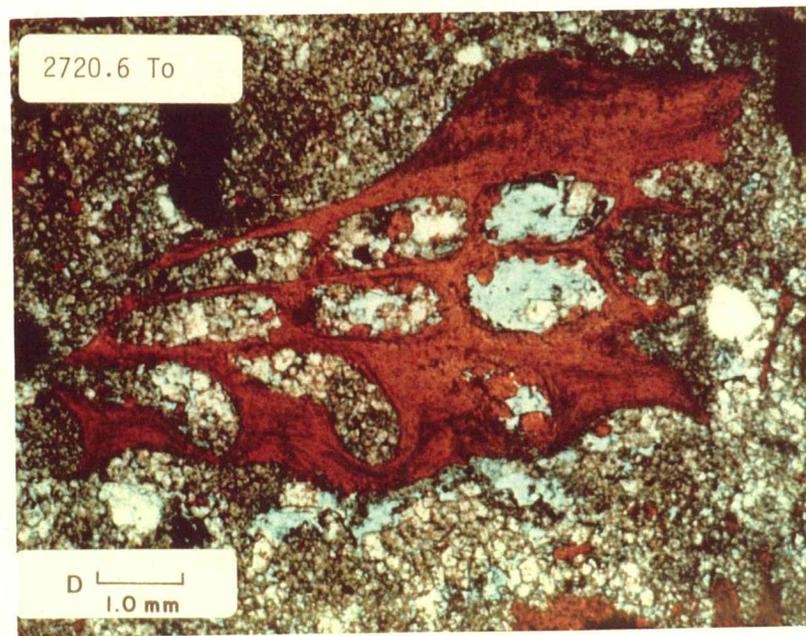
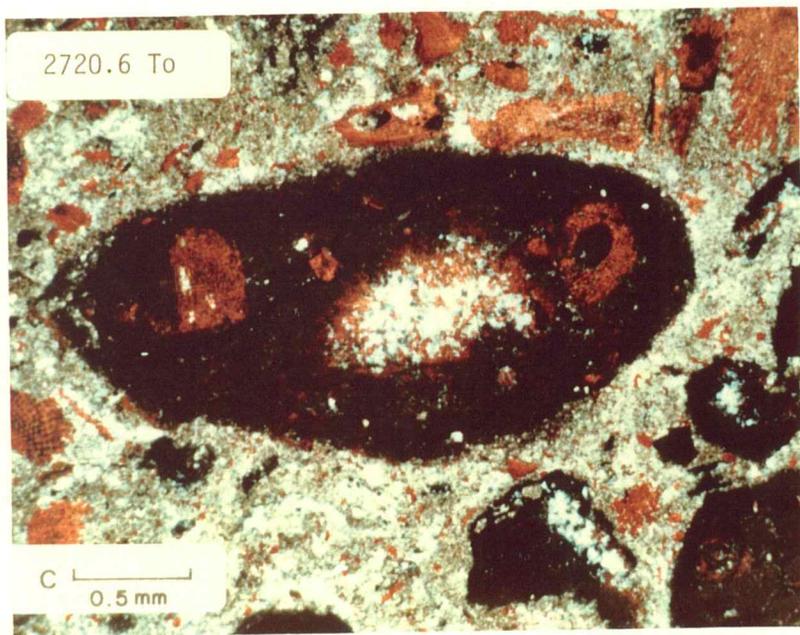
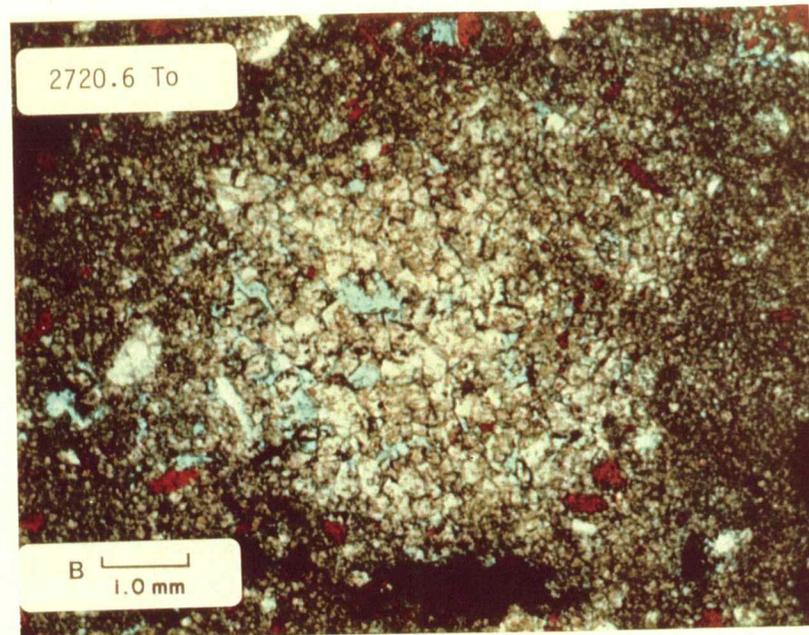
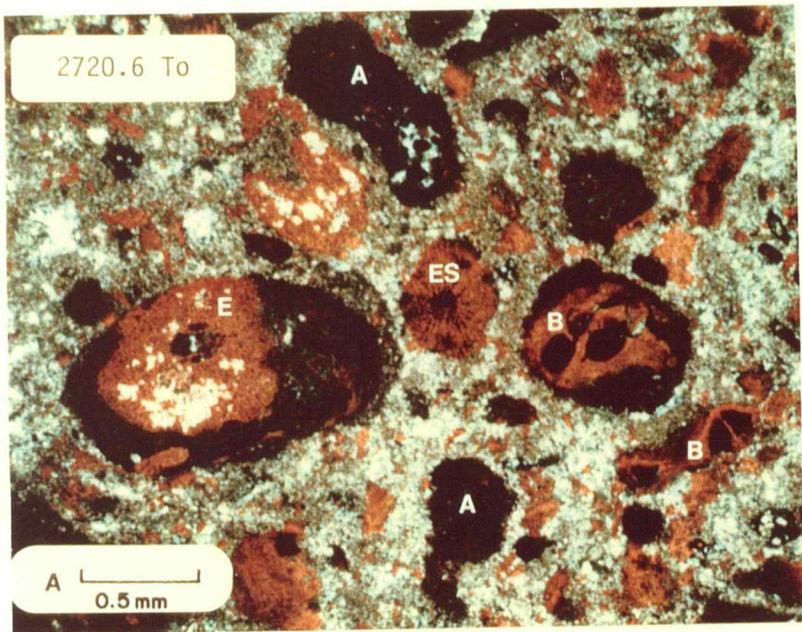
Sample Designation: 2720.6 feet Towanda Formation

View A, 35X, Plane Light. Abundant grain-coating algae is visible in this view also. It coats echinoderms (E), echinoid spines (ES), bryozoans (B), and unidentifiable calcareous material. Note that partial leaching has occurred within some of the algae, producing intraparticle porosity. Also note the partially dolomitized nature of the matrix.

View B, 80X, Plane Light. Scattered areas in this sample contain coarser dolomite, which has larger amounts of intercrystalline porosity (blue). Note that the finer dolomite towards the outside of the photo contains much finer intercrystalline pores. The coarser dolomite may represent dolomitization of a select bioclastic fragment. Intraparticle porosity is noted at upper center.

View C, 35X, Plane Light. This view shows that algae (dark) sometimes has coated more than one grain. In this view, it has coated three separate echinoderm fragments. The echinoderm fragment at center has been partially leached, producing intraparticle porosity. Note the intercrystalline pores throughout the remainder of the view, and the intraparticle porosity within algae at lower right. Just above the large algal grain at center is a bryozoan fragment which also contains intraparticle porosity.

View D, 80X, Plane Light. A well preserved bryozoan fragment can be seen in this photo. Note that it is still calcite, whereas the majority of the matrix is dolomite. Open intraparticle pores, and intraparticle areas have been partially to totally filled with dolomite. Dark material at upper left and upper right is interpreted to be algal. A lone quartz grain is at far right.



Sample Designation: 2730.4 feet Towanda Formation

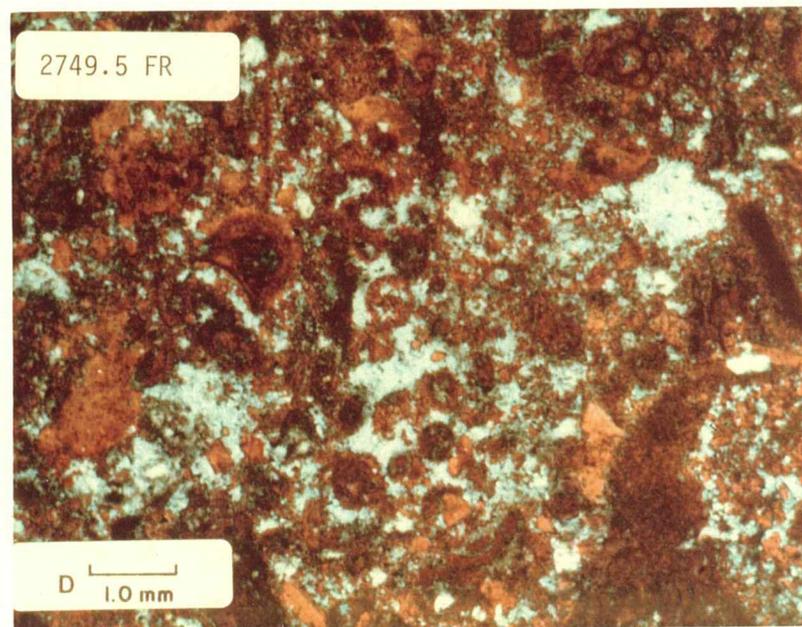
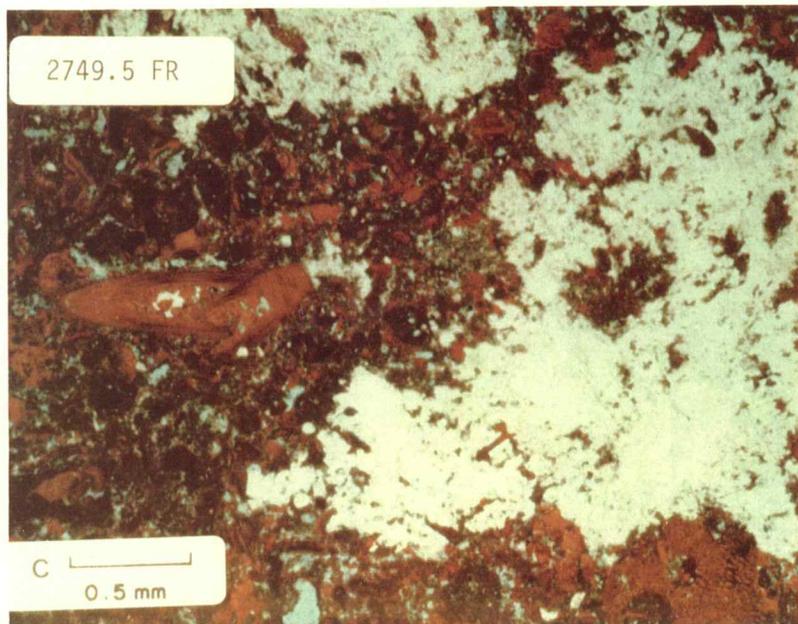
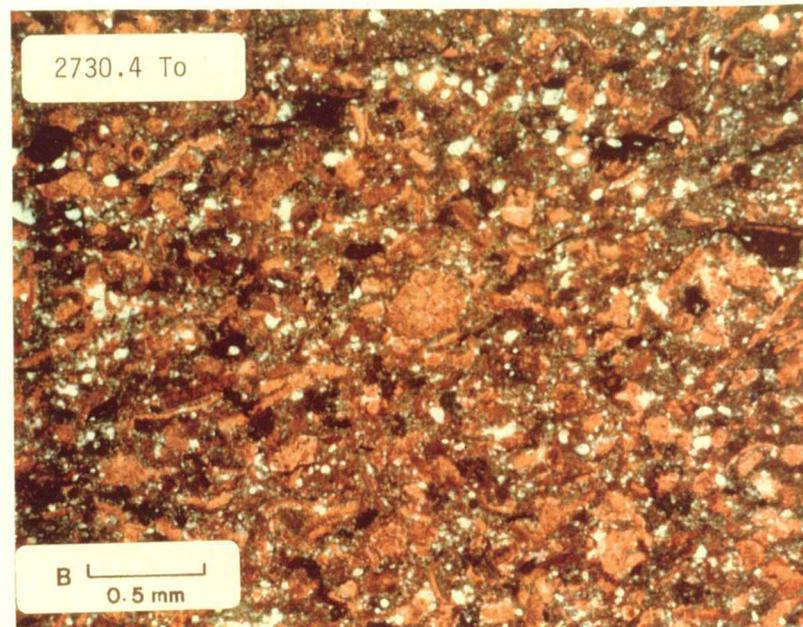
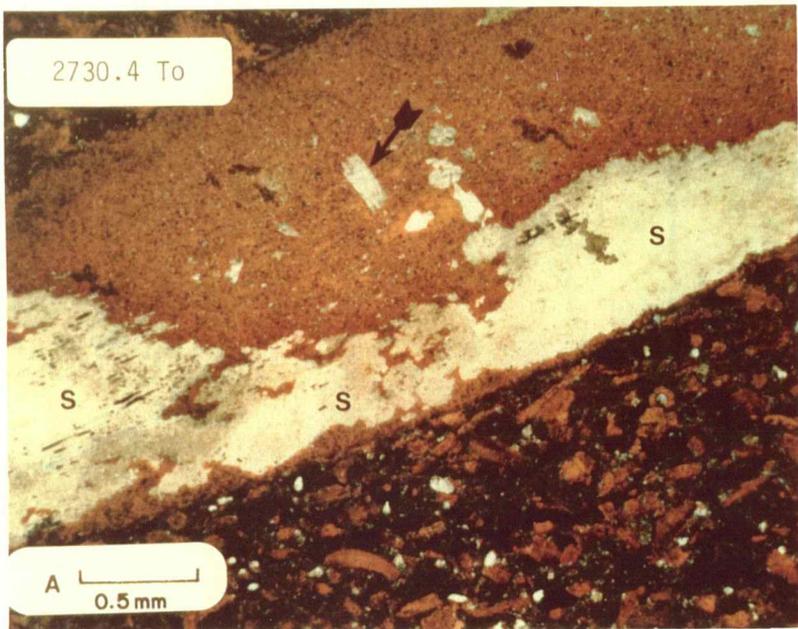
View A, 35X, Plane Light. A large crinoid fragment (top) has been replaced in part by silica (S). Also, a rectangular anhydrite crystal (arrow) is present within this crinoid. This may represent partial replacement by anhydrite; however, anhydrite is not abundant in this sample. The majority of the sample is like that observed at lower left, and is a poorly sorted, bioclastic packstone.

View B, 35X, Plane Light. Abundant crinoid fragments, bryozoan fragments, ostracod and brachiopod shell fragments, as well as foraminifera, are present in this sample. Scattered algal grain coatings can be seen throughout the view (dark). Also note the scattered very fine quartz silt (white). The matrix of this sample is partially dolomitized, and contains very little intercrystalline porosity.

Sample Designation: 2749.5 feet Fort Riley Formation

View C, 35X, Plane Light. In this portion of the sample, anhydrite has partially replaced calcite and possibly dolomite. The anhydrite (white) is interpreted to have moved as a replacement "front" from the right towards the left of this sample. Note the scattered calcite and dolomite remnants within the anhydrite. Also note the broken brachiopod spine (?) at left center of this view. Scattered intraparticle and interparticle porosity is present.

View D, 80X, Plane Light. Relatively abundant interparticle porosity is present in this part of the sample. Light areas are pores, possibly representing the partial leaching of matrix and grains in this sample. Intraparticle porosity is also present within some unidentifiable bioclastic material. Some recrystallization has occurred, but it is not as abundant as in previous samples. Note the lack of dolomite in the matrix, compared to previous samples.



Sample Designation: 2755.5 feet Fort Riley Formation

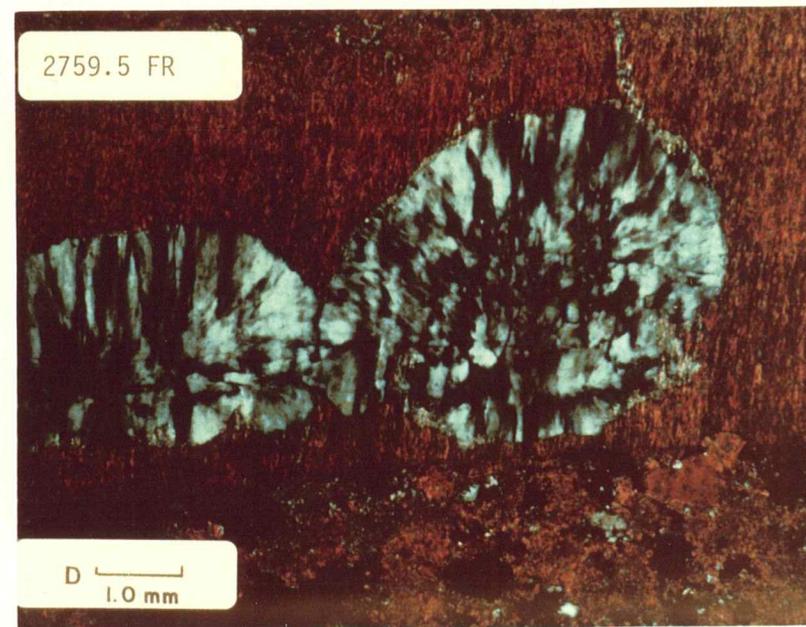
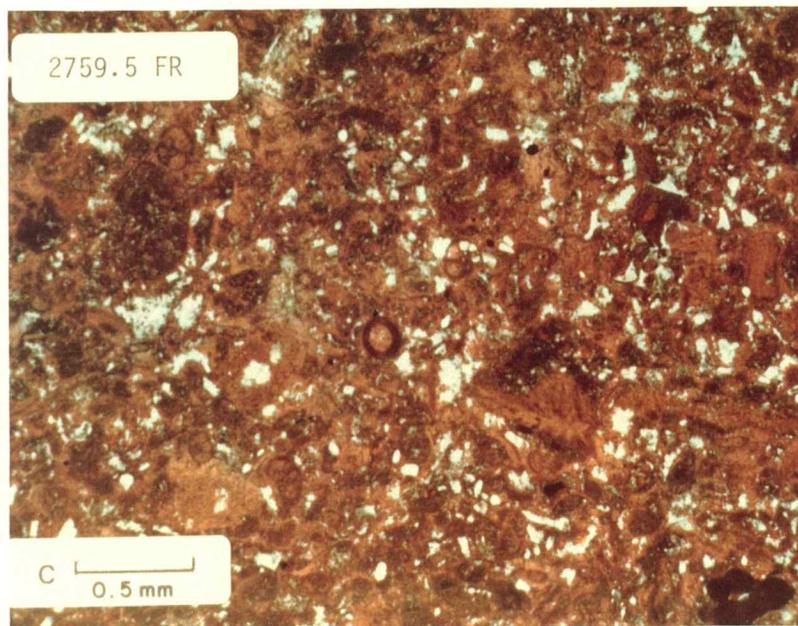
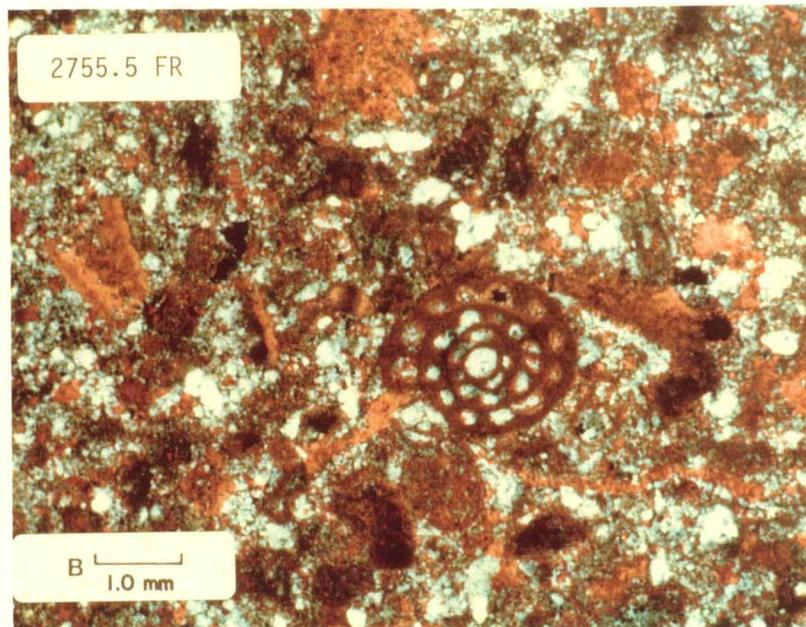
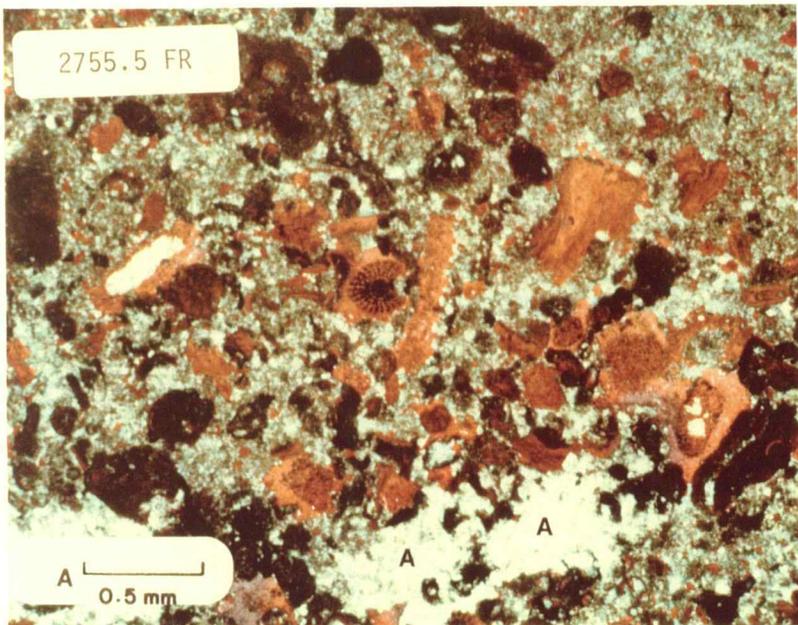
View A, 35X, Plane Light. Echinoderm fragments, echinoid spines, bryozoan fragments, and scattered foraminifera are all present in this sample. Echinoderms and echinoid spines often contain syntaxial rim cement. Some grain-coating algae may also be present at lower right and lower left. Note that partial anhydrite replacement has taken place at the bottom of this photo. Some calcite remnants are present within the anhydrite (A). Note the partially dolomitized matrix throughout the view.

View B, 80X, Plane Light. At center is a foraminifer with intraparticle porosity contained in its original chambers. Note the partially dolomitized nature of the matrix and some of the grains, and the intercrystalline porosity (white areas) throughout the view.

Sample Designation: 2759.5 feet Fort Riley Formation

View C, 35X, Plane Light. Scattered white quartz and feldspar grains can be seen in this limestone. Intraparticle and interparticle porosity is also scattered throughout the view. Bioclasts include brachiopod shell fragments, brachiopod spines, echinoderm fragments, and foraminifera. Note the lack of dolomite.

View D, 80X, Crossed Nicols. A brachiopod shell fragment, partially replaced by chalcedonic quartz, is highlighted here. Note that the replacement occurs from the inside towards the outside of the fragment. Also note the intraparticle porosity (black) at bottom.



Sample Designation: 2764.5 feet Fort Riley Formation

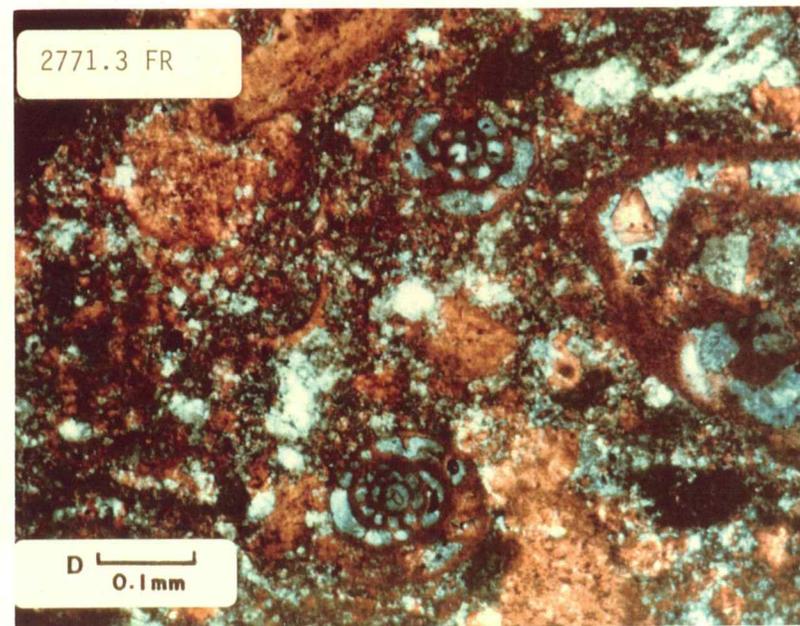
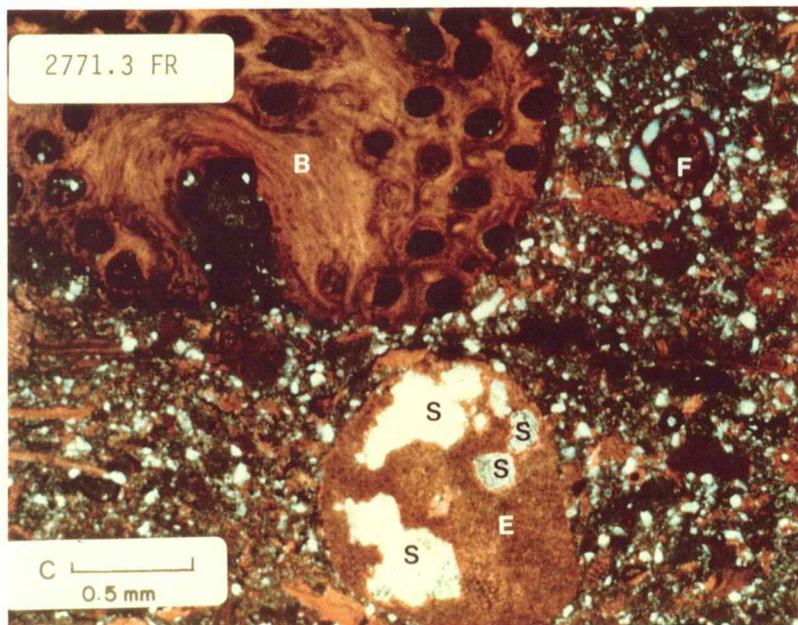
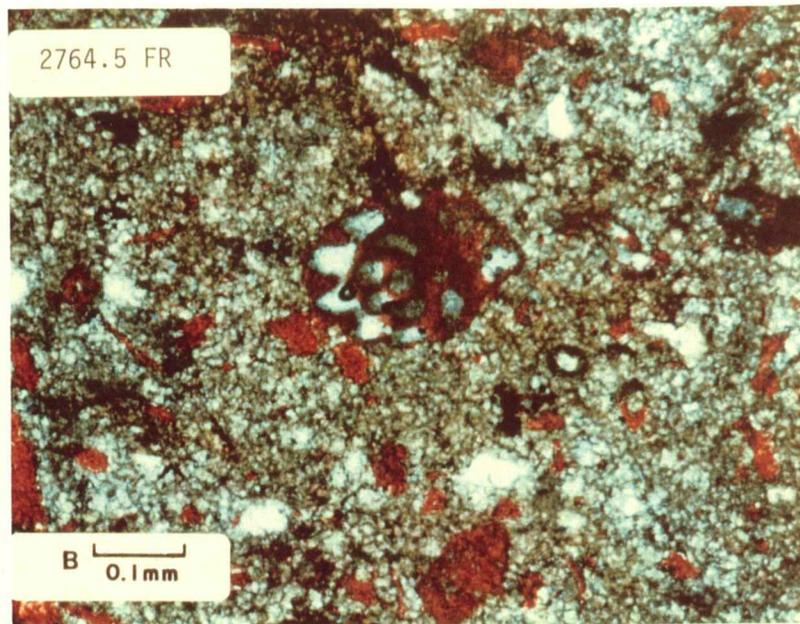
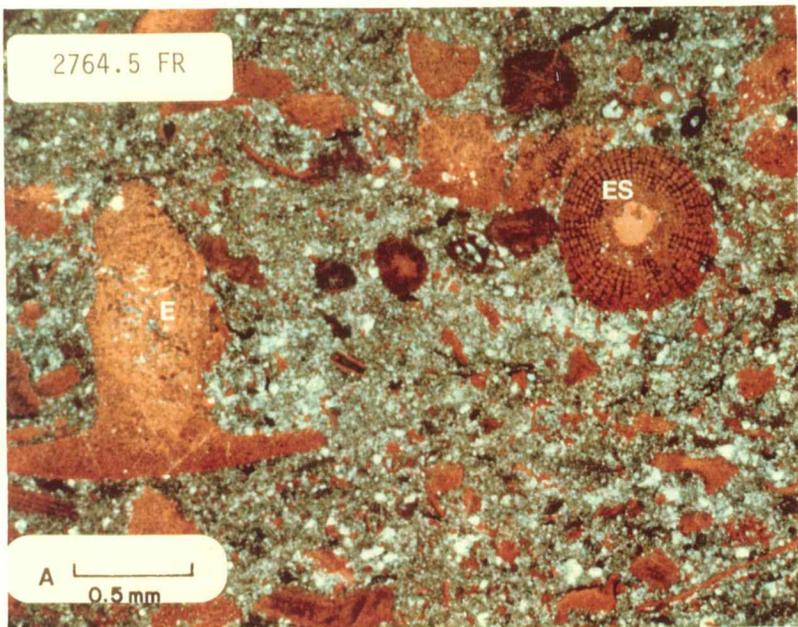
View A, 35X, Plane Light. Scattered echinoderms (E, probably crinoids), echinoid spines (ES), and foraminifera can be seen in this view. Note the partially dolomitized nature of the matrix and some of the bioclasts in this sample. Also note the relative lack of large intercrystalline pores. Very fine intercrystalline pores do exist, and produce relatively good permeabilities in this sample.

View B, 135X, Plane Light. At center is a foram with interparticle porosity. This type of porosity is probably not interconnected with intercrystalline porosity, which can be seen throughout the view. Note the partially dolomitized matrix, and the brown organic material at upper left.

Sample Designation: 2771.3 feet Fort Riley Formation

View C, 35X, Plane Light. A large bryozoan fragment (B) is visible at upper left. At upper right is a foram (F) that contains intraparticle porosity. At bottom center is an echinoderm (E) which has been partially replaced by silica (S). Note the scattered quartz and feldspar silt (white) throughout the view. The matrix is partially dolomitized.

View D, 135X, Plane Light. Two forams with intraparticle porosity are visible in this view. A larger fusulinid, which also contains intraparticle porosity, can be observed at right. The partially dolomitized nature of the matrix has produced fine intercrystalline pores which appear to be fairly well interconnected. Scattered white grains are quartz.



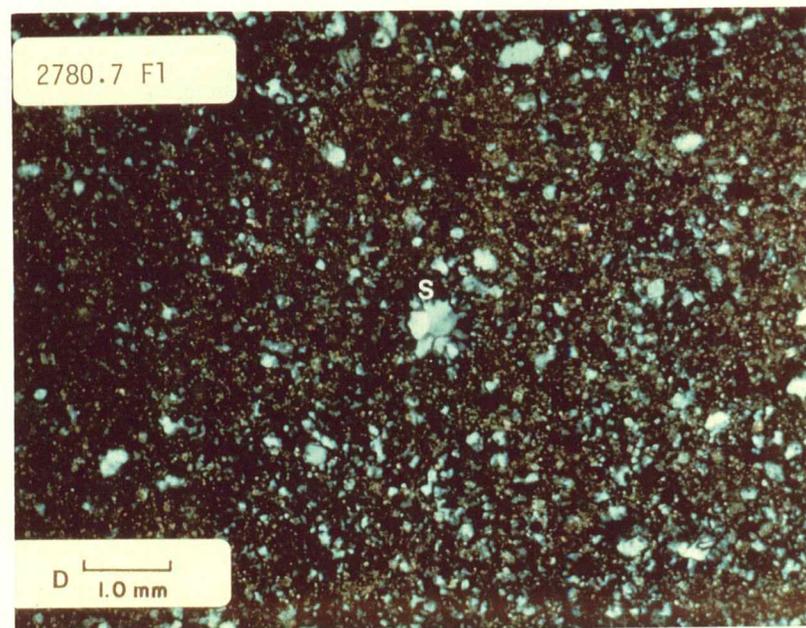
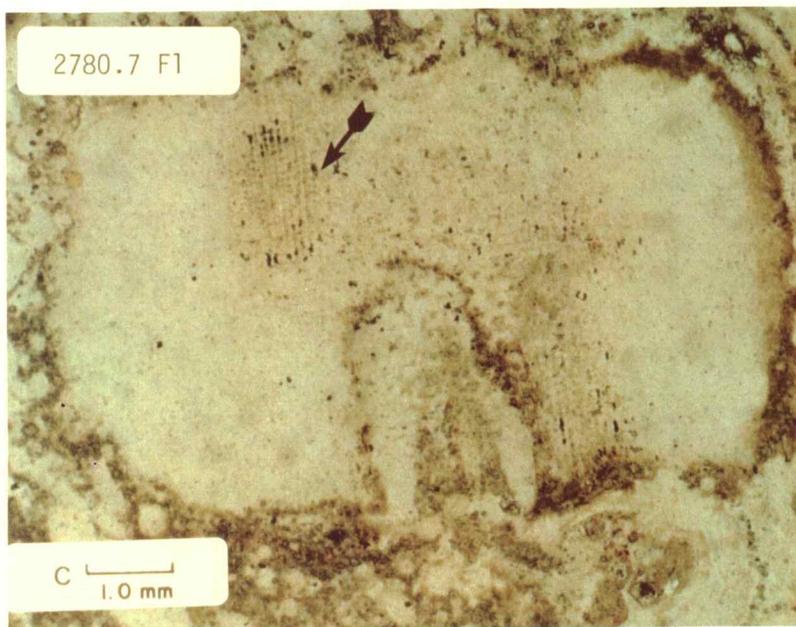
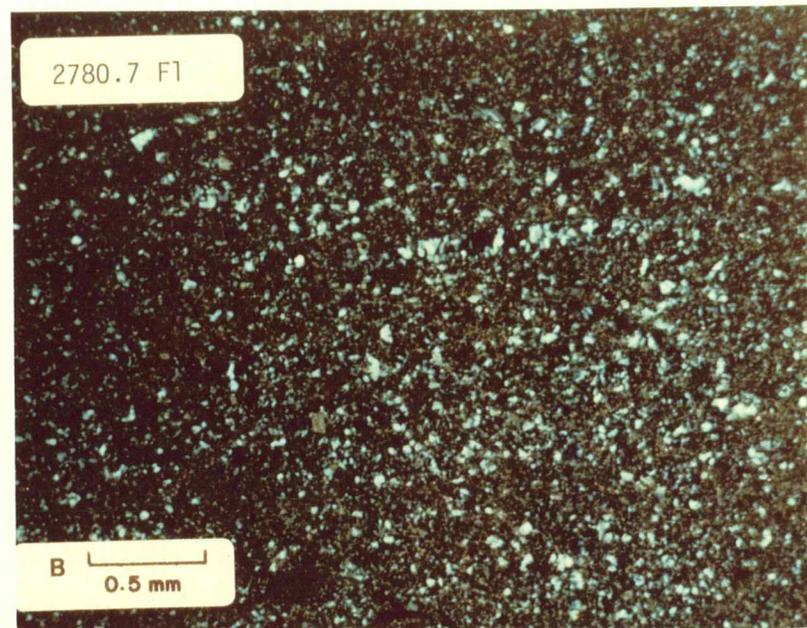
Sample Designation: 2780.7 feet Florence Formation

View A, 35X, Plane Light. This sample is composed of abundant silica, and dolomite. The silica is interpreted to have replaced many bioclasts and much of the matrix in this sample. The elongate particles at center and lower center are interpreted to be spicules, possibly from a sponge.

View B, 35X, Crossed Nicols. This view highlights the low birefringent nature of the silica and the relatively high birefringent nature of the fine dolomite in this sample. The area in this view is the same as that in View A, and one can see that the spicule in View A is composed of microcrystalline quartz.

View C, 80X, Plane Light. Highlighted in this view is a silicified crinoid fragment. The arrow points to the original porous texture preserved after silicification. Note the lack of porosity in this and previous views.

View D, 80X, Crossed Nicols. Again, this view highlights the siliceous and dolomitic nature of this sample. A cross section of a possible spicule can be seen at center (S). Note that much of this silica is microcrystalline, and appears to have replaced calcareous material. Also note the extremely fine nature of the high birefringent dolomite, and the lack of porosity throughout this sample.



Sample Designation: 2792.6 feet Florence Formation

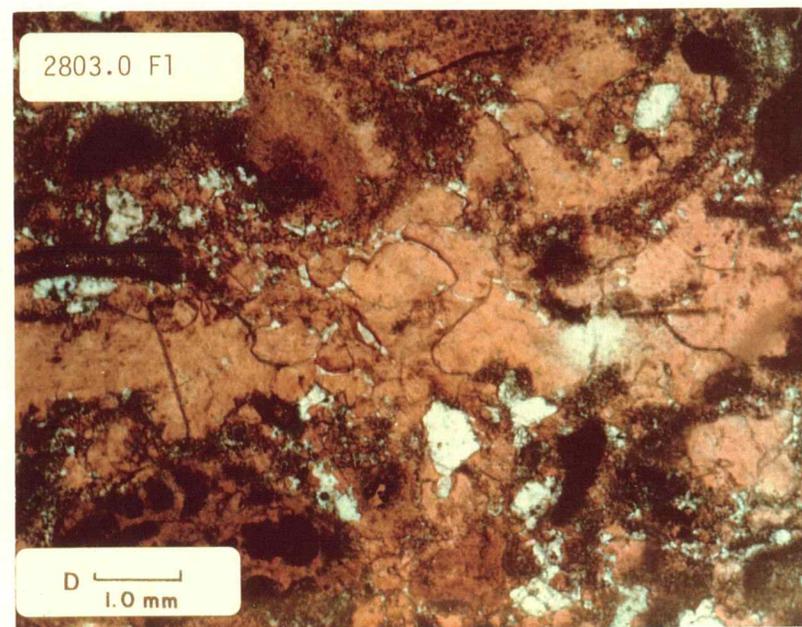
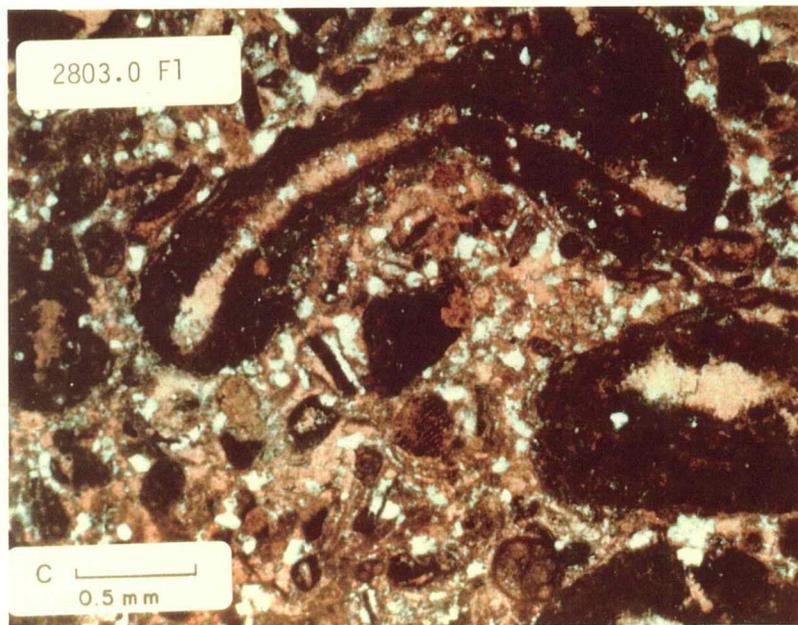
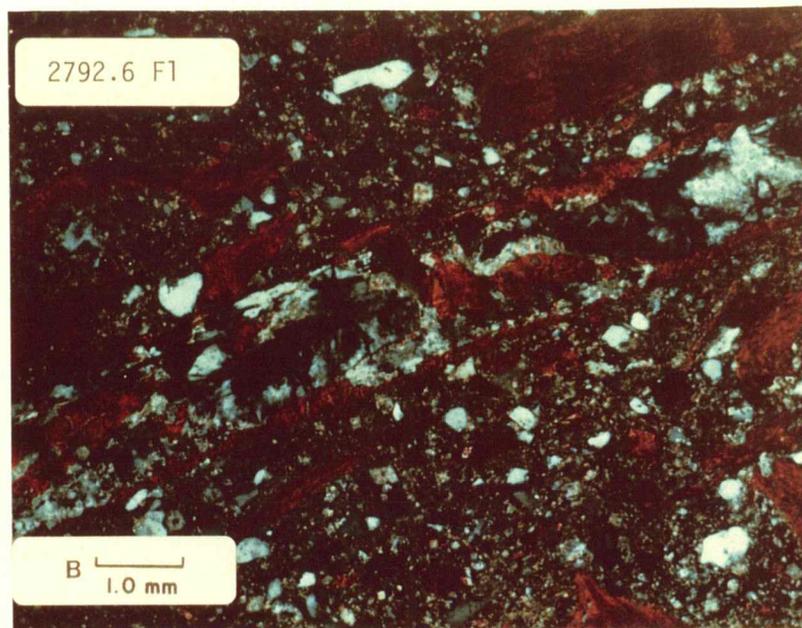
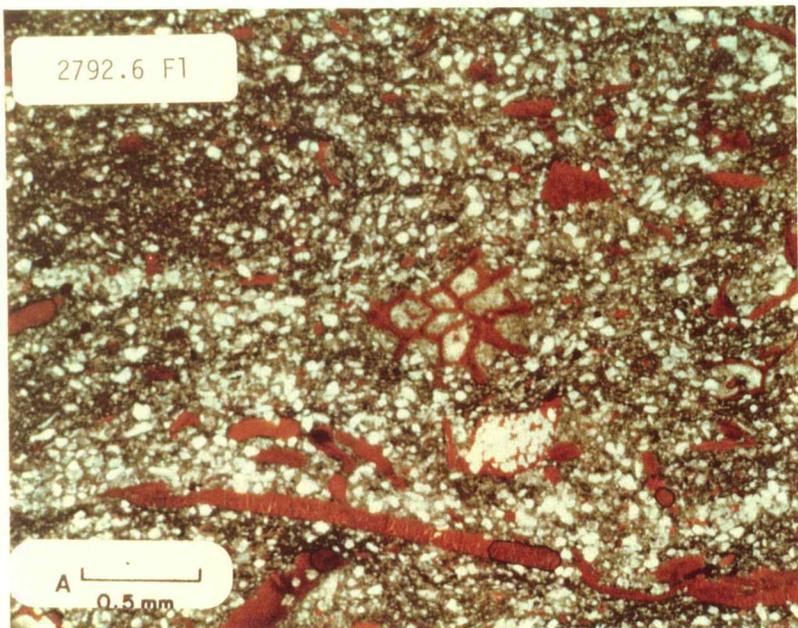
View A, 35X, Plane Light. Brachiopod shell fragments and bryozoan fragments are evident in this view. Scattered white quartz and feldspar silt is also present. The matrix is composed of dolomite; however, some calcite still remains. Partial dolomitization may be responsible for the tight nature of this sample.

View B, 80X, Crossed Nicols. In this view, a brachiopod fragment, which cuts the area from left to right, has been partially replaced by silica. Note the scattered silt and very fine- to fine-grained quartz sand throughout the view. Also note the high birefringent, extremely fine crystalline dolomite matrix. This sample is tight; however, it may contain relatively abundant microporosity.

Sample Designation: 2803.0 feet Florence Formation

View C, 35X, Plane Light. In this sample, abundant grain-coating algae is visible. Mixed in with the algae are small, encrusting forams. Other particles throughout the view include echinoderms, brachiopod shell fragments, bryozoans, and forams. Note the mosaic spar cement which has filled interparticle porosity and rendered this sample tight.

View D, 80X, Plane Light. This view highlights mosaic spar and neomorphic spar cement. Note the micrite remnant (left) within the coarser calcite, indicating neomorphism. A foram with very fine internal dolomite sediment is visible at lower left. A quartz grain is just below center, and a dolomite rhomb is at upper right. This sample is interpreted to have poor reservoir quality, due to the lack of porosity.



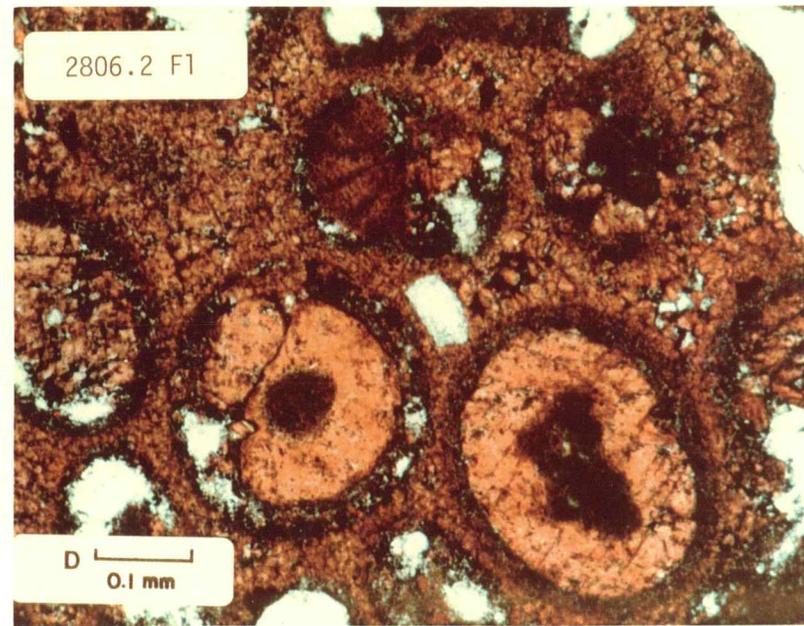
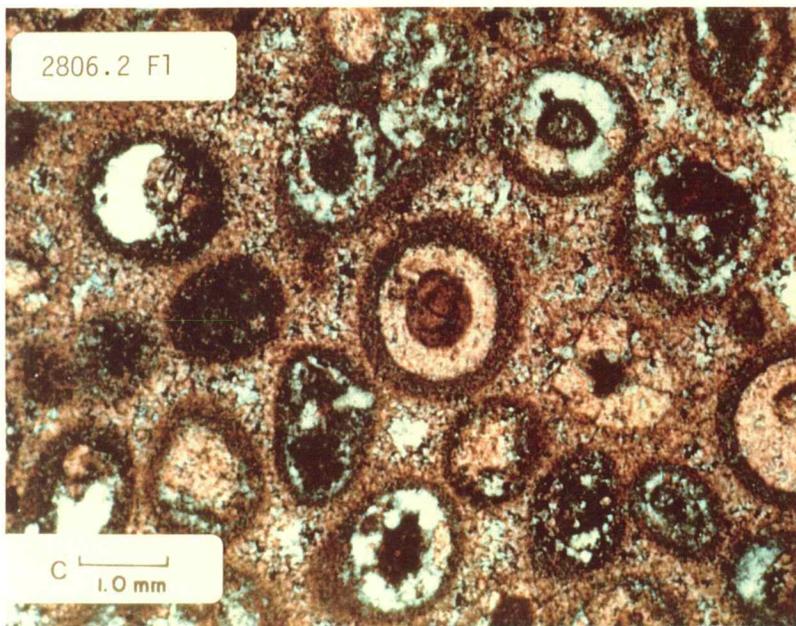
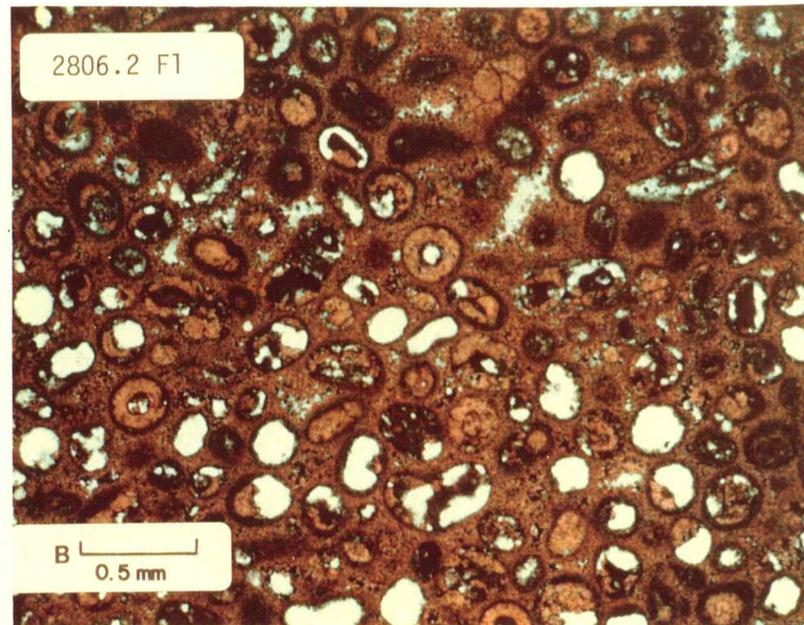
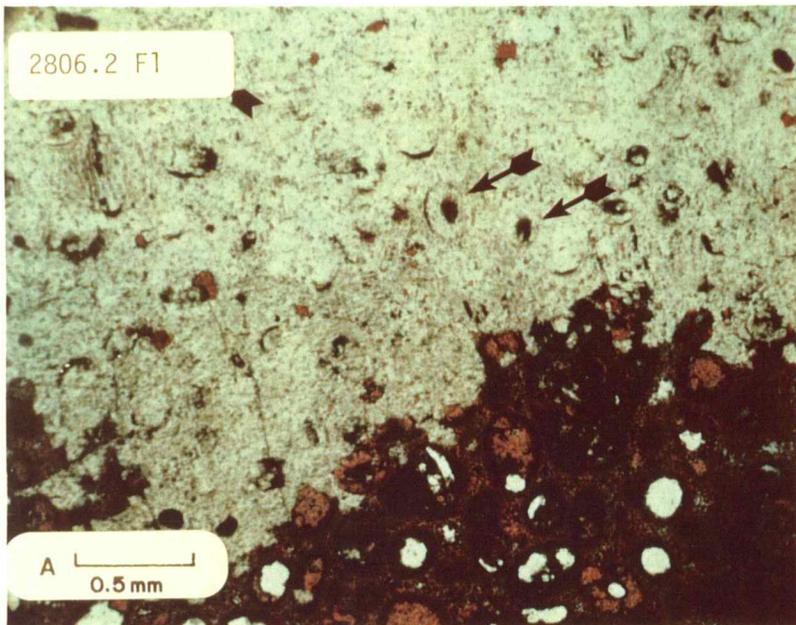
Sample Designation: 2806.2 feet Florence Formation

View A, 35X, Plane Light. This sample is an oolitic packstone. Anhydrite (white, top) has replaced some of the calcite. Within the anhydrite, "ghosts" of ooids can still be seen (arrows).

View B, 35X, Plane Light. The white areas are pores, interpreted to have resulted from the partial leaching of some ooids. These oomoldic pores are isolated and are interpreted to be generally ineffective for production. Some interparticle porosity does exist, mainly at upper right.

View C, 80X, Plane Light. Interparticle pores are present between ooids. Many of these pores are partially filled with isopachous cement; however, some of the centers of the pores are still open and may be effective.

View D, 135X, Plane Light. Higher magnification reveals the partially leached nature of some of the ooids, and the isopachous and mosaic cement which partially to totally fills the interparticle areas. Some interparticle porosity does exist, however. A feldspar grain can be seen at center of this view (white) and is interpreted to be extremely rare in this sample.



Sample Designation: 2810.5 feet Florence Formation

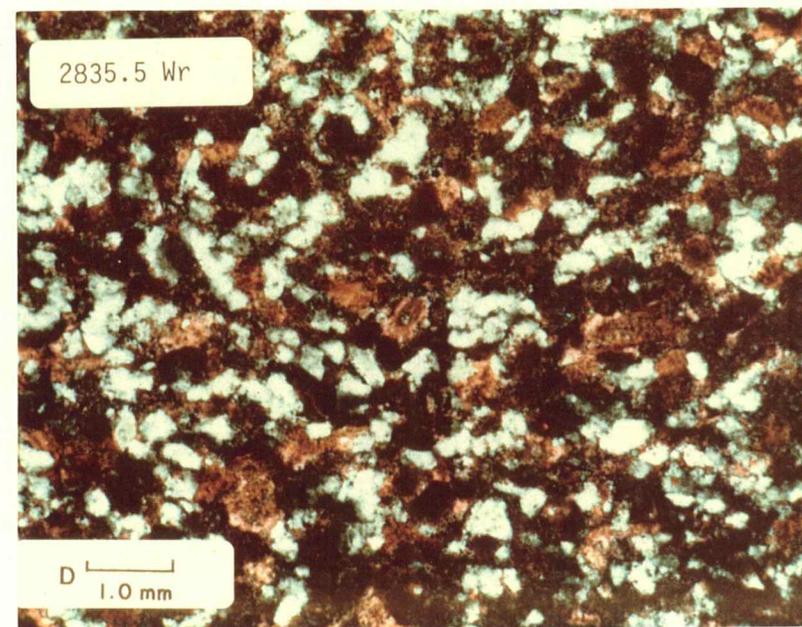
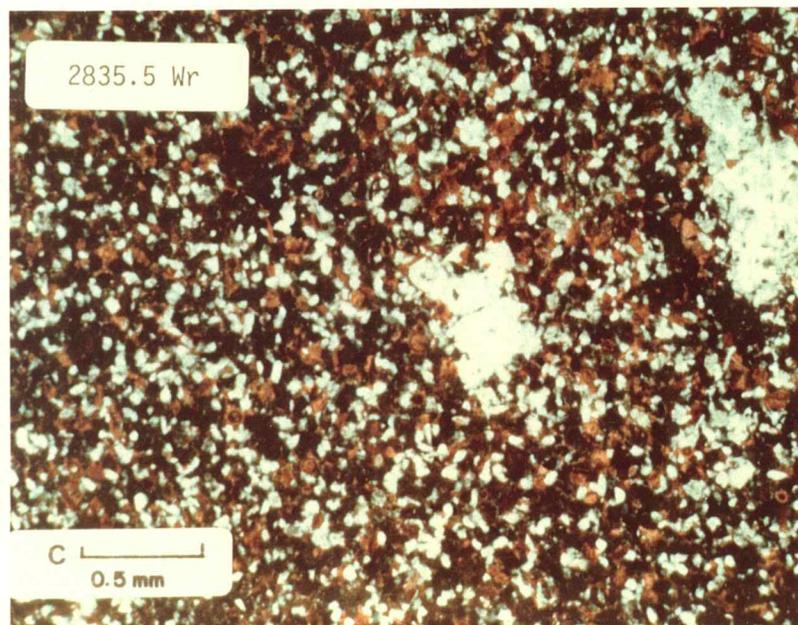
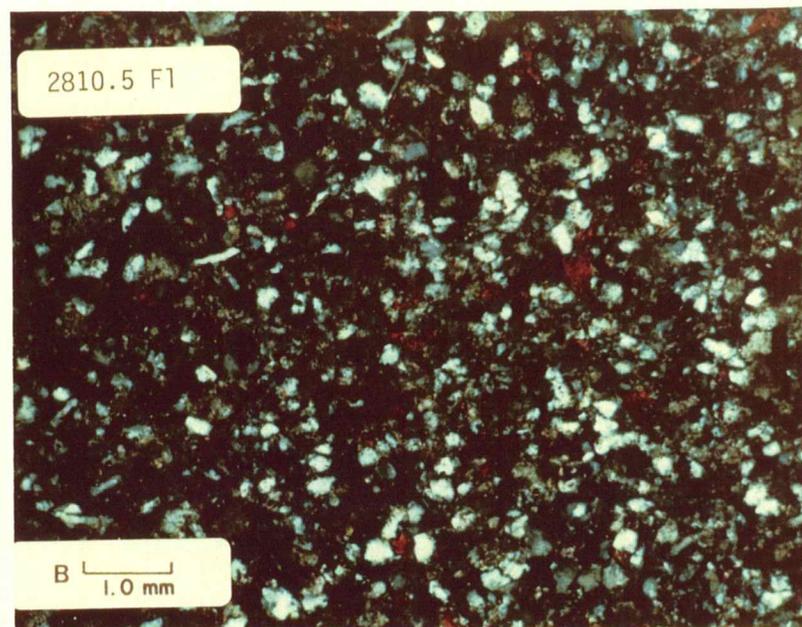
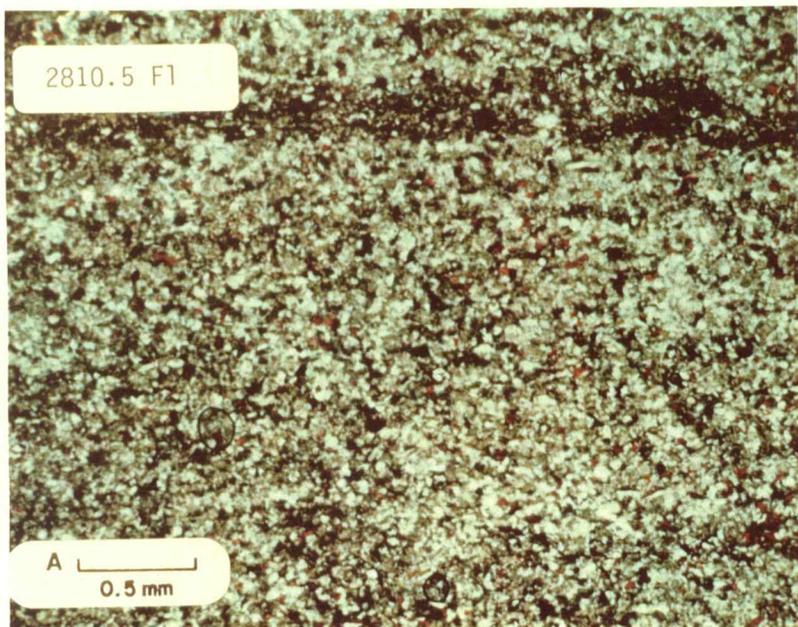
View A, 35X, Plane Light. This sample is composed of quartz, feldspar, micas, and dolomite and calcite cements. Note the shaly lamination at top. Also note the lack of porosity and the fine-grained nature of the clastic material.

View B, 80X, Crossed Nicols. Higher magnification illustrates quartz and feldspar grains cemented by dolomite (high birefringent, extremely fine crystalline material) and calcite (red). Scattered muscovite can be seen at upper left and top center.

Sample Designation: 2835.5 feet Wreford Formation

View C, 35X, Plane Light. This sample is composed of a mixture of quartz, feldspar, calcite, and anhydrite. The large, white crystals at center and upper right are anhydrite, which may be replacing calcite. Note the calcite remnants within the anhydrite. The calcite has a fine particle size. Also note the mixtures of micrite (darker red) and spar (lighter red).

View D, 80X, Plane Light. Higher magnification highlights the micrite, microspar, and spar which make up the calcareous portion of this sample. Scattered quartz and feldspar (white) can be seen throughout the view. Note the lack of porosity in this sample.



Sample Designation: 2839.5 feet    Wreford Formation

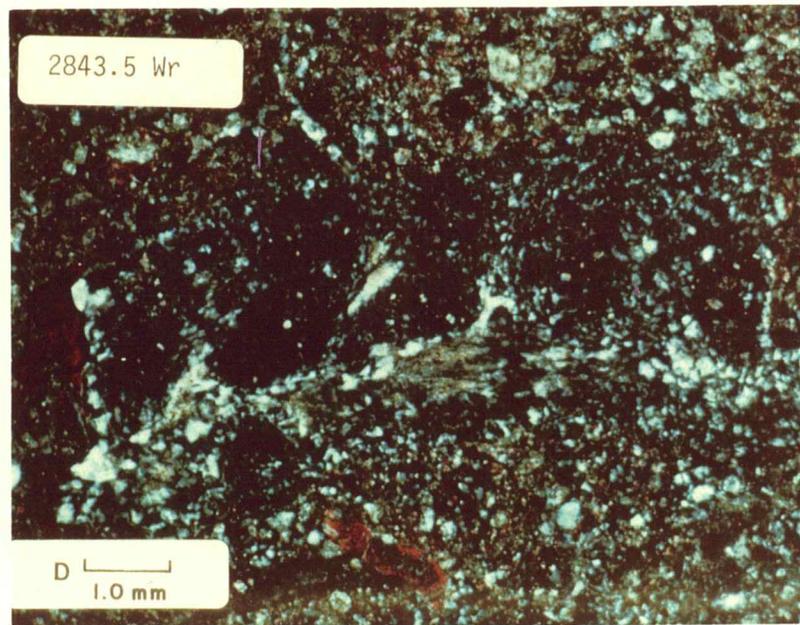
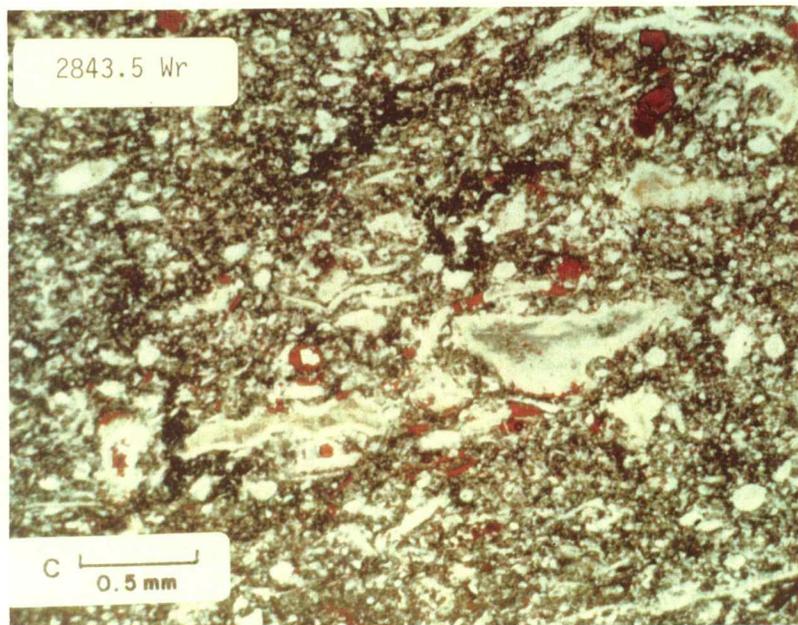
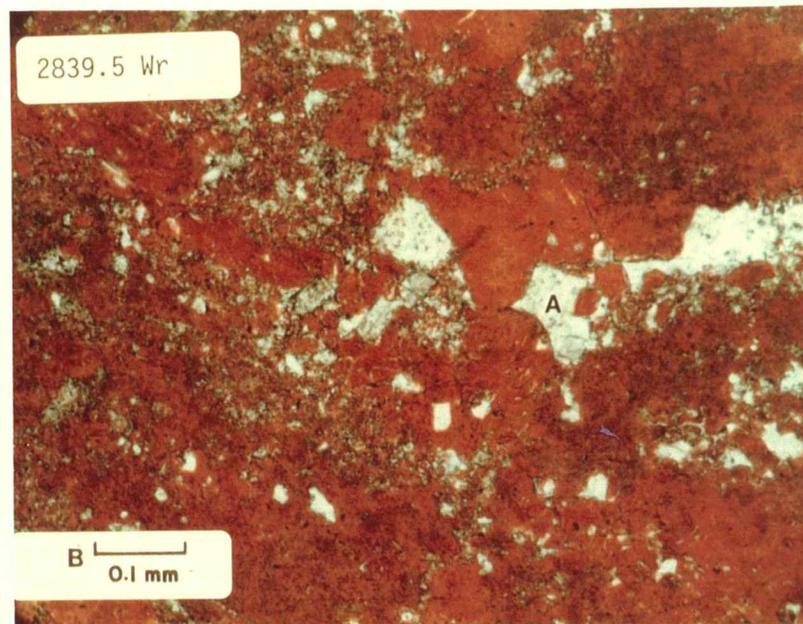
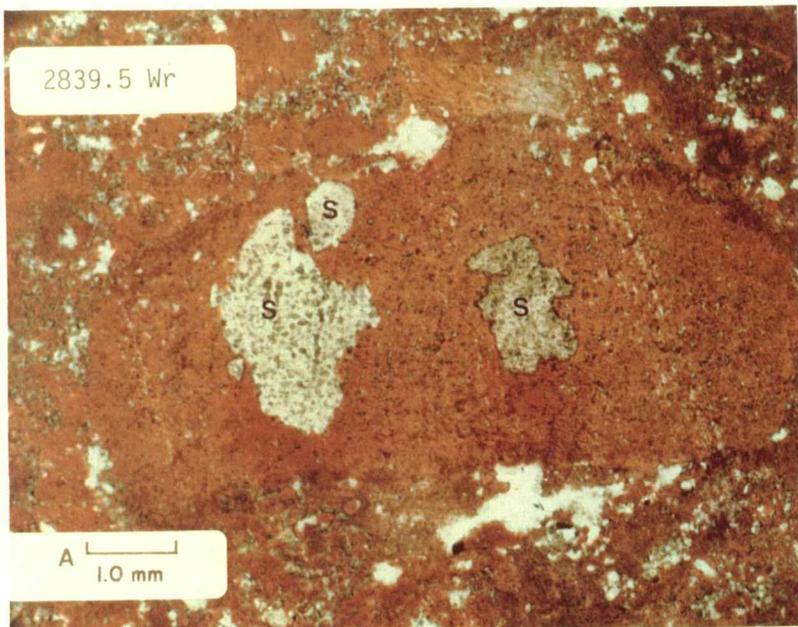
View A, 80X, Plane Light. A large echinoderm fragment, at center, has been partially replaced by silica (S). Note the coarse nature of the calcite in this sample, compared to the previous sample. Also note the lack of porosity, and the partially dolomitized nature of the matrix.

View B, 135X, Plane Light. Anhydrite (A) has filled some intercrystalline pores between sparry calcite crystals. Note that much of this sample has been partially dolomitized (calcite is red; dolomite is brown). Porosity is lacking in this view.

Sample Designation: 2843.5 feet    Wreford Formation

View C, 35X, Plane Light. Abundant silicification has occurred in this sample. Silicified fossil fragments of brachiopods, bryozoans, and echinoderms are scattered throughout this view. Some quartz sand- and silt-sized material is also present. The matrix is dominantly dolomite, but may contain a small amount of clay.

View D, 80X, Crossed Nicols. In the center of this photo is a silicified bryozoan, which now consists of microcrystalline quartz and small amounts of dolomite. At upper center and lower center, note the partially silicified and partially dolomitized nature of the matrix. This sample contains no visible porosity.



Sample Designation: 2852.5 feet Wreford Formation

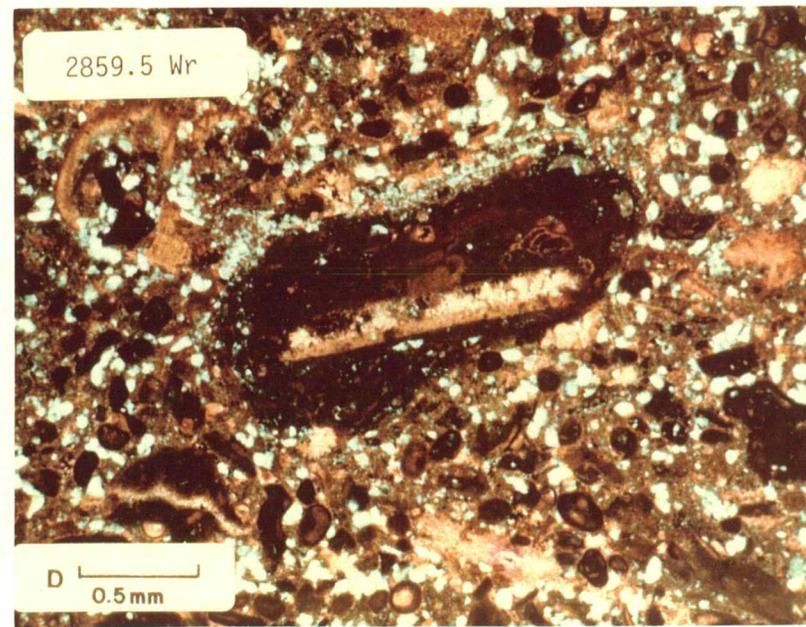
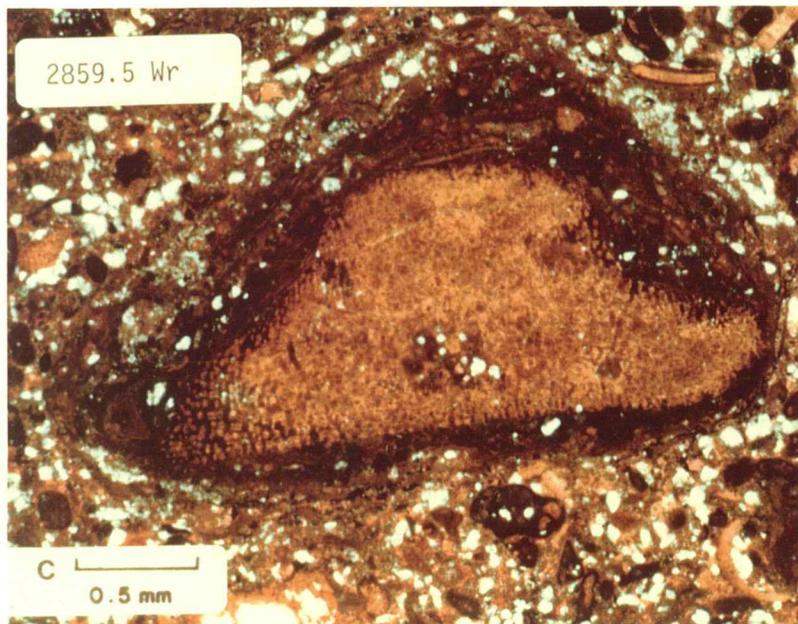
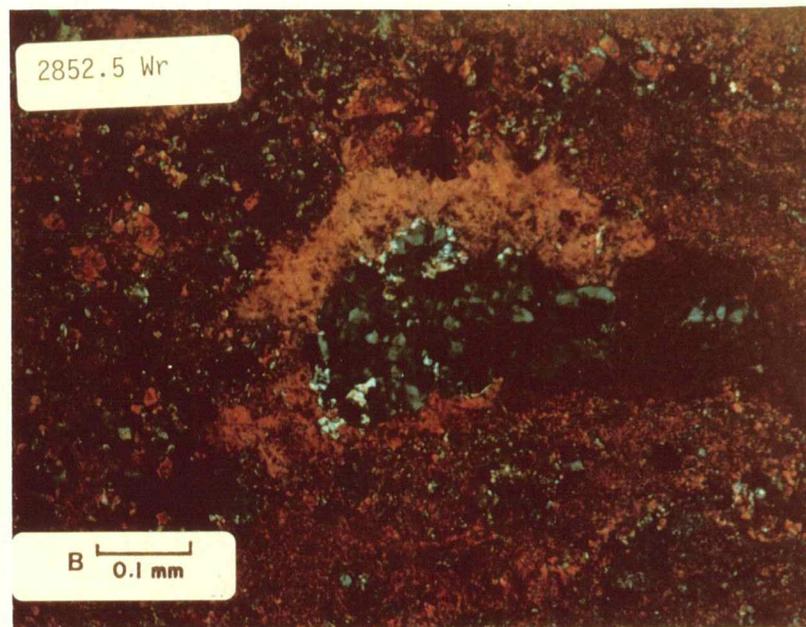
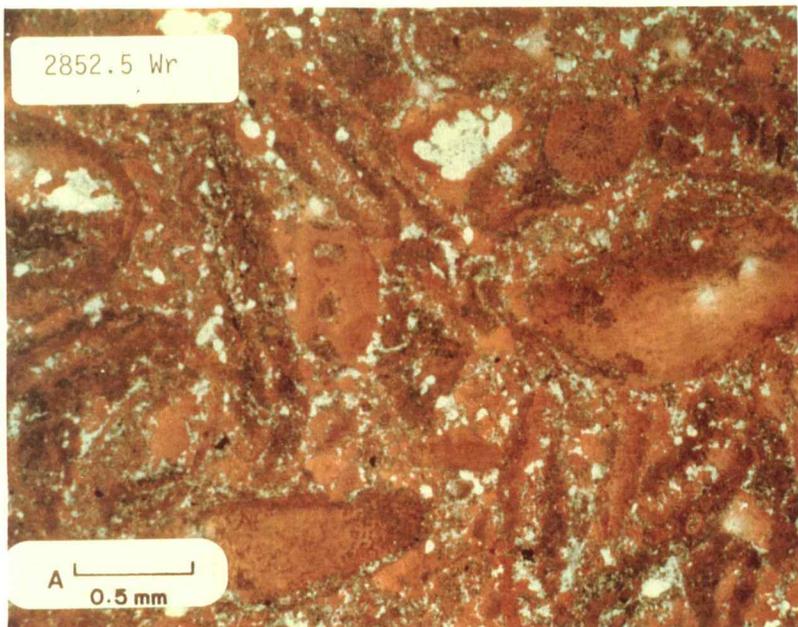
View A, 35X, Plane Light. Scattered echinoderms, echinoid spines, bryozoans, and foraminifera make up this fossiliferous packstone. Minor amounts of very fine calcite and dolomite matrix are present. At upper center, note the echinoderm (probably a crinoid) which has been partially replaced by silica (white). Note the lack of porosity throughout this view.

View B, 135X, Crossed Nicols. This photo highlights the partially silicified echinoderm observed in View A. Note that the central portions of this fossil fragment now consist of microcrystalline quartz. Also note the size gradation of the calcite from micrite to coarse spar.

Sample Designation: 2859.5 feet Wreford Formation

View C, 35X, Plane Light. The crinoid fragment at center is coated with algae and encrusting foraminifera. Note that the matrix is composed dominantly of calcite, with minor amounts of dolomite. Also note the scattered quartz and feldspar sand-sized material throughout the view. This sample contains no visible porosity, and hence very low permeability.

View D, 35X, Plane Light. At center is a brachiopod shell fragment which has been coated with algae and encrusting forams, which can also be observed on the right edge of the photo within the algae. Note the scattered quartz and feldspar sand and silt. Small forams, most of which are encrusting forms, are visible at bottom and left. This thin section contains no visible porosity.



Sample Designation: 2561.5 feet Herrington Formation

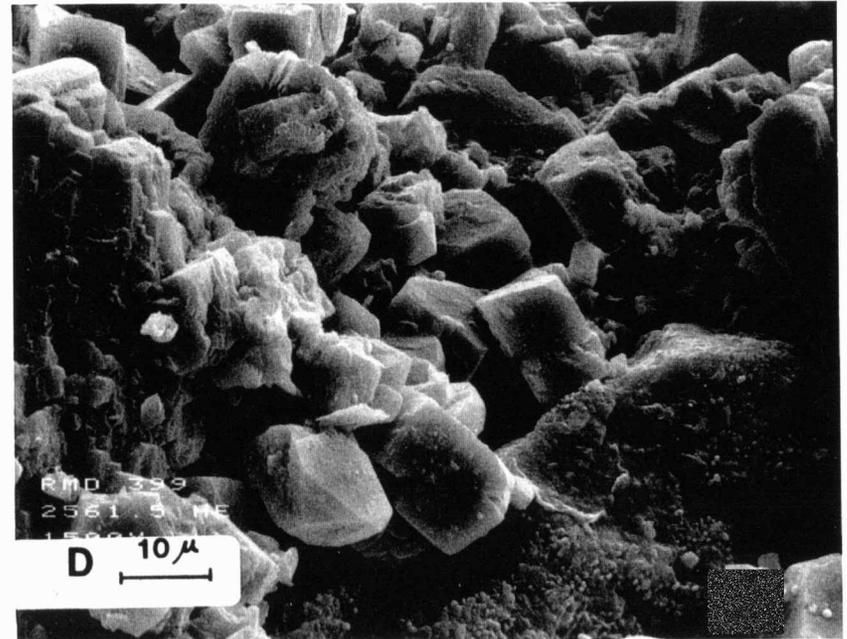
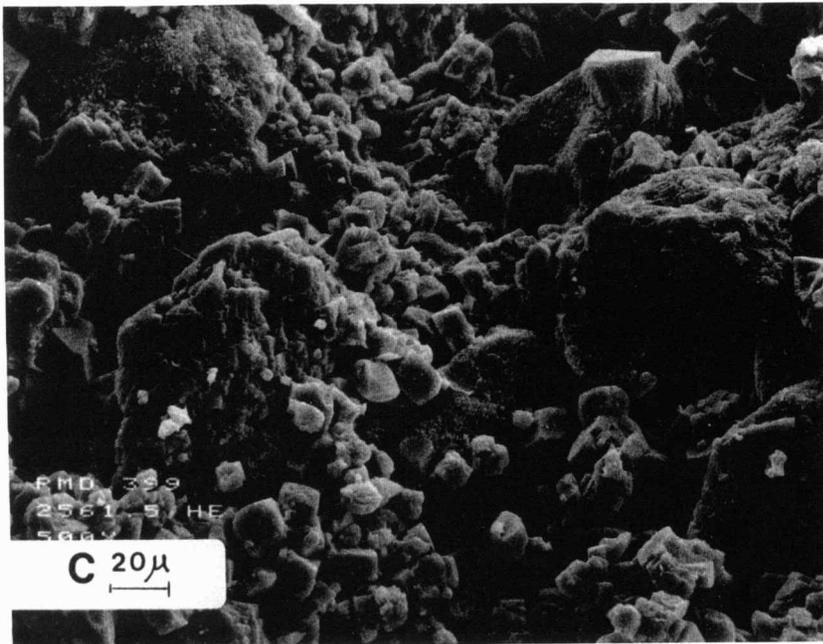
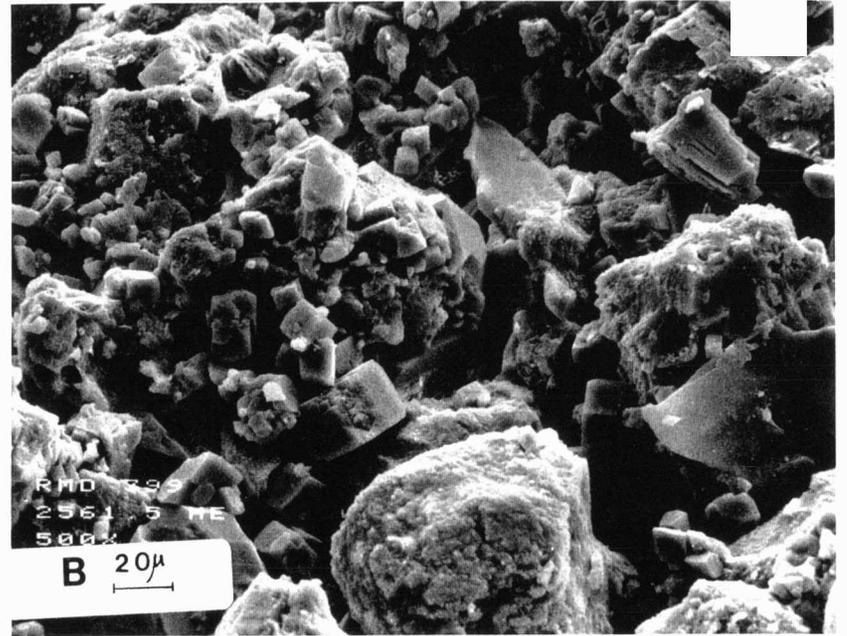
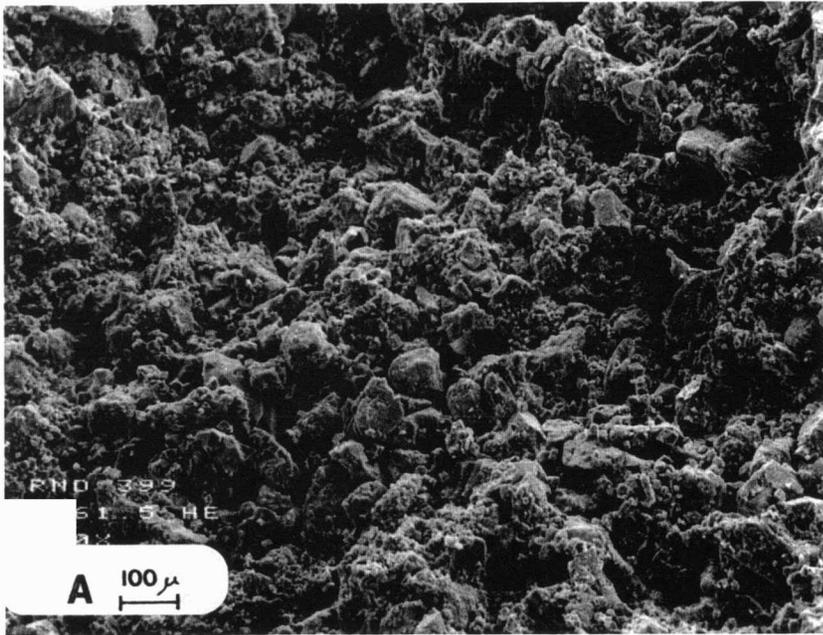
- A. This low magnification view highlights the "clastic" nature of this sample. Quartz and feldspar sand grains are cemented with dolomite and anhydrite. Intergranular porosity is relatively abundant between sand grains, and intercrystalline porosity has developed between fine dolomite rhombs.
- B. Enlargement of the center of View A. Rhombic dolomite cement is visible in intergranular areas between quartz grains; it also coats some quartz and feldspar grains. At upper right, note the leached nature of a larger dolomite rhomb. The quartz grain in the center of the view contains a small quartz overgrowth. Quartz overgrowths are not abundant in this sample. Note the intercrystalline porosity between fine dolomite rhombs at left. At upper right and lower right are intergranular pores.
- C. This view shows dolomite cementing quartz and feldspar grains. The grain at lower left is a partially leached feldspar. Note the cleavage "steps" on this grain. At upper right, a quartz grain exhibits a small quartz overgrowth. Note the intercrystalline porosity in the intergranular dolomite.
- D. Higher magnification of View C illustrates the intercrystalline pores developed within the dolomite cement. Note the feldspar cleavage and the small feldspar overgrowth on the grain at far left.

A - 100X

B - 500X

C - 500X

D - 1500X



Sample Designation: 2593.2 feet Krider Formation

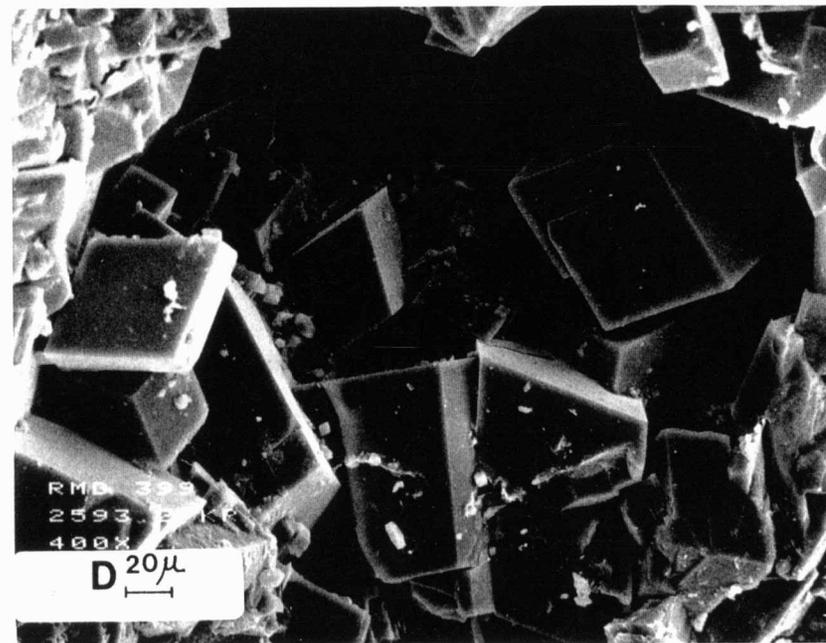
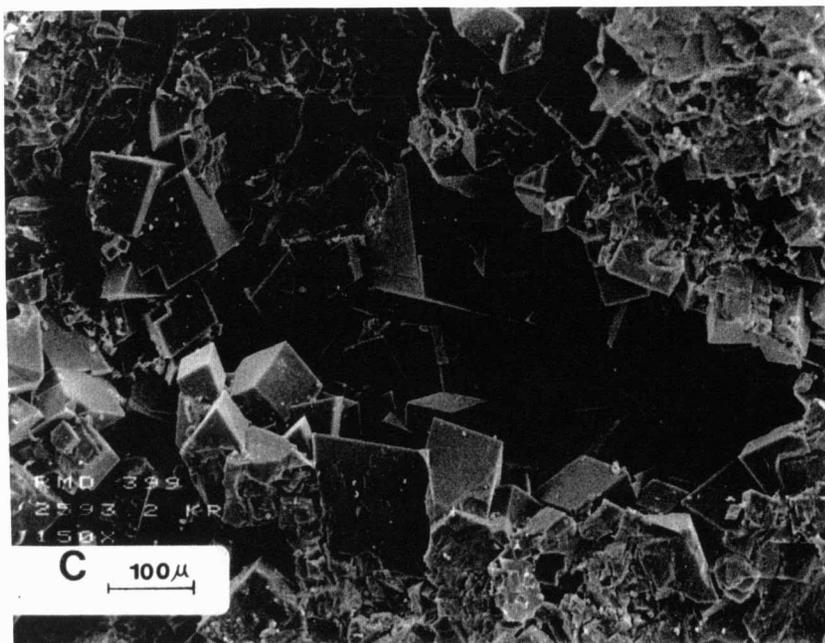
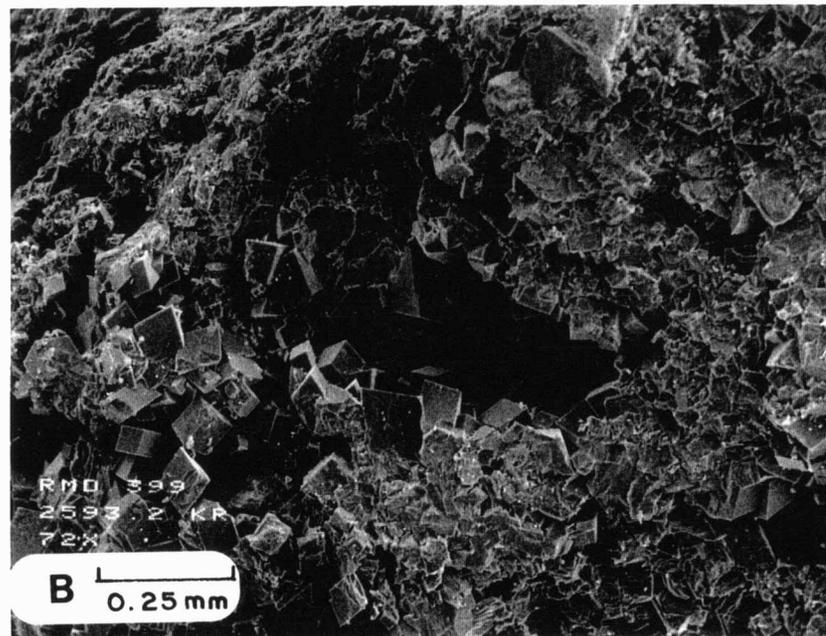
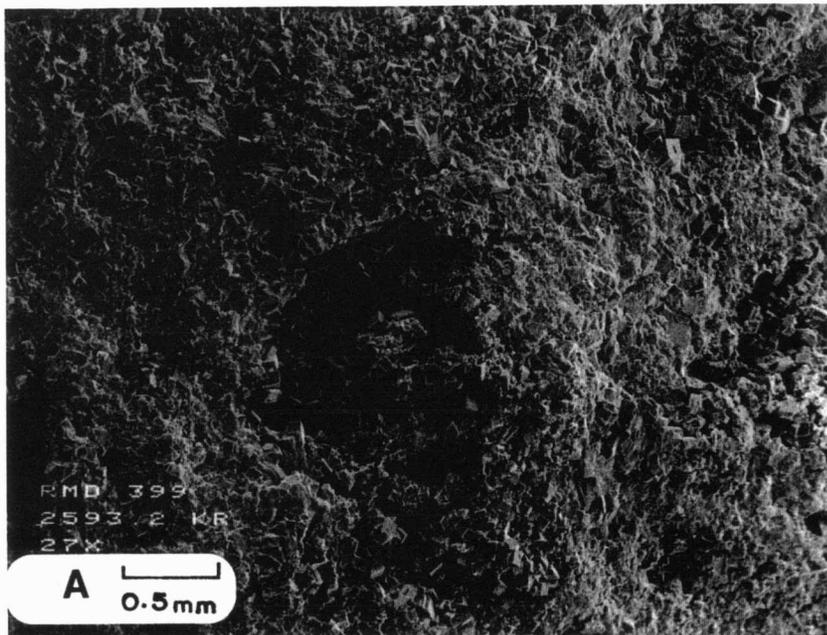
- A. This overview shows the porous nature of this sample. A large vug can be seen at center; it is partially filled with "secondary" dolomite rhombs. Note the intercrystalline pores throughout the view, and their well connected nature.
- B. Higher magnification of the center of View A highlights the vug, which has a lining of secondary dolomite rhombs. Note the "clean" nature of the dolomite, and the absence of fine material. Intercrystalline porosity is abundant and appears to be well connected.
- C. Different view of the same sample highlights another vug, which has a similar lining of secondary dolomite as that shown in View B. Note the interlocking nature of some of the dolomite, and the abundant intercrystalline porosity throughout the view.
- D. High magnification of a different area shows partially interlocking dolomite rhombs. Fine, calcareous and dolomite debris is visible in the intercrystalline areas. Fine material such as this is not abundant in this sample. This sample is interpreted to contain excellent reservoir properties (porosity and permeability).

A - 27X

B - 72X

C - 150X

D - 400X



Sample Designation: 2649.5 feet Winfield Formation

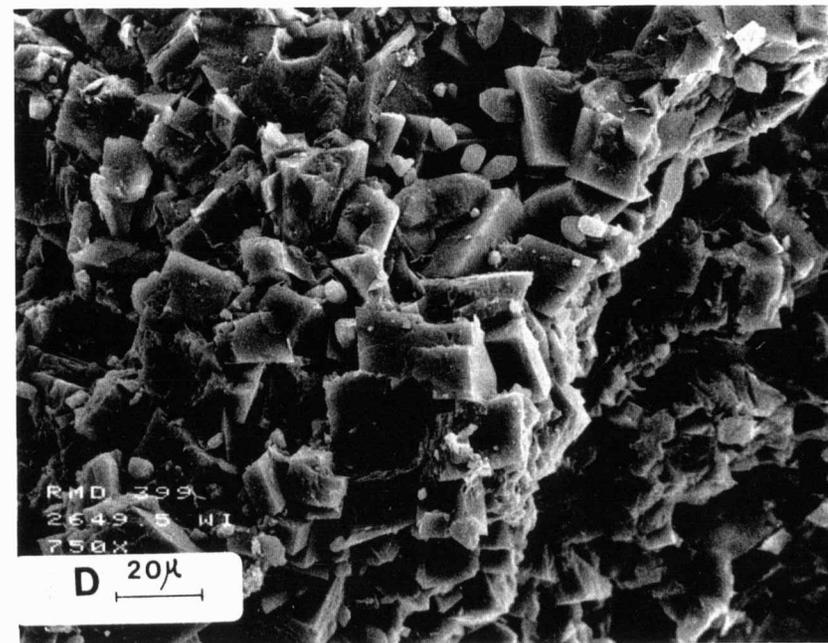
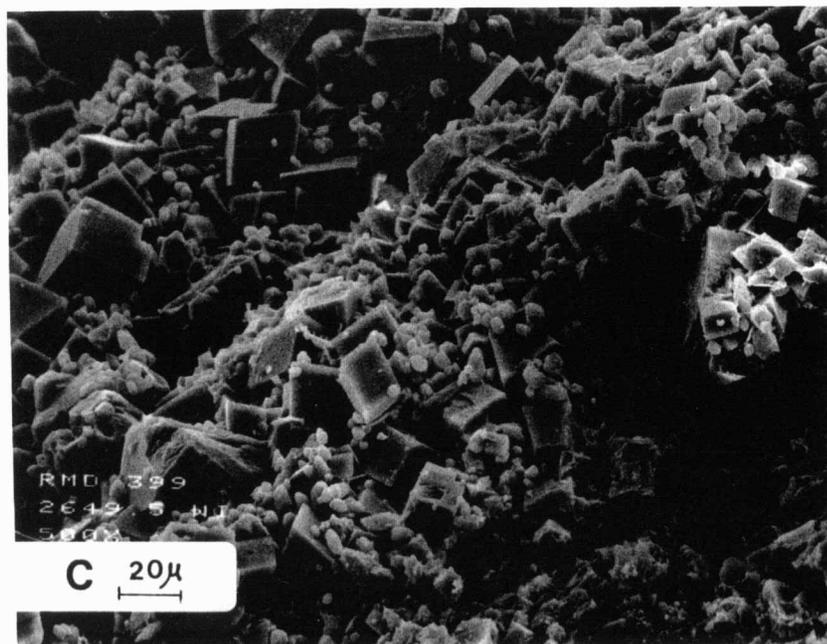
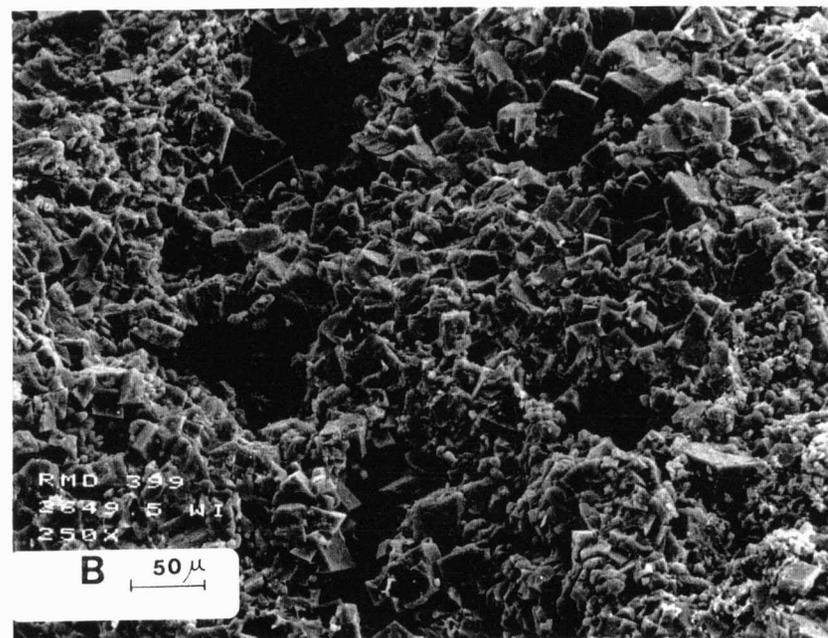
- A. A large anhydrite crystal is at lower right. Intercrystalline and vuggy porosities appear to be abundant in this sample. Scattered pyrite framboids are visible at left of center.
- B. Higher magnification of a different area reveals that this sample is composed of interlocking dolomite and calcite. Scattered vuggy pores are present, most of which are lined with "secondary" dolomite. Note the varying size of material (poor sorting) throughout the view.
- C. This enlargement shows interlocking dolomite rhombs, and fine calcite crystals. This calcite microspar is interpreted to be remnants of partial dolomitization. Intercrystalline porosity has been plugged in part by partial dolomitization with these calcite remnants.
- D. Partial dissolution of some of the dolomite is evident in this photo. Dissolution of dolomite is not abundant, and has not produced much porosity. Fine calcite coats some dolomite crystals and fills intercrystalline areas. This calcite is due to partial dolomitization, and is interpreted to be remnants of original limestone rock material.

A - 100X

B - 250X

C - 500X

D - 750X



Sample Designation: 2716.5 feet Towanda Formation

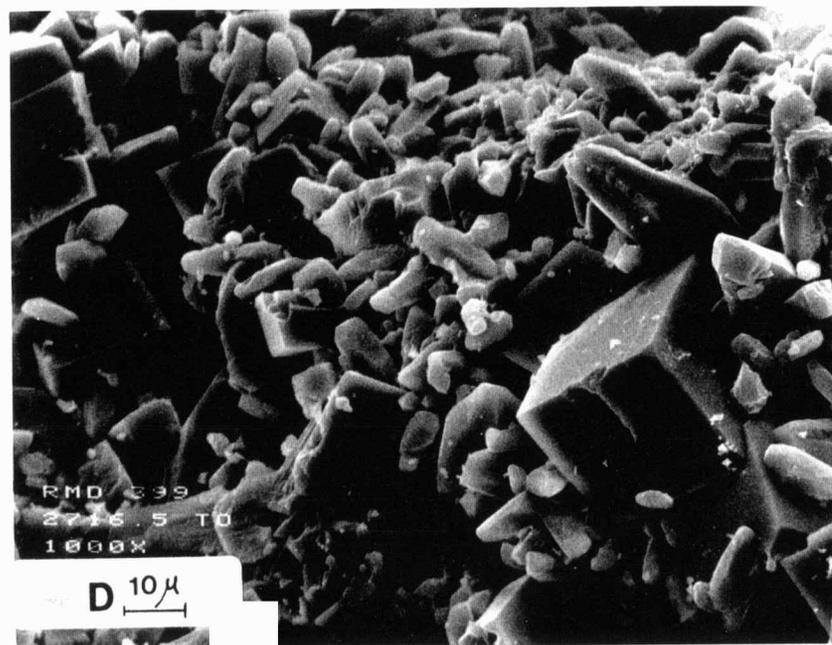
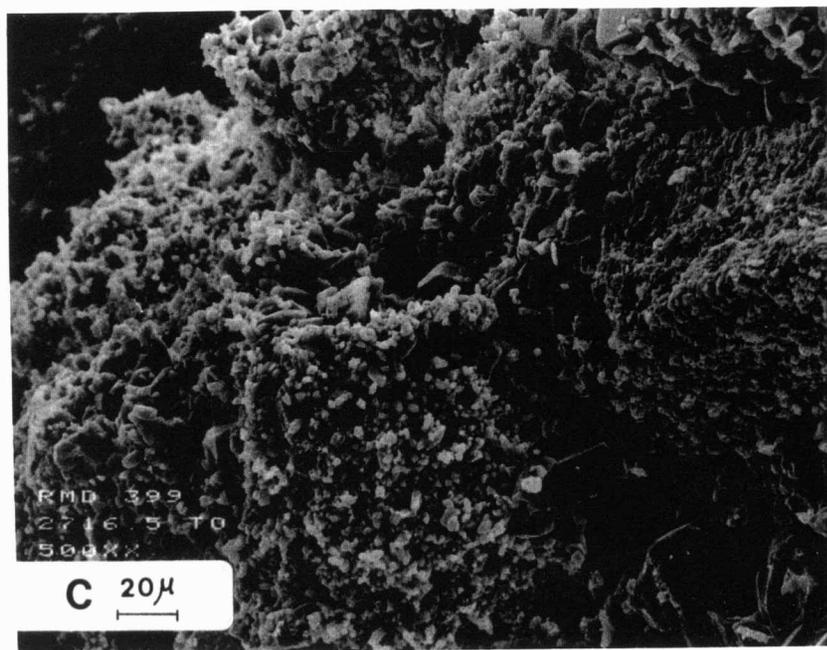
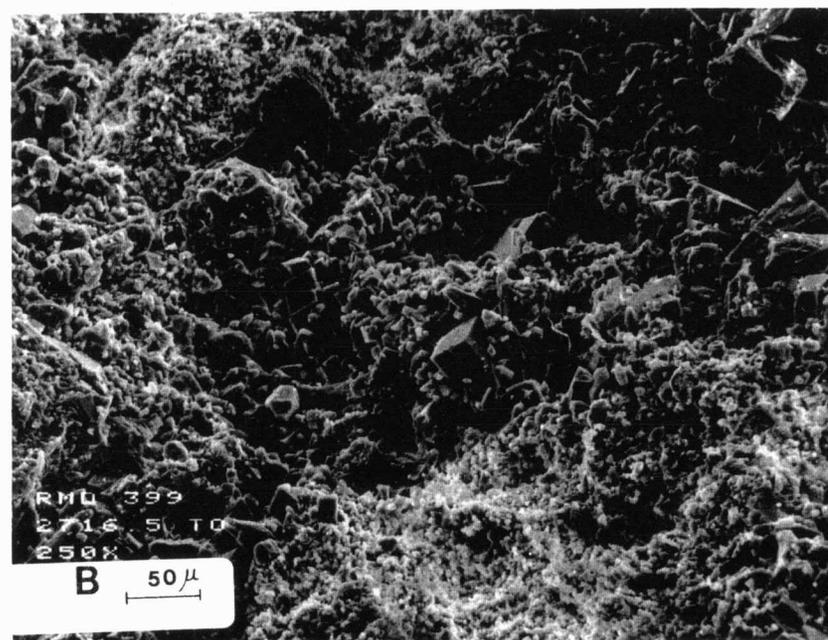
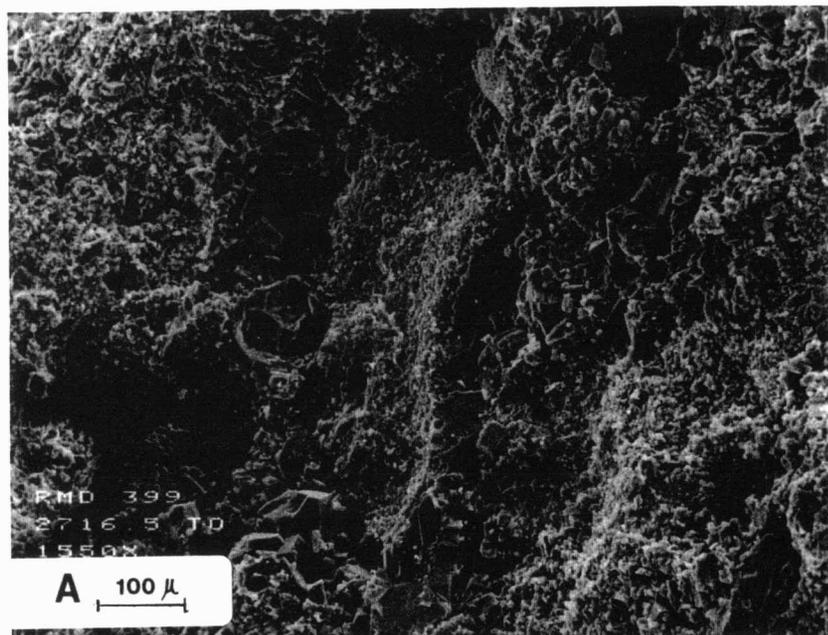
- A. In the center of this view is a large calcite grain, interpreted to possibly be a bioclast, similar to those observed in thin section photomicrographs. Scattered dolomite rhombs and micrite and microspar calcite make up the remainder of this rock. Note the vuggy porosity at the top and lower left of this photo. Also note the fine intercrystalline porosity throughout the view.
- B. Higher magnification reveals the partially dolomitized nature of this sample. Dolomite rhombs are coated and enclosed by very fine sparry calcite and microspar. A small amount of micrite is at lower center. Note that the intercrystalline porosity observed in this view may be partially ineffective, due to the variability in sizes of particles which make up this sample.
- C. Enlargement of the upper left of View B. This view highlights micrite (very fine calcite) and dolomite rhombs. This micrite is interpreted to represent a matrix, which is only partially dolomitized. Note the very fine intercrystalline pores throughout this view. Abundant microporosity may be found in the micrite-dominated areas.
- D. Higher magnification shows partially dolomitized calcite. Calcite crystals (elongate and partially leached) and dolomite rhombs are intimately associated. It is interpreted that partial dolomitization has occluded much pore space with this remnant calcite. It is also interpreted that further dolomitization may have increased the amount of intercrystalline porosity, therefore giving this rock higher permeability.

A - 150X

B - 250X

C - 500X

D - 1000X



Sample Designation: 2764.5 feet Fort Riley Formation

A., B., and C.

Three views of the same area under increasing magnification. These views highlight the relatively tight nature of this sample, as well as its moderately poor sorting. This sample is partially dolomitized, and much calcite remains. Dolomite rhombs are coated with calcite; calcite is noted in intercrystalline pores. The poor sorting, and partially dolomitized nature of this rock give it lower permeability than previous samples. Some of this rock may contain relatively abundant microporosity and very fine intercrystalline porosity, which make this a moderate to poor reservoir rock.

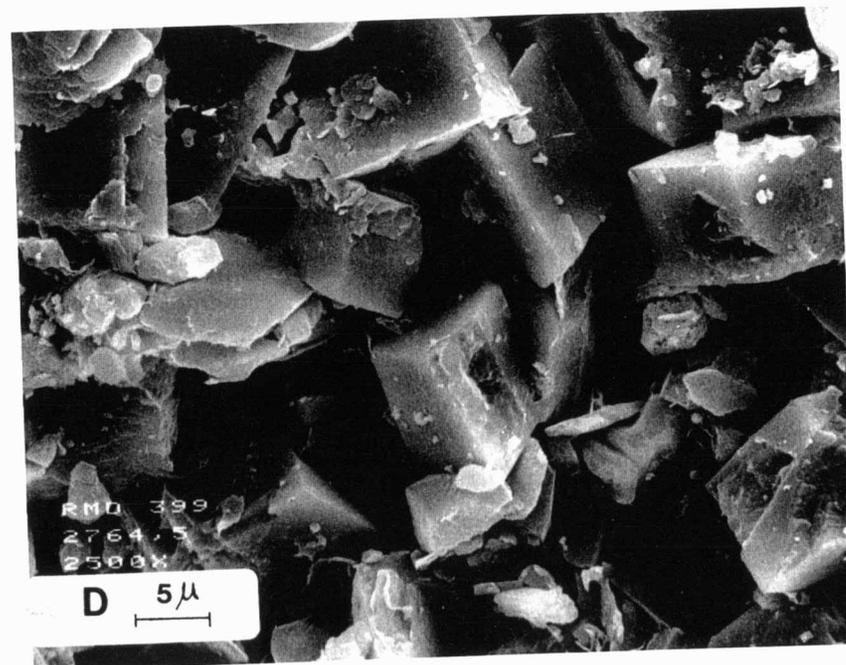
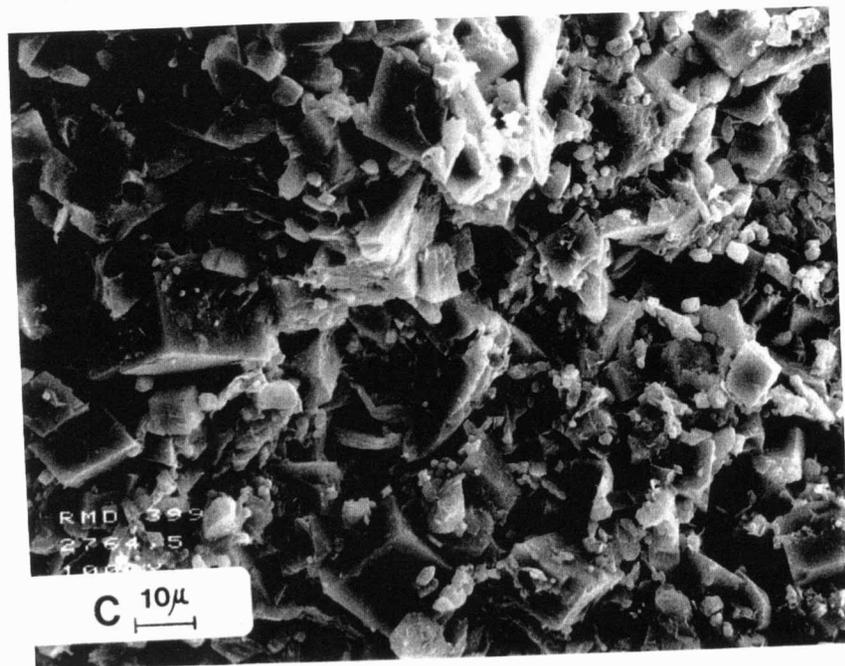
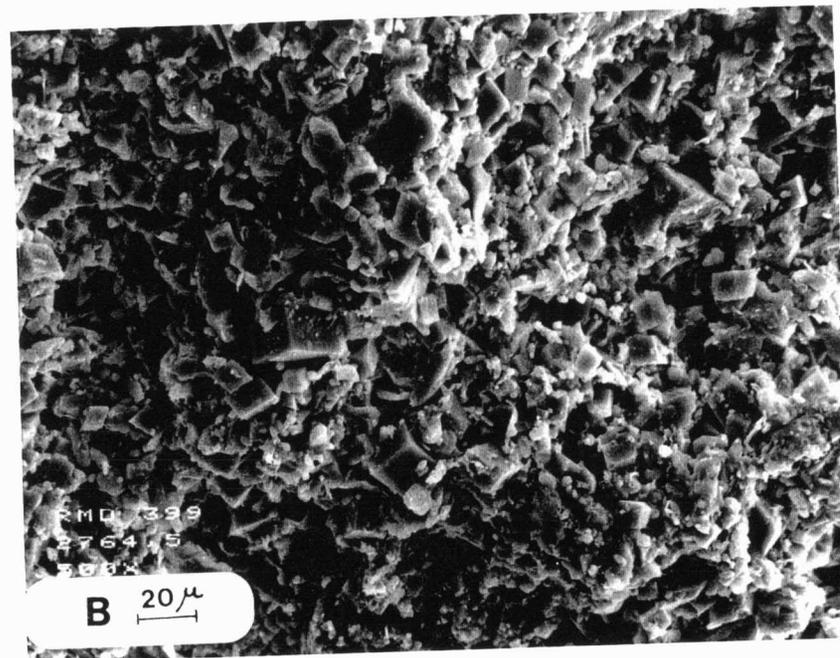
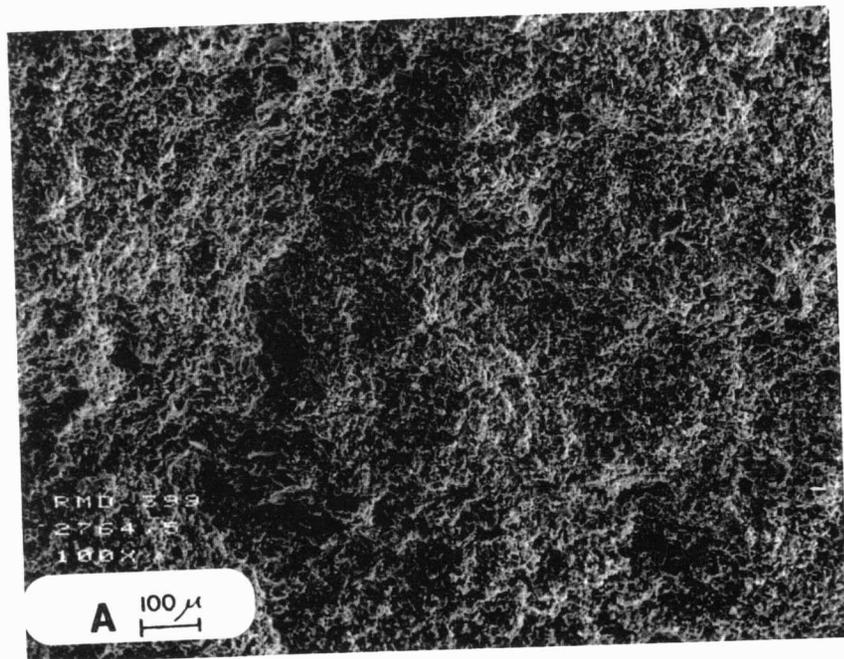
D. High magnification of a different area illustrates the fine nature of intercrystalline pores in this sample. Note the very fine material throughout the view, which may become dislodged and migrate to narrow pore throats during stimulation. Also note the angular nature of the pores in response to the rhombic crystals of the dolomite.

A - 100X

B - 500X

C - 1000X

D - 2500X



Sample Designation: 2803.0 feet Florence Formation

A. This overview illustrates the overall fine nature of this sample, which consists of a mixture of calcite and dolomite. Calcite is commonly observed as the finer material, and dolomite occurs as isolated rhombs. Note that fine intercrystalline porosity is present throughout the view. Coarser areas in view are sparry calcite, interpreted to have resulted from the neomorphism of micrite.

B. and C.

Two views of the same area under increasing magnification, highlighting a vug that has been filled with anhydrite (center) and sparry calcite. Note the intercrystalline porosity between individual calcite crystals. Microporosity is interpreted to be abundant in micrite-rich areas, such as those observed at top center in View C. Very few open vugs are present at this depth. The majority of these vugs have been infilled with sparry calcite (secondary) or anhydrite.

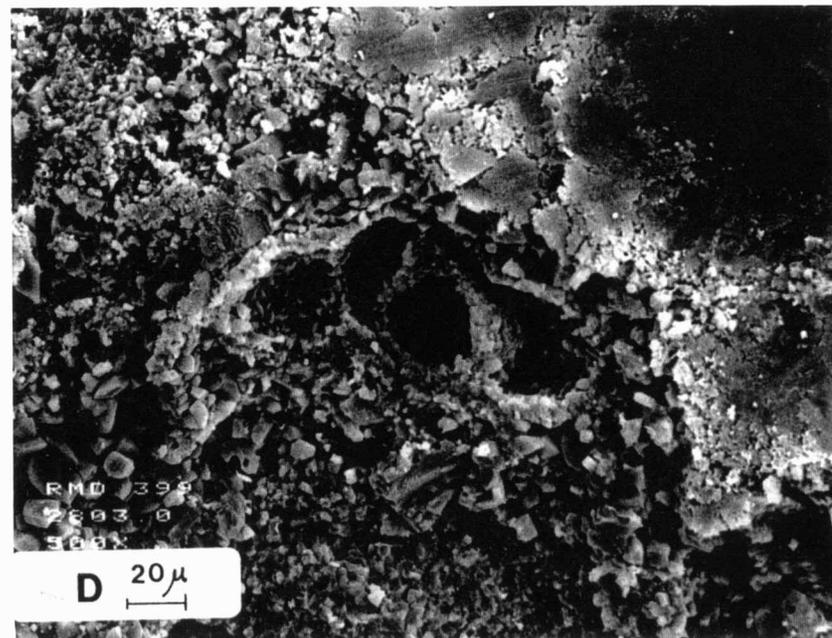
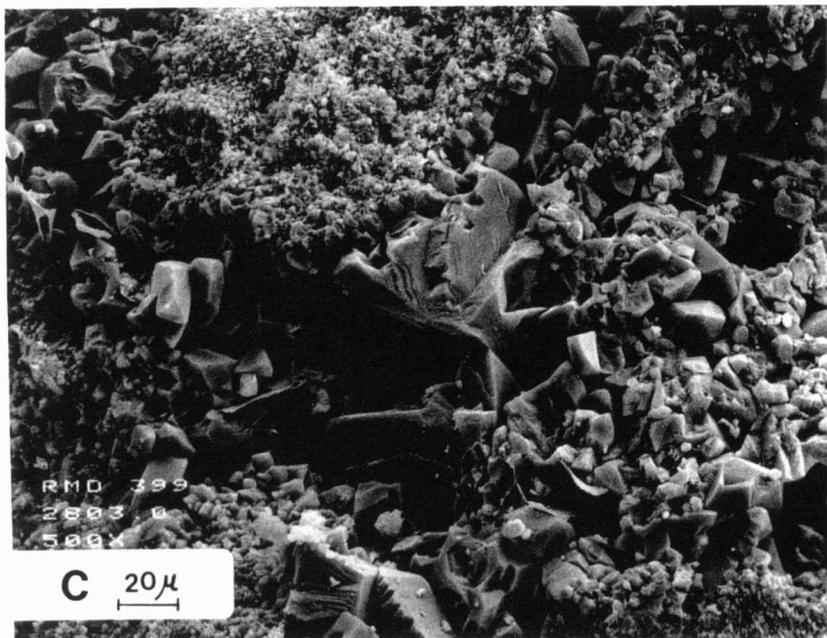
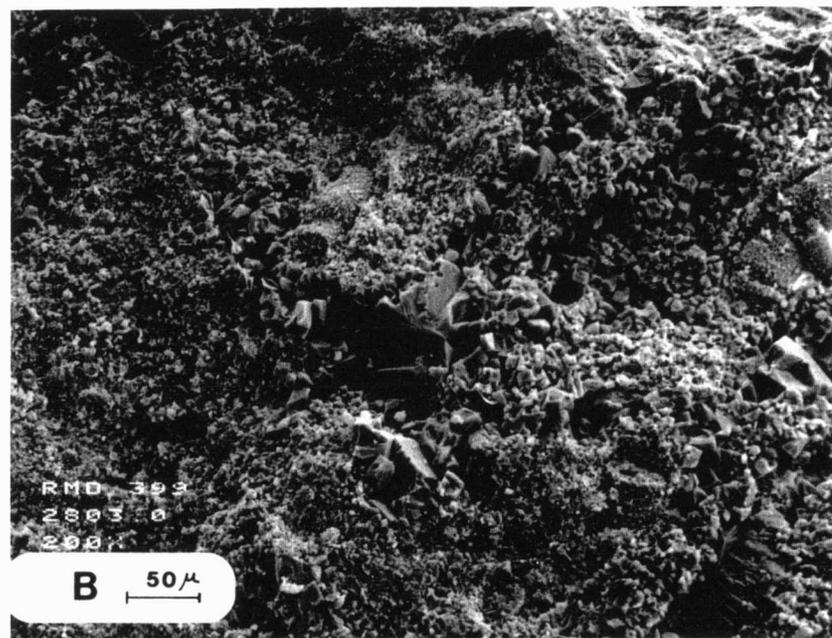
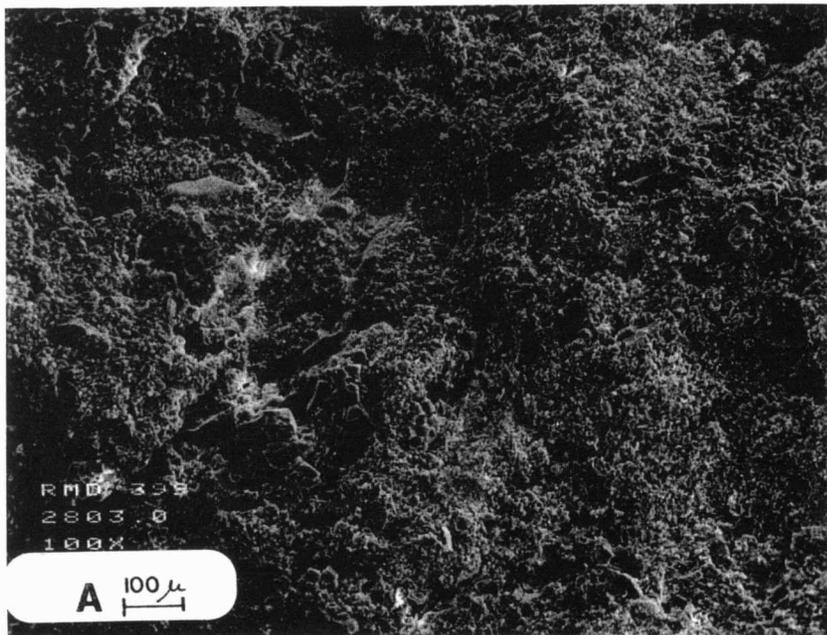
D. At center of this view is a foram, which contains intraparticle porosity. This intraparticle porosity will probably be ineffective due to the lack of interconnection between these pores and the intercrystalline pore system. Note the fine intercrystalline porosity throughout this view. Also note the larger intercrystalline pores at lower left, where the crystal size is also larger.

A - 100X

B - 200X

C - 500X

D - 500X



Sample Designation: 2852.5 feet Wreford Formation

A., B., C., and D.

Four views of the same area under increasing magnification. These views illustrate the extremely fine nature of this sample, which is dominantly calcite, of which most is micrite and microspar size. View D shows the micrite, which is less than 4 microns in diameter. Note the lack of large intercrystalline pores, and the abundance of micropores in this sample. These micropores, found in micrite-rich rocks such as this, are interpreted to be ineffective for the production of oil. Microporosity will tend to retain fluids through surface tension and capillarity.

A - 150X

B - 500X

C - 1000X

D - 2500X

