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SERVICE REPORT

GEOLOGIC AND RESERVOIR CHARACTERIZATION OF THE PERMIAN CHASE GROUP

ANADARKO NORDLING A#1 WELL, STEVENS COUNTY, KANSAS

RESERVOIRS INC.

Prepared for
Anadarko Production Company
Englewood, Colorado

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COMPANY PROPRIETARY

RMD399-A

GEOLOGIC AND RESERVOIR CHARACTERIZATION OF THE PERMIAN CHASE GROUP

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INTRODUCTION

The purposes of this study are to:

1. Characterize lithologies, porosities, and factors controlling porosity of the Permian Chase Group from the Anadarko Nordling 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.

5. Compare results of this study to the Walters A#1 study (RMD399).

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. General core description.
2. Thin section petrology.
3. X-ray diffraction (XRD).
4. Petrophysical data.

Reservoirs, Inc. has assigned job number RMD399-A to this study of the Permian Chase Group cored in the Anadarko Nordling A#1 Well, Sec. 23, T.32S., R.38W., Gentzler Field, Stevens County, Kansas. Three copies of RMD399-A 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-A 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.

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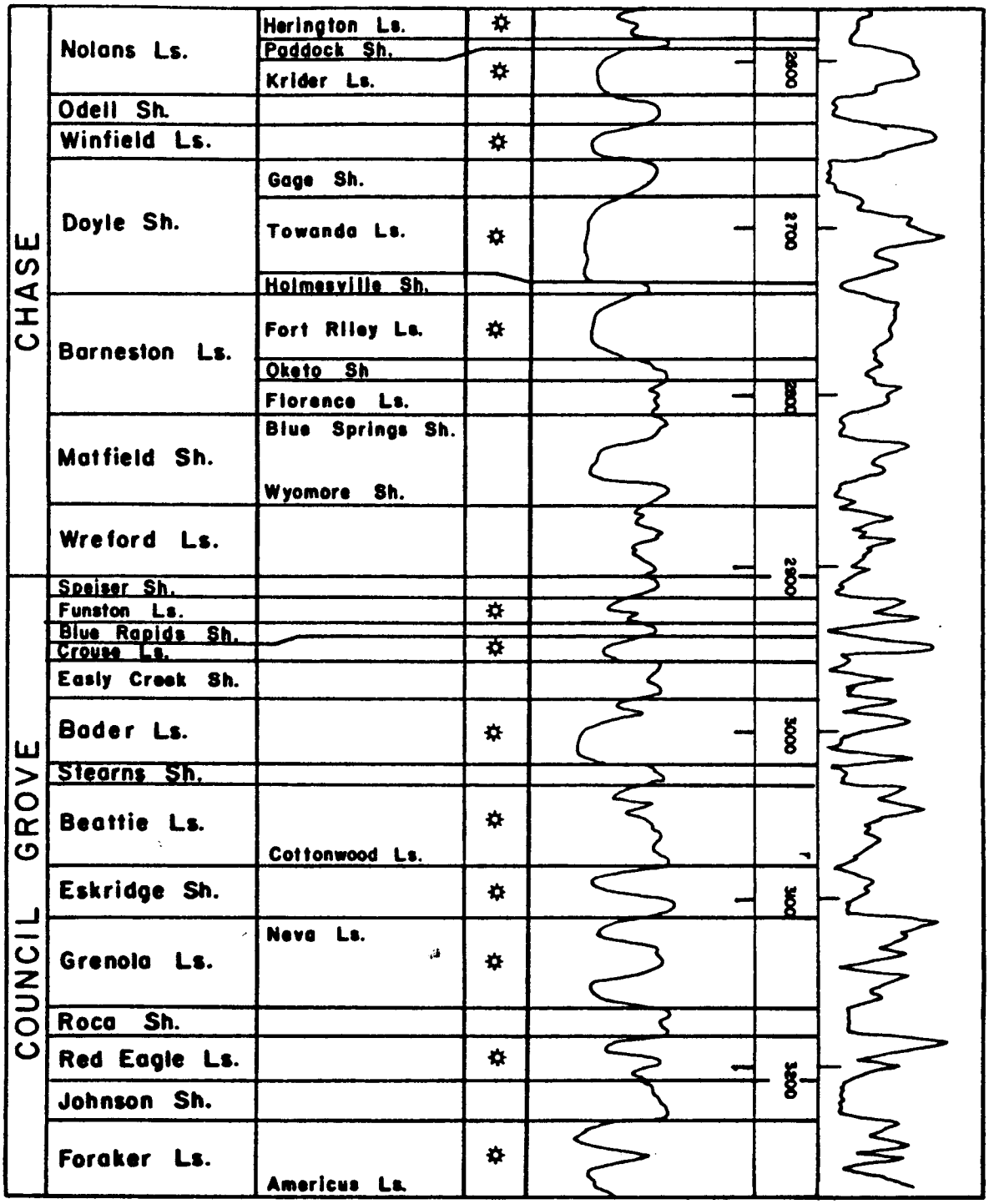


Anadarko Production Company

TYPE LOG OF
CHASE & C-G FORMATIONS
OF KANSAS

Interpretation By: D. CLEAVER

Date: 3-82 Scale:

Provided to Reservoirs, Inc. by Brent Miyazaki,
Anadarko Production Company

SUMMARY

Well and Location:

Anadarko Production Company Nordling A#1, Sec. 23, T.32S., R.38W., Gentzler Field, Stevens County, Kansas.

Formations (core depths): 320'

1. Herrington (2550.0-2585.8 feet).
2. Paddock Shale (2585.8-2593.3 feet).
3. Krider (2593.3-2629.3 feet).
4. Odell Shale (2629.3-2648.8 feet).
5. Winfield (2648.8-2676.0 feet).
6. Gage Shale (2676.0-2703.8 feet).
7. Towanda (2703.8-2750.0 feet).
8. Holmesville Shale (2750.0-2760.5 feet).
9. Fort Riley (2760.5-2797.2 (?) feet).
10. Oketo Shale (2797.2(?)-2808.0(?) feet).
11. Florence Formation (2808.0(?)-2830.0 feet).
12. Matfield Shale (2830.0-2848.8 feet).
13. Wreford (2848.8-2870.0 feet).

Production History:

The principal gas producing intervals in the Chase Group from Gentzler Field, Stevens County, Kansas are the Krider and Winfield Formations. Moderate gas production has come from the Herrington and Towanda Formations. The remaining intervals are typically non-productive (Brent Miyazaki, personal communication).

Dominant Lithologies of Each Formation (based on core description and thin sections (where applicable)):

1. Herrington:

   a. Green and red, anhydritic, silty shale.
   b. Fine- to medium-grained quartz sandstone.

2. Paddock Shale: Dark gray, dolomitic, anhydritic shale.

3. Krider: Fine to medium crystalline, vuggy dolomite.

4. Odell Shale:

   a. Red, dark gray, and greenish, dolomitic shale.
   b. Shaly, silty sandstone.

5. Winfield: Partially dolomitized, anhydritic, fossiliferous limestone wackestone/packstone.

6. Gage Shale: Red and greenish-gray, dolomitic, silty shale.

7. Towanda Formation:

    a. Light gray, sandy, fossiliferous wackestone.
    b. Light brown, sandy dolomite.
    c. Anhydritic, coralline boundstone.
    d. Algal lime wackestone.

8. Holmesville Shale: Reddish-green, dolomitic shale.

9. Fort Riley: Partially dolomitized, fossiliferous lime wackestone-/packstone.

10. Oketo Shale: Dark gray, shaly lime mudstone/wackestone.

11. Florence:

    a. Dark gray to black, fossiliferous lime mudstone/wackestone.
    b. Fine- to medium-grained, calcareous quartz sandstone.

12. Matfield Shale: Massive, mottled, calcareous, red shale.

13. Wreford: Light to dark gray, fossiliferous lime wackestone.

Inferred Environments of Deposition or Formation (based on sedimentary structures, lithologies, and fossils):

The Chase Group in the Nordling Well is interpreted to represent cyclic carbonate shelf deposits. It is also interpreted that five cycles of deposition from subtidal to supratidal (subaerial exposure) are present in the core.

1. Herrington: Intertidal to supratidal (paleosol).
2. Paddock Shale: Nearshore; possibly "lagoonal."
3. Krider: Subtidal.
4. Odell Shale: Intertidal to supratidal (paleosol).
5. Winfield: Subtidal.
6. Gage Shale: Paleosol.
7. Towanda: Marine subtidal to intertidal.
8. Holmesville Shale: Paleosol.
9. Fort Riley: Subtidal.
10. Oketo Shale: Subtidal.
11. Florence: Intertidal (?) to subtidal.
12. Matfield Shale: Paleosol.
13. Wreford: Subtidal.

Porosity Development and Controls:

Seven types of porosity are evident in the Chase Group cored interval from the Nordling A#1 Well (in order of decreasing importance for production):

1. Intercrystalline (particle): between individual crystals/particles.
2. Intergranular: between individual grains.
3. Fracture.

4. Moldic or Vuggy: from selective leaching of framework, matrix, or cement components.

5. Intragranular: within individual grains.

6. Intracrystalline: within individual crystals.

7. Microporosity: pores with aperture radii less than 0.5 microns.

Porosity Types (in decreasing abundance by formation, excluding shale intervals):

1. Herrington:

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

2. Krider:

   a. Vuggy.
   b. Intercrystalline.
   c. Moldic.
   d. Intracrystalline.
   e. Fracture.

3. Winfield:

   a. Intercrystalline (interparticle).
   b. Vuggy.
   c. Moldic.
   d. Intraparticle.
   e. Microporosity.

4. Towanda:

   a. Intercrystalline (interparticle).
   b. Intraparticle.
   c. Microporosity.

5. Fort Riley:

   a. Interparticle.
   b. Intraparticle.
   c. Microporosity.

6. Florence:

   a. Intergranular.
   b. Interparticle.
   c. Microporosity.

7. Wreford:

    a. Interparticle.
    b. Intraparticle.
    c. Intercrystalline.

The best reservoir quality rock observed in the Nordling Well is the Krider Formation. The abundance of well connected porosity is documented. The Herrington Formation exhibits significant amounts of intergranular porosity.

Porosity Controls:

1. Original sediment or particle size.
2. Amount of dolomite vs. calcite. Typically dolomite contains more interconnected pore space.
3. Anhydrite replacement; only locally present.
4. Leaching of unstable material (calcite, dolomite, anhydrite, feldspar, lithic fragments).
5. Stylolitization.
6. Fracturing.
7. Silica replacement; locally present in a nodular texture.
8. Abundance and thickness of interbedded shale and anhydrite.

Diagenesis:

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

1. Dolomitization.
2. Lithification and cementation.
3. Recrystallization of calcite.
4. Silica replacement.
5. Anhydrite replacement.
6. Leaching (mainly associated with subaerial exposure).

Table 1 - Sample List

CORE DEPTH (ft)	FORMATION	THIN SECTION	XRD
2566.2	Herrington	X	
2583.2	Herrington	X	
2600.3	Krider	X	
2608.1	Krider	X	
2612.6	Krider	X	
2620.3	Krider	X	
2624.3	Krider	X	
2633.0	ODell		X
2654.6	Winfield	X	
2669.6	Winfield	X	
2711.3	Towanda	X	
2717.4	Towanda	X	
2727.5	Towanda	X	
2739.3	Towanda	X	
2747.8	Towanda	X	
2765.3	Fort Riley	X	
2778.4	Fort Riley	X	
2788.3	Fort Riley	X	
2800.5	Florence	X	
2817.8	Florence	X	
2820.8	Florence	X	
2855.7	Wreford	X	
2862.7	Wreford	X	
2866.2	Wreford	X	

RESULTS AND INTERPRETATIONS

Lithologies and Thin Section Petrology:

Each formation is discussed separately in this section (refer to Figure 1, General Core Description). The formations will be discussed in descending order to be consistent with the report on the Walters A#1 Well (RMD399).

1. Herrington: Two distinct lithologies are present in the Herrington Formation (2550.0-2585.8 feet) from the Nordling A#1 Well. The upper third of the formation is composed of a dominantly green and some red, silty shale. This shale is commonly dolomitic, and contains scattered anhydrite nodules. A small (less than 6 inches), massive anhydrite unit appears near the base of this shale. This unit exhibits poorly developed "chickenwire" texture. The lower two thirds of the formation is composed of light brown and light gray, fine- to medium-grained sandstone. This unit is partially dolomitic (from dolomite matrix and cement). This lithology is similar to Lithology III in the Walters A#1 Well. By thin section analysis, these sandstones are dolomitic and moderately to well sorted. Dominant framework grains are quartz, which are commonly subangular to angular. Microcrystalline dolomite occurs as cement and matrix throughout, and is present in portions as laminations. Some carbonaceous debris is scattered throughout the dolomite and some anhydrite cement may be present. The lower portion of the Herrington Formation exhibits relatively steep, planar cross bedding and climbing ripple structures. The overall reservoir quality of the sandstone unit is moderate at the top and decreases to poor towards the base due to increasing dolomite matrix and cement and decreasing porosity.

2. Paddock Shale: This formation is composed of a dark gray, dolomitic shale. Anhydrite nodules are scattered throughout. It is interpreted to be similar to Lithology IV in the Walters A#1 Well. The Paddock Shale unit is interpreted to act as a permeability barrier to prevent communication between the Herrington Formation above and the Krider Formation below.

3. Krider: The Krider Formation is present in the Nordling core between 2593.3 and 2629.3 feet. This unit consists of a light brown and light gray, fine to medium crystalline dolomite. This unit is similar to Lithology V in the Walters Well. Abundant open vugs are present, which appear to be the product of selective leaching of bioclastic material. Pyrite is scattered in wispy laminations throughout mostly the upper portion of the unit. Near the top of this unit and at the base of this unit, large anhydrite nodules are present. Partial silica replacement was observed at 2622.5 and 2627.0 feet. Vertical fractures are scattered throughout the unit, and many of them are open and appear to be permeable pathways. Thin section analyses of the Krider Formation indicate it is a very fine to fine crystalline dolomite. Some samples exhibit micrite coatings, interpreted to be grain-coating algae. Other bioclasts observed (all of which are dolomitized) include bryozoan, echinoderm, and brachiopod shell fragments, as well as a few scattered phosphatic fossils which may be

fish debris. Abundant molds and vugs were noted in thin section, as well as relatively abundant intercrystalline porosity. Only traces of anhydrite and anhydrite-filled vugs were observed in thin sections. Development of the vugs appears to have resulted from the selective leaching of bioclastic material, producing molds. These vugs and molds appear to have been accentuated by dolomitization and development of well connected intercrystalline porosity. The overall reservoir quality of the Krider Formation in the Nordling A#1 Well is considered excellent due to the abundant moldic and vuggy porosity and well interconnected intercrystalline pores. It is believed that reservoir quality within this unit has been increased by natural fracturing. Many fractures were observed as open permeable pathways in the core through the Krider section.

4. Odell Shale: This unit is a red shale which turns dark gray at the top and greenish and light brown at the base. It is interpreted that the Odell Shale in the Walters Well (Lithology VI) is very similar to the lithology of the Odell Shale in the Nordling Well. At the base of this unit, the shale grades into a silty, shaly sandstone. No thin sections of this unit were taken.

5. Winfield: The Winfield Formation (2648.8-2676.0 feet) is dominated by a light brown and light gray, lime wackestone/packstone. Abundant fossil debris occurs throughout the interval, including bryozoans, brachiopods, crinoids, and trilobite debris. Relatively abundant stylolites are present. Scattered anhydrite crystals which may represent the replacement of calcite are present at 2670.0 feet. Within the Winfield Formation, two feet of dolomitized rock is present between 2654.0 and 2656.0 feet. A thin section of this thin dolomitized unit shows that it is an anhydritic, calcareous dolomite. The dolomite is dominantly microcrystalline and very fine crystalline. Molds and vugs are present, but are mainly filled with anhydrite. The majority of the bioclasts are still calcareous and are dominated by echinoderms and brachiopod fragments. A few dolomitized echinoderms are also present. Calcite was observed not only in bioclasts but as a patchy cement between dolomite crystals. This may be interpreted as late stage, or incomplete dolomitization. A few quartz grains, interpreted to represent less than 1% of the whole rock, are present. A thin section of the dominant lithology in the Winfield Formation (lime wackestone/packstone) reveals abundant fossil debris. Large, fenestrate bryozoan fragments are present, as well as echinoderms, brachiopods, and trilobite fragments. A micrite matrix occurs throughout most of the sample, and some of it has recrystallized to microspar. A trace of dolomite, which replaces the micrite matrix, is present. Silica replaces echinoderms and brachiopod shell fragments. Micrite envelopes, interpreted to be algal, are present around many of the fossil fragments. Some secondary sparry calcite cement was commonly observed as a syntaxial rim around echinoderm fragments. Vuggy porosity and interparticle porosity are present; however, pore throats are interpreted to be very small due to the poor sorting of bioclastic material and the presence of micrite matrix. The overall reservoir quality of the Winfield Formation is considered fair in the two feet of dolomitized rock, and decreases to poor in the undolomitized portions of the formation.

6. Gage Shale: The Gage Shale is present between 2676.0 and 2703.8 feet. This unit is dominated by a red and greenish-gray shale. A mottled texture, possibly associated with the growth of scattered anhydrite nodules, rooting, and fluctuations of the water table, is present throughout the unit. This unit is similar to Lithology X in the Walters Well. Towards the base of the Gage Shale, the unit becomes silty and more dolomitic. It is interpreted that the Gage Shale will act as a permeability barrier between the Winfield Formation above and the Towanda Formation below.

7. Towanda: The Towanda Formation is present in the Nordling A#1 core between 2703.8 and 2750.0 feet. Four lithologic subdivisions are present within the Towanda Formation. The upper third of the unit is characterized by a light gray, sandy, fossiliferous wackestone. Ostracod and bryozoan fragments are present, as well as relatively abundant echinoderms. Scattered areas of silicification were observed as nodules. Thin section analysis of this lithology shows a calcareous, fossiliferous sandstone. It is interpreted that quartz sand grains are locally abundant, and the overall lithology may be a sandy, fossiliferous limestone. Framework grains of quartz and minor amounts of feldspar are very fine- and fine-grained, subangular and subrounded, and moderately well sorted. Calcareous fossil fragments (mainly foraminifera) are abundant throughout. Anhydrite and calcite cements dominate; however, much of the matrix consists of dolomite mud. Scattered fine vugs are present within the dolomite mud matrix.

   The next unit downward in the Towanda Formation is present at 2720.0 feet. This unit is characterized as an anhydritic, coralline boundstone. Abundant colonial corals, many of which are replaced by silica and anhydrite, are present. The coralline units occur as discrete zones separated by shaly and calcareous laminations. Beneath the coralline zones, approximately 10 feet of light brown, sandy dolomite is present. This unit is partly calcareous, and contains lesser amounts of fossils than the overlying limestone. Thin section analysis of this dolomite reveals it to be a fossiliferous, very fine crystalline dolomite. Identifiable bioclasts include echinoderms, bryozoans, gastropods, and brachiopod shell fragments. Many of the bioclasts remain undolomitized, whereas the matrix is dominantly dolomite. Bioclasts and echinoderms appear to be susceptible to silica replacement, and many are partly silicified. Quartz grains are scattered throughout. Porosity types include intercrystalline, vuggy, and intraparticle. Intercrystalline porosity appears to connect small vugs, giving this rock relatively good permeability. Intraparticle pores within bioclastic fragments tend to be isolated and are interpreted to be ineffective. The lowermost third of the Towanda Formation is interpreted to be an algal wackestone. Abundant grain-coating algae are present around bioclastic particles. Silicification has occurred in this unit and again is present as nodules. Shaly laminations are also present and the unit is partly silty. A thin section of this lower Towanda Formation unit exhibits bryozoan and echinoderm debris. The matrix is commonly composed of dolomite, with minor amounts of calcite. Some of the bioclasts have been partly replaced by anhydrite or silica. Quartz grains are scattered throughout the

dolomitized matrix. The lower part of the Towanda Formation is interpreted to be tight (low permeability), though moderate quality reservoir rock may exist in the dolomitized unit and in the upper fossiliferous wackestone unit. The thin, coralline boundstone (in situ organic framework) unit appears to be tight, and may be a permeability barrier between reservoir quality rock in the upper Towanda and middle to lower Towanda Formation. Porosity in the Towanda Formation appears to be controlled by dolomitization, and leaching of calcareous material.

8. Holmesville Shale: This unit, present from 2750.0 to 2760.5 feet, is characterized by a reddish-green, dolomitic shale. This unit is commonly finely laminated to massive and contains scattered anhydrite nodules. The partly dolomitic and silty nature of this shale is interpreted to be characteristic of the interbedded shales throughout the Chase Group. It is interpreted that the Holmesville Shale is present in the Walters A#1 Well as Lithology XVI. This unit should act as a permeability barrier between the Towanda Formation above and the Fort Riley Formation below.

9. Fort Riley: This formation (2760.5-2797.2 (?) feet) consists of a light brown and light gray, fossiliferous lime wackestone/packstone. This unit is partially dolomitized in spots, and appears to be random. Identifiable fossil material includes crinoids, echinoids, bryozoans, brachiopods, and foraminifera. This unit is very similar to Lithology XVII from the Walters Well. As was observed in the Krider and Towanda Formations, some silicification of calcite has occurred, observed as nodules. These appear to be concentrated near the base of the Fort Riley Formation. Thin section analysis shows that vuggy and interparticle porosities are present. Also observed were some intraparticle pores within fossil fragments. These pores appear isolated and ineffective. The overall reservoir quality of the Fort Riley Formation is interpreted to be moderately poor. Porosity is present only in local areas, and the overall formation is interpreted to contain poor interconnected porosity. The lower contact of the Fort Riley Formation is very difficult to distinguish on the basis of core description. Therefore, the number "2797.2" feet is only an estimation of the contact between the Fort Riley Formation and the underlying Oketo Shale.

10. Oketo Shale: This unit is characterized as a dark gray, shaly mudstone/wackestone. Anhydrite nodules are scattered throughout. Lesser amounts of fossils are present than in the Fort Riley Formation above. The actual location of the Oketo Shale is questionable by core description because upper and lower contacts of this unit are gradational. Therefore, the location of the Oketo Shale at core depths of 2797.2 to 2808.0 feet is only an estimation.

11. Florence: The upper contact of the Florence Formation with the overlying Oketo Shale is indiscrete and was chosen on the basis of color (the Florence Formation is darker than the interpreted Oketo Shale) and amount of fossil material (the Florence Formation contains more fossil material than the interpreted Oketo Shale). This boundary was arbitrarily picked at 2808.0 feet. The Florence Formation extends

downward and is in contact with the underlying Matfield Shale at 2830.0 feet. The Florence Formation is characterized as a dark gray to black, fossiliferous mudstone/wackestone. This unit is similar to the basal portion of Lithology XVIII in the Walters Well. Abundant large, thin-shell brachiopods are present. Anhydrite nodules are scattered throughout the unit. This dark mudstone/wackestone grades downward into a silty sandstone. The sandstone is partly calcareous and contains scattered anhydrite nodules. A trace of burrowing was noted in the lower portion of the Florence Formation. By thin section analysis, the Florence Formation is interpreted to be tight. Very little porosity is present throughout the entire unit. Only traces of isolated intergranular porosity and interparticle porosity are present. In addition to relatively abundant, large brachiopods, other fossil material includes echinoderms, bryozoans, and foraminifera. In the lower portion of this interval, many bioclasts exhibit micrite envelopes, which may be algal in origin. Calcite was observed as a syntaxial cement on many echinoderm fragments. The overall reservoir quality of the Florence Formation is considered poor, due to the tight nature and lack of porosity throughout. The only porosity that exists was observed macroscopically in the lower sandstone portion of the unit.

12. Matfield Shale: This unit is present from 2830.0 to 2848.8 feet. The Matfield Shale is characterized as a massive and mottled, red shale. Many calcareous, vertical, undulatory structures were observed, and are interpreted to possibly be root traces. This unit is similar to Lithology XX in the Walters Well. The tight nature and thickness (20 feet) of the Matfield Shale will render it a permeability barrier between the Florence Formation above and the underlying Wreford Formation. No thin section of this interval was taken.

13. Wreford: The Wreford Formation, present between 2848.8 and 2870.0 feet, consists of a light gray to dark gray, fossiliferous wackestone. Abundant fossil debris includes crinoids, bryozoans, and scattered brachiopods and foraminifera. This lithology is similar to Lithology XXII in the Walters Well. Scattered throughout this unit are silica nodules, which are interpreted to have replaced original calcareous material. The lower portion of this interval is a medium gray, calcareous dolomite. Many fossil fragments are still calcite, whereas the majority of the matrix is dolomite. Identifiable fossil material from thin section includes foraminifera, crinoids, and brachiopods. Only a trace of vuggy porosity, along with minor interparticle and intercrystalline pores, is present. The overall reservoir quality of the Wreford Formation is interpreted to be poor. An overall lack of porosity and poor sorting of carbonate particles render this unit tight.

Inferred Environments of Deposition and Indicators (refer to Figure 1, General Core Description):

The entire Permian Chase Group core from the Anadarko Nordling A#1 Well is interpreted to have been deposited in cyclic sequences on a shallow carbonate shelf. As was observed in the Walters A#1 Well, the Nordling Well also 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 interpreted to be a paleosol) at the top. Because of consistent lithologies, and stratigraphic succession between the Nordling and Walters Wells, a direct correlation of sedimentary cycles may be observed. The following discussion of each cycle may be correlated to the five cycles discussed in the report on the Walters A#1 Well (RMD399).

1. Cycle 1 (2870.0-2830.0 feet): In the Nordling Well, the lowermost cycle in the cored interval extends from the base of the core (2870.0 feet, Wreford Formation) to 2830.0 feet (base of the Florence Formation). The Wreford Formation is interpreted to represent subtidal deposition. The presence of normal marine fauna (crinoids, bryozoans, brachiopods, and forams) was noted. As regression progressed, it is interpreted that an intertidal zone may have formed. No well developed intertidal zone, however, was noted in the Nordling Well. The uppermost Wreford Formation may represent this intertidal zone, but it is not very distinct. Overlying the Wreford Formation is the Matfield Shale, which is massive and mottled and commonly red. It is interpreted that the Matfield Shale represents paleosol development during maximum regression. Abundant leaching and alteration took place during the development of the paleosol, and the remaining material is considered to be a residuum of the original rock. The red portions of this shale unit are interpreted to have been oxidized by being present and subaerially exposed above the water table. Possible evaporation and concentration of trapped waters during subaerial exposure may have formed scattered anhydrite nodules. The introduction of silt at the upper portion of the Matfield Shale may indicate the transportation of coarser clastic material as marine waters were beginning to transgress.

2. Cycle 2 (2830.0-2750.0 feet): This cycle begins at the base of the Florence Formation (2830.0 feet) and ends at the base of the Towanda Formation (2750.0 feet). The lowermost Florence Formation is a silty sandstone unit, which may represent an intertidal zone. This zone is commonly burrowed and wavy laminated. Overlying the sandstone are carbonate units which include the upper portion of the Florence Formation, the Oketo Shale, and the Fort Riley Formation. It is interpreted that this entire carbonate sequence represents subtidal deposition during transgression, through maximum transgression, and regression of the marine waters. The Oketo Shale unit of dark gray, shaly mudstone may represent a period of maximum transgression. Because fewer fossils are present, lack of nutrients, and/or possible deposition below the clear, oxygenated zone may be indicated. The Fort Riley Formation, overlying the Oketo Shale, therefore, would represent the major part of the regressive portion in this depositional cycle. The uppermost portion of the Fort Riley Formation

becomes silty and shaly, and may represent the rapid regression of an intertidal zone. The overlying Holmesville Shale is present as a reddish-green, dolomitic shale. This unit is interpreted to represent a paleosol, developed similarly to the Matfield Shale in Cycle 1. The residual material is commonly siliciclastic and dolomite, interpreted to be less soluble material. The silicification of calcite in nodular texture in the Fort Riley Formation may represent waters moving downward associated with the subaerial exposure of the Holmesville Shale. These waters could mix with subsurface waters and formulate the proper conditions for the replacement of calcite by silica. The red portion of the Holmesville Shale is interpreted to represent oxidation by subaerial exposure above the water table. The greenish portion of the shale may represent stands of higher water table, and reduction of portions of the Holmesville Shale.

3. Cycle 3 (2750.0-2676.0 feet): The third depositional cycle in the Nordling A#1 Well begins at the base of the Towanda Formation (2750.0 feet) and extends through the overlying Gage Shale to the base of the Winfield Formation (2676.0 feet). The algal wackestone, sandy dolomite, and coralline boundstone of the Towanda Formation are interpreted to represent subtidal deposition. Deposition probably occurred within the photic zone, and may have periodically been affected by wave and tidal action.

   The presence of quartz grains throughout much of the Towanda Formation indicates a relatively close clastic source. This may be explained by proximal streams incised into a nearby tidal flat.

   In the Walters A#1 Well, an anhydritic dolomite unit was noted in the middle of the Towanda Formation. This unit was observed in the Nordling A#1 Well as a partially replaced, coralline boundstone. The original carbonate material has been highly altered and replaced by silica and anhydrite, but is interpreted not to represent a supertidal flat, as suggested by the Walters A#1 Well. It is postulated that this zone in the Walters Well is similar, except that all coralline textures may have been obliterated.

   As in the previous cycles, intertidal zones are difficult to isolate. The presence of a sandy, fossiliferous wackestone at the top of the Towanda Formation, and the silty nature of the base of the Gage Shale may represent the intertidal zone developed during regression of marine waters. The overlying Gage Shale is interpreted to represent a paleosol and is probably the residual material of much leaching and subaerial exposure. Again, the reddish portions of the shale unit represent weathering and oxidation above the water table, whereas intermittent greenish shale suggests a higher water table and reduction, for relatively short periods of time.

4. Cycle 4 (2676.0-2629.3 feet): The fourth sedimentary cycle in the Nordling A#1 core begins at the base of the Winfield Formation (2676.0 feet) and extends through the overlying Odell Shale to the base of the Krider Formation (2629.3 feet). The subtidal portion of this cycle is evident in the Winfield Formation. This lime wackestone/packstone contains abundant fossil debris, interpreted to have been derived from

a shallow carbonate shelf. The relatively large and unbroken nature of some bryozoans may indicate in situ deposition and little reworking of much of the fossil material. Water depth, therefore, was within the photic zone, and sufficient nutrients are interpreted to have been supplied by currents and wave action to support the biological community. The base of the overlying Odell Shale is observed as a silty, shaly sandstone which may represent the intertidal portion of this cycle. Because of the discrete nature of this intertidal zone, it may not be consistent laterally into adjacent wells other than the Walters A#1. The upper portion of this cycle is represented by the Odell Shale, which is a red shale that is greenish and light brown at the base, where the unit grades into a sandstone. This shale is interpreted to represent a paleosol, developed similarly to the Gage Shale, the Holmesville Shale, and the Matfield Shale. The mottled red and green coloration indicates weathering related to fluctuations in the water table. Leaching, oxidation, and reduction are common in paleosol development.

5. Cycle 5 (2629.3-2550.0 feet): The uppermost cycle in the Nordling Well begins at the base of the Krider Formation (2629.3 feet) and extends to the top of the core inclusive of the Herrington Formation (2550.0 feet). The Krider Formation is interpreted to be subtidal, although dolomitization has obliterated many original textures. Ghosts of bioclastic material were observed in thin section, and it is interpreted that a normal shallow marine fauna is present. Because the Krider Formation is more completely dolomitized than other subtidal units throughout the core, the subtidal interpretation for these rocks is only speculative.

   The overlying Paddock Shale is a dark gray and dolomitic shale, and interpreted not to represent a paleosol, but rather possibly "lagoonal" deposition. This deposition may have occurred behind some physical barrier, and represents extremely low energy and deposition of suspended sediment, dominantly clay. The intertidal zone in this cycle is interpreted to be represented by the sandstone interval in the Herrington Formation. Burrowing and ripple laminations suggest low turbulence, shallow marine deposition. Clastic material may be derived from streams and rivers, and possibly longshore currents, moving sand-sized sediment by saltation and traction. The uppermost Herrington unit in the Nordling core represents the supratidal and paleosol portions of this cycle. A thin, poorly developed, "chicken-wire" anhydrite unit towards the base of the Herrington Formation indicates minor tidal flat development with hypersaline waters.

   Continued evaporation and regression resulted in paleosol development, reflected by the shale at the top of the cored interval. This shale is similar to other paleosol units throughout this core and the Walters core, and is mottled green and red. The probable cause of the mottling was a fluctuating water table. Fluctuating water table is interpreted to have moved oxidation and reduction zones up and down, possibly related to shifts in marine water levels. Another interpretation is that wet and dry seasons may have been present, resulting in raising and lowering of the water table, and producing reduction (green) and oxidation (red), respectively.

Environmental Generalizations:

1. Relatively low energy: Lack of well developed sand beaches, no distinct "storm" deposits, and zones of extensive bioturbation.

2. Predominantly normal marine salinities: Suggested by normal marine fauna throughout the core, and the lack of bedded anhydrite and halite.

3. Shallow water: Deposition is interpreted to have occurred mostly within the photic zone, and documented by the presence and local abundance of grain-coating algae, as well as the development of a thin, coralline boundstone unit within the Towanda Formation.

4. Cycle sedimentation: Reflected in the five shoaling upward sequences, each capped by moderately well developed paleosols.

5. Fluctuating water table at the top of each cycle (probably in response to rising and lowering sea level) or wet and dry seasons: Reflected in the red and green coloration of paleosols (Matfield Shale, Holmesville Shale, Gage Shale, Odell Shale, and upper Herrington Shale).

6. Relative proximal clastic source: Reflected in local "intertidal" siltstone and sandstone units and dispersed sand and silt throughout much of the core. It is interpreted that much of this clastic material was transported to the carbonate shelf area by streams and rivers originating in an adjacent upland.

Diagenetic Events:

Petrographic evidence indicates that the diagenetic history of the cored interval involved "normal" marine, fresh, and some hypersaline waters. Subaerial exposure also affected the uppermost unit (paleosol) in each depositional cycle. Diagenetic events in the Nordling A#1 Well are essentially identical to those in the Walters A#1 Well.

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

1. Recrystallization: In the carbonates, recrystallization of fine carbonate material to microspar and sparry calcite has reduced some porosity. Primary porosity in carbonates at the time of deposition is interpreted to be relatively high (commonly 30 to 50% and possibly higher). Recrystallization has therefore reduced this number significantly. Because faunal constituents present are assumed to have originally been composed of aragonite and high magnesium-calcite, and the carbonate mud was probably low magnesium-calcite, recrystallization most likely occurred at different rates.

2. Cementation: Marine and fresh water carbonate cements, as well as anhydrite and dolomite, have reduced porosity in all carbonate rocks. Cementation has also reduced some porosity in the sandstone

units (principally the Herrington Formation). Carbonate cement types are dominated by isopachous rim cements, and syntaxial cements on fossil grains. Some late-stage calcite cementation was observed in some of the dolomitized units such as the Krider Formation, and in the dolomite portion of the Towanda Formation.

3. Dolomitization: Dolomitization has greatly increased porosity in completely dolomitized intervals, principally the Krider Formation. As was observed in the Walters A#1 Well, the Krider Formation contains abundant vuggy and intercrystalline pores. This resulted in a well developed, well interconnected pore system. In partially dolomitized intervals, remnant calcite is present as micritic matrix, and original fossil material. Much of this calcite occludes pore space. Original particle size probably has affected rates of dolomitization. Finer grain material (micrite) may have dolomitized at a slower rate than coarser (bioclastic) -grained material.

4. Leaching: Leaching of bioclastic material has formed molds and vugs in much of the carbonate units in the Nordling core. Leaching of dolomite and calcite matrix, calcite and dolomite cements, as well as a few unstable framework grains, have increased porosity in the sandstones of the Herrington Formation and lower Florence Formation. It is interpreted that much of this leaching may have occurred during the development of paleosol material at the top of each cycle. Downward percolating waters undersaturated with respect to unstable constituents may have initiated the dissolution of many of these grains and particles.

5. Anhydrite replacement: Anhydrite replacement generally has had little effect on the Nordling A#1 core. Some anhydrite infilling of vugs has somewhat reduced porosity in local areas, however.

6. Silica replacement: Silicification of carbonate material exists in nodular form in many units throughout the core. It is interpreted that this replacement is only localized, and no completely replaced beds were observed that were completely replaced by silica, the source of which is somewhat questionable. Significant amounts of silica may have been derived by the leaching of material during the development of paleosols. This downward percolating water may have mixed with subsurface waters to produce conditions conducive to the replacement of calcite by silica. The effect of silica replacement on porosity is generally minimal. A thin section through a siliceous nodule in the Towanda Formation reveals it contains abundant micropores and relict limestone textures. These microporous, siliceous areas are interpreted not to have significantly increased overall porosity and reservoir quality of these units.

TABLE 3

Porosity Types, Abundances, Lithologies, and Interpreted Potential Reservoir Quality
(excluding shale units)

Formation (Core Depth-ft.)	Porosity Types	Abundance	Interpreted Effectiveness	Interpreted Potential Reservoir Quality	Dominant Lithology
Herrington (2550.0-2585.8)	Intergranular	MA	E	Moderate	Sandstone
	Microporosity	MA	I (generally)		
	Intragranular	NA	I - without connection to intergranular system		
Krider (2593.3-2629.3)	Vuggy	A	E due to abundant	Excellent	Dolomite
	Moldic	A	E intercrystalline porosity		
	Intercrystalline	A	E		
	Intracrystalline	NA	I (generally)		
	Fracture	MA (locally)	E (where open)		
Winfield (2648.8-2676.0)	Intercrystalline (particle)	MA	E	Moderate	Limestone
	Vuggy/Moldic	MA	E - if connected to intercrystalline porosity		
	Intraparticle	MA	I (generally)		
	Microporosity	A (in micrite-rich rocks)	I (generally		
Towanda (2703.8-2750.0)	Intercrystalline (particle)	MA	E	Moderate	Limestone/ Dolomite
	Intraparticle	NA	I		
	Microporosity	NA	I (generally)		
Fort Riley (2760.5-2797.2)	Interparticle	MA	E	Moderate - Poor	Limestone
	Intraparticle	NA	I		
	Microporosity	NA	I (generally)		
Florence (2808.0-2830.0)	Intergranular	NA	E (locally)	Poor - carbonates Moderate - sandstones (Interpreted)	Limestone/ Sandstone
	Interparticle	NA	E (locally)		
	Microporosity	NA	I		
Wreford (2848.8-2870.0)	Interparticle	NA	E (locally)	Poor	Limestone/ Dolomite
	Intraparticle	NA	I		
	Microporosity	A (in micrite-rich rocks)	I		

Abundance: A - Abundant NA - Not abundant MA - Moderately abundant

Effectiveness: E - Effective I - Ineffective

PLATE 4

A. 2751.0 feet: Holmesville Shale. Reddish-green, dolomitic shale. Note the somewhat mottled texture and lack of sedimentary structures.

B. 2770.0 feet: Fort Riley Formation. Light brown and light gray, fossiliferous wackestone/packstone. Dark areas are areas of anhydrite replacement. Note the portions of anhydrite nodules on the left side of the slab. Also note the scattered bioclastic debris throughout.

C. 2796.0 feet: Fort Riley Formation. Silica replacement is observed as nodular areas, which are lighter in color. Note the scattered anhydrite nodules and the scattered bioclasts, many of which are fusulinids.

D. 2818.0 feet: Florence Formation. Dark gray to black, fossiliferous mudstone/wackestone. Note the large, thin-shell brachiopods, and the white crinoid fragments throughout.

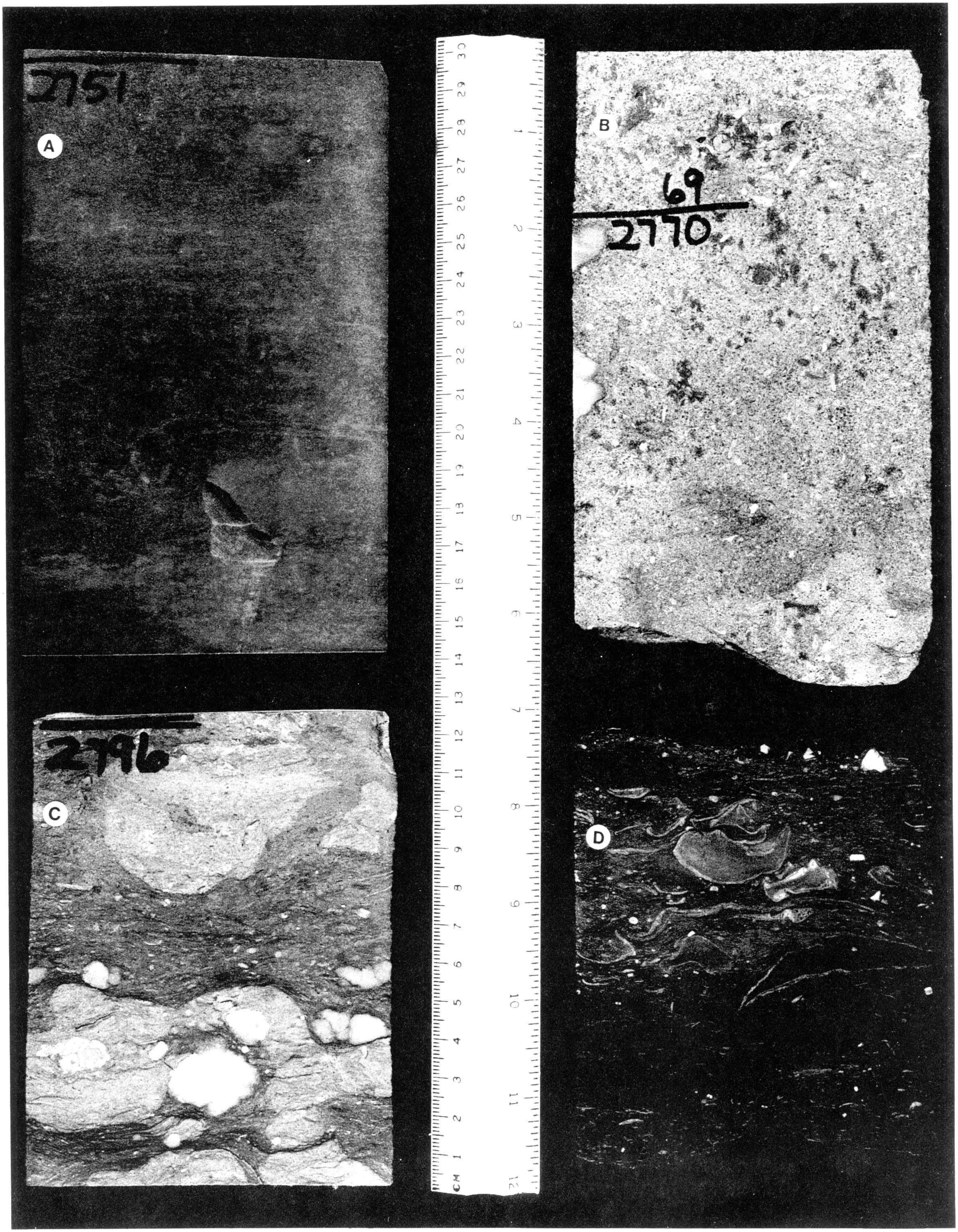

2751
A
B
69
2770
2796
C
D

PLATE 5

A. 2827.0 feet: Florence Formation. Shaly, silty sandstone. Note the wavy laminations and the trace of burrowing (disrupting laminations) throughout. A small, closed fracture which offsets laminations may be observed at upper right.

B. 2844.0 feet: Matfield Shale. Mottled, red shale. Note the calcareous, vertical, undulatory structures, which are interpreted to possibly be root traces.

C. 2863.0 feet: Wreford Formation. Light gray to dark gray, fossiliferous wackestone. Areas of silica replacement are observed as light-colored nodules. Note the shaly laminations and poorly developed stylolites at center.

D. 2867.0 feet: Wreford Formation. Medium gray, calcareous dolomite. Note the abundant scattered, bioclastic material, most of which is still calcite. The matrix of this sample is dominantly dolomite. Note the poorly developed stylolites at the bottom of the slab. Darker fossil grains in this slab are commonly coated by algae.

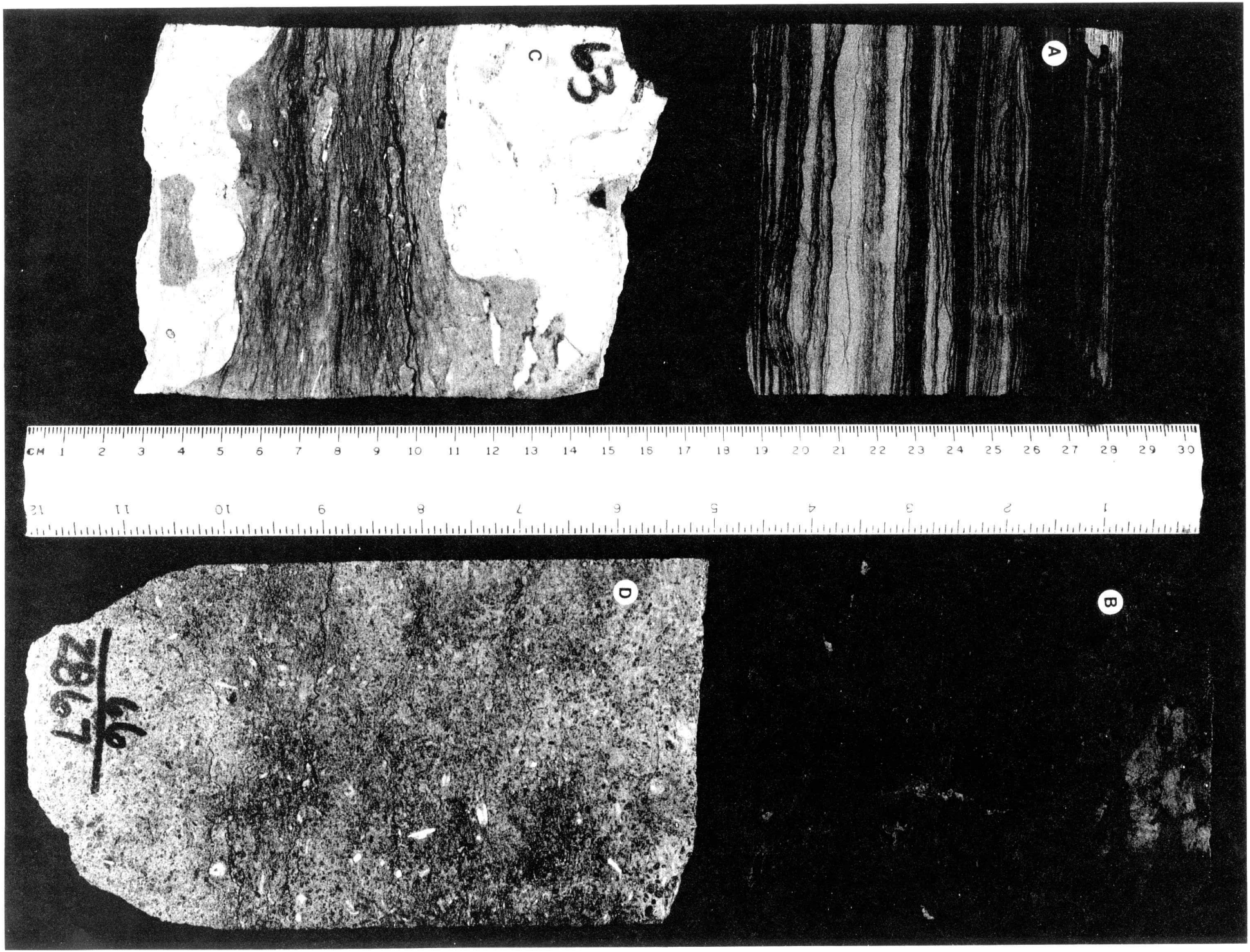

C
53
A
CM 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
D
B

TABLE 2

Summary of X-ray Diffraction Data

		Bulk						<5μ		
Depth (ft)	Formation	Quartz	Feldspar	Calcite	Dolomite	Anhydrite	Total Clay Minerals	Illite	Chlorite	Expandable Mixed-layer
2633.0	Odell	38	2	1	44	tr	15	56	28	16

This sample of the Odell Formation is interpreted to represent residual material from the development (leaching, weathering, oxidation, etc.) of this paleosol unit. Note the relative abundance of siliciclastic and clay material.

THIN SECTION PETROLOGY - REMARKS

Sample (ft.)	
	Herrington Formation
2566.2	Dolomitic sandstone. This sandstone is very fine- to fine-grained, subangular to angular, and moderately sorted. Microcrystalline dolomite occurs as cement throughout. Vuggy porosity is abundant in the cement. Several anhydrite-filled vugs are present. Pyrite is disseminated throughout.
2583.2	Dolomitic sandstone. This sandstone is very fine-grained, subangular to angular, and well sorted. Microcrystalline dolomite is present in portions of the sample as laminae. Abundant carbonaceous debris occurs in the dolomite. Some anhydrite cement may be present. The sample exhibits steep, planar crossbedding.
	Krider Formation
2600.3	Algal dolomite. This very fine to fine crystalline dolomite exhibits abundant vuggy and intercrystalline porosity. Ootoid algae appear to be abundant throughout. A number of vugs have been filled with anhydrite. Bryozoan and echinoderm debris also appears to be scattered throughout.
2608.1	Dolomite. Intercrystalline and vuggy porosity is abundant in this very fine to fine crystalline dolomite. Many of the vugs appear to be dissolution-enhanced molds. Algal (?) material appears to occur in much of the sample. Some anhydrite-filled vugs are present. A few echinoderm fragments were noted.
2612.6	Algal dolomite. This very fine to fine crystalline dolomite also appears to contain abundant ootoid algae (?). Vuggy and intercrystalline porosity is abundant throughout. A number of anhydrite-filled vugs are present. Several echinoderm fragments were noted.
2620.3	Very fine crystalline dolomite. Intercrystalline and vuggy porosity is also very abundant throughout this sample. Several anhydrite-filled vugs are present. A phosphatic fossil fragment was noted.
2624.3	Fossiliferous dolomite. This very fine crystalline dolomite contains scattered calcareous bioclasts. This material is mostly brachiopod shell fragments and some bryozoan debris. Intercrystalline, vuggy, and moldic porosity occurs throughout. A trace of anhydrite was noted.
	Winfield Formation
2654.6	Anhydritic, calcareous dolomite. This dolomite is microcrystalline to very fine crystalline. Anhydrite-filled molds and vugs occur throughout. Calcareous bioclasts (echinoderms and

Wreford Formation

2855.7 Dolomitic packstone. Echinoderms, bryozoans, and shell fragments are abundant throughout the sample. Forams are also present. Many of the bioclasts exhibit algal micrite envelopes. Syntaxial calcite cement is present around some of the bioclasts. Some of the fossils have been partly replaced by anhydrite and silica. Quartz is scattered throughout. The matrix has been largely dolomitized.

2862.7 Fossiliferous chert. This sample contains abundant silicified, bioclastic debris. Most of this material appears to be brachiopod debris and sponge spicules. One portion of the sample is calcareous and dolomitic, with abundant bioclastic debris. A large bryozoan is present. Several fractures filled with calcite and anhydrite were noted. Vuggy porosity occurs in much of the chert.

2866.2 Sandy, fossiliferous dolomite. Very fine-grained quartz is abundant throughout the sample. Bioclastic debris occurs throughout and includes echinoderms, forams, bryozoans, trilobites, pelecypods, and brachiopods. Some of the fossils have algal envelopes. Some have been partly silicified. A trace of vuggy porosity occurs.

APPENDICES

General Core Description

Selected Core Photos

X-ray Diffraction Data

Thin Section Petrology Remarks

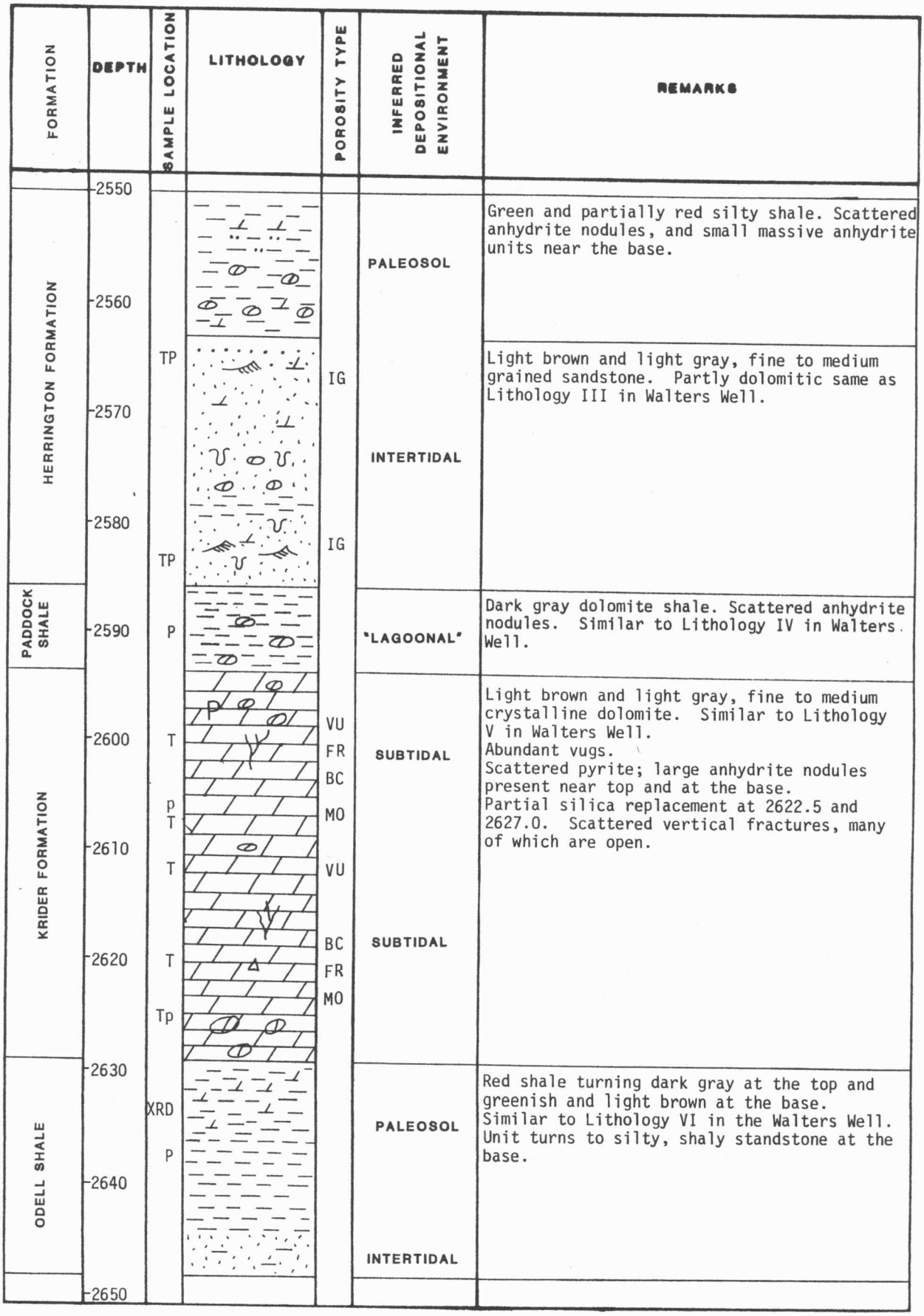
Thin Section Photomicrographs

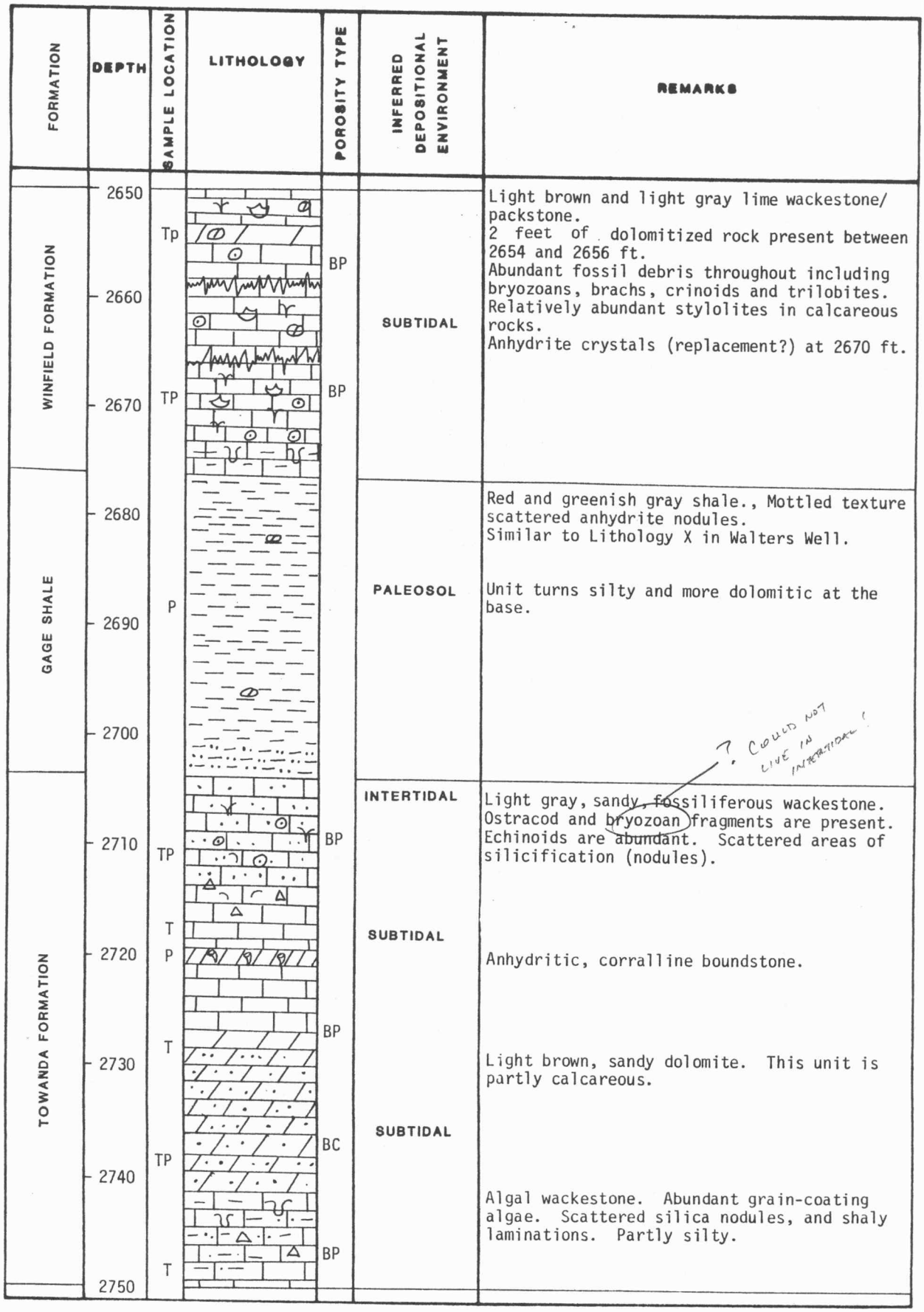
GENERAL CORE DESCRIPTION

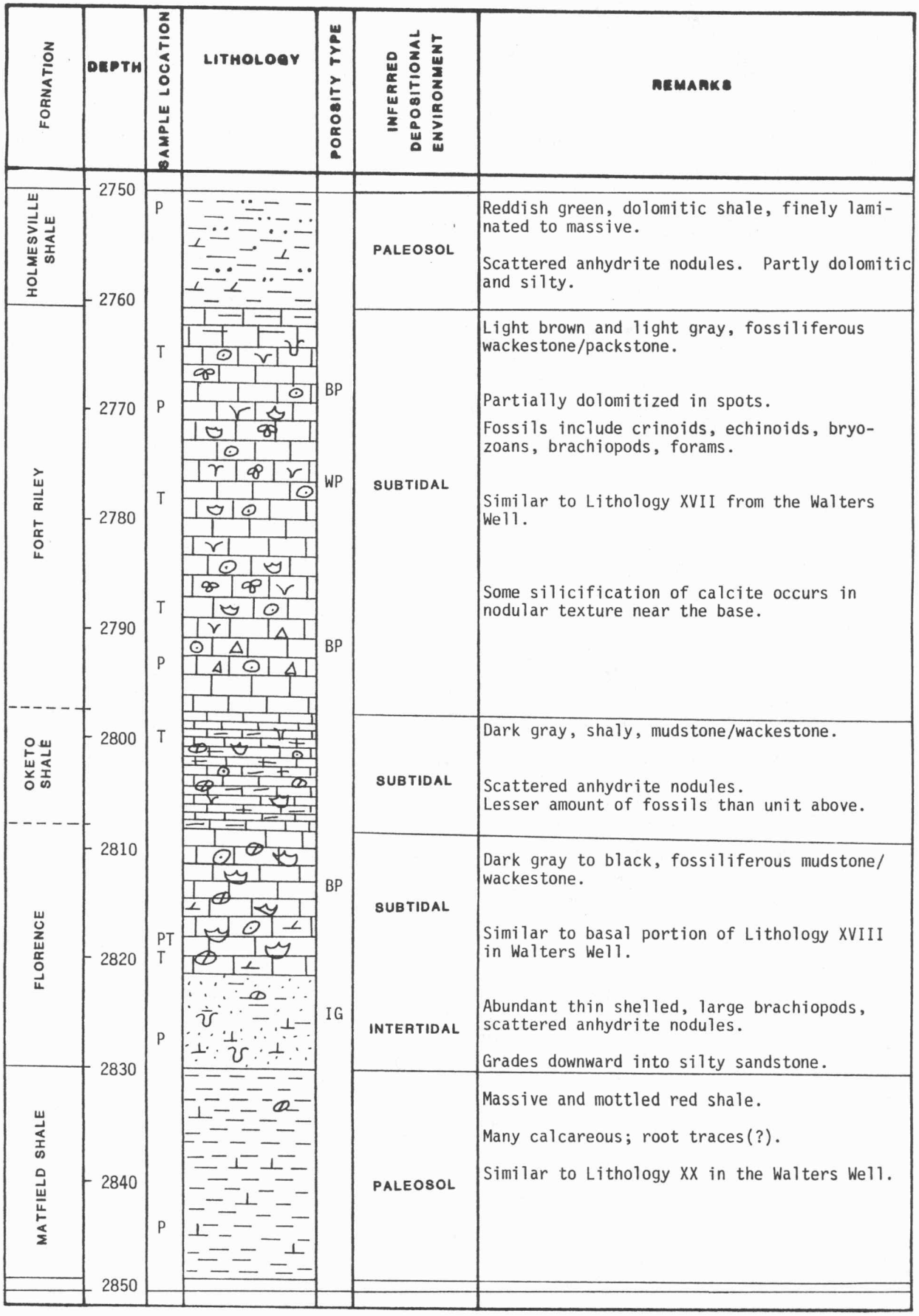
ANADARKO PRODUCTION COMPANY

NORDLING A#1 WELL

STEVENS COUNTY, KANSAS




FORMATION
DEPTH
SAMPLE LOCATION
LITHOLOGY
POROSITY TYPE
INFERRED DEPOSITIONAL ENVIRONMENT
REMARKS
WINFIELD FORMATION
GAGE SHALE
TOWANDA FORMATION
2650
2660
2670
2680
2690
2700
2710
2720
2730
2740
2750
Tp
TP
P
T
BP
BC
SUBTIDAL
PALEOSOL
INTERTIDAL
Light brown and light gray lime wackestone/ packstone.
2 feet of dolomitized rock present between 2654 and 2656 ft.
Abundant fossil debris throughout including bryozoans, brachs, crinoids and trilobites.
Relatively abundant stylolites in calcareous rocks.
Anhydrite crystals (replacement?) at 2670 ft.
Red and greenish gray shale., Mottled texture scattered anhydrite nodules.
Similar to Lithology X in Walters Well.
Unit turns silty and more dolomitic at the base.
?. COULD NOT LIVE IN INTERTIDAL
Light gray, sandy, fossiliferous wackestone.
Ostracod and bryozoan fragments are present.
Echinoids are abundant. Scattered areas of silicification (nodules).
Anhydritic, corralline boundstone.
Light brown, sandy dolomite. This unit is partly calcareous.
Algal wackestone. Abundant grain-coating algae. Scattered silica nodules, and shaly laminations. Partly silty.


FORMATION
DEPTH
SAMPLE LOCATION
LITHOLOGY
POROSITY TYPE
INFERRED DEPOSITIONAL ENVIRONMENT
REMARKS
HOLMESVILLE SHALE
FORT RILEY
OKETO SHALE
FLORENCE
MATFIELD SHALE
2750
2760
2770
2780
2790
2800
2810
2820
2830
2840
2850
P
T
P
T
T
P
T
PT
T
P
P
BP
WP
BP
BP
IG
PALEOSOL
SUBTIDAL
SUBTIDAL
SUBTIDAL
INTERTIDAL
PALEOSOL
Reddish green, dolomitic shale, finely laminated to massive.
Scattered anhydrite nodules. Partly dolomitic and silty.
Light brown and light gray, fossiliferous wackestone/packstone.
Partially dolomitized in spots.
Fossils include crinoids, echinoids, bryozoans, brachiopods, forams.
Similar to Lithology XVII from the Walters Well.
Some silicification of calcite occurs in nodular texture near the base.
Dark gray, shaly, mudstone/wackestone.
Scattered anhydrite nodules.
Lesser amount of fossils than unit above.
Dark gray to black, fossiliferous mudstone/wackestone.
Similar to basal portion of Lithology XVIII in Walters Well.
Abundant thin shelled, large brachiopods, scattered anhydrite nodules.
Grades downward into silty sandstone.
Massive and mottled red shale.
Many calcareous; root traces(?).
Similar to Lithology XX in the Walters Well.

NORDLING A#1 Continued

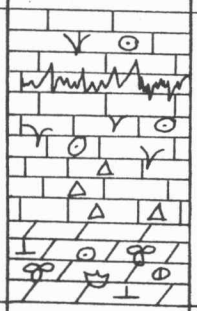
FORMATION	DEPTH	SAMPLE LOCATION	LITHOLOGY	POROSITY TYPE	INFERRED DEPOSITIONAL ENVIRONMENT	REMARKS
	2850					
WREFORD FORMATION		T		BP	SUBTIDAL	Light gray to dark gray, fossiliferous wackestone. Abundant crinoids, bryozoans, and scattered brachiopods and forams. Similar to Lithology XXII in Walters Wells.
	2860	PT		WP		Scattered silica replacement nodules. Medium gray, calcareous dolomite.
		T				
		P		BC		Many fossils are calcareous, while matrix is dolomite.
	2870					

PLATE 1

A. 2566.0 feet: Herrington Formation. Light brown to light gray, fine- to medium-grained sandstone. Note the inclined laminations across the center of this slab, indicating cross stratification.

B. 2583.0 feet: Herrington Formation. This gray, fine- to medium-grained sandstone exhibits climbing ripple lamination. Some burrowing has somewhat homogenized portions of this slab; however, the cross stratification may still be seen.

C. 2591.0 feet: Paddock Shale. Dark gray, dolomitic shale. Note the relatively abundant scattered anhydrite nodules. Also note the small, calcite-filled fractures on the bottom half of this slab.

D. 2607.0 feet: Krider Formation. Light brown, fine to medium crystalline dolomite. Note the abundant open vugs. Also note the dark, bioclastic material, preserved even though this sample is completely dolomitized.

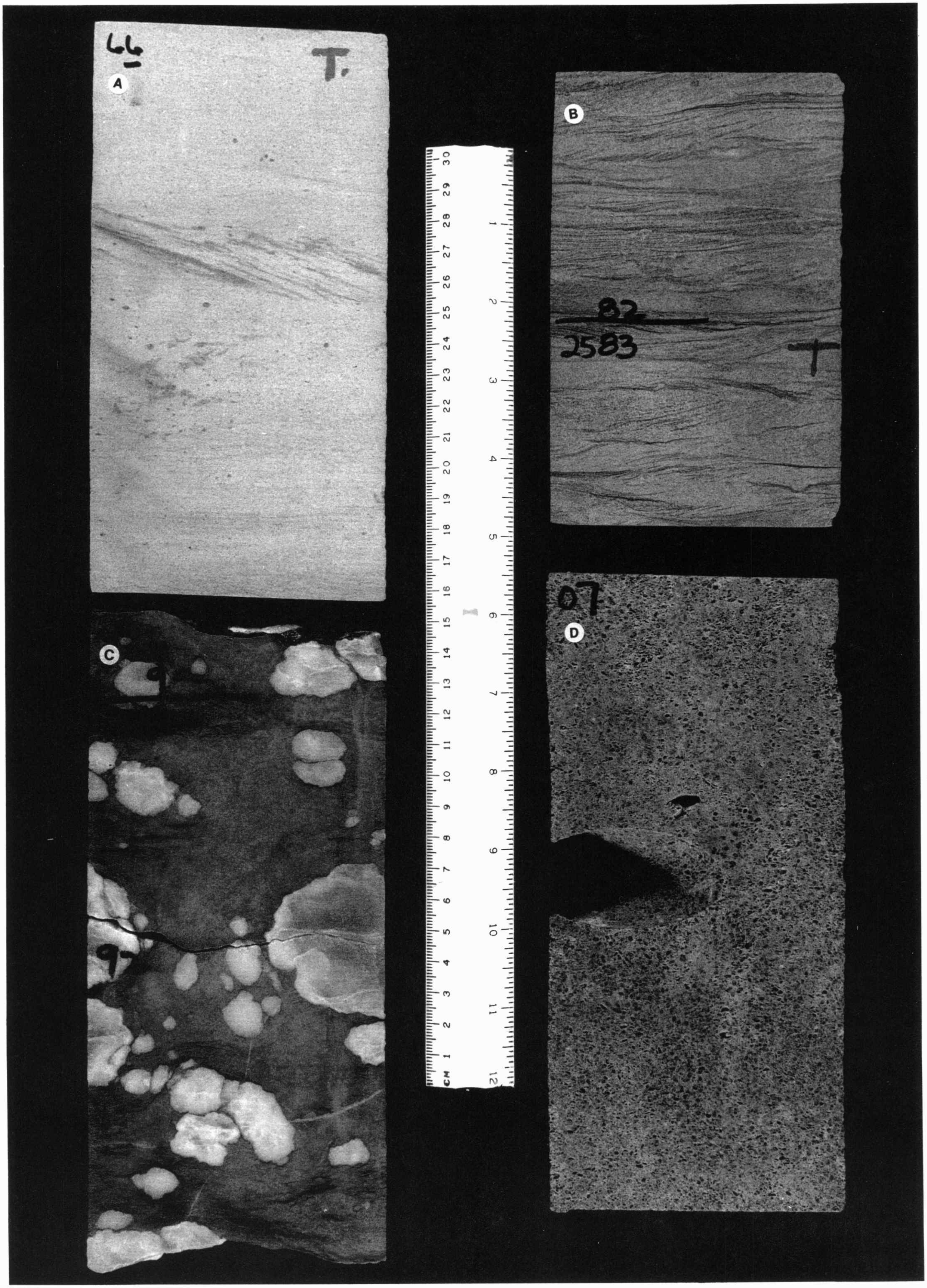

A
B
82
2583
C
D
07

PLATE 2

A. 2626.0 feet: Lower Krider Formation. Light brown, finely crystalline dolomite. Note the abundant very fine vugs, and sucrosic texture of this dolomite. Also note the small anhydrite nodule at the footage break between 25 and 26.

B. 2637.0 feet: Odell Shale. Red and greenish-gray, mottled shale. Note the hairline fractures towards the bottom of this slab, and the mottled texture due to color variations.

C. 2655.0 feet: Winfield Formation. Light brown and light gray, lime wackestone/packstone. Note the abundant fossil debris throughout this slab. Also note the lack of vugs, as was observed in previous Krider Formation slabs.

D. 2669.0-2670.0 feet: Winfield Formation. This light brown, lime wackestone/packstone shows abundant fossil material in the upper portions of the slab. Note the white crinoid fragments. In the lower portion of the slab, anhydrite crystals (dark) have partially replaced some of the original calcite.

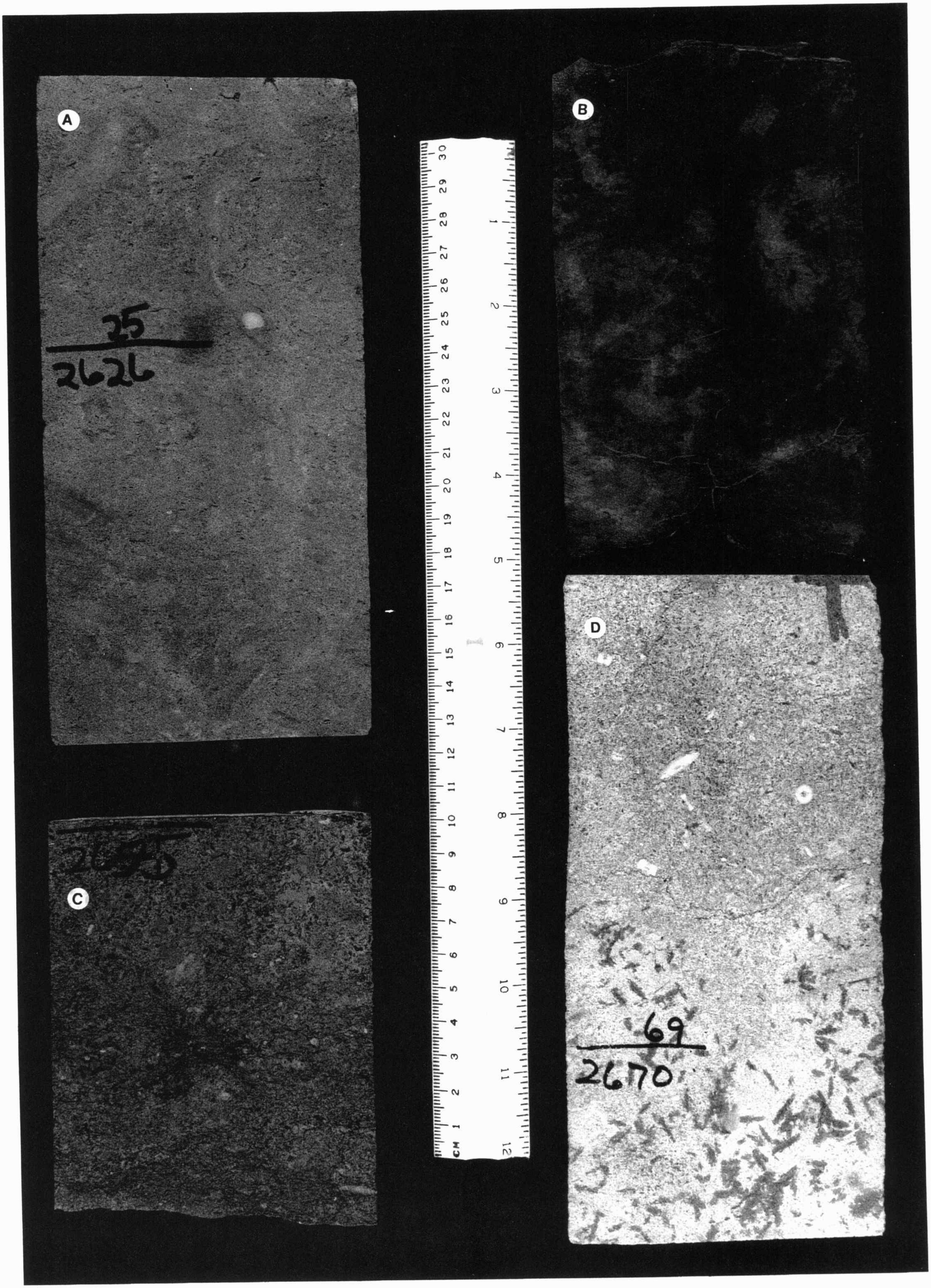

A
25
2626
B
C
D
69
2670

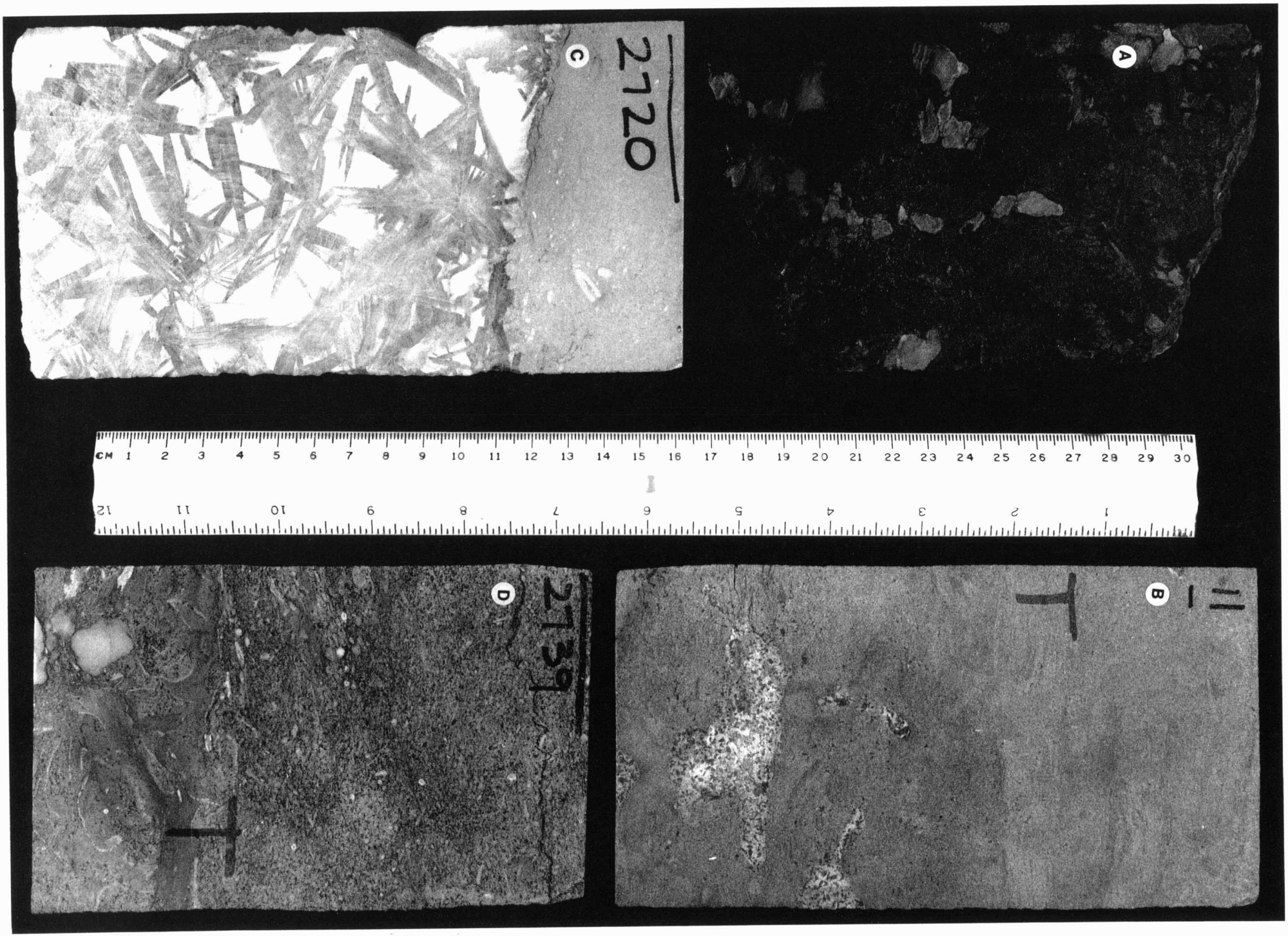
PLATE 3

A. 2689.0 feet: Gage Shale. Red and greenish-gray shale. Note the mottled texture and the scattered anhydrite nodules.

B. 2711.0 feet: Towanda Formation. Light gray, sandy, fossiliferous wackestone. The light, nodular areas towards the bottom of this slab are areas of silica replacement. Small, dark anhydrite crystals are associated with these siliceous nodules.

C. 2720.0 feet: Towanda Formation. Anhydritic, coralline boundstone. Light areas are coral, which has been replaced by silica. Numerous lath-shaped anhydrite crystals appear to have also replaced original coralline material.

D. 2739.0 feet: Towanda Formation. Light brown, sandy dolomite. Note the abundant fossil material preserved in this partially dolomitized rock. Also note the anhydrite nodules at lower left, and the stylolite in the upper portions of the slab.


C
2720
A
CM 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
12 11 10 9 8 7 6 5 4 3 2 1
D
2139
B

Sample Designation: 2566.2 feet Herrington Formation

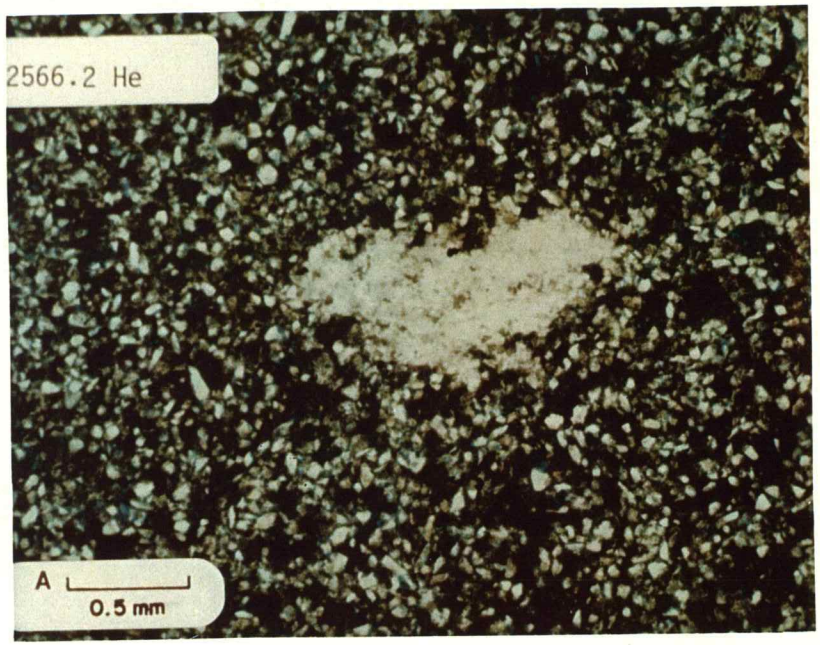
View A, 35X, Plane Light. This dolomitic sandstone is very fine- to fine-grained, subangular to angular, and moderately sorted. The white patch at center is anhydrite. Note the abundant porosity throughout, created by dissolution of the dolomite matrix.

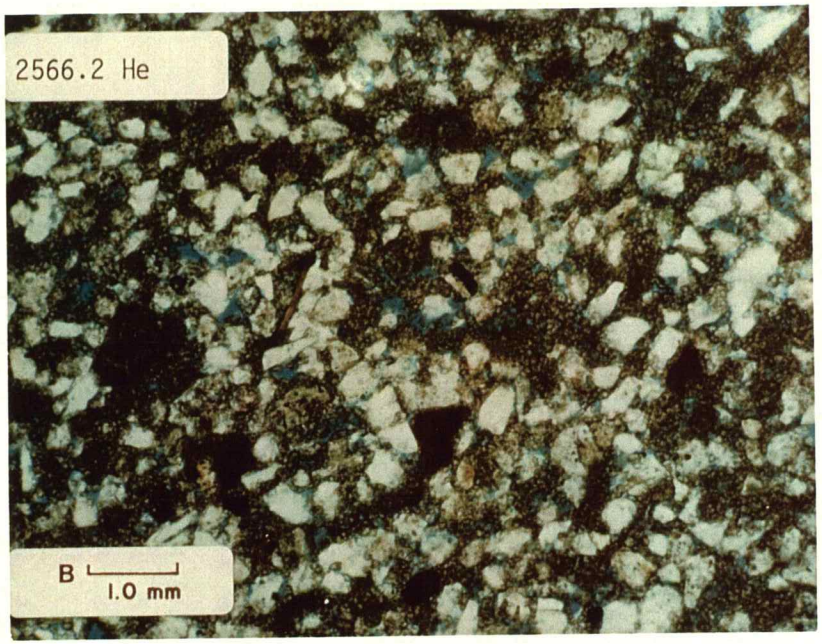
View B, 80X, Plane Light. This is a closer view of the microcrystalline dolomite matrix that cements this sandstone. Notice the vuggy porosity within the dolomite, which is due to dissolution. The elongate grain just left of center is biotite. The opaque grains at bottom are pyrite.

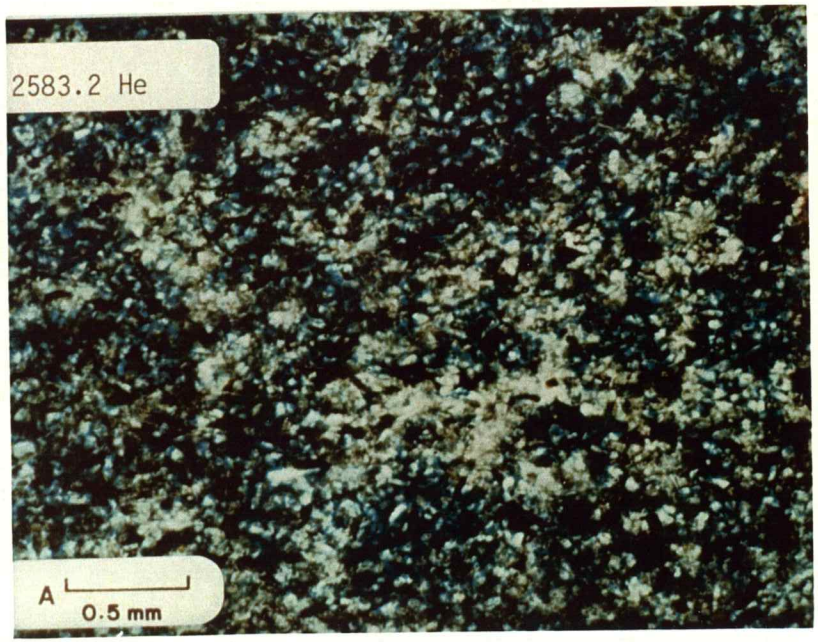
Sample Designation: 2583.2 feet Herrington Formation

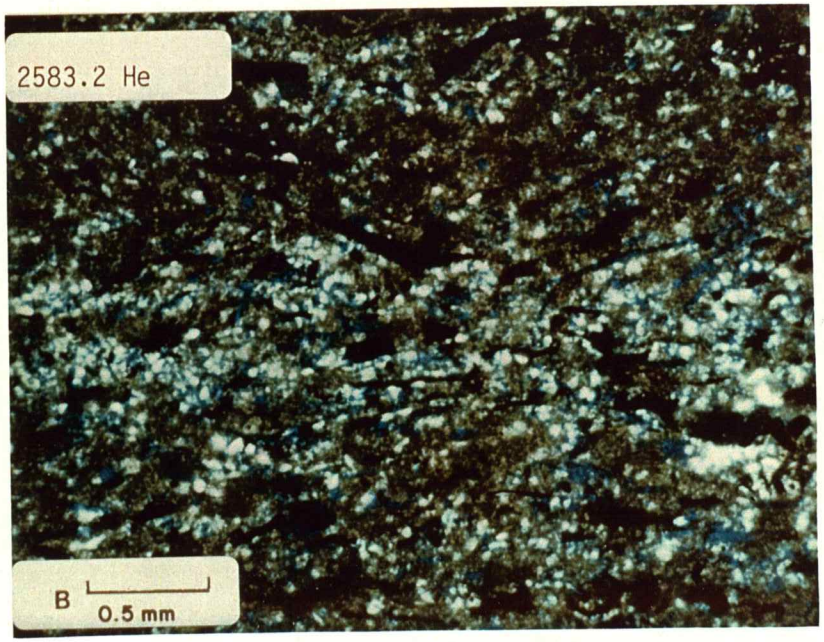
View A, 35X, Plane Light. This dolomitic sandstone is very fine-grained, subangular to angular, and well sorted. The opaque material scattered throughout the view is carbonaceous debris.

View B, 35X, Plane Light. The green areas throughout this photo are microcrystalline dolomite. Some of the elongate, opaque material is interpreted to be altered biotite. Much of this material is also pyritic, carbonaceous debris. Some vuggy porosity may be observed throughout the dolomite.


2566.2 He
A
0.5 mm


2566.2 He
B
1.0 mm


2583.2 He
A
0.5 mm


2583.2 He
B
0.5 mm

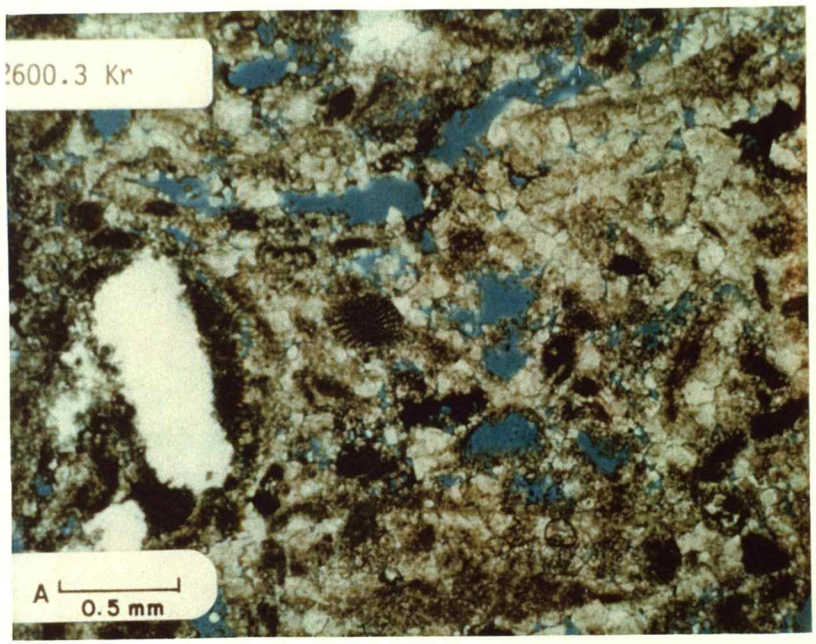
Sample Designation: 2600.3 feet Krider Formation

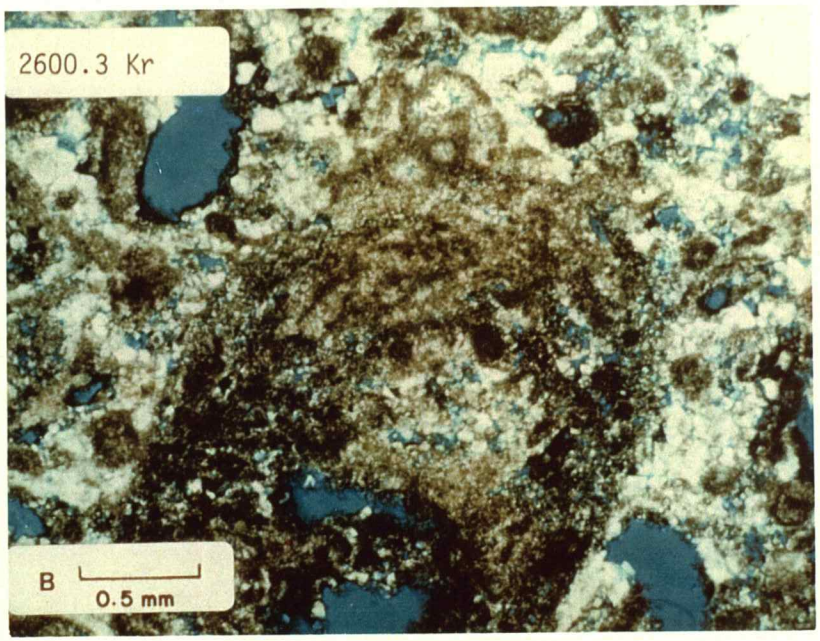
View A, 35X, Plane Light. This very fine to fine crystalline dolomite exhibits abundant vuggy and intercrystalline porosity. The large, white patch on the left side is anhydrite. The bioclast at center is an echinoderm.

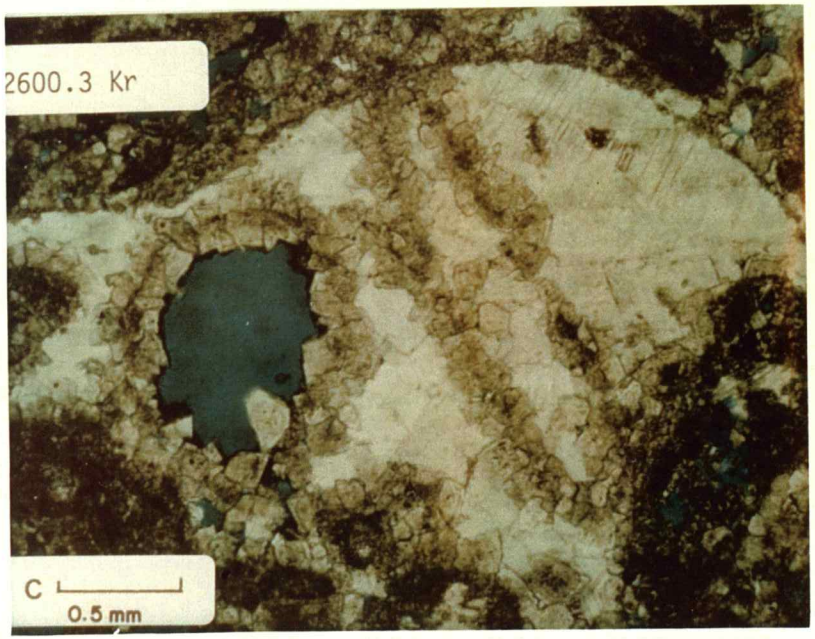
View B, 35X, Plane Light. The circular structure at center is interpreted to be algal. What is interpreted to be an encrusting foram may be seen on top of the algae. Algae appear to be very abundant throughout this sample. Again, note the abundant vuggy and intercrystalline porosity.

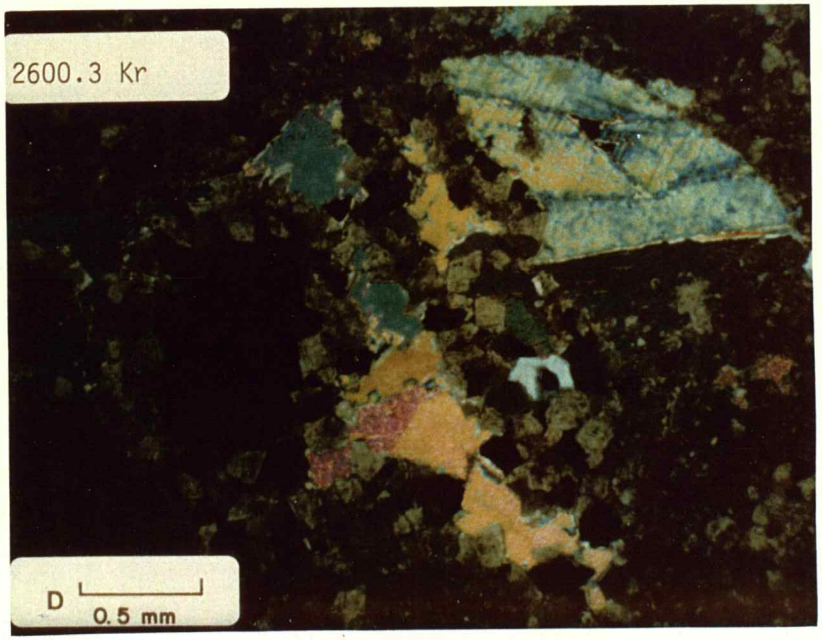
View C, 35X, Plane Light. The large white area in this view is a vug or mold which has been filled by anhydrite. Note the large vug on the left side which may be due to dissolution of anhydrite.

View D, 35X, Crossed Nicols. This is the same area as that in View C. The high birefringence of anhydrite is easily distinguished from the surrounding dolomite. This anhydrite is also interpreted to be filling material rather than replacement.


2600.3 Kr
A
0.5 mm


2600.3 Kr
B
0.5 mm


2600.3 Kr
C
0.5 mm


2600.3 Kr
D
0.5 mm

Sample Designation: 2608.1 feet Krider Formation

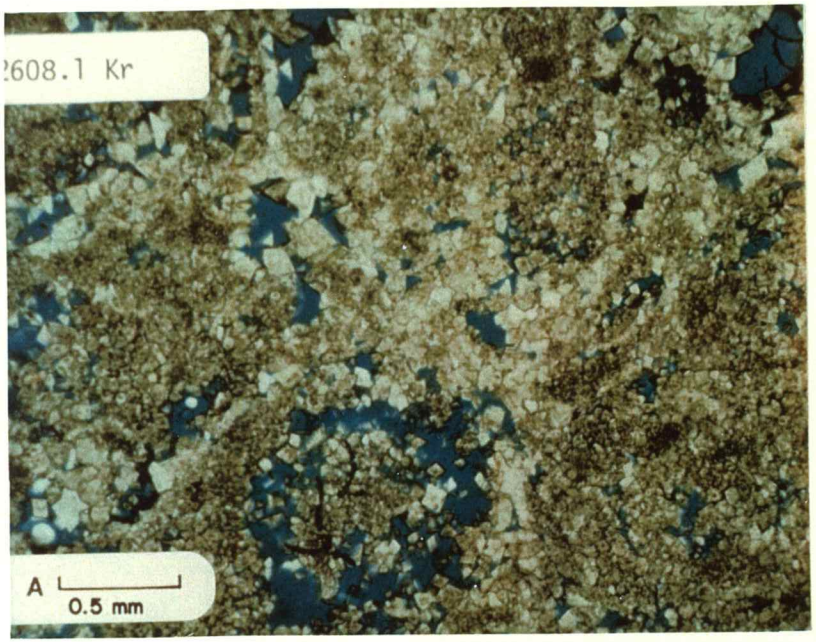
View A, 35X, Plane Light. This very fine to fine crystalline dolomite contains abundant vuggy and intercrystalline porosity. Some of the vugs are interpreted to be dissolution-enhanced molds.

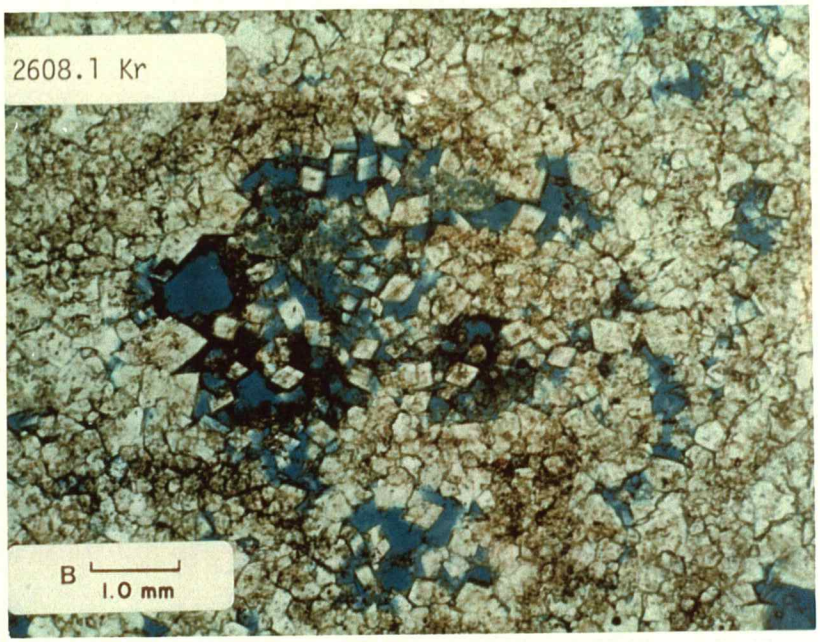
View B, 80X, Plane Light. This is a closer view of one of the vugs in this sample. The circular nature of this vug suggests it may originally have been an echinoderm. The dark material is probably clay.

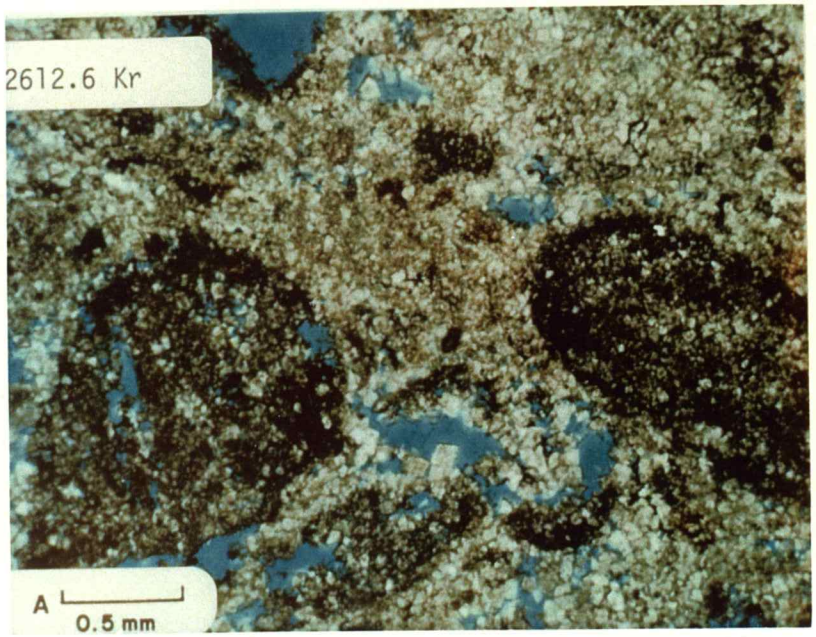
Sample Designation: 2612.6 feet Krider Formation

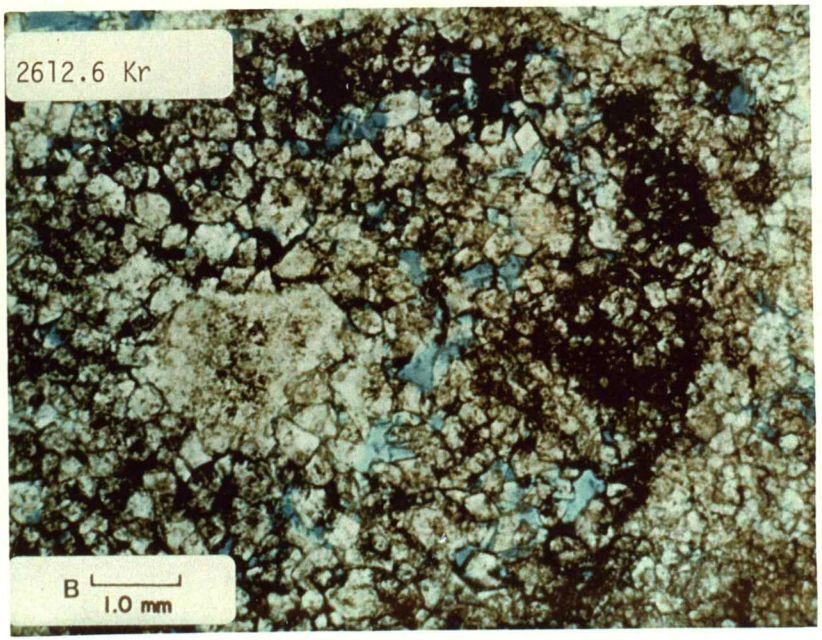
View A, 35X, Plane Light. This very fine to fine crystalline dolomite also contains abundant vuggy and intercrystalline porosity. The dark areas appear to be organic in nature and outline the original particle size. These areas may also be algal in nature.

View B, 80X, Plane Light. This is a closer view of one of the organic structures in this sample. The circular nature of this dark area suggests it may originally have been an echinoderm. Note the intercrystalline porosity within this area.


2608.1 Kr
A
0.5 mm


2608.1 Kr
B
1.0 mm


2612.6 Kr
A
0.5 mm


2612.6 Kr
B
1.0 mm

Sample Designation: 2620.3 feet Krider Formation

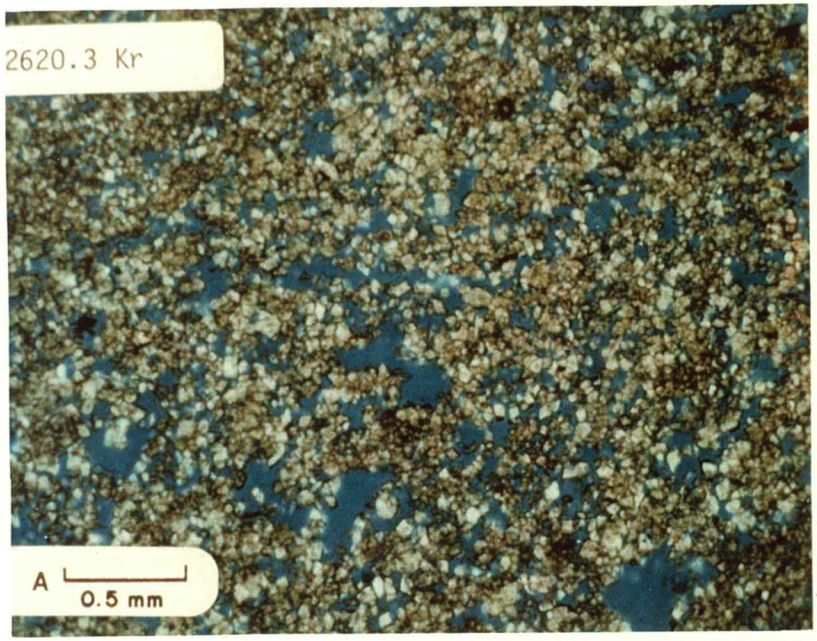
View A, 35X, Plane Light. This very fine crystalline dolomite exhibits very abundant vuggy and intercrystalline porosity.

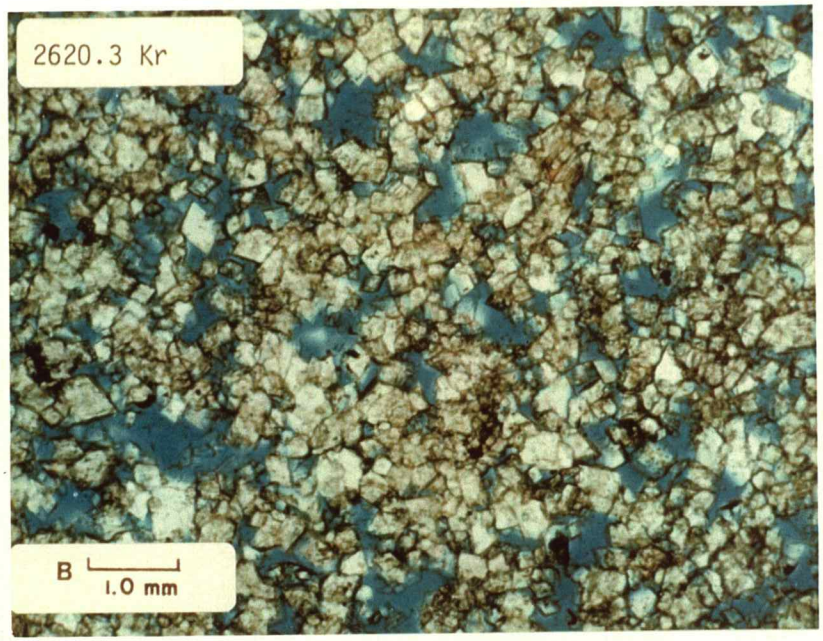
View B, 80X, Plane Light. This is a closer view of some of the abundant intercrystalline and vuggy porosity in this sample.

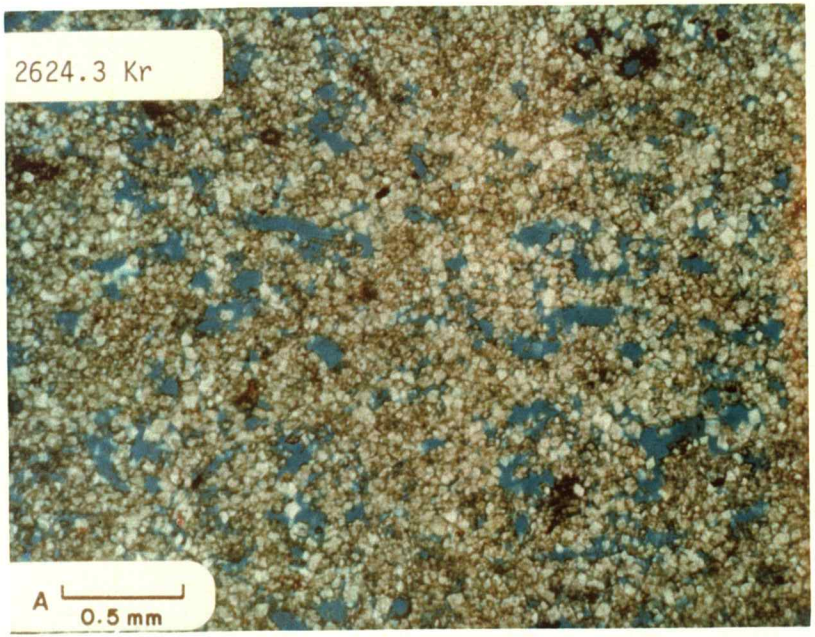
Sample Designation: 2624.3 feet Krider Formation

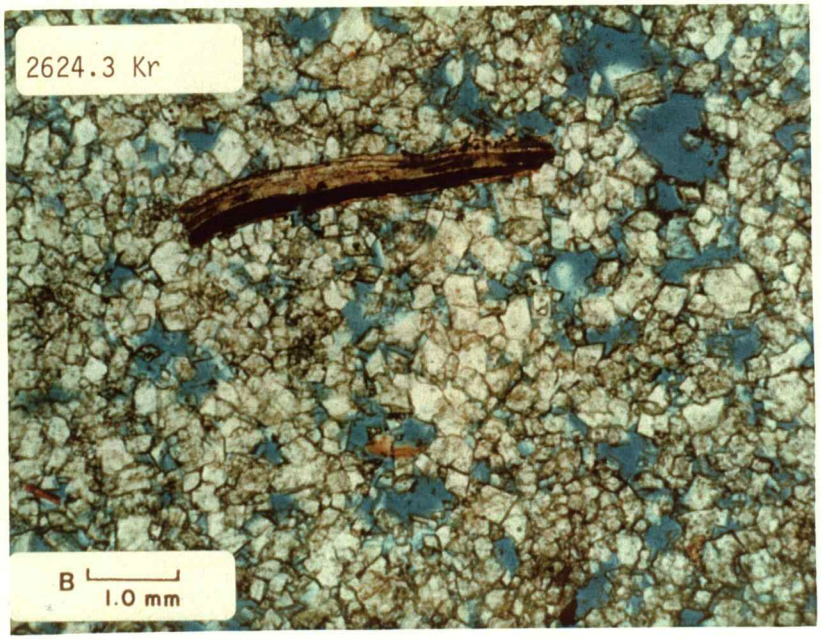
View A, 35X, Plane Light. This very fine crystalline dolomite also contains abundant vuggy and intercrystalline porosity. Some of this vuggy porosity appears to be from leached bioclasts. The scattered red material throughout is fossil fragments.

View B, 80X, Plane Light. The large fragment in this view is a phosphatic shell fragment. Note the abundant intercrystalline and vuggy porosity.


2620.3 Kr
A
0.5 mm


2620.3 Kr
B
1.0 mm


2624.3 Kr
A
0.5 mm


2624.3 Kr
B
1.0 mm

Sample Designation: 2654.6 feet Winfield Formation

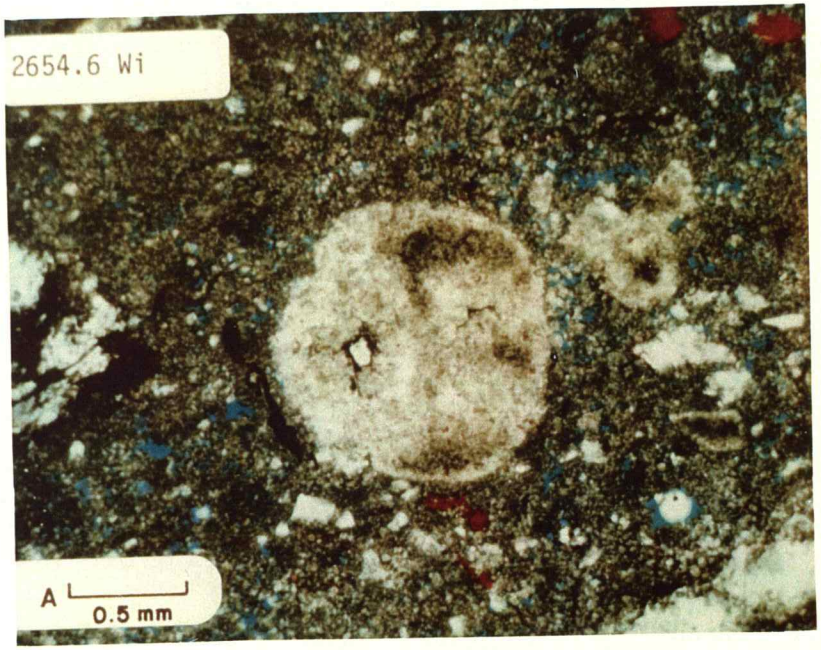
View A, 35X, Plane Light. The large, circular structure in this microcrystalline dolomite is a dolomitized echinoderm fragment. The scattered red patches are calcite cement. The white material at lower right is anhydrite. Note the intercrystalline and vuggy porosity throughout.

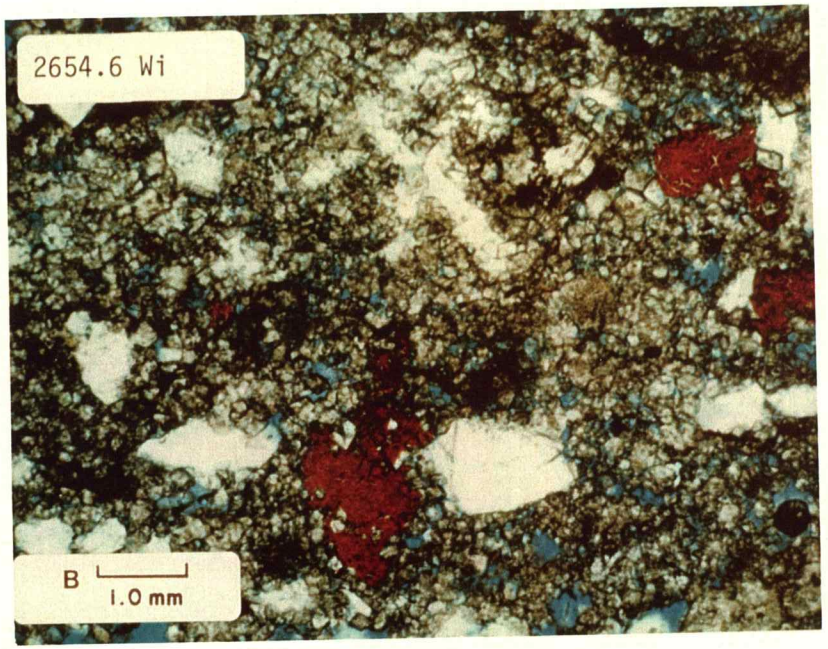
View B, 80X, Plane Light. This is a closer view of some of the cements in this dolomite. The white material in the upper portion of the photo is anhydrite cement. The red areas are calcite cement. The white grains in the lower portion of view are quartz. Again, note the intercrystalline and vuggy porosity throughout.

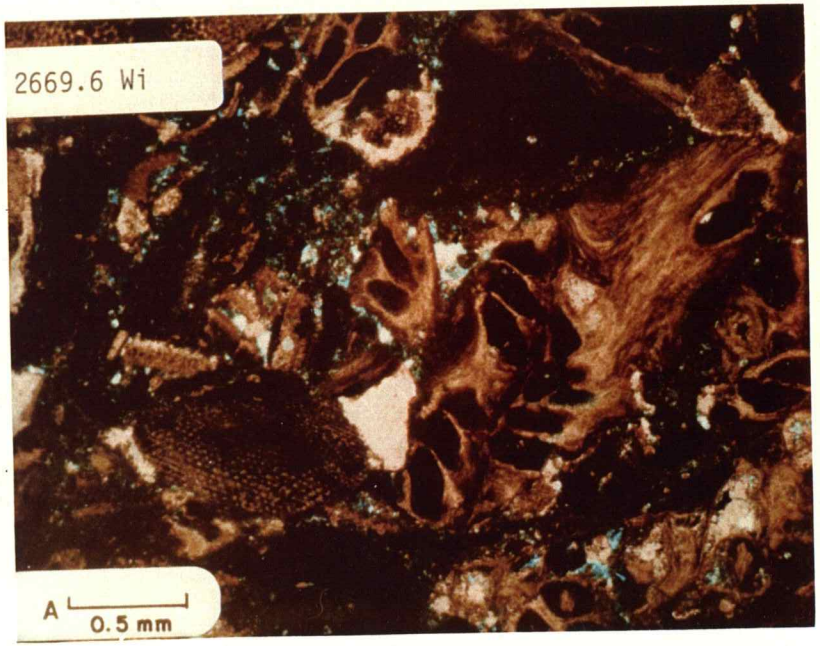
Sample Designation: 2669.6 feet Winfield Formation

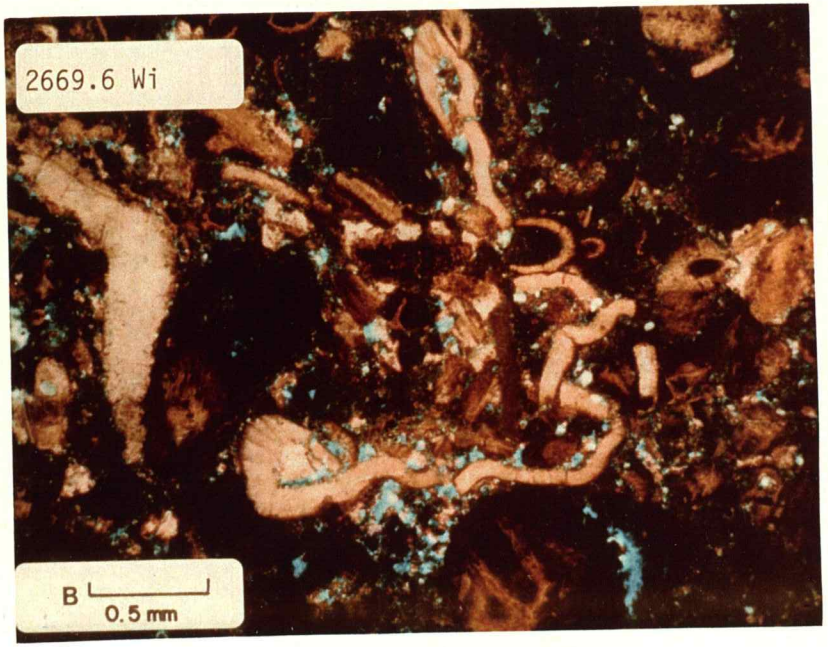
View A, 35X, Plane Light. This packstone contains abundant echinoderm and bryozoan debris. Most of the material in this photo is bryozoan. The circular fragment at lower left is an echinoderm. Note the light pink, sparry calcite cement. Also note the interparticle porosity.

View B, 35X, Plane Light. Most of the material in this photo consists of trilobites. The surrounding calcareous matrix has been largely dolomitized. Note the scattered vuggy porosity.


2654.6 Wi
A
0.5 mm


2654.6 Wi
B
1.0 mm


2669.6 Wi
A
0.5 mm


2669.6 Wi
B
0.5 mm

Sample Designation: 2711.3 feet Towanda Formation

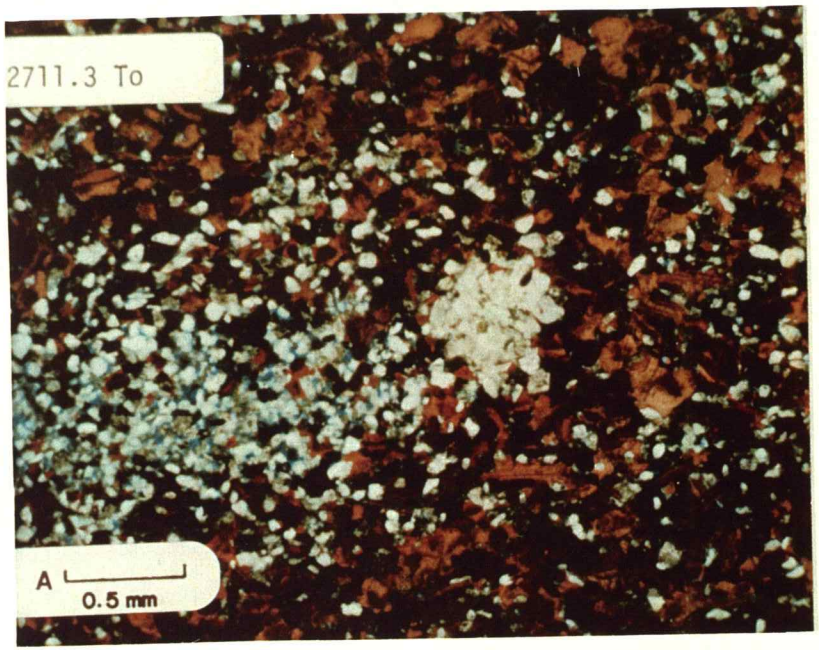
View A, 35X, Plane Light. This calcareous sandstone is very fine- to fine-grained, subangular to sub-rounded, and well sorted. Note the abundant bioclastic material, most of which appears to be echinoderms and foraminifera. Note the intergranular porosity at left. The white patch at center is anhydrite cement.

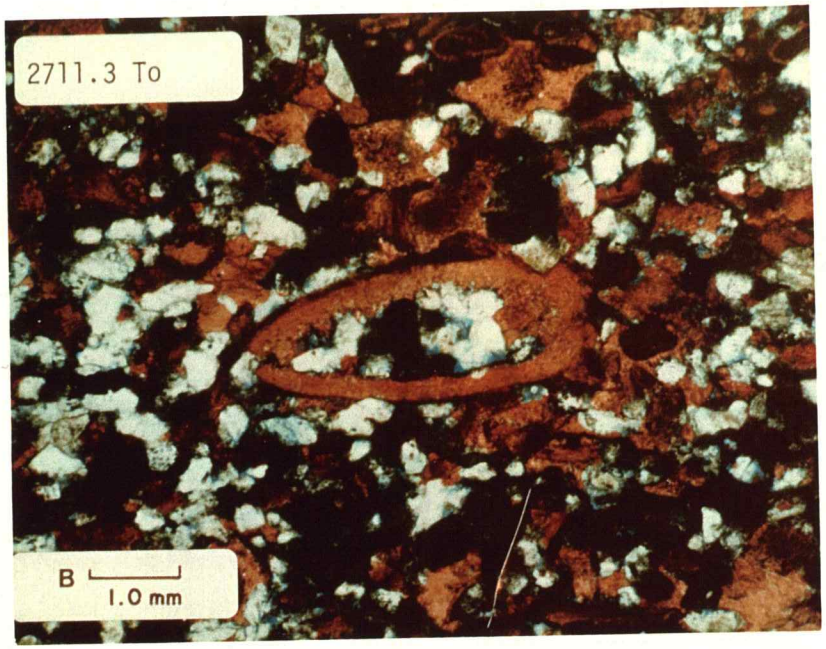
View B, 80X, Plane Light. The fossil fragment at center appears to be an ostracod. Some other small fossil fragments may also be observed. Note the abundant calcite cement. Some intergranular porosity is visible.

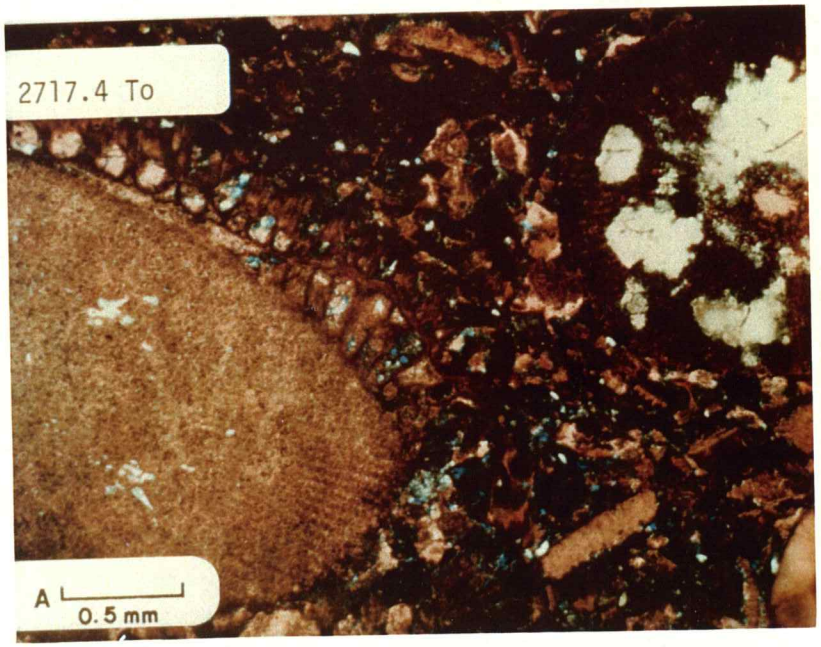
Sample Designation: 2717.4 feet Towanda Formation

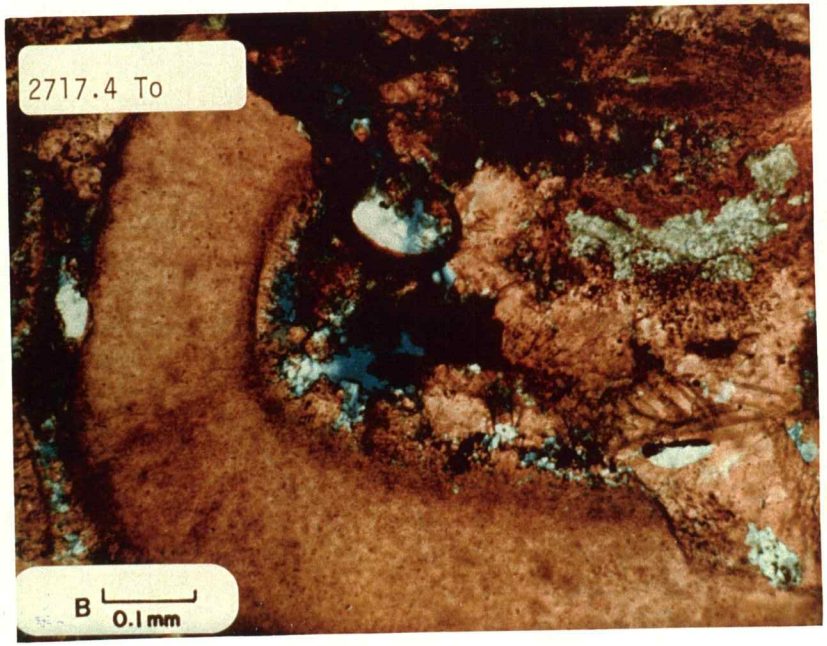
View A, 35X, Plane Light. The large calcareous fragments in view are echinoderms. Note the encrusting bryozoan on the echinoderm at left. The fragment in the lower right corner is a trilobite. Note that the echinoderm at upper right has been partly silicified. Some vuggy porosity may be seen throughout the matrix.

View B, 135X, Plane Light. The large fossil fragment in view is a trilobite. Note the syntaxial calcite cement around the edges of this fossil fragment. Also note the sparry calcite cement at right. Some calcareous material in this area appears to be silicified. Note the vuggy porosity.


2711.3 To
A
0.5 mm


2711.3 To
B
1.0 mm


2717.4 To
A
0.5 mm


2717.4 To
B
0.1 mm

Sample Designation: 2717.4 feet Towanda Formation

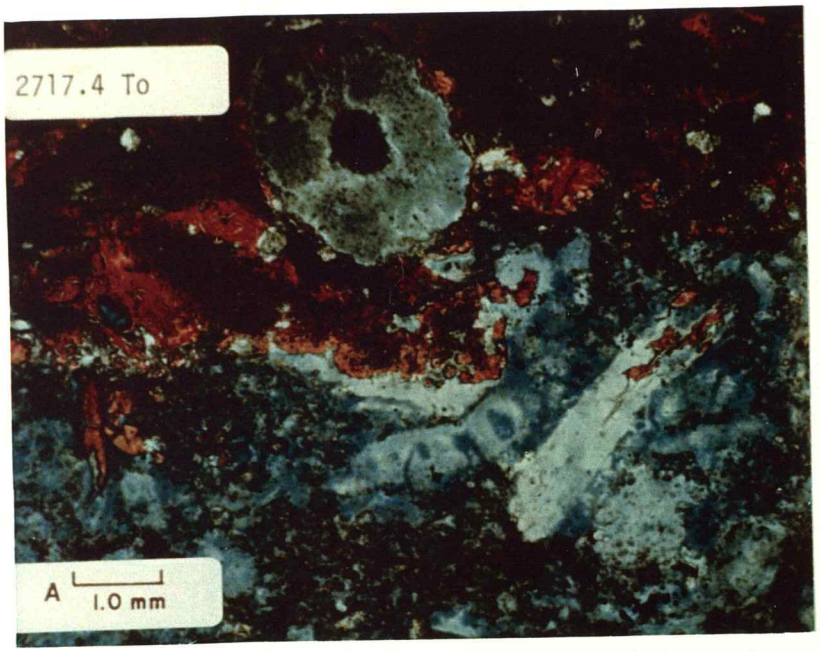
View A, 80X, Plane Light. The large, circular fragment in the upper portion of this photo is a silicified echinoderm. Another fossil fragment, which has been silicified, is visible at lower right. Note the remnants of calcite. Isopachous calcite cement surrounds some of the calcareous areas. The green areas in the lower portion of the photo are dolomite.

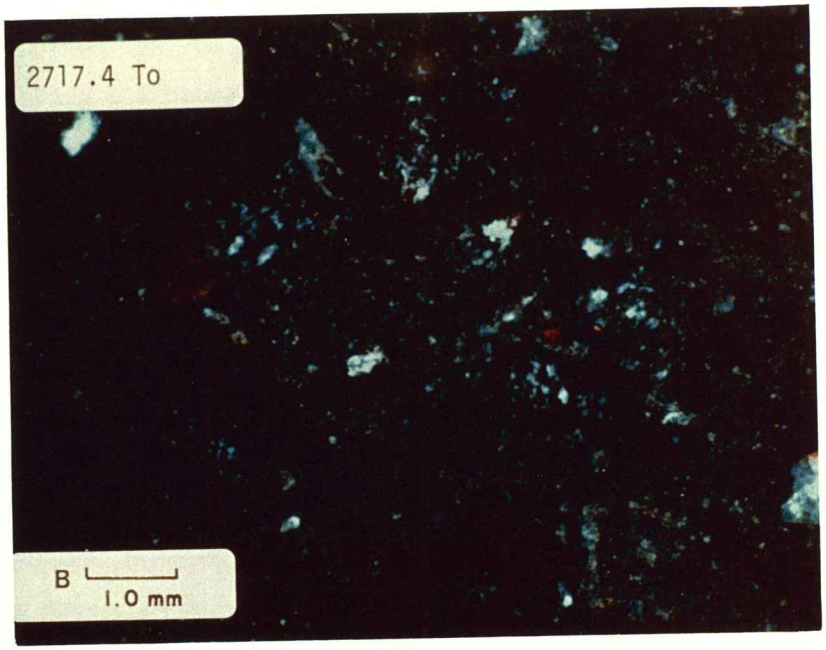
View B, 80X, Crossed Nicols. This is a closer view of a silicified area in this sample. Note the calcite remnants.

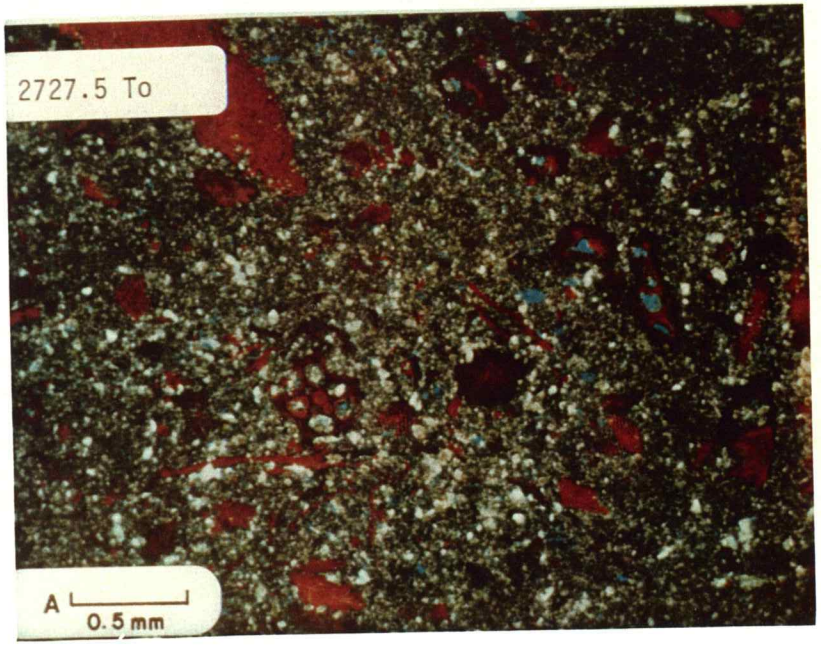
Sample Designation: 2727.5 feet Towanda Formation

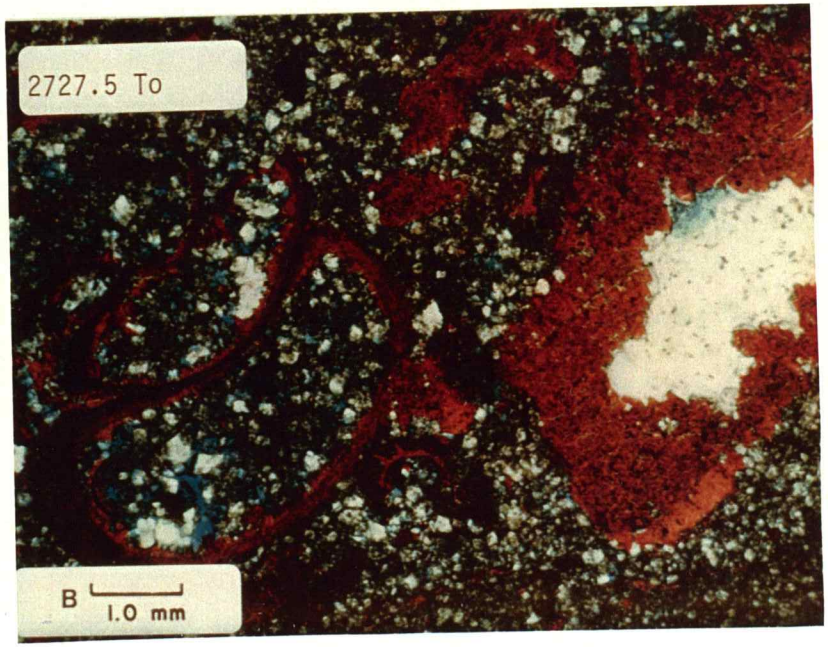
View A, 35X, Plane Light. This very fine crystalline dolomite contains scattered fossil fragments. Most of the fragments in this view are echinoderms and bryozoans. Some of these calcareous patches may also be remnants of incomplete dolomitization. Note the intercrystalline porosity and also the organic porosity within some of the fossil fragments.

View B, 80X, Plane Light. The large bioclast on the left side of this view is a gastropod. Note the porosity within this fossil. The large fragment on the right side of this view is an echinoderm. Note the partial silicification of this fragment.


2717.4 To
A
1.0 mm


2717.4 To
B
1.0 mm


2727.5 To
A
0.5 mm


2727.5 To
B
1.0 mm

Sample Designation: 2739.3 feet Towanda Formation

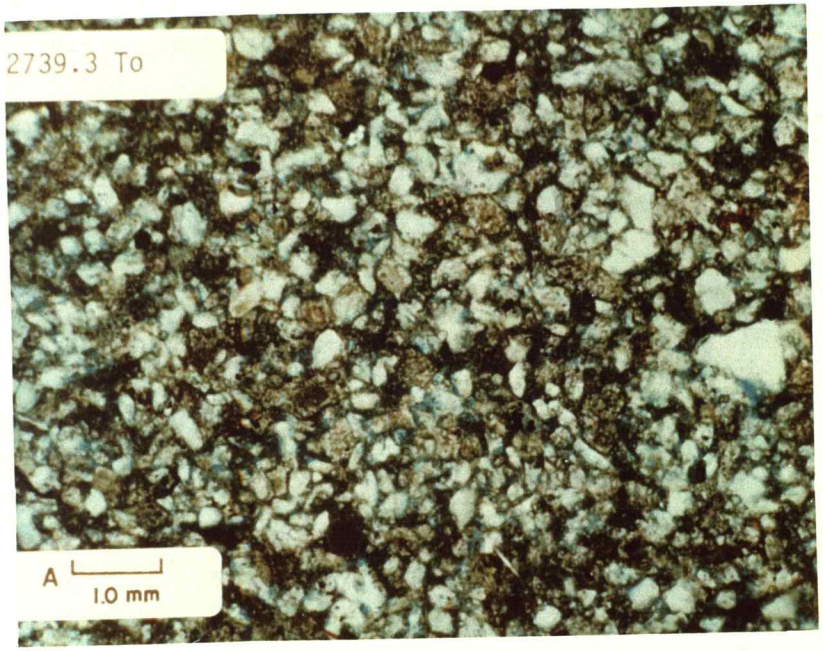
View A, 80X, Plane Light. This sandstone is very fine-grained, subangular to subrounded, and well sorted. Note the intergranular porosity throughout the dolomite matrix. Some small patches of calcite cement may be noted.

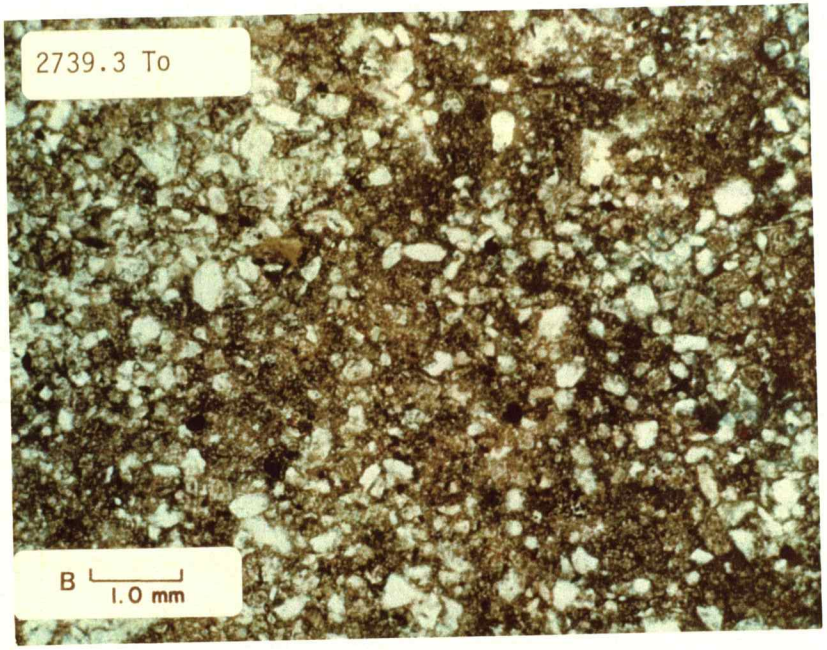
View B, 80X, Plane Light. This portion of the sample contains more dolomite matrix and less porosity. Much of the opaque material throughout this photo is carbonaceous debris.

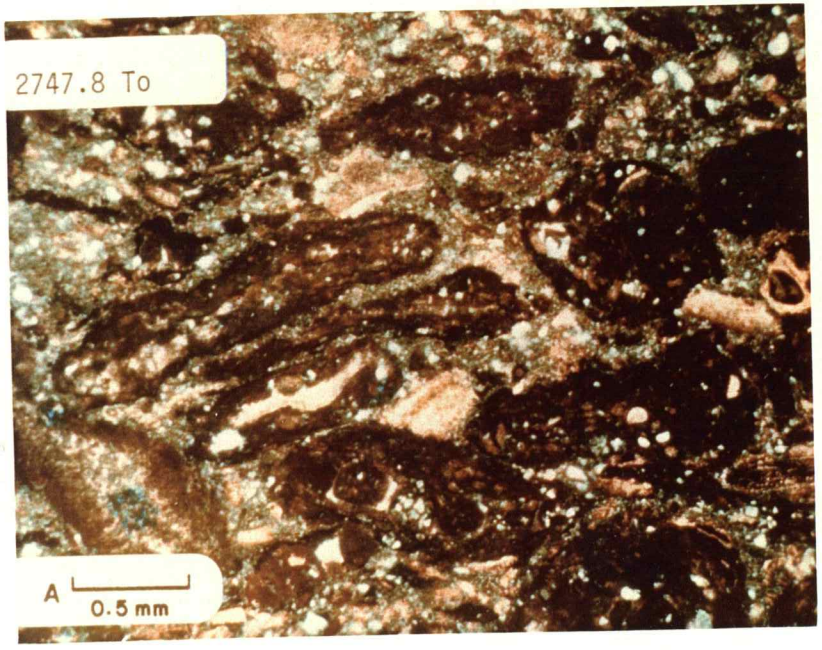
Sample Designation: 2747.8 feet Towanda Formation

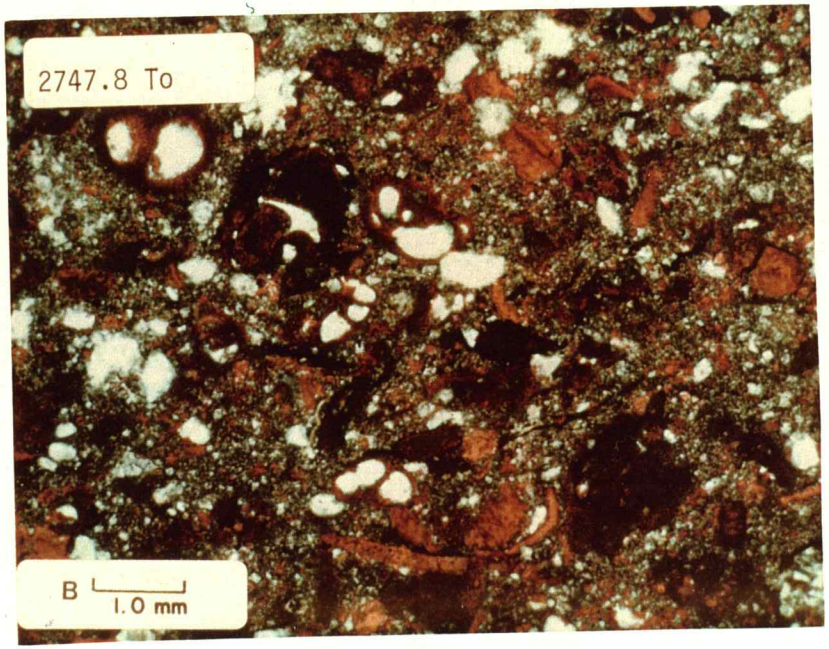
View A, 35X, Plane Light. This wackestone contains abundant bryozoan and echinoderm debris. Many of these fossil fragments exhibit algal micrite envelopes, as observed in this view. Note the mostly dolomitized matrix surrounding the algae. Some porosity may be observed at lower left.

View B, 80X, Plane Light. This view also shows some of the abundant bioclastic debris throughout this sample. Note the microcrystalline dolomite matrix. Much of the white material is quartz grains.


2739.3 To
A
1.0 mm


2739.3 To
B
1.0 mm


2747.8 To
A
0.5 mm


2747.8 To
B
1.0 mm

Sample Designation: 2765.3 feet Fort Riley Formation

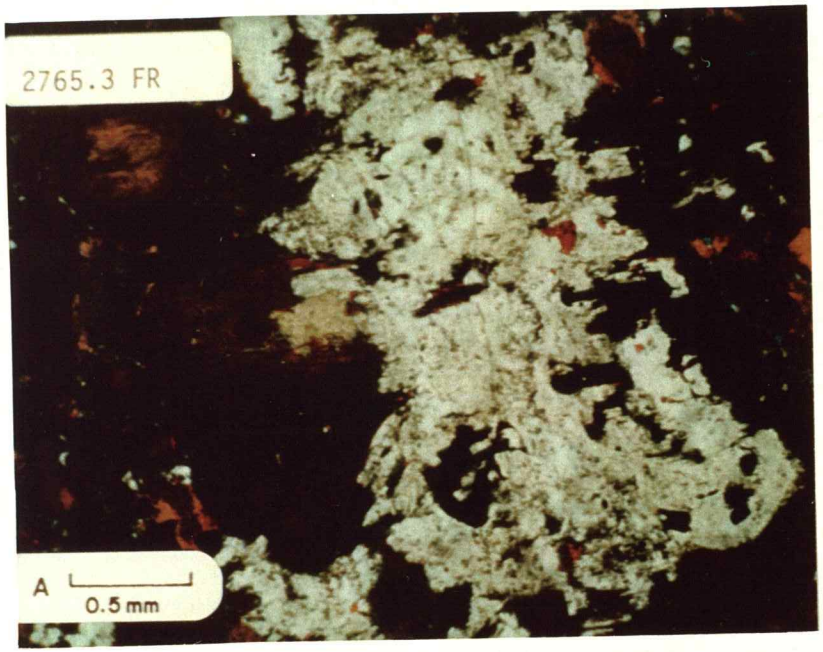
View A, 35X, Plane Light. The calcareous material in view has been partially replaced by anhydrite. Note the calcite remnants within the anhydritic portion.

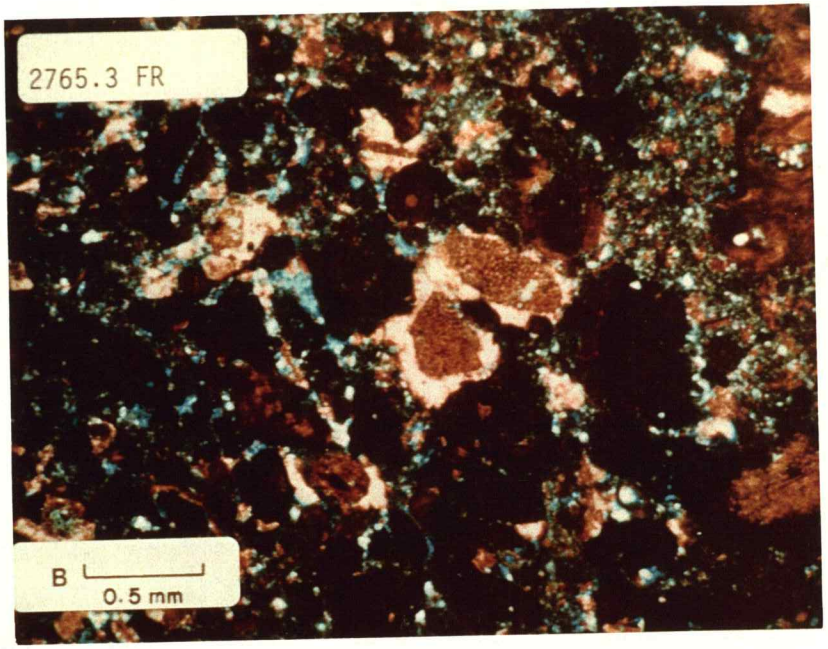
View B, 35X, Plane Light. Echinoderms, bryozoans, and forams are visible throughout this view. Note the syntaxial calcite cement surrounding the echinoderm fragments at center. Part of the dolomite matrix is visible at upper right. Note the interparticle porosity.

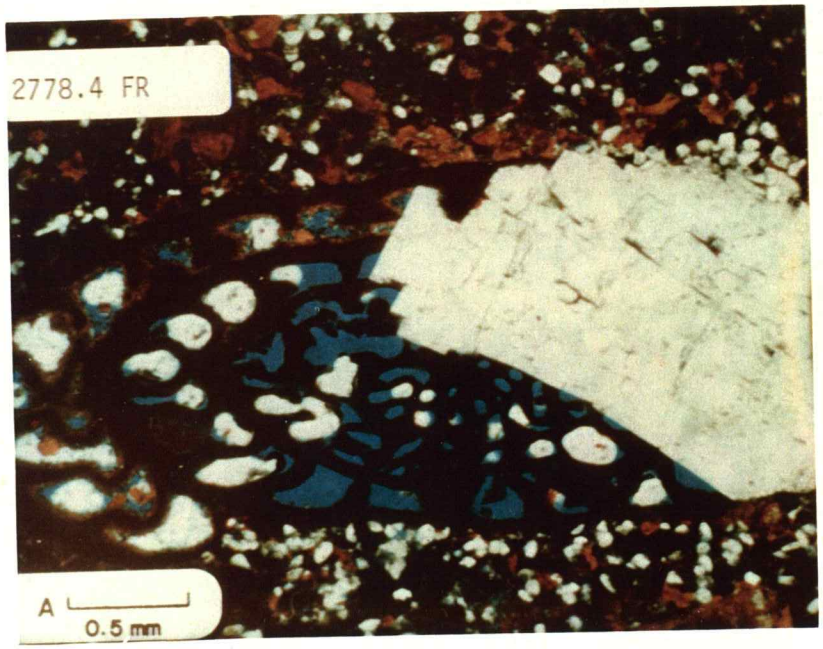
Sample Designation: 2778.4 feet Fort Riley Formation

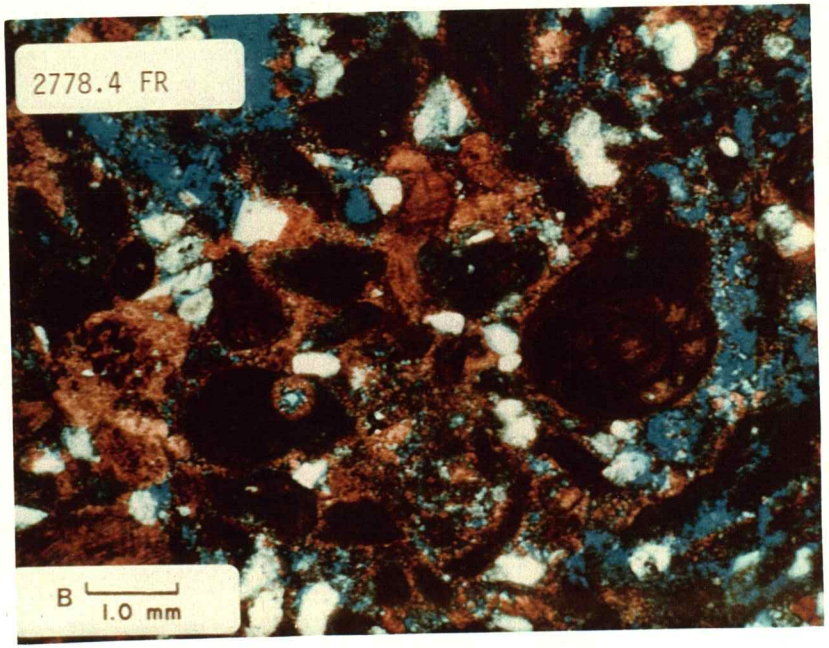
View A, 35X, Plane Light. The large bioclast across this view is a fusulinid. Note that anhydrite has replaced the right portion of this fossil and also filled in some of the chambers. The remaining porosity within this fusulinid is considered organic. Note the abundant quartz throughout the matrix surrounding this bioclast.

View B, 80X, Plane Light. This view also shows some of the abundant bioclastic material in this sample. Many of these fragments are forams. Note the abundantly scattered quartz. Also note the abundant vuggy porosity.


2765.3 FR
A
0.5 mm


2765.3 FR
B
0.5 mm


2778.4 FR
A
0.5 mm

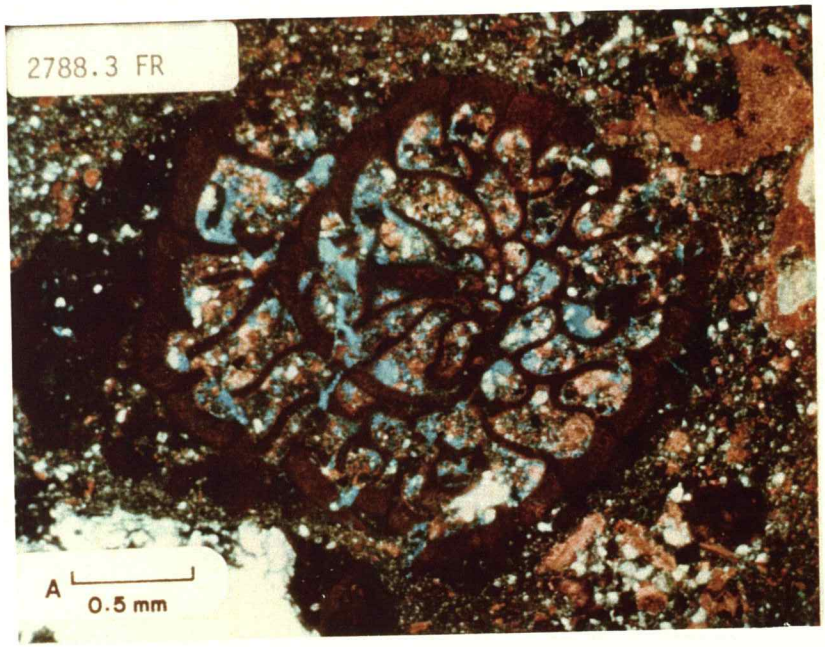

2778.4 FR
B
1.0 mm

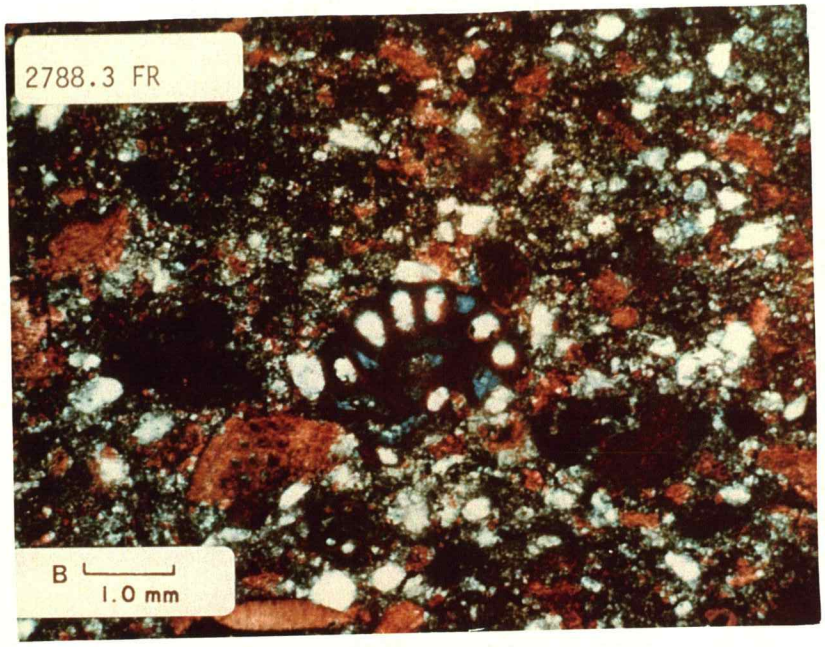
Sample Designation: 2788.3 feet Fort Riley Formation

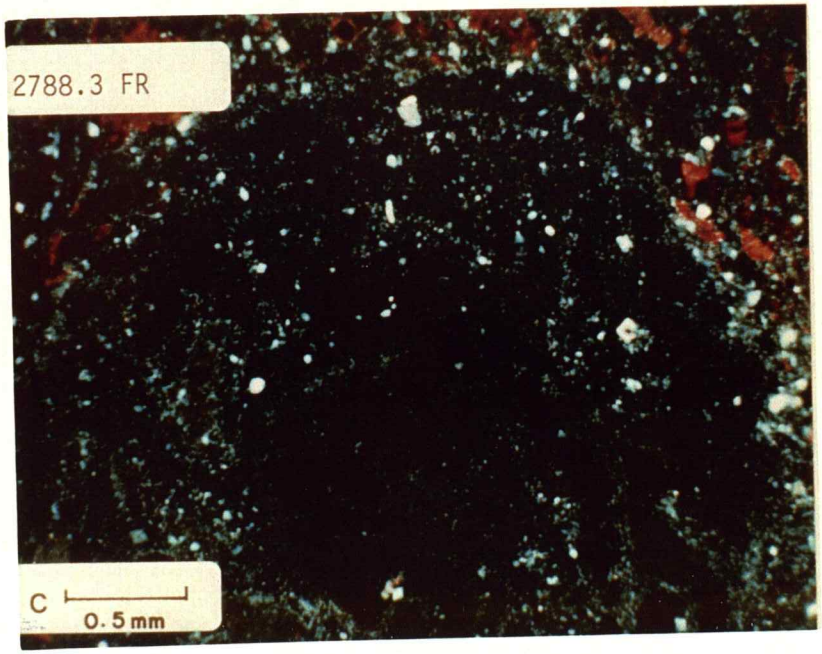
View A, 35X, Plane Light. The large bioclast in this view is a cross section of a fusulinid. Note the organic porosity within the chambers of this fossil. The surrounding dolomite matrix is very sandy. Some echinoderms may be noted at upper right. Anhydrite has partly replaced a bioclast at lower left.

View B, 80X, Plane Light. This view highlights some of the abundant bioclastic debris throughout this sample. Most of this debris is composed of echinoderms, bryozoans, and foraminifera. The bioclast at center is a foram. Note the organic porosity within this fossil. Also note the abundant quartz scattered throughout.

View C, 35X, Crossed Nicols. This view shows a portion of a fusulinid which has been replaced by anhydrite. If the stage is rotated to near extinction, the original chamber walls may be observed through the anhydrite. Note the scattered quartz.


2788.3 FR
A
0.5 mm


2788.3 FR
B
1.0 mm


2788.3 FR
C
0.5 mm

Sample Designation: 2800.5 feet Florence Formation

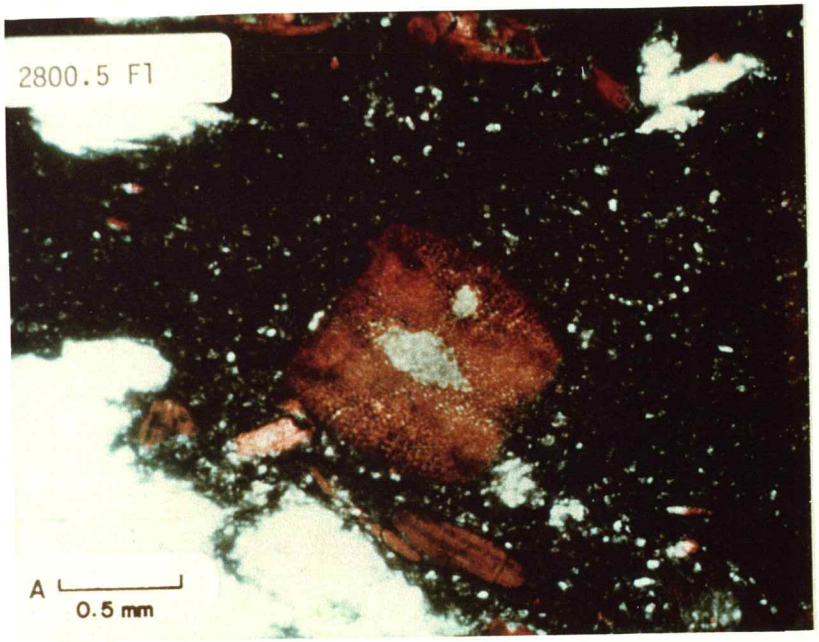
View A, 35X, Plane Light. This dolomitic shale contains abundant bioclastic debris. The square bioclast at center is an echinoderm. Note that the center of this bioclast has been silicified. The large, white area at lower left is anhydritic. Some bryozoan fragments may be seen at top.

View B, 35X, Plane Light. The large fragment in the lower portion of this view is a bryozoan. Note the scattered quartz. The shaly matrix is very dolomitic.

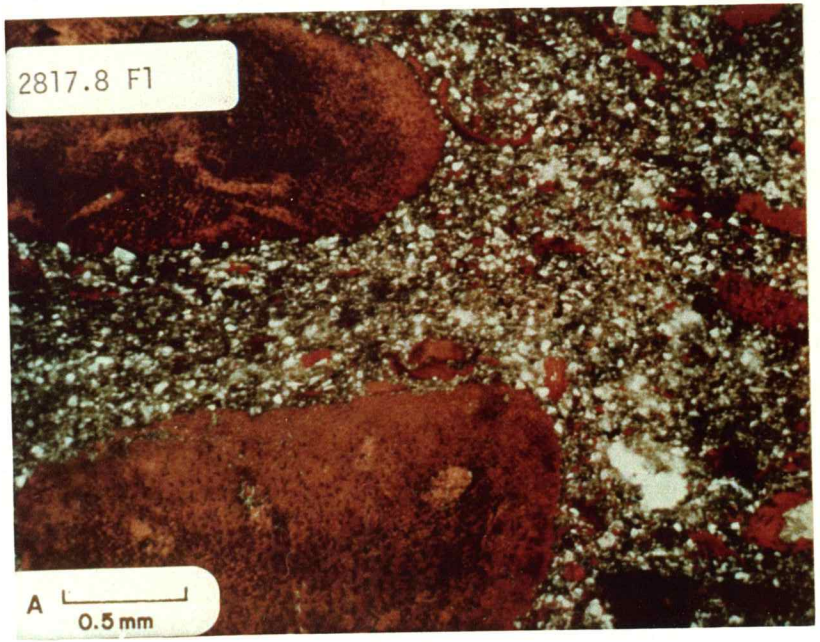
Sample Designation: 2817.8 feet Florence Formation

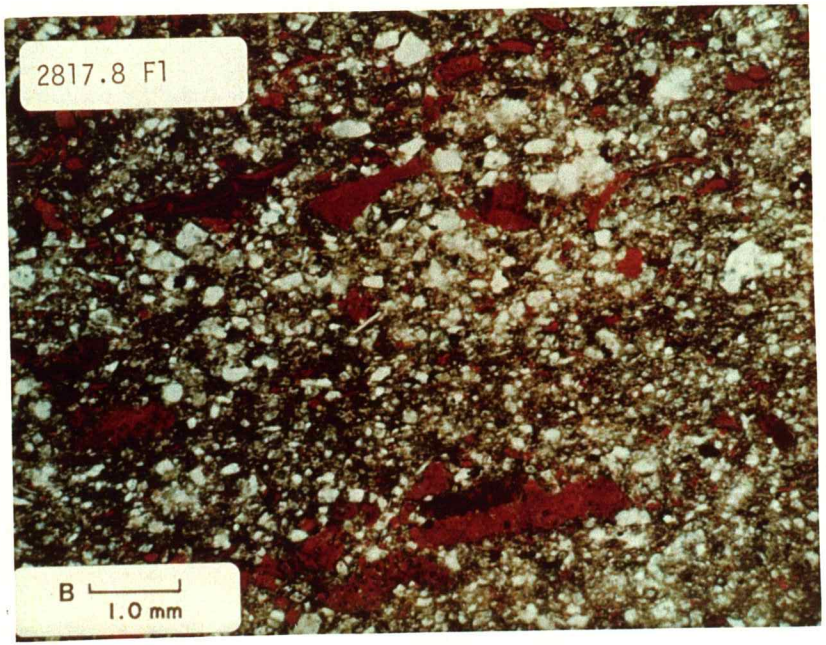
View A, 35X, Plane Light. This dolomite contains abundant very fine-grained quartz and silt. The large, calcareous fragments in this view are echinoderms.

View B, 80X, Plane Light. This closer view also shows the very silty and sandy nature of this dolomite. Note the abundant bioclastic debris. Most of this debris is from echinoderms. Some shale fragments are also present.


2800.5 F1
A
0.5 mm


2800.5 F1
B
0.5 mm


2817.8 F1
A
0.5 mm


2817.8 F1
B
1.0 mm

Sample Designation: 2820.8 feet Florence Formation

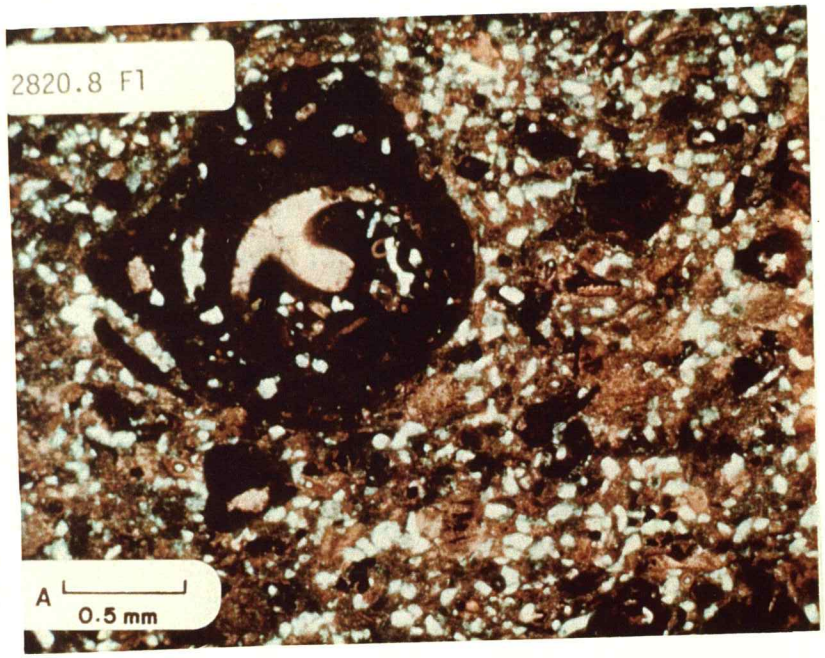
View A, 35X, Plane Light. The large bioclast in this view exhibits an algal micrite envelope. An encrusting bryozoan also appears to be located on this gastropod. This sample contains abundant very fine-grained quartz. Note the other abundant bioclastic debris.

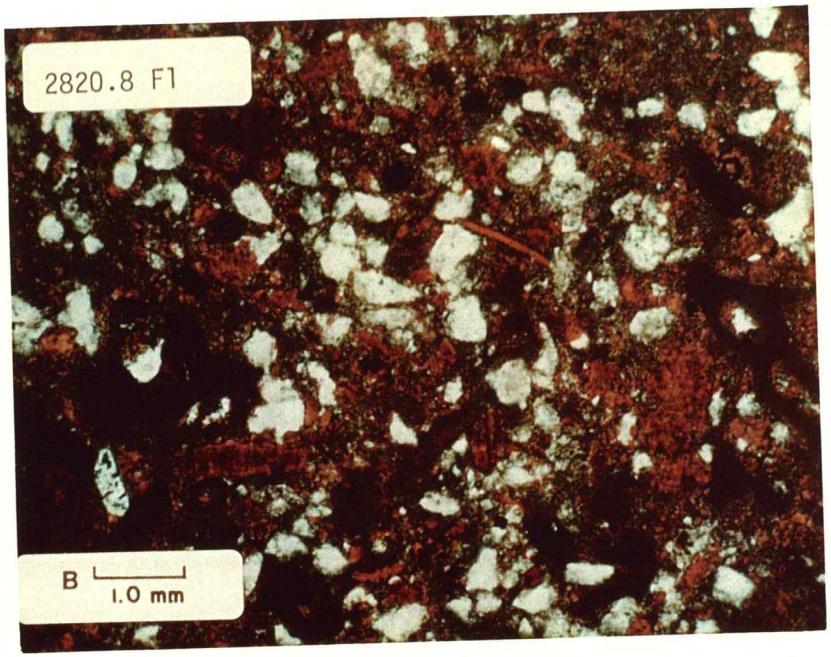
View B, 80X, Plane Light. This is a closer view of the abundant quartz throughout this sample. Note the partly dolomitized, calcareous matrix. Some scattered fossil debris may be seen throughout.

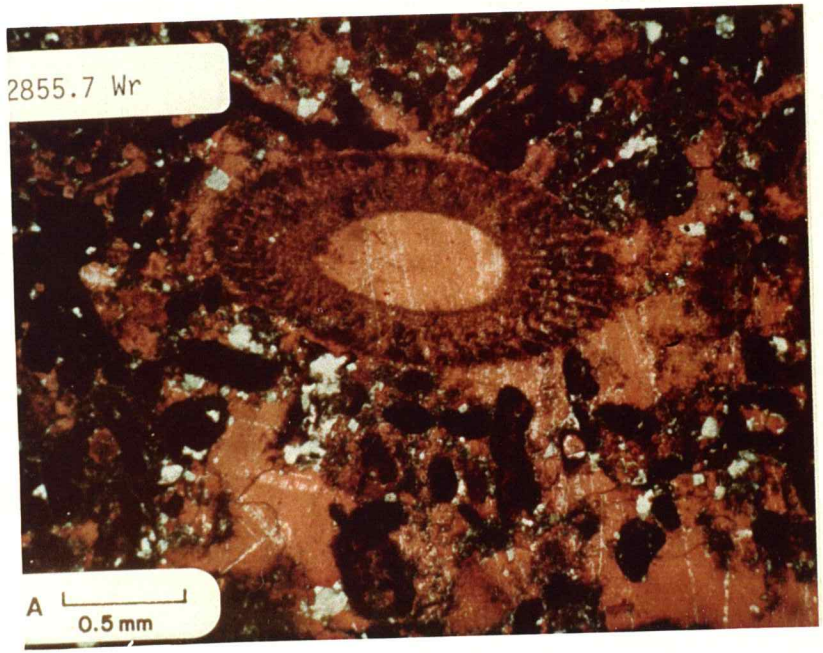
Sample Designation: 2855.7 feet Wreford Formation

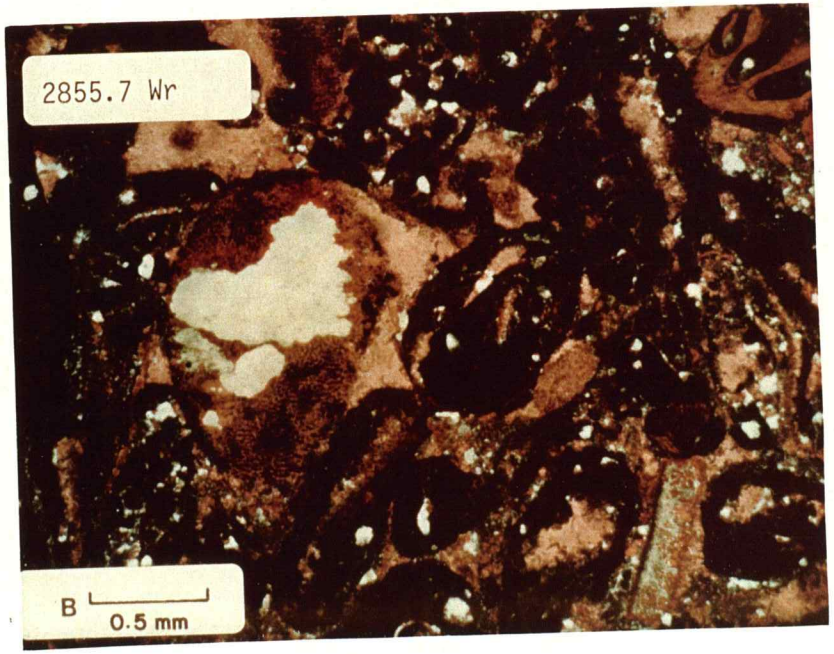
View A, 35X, Plane Light. The large bioclast at center is an echinoderm spine. Note the syntaxial calcite cement filling the center of this spine and also around the edges. Numerous other bioclastic fragments in this view appear to be coated by algae. Some quartz is scattered throughout.

View B, 35X, Plane Light. The echinoderm just left of center has been partly silicified. Note the syntaxial rim cement around this echinoderm. Note the abundant algal-coated bioclasts throughout. A bryozoan may be observed in the upper right corner of view.


2820.8 Fl
A
0.5 mm


2820.8 Fl
B
1.0 mm


2855.7 Wr
A
0.5 mm


2855.7 Wr
B
0.5 mm

Sample Designation: 2862.7 feet Wreford Formation

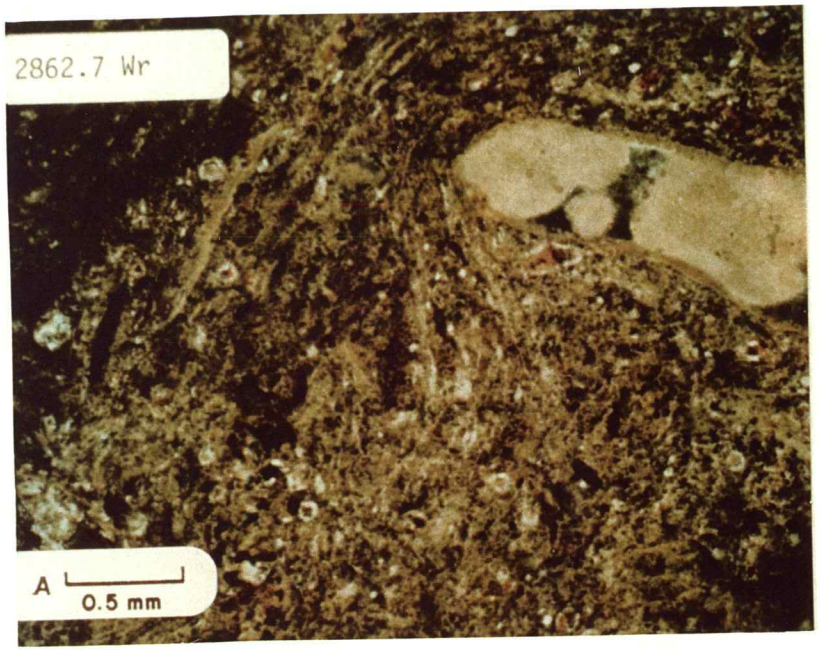
View A, 35X, Plane Light. This rock appears to be a fossiliferous chert. The numerous small, circular bioclasts throughout this view are interpreted to be sponge spicules. The large fragment at upper right is a silicified bryozoan.

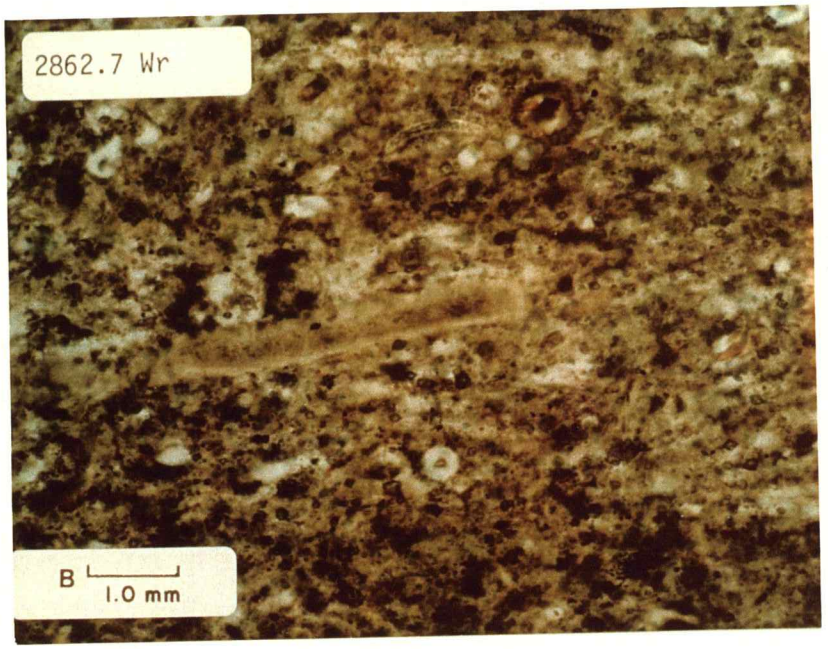
View B, 80X, Plane Light. This view highlights the siliceous nature of this sample. Much of the bioclastic material appears to be sponge debris. The opaque material is interpreted to be organic.

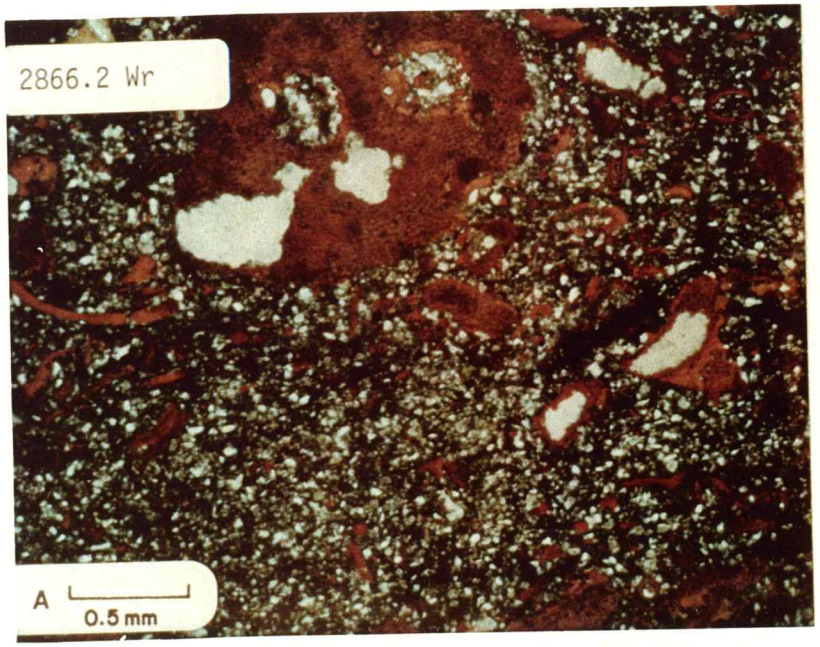
Sample Designation: 2866.2 feet Wreford Formation

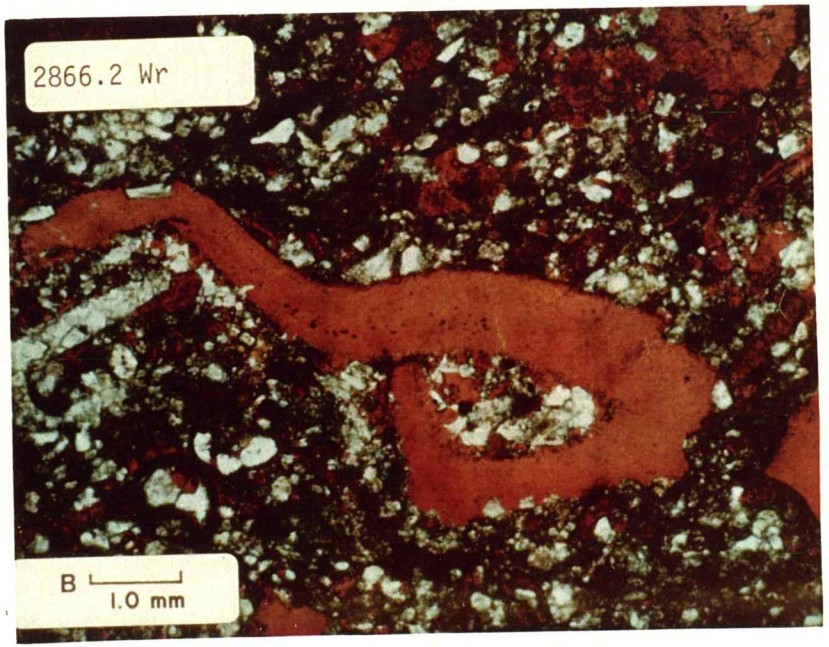
View A, 35X, Plane Light. Very fine-grained quartz is abundant throughout this dolomite. Bioclastic debris is also abundant throughout. This material consists largely of bryozoans, echinoderms, and shell fragments. Note that some of the echinoderms have been partly silicified.

View B, 80X, Plane Light. The large bioclast in this view is a trilobite fragment. Note the other bioclastic debris. Also note the abundant quartz throughout the dolomite matrix.


2862.7 Wr
A
0.5 mm


2862.7 Wr
B
1.0 mm


2866.2 Wr
A
0.5 mm


2866.2 Wr
B
1.0 mm