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CENTRAL DIVISION

GEOLOGICAL REPORT NO. 13-A

APRIL, 1963

EXAMINATION OF PENNSYLVANIAN CARBONATE BANKS IN SOUTHWESTERN KANSAS

by

HAROLD A. BROWN

CONTENTS

EXAMINATION OF PENNSYLVANIAN CARBONATE BANKS IN SOUTHWESTERN KANSAS

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SUMMARY

Thick calcium carbonate bank deposits are found in the Lansing-Kansas City and Des Moines groups (Pennsylvanian) of the Hugoton Embayment in southwestern Kansas. Oölites and other calcarenite were deposited in shallow, high energy environments overlying pre-existing carbonate mounds. Some evidence indicates that the mounds are of organic origin. The occurrence of oil or gas production is related to thick accumulation of calcarenite which is coincident with structural highs. On the Dodge City Shelf, individual zones are thinner and remain fairly constant in thickness, indicating that banks are not developed in this area.

These mounds had very little if any influence on the surrounding depositional environments; therefore no off-bank facies can be identified. The location of these banks has no apparent correlation with older pre-existing structure.

There is a good correlation between thickness of individual zones and lithology. Shallow water micrites occupy the thin areas while the bank facies are confined to areas which are often two or three times thicker. The areal size of the banks varies from a few hundred feet to 6 or 8 miles in width. Length also varies up to 15 or 20 miles. Four zones were isopached and superimposed on present day Lansing structure. The more favorable areas for future Lansing-Kansas City and Des Moines production are delineated by this mapping procedure.

INTRODUCTION

Recent studies of the subsurface and outcrops of the Lansing-Kansas City and Des Moines strata have revealed that moundlike calcium carbonate banks are present in the section throughout much of Kansas. Production from these rocks was established about 50 years ago in south-central Kansas. Later exploratory drilling found Lansing production on the Central Kansas Uplift. In the last ten years these same groups of rocks were found productive in southwestern Kansas. In the past, little attention has been given to the relation between production and the depositional origin of the reservoir rock.

PURPOSE

The purpose of this paper is to describe and gain a better understanding of the stratigraphic and structural parameters associated with Lansing-Kansas City and Des Moines carbonate reservoirs in southwestern Kansas.

It is also intended to discuss further and expand upon the concepts set forth in Central Division Geological Report No. 13, September, 1962.

CONCLUSIONS

1. Lansing-Kansas City and Des Moines oil and gas reservoirs in southwestern Kansas are combined structural and stratigraphic traps. The production occurs in calcarenite facies of thickened carbonate banks which are coincident with structural highs.

2. There is a good correlation between thickness of individual zones and lithology; where calcarenite banks are present the zones are anomalously thick. Future exploration programs should include isopach maps of each prospective zone as well as seismic structure maps.

3. The occurrence of carbonate banks cannot be predicted by association with pre-existing structure or by identification of off-bank facies in the subsurface.

4. Oösparite very often has an oömoldic texture resulting from removal of oöliths. However, the residual spherical voids probably contribute very little to the reservoir capacity of the carbonate bodies. Primary interparticle porosity is vital.

RECOMMENDATIONS

1. It is recommended that the Liberal District initiate a program to evaluate the structural aspect of the four preferred areas outlined in this report. Further action on these areas would be governed by the results of this evaluation and the lease situation in the areas.

2. It is further recommended that the search for Lansing-Kansas City reservoirs be actively continued by district personnel utilizing lithologic and structural mapping techniques described in this report.

DISCUSSION

Occurrence of Oil in Lansing-Kansas City and Des Moines

The sedimentary events in the Lansing-Kansas City and Des Moines groups (Pennsylvanian) are discussed in Central Division Geological Report No. 13, September, 1962. Four major sedimentary cycles occur within this section of rocks, as shown on Exhibit No. 1. The rocks at the base of each cycle are micritic, dark brown to gray, dense, and occasionally shaly. These rocks are interpreted as being deposited in deeper quiet water. Upward, the rocks become lighter colored through shades of brown, tan, and white. The lighter colored micrites are soft, chalky, and non-indurated, implying deposition in shallow quiet water. Oölites and other calcarenite, which were deposited in shallow, turbulent water, are at or near the top of each cycle. The curve on the right illustrates the implied depth of water in which the sediments were deposited. The sea was the shallowest at or near the top of each cycle.

The present study reveals that most of the pay zones in all of the fields are confined to the "B", "G", "J", and "N" zones which occur near the top of each sedimentary cycle (Exhibit No. 1).

This empirical observation suggests that each cycle is a separate reservoir. Therefore, the study deals entirely with the "B", "G", "J", and "N" zones.

Within the area studied, all of the better Lansing-Kansas City and Des Moines production has been confined to Eubank, Lemon, and Victory fields in western and southern Haskell County. Five stratigraphic cross sections in these fields are presented on Exhibits 2 and 3. They are arranged with a good electric log marker at or near the base of each zone as the datum. Structural position of each well is shown by the profile below each section.

Changes in thickness are readily apparent in all zones. Oil or gas production is confined to thick areas coincident with structure.

Thickness changes are related to changes in carbonate lithology. Thin areas are entirely calm water micritic rocks composed mostly of silt size lime mud. Calcarenite (intrasparite, oösparite, or biosparite) composed of sand size carbonate grains is usually at the top of the zone and confined to thicker areas.

Cross Sections A-A' and B-B' (Exhibit No. 2) illustrate conditions in the "B" zone. Drill cuttings are mostly unavailable in Cross Section A-A'. The section shows thickness relationship to structure and production in the Eubank and North Satanta fields.

Petrographic examination of three cores, supplemented with drill cuttings (Cross Section B-B'), reveals a gradual vertical change in lithology. A light tan micrite with variable amounts of fine bioclastic debris and larger crinoid and bryozoa fragments is present over a large area at the base of the zone (Specimens 4, 5, and 6, Plate 1; and Specimen 6, Plate 2). The crinoid-bryozoa facies grades upward through a tan nonfossiliferous micrite into a micritic foram-fusulinid facies (Specimens 1, 2, and 3, Plate 1; and Specimens 1 and 3, Plate 2) characterized by many fusulinids and other small benthonic forams. This facies is moderately dolomitic in local areas and grades laterally into biointrasparite (Specimen 2, Plate 2) that is oil productive in the Victory field. Similarly, in the Lemon field gas production is found in a thickened zone of biointrasparite (Specimen 4, Plate 2) overlying the foram-fusulinid facies. Here the clastic unit grades laterally into a smooth dark gray calcareous shale.

Cross Section C-C' (Exhibit No. 3) illustrates stratigraphic conditions in the "G" zone.

The thick area is nearly three times as thick as the flanking thin areas, being much more pronounced than in the "B" zone. The lithologic association is the same, with the quiet water micrite related to the thin areas and the high energy biointrasparite confined to the thicker localities.

The rock at the base of the zone is a tan micrite with various amounts of fine bioclastic debris and larger fragments of crinoid and bryozoa (Specimens 4 and 5, Plate 3). The zone is locally dolomitic. Over a short vertical distance this facies changes upward into biointrasparite (Specimens 1 and 2, Plate 3). It may be that the lateral facies equivalent of the biointrasparite is represented by gray shale. This, however, is not readily apparent since the thickness of the overlying shale unit remains fairly constant.

Cross Section D-D' (Exhibit No. 3) illustrates stratigraphic conditions in the "J" zone. The thick area is often over two or three times as thick as the surrounding thin areas. The change in thickness is usually spread over a distance of several miles.

The basal portion of the "J" zone is a dark gray, dense, nonfossiliferous micrite (Specimen 5, Plate 2). Vertically, this facies gradually becomes soft, white, nonindurated chalk (Specimen 4, Plate 4). Oösparite (Specimen 1, Plate 4) is deposited next on top of the chalk. Again, it may be that the lateral facies equivalent to the oölites is represented by gray shale.

Cross Section E-E' (Exhibit No. 3) illustrates the "N" zone in the same manner as the three previous zones. The thick area is up to four times as thick as the flanking areas. A tan micrite containing fine carbonate debris and larger crinoid and bryozoa fragments (Specimens 2, 5, and 6, Plate 4) is widespread at the base of the zone. Upward, and in the thick area, this facies grades into oösparite (Specimen 3, Plate 4).

In addition to the detailed studies illustrated on the cross sections, electric logs, commercial sample logs, and scout tickets were examined in many of the fields in southwest Kansas producing from Lansing-Kansas City or Des Moines carbonate rocks. In each case production is restricted to thickened high energy calcarenite deposits, but occurs only at structurally high positious within these thick belts.

Carbonate buildups apparently were marine bank areas where the sea floor, due to more rapid sedimentation, became slightly shallower than the surrounding bottom environments. Banks were built up to or perhaps slightly above average wave base where agitated water deposited oölites, lithoclasts, or bioclastic debris across the top of moundlike protrusions above the sea floor.

Analogy to Other Bank Deposits

Modern carbonate banks were observed in Florida Bay by the writer during the Pan American Carbonate Seminar in June of 1961. Here a marine grass, Thallassia (Turtle grass), acts to accelerate sedimentation and trap sediment in certain areas causing significant relief on the sea floor.

Ancient mud banks were observed in the Hueco Mountains of West Texas on this same Seminar. The algae Ivanovia (?) acted as the sediment binding agent.

Lansing carbonate banks were examined at the outcrop in Montgomery County, Kansas during the Kansas Geological Society Field Conference in September, 1962. Ivanovia (?) is the sediment binding agent in these mounds; however, in a few mounds this was not readily apparent.

The subsurface carbonate bank occurrences described above, and shown on Cross Sections A-A' through E-E', are markedly similar in lithology and geometric shape to those seen at the outcrop with the exception that the sediment building agent cannot be definitely identified.

Relation to Pre-existing Structure

The isopach map from the base of the "J" zone to the top of the 13-Fingered limestone (Exhibit No. 4) shows a gradual thickening of the interval to the southwest. This interval thins over the older known structures in the area. However, there does not appear to be any relation between the isopach thin localities and the position of carbonate banks in the "J" zone.

A series of other isopach maps were built (not enclosed in this report, but intervals listed in Appendix) of various intervals in the Lansing-Kansas City and Des Moines. The linear trend of the carbonate mounds generally parallel the isopach lines, but there is no apparent relation between an isopach thin and the position of any carbonate bank.

Off-Bank Facies

Lithologic differences of the rocks deposited on opposite flanks of these mounds are apparently insignificant.

The rock texture of the foram-fusulinid facies in the "B" zone (Cross Section B-B') remains fairly constant on both sides of the thickened zone of biointrasparite in the Victory Field. Comparison of samples from the south and north sides of the bank indicates that environmental conditions on both sides were very similar.

In the remaining "G", "J", and "N" zones (Exhibit No. 3), it is possible that the off-bank rock equivalent to the calcarenite deposits is represented by shale. There is no significant change in the underlying carbonate facies.

It is probable that these bank deposits were not a barrier in the sense that reefs are. They had very little if any influence on the surrounding environments; therefore, if any change in the rock from one flank to the other is present, it is extremely slight.

These bodies, having no effective framework builders, offered very little wave resistance and should not be termed reefs.

Porosity Development

Three kinds of high energy carbonate rocks (calcarenite) are recognized within the area studied. They are biosparite, intrasparite, and oösparite with various degrees of mixing in certain zones. All of these rocks were deposited with high primary interparticle porosity. Subsequent burial and cementation with sparry calcite cement has destroyed to various degrees part of this porosity.

In several zones, oöliths have been removed, leaving an oömoldic texture to the rock. Surrounding the spherical voids (molds), there is a shell-like layer of sparry calcite which has effectively destroyed any connection that one void may have with another.

Specimen 3, Plate 3, is an oösparite and was cut from the center of a hand size core chip which was impregnated with blue resin in a vacuum tube. The blue impregnating material has entered only the interparticle pore space (effective porosity). This indicates that the molds are not a part of any effective porosity network and probably contribute very little to the rock permeability or reservoir capacity. This may explain why, in certain cases, where the interparticle porosity has been reduced by cementation, rocks are seemingly porous in drill cuttings but do not yield significant amounts of fluid on a wireline or drill stem test.

Specimen 6, Plate 3, was prepared in the same manner but is a biosparite. The impregnating material has entered all void areas including the hollow centers of the fossils. Nearly all marine invertebrates have one or more natural openings in their outer shell. It is reasoned that the void areas inside of a fossil in zones of this type may be part of a network of effective porosity.

Structural Influence on Oil Accumulation

From the limited core analysis available, permeability was plotted versus porosity in chart form for the "B" (Exhibit No. 5A), "G" (Exhibit No. 5B), and "J" zones (Exhibit No. 5C). The intercepts of these two parameters are quite erratic in all three zones. The general trend, however, is for the permeability to increase as the porosity increases. A few of the points are quite porous with very little permeability, particularly in the "J" zone.

The water bearing points are distinguished from the hydrocarbon points. In all three zones these points are randomly intermixed with each other with no clear-cut trend for the hydrocarbon points to be concentrated at one end of the curve. Within the zone of favorable lithology, hydrocarbon accumulations are controlled largely by structure. If permeability variations were responsible for the occurrence of Lansing-Kansas City and Des Moines oil accumulations, the hydrocarbon points would be expected to concentrate at one end of the curve; this is not the case.

Method of Exploration

It has been shown that oil occurrences in the Lansing-Kansas City and Des Moines are a result of combined lithological (thickened zones of calcarenite) and structural development; also, there is a good correlation between thickness of a certain zone and lithology.

Regional isopach maps were built of the "B", "G", "J", and "N" zones. In the "B" zone (Exhibit No. 6) the linear trend of the thickened banks is generally northwest-southeast with a few trending east-west. The thick areas are also confined to the Hugoton Embayment with the thickness remaining fairly constant on the Dodge City Shelf. The lithology in the thin areas is fairly constant throughout southwest Kansas. Regionally the zone thins to the northeast.

The outlines of the bank areas are superimposed on a Lansing structure map on Exhibit No. 7. Areally, it is most apparent that all of the production has occurred in the thick areas which are coincident with structural highs.

The more favorable areas for future production from this zone are colored in yellow (Exhibit No. 7).

The "G" (Exhibit No. 8), "J" (Exhibit No. 10), and "N" zones (Exhibit No. 12) were isopached in the same manner as the "B" zone. Examination of commercial sample logs confirms that lithologically all of these thick trends are calcarenite except two in the "G" zone (Exhibit No. 8). These thick areas are in the northwestern portion of the area investigated and are interpreted as chalk mounds that were slightly elevated above the sea floor, but the water turbulence was not sufficient to deposit calcareous debris across the top.

The linear trend of the banks in these zones is also northwest to southeast. Excepting the "J" zone, the thickness remains fairly constant in the Dodge City Shelf area with nearly all of the bank development concentrated in the Hugoton Embayment. It is believed that these banks occur in a sedimentary environment associated with a broad hinge area separating the shelf area to the northeast from the Anadarko Basin to the south.

The areal size of these banks is variable. The width varies from a few hundred feet to 6 or 8 miles. Length is equally variable, varying up to 15 or 20 miles.

The outlines of the bank areas in these three zones are superimposed on a Lansing structure map (Exhibits 9, 11, and 13). Similar to the "B" zone, production from these zones has occurred in the thick areas and on structural highs.

The preferred areas for future production from these zones are colored in yellow.

The producing fields in Haskell County are unique in that all four zones are superimposed upon each other. In a few instances the four zones are indicated productive from the same well.

Exhibit No. 14 is a composite map with the preferred exploratory areas from all four zones presented on the Lansing structure. There are four areas outlined which are considered prime areas for future Lansing-Kansas City production. Shows of oil, subsurface well control, or number of potential pay zones are favorable factors in these areas.

<u>Preferred Area No. I</u> - Most of this area lies in T. 26S, R. 42W, Hamilton County. Present well control indicates that the "J" and "N" zones are anomalously thick in the area. The well in 14-26S-42W is high to the east regional dip, suggesting the possibility of structural development in the area. Drill stem testing has revealed no significant shows of oil or gas from either zone in the area.

<u>Preferred Area No. II</u> - Most of this area lies in T. 25S, R. 39W, Hamilton County. Existing well control indicates that the "B" and "J" zones are thick in the area. Wells in 8-25S-38W, 4-26S-38W, and 28-26S-38W are all high to the east regional dip, indicating a broad positive feature within the area. No significant shows of oil or gas have been encountered from either zone.

<u>Preferred Area No. III</u> - This area lies in Twps. 28 and 29S, R. 32W, Haskell County. The "G" zone is the only horizon which is built up to any anomalous thickness in this area. However, the well in 13-29S-32W encountered the following show on drill stem test: 4477-89', recovered 325' oil + 10' S.W., BHP 1340#. The zone was later perforated and yielded 15 gallons of fluid per hour, 10% of which was oil. It is believed that a northwest, updip location from this well would have an excellent chance of finding the "G" zone productive.

<u>Preferred Area No. IV</u> - This area lies in T. 26S, R. 27W, Lane County. Only the "J" zone is indicated to be thick in this area, but the anomaly is well established by existing wells. A broad low relief structure is also indicated in the area. No shows of oil or gas have been encountered in the area.

It is believed that exploratory work for Lansing production in any area should include a program to isopach the favorable trends of desirable lithology. Subsurface mapping is adequate in some areas to focus attention on the structural aspect of certain lithologic fairways. However, seismic methods should be used to localize potential areas.

APPENDIX

Occurrence of Oil in Lansing-Kansas City and Des Moines

The following is a list of wells in Haskell County that are producing from zones other than the "B", "G", "J", or "N".

Name of Well	Producing Zone	Remarks Concerning the "B", "G", "J", or "N" Zones
Pan Am #C-1 Black SW NE 17-30S-33W	"R" zone	"N" zone - WLT rec. water, may be filtrate. Quiet water facies.
Pan Am #F-1 Black NE SW 17-30S-33W	"C" zone	"B" zone also productive.
Pan Am #4 Black NE SE 17-30S-33W	"C" zone	"B" zone not tested - E log indicates also productive.
Pan Am #I-1 Miller NW SE 33-29S-33W	"P" zone	"N" zone not tested. Quiet water facies.
Pleasant Prairie #1 Pollyanna SE SE 36-27S-35W	"C" zone	"B" zone not tested. Quiet water facies.
Graham-Michealis #2-23 Eubank SW SW 23-28S-34W	"C" zone	"B" zone not tested. Depositional facies unknown.
CSO #A-2 Moody SE NW 3-29S-34W	"C" zone	"B" zone also productive.
United Prod. #6 Gregg SE NE 4-29S-34W	"C" zone	"B" zone not tested. E log indicates also productive.
White Eagle #B-1 Eubank NW SW 28-28S-34W	"K" zone - DST	"J" zone - DST indicates productive?
United Prod. #4 Eubank SE SW 32-28S-34W	"K" zone	"J" zone not tested. Quiet water facies.
CSO #U-1 Hall NW NE 5-29S-34W	"K" zone	"J" zone - DST rec. SWCM - Quiet water facies.
United Prod. #2 Gregg NW NE 4-29S-34W	"K" zone - DST	"J" zone also productive.
Coppinger #1 Koenig NE NW 12-29S-34W	"K" zone - DST	"J" zone DST indicates may also be productive.

Identification of Deep and Shallow Water Facies

The deeper water carbonate rocks (Specimen 5, Plate 2) in the lower portion of each cycle are dark colored, dense (nearly lithographic), rarely porous, and usually nonfossiliferous. Upward, the rocks grade through shades of gray, tan, light tan, and white. The light colored shallow water rocks (Specimen 4, Plate 4) are soft, chalky, nonindurated, sometimes dolomitic, and usually fossiliferous. Forams and crinoid, bryozoa, and mollusc fragments dominate the assemblages. Distinguishing this difference in rock facies can best be done under the binocular microscope.

Sediment Binding Agents

Anomalous thickness associated with carbonate banks is apparently caused by agents which accelerated carbonate precipitation and trapped and held the sediment in one place causing slight relief on the sea floor.

Ten thin sections of the chalk facies in the "J" zone (Exhibit No. 3) were examined by Karl W. Klement of the Pan American Research Laboratory for evidence of algal remains. Klement reports (personal communication) in his letter of November 7, 1962, that no algae could be found; but stated that diagenetic recrystallization may have destroyed such evidence.

Fossil remains in the "B", "G", and "N" zones suggest that crinoids or bryozoa or both may have been effective baffles which trapped and held the sediment in place.

Off-Bank Facies

Carbonate banks may in some cases have an effect on their surrounding environments causing a change in the type of sediments found on their flanks. A series of samples from wells in the enclosed cross sections (Exhibits 2 and 3) indicate that no significant environmental or lithologic change from one flank to the other is apparent. The following photomicrographs illustrate this relationship: "B" zone, Specimens 4, 5, and 6, Plate 1; Specimen 6, Plate 2 (Cross Section B-B', Exhibit No. 2); "G" zone, Specimens 4 and 5, Plate 3 (Cross Section C-C', Exhibit No. 3); and "N" zone, Specimens 2, 5, and 6, Plate 4 (Cross Section E-E', Exhibit No. 3).

Relation to Pre-existing Structure

Several intervals within the Lansing-Kansas City and Des Moines were isopached to determine if pre-existing structure was in any way responsible for the location of carbonate banks. The following intervals were mapped:

Base of "J" zone to top of 13-Fingered Limestone (Exhibit No. 4).

Base of "J" zone to top of "Morrow".

Base of "G" zone to top of "M" zone (Des Moines).

Base of "N" zone to top of 13-Fingered Limestone.

All of the above intervals thicken gradually into the Anadarko Basin to the south. Thin intervals are closely associated with older structure, but there is no clear correlation with the position of any carbonate bank.

Literature Discussion

Many occurrences of carbonate banks in the Pennsylvanian and Mississippian of the Mid-Continent region are cited in the literature.

The Plattsburg Bank (Lansing) in Wilson and Montgomery counties, Kansas, has been described at the surface by Harbaugh (1962). The basal carbonate unit in this bank is made up largely of skeletal fragments, sponges, algal (?) pellets and a small amount of leaf-like algae. The overlying crystalline facies sharply thickens in the area of the bank. This facies is made up entirely of lime mud and conspicuous leaflike algae which acted as the sediment binding agent. Calcarenite, consisting of skeletal "hash", fusulinids, and lithoclasts, were deposited across the thicker parts of the crystalline facies. This bank is about eight miles wide and at least 13 miles long. No off-bank facies could be identified. The overlying Vilas shale thins sharply over the crest of the bank suggesting that this shale may represent the off-bank facies.

Harbaugh has described in less detail numerous other occurrences of thickened banks of various sizes in this same vicinity. Bank facies vary from one mound to the other, but in nearly all cases there is a sharp contrast in lithology between the thick sections and the thin flanking areas.

Imbrie et al (1959) describe the extensive Greenwood Shoal of southeastern Kansas. This shoal in the Permian, Beattie limestone trends northeast-southwest, underlying several counties. There is some evidence that this shoal was an effective barrier which restricted marine circulation thereby causing salinity changes between the Kansas Shelf Lagoon and the Arkansas Embayment. The Cottonwood member of the Beattie remains remarkably constant in thickness throughout Kansas except in the locality of the shoal where it thickens rather sharply. Facies changes are associated with this thickening. The algae Anchicodium, associated with bryozoa and other algae, acted as the sediment binding agents. Fusulinids and bioclastic debris are associated with the relatively thin flanking areas.

Troell (1962) discusses the occurrence of thickened bioherms in the Mississippian, St. Joe limestone in southwestern Missouri. These carbonate mounds are made up almost entirely of lime mud with bryozoa acting as the sediment binding agent. Compared to occurrences described by Harbaugh and Imbrie, these Mississippian mounds are quite small, being about 30 feet thick and ranging up to about 300 feet long.

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Harbaugh, J. W. (1962), "Geologic Guide to Pennsylvanian Marine Banks, Southeast Kansas," Kansas Geological Society Guide Book to the 27th Field Conference, pp. 13-67.

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Klement, Karl W. (1962), Pan American Research Laboratory (Personal Communication, Letter Dated November 7, 1962).

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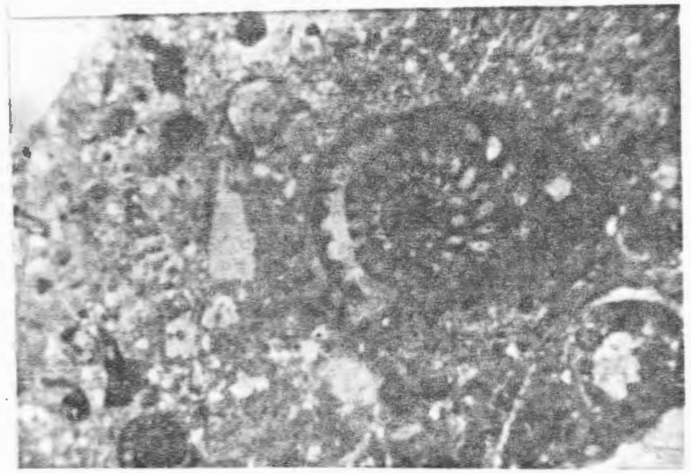
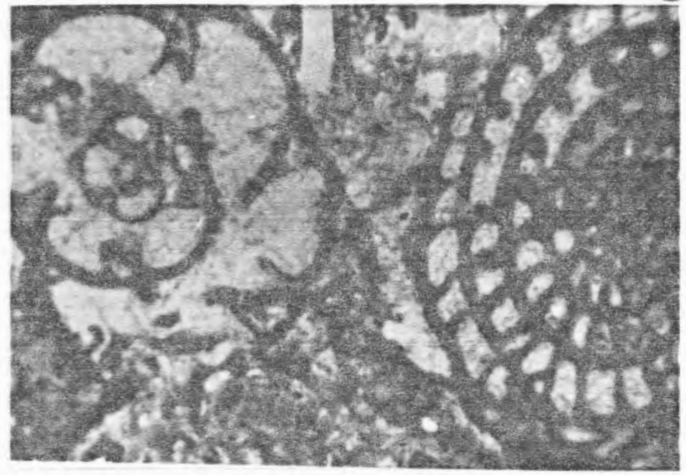
ILLUSTRATIONS

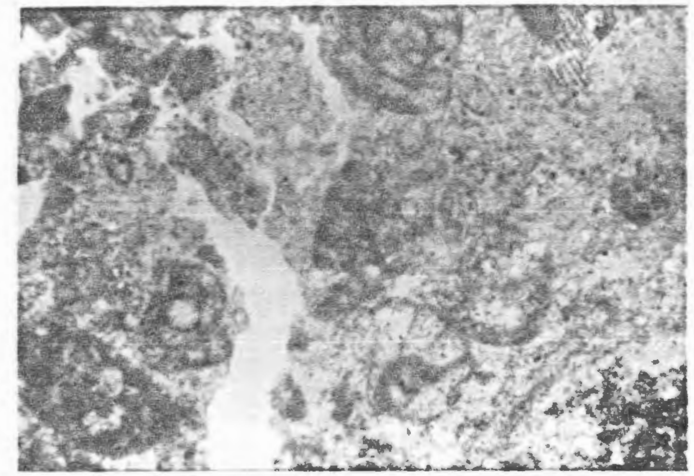
PLATE 1 - CENTRAL DIVISION GEOLOGICAL REPORT NO. 13-A (1963)
PHOTOMICROGRAPHS OF THIN SECTIONS



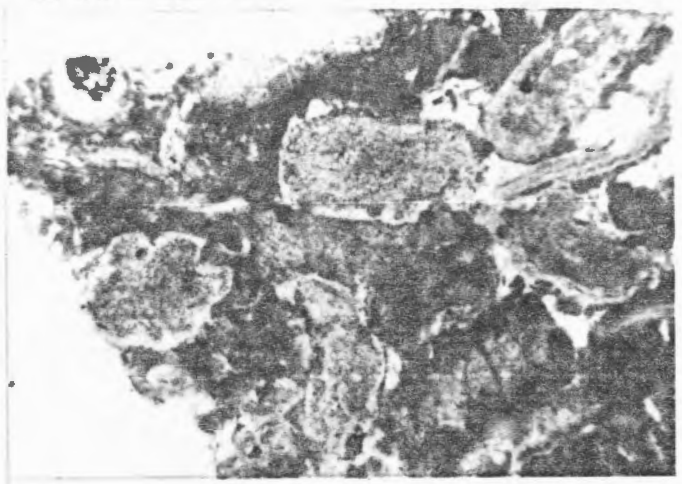
Specimen 1 - "B" zone, foram-fusulinid facies, biomicrite, cross section B-B'. Forams, fusulinids, and other fine bioclastic debris. (x 17.5) Plain light. Pan American #1 Correll 4180-90' SW NE 8-30S-33W



Specimen 2 - "B" zone, foram-fusulinid facies, biomicrite, cross section B-B'. Blue plastic entered vugs in matrix. Fusulinid on right, foram on left. (x 17.5) Plain light. Pan American #3 Black 4162-63' NE NE 17-30S-33W



Specimen 3 - "B" zone, foram-fusulinid facies, biomicrite, cross section B-B'. Many small benthonic forams in lime mud matrix. Clear area plucked out of thin section. (x 50) Plain light. Pan American #C-1 Black 4150-60' SW NE 17-30S-33W

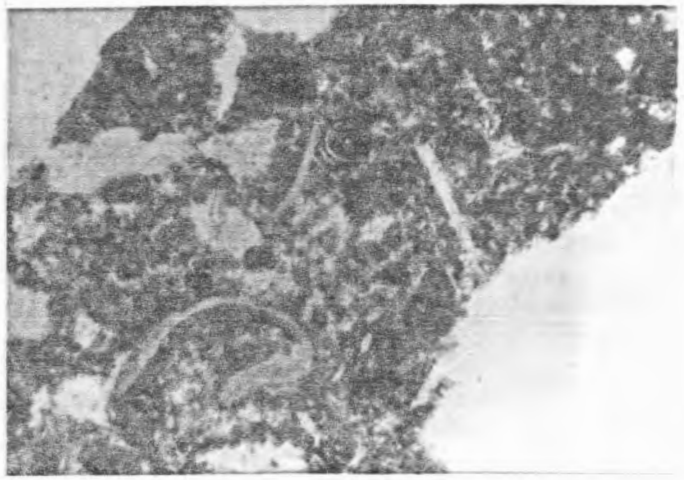


Specimen 4 - "B" zone, crinoid-bryozoa facies, biomicrite, cross section B-B'. Mostly crinoid fragments with bryozoa fragments in lower right. (x 17.5) Plain light. Pan American #1 Correll 4210-20' SW NE 8-30S-33W

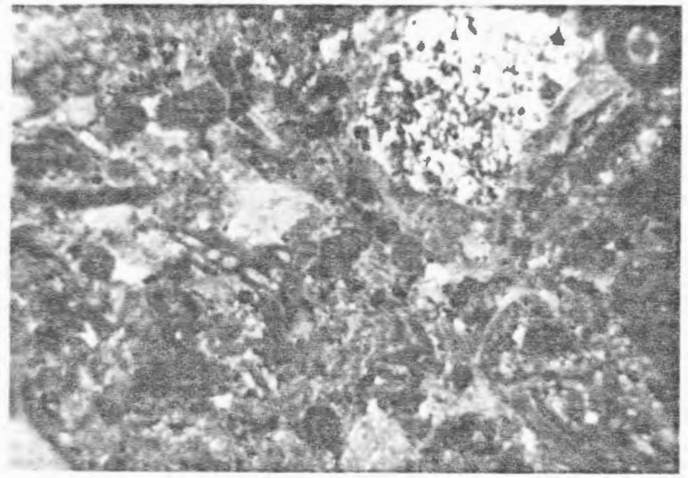
Specimen 5 - "B" zone, crinoid-bryozoa facies, biomicrite, cross section B-B'. Crinoid and bryozoa fragments with fusulinid in lime mud matrix. (x 17.5) Plain light. Pan American #3 Black 4188-89' NE NE 17-30S-33W

Specimen 6 - "B" zone, crinoid-bryozoa facies, biomicrite, cross section B-B'. Crinoid and bryozoa fragments and other fine bioclastic debris in lime mud matrix. (x 17.5) Plain light. Pan American #C-1 Black 4170-80' SW NE 17-30S-33W

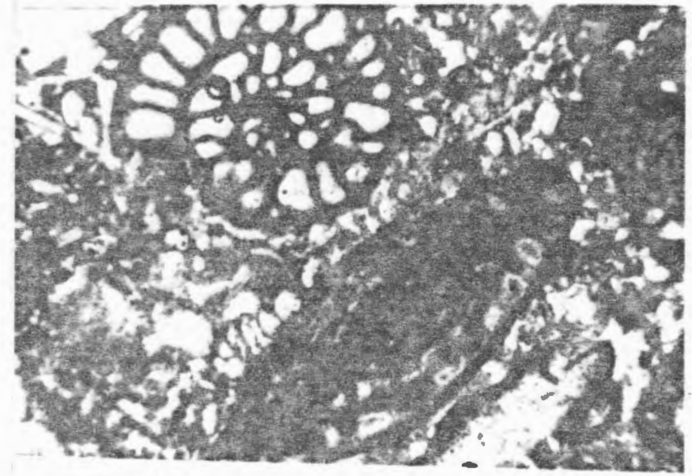
PLATE 2 - CENTRAL DIVISION GEOLOGICAL REPORT NO. 13-A (1963)
PHOTOMICROGRAPHS OF THIN SECTIONS



Specimen 1 - "B" zone, foram-fusulinid facies, biomicrite, cross section B-B'. Small benthonic forams and other fine bioclastic debris. Light areas are dolomite? (x 17.5) Plain light. Pan American #B-1 Summers 4160-70' NE SW 20-30S-33W

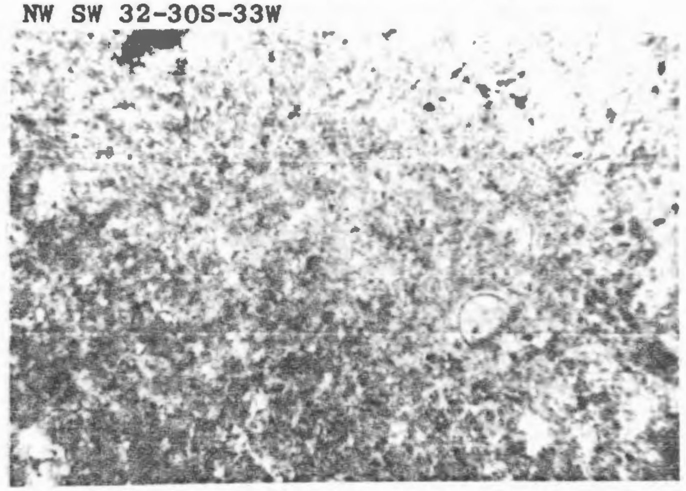


Specimen 2 - "B" zone, clastic facies, biosparite, cross section B-B'. Dark areas indicate interparticle porosity. Impregnated with blue plastic. Calcite stained red. (x 17.5) Crossed nicol. Cities Service #C-1 Conover 4132-33' NW SW 32-30S-33W

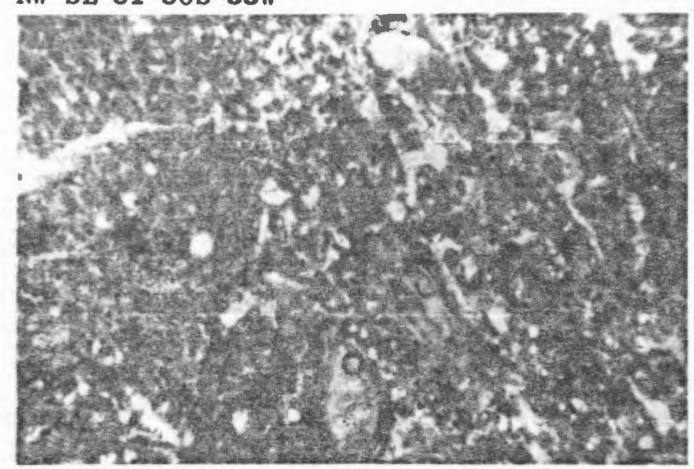


Specimen 3 - "B" zone, foram-fusulinid facies, biomicrite, cross section B-B'. Mostly fusulinids and other forams. Light areas are dolomite. Calcite stained red. (x 17.5) Plain light. Cities Service #D-2 Conover 4150-51' NW SE 31-30S-33W

Specimen 4 - "B" zone, clastic facies, pay zone, biointrasparite, cross section B-B'. Rounded lithoclasts and bioclastic debris. (x 50) Plain light. Pan American #C-1 Black 4140-50' SW NE 17-30S-33W

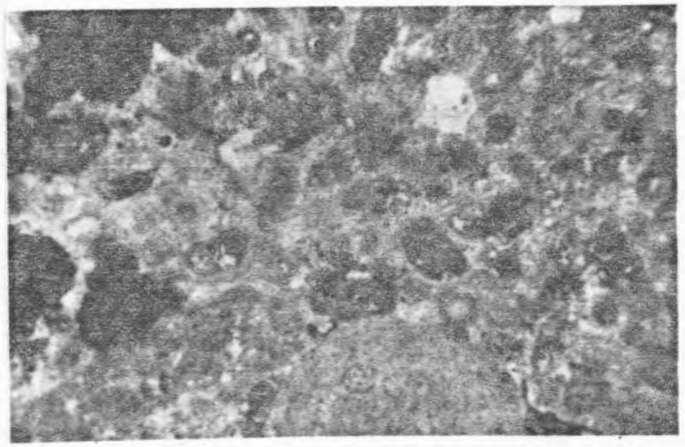


Specimen 5 - "J" zone, deep water facies, micrite, cross section D-D'. Dense, indurated, non fossiliferous. Dark colored under binocular microscope. Compare to Specimen 4 - Plate 4. Pan American #2 Schnellbacher 4610-20' SE SE 30-30S-33W

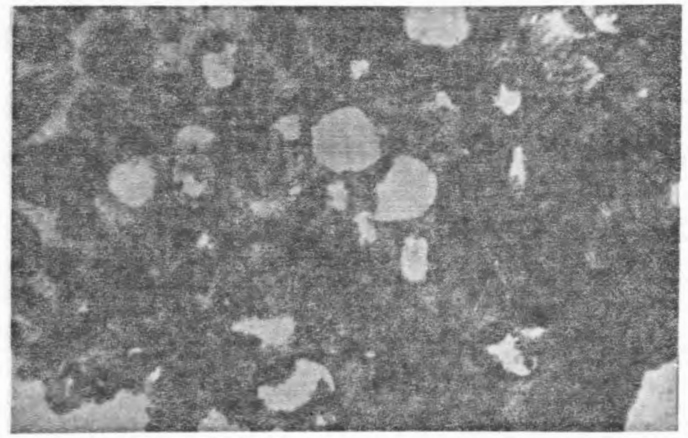


Specimen 6 - "B" zone, crinoid-bryozoa facies, biomicrite, cross section B-B'. Bryozoa fragments in lime mud matrix. Matrix is dolomitic. (x 17.5) Plain light. Pan American #D-2 Conover 4174-75' NW SE 31-30S-33W

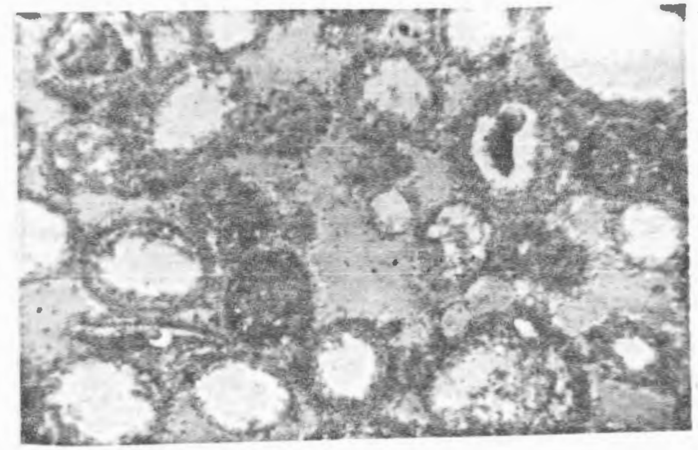
PLATE 3 - CENTRAL DIVISION GEOLOGICAL REPORT NO. 13-A (1963)
PHOTOMICROGRAPHS OF THIN SECTIONS



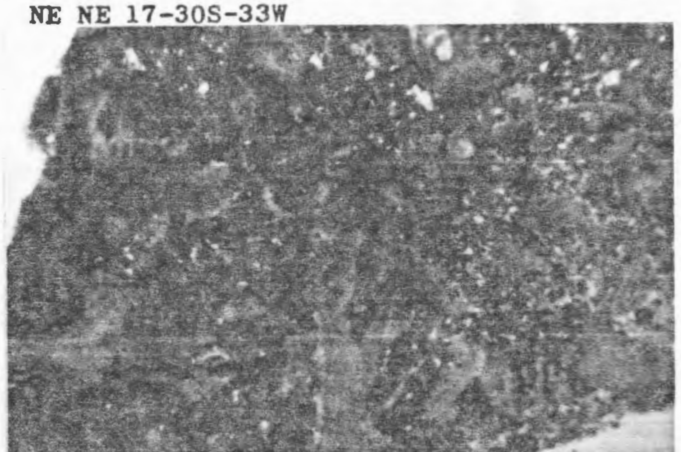
Specimen 1 - "G" zone, clastic facies, biointrasparite, cross section C-C'. Rounded lithoclasts and bioclasts. Blue plastic indicates porosity. Calcite stained red. (x 17.5). Plain light. Pan American #3 Black 4418-19' NE NE 17-30S-33W



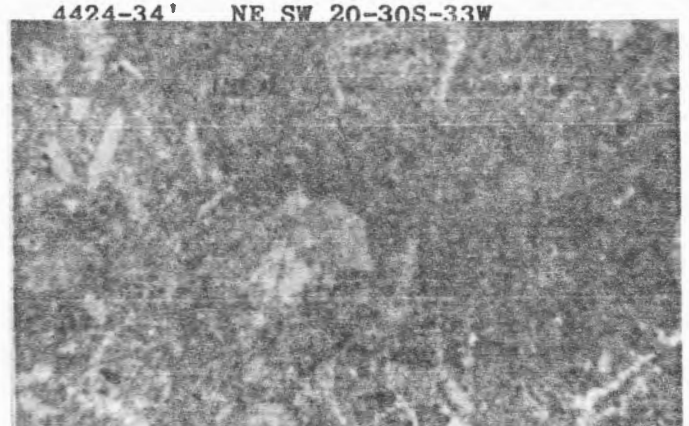
Specimen 2 - "G" zone, clastic facies, biointrasparite, cross section C-C'. Rounded lithoclasts and bioclasts. Light areas are oömoldic voids where clast has been removed. One half calcite stained red. (x 17.5) Plain light. Pan American #B-1 Summers, 4424-34' NE SW 20-30S-33W



Specimen 3 - "C" zone, oösparite, cross section B-B'. Clear areas are oömoldic voids. Blue plastic has entered only interparticle porosity. Calcite stained red. (x 17.5) Plain light. Pan American #3 Black 4210-11' NE NE 17-30S-33W



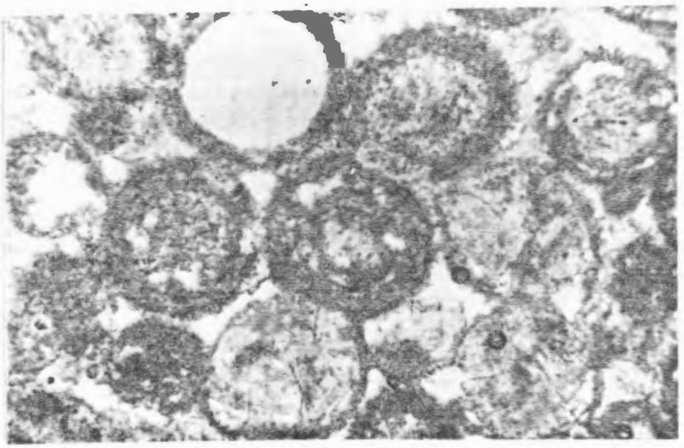
Specimen 4 - "G" zone, crinoid-bryozoa facies, biomicrite, cross section C-C'. Light areas in mud matrix are dolomite rhombs. Calcite stained red. (x 17.5) Plain light.
Pan American #1 Correll 4440-50'
SW NE 8-30S-33W



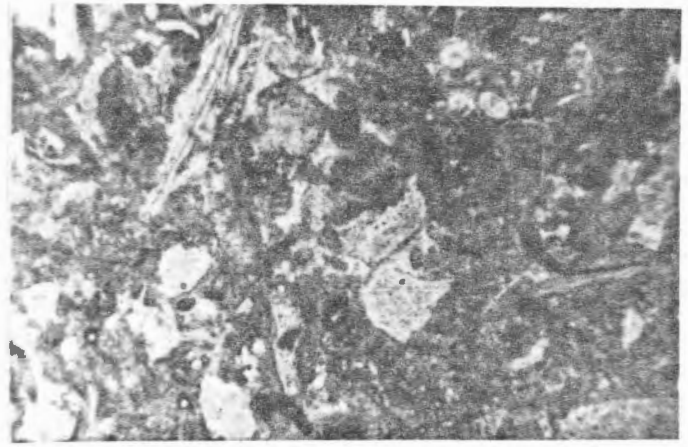
Specimen 5 - "G" zone, crinoid-bryozoa facies?, biomicrite, cross section C-C'. Few bioclasts are recrystallized. One half calcite stained red. (x 17.5) Plain light.
Cities Service #C-1 Blair 4410-18'
SE SW 29-30S-33W

Specimen 6 - "B" zone, biosparite, cross section B-B'. Pale blue areas are plastic which have entered all porosity. Center of clast in upper right not entered by plastic. Calcite stained red. (x 17.5) Plain light. Pan American #3 Black 4184-85' NE NE 17-30S-33W

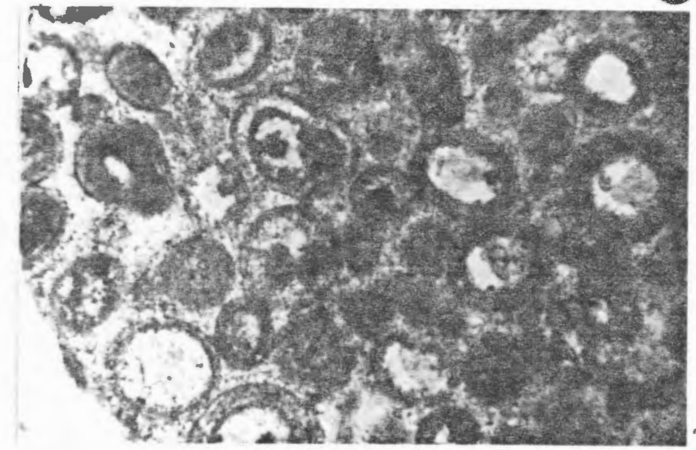
PLATE 4 - CENTRAL DIVISION GEOLOGICAL REPORT NO. 13-A (1963)
PHOTOMICROGRAPHS OF THIN SECTIONS



Specimen 1 - "J" zone, clastic facies, oösparite, cross section D-D'. Recrystallized oölites. Dolomite filling several voids. Good interparticle porosity. Calcite stained red. (x 17.5) Plain light. Cities Service #D-2 Conover 4583-84' NW SE 31-30S-33W



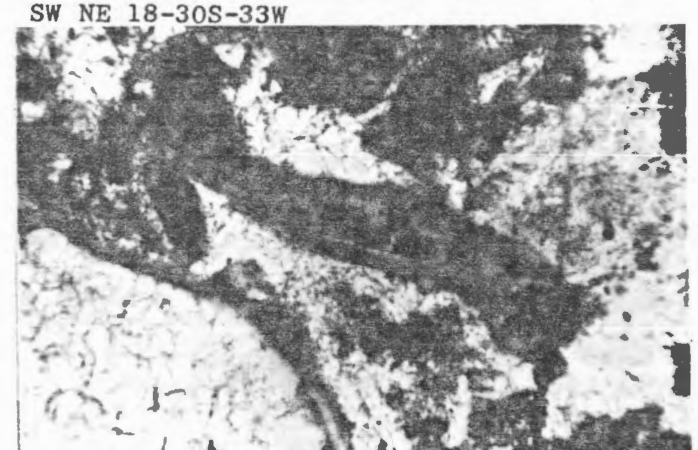
Specimen 2 - "N" zone, crinoid-bryozoa facies, biomicrite, cross section E-E'. Crinoid and bryozoa fragments floating in lime mud matrix. (x 17.5) Plain light. Pan American #E-1 Black 4790-4800' SW NE 18-30S-33W



Specimen 3 - "N" zone, clastic facies, oösparite, cross section E-E'. Oölites are mostly recrystallized. Few residual oömolds. One half calcite stained red. (x 17.5) Plain light.
Pan American #E-1 Black 4724-32'
SW NE 18-30S-33W

Specimen 4 - "J" zone, chalk facies, micrite, cross section D-D'. Non fossiliferous. Stylolites very common. Shallow water, compare with Specimen 5 - Plate 2. Nonindurated light colored under binocular microscope.
Cities Service #D-2 Conover 4609-10'
NW SE 31-30S-33W

Specimen 5 - "N" zone, crinoid-bryozoa facies, biomicrite, cross section E-E'. Bryozoa fragments and oölites floating in lime mud matrix. Matrix partially recrystallized. (x 17.5) Plain light.
Braden #1 Groth 4850-60'
NE NE 31-29S-33W



Specimen 6 - "N" zone, crinoid-bryozoa facies, biomicrite, cross section E-E'. Recrystallized lime mud matrix. Bryozoa fragments and other bioclastic fragments. (x 17.5) Plain light.
Pan American #1 Schnellbacher 4810-20'
NW SE 30-30S-33W