PETROLOGY AND STRATIGRAPHIC CORRELATION OF THE SUBSURFACE "HOGSHOOTER" LIMESTONE (UPPER PENNSYLVANIAN, MISSOURIAN) IN LOGAN, OKLAHOMA, LINCOLN, AND CREEK COUNTIES, OKLAHOMA.

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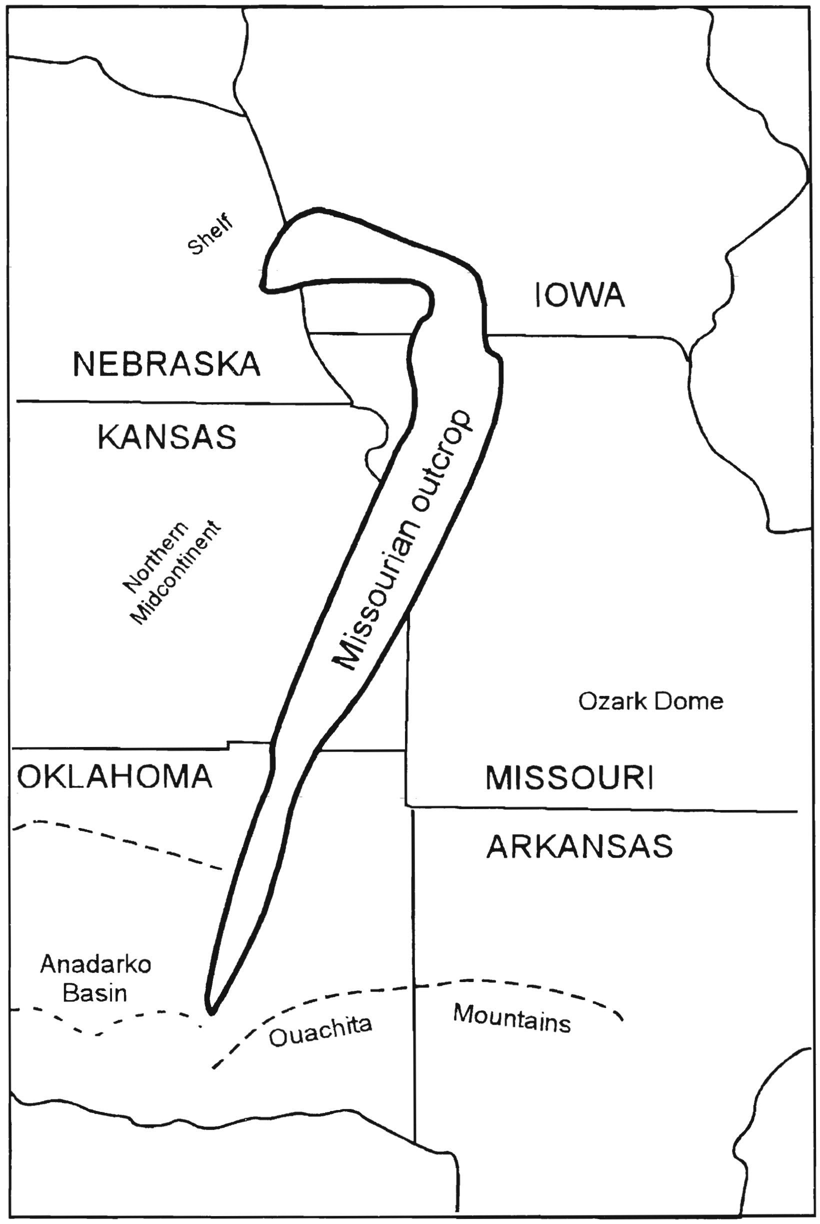

Fig 1. Extent of Missourian outcrop belt. After Niemann (1986).

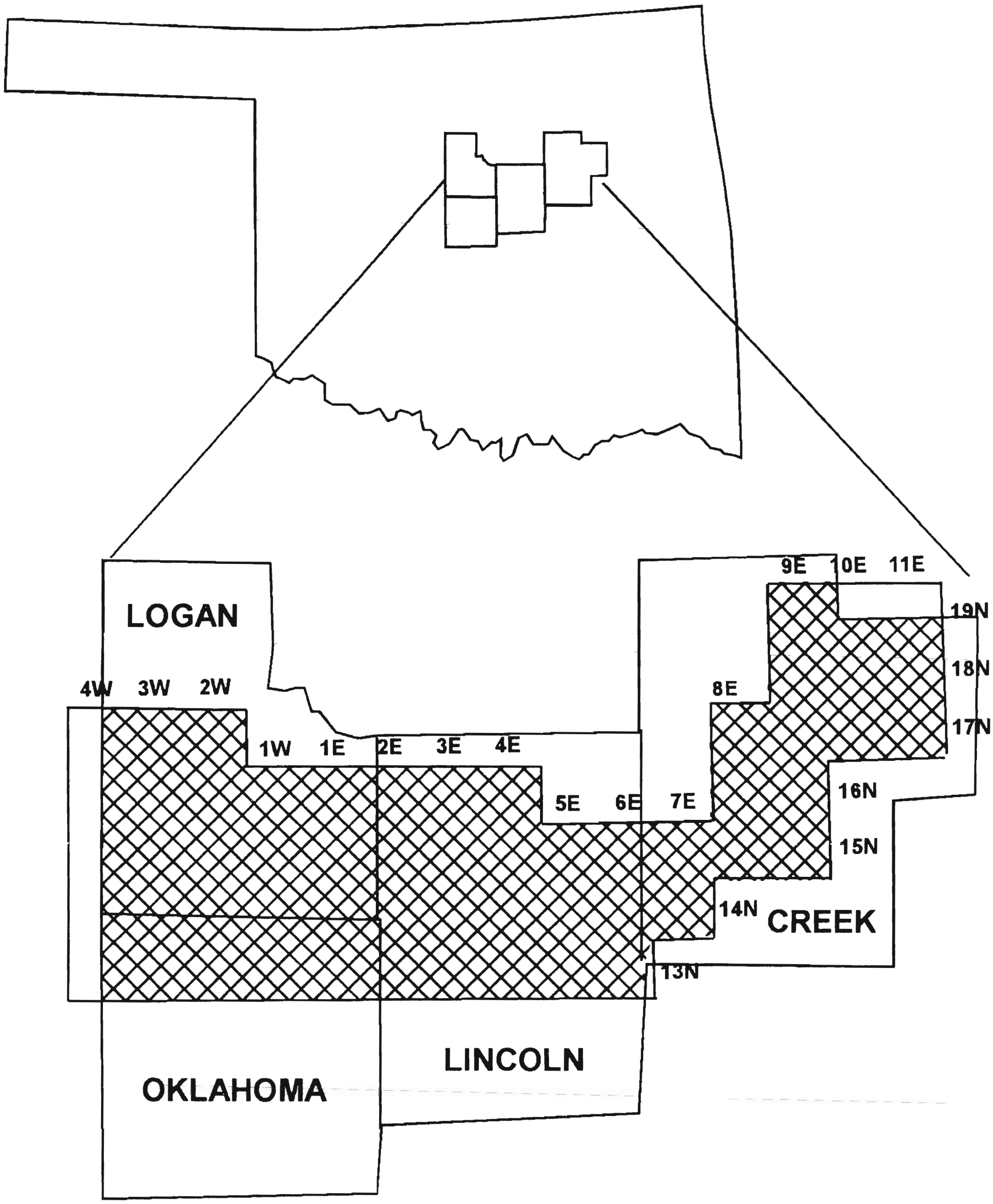

Fig. 2. Location of the study area.

A correlation between the outcrop and subsurface "Hogshooter" is useful in interpreting: (1) The regional stratigraphy and depositional environment of the Late Pennsylvanian, more specifically of the "Hogshooter" limestone, can be suggested, and (2) The correlation between porous, possibly reservoir-quality zones visible in outcrop and with subsurface units for exploration purposes.

Methodology

In order to correlate the surface exposures of the Hogshooter Formation to the subsurface, it was necessary to obtain core data. Four cores were acquired from the Oklahoma Geological Society in Norman for this study (listed from east to west): Shell Oil Company, Bunyard #1 (NE NE SE, Section 31, T. 15 N., R. 7 E., Creek County), Gulf Oil Company, Kightlinger #1 (NW SE NW, Section 22, T. 17 N., R. 3 W., Logan County), Gulf Oil Company, L. L. Tontz #1 (SW SW NW, Section 27, T. 17 N., R. 3 W., Logan County), and Cameo Oil Compay, Jeanette #2-23 (SW NE SW, Section 23, T. 14 N., R. 4 W., Oklahoma County). Each core was slabbed and displayed for examination at foot by foot intervals (Appendix B). A total of 22 depths were selected from the 4 cores for detailed examination. These intervals contained visible lithologic or facies changes. Thin sections were prepared for each of these 22 samples. Each thin section was examined photographically and 6 to 10 point counts were used to establish composition. Photomicrographs of generalized petrography were taken using plane- and cross-polarized light were made for each. Samples and photographs of the outcropping

“Hogshooter” near Ramona, Oklahoma were taken to find noticeable resemblances between surface and subsurface units.

Spontaneous potential and resistivity curves were utilized from 34 wells to create 6 generalized cross sections and established stratigraphic correlations and to interpret depositional environment (Fig. 3, Fig. 4). Wells included in the cross-sections were chosen based on location, predetermined cross-section lines between the four core locations, and the presence of the “Hogshooter” limestone signature on the well log. These cross sections serve to connect the four cores of this study to the “Hogshooter” limestone outcroppings in eastern Creek and western Tulsa Counties and to provide useful stratigraphic information on the “Hogshooter” across Central Oklahoma.

Previous Investigations

The Hogshooter Formation was so-named by Ohern (1914) for an outcrop along Hogshooter Creek in Washington County, Oklahoma (T26N, R14E). The Winterset limestone was first named by Tilton and Bain (1897) at Winterset, Iowa, and was later shown by Moore (1932) as the top unit of the Dennis Formation in Kansas. In 1910, Ohern classified the local algal limestone visible in outcrop west of Tulsa, Oklahoma, as the Lost City Limestone. Jewett (1932) labeled the limestone and overlying shale above the Galesburg Shale in Kansas the Canville Limestone and the Stark Shale. Oakes (1940) was the first to assign all four members to the Hogshooter Formation of Oklahoma.

Many studies have been completed on the outcropping Hogshooter Formation in northeastern Oklahoma (Oakes, 1940; Dille and Warren, 1952; Hansen, 1957; Oakes,

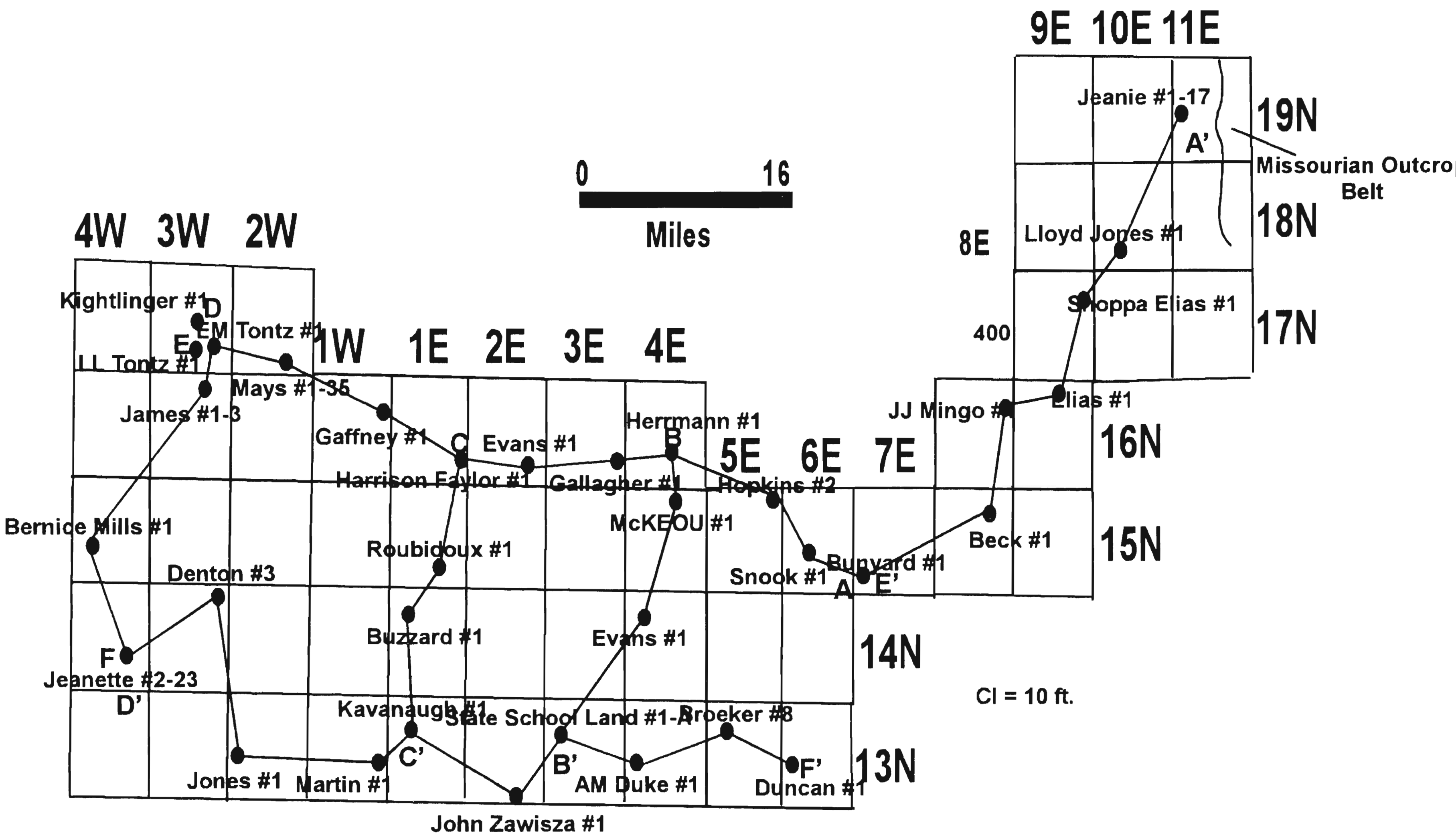

Fig. 3. Map displaying location of 34 wells and 6 cross-sections within the study area.

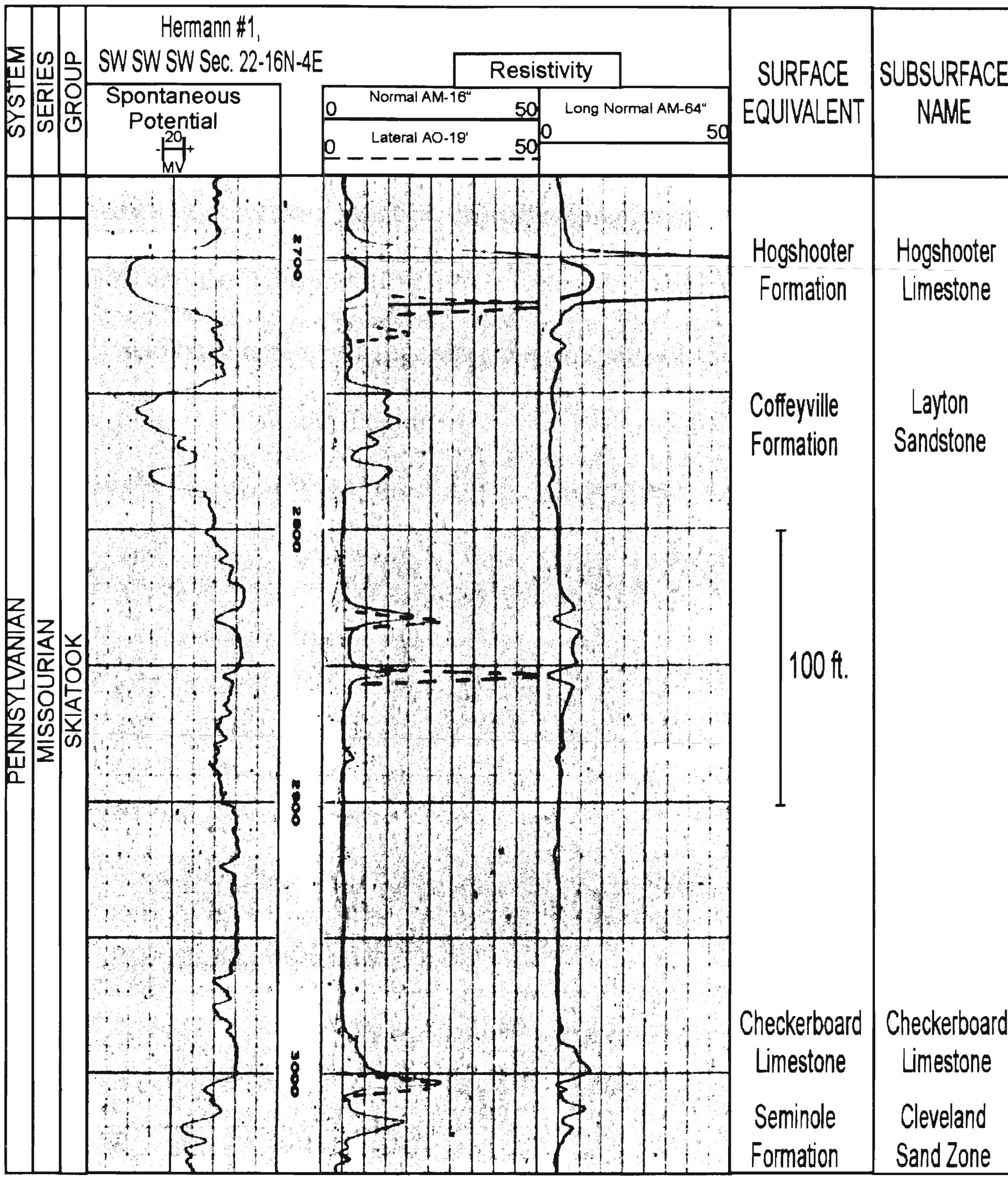

Fig 4. Type electric log for the Hogshooter interval.

1959; Cronoble, 1951; Cronoble and Mankin, 1963; Bennison, 1973; Strimple and Cocke, 1973; Niemann, 1986). In the subsurface, the "Hogshooter" has been used as a marker in studies of other units, such as the underlying Layton sandstone (Bross, 1960; Ekebafe, 1973) and the overlying Cottage Grove sandstone (Towns, 1978). Several surveys have also been conducted regarding the generalized subsurface geology of Creek, Lincoln, Logan, and Oklahoma Counties (Carver, 1947; Akmal, 1950; Nolte, 1951; McKenny, 1952; Ferguson, 1954; Ford, 1954; Graves, 1954; Cole, 1955; Maddox, 1955; Oakes, 1955; Blumenthal, 1956; Furlow, 1956; Miller, 1959; Greer, 1961; Kunz, 1961; Kurash, 1961; Ferguson, 1962; Smith, 1986).

CHAPTER II

GEOLOGIC SETTING

Regional Setting

The study area was located approximately 9 degrees south of the equator in the Early Pennsylvanian, approximately 4 degrees south of the equator in the Late Pennsylvanian, and most likely had a temperate or tropical environment (Jorgenson, 1989). In the Early Pennsylvanian, the Central Oklahoma Platform (Fig. 5) was still forming, and much of northern and central Oklahoma was exposed (Jorgenson, 1989). The Nemaha Ridge was continuing to uplift, cutting through western Logan and Oklahoma Counties (Fig. 6). This uplift stretches from southeastern Nebraska to south-central Oklahoma and lies directly west of the westernmost wells in this study. The pre-Seminole Caney River arch borders the study area to the northeast, forming a northwesterly-southeasterly-oriented ridge in Osage, northern Tulsa, and Rogers Counties. Chenoweth (1965) suggests that the Caney River arch formed during carbonate deposition of the "Checkerboard" and "Hogshooter", causing deposition to occur on the flanks of the arch. By the Middle and Late Pennsylvanian, the cyclic fluctuations in sea level inundated most of Oklahoma, the Amarillo-Wichitas, Arbuckles, Ouachitas, and the Nemaha Ridge were positive features in Oklahoma, while the Anadarko and Arkoma Basins were subsiding (Jorgenson, 1989) (Fig. 7).

Stratigraphic Reefs

The Hogshooter Limestone has been referred to as consisting of "reefs" by several authors. One purpose of this study is to examine the "Hogshooter" and determine

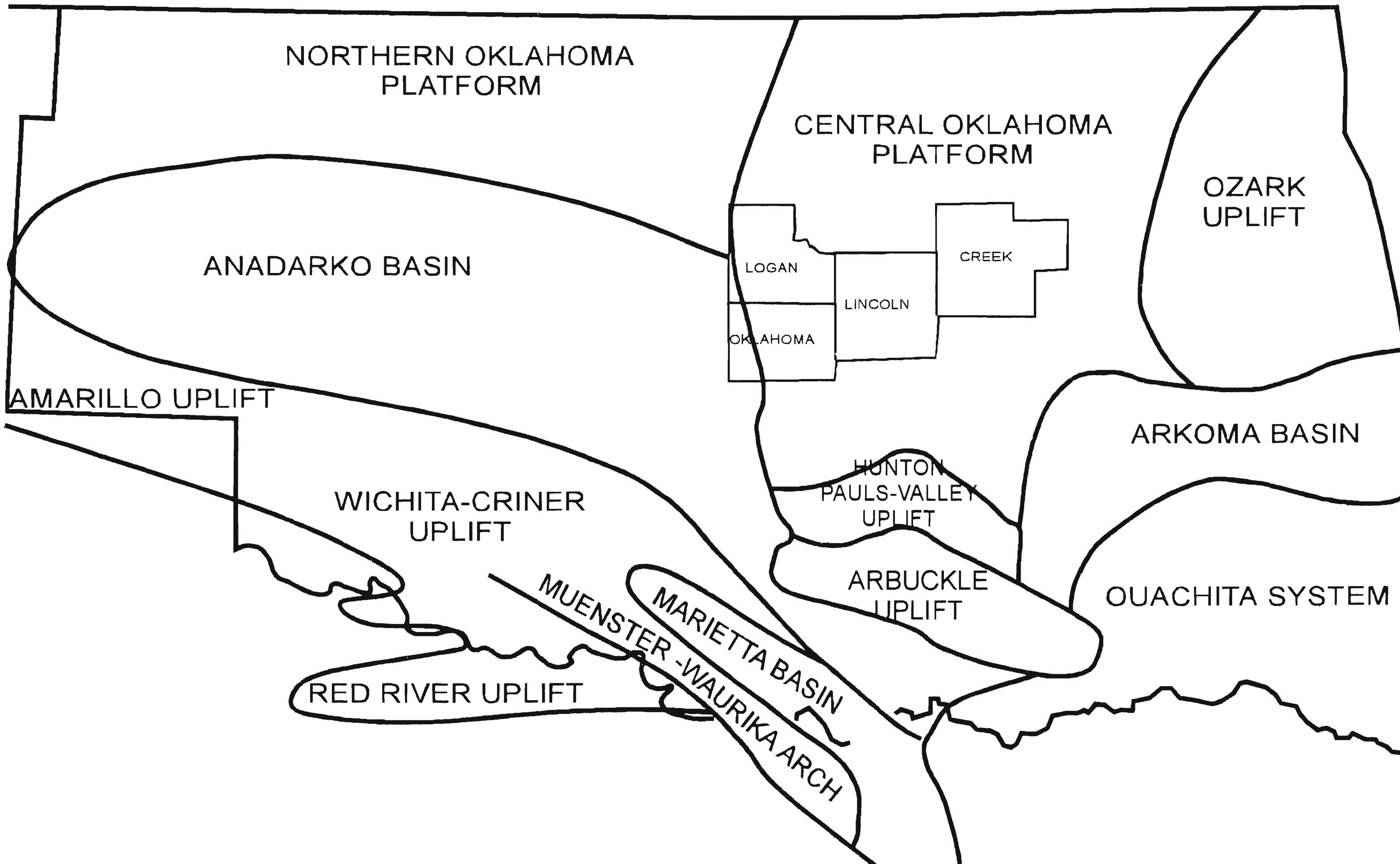

Fig. 5. Tectonic map showing major structural features of Oklahoma and relativity to the current area undergoing investigation. Modified from Arbenz (1956) and Al-Shaieb and Shelton (1977).

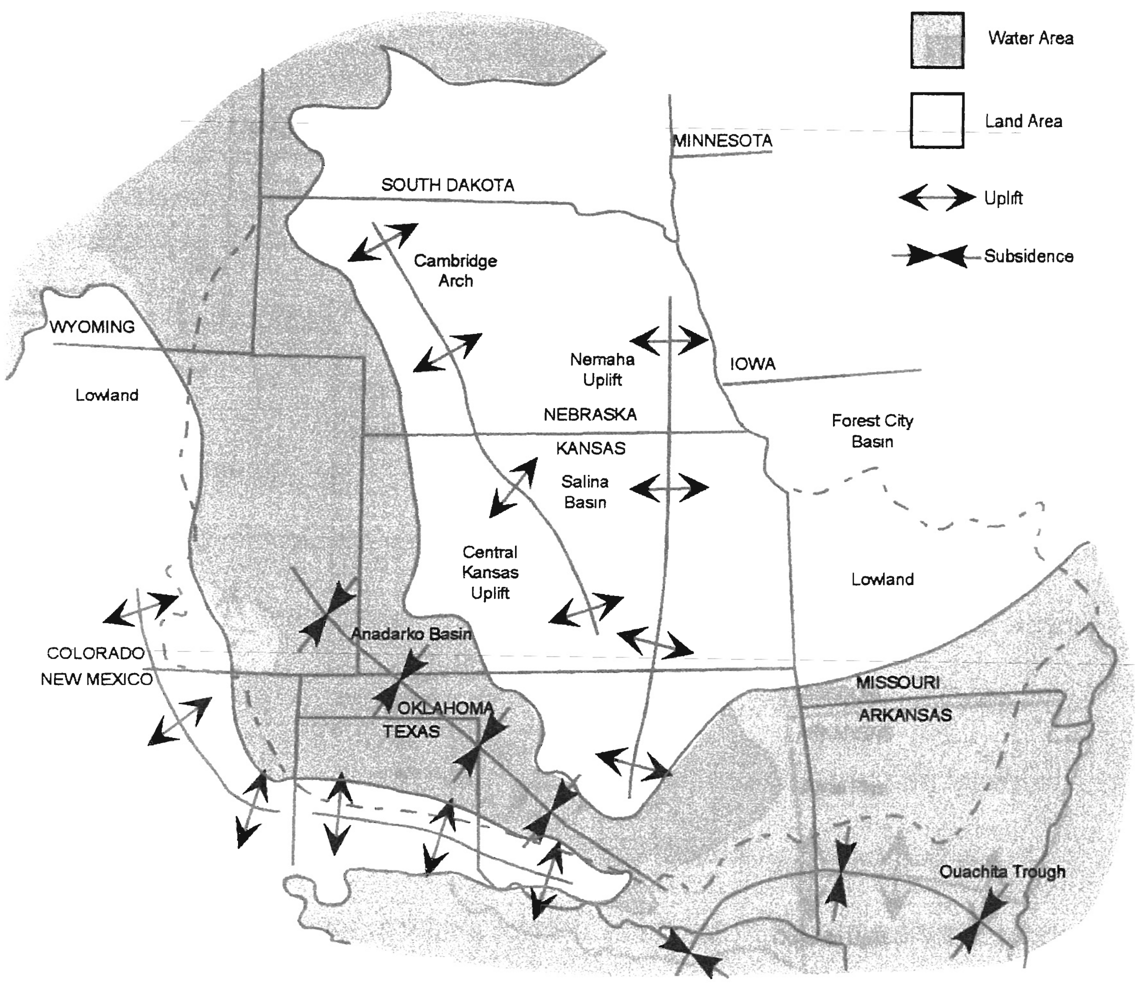

Fig. 6. Early Pennsylvanian structural and hydrological features in the central United States. Modified from Jorgenson (1989).

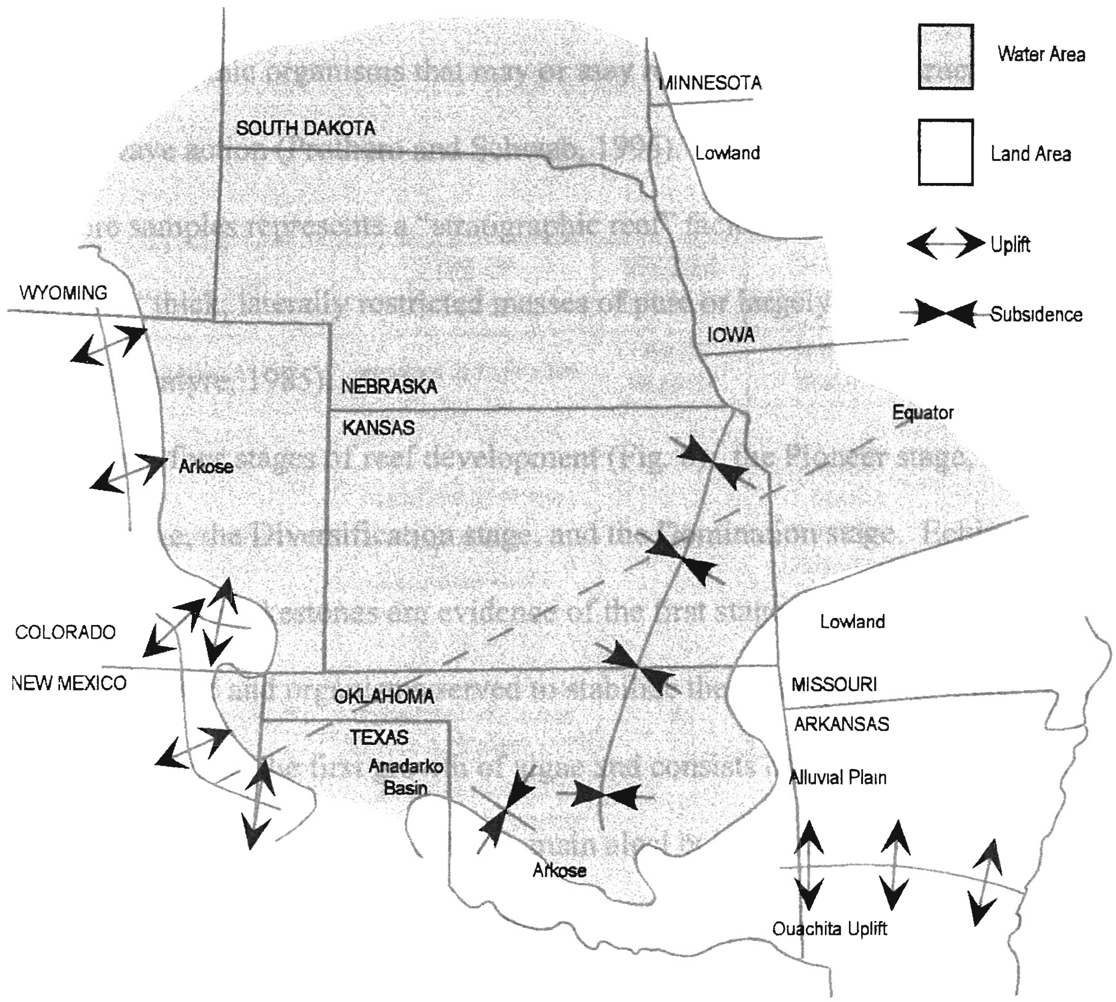

Fig. 7. Late Pennsylvanian structural and hydrological features in the central United States. Modified from Jorgenson (1989).

possible depositional models. To understand the Hogshooter Limestone, the difference between a "reef" and a "bioherm" must be explained. A reef is a buildup that is *grown* upwards by organisms and has a wave-resistant framework. A bioherm is an *in situ accumulation* of benthic organisms that may or may not have a definite structure or resistance to wave action (Prothero and Schwab, 1996). The "Hogshooter" limestone visible in core samples represents a "stratigraphic reef" facies where one to several bioherms form "thick, laterally restricted masses of pure or largely pure carbonate rock" (James and Macintyre, 1985).

There are four stages of reef development (Fig. 8): the Pioneer stage, the Colonization stage, the Diversification stage, and the Domination stage. Echinoderm-rich packstones and wackestones are evidence of the first stage, where skeletal limey sands were deposited and organisms served to stabilize the underlying substrate. The second stage represents the first growth of algae and consists of fairly thin layers of bafflestone or floatstone. Above this layer, main algal build-up occurs and is characterized by thick framestone with a micritic mud matrix. The final stage takes place when the reef build-up reaches sea-level and algal growth declines. This may form an algal-laminated bindstone or framestone visible at the top of the sequence (James and Macintyre, 1985).

Carbonate mound/bioherm structure is similar to that of a reef, but there are unique lithological and stratigraphic differences (Fig. 9). Mounds/bioherms are generally made up of four main facies: the basal bioclastic lime mudstone to wackestone pile, the mound core, the capping facies, and the flanking facies (James and Macintyre, 1985). Bioclastic lime mudstone to wackestone that lacks baffling organisms (such as algae)

STAGE	TYPE OF LIMESTONE	SPECIES DIVERSITY	SHAPE OF REEF BUILDERS
DOMINATION	bindstone to framestone	low to moderate	Laminate encrusting
DIVERSIFICATION	framestone (bindstone) mudstone to wackestone matrix	high	domal massive lamellar branching encrusting
COLONIZATION	bafflestone to floatstone (bindstone) with a mud stone to wackestone matrix	low	branching lamellar encrusting
STABILIZATION	grainstone to rudstone (packstone to wackestone)	low	skeletal debris

Fig. 8. Stages of reef growth from James (1979).

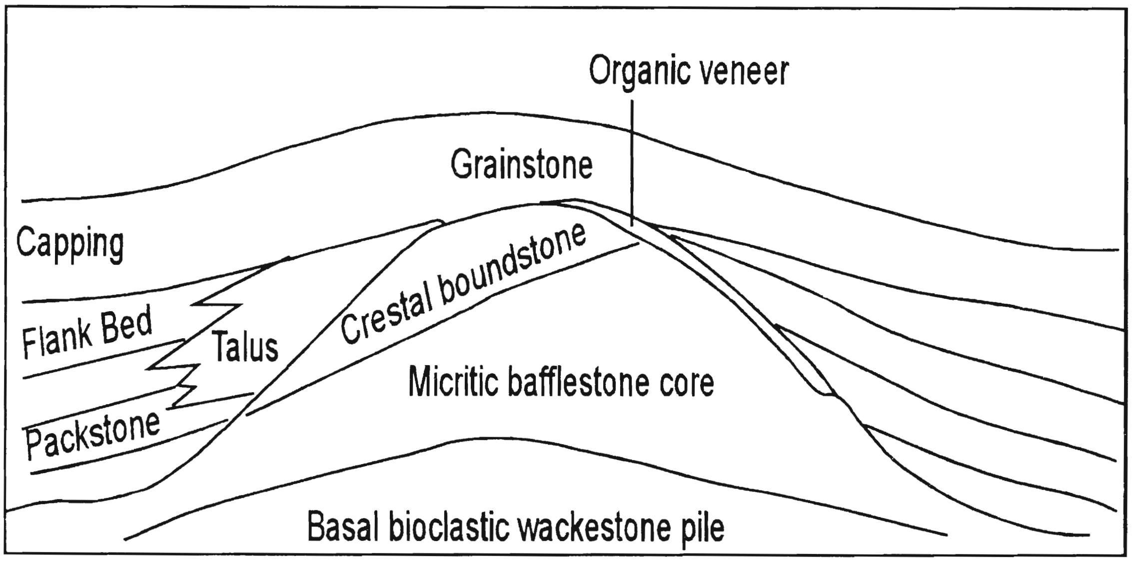

Fig. 9 Idealized carbonate mound (modified from James and Macintyre, 1985)

forms the base of the mound and provides a surface where the baffling organisms of the core can begin to grow and accumulate. The mound core contains a basal bioclastic wackestone, overlain by a micritic algal bafflestone and, occasionally, a crestal boundstone or organic veneer at the very top. As the mound develops, skeletal debris is washed over the sides and deposited in carbonate mud on the flanks of the core, forming the flanking facies. The flanking facies continue to build upward with the mound core. When carbonate growth has ceased, skeletal debris and other sediments are deposited on top of the core and flanking facies, forming the capping facies of the mound. An excellent example of all four mound facies can be seen near Sand Springs, Tulsa County, Oklahoma where the Lost City limestone member outcrops along Highway 51 (Fig. 10).

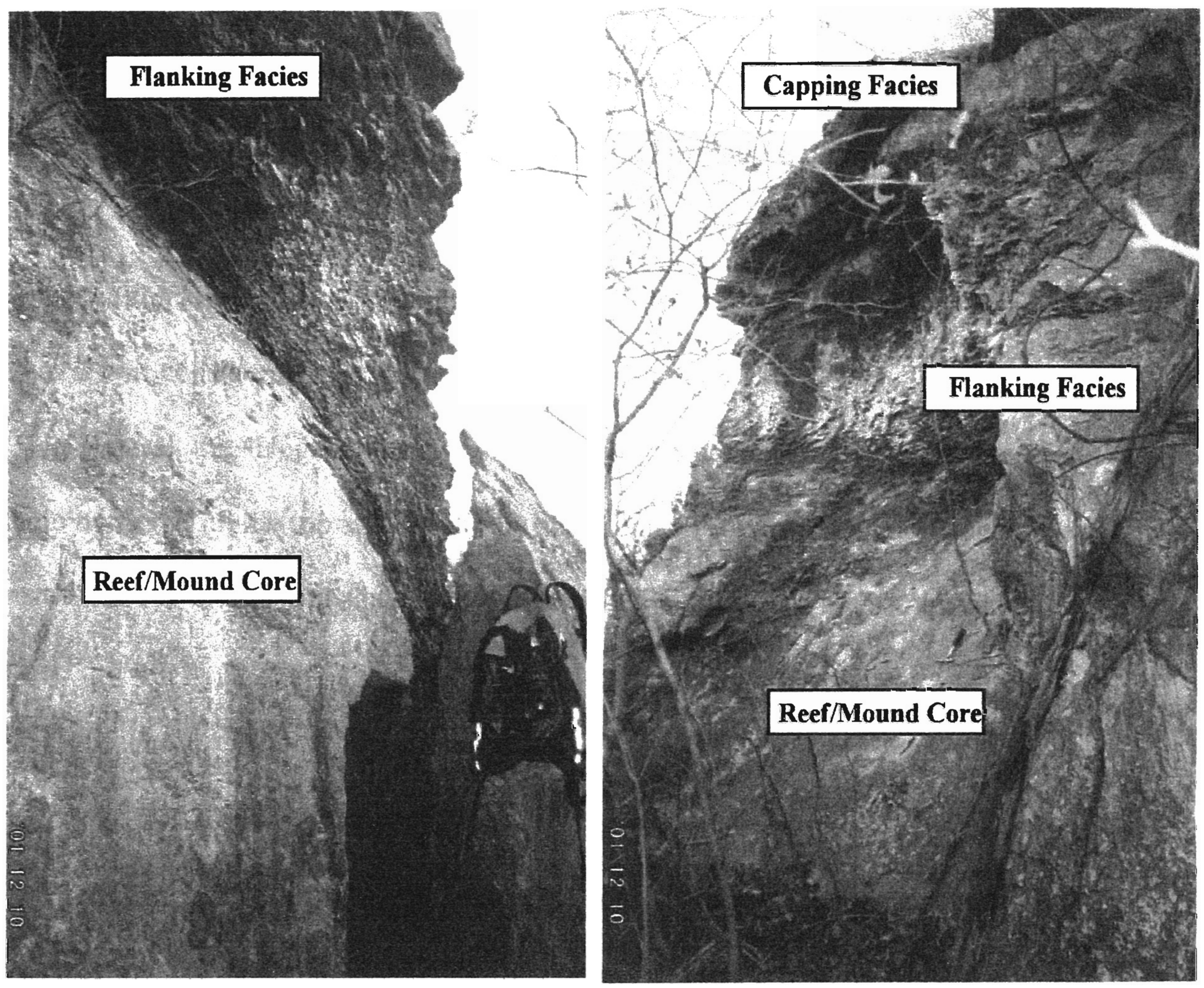

Fig. 10. Photographs of Lost City limestone member in quarry off of Highway 51, near Sand Springs, Oklahoma. Notice the dip of the flanking facies over the reef/mound core. The capping facies consists of very resistant crinoidal limestone.

CHAPTER III

STRATIGRAPHIC FRAMEWORK

The "Hogshooter" limestone ranges in thickness from approximately 5 to 40 feet throughout the study area. It overlies the Coffeyville Formation, consisting of between 120 to 500 feet of interbedded shale and sandstone, including the Layton sandstone unit that ranges in thickness from approximately 0 to 100 feet. The Checkerboard limestone is the basal unit considered in this study.

In general, the "Hogshooter" is composed of limestone or interbedded limestone and shale bordered on the top and bottom by shale units. The limestone thickens toward the west while the underlying shale and sandstone units thicken to the southeast and northeast.

Stratigraphy

The Hogshooter Formation in Oklahoma consists of four members: the Canville Limestone, the Stark Shale, the Lost City Limestone, and the Winterset Limestone. The Winterset member is further divided into four submembers by Oakes (1940), Hansen (1957), Cronoble (1961), Cronoble and Mankin (1965), and Niemann (1986) in acknowledgement of differing lithofacies. Descriptions of the underlying Coffeyville Formation and the "Hogshooter" members are summarized briefly below in order to propose a possible correlation between the limestones in the core with those involved in surface studies (Fig. 11).

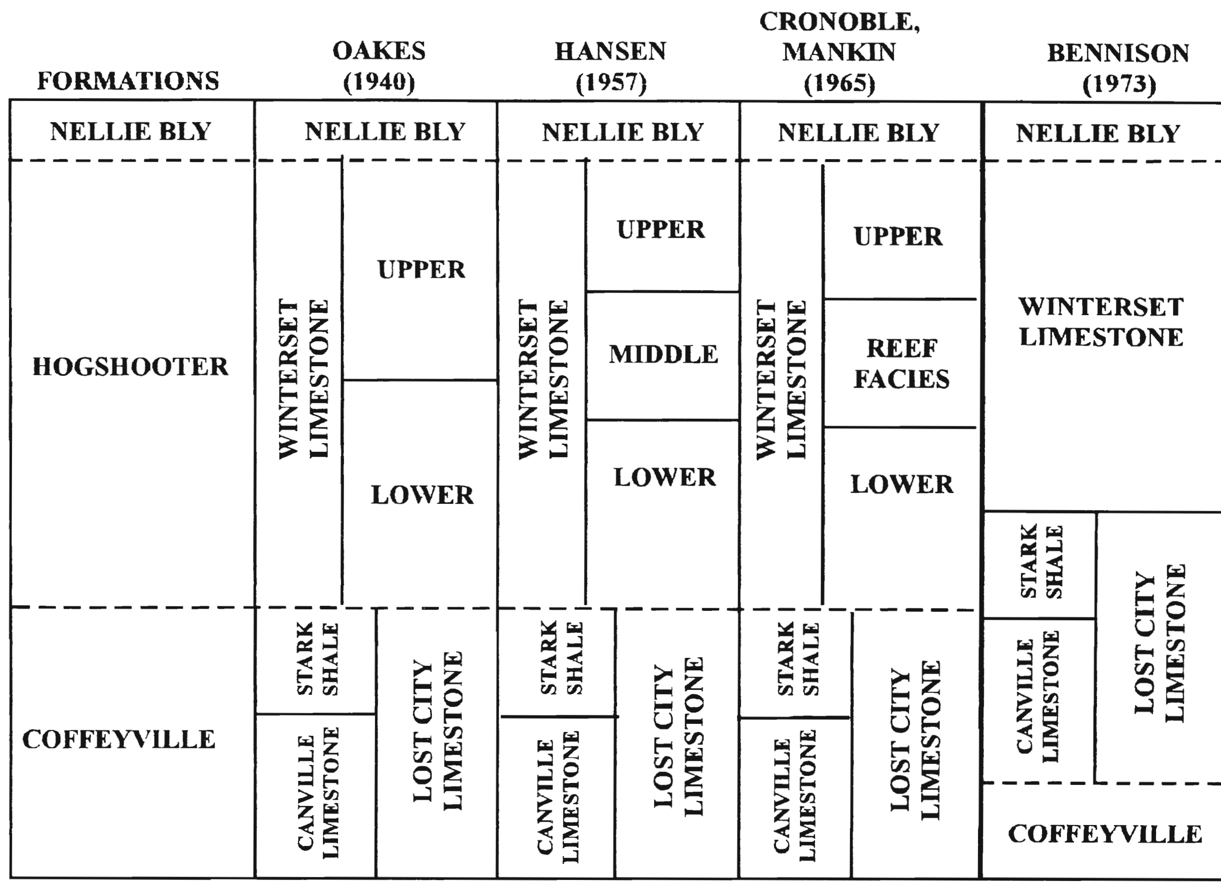

Fig. 11. Comparitive chart of Hogshooter stratigraphy and nomenclature from previous investigations.

Coffeyville Formation. The Coffeyville Formation is bounded at the base by the Checkerboard Limestone and at the top by the Hogshooter Limestone. The "Coffeyville" consists of 200 to 300 feet of interbedded sandstones, shales, and siltstones, and was named for an outcropping near Coffeyville, Kansas by Schrader and Haworth (1905). At the surface, in western Tulsa County, the lower and middle Coffeyville consists of gray shales and thin sandstone lenses. The upper part of the formation is made up of a 20 to 50-foot sandstone interval that correlates with the prolific Layton sandstone in the subsurface, as well as an upper, thin sandstone unit (3 to 5 feet thick), and 20 to 25 feet of interbedded shale and thin coal beds. The Cedar Bluff coal sits on top of the Layton in western Tulsa County and is visible beneath the Lost City Limestone in the Sand Springs area (Bennison, 1973). The Coffeyville Formation is only visible in the Cameo, Jeanette #2-23 core. However, the interbedded sandstones and shales of the "Coffeyville" that are visible in well logs can be used to explain depositional patterns and environments.

Canville Limestone Member. The Canville limestone member was first examined by Jewett (1932) as the basal member of the Dennis Formation of Kansas. Oakes (1940, p. 43) observed a "dense, fine-grained siliceous limestone" in Washington County, Oklahoma, approximately one foot in thickness. Hansen (1957) and Cronoble (1961) referred to this limestone as being a local deposit whereas the Canville continues thinning southward until it pinches out into the Coffeyville Formation in southern Washington County, Section 6, T 25 N, R 14 E). It is a gray to brownish gray, silty limestone with distinctive vertical joints (Hansen, 1957). According to Oakes (1940), the Canville member is only about 1 foot thick in outcrop and is conformably overlain by the Stark shale (Fig. 12).

Stark Shale Member. The Stark shale member consists of up to ten feet of carbonaceous, black, fissile shale bounded on the top and bottom by brown and gray clay-rich shales (Cronoble, 1961). First studied by Jewett (1932) in Madison County, Iowa, the Stark shale conformably overlies the Canville limestone and underlies the lower Winterset limestone. In northeastern Oklahoma, the Stark shale reaches its maximum thickness (in outcrop) of ten feet in northern Washington County (Oakes, 1940), and gradually thins out into northern Tulsa County where the Lost City Limestone Member replaces it and the Canville Member.

Lost City Limestone Member. The Lost City Limestone Member was first described from outcrops in western Tulsa County, Oklahoma by Ohern (1910). The Lost City represents a localized algal wackestone and packstone (bioherm) deposit (Fig. 13). Thickness ranges from approximately 3 feet in western Nowata County, to almost 50 feet between Tulsa and Sand Springs (Hansen, 1957) where the main bioherm core/algal mound is located. Niemann (1986) described four lithofacies making up the Lost City limestone: (1) sparry, brecciated algal calciculite (representing the main bioherm/mound core), (2) algal calciculite, (3) dark crinoidal calciculite, and (4) skeletal calciculite. The dark crinoidal calciculite formed on the flanking facies of the mound core and can be found (in outcrop) as far as southeastern Creek County (T 14 N, R 10 E). A similar lithology exists in the 4 cores, and the same limestone thickness is found in the western part of the study area. However, because the Lost City Limestone is referred to in the

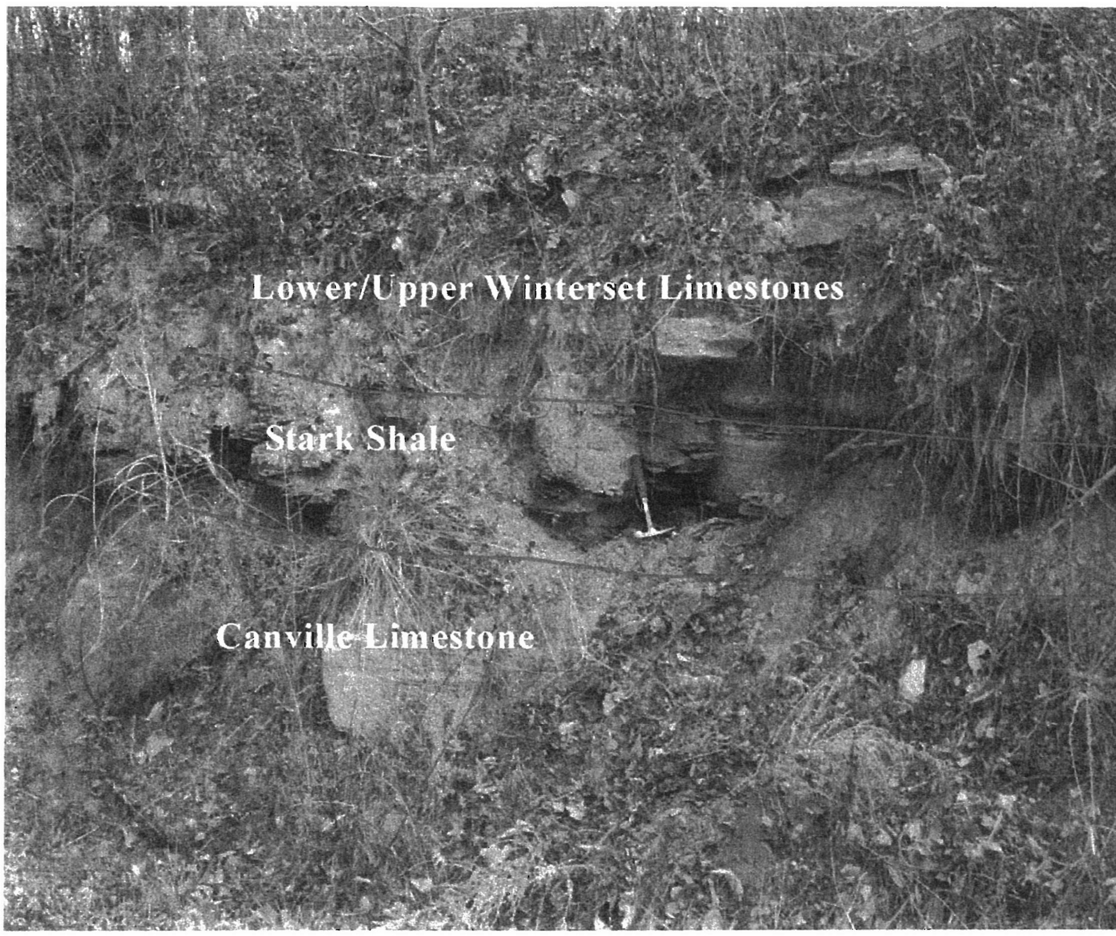

Fig. 12. Outcrop photograph taken southeast of Bartlesville, Oklahoma showing the blocky Canville Limestone, the black Stark Shale, and thin Lower and Upper Winterset Limestone units.

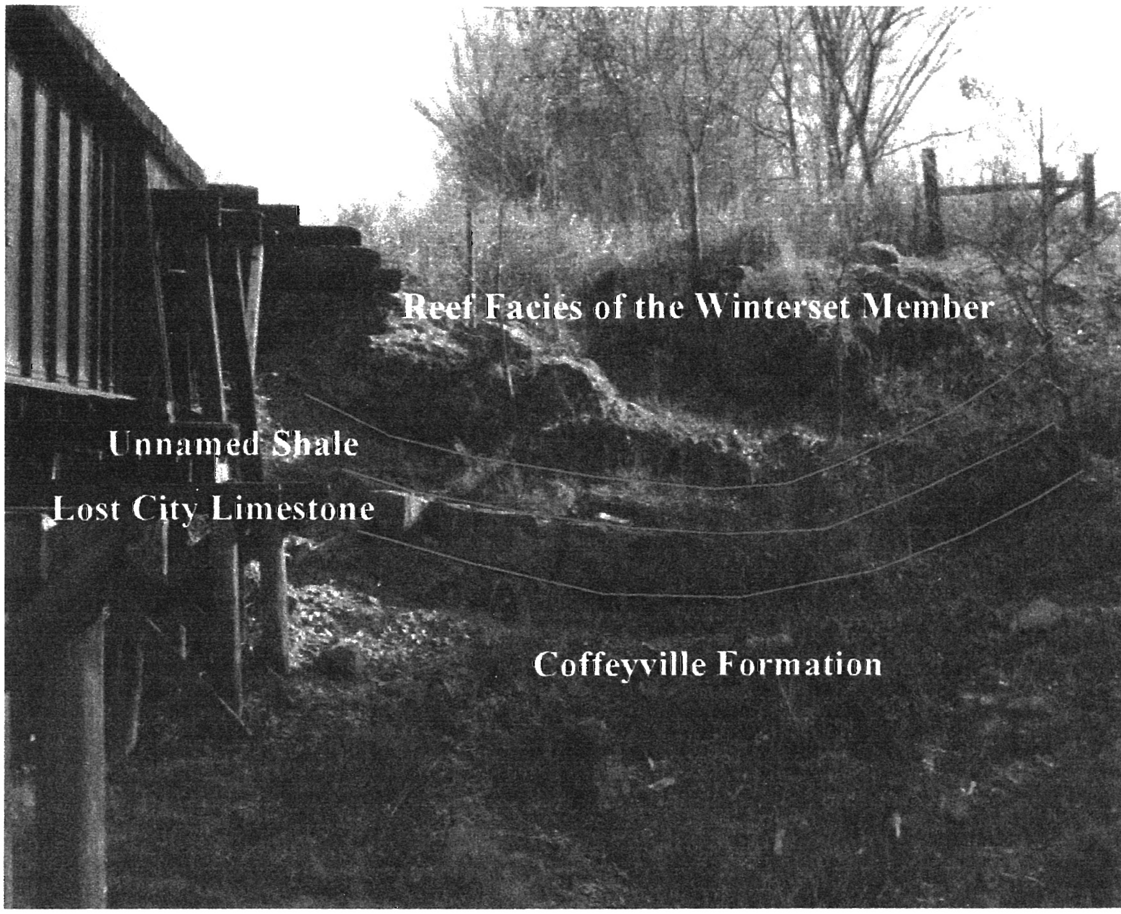

Fig. 13. Outcrop photograph taken near Ramona, Oklahoma showing the relationship between the Lost City Limestone and the Reef Facies of the Winterset Member.

literature as a localized event, it would be difficult to correlate the outcropping Lost City Member with westernmost wells.

Winterset Limestone Member. Tilton and Bain (1897) were the first to study the Winterset limestone in Winterset, Iowa. It was then further subdivided by Oakes (1940) into two submembers, the Lower and Upper Winterset submembers. Hansen (1957) further subdivided the Winterset, adding a Middle Winterset submember. Finally, Cronoble and Mankin (1965) excluded the Middle Winterset submember from their study and added the Reef Facies of the Winterset Member to include reef facies of the lower and upper Winterset submembers. For this study, all four submembers will be reviewed.

- Lower Winterset Submember. The lower Winterset (as seen in outcrop) is commonly tan to brown-gray biosparrudite or oosparite and contains abundant dark brown to black phosphatic nodules and rounded glauconite grains (Cronoble and Mankin, 1965). Sand and silt-sized terriginous grains are also abundant, along with crinoids and foraminifera. Algae and other skeletal grains are generally lacking. Phosphate found at the base of the Gulf, L.L. Tontz #1 core might represent the upper portion of the Lower Winterset, or the lower part of the Middle Winterset Submember. Lack of abundant phosphate in the other 3 cores suggests that the Lower Winterset is not present.
- Middle Winterset Submember. Hansen (1957) further subdivided the Middle Winterset into lower and upper

portions. The lower part consists of a biomicrite with abundant brachiopod and bryozoan remains and a trace of phosphate. Sparry calcite regularly fills or partially fills secondary, sheltered porosity. The upper part of the Middle Winterset can consist of an algal biomicrite, micrite, or pelsparite. Brecciation and thin layers of limestone-patched shales are common in both parts of the submember.

- Upper Winterset Submember. Four lithologies were described by Hansen (1957) for the Upper Winterset submember. Foraminifera, bryozoans, crinoids, peloids, and sparry calcite are most common in the basal biomicrite lithofacies, which is usually overlain by a crinoid- and clay-rich limestone. Black shale overlies the foraminiferal biomicrite on outcrop and contains mostly clay, crinoids, and fusilinids. Large, ellipsoidal, calcareous concretions can also be found within this unit. Finally, sandy limestone with crinoids and fusilinids overlies the black shale.
- Reef Facies of the Winterset Member. Cronoble and Mankin (1965) described two "reef" facies in Washington County, Oklahoma. It was determined that these reefs developed locally. The base of the Reef Facies consists of a partially brecciated, skeletal-algal biomicrite, overlain by

non-skeletal, algal microsparite. An irregularly bedded crinoidal biosparite and unit with abundant fenestrate bryozoans cap the "reef" core.

Nellie Bly Formation. The Hogshooter Formation is overlain by the Nellie Bly Formation, which was first studied by Ohern (1914) near Nellie Bly Creek in Washington County, Oklahoma. It consists of silty shale, sandstone, and patchy, sandy limestone that appear to sit conformably on top of the "Hogshooter" and below the "Dewey" limestone.

CHAPTER IV

CORE DESCRIPTIONS AND PETROGRAPHY

Four cores representing the subsurface "Hogshooter" limestone in southwestern Creek, east-central Logan, and northern Oklahoma Counties were examined and analyzed. 22 thin sections were cut at predetermined intervals within each of the four cores to represent visible facies, or lithologic changes. The cores are described below from easternmost to westernmost. Embry and Klovan's (1972) modification of Dunham's (1962) classification of limestone based of depositional texture was used to name core lithologies (Fig. 14). Generalized core and thin section descriptions can be viewed in Appendix B.

Shell, Bunyard #1 (1590-1575 feet). The basal bafflestone is composed of mainly algae, encrusting bryozoans, echinoderms, traces of phosphate, and gastropod and brachiopod fragments surrounded by micritic mud (Fig. 15; Fig. 16). At about 1585 feet, algal content gradually decreases, as does the average size and appearance of skeletal remains (Fig. 17). A small amount of echinoderm-rich, dark gray mud occurs at 1582 feet. At 1580 feet, there are few easily recognizable algal or skeletal grains, mainly just sparry calcite surrounded by slightly hematitic micrite. Thin section analysis suggests that the increase in sparry calcite and decrease in micrite is directly related to porosity development. Porosity is highest in this section of the core (approximately 3%) due to secondary fractures and dissolution of calcite spar. Algal and skeletal content increases

<table>
<tr><td colspan="6">Original components not organically bound during deposition</td><td colspan="3">Originial components organically bound during deposition</td></tr>
<tr><td colspan="4">of the allochems, less than 10% > 2 mm diameter</td><td colspan="2">of the allochems more than 10% > 2 mm</td><td colspan="3">boundstone</td></tr>
<tr><td colspan="3">contains carbonate mud (particles less than 0.03 mm diameter)</td><td>mud absent</td><td rowspan="3">matrix supported</td><td rowspan="3">grain supported</td><td rowspan="3">organisms acted as baffles</td><td rowspan="3">organisms encrusting and binding</td><td rowspan="3">organisms building a rigid framework</td></tr>
<tr><td colspan="2">mud-supported</td><td colspan="2" rowspan="2">grain supported</td></tr>
<tr><td>less than 10% grains</td><td>more than 10% grains</td></tr>
<tr><td>mudstone</td><td>wackestone</td><td>packstone</td><td>grainstone</td><td>floatstone</td><td>rudstone</td><td>bafflestone</td><td>bindstone</td><td>framestone</td></tr>
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Fig. 14. Classification of limestones based on depositional texture (after Dunham, with modifications of Embry and Klovan).

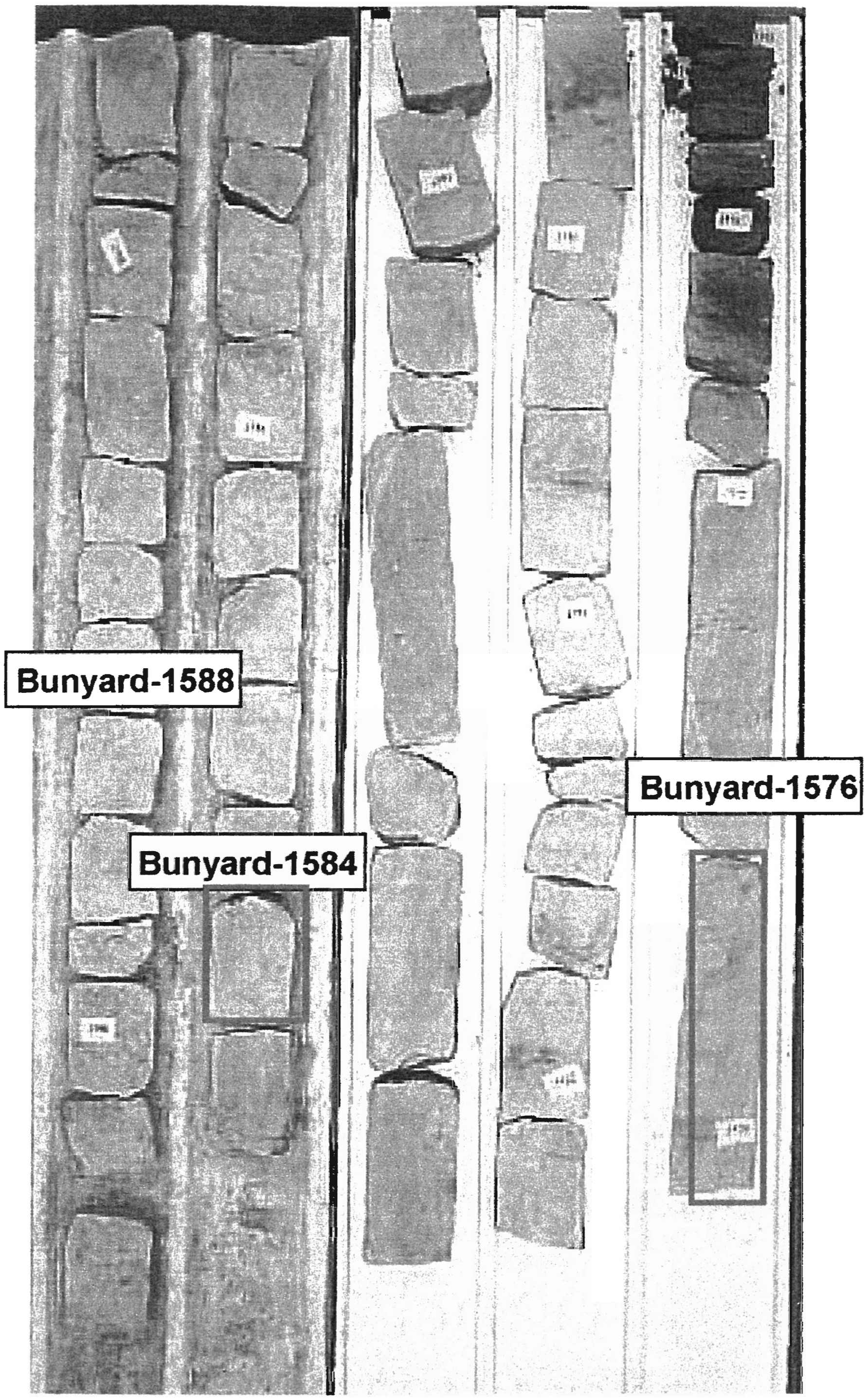

Fig. 15. Bunyard #1 Core from 1590 to 1575 feet, Creek County, Oklahoma, T 15 N, R 7 E, Section 31 NE NE SE. Core photo locations outlined in red, and thin section locations in black boxes.

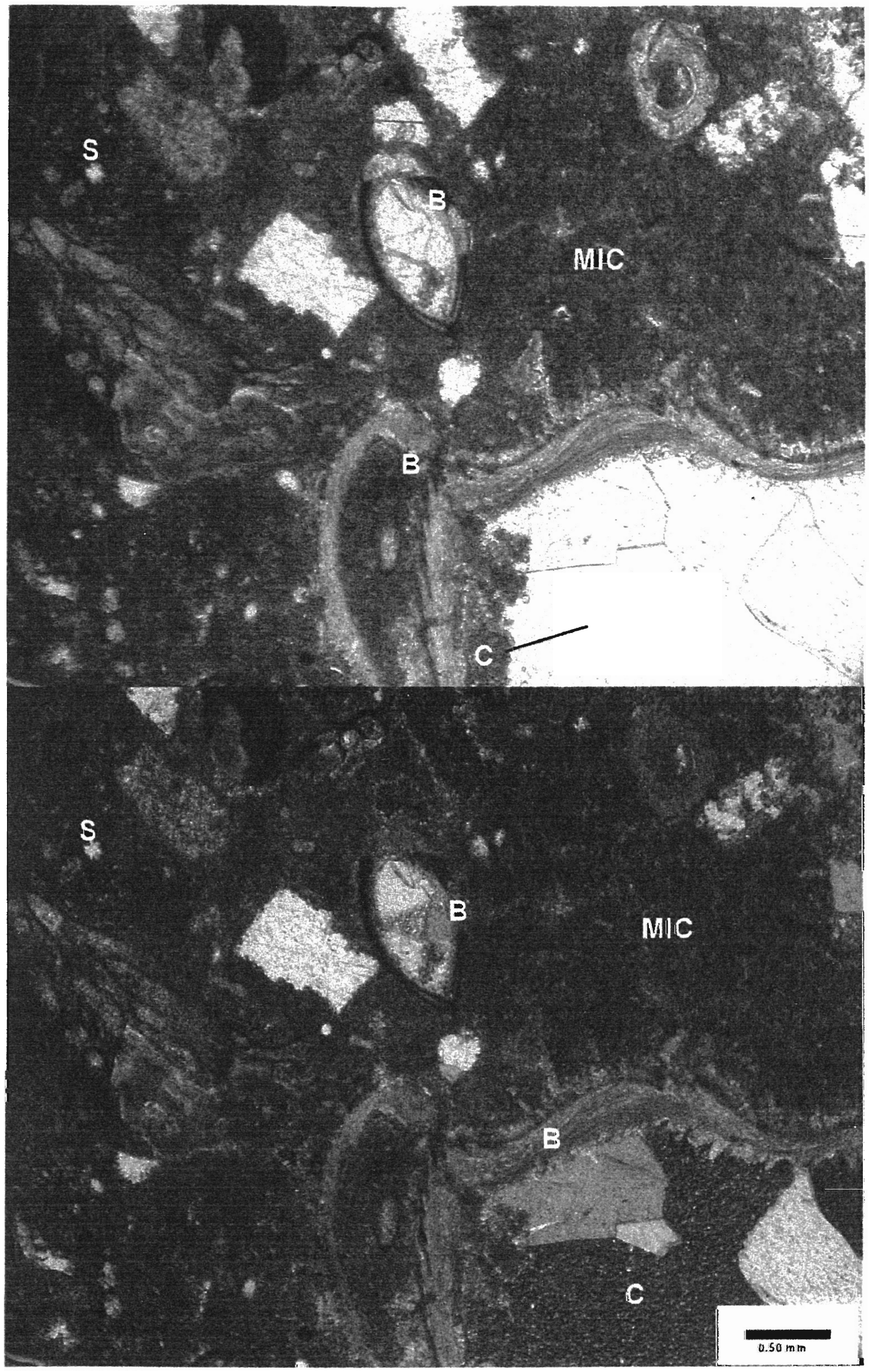

Fig. 16. Well-preserved brachiopods (B), tetraxon sponge spicules (S), and calcite spar (C) in micritic mud (MIC). Sheltered porosity has been completely filled by sparry and dogtooth calcite (Bunyard-1588).

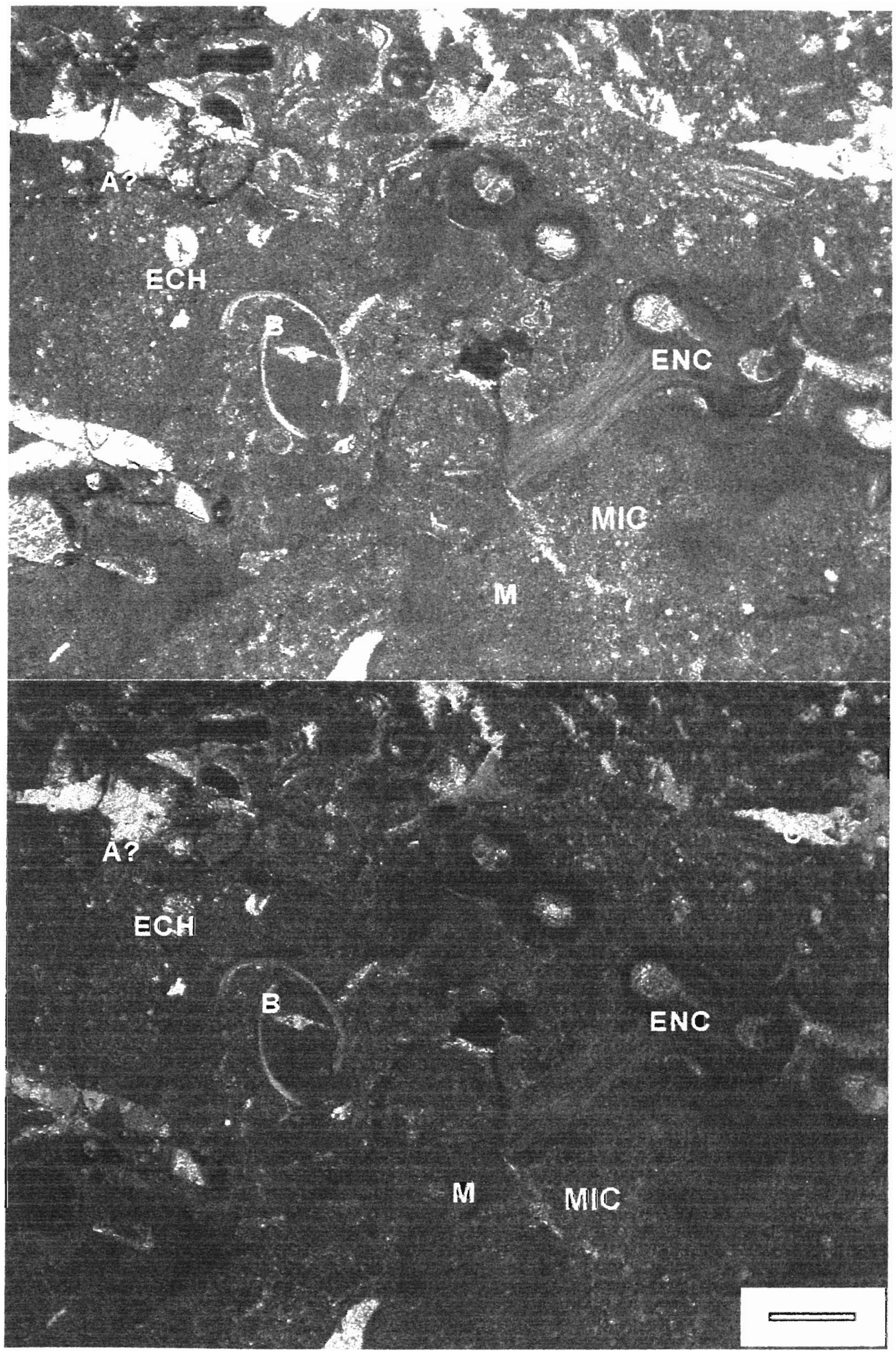

Fig. 17. Brachiopods (B), echinoderms (ECH), and calcite spar (C) in micritic cement (MIC). Notice the lineation of the encrusting organisms (ENC) on the edge of an algal blade (A?) that has been completely replaced by micrite (Bunyard-1584).

dramatically between 1578 and 1577 feet, and the amount of sparry calcite begins to decline (Fig. 18; Fig. 19). Echinoderm-rich mud, however, continues to be deposited within this upper algal bafflestone unit (Fig. 20). The "Hogshooter" is capped by slightly non-calcareous, fissile, dark gray-black shale at 1576 feet.

Gulf, Kightlinger #1 (4892-4912 feet). The light gray to tan algal bafflestone-wackestone at the base contains algal blades with encrusting bryozoans, echinoderms, and brachiopod and gastropod fragments in a micritic mud (Fig. 21; Fig. 22). Microspar can be found outlining sparry algal blades. In some cases, the microspar has completely replaced the algal blade and the surrounding micrite, leaving encrusting bryozoans to delineate blade edges. Above 4905 feet, algae, and consequently microspar, content decreases as the amount of slightly hematitic, peloidal micrite increases (Fig. 23). Dark gray to black, echinoderm-rich, mud wisps are also slightly more abundant farther up-section. A dark gray zone of brecciation exists between 4894 and 4895 feet where pyrite and hematite are fairly common (Fig. 24; Fig. 25). Thin section analysis shows very little porosity throughout this core. However, overall examination of the core shows a highly fractured zone within this area of brecciation. While most of the fractures are filled by calcite spar, a fair amount of porosity (approximately 3-4%) is evident in hand sample. A contact between the brecciated material and another light gray, algal bafflestone occurs at 4894 feet. The overlying and underlying shales were not cored.

Gulf, L. L. Tontz #1 (4972-4989 feet). Phosphate- and echinoderm-rich micritic mud interbedded with dark gray-black, echinoderm-rich, mud wisps are the main constituents found at the base of the "Hogshooter" in this core (Fig. 26). Algae become the dominant constituent at about 4986.1 (Fig. 27). Well preserved algal blades,

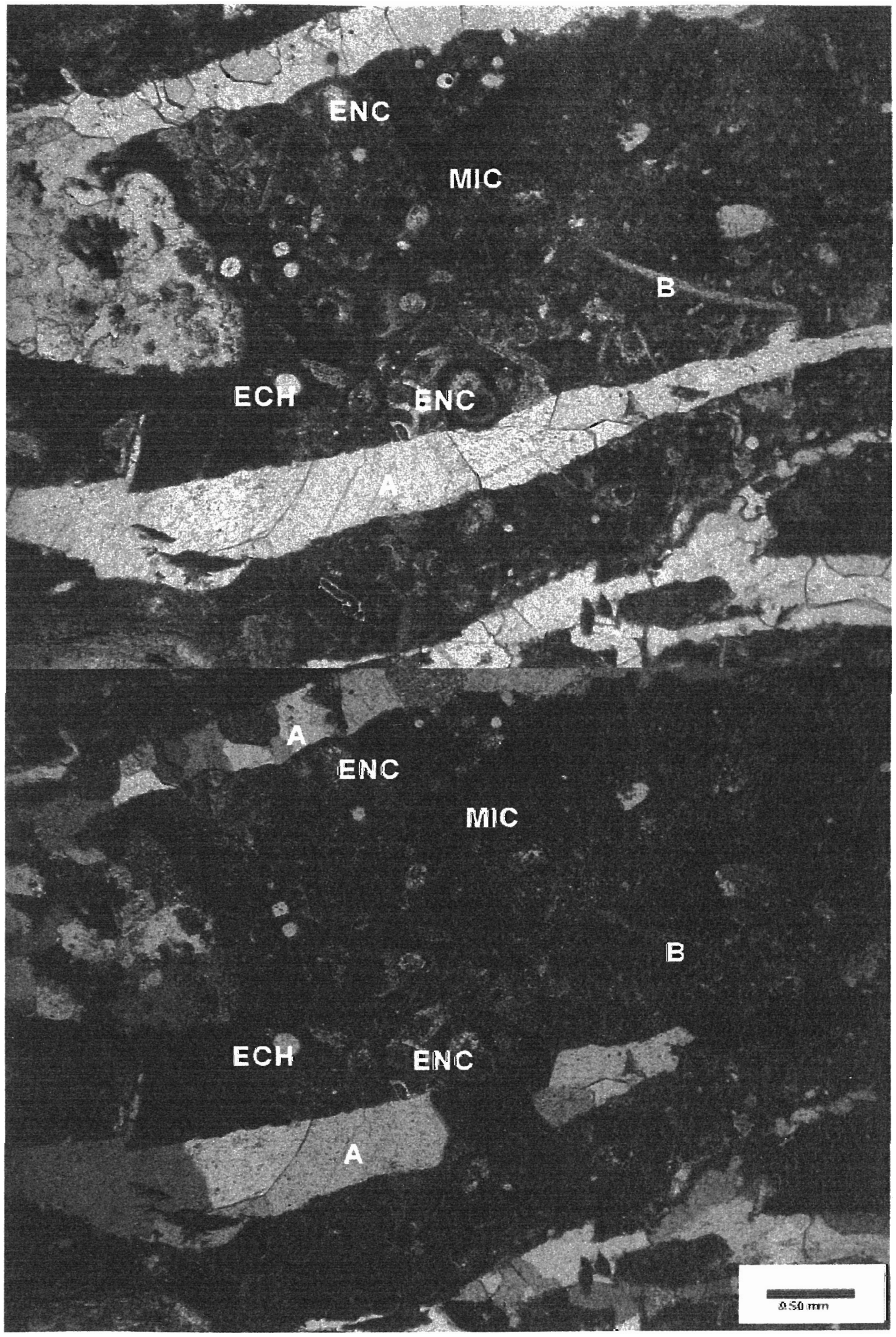

Fig. 18. Encrusting organisms (ENC) attached to sparry algal blades, fragmented brachiopods (B), and tiny echinoderms (E) surrounded by micritic mud (MIC) (Bunyard-1577).

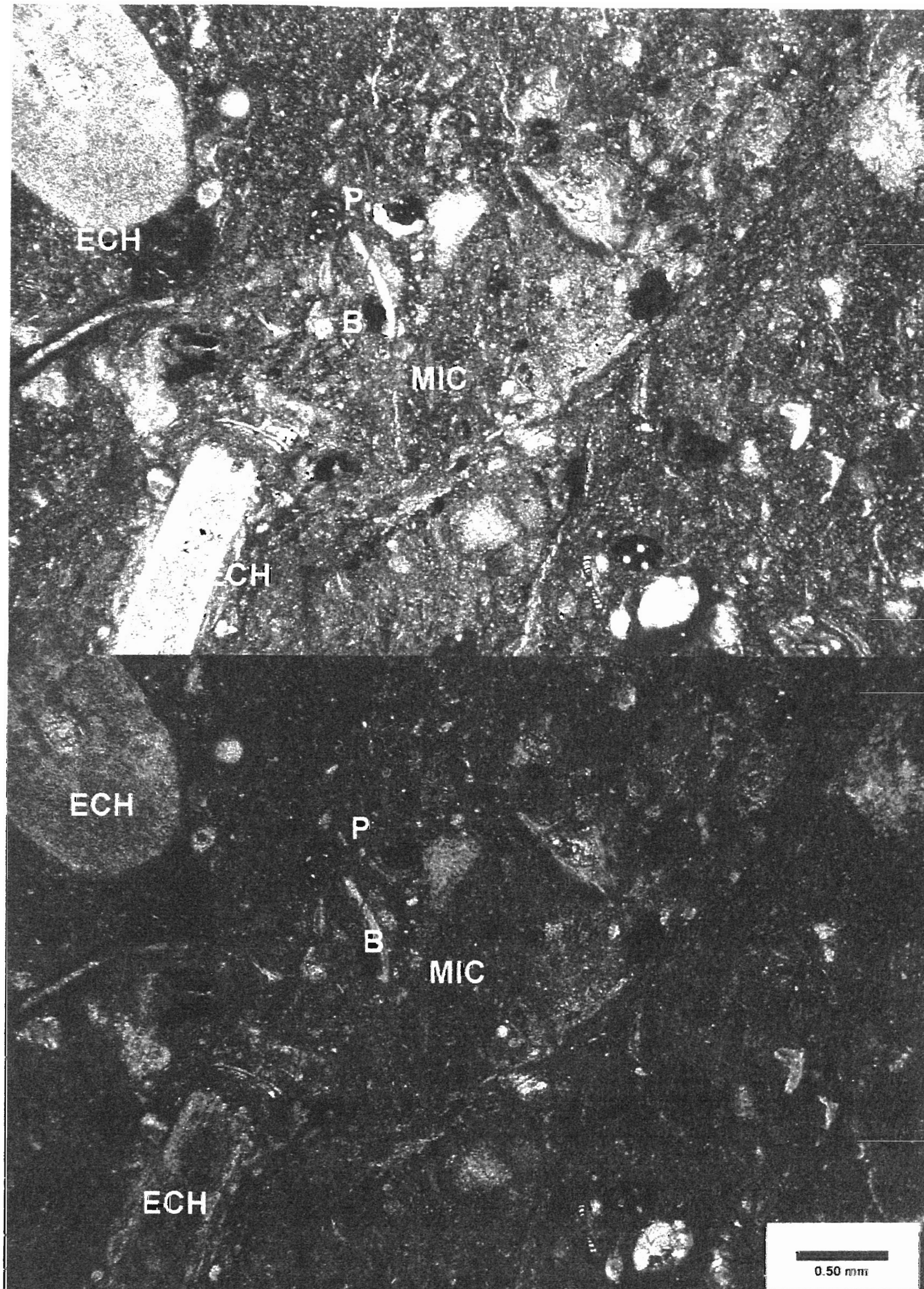

Fig. 19. Dominant micrite (MIC) with abundant echinoderm (ECH) and brachiopod (B) fragments. Secondary porosity (P) is formed by micro-fractures in the micritic cement (Bunyard-1576).

A B

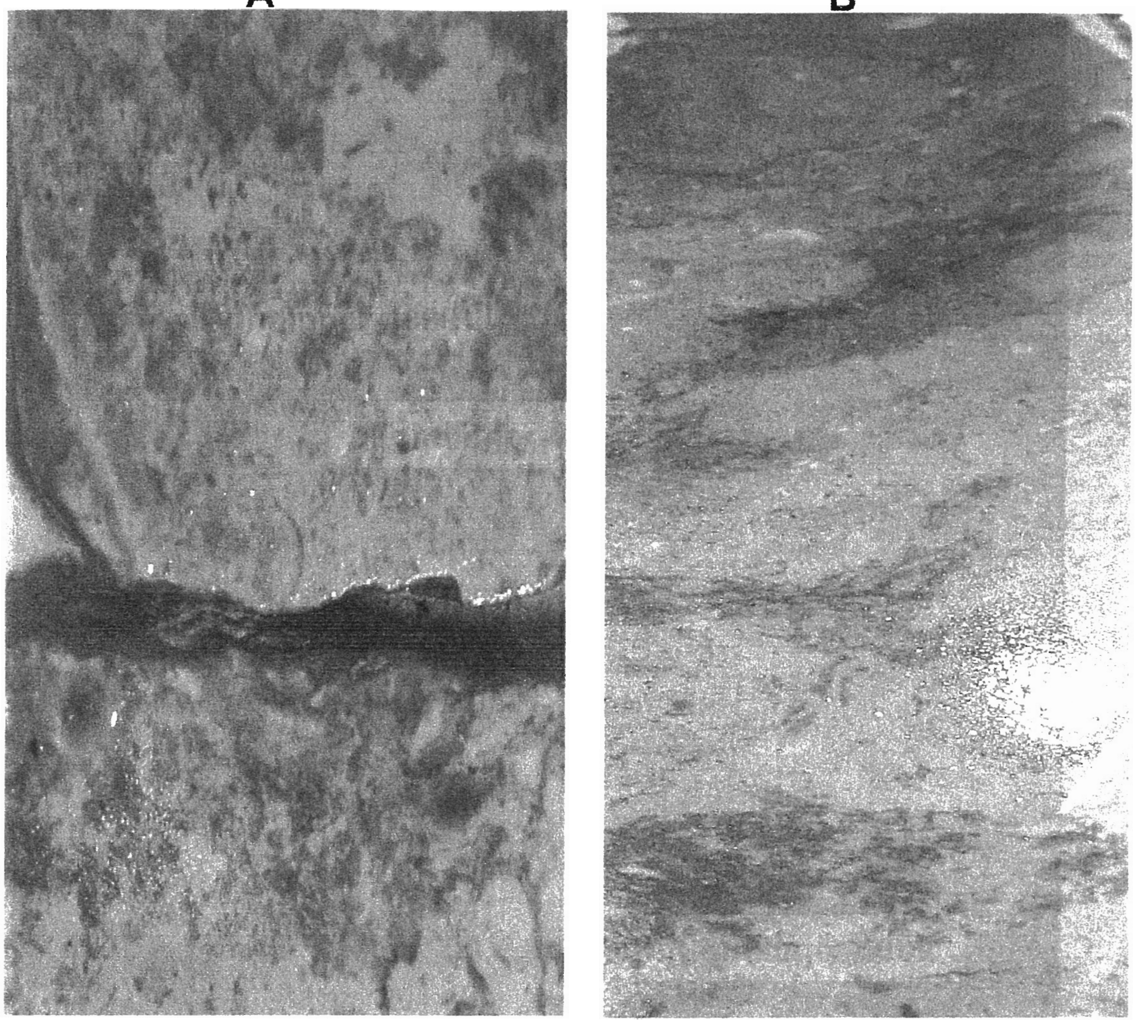

Fig. 20. Photographs of Bunyard #1 core at 1586 feet (A) and 1578 feet (B). (A) represents the basal algal bafflestone of the core and (B) shows the beginning of the second shoaling upward sequence, where algae and skeletal content increase. Terrestrial mud is also becoming more common.

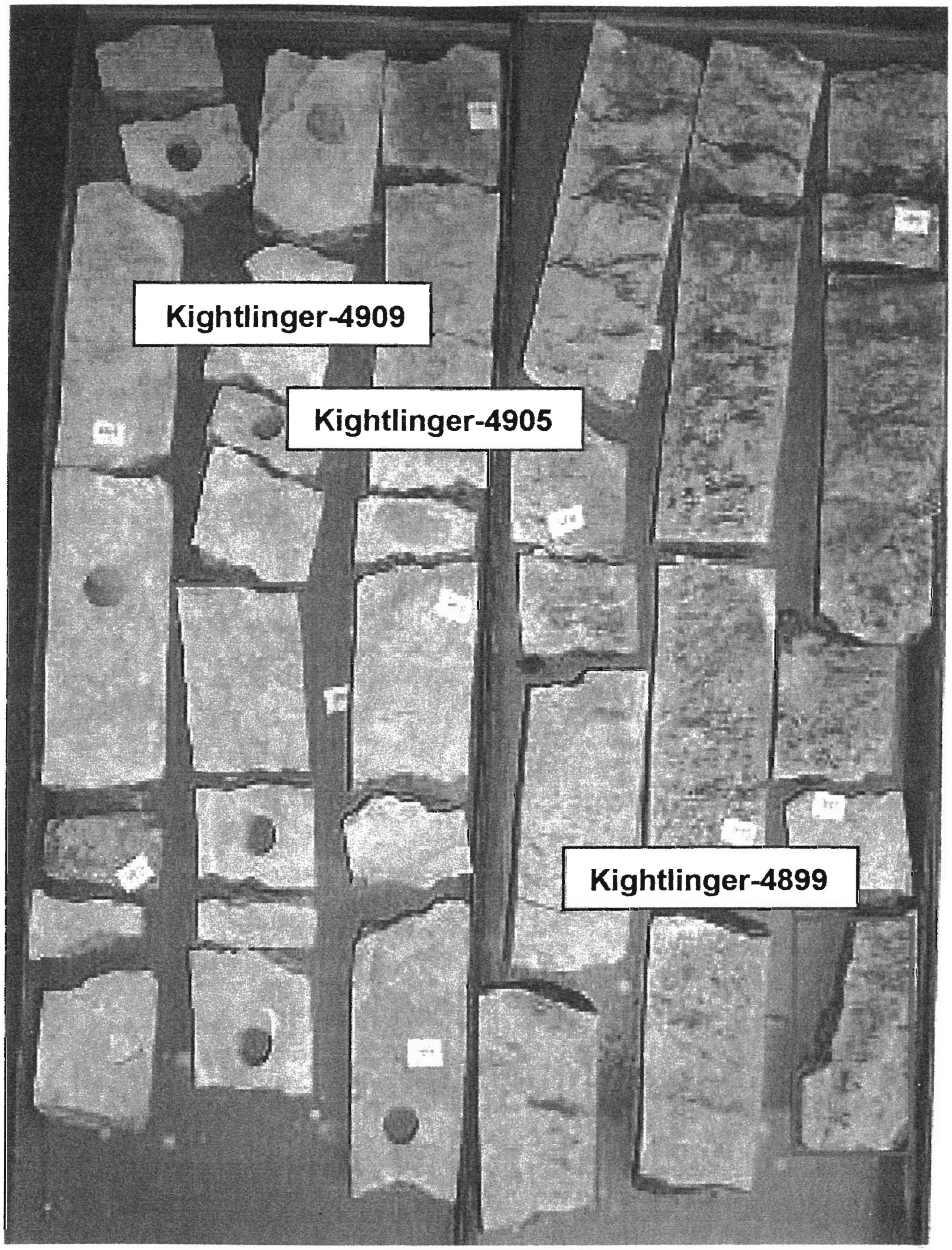

Fig. 21. Kightlinger #1 Core from 4912 to 4892 feet, Logan County, Oklahoma, T 17 N, R 3 W, Section 22. Close-up core photo locations outlined in red, and thin section locations listed in black boxes.

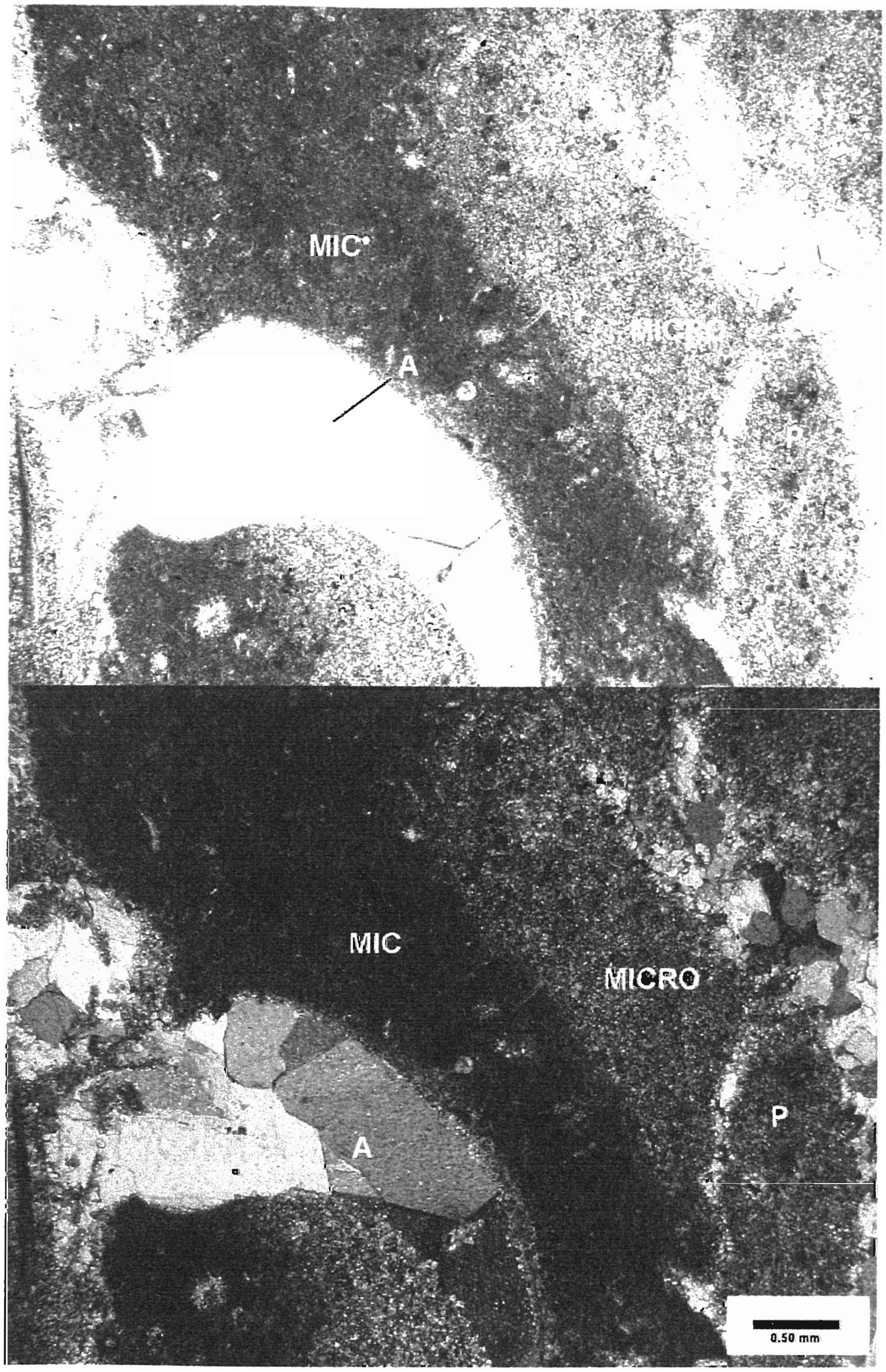

Fig. 22. Large algal blades (A) in micrite cement (MIC). The presence of microspar (MICRO) suggests a transitional phase between calcite spar and micrite. Secondary porosity (P) is created by dissolution of cements (Kightlinger-4909).

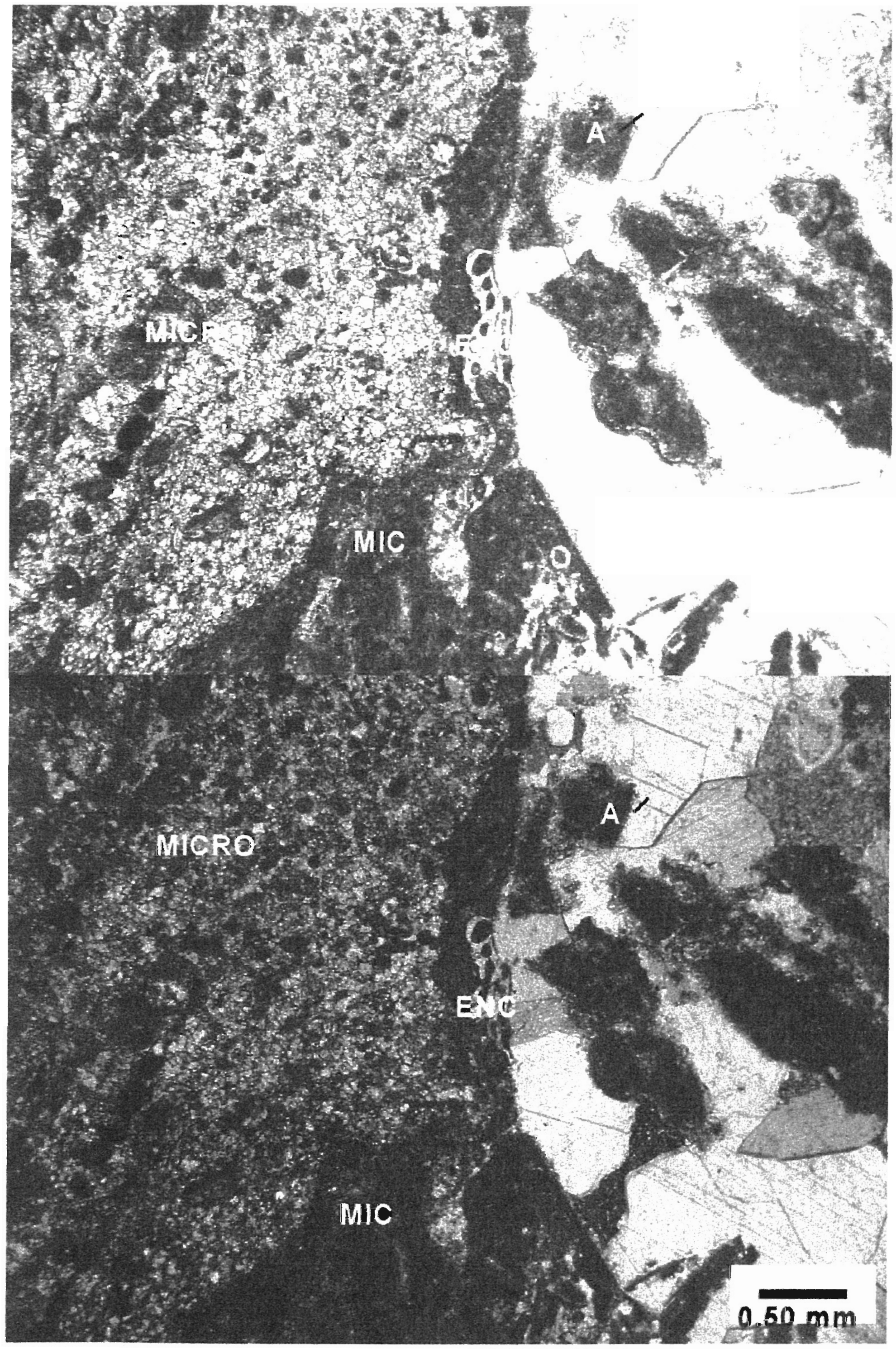

Fig. 23. Sparry algal blade (A) with encrusting bryozoans attached (ENC). Algae is surrounded by microspar (MICRO) derived from recrystallized algal blades and micrite cement (MIC) (Kightlinger-4905).

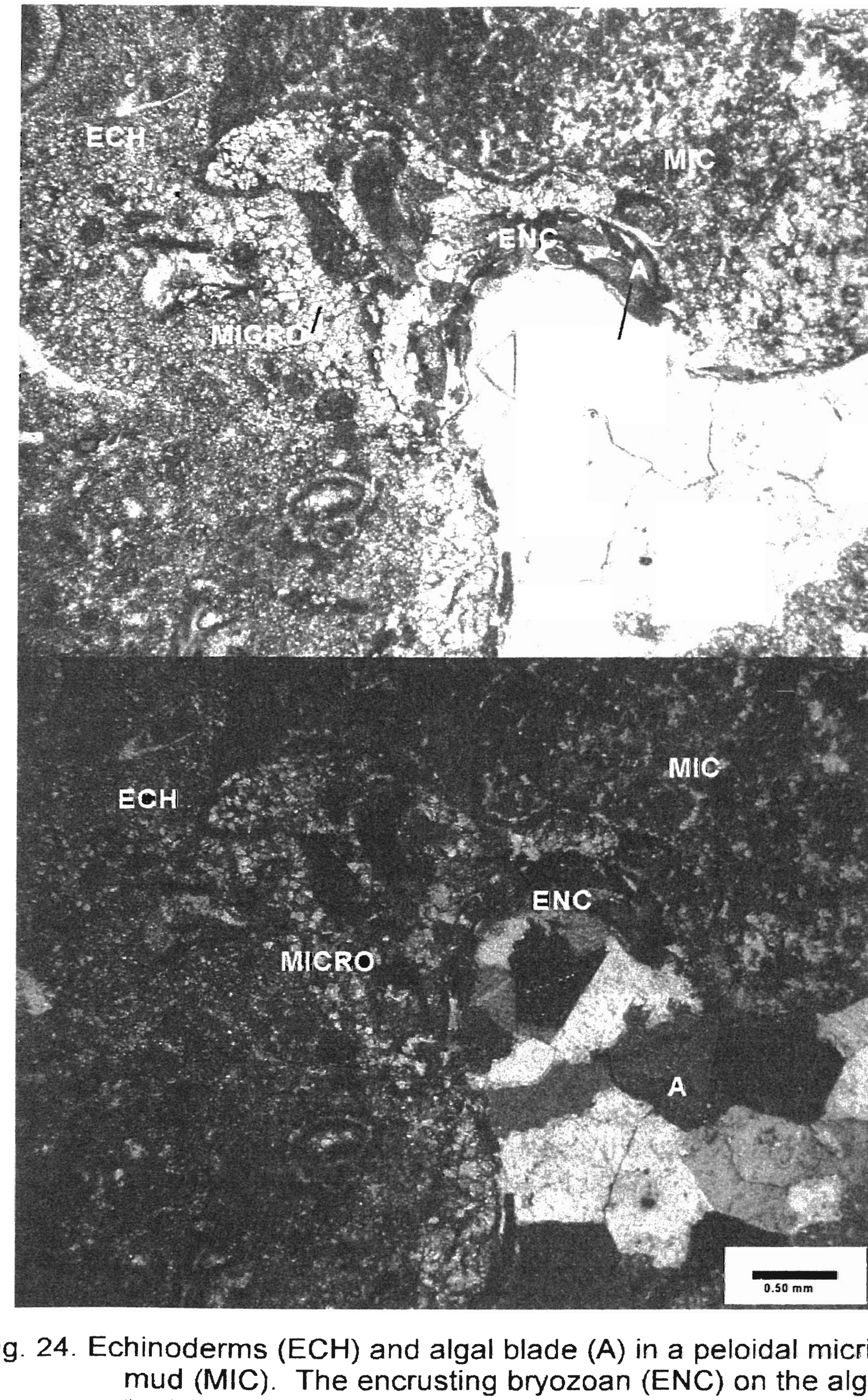

Fig. 24. Echinoderms (ECH) and algal blade (A) in a peloidal micrite mud (MIC). The encrusting bryozoan (ENC) on the algal "nub" has been completely filled in by calcite microspar (MICRO) (Kightlinger-4899).

A B

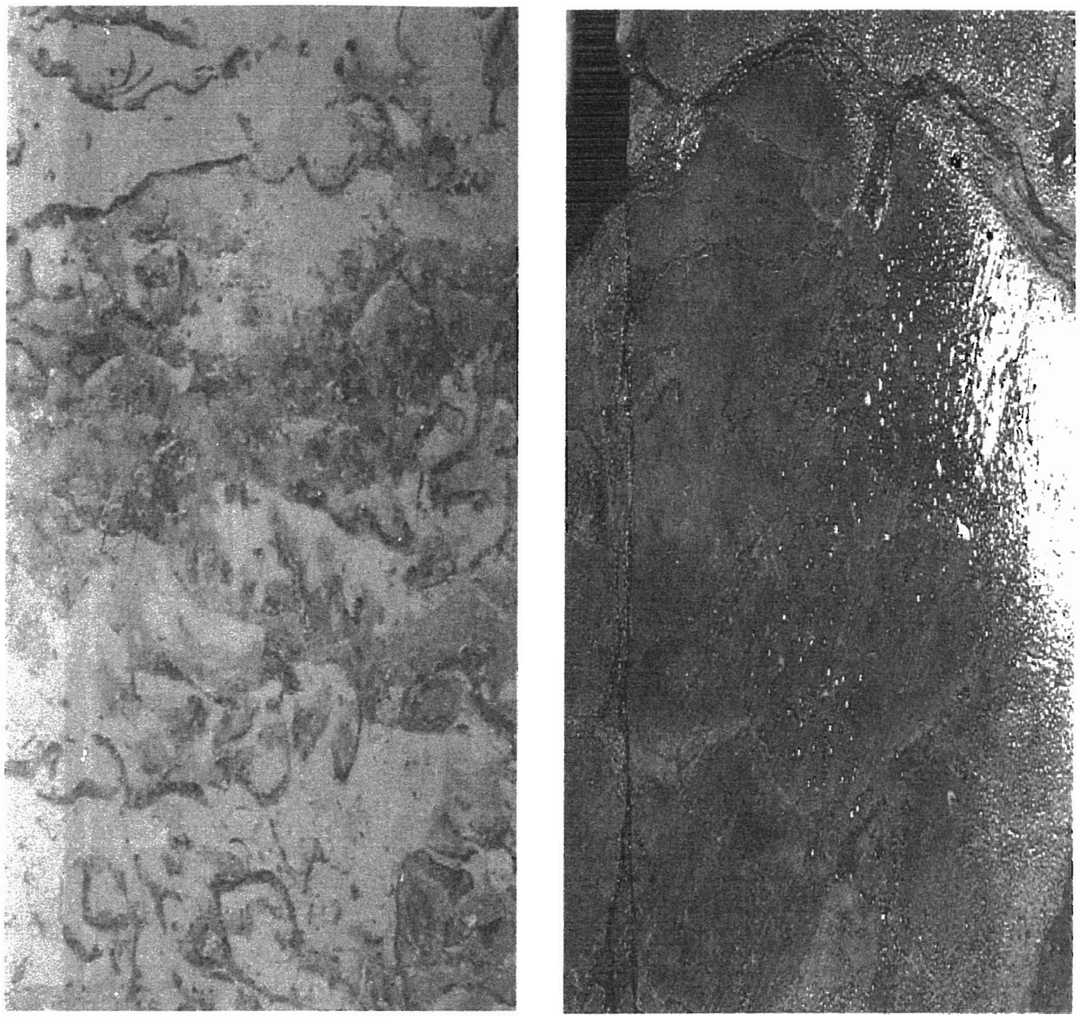

Fig. 25. Core photos of the Kightlinger #1 core at 4910 feet (A) and 4895 feet (B). (A) shows large algae blades and skeletal fragments in a micritic matrix. The brecciated zone visible in (B) contains large visible fractures that account for most of the porosity in the Kightlinger #1 core.

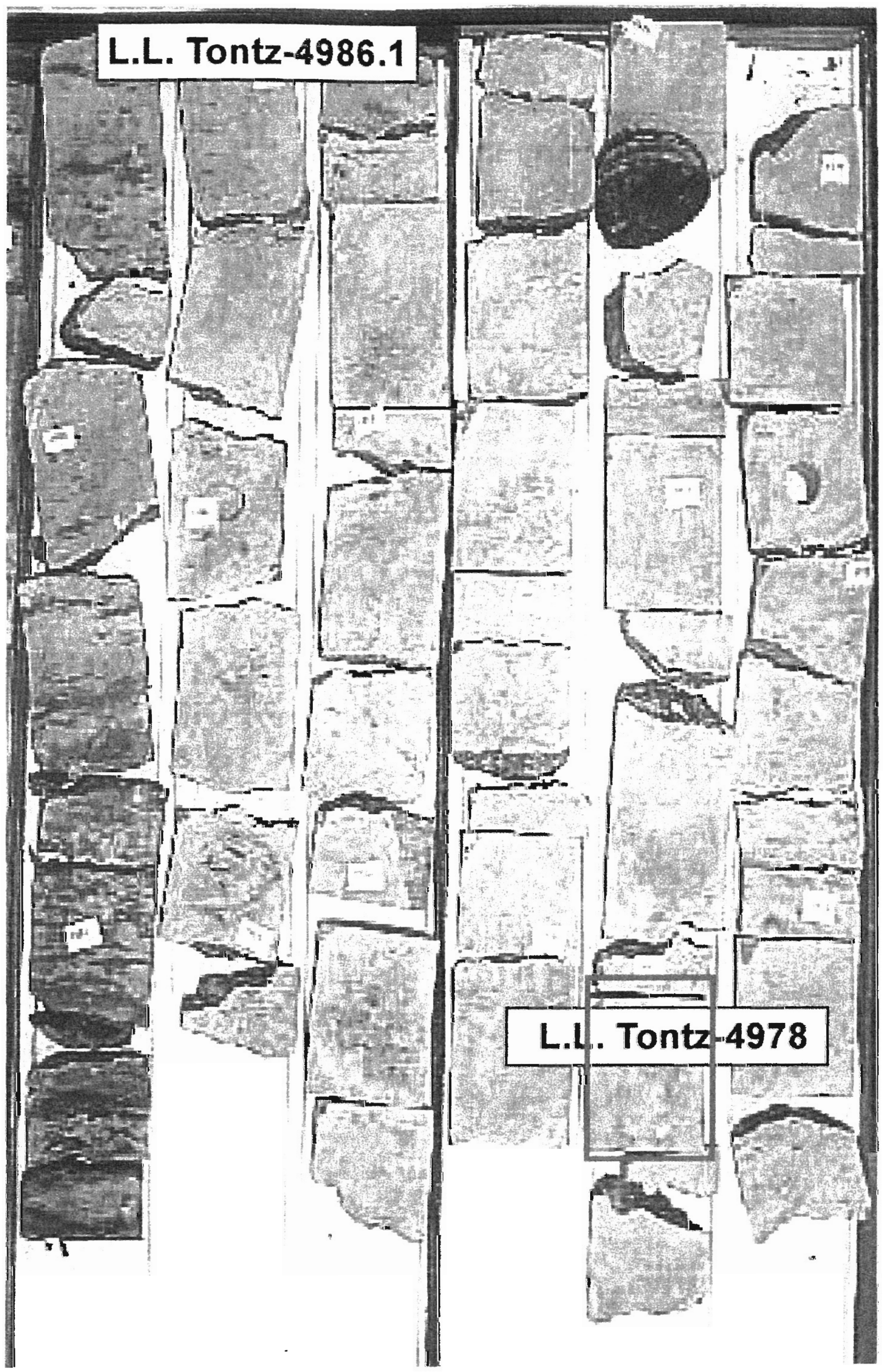

Fig. 26. L. L. Tonts #1 Core from 4989 to 4972 feet, Logan County, Oklahoma, T 17 N, R 3 W, Section 27. Core photo locations are outlined in red, and thin section locations are listed in the black boxes.

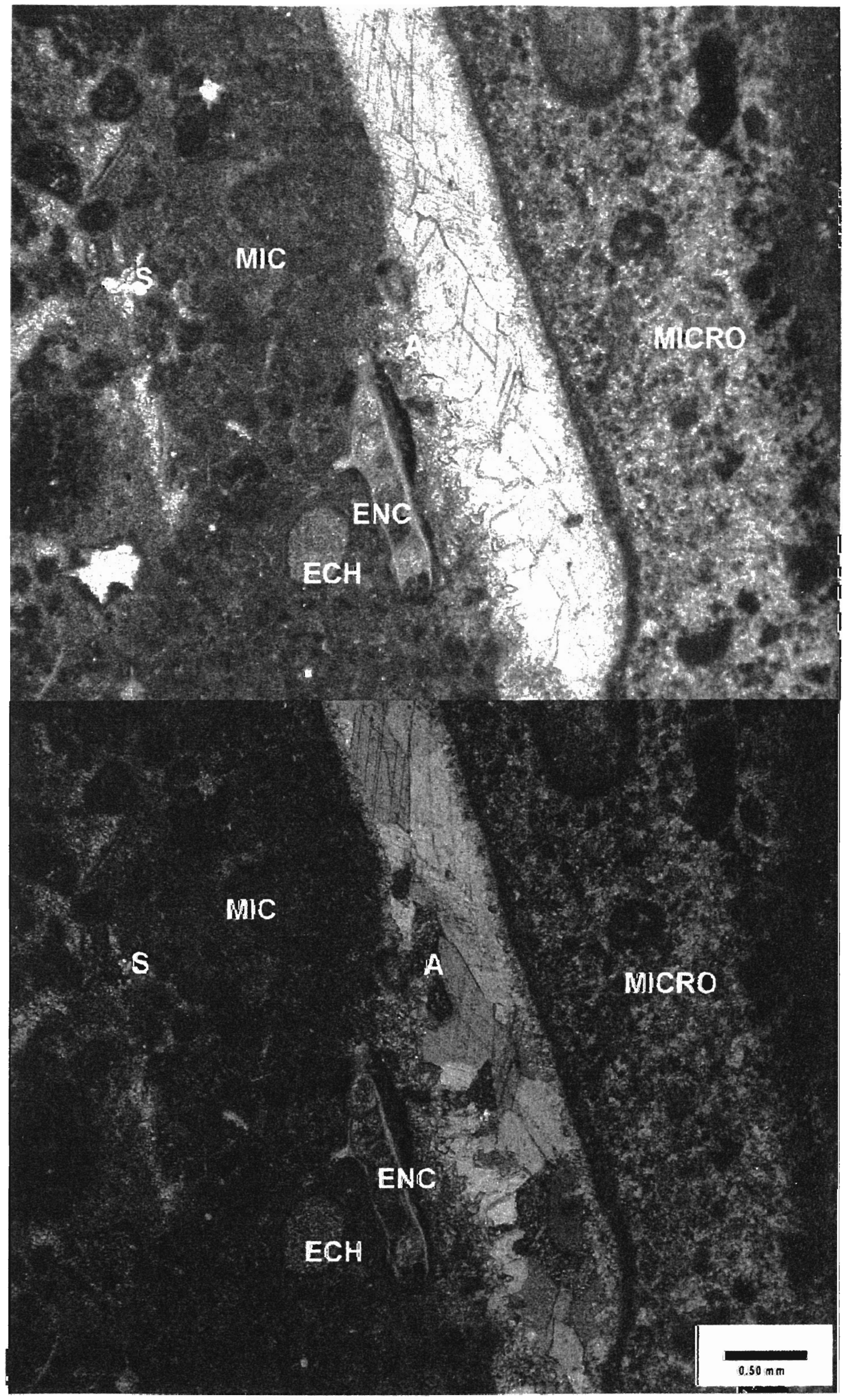

Fig. 27. Sponge spicules (S), echinoderms (ECH), and microspar (MICRO) in peloidal micrite cement (MIC). An encrusting bryozoan (ENC) is attached to the edge of an algal blade (A) (L. L. Tontz-4986.1).

surrounded by peloidal, slightly hematitic micrite, echinoderms, encrusting bryozoans, traces of phosphate, and monaxon and tetraxon sponge spicules, form a light gray-pink bafflestone. Microspar is found throughout this core surrounding, or representing recrystallized algal blades and micrite. Sparry calcite fills secondary pore spaces, such as vugs, almost completely. In hand sample, vugs increase in size up-section. These large vugs are filled with milky-white, sometimes powdery, calcite cement and may be linked to nearby karstification (Fig. 28). In thin section, it appears that most of the porosity appears around 4978 feet (approximately 2-3%) as vugs and micro fractures become more abundant (Fig. 29). Examination of the core shows that the "Hogshooter" is fractured throughout; however, the majority of these fractures are filled by calcite cement. The top of the limestone is marked by calcareous black shale. Well log analysis shows that approximately 41 feet of the "Hogshooter" that overlies the L.L. Tontz #1 core is missing. The basal limestone herein described appears to be overlain by thin sandstone unit, followed by an upper limestone unit.

Cameo, Jeanette #2-23 (5421-5479 feet). The Cameo, Jeanette #2-23 core is the most complete of all four cores (Fig. 30). The base of the core is marked by dark gray-black, crinoidal shale overlain by a dark gray, brecciated zone consisting of algae, microspar, bryozoans, echinoderms, oncoids and small brachiopod fragments in peloidal micrite mud (Fig. 31). Brecciation continues until about 5456 feet. The contact between the brecciated zone and the overlying light tan-gray, algal bafflestone is missing from the core. The tan-gray bafflestone is made up of echinoderms, encrusting bryozoans, brachiopods, gastropod fragments, spiraling foraminifera, and calcite spar, most likely the recrystallized remnants of algal blades, or the surrounding micrite mud. Porosity is

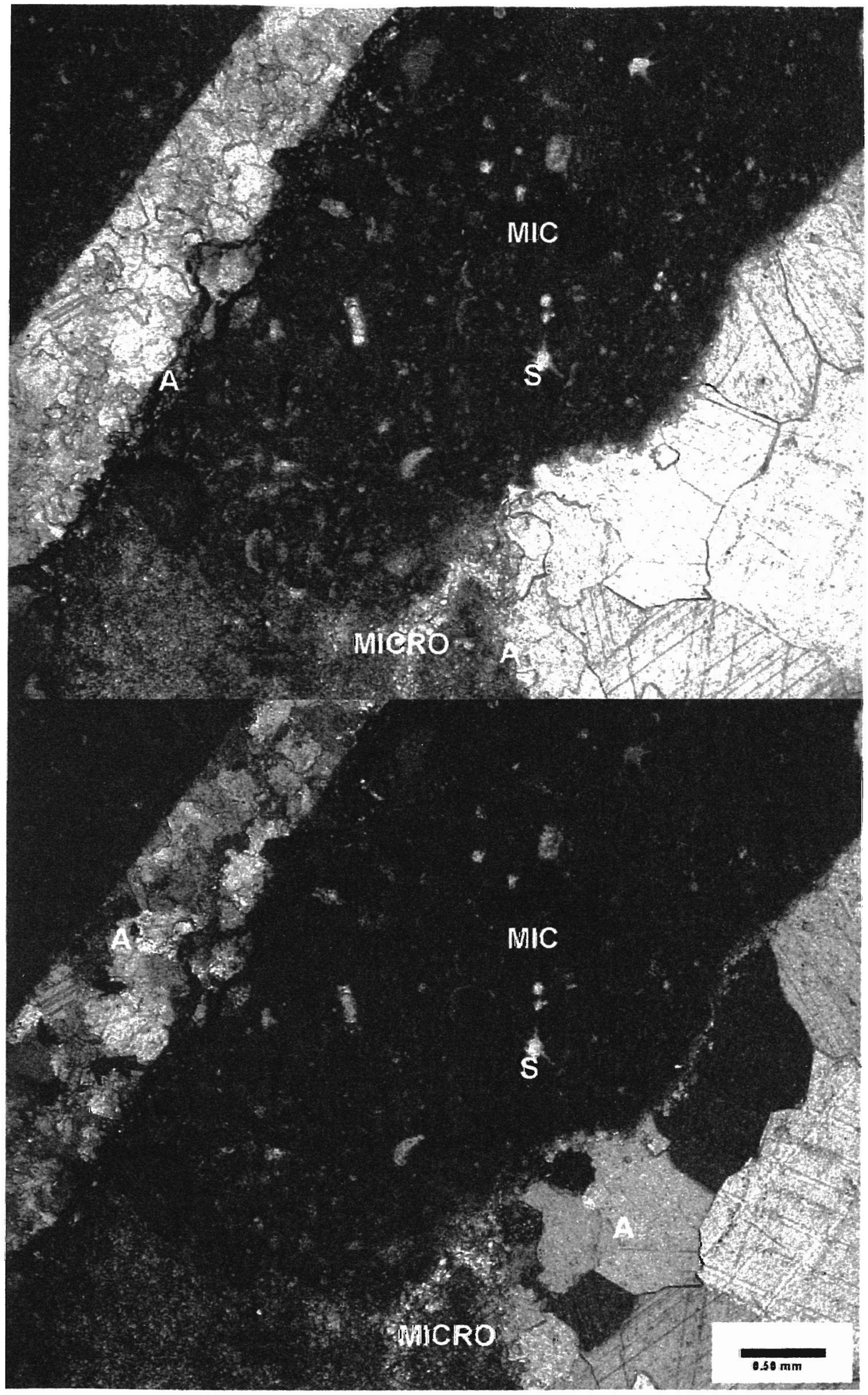

Fig. 28. Sparry algal blades (A) and sponge spicules (S) in micrite cement (MIC). Microspar (MICRO) is found where algae is recrystallizing into micrite (L. L. Tontz-4978).

Fig. 29. Core photo of the L. L. Tontz #1 at 4978 feet showing fracture and vug filling by milky white calcite. Much of the porosity found in this core is accounted for at around this depth due to unfilled or partially unfilled fractures and vugs.

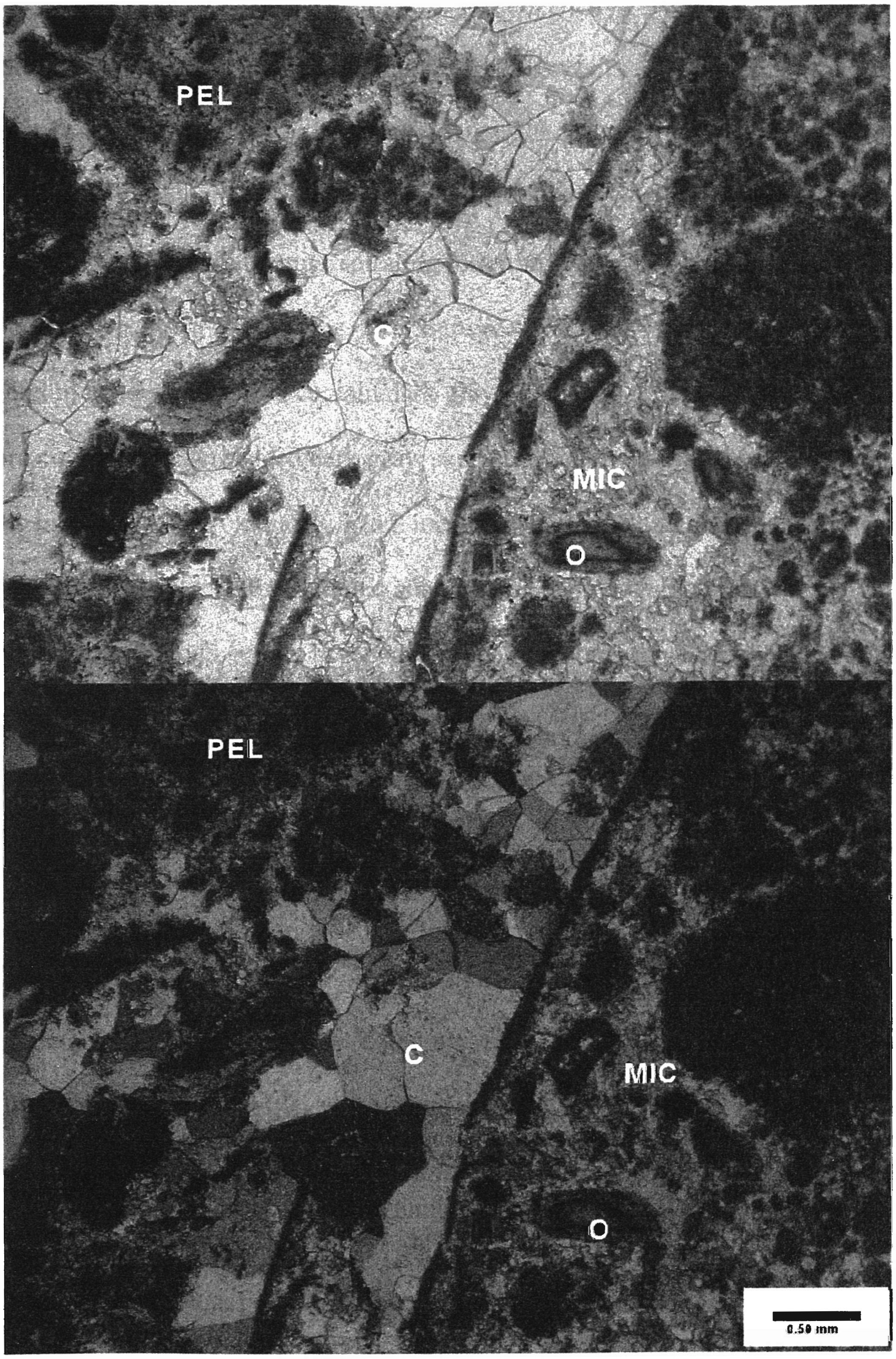

Fig. 31. Sparry calcite (algal remnants?) (C), microspar (MIC), and oncoids (O) in a peloidal (P), micritic cement (M) (Jeanette-5476).

greatest around 5448 feet (approximately 7%) where sparry calcite and algal blades have been dissolved (Fig. 32). In hand sample, this zone contains a fair amount of porosity, though many of the vugs and fractures have been filled by calcite.

The porous algal bafflestone is overlain by a dark gray wackestone to packestone containing abundant echinoderms, spiraling foraminifera, bryozoans, and brachiopod and gastropod fragments in micrite (Fig. 33). Between 5440 and 5441 feet, vertical fractures are found in hand samples and contain dark gray-black mud (Fig. 34). Above 5440 feet, the core consists of interbedded dark gray, skeletal wackestone with large, rounded, micritic intraclasts (approximately 1 to 2 inches in diameter) and crinoidal, dark gray-black shale. Fine- to very-fine-grained quartz, large echinoderms (mostly crinoids), fragmented brachiopods, pyrite, bryozoans, and a few ooids can be found around 5425 feet in a hematitic, terriginous mud matrix (Fig. 35). Black, calcareous, crinoidal shale that overlies the "Hogshooter" is visible above 5424 feet.

Phylloid Algae

The regional occurrence of phylloid algae in Pennsylvanian carbonate build-ups is very common and could not be ignored in this study, as phylloid algal blades are found in all four "Hogshooter" cores. There are three main types of phylloid calcareous algae that grew during the Pennsylvanian: *Archaeolithophyllum, Eugonophyllum,* and *Ivanovia* (James and Macintyre, 1985). Phylloid algae are recognized as aragonitic, upright calcareous plants that can grow to 10 cm or more in height, with broad, curved, leaf, or blade-like structures around a central stalk (Vague, 1993).

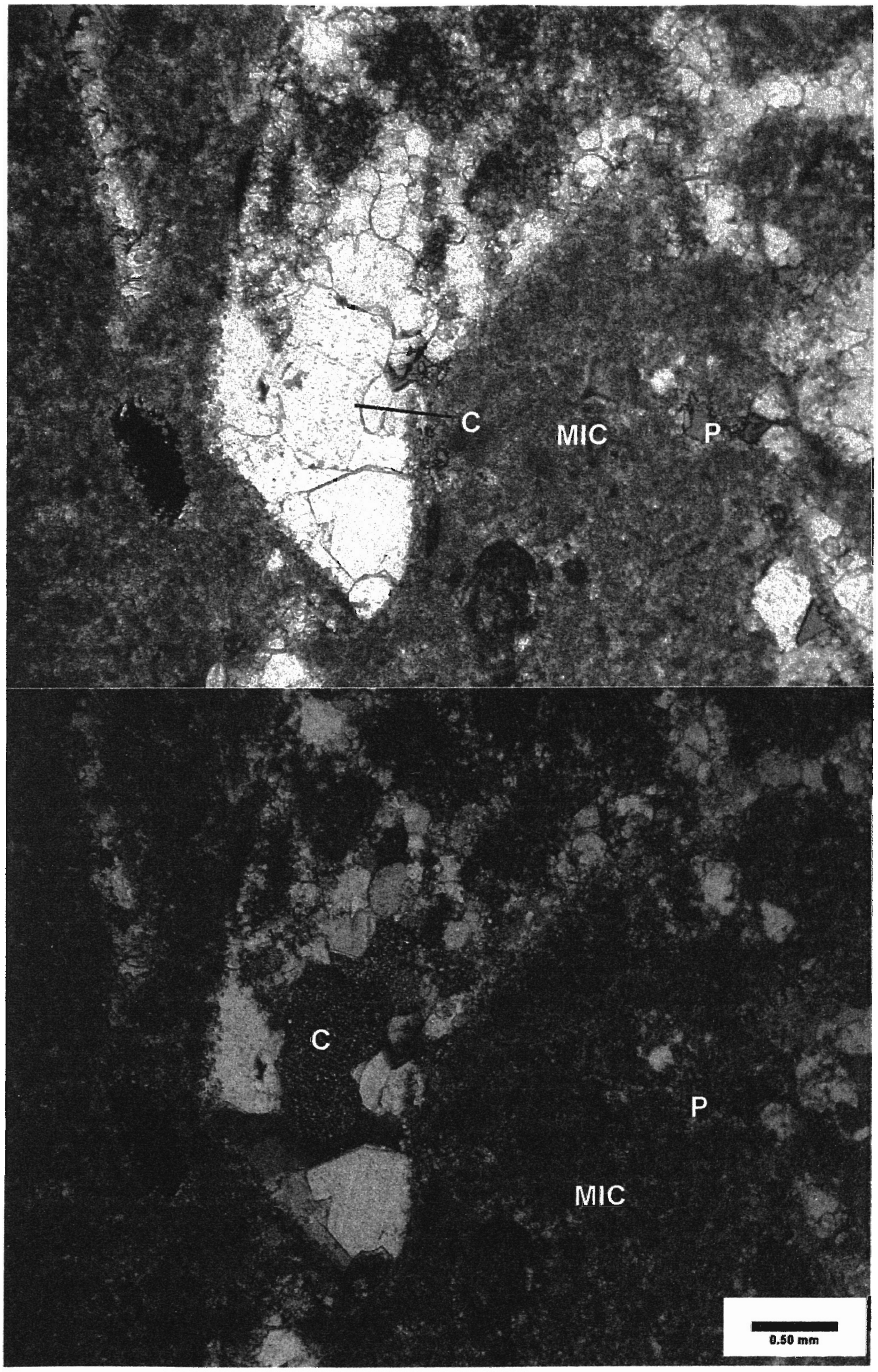

Fig. 32. Calcite spar (C), possible remnants of algal blades, in micrite cement (MIC). Secondary porosity (P) is found where calcite spar is dissolved (Jeanette-5448).

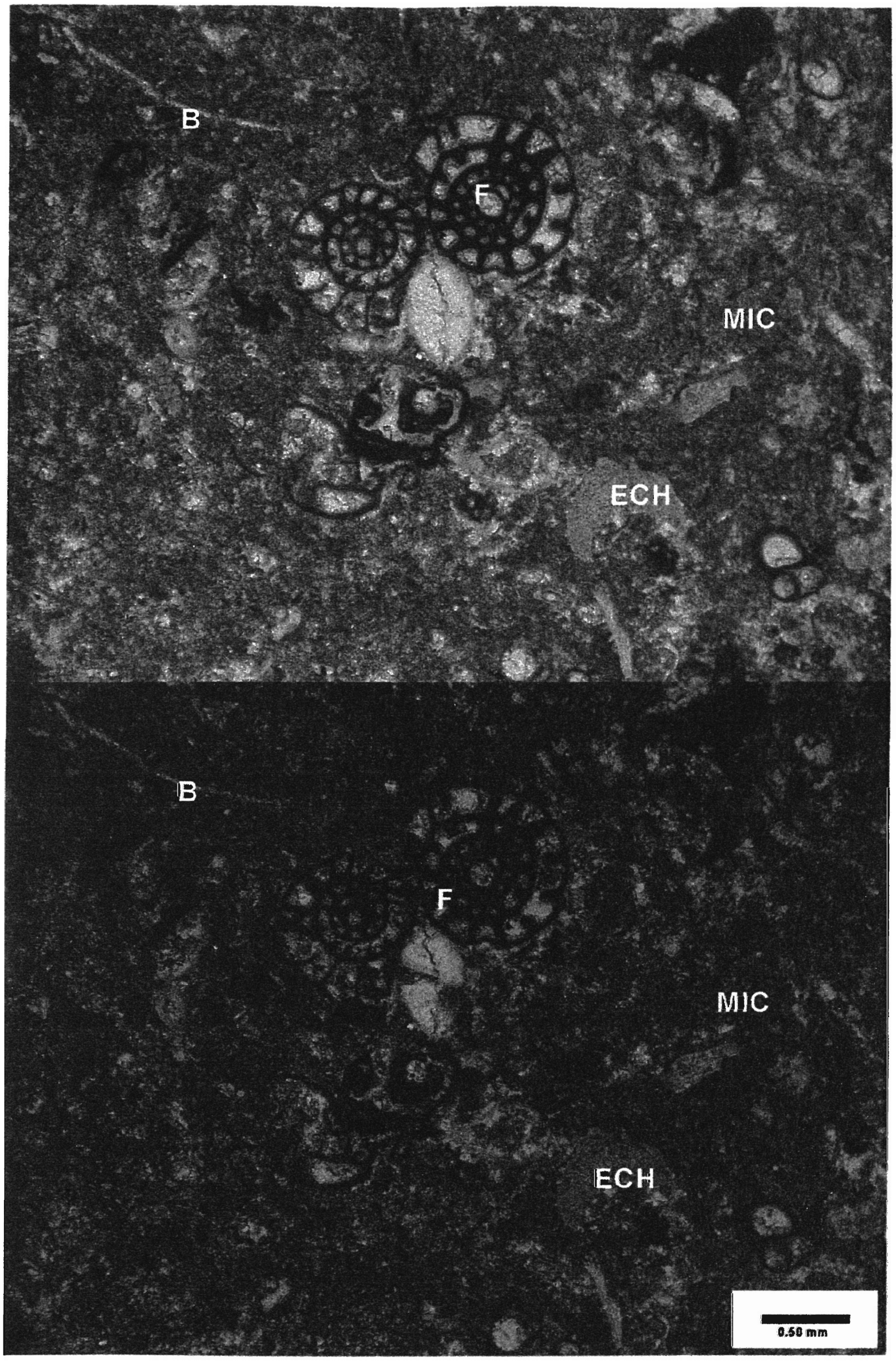

Fig. 33. Fragmented brachiopods (B), spiraling foraminifera (F), and echinoderms (ECH) in a mainly micritic cement (MIC) (Jeanette-5446).

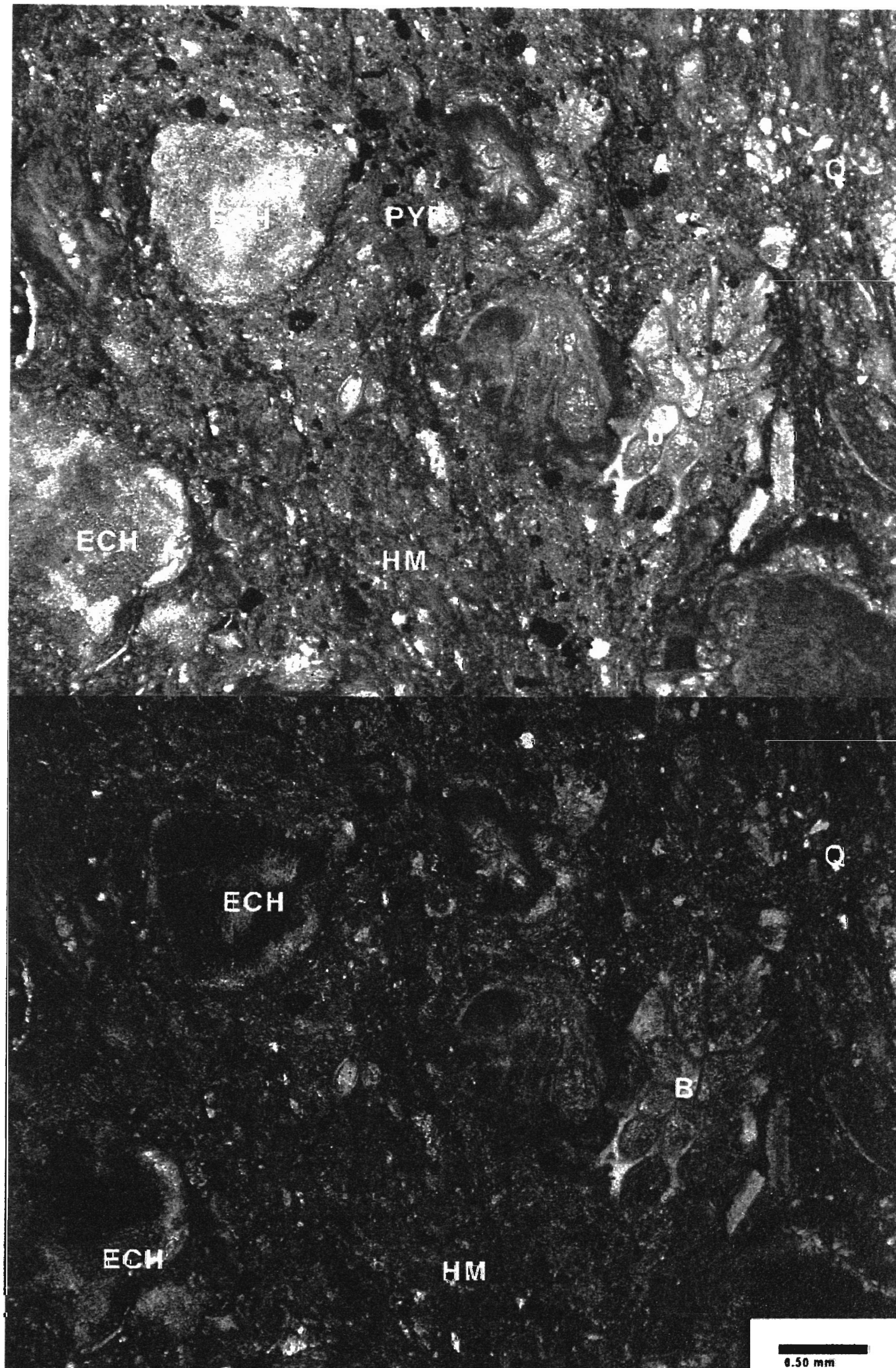

Fig. 34. Large echinoderm fragments (ECH), bryozoans (B), pyrite (PYR), and quartz grains (Q) in a hematitic mud matrix (HM) (Jeanette-5425).

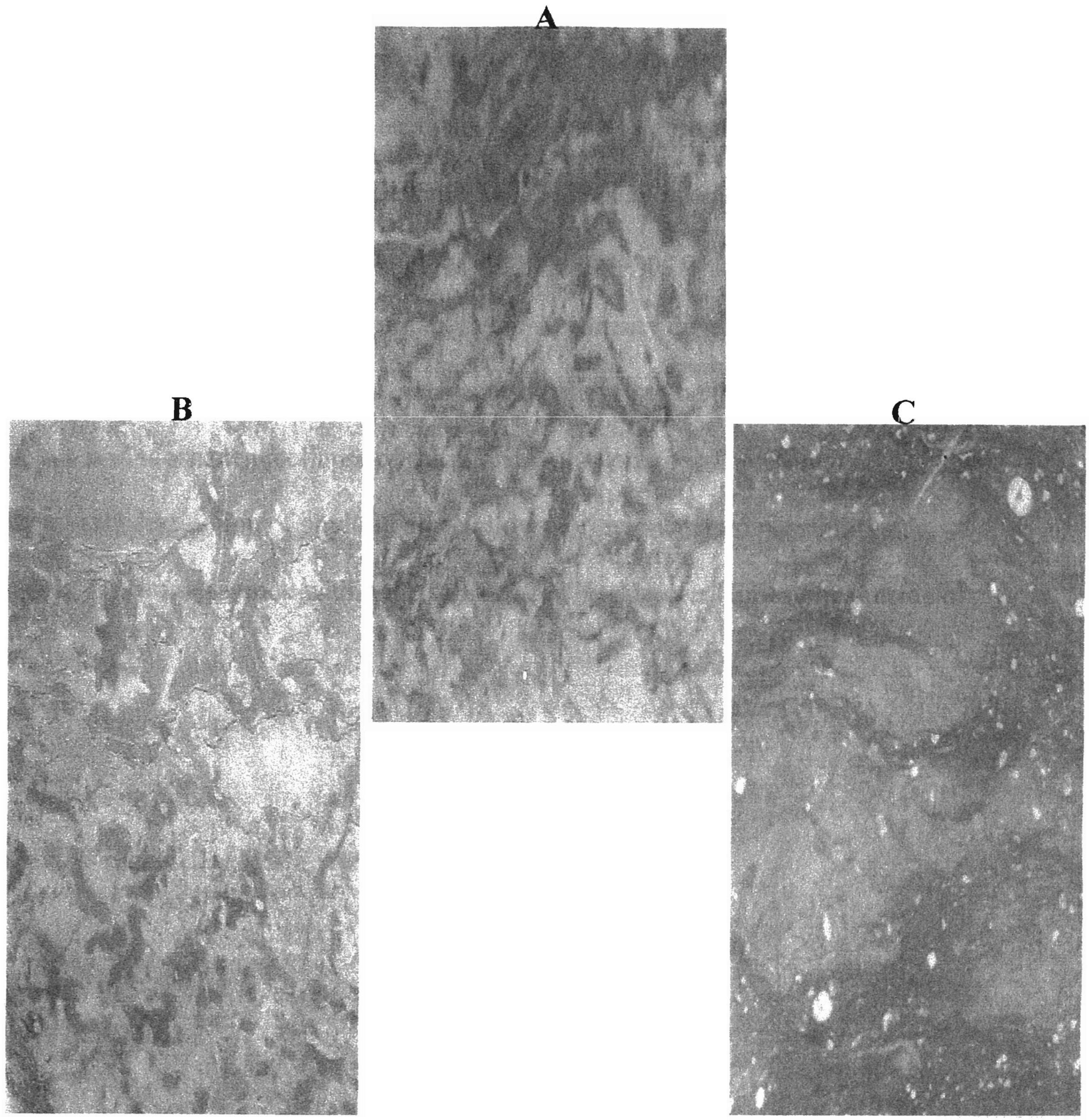

Fig. 35. Core photos of the Jeanette #2-23 core at 5473 feet (A), 5442 feet (B), and 5429 feet (C). (A) shows the dark gray algal breccia at the base of the core. (B) displays a dark gray skeletal wackestone/packstone above the tan-gray porous unit. (C) Dark gray mud with gray limestone intraclasts, and crinoid fragments.

Dissolution of the aragonitic algal blades is regarded as the most important process in the formation of secondary porosity in the "Hogshooter". Dissolution of algae at the top of algal mounds/bioherms accounts for 1 to 15 % porosity in the highly prolific Oswego limestone (Pennsylvanian, Desmoinesian) of Oklahoma and Kansas (Forbes, 1993). Phylloid algae are also found in the Strawn Limestone of New Mexico, where algal dissolution is also the most important factor in porosity development (Vague, 1993). Brecciation within the reef or mound cores is also believed to be the result of algal dissolution and subsequent collapse of the micritic-mud matrix. Therefore, the abundance and dissolution of phylloid algae allows for the increased possibility of finding reservoir-quality rock within the subsurface "Hogshooter" limestone outside of the study area.

CHAPTER V

SUBSURFACE STRATIGRAPHIC CORRELATION

To obtain a more accurate correlation over such a large study area, six cross-sections were made utilizing 32 wells in 32 Townships in western Logan, northeastern Oklahoma, northern Lincoln, and Creek Counties. Cross-section A-A' serves to connect the southern section of the Missourian outcrop belt with the main study area. Three markers were used in this study listed here in ascending order: the top of the "Checkerboard" limestone marker, and the base and top of the "Hogshooter" limestone marker. The top of the "Checkerboard" was used as the datum line in order to demonstrate (as accurately as possible) the true orientation and stratigraphy of the overlying "Coffeyville" and "Hogshooter" Formations. It should be noted that the "Hogshooter" maintains a similar Spontaneous Potential (S.P.) deflection curve in all wells across the study area.

Correlation Sections

North-South Cross-Sections

Three north-south cross-sections were constructed and labeled (from east to west) B-B' (Pl. 2), C-C' (Pl. 3), and D-D' (Pl. 4). The "Hogshooter" limestone in cross-section B-B' and D-D' thickens to the north-northeast, whereas in cross-section C-C', the limestone thickens slightly to the south. The thickness of the interbedded shale and sandstone unit between the top of the "Checkerboard" marker and the base of the

"Hogshooter" marker appears to remain fairly constant with the amount of sandstone increasing only slightly to the south.

Cross-Section B-B'. This cross-section consists of four wells and shows very little lateral variation in thickness of the "Hogshooter" limestone. Thickness ranges from approximately 10 to 25 feet across the area. Underlying shale and sandstone units are between 200 and 380 feet thick and thicken to the south suggesting that terrestrial sediment was prograding into the area from the south. The "Hogshooter" unit has a gradient of approximately 0.44 feet per mile (ft/mi) over about 26 miles.

Cross-Section C-C'. Cross-section C-C' shows little to no variation in limestone thickness over four wells representing almost 20 miles. Shale and sandstone units underlying the "Hogshooter" also remain fairly constant in thickness which increases toward the south, suggesting northward progradation of the Late Pennsylvanian shoreline. The "Hogshooter" unit ranges in thickness between 10 and 20 feet and has a gradient of approximately 0.24 feet per mile (ft/mi).

Cross-Section D-D'. Shale makes up the majority of units overlying the "Checkerboard" marker in the four wells of cross-section D-D'. Thickness stays fairly steady at about 110 to 120 feet. In the south, however, the Layton sandstone is either absent, or is no longer detectable in well logs. The overlying limestone has a gradient of about .23 feet per mile (ft/mi) and varies in thickness from about 25 feet in the north to 50 feet in the south.

East-West Cross-Sections

Three cross-sections were constructed to connect the Missourian outcrop with the study area. These were labeled (from east to west): A-A' (Pl. 1), E-E' (Pl. 5), and F-F'

(Pl. 6). Cross-section A-A' allows for the correlation of the outcrop to the subsurface and shows a slight increase in limestone thickness toward the southeast. E-E' and F-F' show a more prominent increase in limestone thickness toward the western part of the study area.

Cross-Section A-A'. Cross-section A-A' trends northeast/southwest for approximately 42 miles and includes seven wells. The Layton Sandstone decreases in thickness and depth toward the southwest, until it appears to be missing in the 1-17 Jeanie well (Section 17, T. 19 N., R. 11 E.) and is replaced by shale. Thickness of the shale and sandstone interval is between about 350 and 470 feet. The "Hogshooter" limestone varies in thickness and gradient, from about 10 to 25 feet at approximately 0.59 to 2.13 feet per mile (ft/mi). Two shoaling upward sequences, algal and skeletal grain content visible in the Shell, Bunyard #1 core (Section 31, T. 15 N., R. 7 E.) may indicate the flanking facies of a nearby bioherm core. To the northeast, the limestone generally thickens towards the outcropping bioherm in northeastern Creek County.

Cross-Section E-E'. The shale and sandstone interval above the "Checkerboard" marker increases dramatically in thickness from west to east, from about 110 to over 340 feet. The Layton sandstone is barely recognizable in the westernmost wells and suggests a prograding shoreline that brought terriginous sediment into the study area from the east. This can be assumed due to the decrease in thickness of interbedded shale and sandstone from east to west across the study area. Limestone thickness begins to decrease slightly toward the west. The gradient appears to be between 0.51 and 3.8 feet per mile (ft/mi), where the greatest declination and change in thickness is found between the Blue Quail Oil and Gas, Mays #1 (Section 35, T. 17 N., R. 2 W.) and Darrett Petroleum and D. S.

Pace et. Al., Gaffney #1 (Section 12, T. 16 N., R. 1 W.) wells. Gulf, Kightlinger #1 (Section 22, T. 17 N., R. 3 W.) and Gulf, L. L. Tontz #1 (Section 27, T. 17 N., R. 3 W.) are closest to the westernmost well in this cross-section.

Cross-Section F-F'. Cross-section F-F' shows a similar trend as that of cross-section E-E' where the shale and sandstone interval overlying the "Checkerboard" marker increases in thickness toward the east of the study area. The Layton Sandstone grades laterally into mostly shale from west to east and is harder to recognize in T. 14 N., R. 7 E. The entire "Coffeyville" interval ranges from about 90 to 475 feet in thickness from west to east. The overlying limestone decreases in thickness to the west (basinward) where it may eventually shale out.

Proposed Depositional Environments of Cored Intervals

To determine depositional environments in the study area, 15 feet of the Shell, Bunyard #1, 20 feet of the Gulf, Kightlinger #1, 17 feet of the Gulf, Tontz #1, and 58 feet of the Cameo, Jeanette #2-23 cores were measured and examined. James (1983) clarifications of stratigraphic and ecologic reefs, James and Macintyre's (1985) examples of stratigraphic reefs and mounds, Prothero and Schwab's (1996) explanations of "reefs" and "bioherms", and outcrop samples and photos were compared with core, well log, and thin section data to suggest facies and depositional environments for the core samples (Fig. 36).

Two shoaling upward sequences are visible in the Shell, Bunyard #1 core. The first of these sequences is between 1590 and approximately 1578 feet and is marked by the gradual decrease in algal content and the disappearance of skeletal grains. The

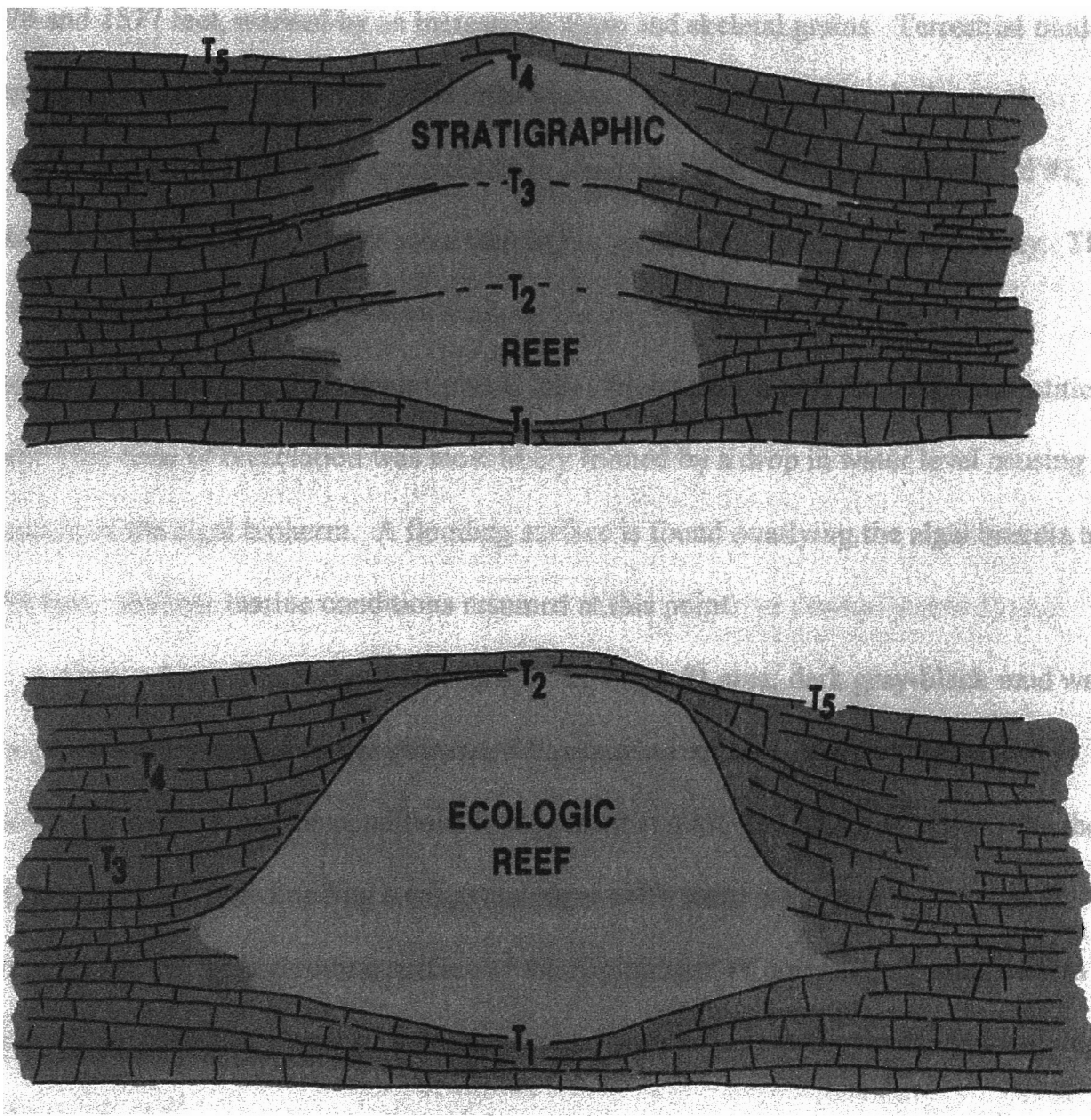

Fig. 36. A sketch illustrating the difference between a stratigraphic and ecologic reef (from James, 1983)

second shallowing upward sequence shows a gradual decrease in water level between 1578 and 1577 feet, marked by an increase in algae and skeletal grains. Terrestrial mud then washed into the area as the water level became shallower, stifling algal growth.

Around the same time, approximately 144 miles west-northwest of Bunyard #1, similar biological accumulations were forming in present-day central Logan County. The Gulf, Kightlinger #1 core suggests a shallow marine, low to moderate-energy environment at the base that shoals upward into a brecciated, highly fractured, hematitic zone. This zone of brecciation was most likely formed by a drop in water level causing exposure of the algal bioherm. A flooding surface is found overlying the algal breccia at 4894 feet. Shallow marine conditions resumed at this point.

Only a few miles away, in the Gulf, L. L. Tonts #1 area, dark gray-black mud was being deposited, possibly on the shoreward flanks of a reef core. A flooding surface followed by shallow marine conditions is suggested at 4986 feet where algae become the main constituent. This flooding surface and algal bafflestone may, in fact, correlate laterally with the upper flooding surface of the Kightlinger #1 core. Terriginous mud in the top of the core likely washed into the area and became part of the flanking or capping facies of the reef.

The Cameo, Jeanette #2-23 core was taken approximately 51 miles southwest of the Gulf, L.L. Tontz #1 and Gulf, Kightlinger #1 cores. The base of the Cameo, Jeanette #2-23 is a dark gray, crinoidal mud, possibly deposited on the shoreward flank of an algal bioherm. It is overlain by a brecciated zone. Water level rose, creating shallow marine conditions, algae accumulated, and then brecciation began as the water level fell. The contact between the brecciated zone and overlying algal bafflestone is missing, but a flooding surface can be inferred. Shallow marine conditions continued and a reef-like environment prevailed for some time. The overlying dark gray wackestone contains little to no algae, but abundant skeletal grains. This suggests an increase in water depth that stifled algal growth. This was succeeded by dark gray to black, terriginous mud that washed into the area. Intraclasts from the underlying limestone and ooids found in this mud suggest a slightly higher-energy environment and periods of storm-like currents. Increased amounts of fine-grained quartz hint at a near-shore, possibly lagoonal environment where progradation of the shoreline into the basin was beginning to occur.

From all four cores, several general statements about depositional environment can be made: (1) A shallow marine environment persisted across the study area during "Hogshooter" deposition; (2) Depositional environments for the four cores (with consideration to cross-sections) may have been as part of a stratigraphic reef complex where several small bioherms were built up after and prior to the migration of terrigenous sediment into the area. (3) There is very little evidence for constant wave action within the limestone unit. Skeletal debris was most likely deposited by storm currents or low to medium-energy currents moving across the reef crest. (4) An isopach sketch of the area suggests that at the beginning of "Hogshooter" deposition, "Coffeyville" shales and sandstone formed an area of positive relief in the southeastern and northeastern townships (Fig. 37). This suggests that "Hogshooter" deposition upon these positive features occurred *after* limestone deposition in the west toward the deeper basin.

Proposed Surface to Subsurface Correlation

To properly correlate the outcropping "Hogshooter" limestone to the subsurface, several factors were taken into consideration. The petrology of the four available cores was compared with the research of previous studies (such as Oakes, 1940, 1952, 1963; Hansen, 1957; Niemann, 1986) to discover similarities and differences in lithology. Well logs and cross-sections were used to determine the stratigraphic distribution and thickness of the "Hogshooter" limestone from the outcrop to the cored wells. Distribution of the surface "Hogshooter" members described by previous authors was also considered for the distribution of the subsurface limestone members. However, because the limestone is referred to as the "Hogshooter" in the subsurface, and is not referred to by its individual members, a zoning system was established to better identify and correlate similar lithologic units and facies from well to well. Zones are labeled according to what facies they represent: basal lime mudstone to wackestone facies (BM-1, BM-2), bioherm facies (B-1, B-2), and capping facies (C-1, C-2). These zones were then placed beside each core's well logs to correlate the log signatures with the different facies. Correlation between the log signatures was then attempted.

The skeletal algal bafflestone at the base of the Shell, Bunyard #1 core (1590-1585 feet) is a bioherm deposit and is herein labeled B-1. The bioherm is capped by crinoidal mudstone and wackestone that is labeled C-1/BM-2. Another bioherm (B-2) accumulated on top of the BM-2 unit, followed by non-calcareous mudstone representing the base of the Nellie Bly Formation. Zones B-1, C-1, BM-2, and B-2 may correspond with the Lost City Limestone or the lower and upper parts of the Middle Winterset submember (Fig. 38).

The bottom 7 feet of the Gulf, Kightlinger #1 core most likely represents the Lost City Member or the Middle Winterset submember due to the abundance of algae, brecciation, and skeletal grains and is identified as zone B-1 (Fig. 39). The peloidal

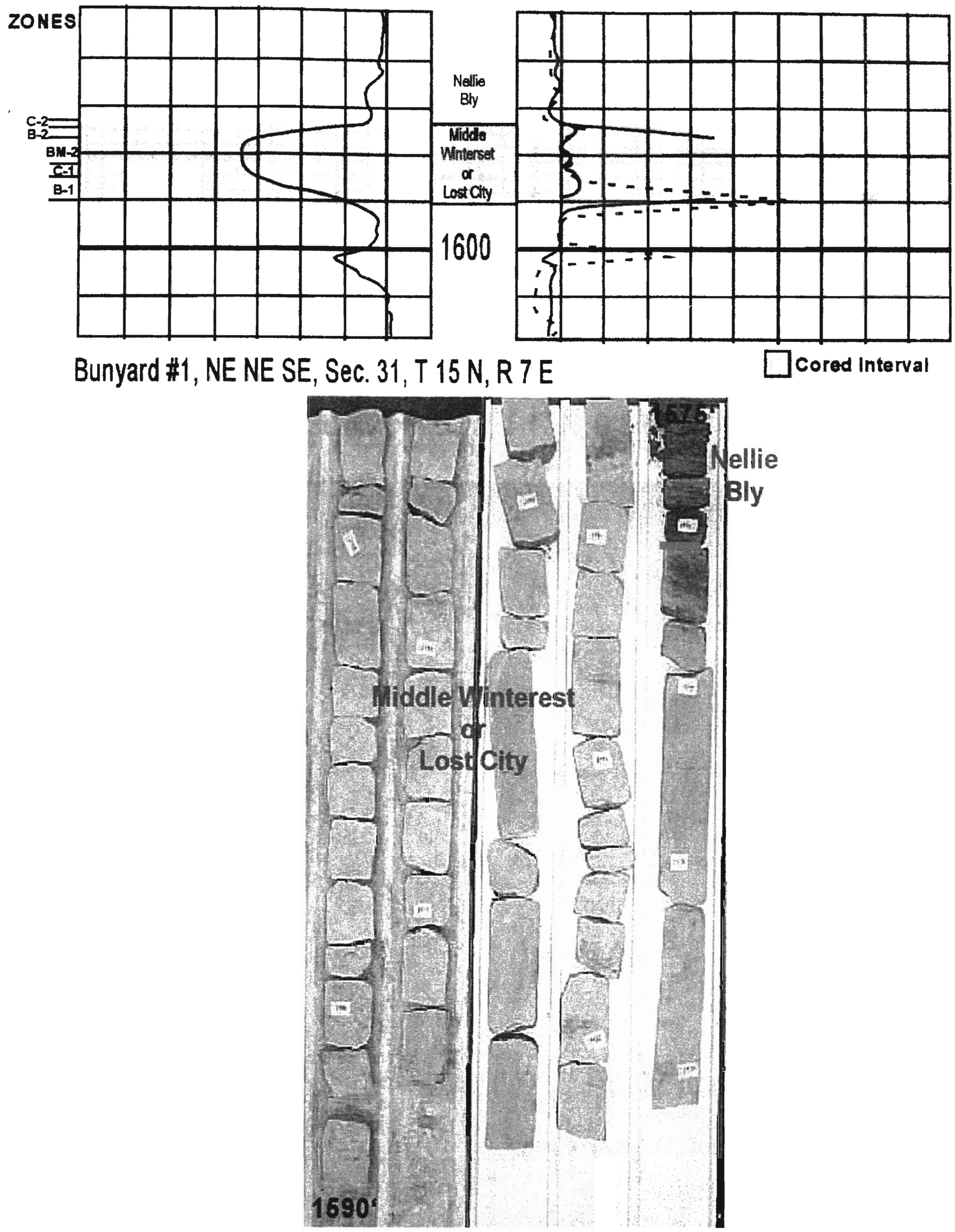

Fig. 38. Well log and core photo of the Shell, Bunyard #1 well, showing submember distribution and the base of the Nellie Bly Formation. Facies zones are listed as they are found in the core. The S.P. signature (left track) is very similar to those of other wells within the study area.

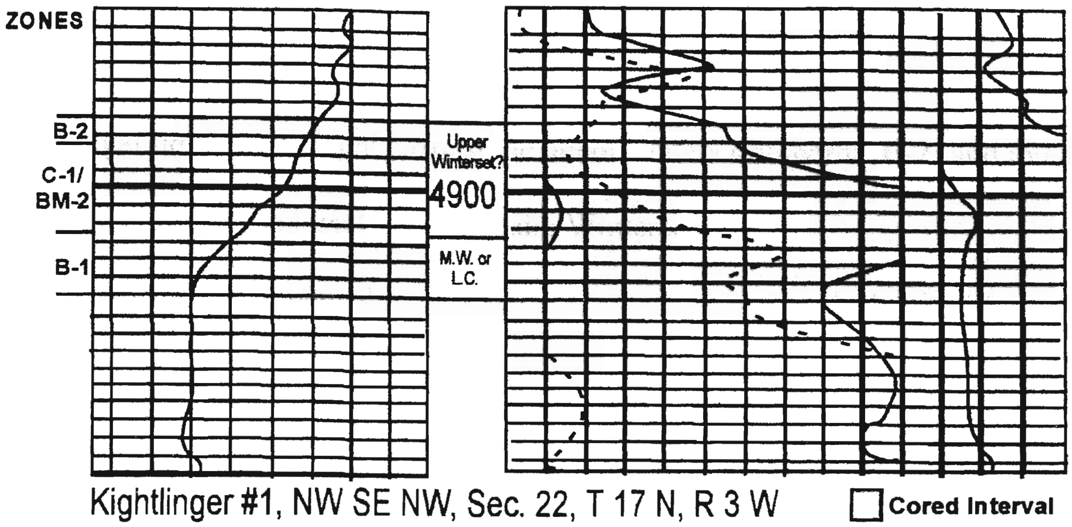

Fig. 39. Well log and core photo of the Kightlinger #1 well. Facies zones and proposed members/submembers are listed as they are found in the core.

wackestone to packstone between 4905 and 4895 is labeled C-1/BM-2 and most likely represents the capping facies and/or the basal lime mudstone to wackestone facies. The overlying algal breccia and algal bafflestone denote another bioherm (B-2) and most likely represent either the Lost City or Middle Winterset.

The Lower Winterset submember might be represented at the base of the Gulf, L. L. Tontz #1 core where small, brown phosphate nodules, crinoids, and sparry calcite are rather common in a wackestone to packstone matrix (BM-1) (Fig. 40). Less than a foot of this zone is represented in the core. Traces of phosphate, along with the abundance of algae, peloids, monaxon and tetraxon sponge spicules, and large fenestrate bryozoans above are suggestive of the Lost City or the lower and upper sections of the Middle Winterset Submember and are considered as zone B-1. The overlying calcareous, black shale represents the beginning of the migration of terrigenous sediment into the area and serves as the capping facies (C-1) for the upper bioherm (B-1).

The crinoidal, fissile, black shale at the very base of the Cameo, Jeanette #2-23 core may represent the top of the Coffeyville Formation or a shale break in the limestone where there was a sudden influx of mud into the system (BM-1) (Fig. 41). Lost City or Middle Winterset deposition is represented above the black shale where traces of phosphate, fenestrate bryozoans, peloids, abundant phylloid algae, echinoderms, and other skeletal grains are visible in a thick, highly brecciated zone. The tan-gray, porous, algal bafflestone marks the upper portion of this bioherm (B-1). The overlying, dark-gray wackestone to packestone may correspond to the skeletal biomicrite facies of the Upper Winterset. This unit is overlain by crinoidal, argillaceous limestone interbedded with the crinoidal black shale marking the top of the Upper Winterset in the core.

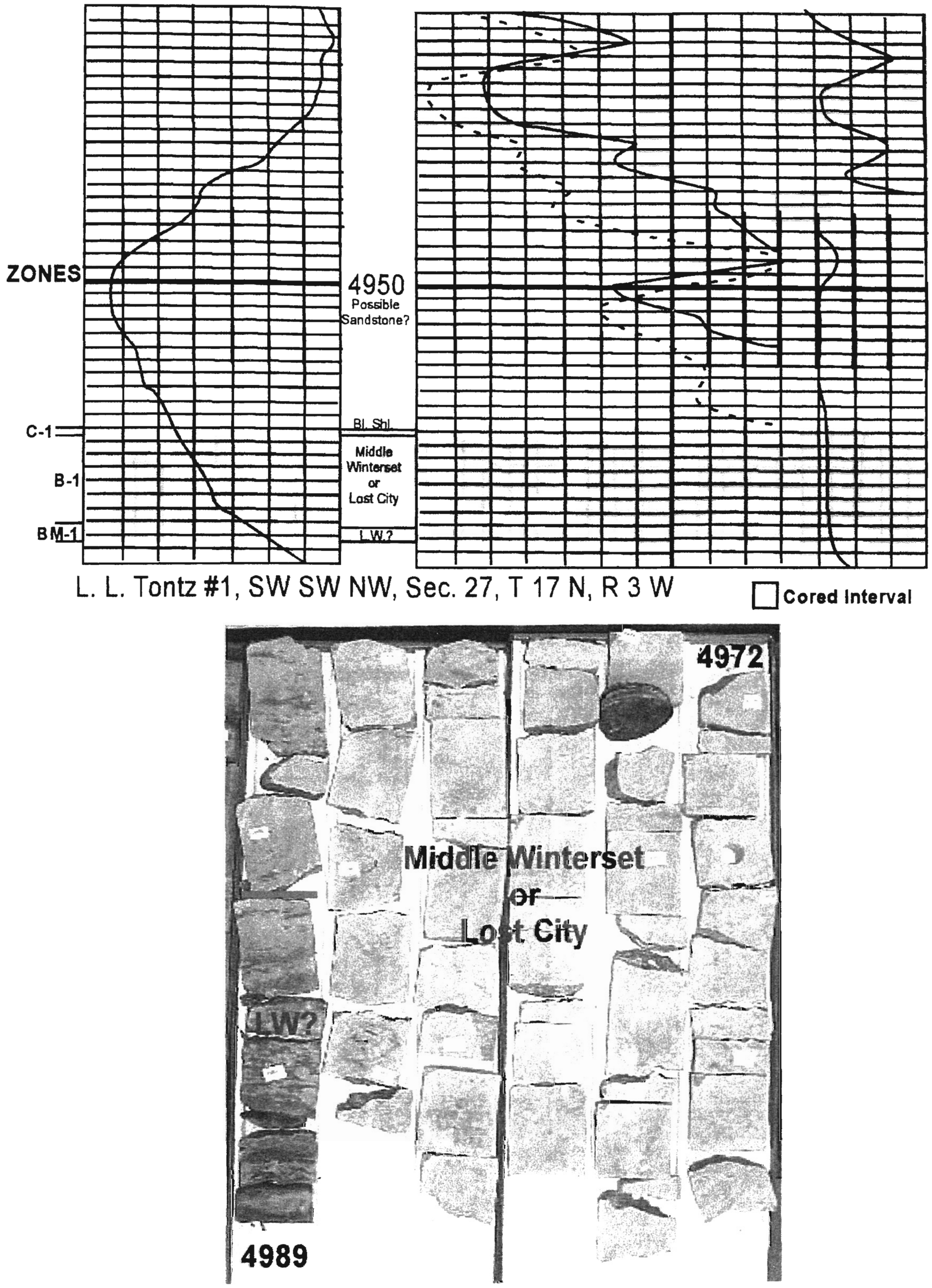

Fig. 40. Well log and core photo of the L.L. Tontz #1 well. Core taken from a depth of 4972 to 4989 feet. L.W.? may represent the upper part of the Lower Winterset submember.

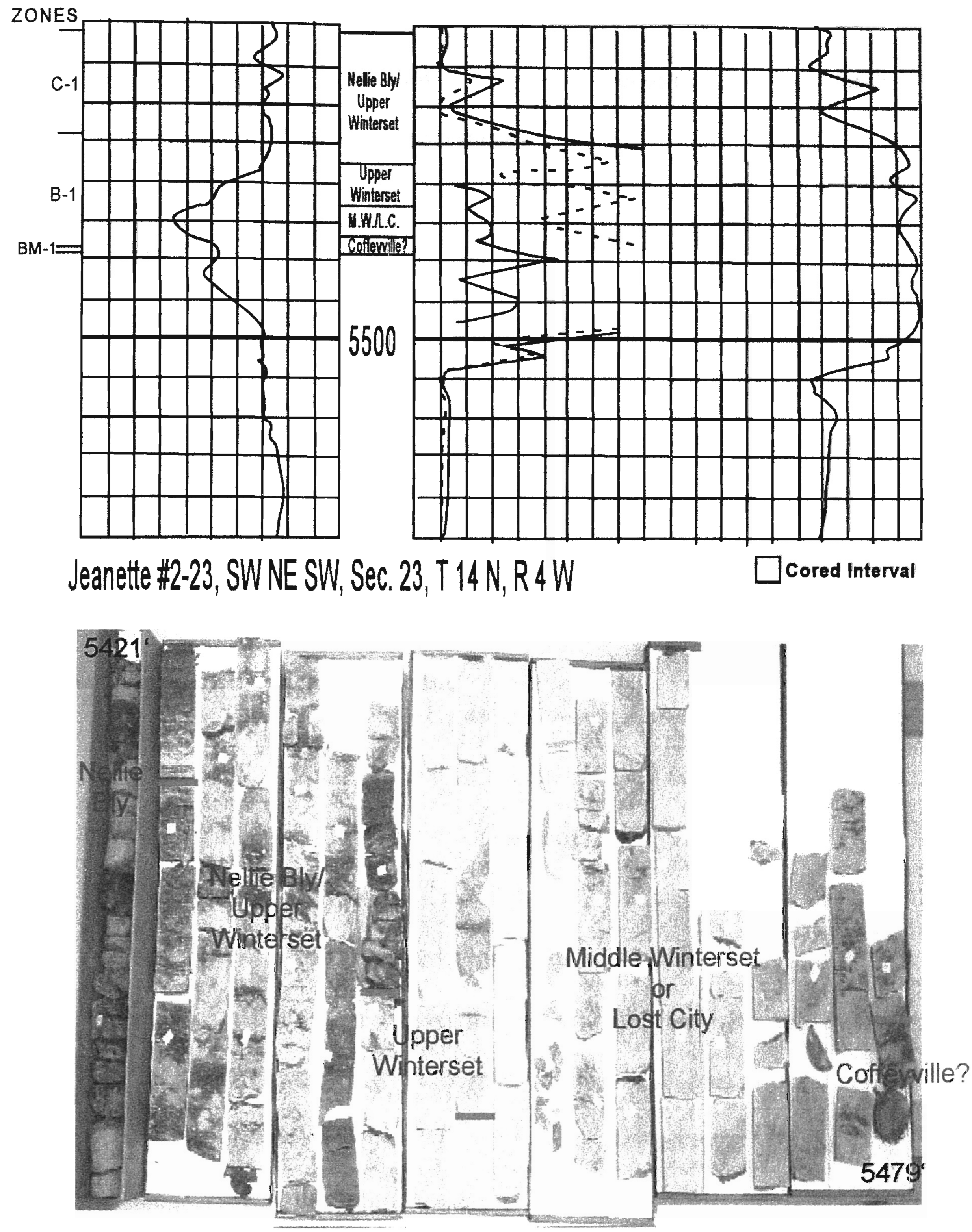

Fig. 41. Well log and core photo of Jeanette #2-23 well showing distribution of the "Hogshooter" submembers, as well as the top of the Coffeyville (?) Formation and the base of the Nellie Bly.

Slightly- to non-calcareous, black fissile shale at the top of the core denotes the lowest shale of the overlying Nellie Bly Formation. The upper 26 feet of the core represent the capping facies (C-1) of the bioherm and the influx of terrigenous sediment into the system.

By placing the zones referred to above alongside of each well's log signature, it is possible to correlate zones across the study area. The negative S.P. deflection at the base of the "Hogshooter" most likely shows some type of bioherm deposit. The capping facies and basal lime mudstone to wackestone pile overlies the first bioherm and is represented by a more constant S.P. deflection between approximately -40 and -65 millivolts. Finally, the positive S.P. deflection at the top of the "Hogshooter" may consist of another bioherm unit followed by its capping facies showing a gradational contact between the "Hogshooter" and the "Nellie Bly".

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to correlate the previous work done on the outcropping Hogshooter Formation to the "Hogshooter" in the subsurface, taking into consideration similarities and differences in petrology, depositional environment, stratigraphy, and changes in overall geometry across southern Logan, northern Oklahoma, Lincoln, and Creek Counties, Oklahoma. This information was then utilized to obtain conclusions listed below.

1. The section between the Hogshooter Limestone and the Checkerboard Limestone thickens to the southeast of the study area. The "Hogshooter" thins toward the basin in the west and most likely shales out farther west.
2. An isopach sketch combined with cross-section analysis suggests that at the beginning of "Hogshooter" deposition, Coffeyville shales and sandstone formed an area of positive relief in the southeastern and northeastern parts of the study area. This suggests that "Hogshooter" deposition upon these positive features occurred after carbonate deposition in the west (basinward). Thinner carbonate units deposited upon these areas of positive relief were most likely laid down slowly with the transgression of the Late Pennsylvanian sea.
3. Core and thin section analysis, when compared with the outcropping Hogshooter Formation and descriptions of individual "Hogshooter" members made by previous authors, shows that distribution of the Lower

Winterset submember may be found as far as Section 22, T. 17 N., R. 3 W. (Gulf, Kightlinger #1). Lost City or Middle Winterset distribution appears much more widespread and is visible in all four cores and, most likely, throughout the study area. The Upper Winterset submember may be present at Section 22, T. 17 N., R. 3 W. (Gulf, Kightlinger #1), and Section 23, T. 14 N., R. 4 W. (Cameo, Jeanette #2-23).

4. By separating individual facies found within each core, creating a zoning system based on these facies, and then comparing these zones with the well logs (more specifically the recorded Spontaneous Potential deflection curve), it is possible to correlate the zones across the study area.
5. Bioherm facies can be found at two locations on the S.P. curve: (1) at the base of the "Hogshooter" Marker where the S.P. deflection goes negative, and (2) at the top of the "Hogshooter" Marker where the S.P. deflection begins to go to the right (positive). Where the S.P. deflection ceases to move in the negative or positive directions (at the bend in the curve), a capping facies or basal lime mudstone to wackestone pile may be present. Based on S.P. deflections visible in cross-section, these facies can be correlated across the study area.
6. Porosity was generally very low in all four cores. Brecciated, highly fractured zones, vugs, and other forms of secondary porosity can be traced to bioherm deposits/algal accumulations.

7. Phylloid algae play a major role in porosity development in the "Hogshooter" limestone. Dissolution of algal blades (along with skeletal grains) causes the formation of vugs and brecciated zones.
8. Further study can be performed on a more local scale or with a larger number of wells to map the geometry and location of the "Hogshooter" throughout the study area. This may reveal the existence of raised topographic structures (such as algal mounds) which can serve as traps for hydrocarbon. Surveys performed outside of this study area might be used to not only confirm the existence of the Lost City Limestone or the Winterset Submembers in the subsurface, but also to provide a more detailed paleoenvironmental interpretation.

7. Phylloid algae play a major role in porosity development in the "Hogshooter" limestone. Dissolution of algal blades (along with skeletal grains) causes the formation of vugs and brecciated zones.
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REFERENCES

Bennison, A. P. "Pennsylvanian rocks of the Tulsa area." Tulsa Geological Society Digest 37 (1973): 51-59.

Bross, G. L. "Distribution of Layton Sandstone (Pennsylvanian) Logan County, Oklahoma." Shale Shaker, v. 11, no. 2 (1960): 2-12.

Cocke, J.M. and Strimple, H.L. Distribution of algae and corals in upper Pennsylvanian Missourian rocks in northeastern Oklahoma: Geological Society of America, South-Central Section, 1967.

Cronoble, W.R. "Petrology of the Hogshooter Formation (Missourian), Washington and Nowata counties, Oklahoma." unpublished Masters Thesis, University of Oklahoma, 1961.

________. "Facies relationships in an adjacent to limestone buildups of the Coffeyville and Hogshooter formations (Missourian), Washington and Nowata counties, Oklahoma." Kansas Geological Society, 27th Field Conference, 1962: 116-123.

Cronoble, W.R. and Mankin, C.J. "Genetic Significance of Variations in the Limestones of the Coffeyville and Hogshooter Formations (Missourian), Northeastern Oklahoma." Journal of Sedimentary Petrology, v. 33, no. 1 (1963): 73-86.

Chenoweth, P.A. "Caney River arch, a pre-Seminole uplift in northeastern Oklahoma." Oklahoma Geology Notes, v. 25, no. 11 (1965): 279-286.

Dunham, R.J. "Classification of Carbonate Rocks According to Depositional Texture." Amer. Assoc. Petrol. Geol. Mem. 1 (1962): 108-121.

Ekebafe, S.B. "Stratigraphic analysis of the interval from the Hogshooter Limestone to the Checkerboard Limestone: A subsurface study of North Central Oklahoma." unpublished Masters Thesis, University of Tulsa, 1973.

Embry, A.F., and Klovan, J.E. "Absolute Water Depth Limit of Late Devonian Paleoecological Zones." Geol. Rundschau. 61 (1972): 672-686.

Ferguson, D.B. "Subsurface geology of Northern Lincoln County, Oklahoma." Shale Shaker, v. 14, no. 10 (1964): 4-18.

Forbess, D. "Petrology and Paleoecology of the Oswego Limestone (Pennsylvanian, Desmoinesian) in Beaver County, Oklahoma, and Seward County, Kansas.": unpublished Masters Thesis, Southern Illinois University at Carbondale, 1993.

Hansen, B.V."The Stratigraphy and Petrogenesis of the Hogshooter Formation in Northeastern Oklahoma.": unpublished Masters Thesis, University of Tulsa, 1957.

James, N.P. "Reefs." Facies models: Geoscience Canada Reprint Series 1 (1979): 121-133.

_____. "Reef environments." Amer. Assoc. of Pet. Geol. Mem. 33 (1983): 346-440.

James, N.P., and Macintyre, I.G. "Carbonate Depositional Environments: Modern and Ancient." Colorado School of Mines Quarterly, v. 80, no. 3 (1985).

Jorgensen, D.G. "Paleohydrology of the Anadarko Basin, Central United States." Oklahoma Geological Survey Circular 90 (1989): 176-193.

Niemann, W.L. "Stratigraphy, depositional history, and diagenesis of the Lost City Limestone Member of the Hogshooter Formation (Missourian, Upper Pennsylvanian) in Northeastern Oklahoma.": unpublished Masters Thesis, University of Iowa, 1986.

Oakes, M.C. "Geology and mineral resources of Washington County, Oklahoma." Oklahoma Geological Survey Bulletin, v. 62 (1940).

_____, 1952. "Geology and mineral resources of Tulsa County." Oklahoma Geological Survey Bulletin, v. 69 (1952).

_____, 1959. "Geology of Creek County." Oklahoma Geological Survey Bulletin, v. 81 (1959).

_____, 1963. "Geology and water resources of Okmulgee County." Oklahoma Geological Survey Bulletin, v. 91 (1963).

Prothero, D.R., and Schwab, F. Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy. New York: W.H. Freeman and Company, 1996.

Rigby, J. K. Phylum Porifera: Fossil Invertebrates, 1st ed., 1987. 116-139.

Schrader, F. C., and Haworth, E. "Economic Geology of the Independence Quadrangle, Kansas." U. S. Geological Survey Bulletin 296 (1906): 14.

Strimple, H.L. and Cocke, J.M. "Tabulate corals and echinoderms from the Pennsylvanian Winterset Limestone, Hogshooter Formation, northeastern Oklahoma." Bulletin of American Paleontology, v. 64, no. 279 (1973): 141-167.

Towns, D.J. "Distribution, depositional environment, and reservoir properties of the Pennsylvanian Cottage Grove Sandstone, South Gage Field, Oklahoma; Part 1." Shale Shaker, v. 29, no. 3 (1978): 52-61.

Vague, D.D. "Petrology of Phylloid Algal Mounds, Strawn Limestone, South Humble City Field, Lea County, New Mexico." unpublished Masters Thesis, University of New Orleans, 1993.

APPENDIX A

NAMES, LOCATIONS, AND RELEVANT DEPTHS OF WELLS USED IN CORRELATION SECTIONS

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Well Name	Operator Name	Location	Hogshooter Top	Hogshooter Base	Layton Top	Checkerboard Top
Bunyard #1	Shell Oil	T15N R7E SEC 31 NENESE 330 FNL 330 FEL	1570	1590	1725	1950
Beck #1	Mercury Drilling Co. & P.G. Lake Inc.	T15N R8E SEC 11 NENESW	1140	1150	1205	1440
J.J. Mingo #1	Pecos Exploration	T16N R8E SEC 12 SENENE	1165	1180	1210	1525
Elias #1	Bristow Resources	T16N R9E SEC3 CNWNESE	906	916	940	1297
Shoppa Elias #24	Bristow Resources	T17N R9E SEC 12 E/2SESW 660 FSL 2145 FWL	685	715	755	1105
Lloyd Jones #1	Henderson Exploration Co.	T18N R10E SEC 28	698	715	765	1104
Jeanie #1-17	CJCC Inc.	T19N R11E SEC 17 SENWSE 1620 FSL 970 FWL	182	220	241	551
Herrmann #1	D.F. O'Rourke	T16N R4E SEC 22 SWSWSW	2695	2720	2750	2995
McKEOU #1	Davon Oil Company	T15N R4E SEC 3 NWNWSE	2665	2685	2715	2980
Evans #1	Hilmer & Messenger	T14N R4E SEC 8 S1/2SWSE	2784	2800	2835	3095
State School Land #1-A	Pipe Sales Corp.	T13N R3E SEC 16 NENENW	3290	3309	3320	3646
Roubidoux #1	Walter Duncan & Randall Morton	T15N R1E SEC 27 SENWNW	3785	3800	3815	4050
Buzzard #1	R.M. Jordan	T14N R1E SEC 8 SWSWNW	4098	4110	4142	4380
Kavanaugh #1	Harper & Turner	T13N R1E SEC 9 SWNWNW	4080	4098	4110	4385
Jeanette #2-23	Cameo Oil Company	T14N R4W SEC 23 SWNESW	5460	5490	5560	5622
Bernice Mills #1	Champlin Oil & Reg. Co.	T15N R4W SEC 20 CNWNW	5575	5622	5690	5745
James #1-3	Atlas Oil Inc.	T16N R3W SEC 3 CNWNW	4838	4868	4929	5002
E.M.Tontz #1	Rancho Oil	T17N R3W SEC 26 NENENW 330 FNL 330 FEL OF NW/4	4870	4896	4935	5024
Mays #1-35	Blue Quail O&G	T17N R2W SEC 35 NESENE 930 FSL 2310 FWL	4473	4510	4550	4654
Gaffney #1	Wolfe Drilling Co.	T16N R1E SEC 12 NENENW	4094	4104	4128	4356
Harrison Faylor #1	McCarty & Coleman	T16N R1E SEC 25 NWNENE	3635	3648	3670	3905
Evans #1	Javelin Oil Co.	T16N R2E SEC 26 NENENE	3450	3460	3472	3723
Gallagher #1	Arthur & Marcel Silberman	T16N R3E SEC 25 SWNWSW	3016	3031	3085	3312
Hopkins #2	Harris & Suppes	T15N R5E SEC 1 E1/2NWNWNW 2310 FSL 480 FWL OF NW/4	2200	2208	2225	2472
Snook #1	Davidor & Davidor	T15N R6E SEC 21 SWSWSW	2020	2035	2140	2373
Duncan #1	Montejas Expl. & Prod.	T13N R6E SEC 19 NWNWSW 2310 FSL 330 FWL	1940	1952	2060	2334
Denton #3	Ashland	T14N R3W SEC 1 CSWSW	5085	5138	5160	5284
Jones #1	Amerada	T13N R2W SEC 19 CSWSE	5105	5119	5120	5375
Martin #1	Gutowsky Bros. & Ivan Otstot	T13N R1W SEC 24 NENWSW	4530	4555	4580	4835
John Zawisza #1	Manahan Oil Co.	T13N R2E SEC 34 SWSWNW	3739	3760	3775	4085
A.M. Duke #1	A.J. Slagter	T13N R4E SEC 19 NESENE	2975	2986	3040	3339
Broeker #8	Sinclair	T13N R5E SEC 9 NESWSW	2310	2325	2415	2681
Kightlinger #1	Gulf Oil Corp.	T17N R3W SEC 22 NWSENW	4892	4912	NA	NA
L.L. Tontz #1	Gulf Oil Corp.	T17N R3W SEC 27	4972	4989	NA	NA

APPENDIX B

THIN SECTION DATA
AND
CORE PETROLOGS

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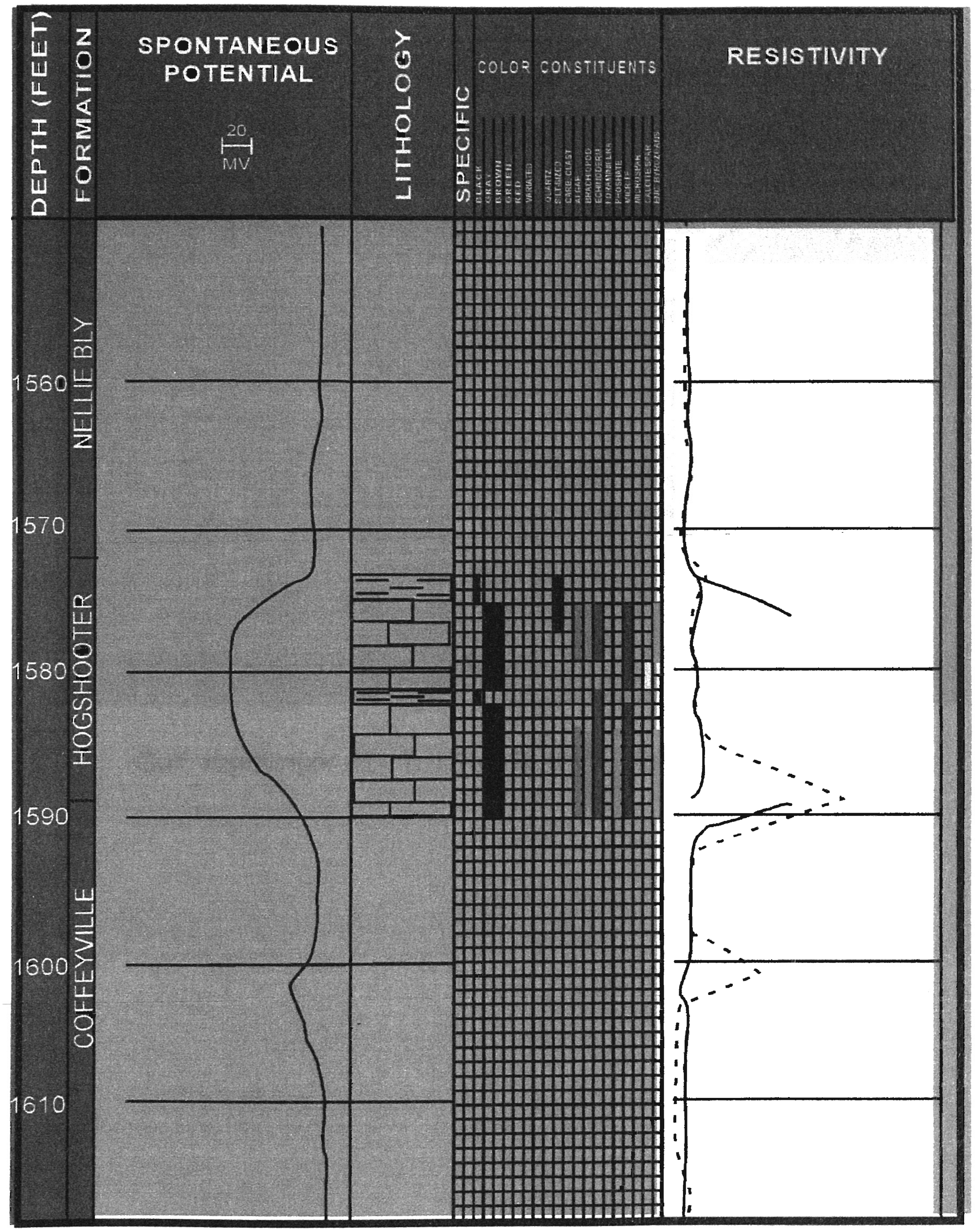
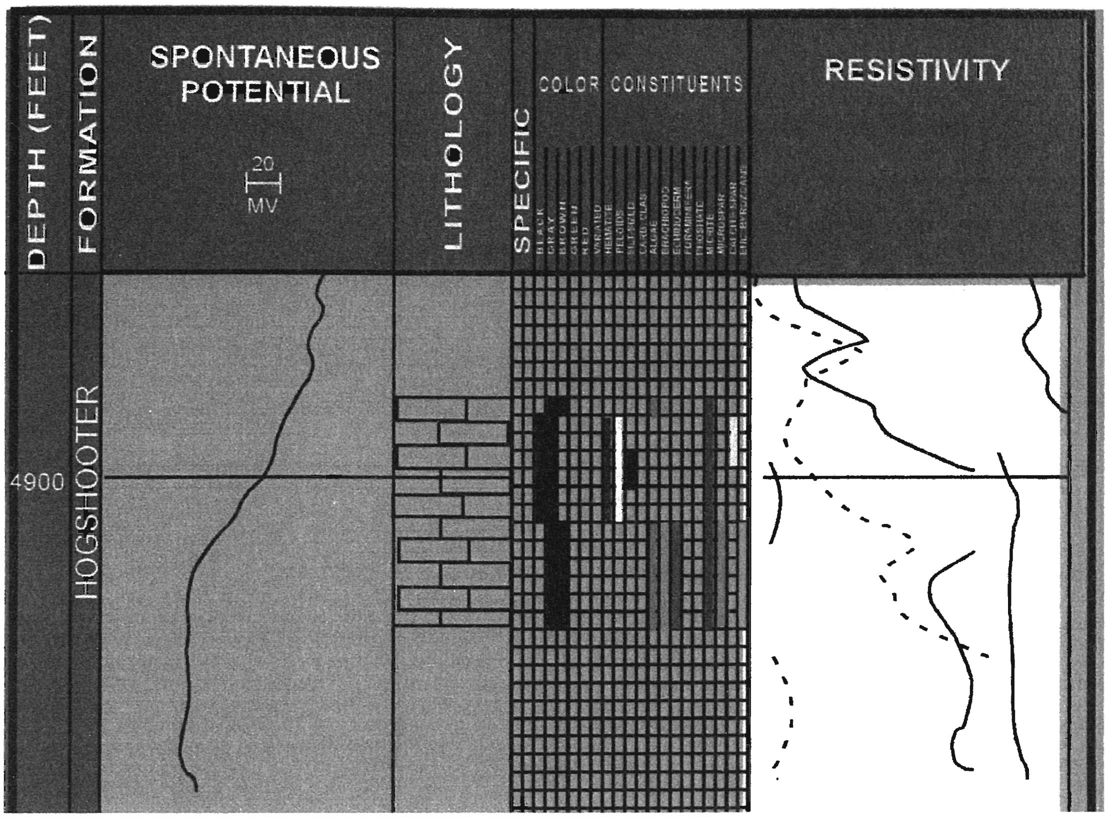
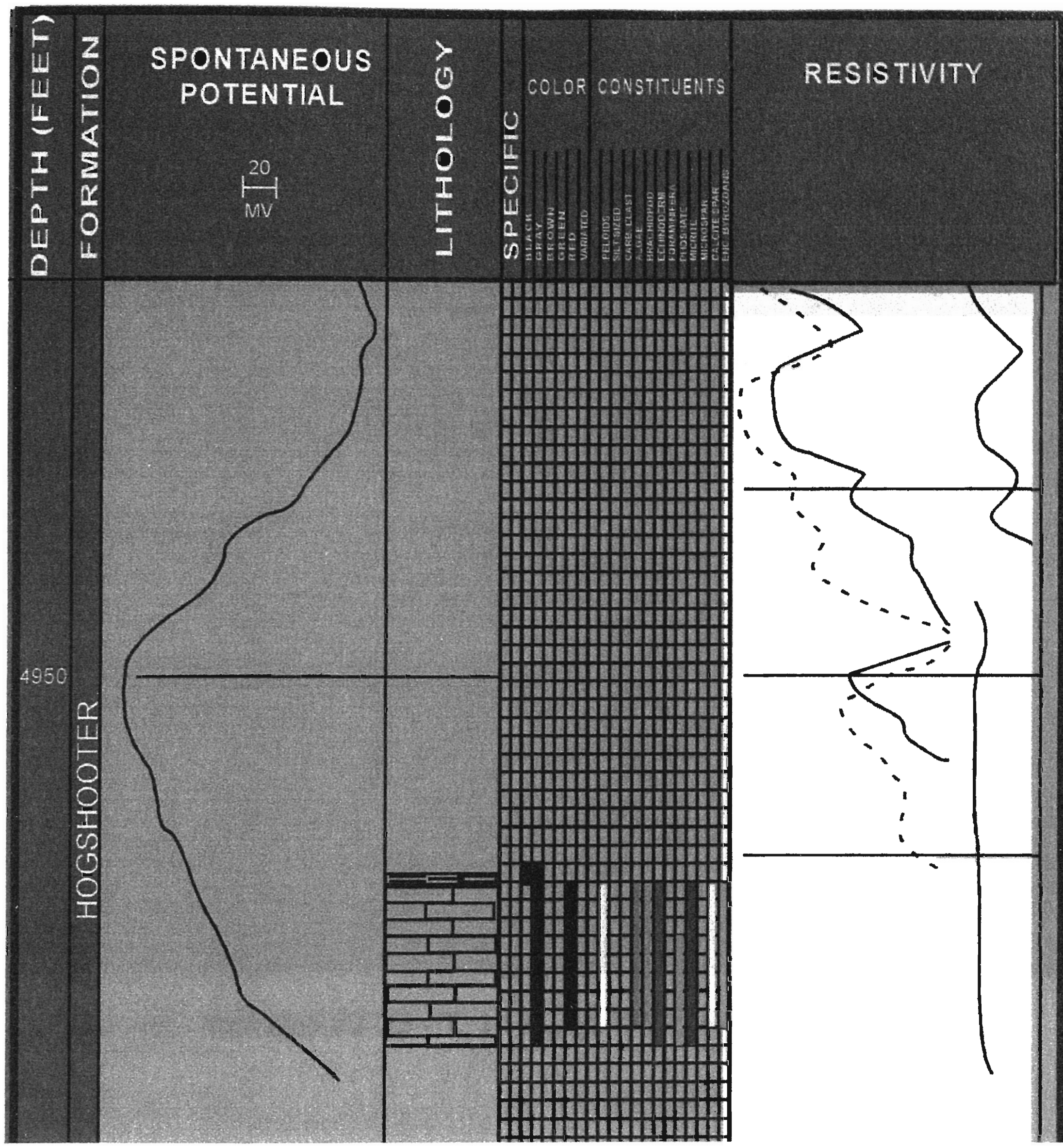
CORE PETROLOGS



Shell, Bunyard #1 - T. 15 N., R. 7 E., Sec. 31 NE NE SE

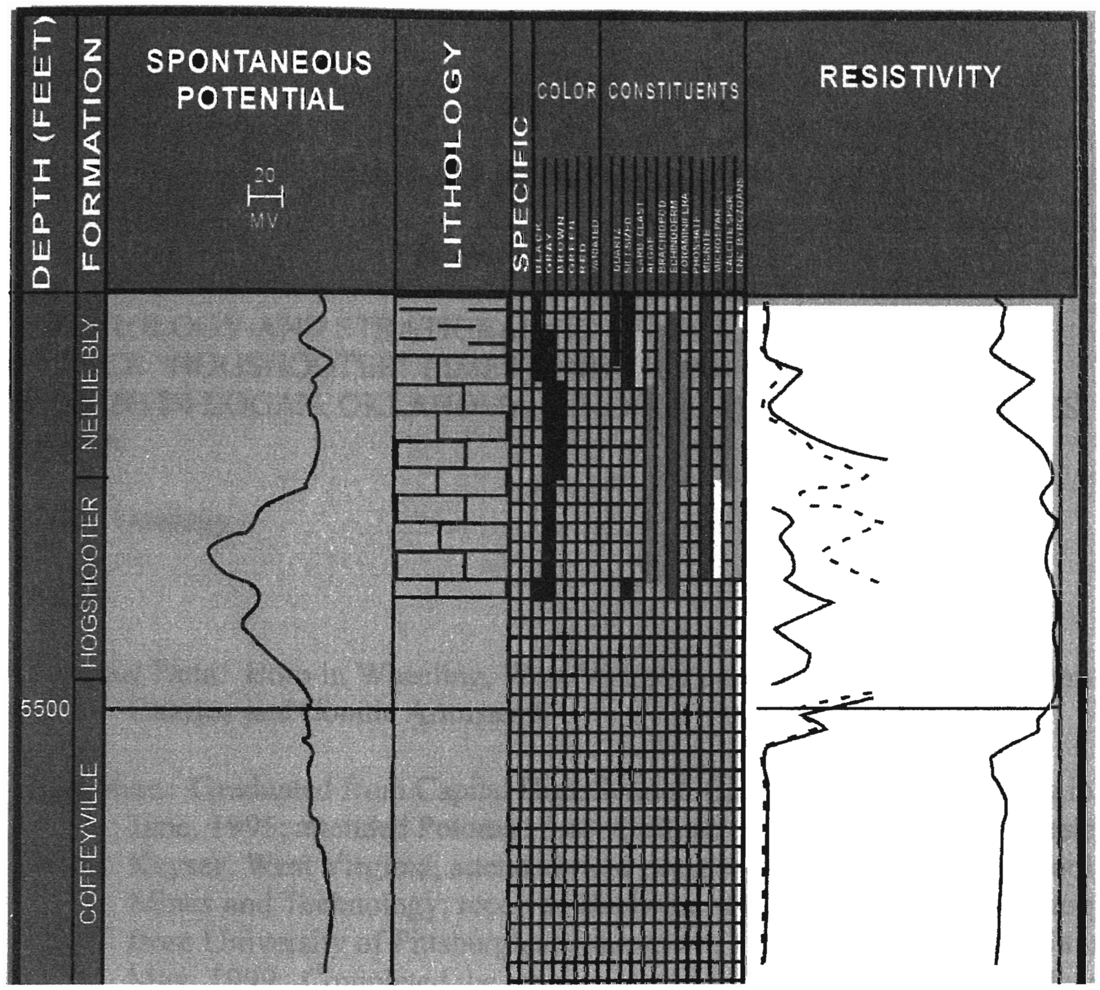


Gulf, Kightlinger #1 - T. 17 N., R. 3 W., Sec. 27 SW SW NW



Gulf, L. L. Tontz #1 - T. 17 N., R. 3 W., Sec. 22 NW SE NW

APPENDIX B CONT.



Cameo, Jeanette #2-23 - T. 14 N., R. 4 W., Sec. 23 SW NE SW

VITA

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Master of Science

Thesis: PETROLOGY AND STRATIGRAPHIC CORRELATION OF THE SUBSURFACE "HOGSHOOTER" LIMESTONE (UPPER PENNSYLVANIAN, MISSOURIAN) IN LOGAN, OKLAHOMA, LINCOLN, AND CREEK COUNTIES, OKLAHOMA

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