7-4-14E

CORE STUDY OF THE UPPER PART OF THE MIDDLE ORDOVICIAN VIOLA LIMESTONE, McCLAIN AND McCLAIN SW FIELDS, NEMAHA CO., KANSAS

REPORT NO. RMG84-06

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INTRODUCTION

Core study of the upper part of the Middle Ordovician Viola Limestone in three wells in McClain and McClain SW fields, Nemaha Co., Kansas is presented at the request of the Wichita, Kansas office. The cores are from the Pendleton Land and Exploration McClain #1 and the Petro Lewis Potts #1, both of McClain field, and the Cities Service Wessel "A" #1 of McClain SW field. Both fields are located along the western flank of the Forest City basin in northeastern Kansas (Fig. 1).

The stratigraphy, structural history, and paleogeographic setting of the study area were presented by Daryl Duvall and Roger Boeken in an April, 1983 company report. Additionally, they discussed the discovery (December, 1981) and production history of McClain field. Duvall and Boeken stated that McClain field is a structural trap producing from the Viola Dolomite (at ~3450') and Upper Simpson Sandstone (at ~3650'). The Viola averages 150'-160' thick, unconformably overlies Middle Ordovician Simpson rocks, and is abruptly overlain by the Upper Ordovician Maquoketa Shale. There are 14 producing wells in the McClain field. Two wells were drilled in the McClain SW field; neither of these wells is currently producing.

CORE DESCRIPTION AND WIRELINE LOG ZONES

Using wireline logs Duvall and Boeken recognized four zones in the upper part of the Viola in McClain field (Fig. 2). In

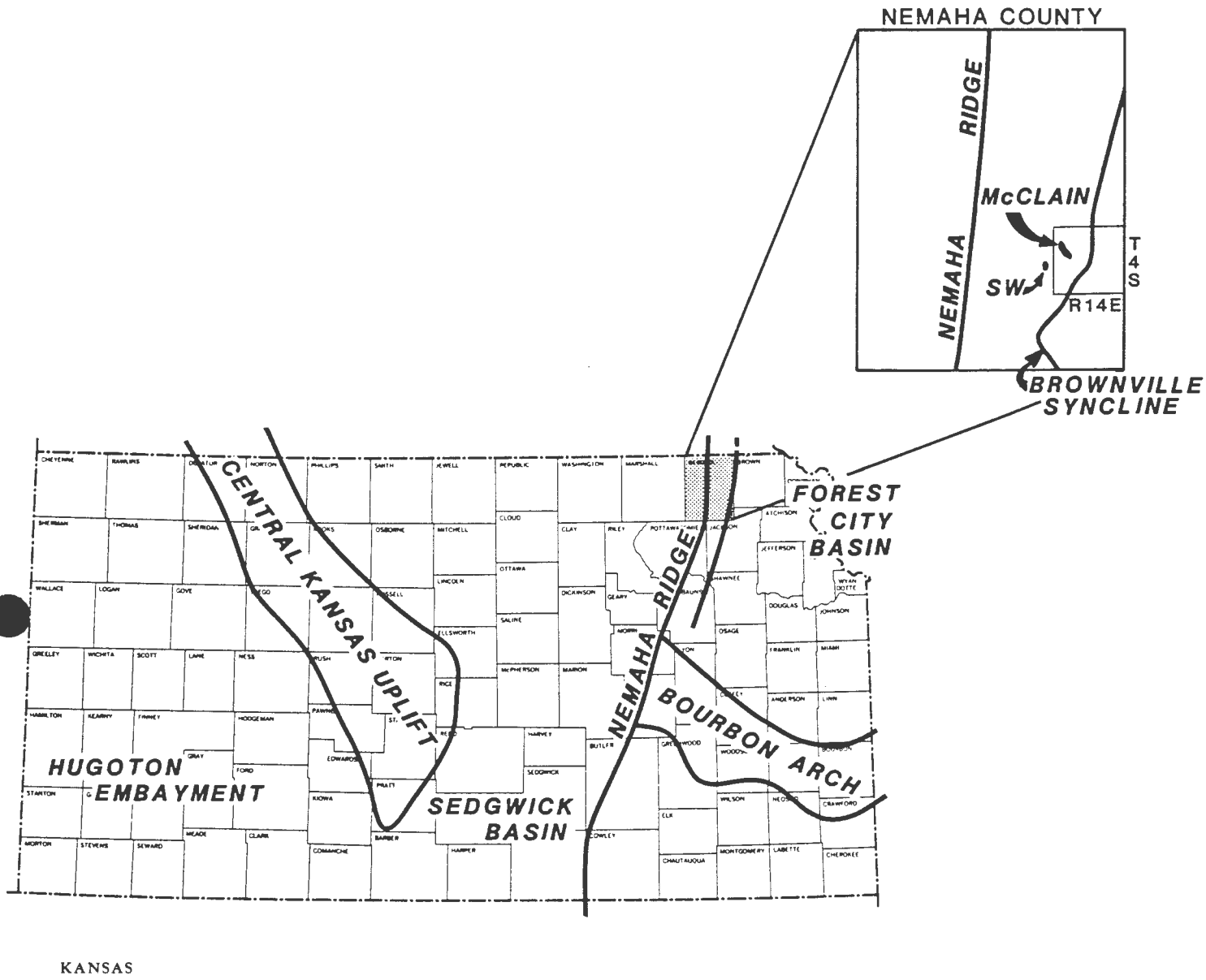


Figure 1. Location of McClain and McClain SW fields on the western flank of the Forest City basin, Nemaha Co., Kansas.

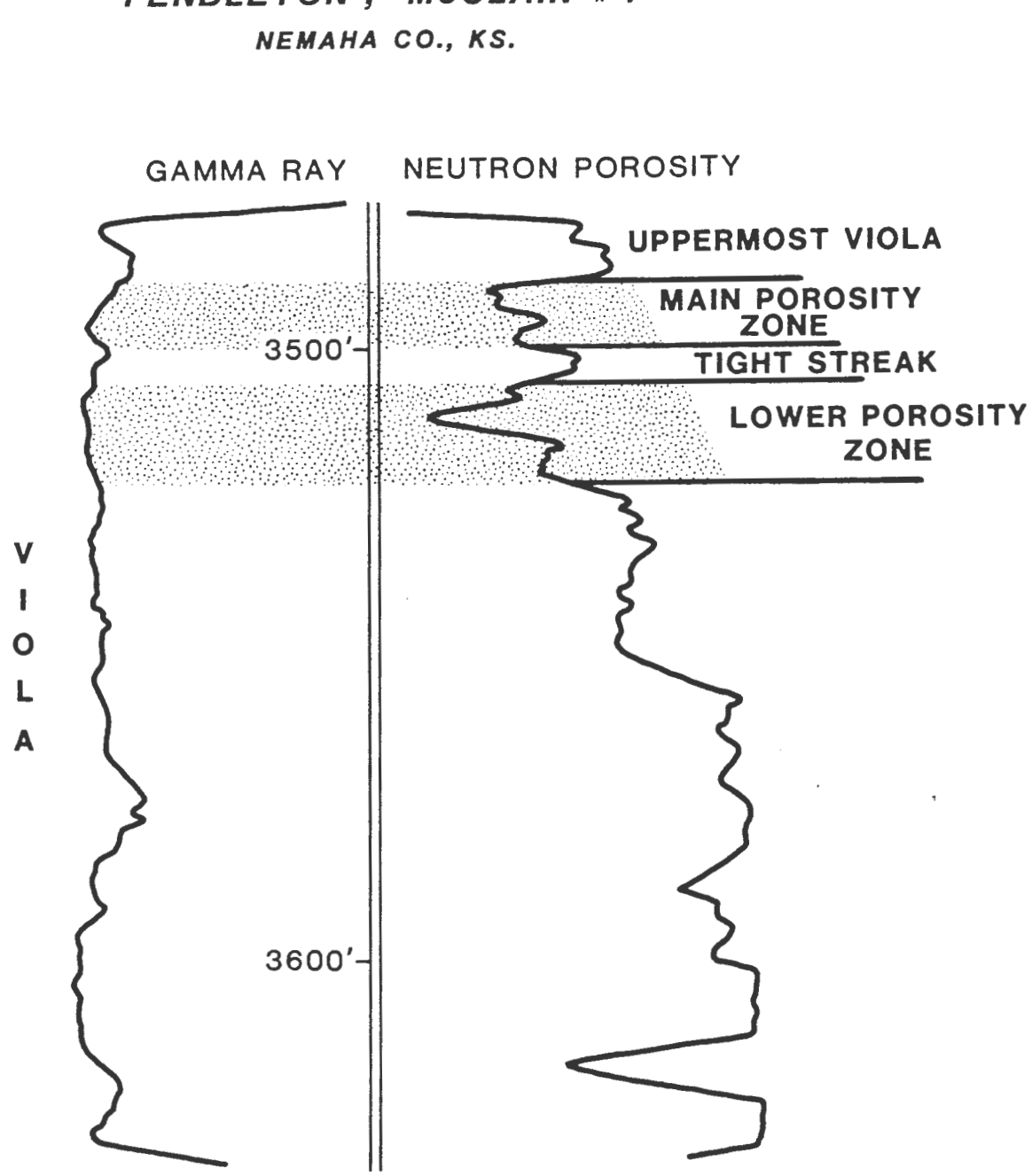


Figure 2. Duvall and Boeken's wireline log zones for the upper part of the Viola Limestone, McClain field, Nemaha Co., Kansas.

descending order these zones are: the "uppermost Viola" referring to the uppermost 10'-12' of the Viola characterized by low porosity and permeability, the "main porosity zone" which is the producing interval where it falls above the oil/water contact, the "tight streak", and the "lower porosity zone". These zones are indicated on wireline logs for the McClain #1, Potts #1, and Wessel "A" #1 in Figure 3. In addition, these zones can be identified in core (Figs. 4-6).

Duvall and Boeken's uppermost Viola zone was cored only in the Wessel "A" #1 where it corresponds to core unit VI (Fig. 6). Unit VI is an argillaceous, medium to finely crystalline dolomite with poor permeability and poor to negligible porosity. The unit is a burrowed, echinoderm wackestone (Pl. I A). To what extent this zone might act as an imperfect seal above the main porosity zone is uncertain. However, oil staining is present in the upper 4.5' of Unit VI suggesting the uppermost Viola in this well does not form a perfect seal above, but rather is in communication with, the main porosity zone reservoir.

The main porosity zone was cored, at least in part, in all three wells (Figs. 4-6). It is a medium to coarsely crystalline dolomite with fair to good porosity including biomoldic, intergranular, fracture, and vuggy. In places the zone is mottled. Depositional textures are difficult to distinguish due to pervasive dolomite and in places strong oil staining. For the most part, the zone appears to have been an echinoderm packstone and grainstone (Pl. I B, C, and D). Porosities in this zone are highest

in the McClain #1 and Potts #1.

Duvall and Boeken's tight streak which separates the main and lower porosity zones is, as they stated, "not uniformly tight in all wells" (Figs. 4-6). This zone is a mottled (bioturbated), medium crystalline dolomite and was probably an echinoderm wackestone, packstone and locally grainstone (Pl. II A and B). Again, depositional textures are obscured by pervasive dolomite. Porosity in this zone is generally poor and includes biomoldic and less commonly, intergranular, vuggy, and fracture.

The upper part of the lower porosity zone is a medium to coarsely crystalline dolomite and has fair to very good porosity including intergranular, moldic, and fracture. This zone appears to have been an echinoderm grainstone and packstone. Planar and low-angle cross-stratification are generally present (Pl. II C and D). The lower part of the lower porosity zone includes two lithologies: mottled, medium crystalline dolomite (echinoderm wackestone/packstone) with fair porosity including biomoldic, fracture, vuggy, and in places intergranular (Pl. III B), and finely crystalline dolomite mudstone with intercrystalline and fine moldic porosity generally too small to be visible on the slabbed core surface (Pl. III A).

Below the lower porosity zone the Viola is a mottled (bioturbated), medium crystalline dolomite, probably bioclast wackestone and mudstone, with poor to negligible porosity (Pl. III C).

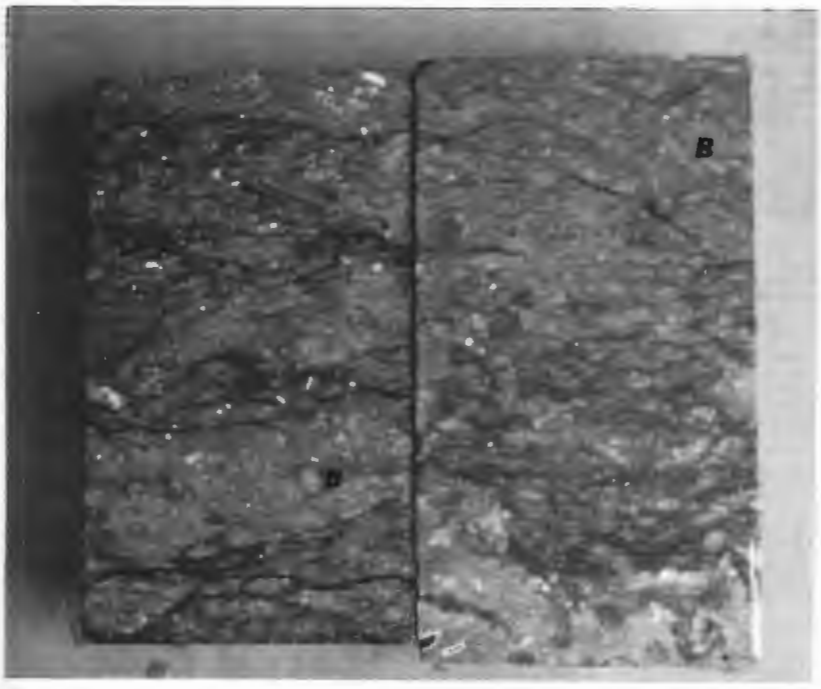
Because the zones of Duvall and Boeken were defined on

PLATE I.

A. Burrowed (B), argillaceous, medium to finely crystalline dolomite (echinoderm wackestone) of the uppermost Viola zone (Wessel "A" #1, (left) 3492.3' and (right) 3496.3').

B. C.&D. Oil stained, medium to coarsely crystalline dolomite (echinoderm grainstone, packstone, and in places wackestone) of the main porosity zone, porosity includes biomoldic (M), intergranular, vuggy (V), and fracture (F) (B: McClain #1, 3501.2'; C: Wessel "A" #1, (left-wet sample) 3499.3' and (right) 3500.3'; D: Potts #1, 3457').

Slabbed cores are 3" to 3.5" in width.



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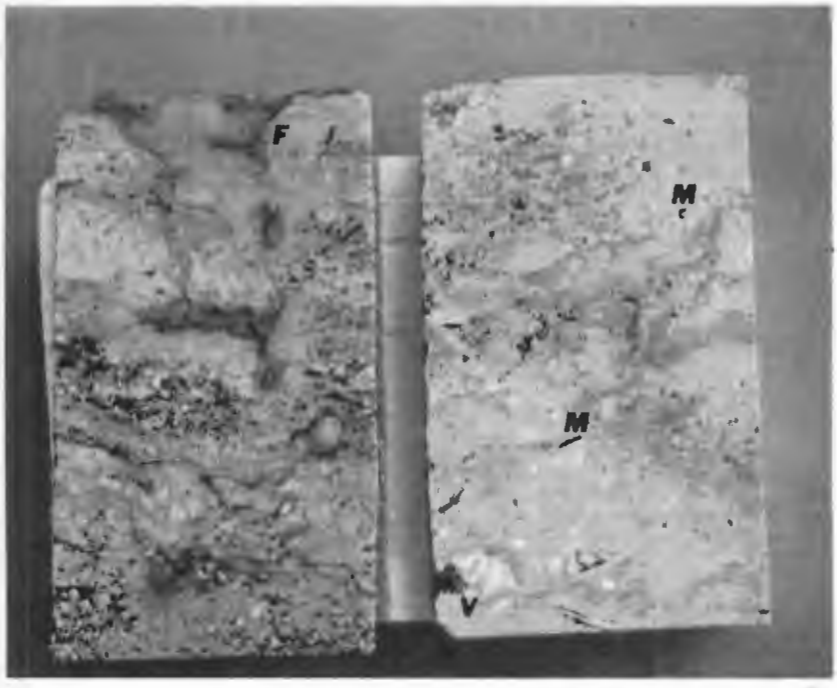
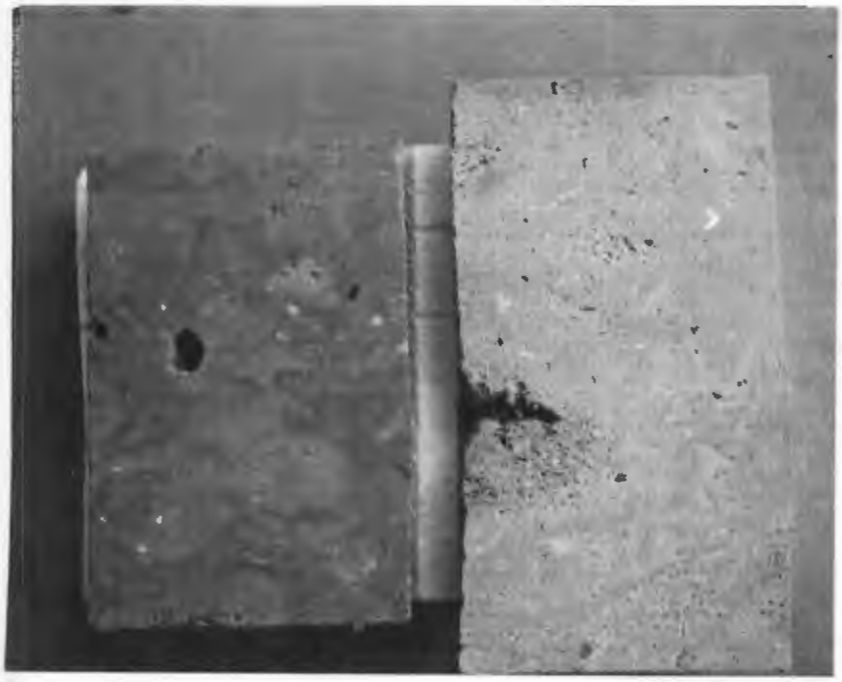


C

D

PLATE I



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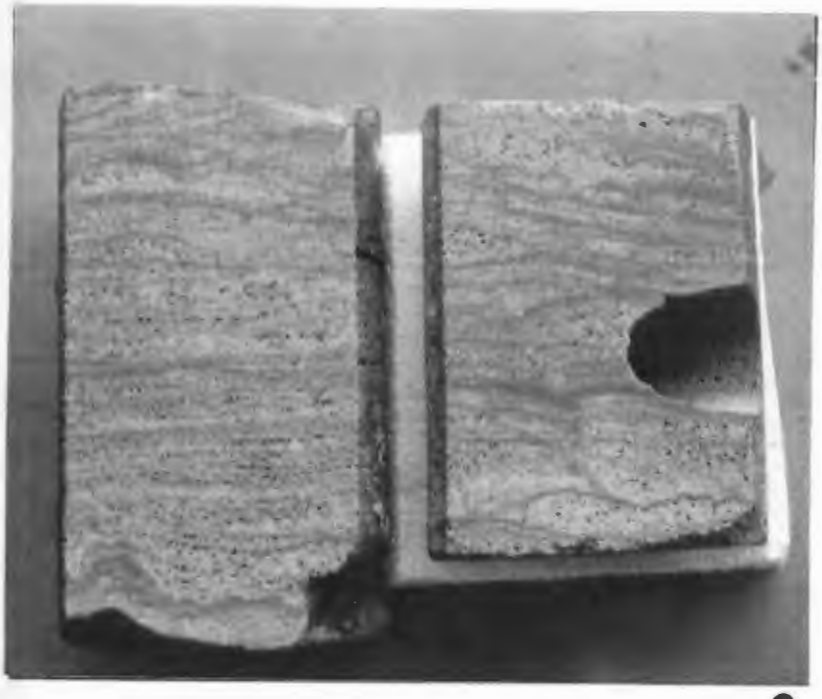
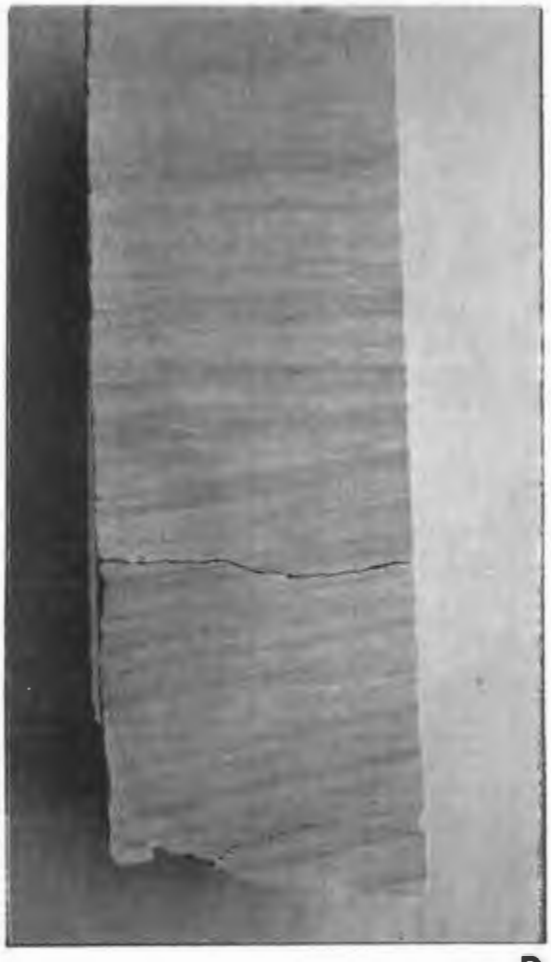


C



D

PLATE II

PLATE II.

A. and B. Burrow mottled, medium crystalline dolomite (echinoderm wackestone) of the tight streak, note patchy distribution of porosity with better porosity in the more coarsely crystalline, light-colored areas (A: Wessel "A" #1, 3513' (sample on left is wet); B: Potts #1, 3463').

C. and D. Low-angle cross-stratified and planar laminated, coarsely to medium crystalline dolomite (echinoderm grainstone) of the upper and middle parts of the lower porosity zone (C: McClain #1, 3514.5'; D: Potts #1, 3481').

Slabbed cores are 3" to 3.5" in with.

PLATE III.

A. and B. Fine to medium crystalline, dolomite mudstone (and wackestone?) of the lower part of the lower porosity zone, note white chert nodule, fractures, and red staining (R) in photo A and burrow mottling in samples in photo B (A: Potts #1, 3490'; B: McClain #1, (left) 3522 and (right) 3520.8.

C. Mottled, fine to medium crystalline dolomite (bioclast wackestone) below the lower porosity zone (McClain #1, 3544').

Slabbed cores are 3" to 3.5" in width.

A

B

C

PLATE III

DUVALL AND BOEKEN'S ZONES	GENERAL DESCRIPTION (CORE)
UPPERMOST VIOLA	ARGILLACEOUS, MEDIUM TO COARSELY CRYSTALLINE DOLOMITE (ECHINODERM WACKESTONE) WITH POOR POROSITY INCLUDING BIOMOLDIC AND RARE VUGGY.
MAIN POROSITY ZONE	MEDIUM TO COARSELY CRYSTALLINE DOLOMITE (ECHINODERM PACKSTONE AND GRAINSTONE) WITH FAIR TO GOOD POROSITY INCLUDING BIOMOLDIC, INTERGRANULAR, FRACTURE, AND VUGGY.
TIGHT STREAK	MOTTLED (BIOTURBATED), MEDIUM CRYSTALLINE DOLOMITE (ECHINODERM WACKESTONE, PACKSTONE AND LOCALLY GRAINSTONE) WITH GENERALLY POOR POROSITY INCLUDING BIOMOLDIC AND LESS COMMONLY VUGGY, INTERGRANULAR, AND FRACTURE.
LOWER POROSITY	FINE TO COARSELY CRYSTALLINE DOLOMITE; UPPER PART IS LOW-ANGLE CROSS-STRATIFIED AND PLANAR LAMINATED (ECHINODERM AND OOID(?) GRAINSTONE) WITH FAIR TO VERY GOOD POROSITY INCLUDING MOLDIC, INTERGRANULAR, AND FRACTURE. LOWER PART IS MOTTLED (ECHINODERM WACKESTONE/PACKSTONE AND DOLOMITE MUDSTONE) WITH FAIR POROSITY INCLUDING BIOMOLDIC, FRACTURE, VUGGY, AND INTERCRYSTALLINE.
UNNAMED ZONE BELOW LOWER POROSITY	MOTTLED (BIOTURBATED), MEDIUM CRYSTALLINE DOLOMITE (BIOCLAST WACKESTONE AND MUDSTONE) WITH POOR TO NEGLIGIBLE POROSITY INCLUDING BIOMOLDIC, VUGGY, INTERCRYSTALLINE, AND FRACTURE.

TABLE I

the basis of wireline log porosity they do not, in all cases, coincide with core units which are defined by a number of criteria including carbonate rock type, sedimentary structures, grain types, argillaceous content, and porosity. Still, there is a correlation between wireline log zones and lithology as described above and summarized in Table I.

DEPOSITIONAL ENVIRONMENT

Bioturbation and biota (echinoderms, brachiopods, and bryozoans) in most of the upper part of the Viola in this study suggest deposition on a relatively shallow, open-marine shelf in waters a few meters to a few tens of meters deep. Burrow mottled, bioclast wackestone and packstone within and below the lower porosity zone and within the tight streak reflect deposition below wave base in relatively quiet marine waters. Deposition in shallow, more agitated, marine waters near or above wave base is suggested by planar and cross-stratified grainstone of the lower porosity zone and grainstone/packstone of the main and lower porosity zones. Mudstones of the lower part of the lower porosity zone may record shallow, restricted subtidal deposition.

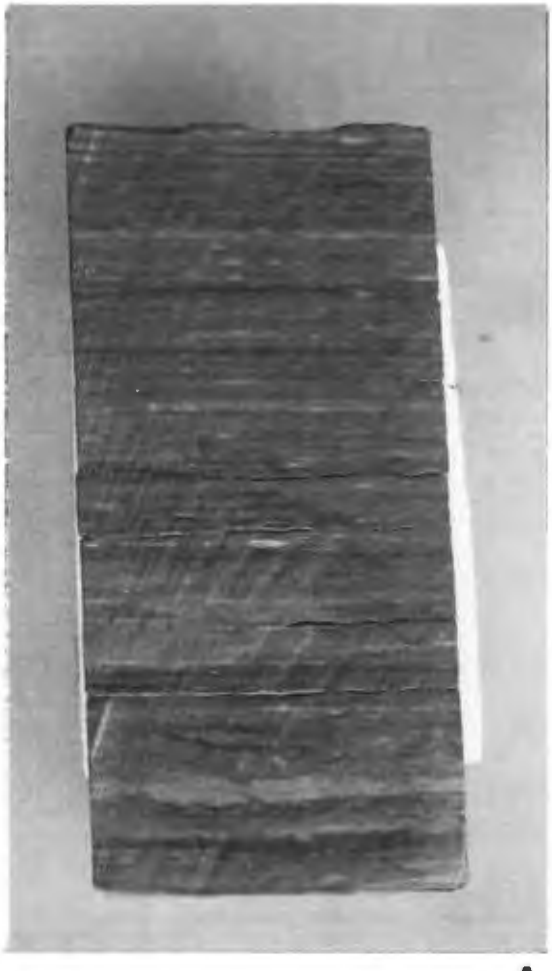
The uppermost Viola in the Wessel "A" #1 records increased detrital influx, the upper 0.5' of the Viola becoming progressively more argillaceous upward toward an abrupt contact with overlying shale and fine sandstone of the Maquoketa Shale (Fig. 6 and

PLATE IV.

A. Parallel laminated fine sandstone and shale of the lower part of the Maquoketa Shale (saw marks visible on slabbed surface) (Wessel "A" #1, 3485.5').

B. Contact (C) of the Viola Limestone (uppermost Viola zone) and overlying Maquoketa Shale, note pyritized skeletal debris just above contact and the disrupted nature of the Viola (Wessel "A" #1, 3486.5').

Slabbed cores are 3" to 3.5" in width.



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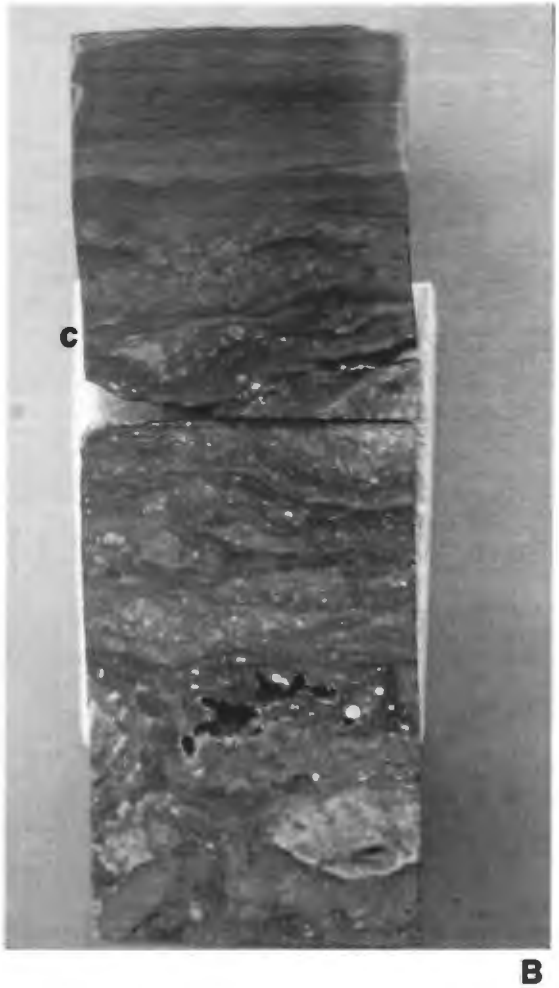


B

PLATE IV

Pl. IV A and B). The upper 0.5' of the Viola has a disrupted appearance which may be due to bioturbation (or alternatively dissolution of carbonate and infill of subsequent cavities by argillaceous material?). Pyritized skeletal debris at the Viola/ Maquoketa contact reflects reducing conditions and perhaps slow deposition. Slightly deeper water shelf deposition is suggested by parallel laminated fine sandstone and shale of the lowermost Maquoketa Shale.

DIAGENESIS

Fine to coarsely crystalline dolomite composes over 95% of the Viola in cores from this study. It replaces both micrite matrix and grains and appears to occur as void-filling cement. For the most part, the dolomite is thought to have formed relatively early in the fresh water-marine phreatic mixing zone (Fig. 7). Depositional textures (e.g., grains and types of porosity) are difficult to distinguish due to pervasive dolomite.

Primary intergranular porosity is important in the main and upper part of the lower porosity zones. It is negligible, however, in the uppermost Viola and in mudstones and wackestone of the tight streak, lower porosity zone, and interval below the lower porosity zone. Intergranular porosity in grainstones and packstones of the porous zones may be partially filled by dolomite.

Secondary biomoldic porosity occurs throughout the upper

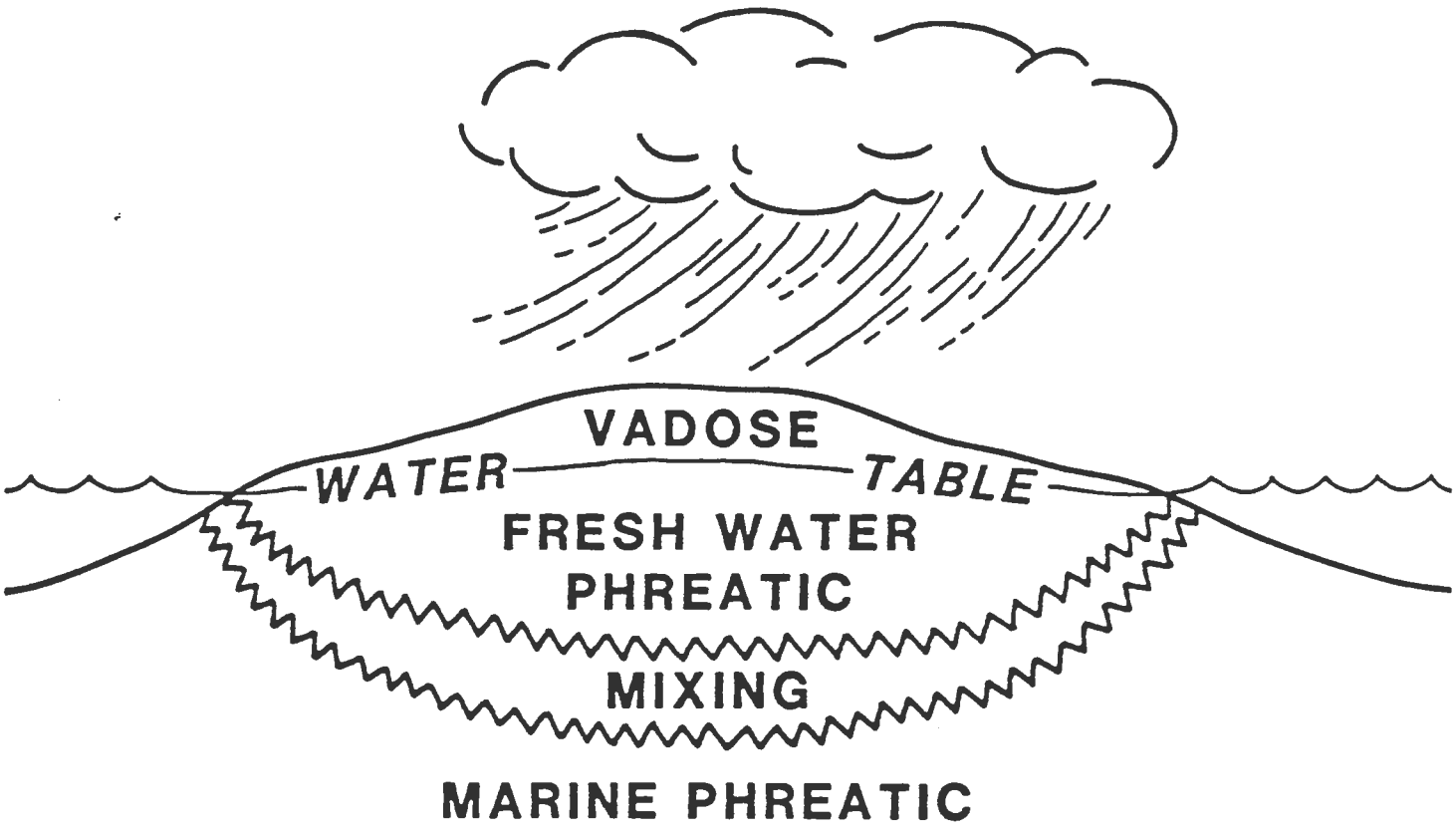


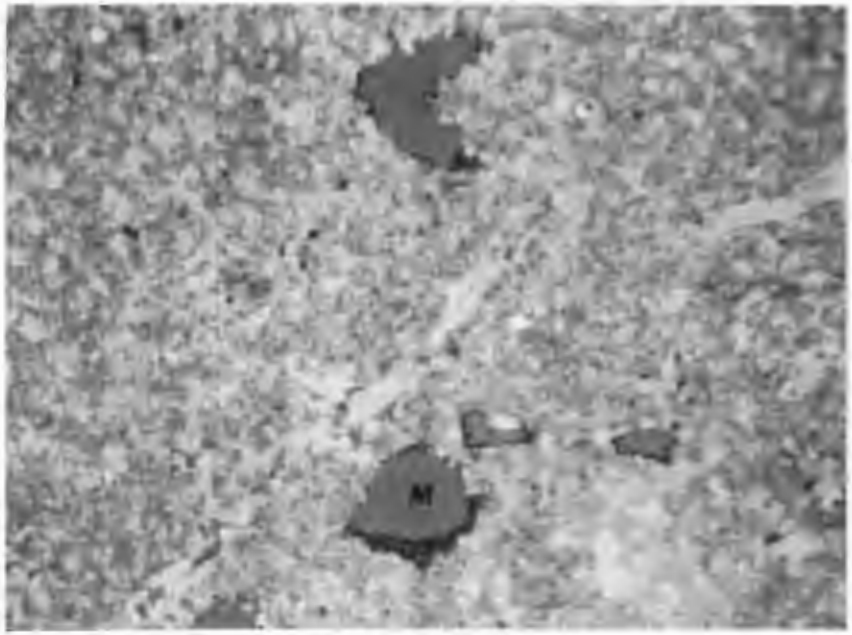
Figure 7. Idealized, shallow-subsurface, carbonate diagenetic environments, not to scale.

PLATE V.

A. and B. Biomoldic (M) and intercrystalline (X) porosity in medium to finely crystalline dolomite (echinoderm-brachiopod wackestone) below the lower porosity zone, note partially leached and silicified brachiopod fragments in photos A and B and echinoderm mold in the upper part of photo A. Blue epoxy fills most of the porosity (A: Potts #1, 3494.1'; B: McClain #1, 3532.2').

C. and D. Biomoldic (M) and intergranular (I) porosity in medium to coarsely crystalline dolomite (echinoderm (E) grainstone) of the main porosity zone (photo C) and tight streak (photo D), blue epoxy fills most of the porosity (C: McClain #1, 3501.8; D: Potts #1, 3461.4').

Long dimension of field of view in photomicrographs is approximately 3 mm; magnification is 18.7 x. Photos taken under plane light.



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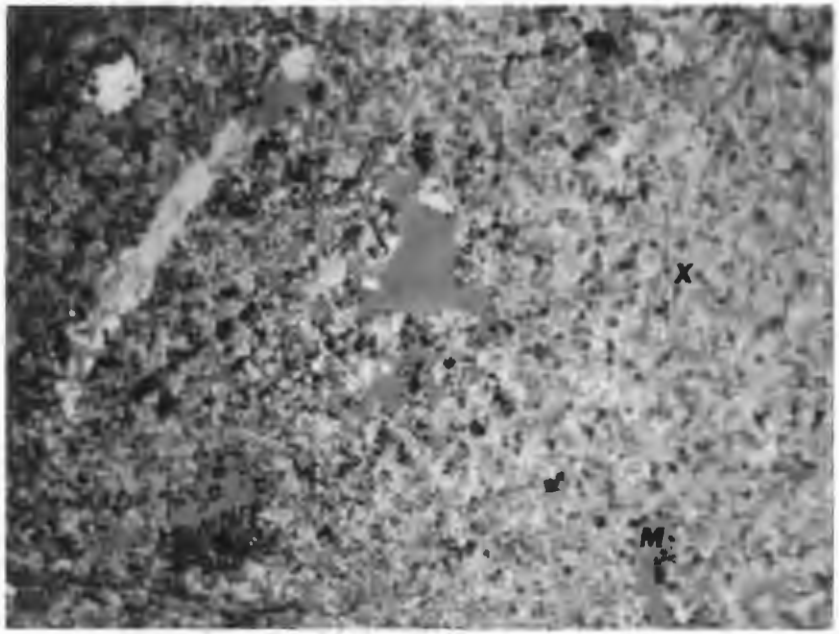

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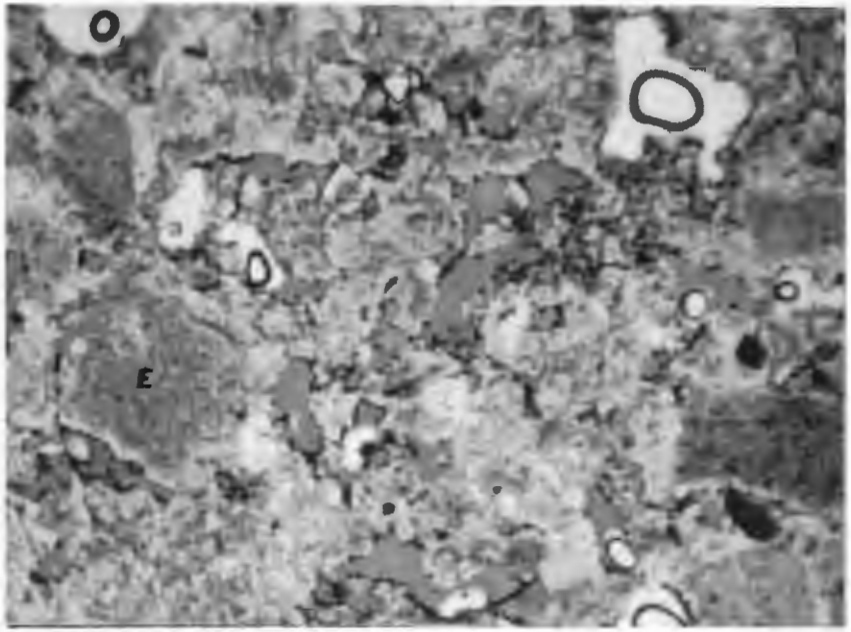

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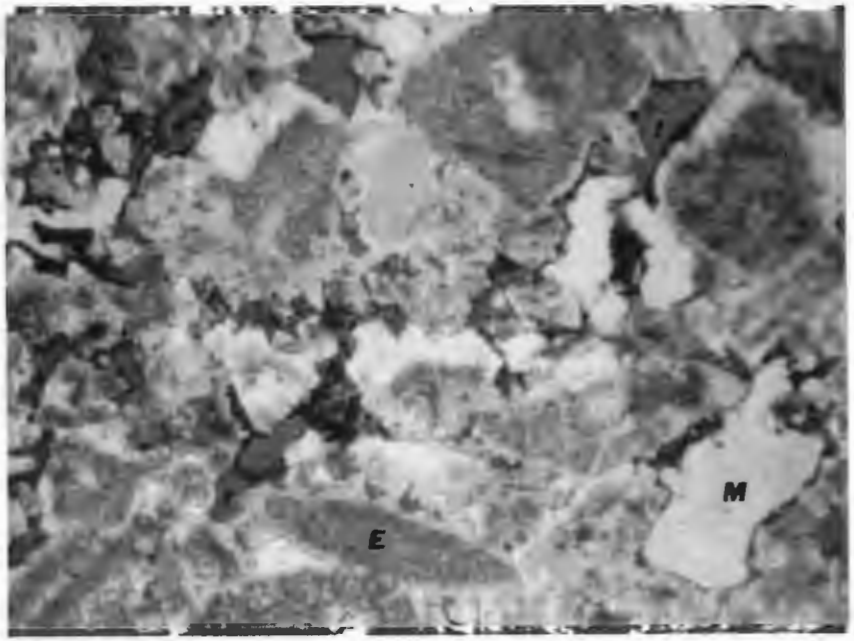


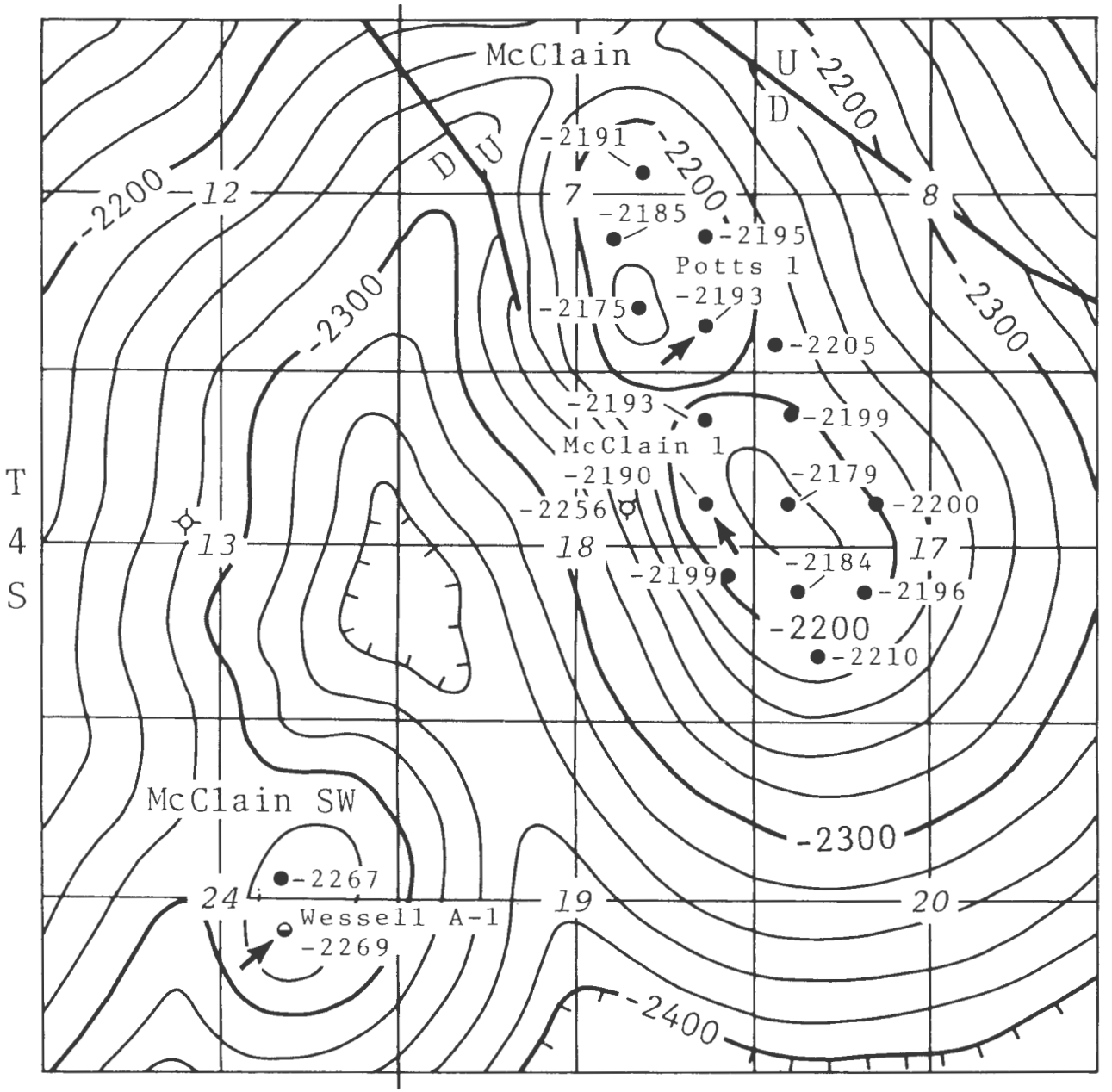
D

PLATE V

PLATE V

part of the Viola in all of the zones recognized by Duvall and Boeken. Intercrystalline, vuggy, and fracture porosity though significantly less important volumetrically (excluding the lower part of the lower porosity zone where intercrystalline porosity may be important), likewise, occur throughout much of the upper part of the Viola. Secondary biomoldic, intercrystalline, and vuggy porosity is thought to have formed after the major phase of dolomite formation and records relatively early, fresh-water dissolution of undolomitized grains (resulting in biomoldic porosity) and micrite matrix (resulting in intercrystalline porosity) in the fresh water phreatic zone. Fractures are vertical, commonly hairline, equally numerous in cores from all three wells, and probably formed during structural deformation of the area. A later stage of dolomite formation may have occurred represented by coarsely crystalline dolomite present in some vugs. Photomicrographs of porosity types are shown in Plate V.

There does not appear to be evidence of a late, post-fracturing "secondary recrystallization" and porosity formation discussed by Duvall and Boeken. The higher porosities in the structurally higher wells, reported by Duvall and Boeken, may be due to greater fresh-water dissolution of carbonate or better primary intergranular porosity on the upper part of an Ordovician paleohigh whose location approximates that of the present structure at McClain field.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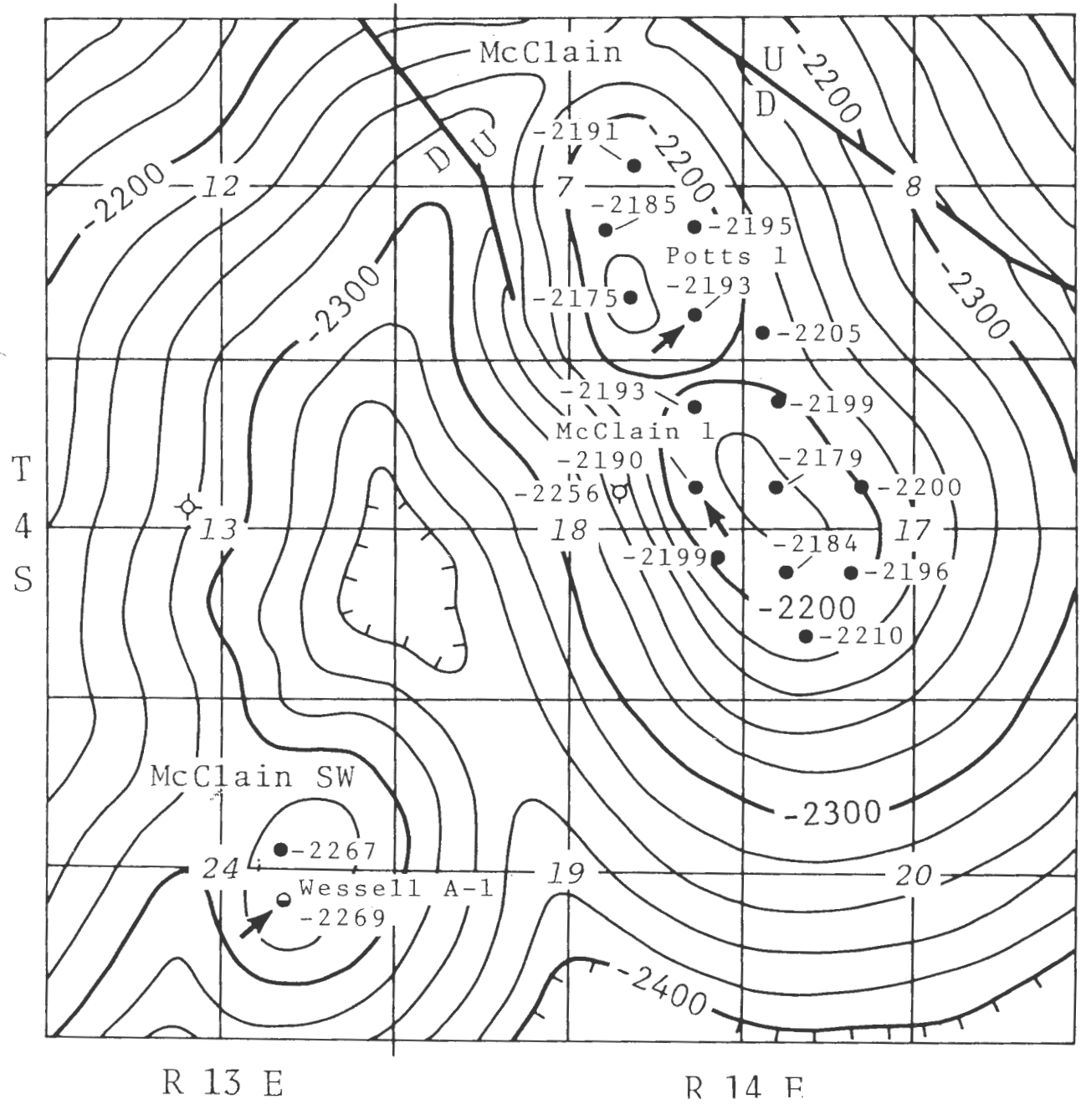
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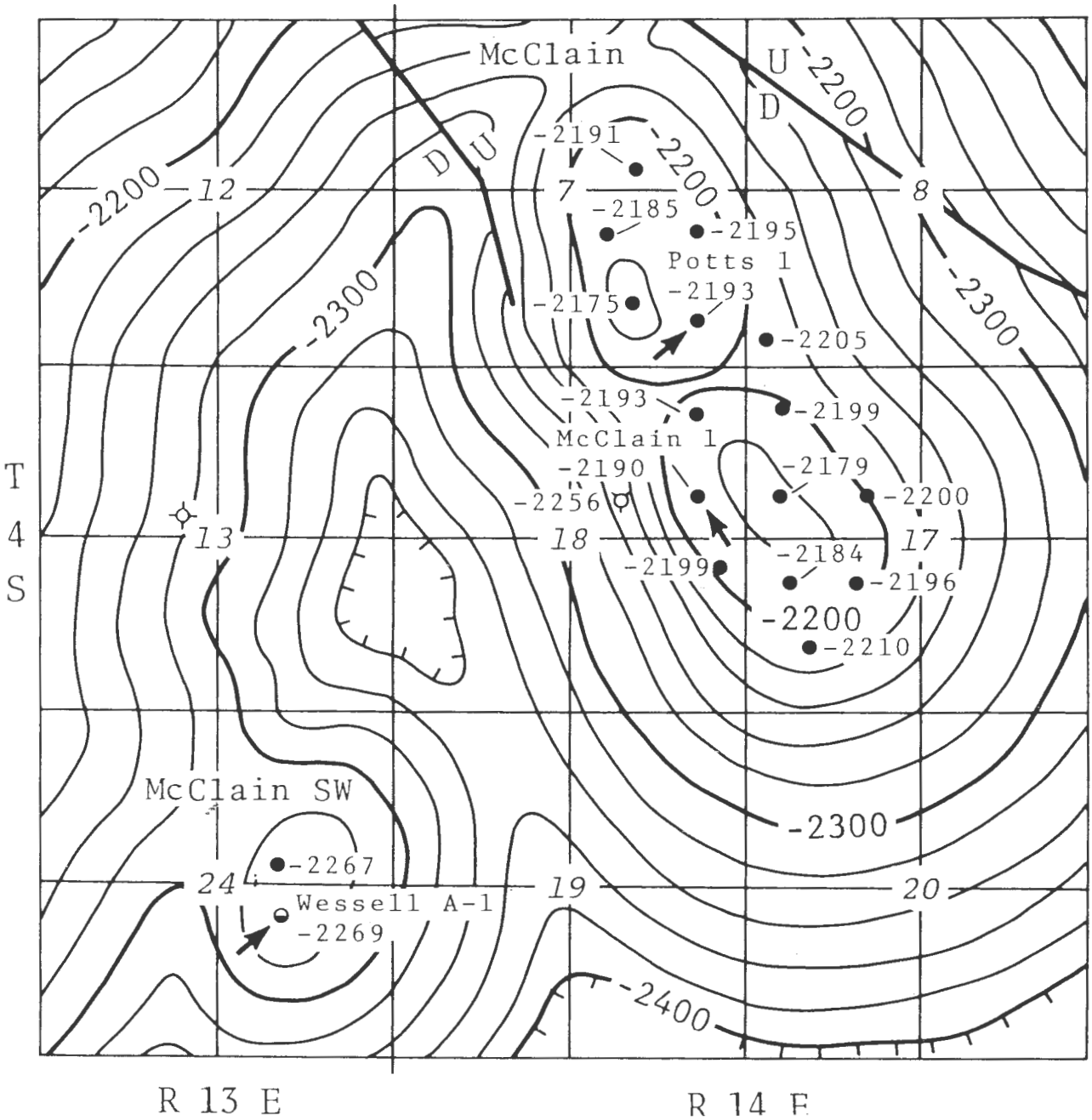
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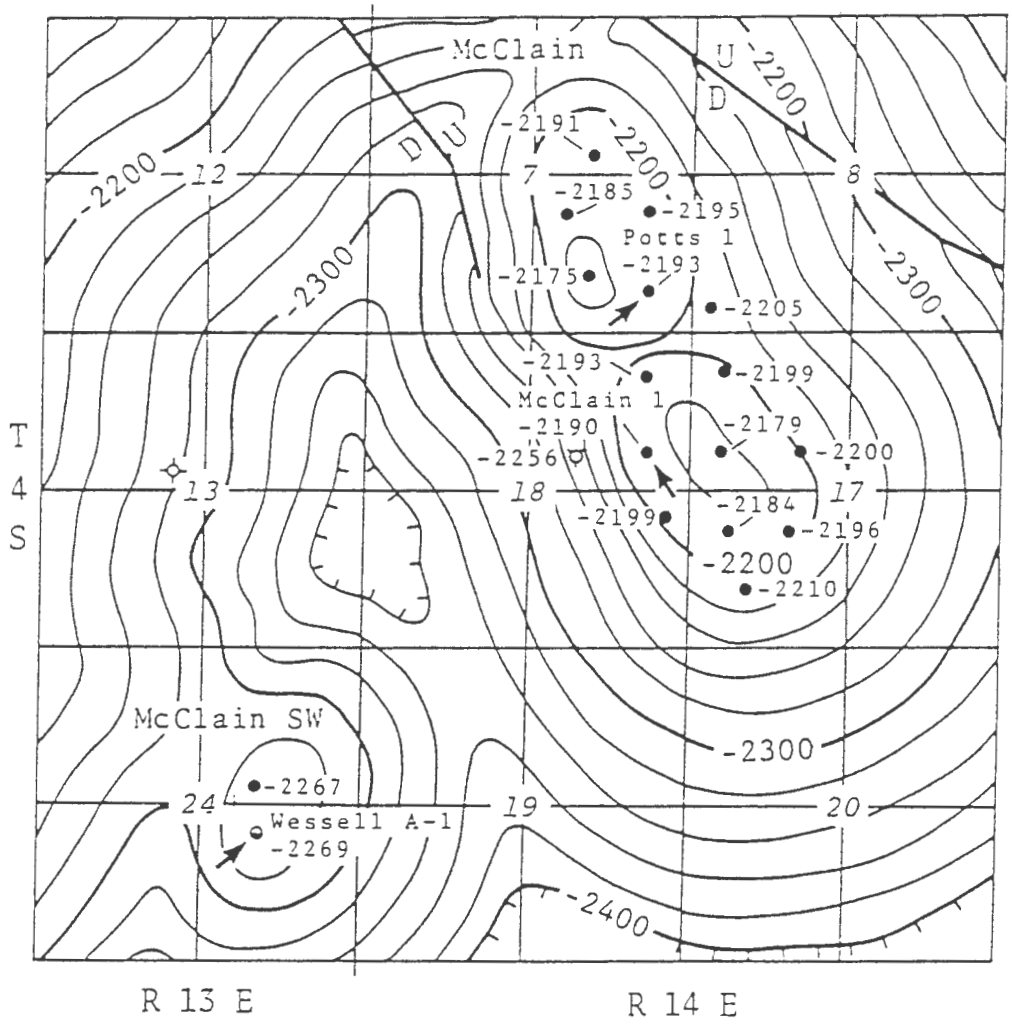
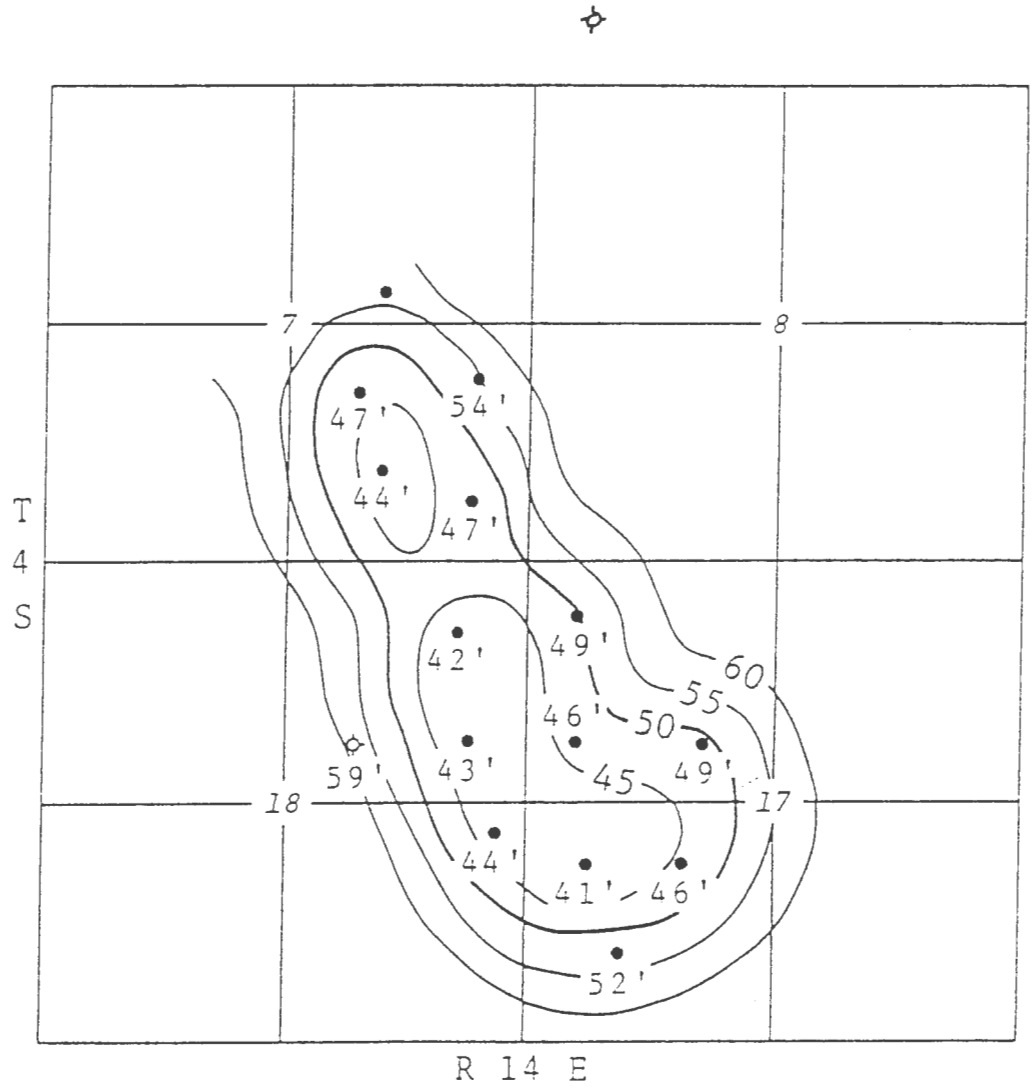


contour interval = 20 feet

FIGURE 2—Viola structure McClain and McClain SW fields, Nemaha County, Kansas. Arrows indicate wells in which the upper part of the Viola Limestone was cored.



contour interval = 5 feet

FIGURE 8—Lower Simpson Sandstone isopach, McClain field, Nemaha County, Kansas.

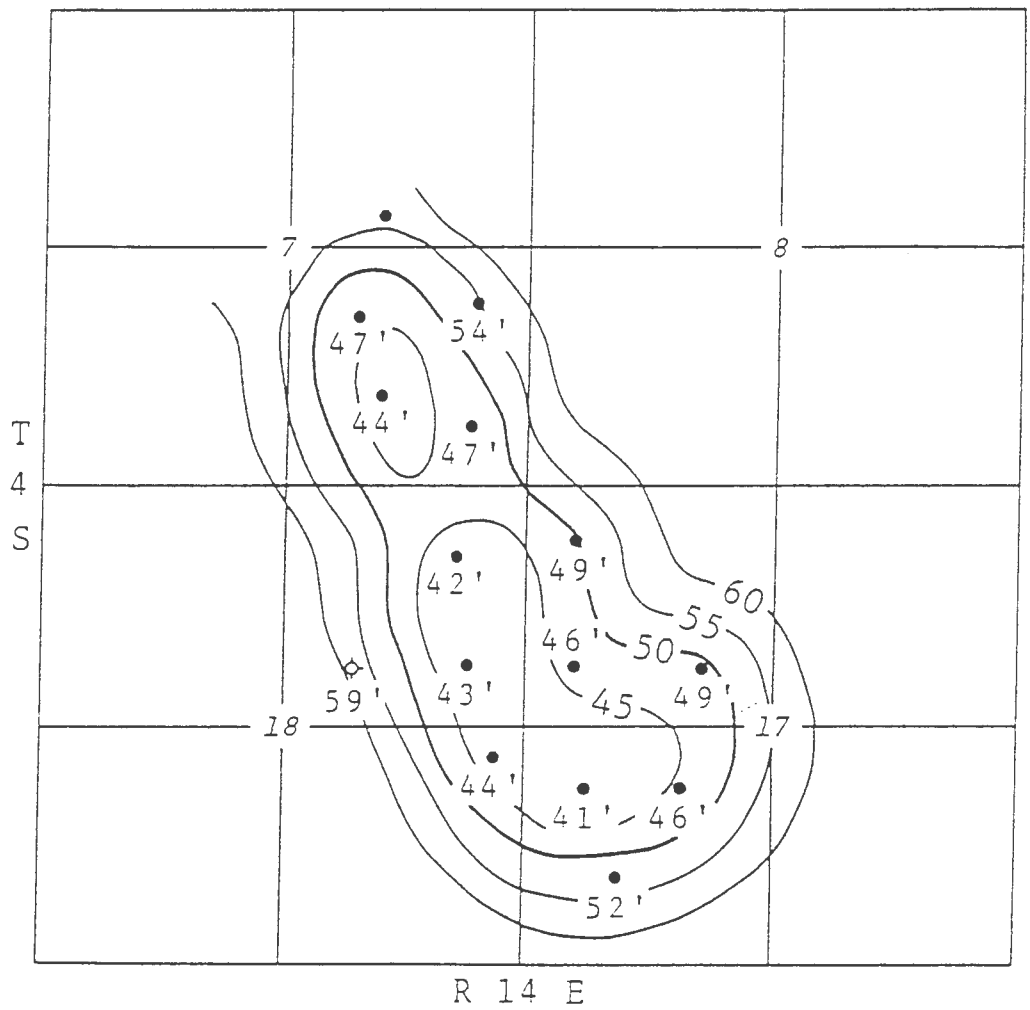
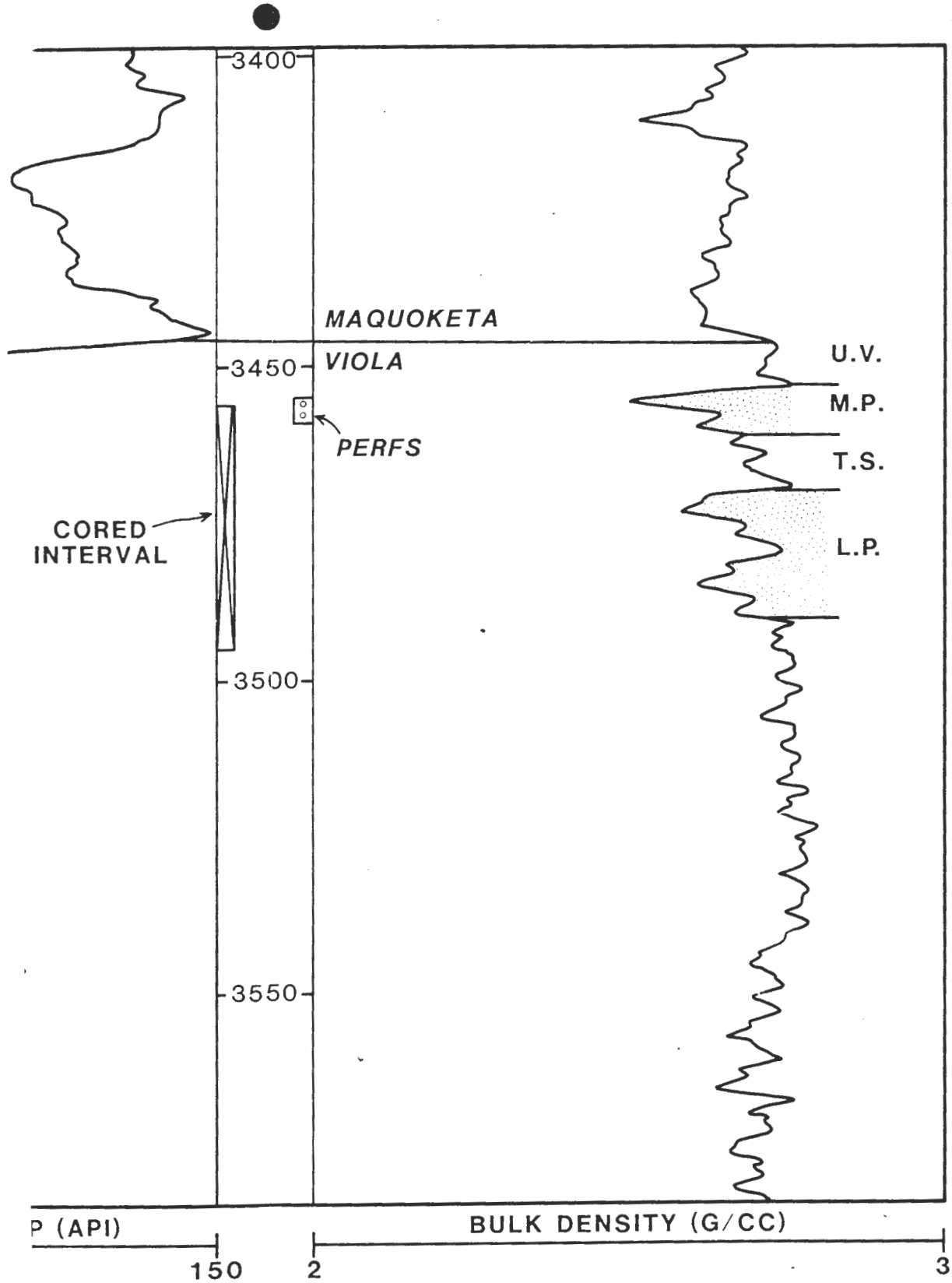


FIGURE 8—Lower Simpson Sandstone isopach, McClain field, Nemaha County, Kansas.

PETRO LEWIS, POTTS #1
C-SE-SE SEC. 7 T4S R14E
NEMAHA CO., KS.



DUVALL
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ID BOEKEN'S
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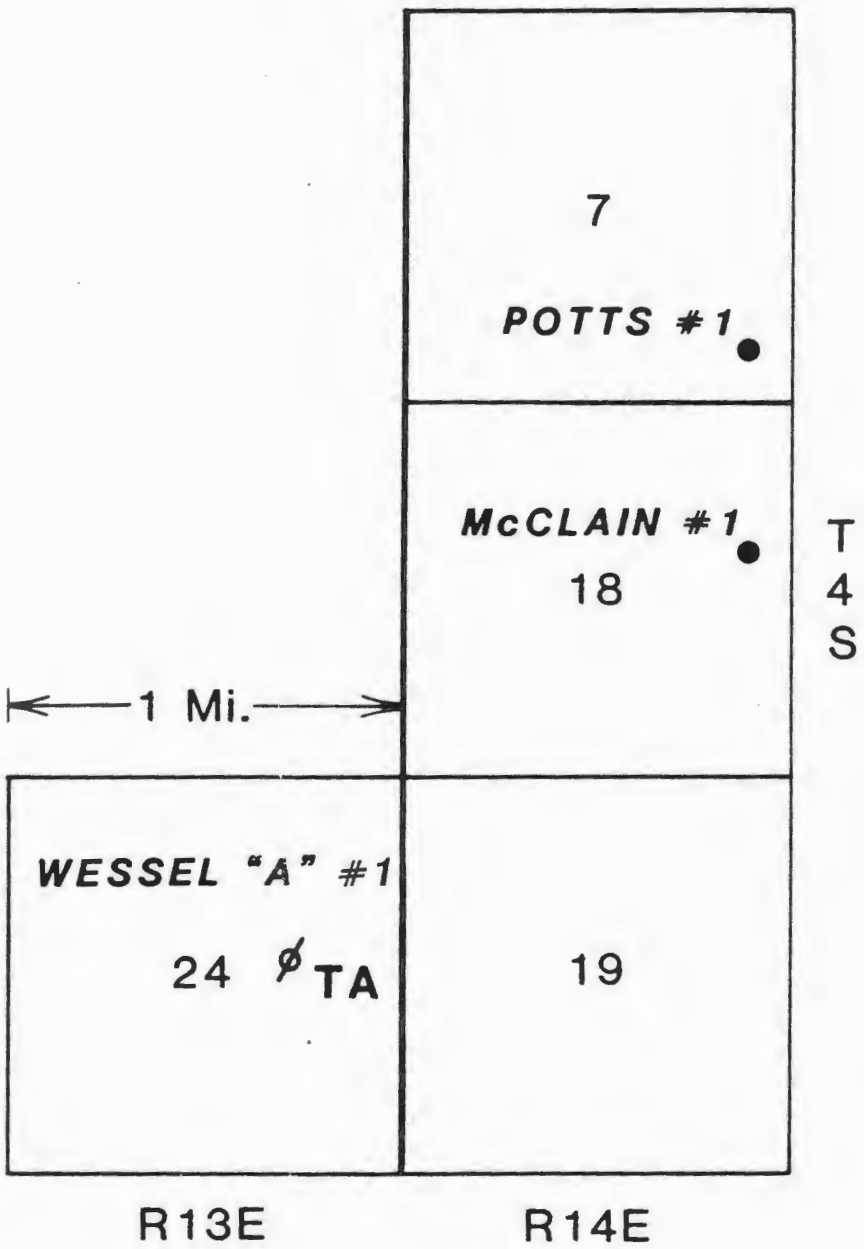

Figure 3. Duvall and Boeken's wireline log zones for the upper part of the Viola in the Wessel "A" #1 (McClain SW field), McClain #1 (McClain field), and Potts #1 (McClain field).

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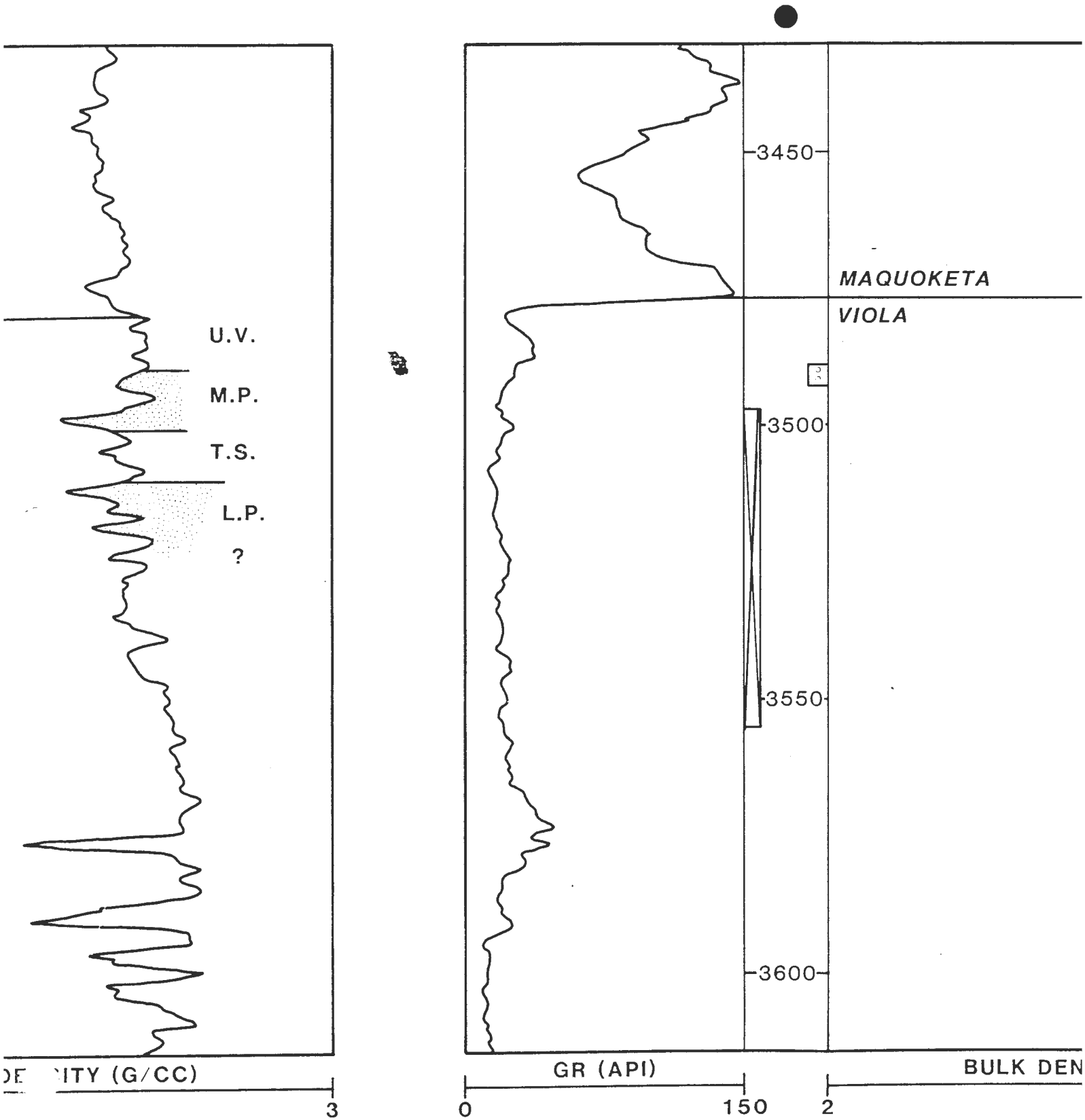
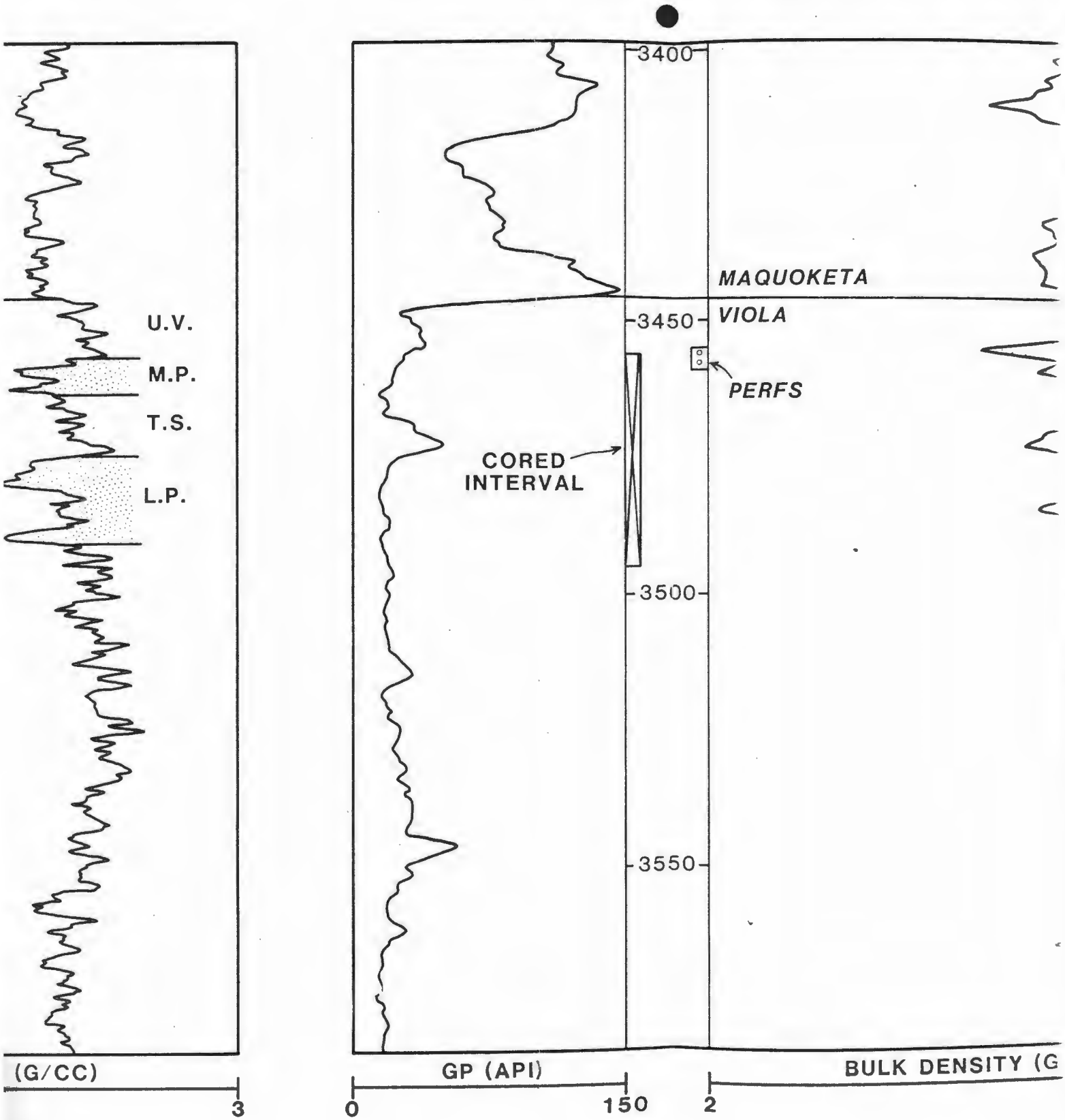
S R13E

PENDLETON LAND AND EXPLORATIC
C-SE-NE SEC. 18 T4S R
NEMAHA CO., KS.

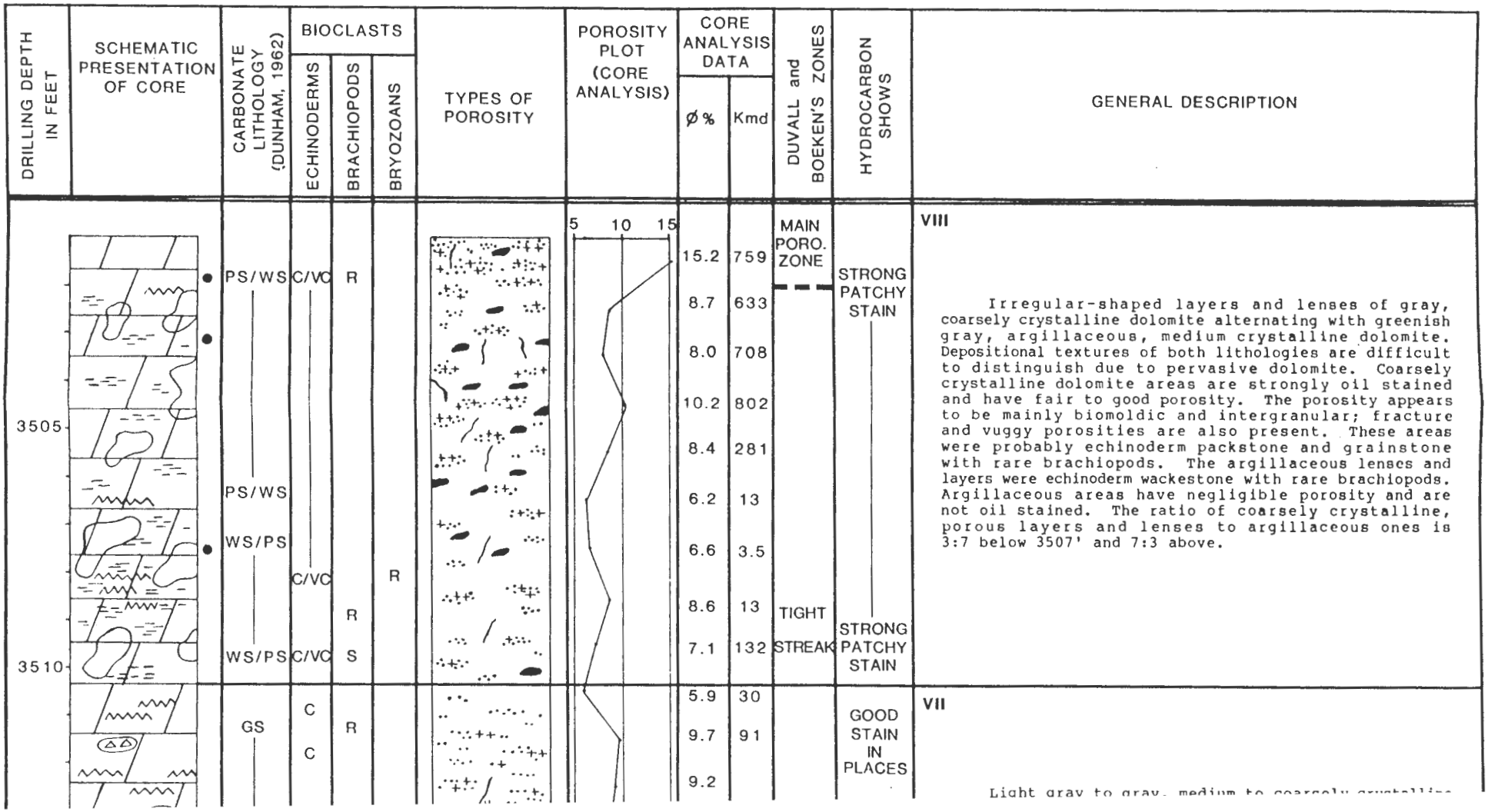


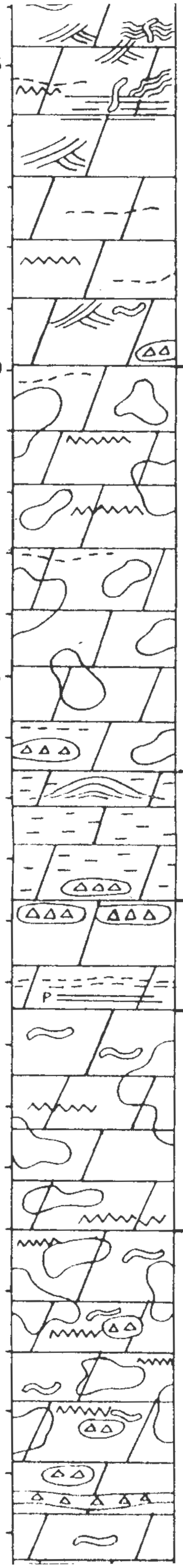
McCLAIN #1

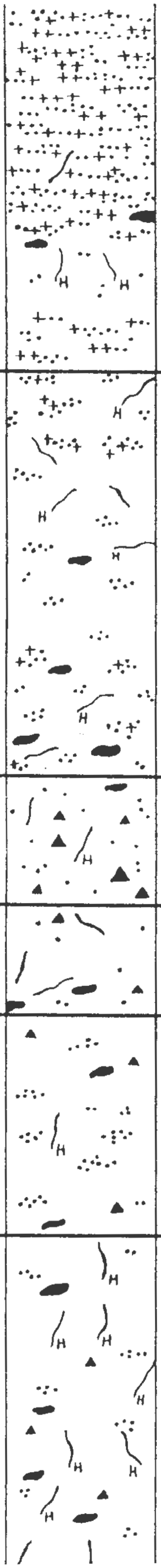
PETRO LEWIS, POTTS #1
C-SE-SE SEC. 7 T4S R14E
NEMAHA CO., KS.

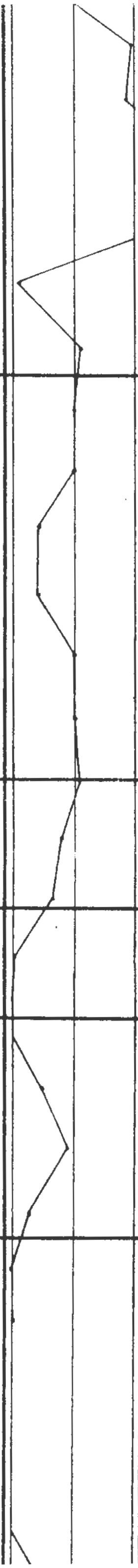


PENDLETON LAND AND EXPLORATION, McCLAIN #1,
McCLAIN FIELD, NEMAHA CO., KANSAS









	●		?			14.6	817		MINOR STAIN IN PLACES
3515			O						
			O			14.2	282	LOWER PORO. ZONE	
			I			20.2	243		
	●		D						
			S			16.9	620		MINOR STAIN IN PLACES
			?			5.5	3.1		
		GS				10.6			
3520		PS/WS	VC			9.9	29		VERY FAINT STAIN
						10.0	88		
	●		C?	R		7.2	2.7		
						7.2	2.7		
			VC?	R		10.0	6.0		
3525						10.0	36		
		PS/WS	C?	R		10.3	12		
		MS				9.0	15		
		MS	R	R		8.2	1.8		
		MS	R	R		5.0	1.6		
3530			R	R		4.8	2.6		
		WS	MC	C					
				MC	R	7.5	2.6		
	●		MC	C	R	9.5	0.6		
		WS		C		6.4	11		
3535		MS	R	R		4.8	6.5		
	●					4.9	5.4		
						3.2	0.4		
		MS	R			4.5	3.4		
						3.7	1.3		
		WS/PS	C						

... largely deformed or undulose and rarely disrupted by vertical burrows. Greenish gray argillaceous material occurs as laminae in the lower part of the unit and is concentrated along stylolites in the upper part. Porosity is fair to good and appears to include intergranular and moldic. Vugs and fractures are rare in the lower part of the unit. In places (e.g., 3517'), molds are circular to slightly elliptical in cross section and may be leached ooids. In addition, ghosts of echinoderms are seen in the upper 2' of the unit. Elsewhere, however, grains can not be distinguished due to pervasive dolomite. The unit was probably a grainstone. Oil staining is patchy and increases upward in the unit.

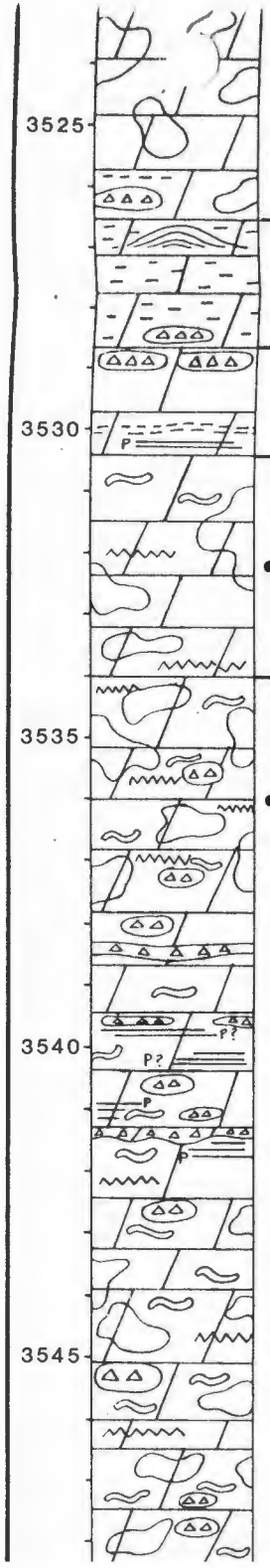
VI Light gray/gray, mottled, medium to coarsely crystalline dolomite locally with greenish gray argillaceous laminae. Light gray areas are coarser crystalline and have higher porosity (in places good); gray areas are medium crystalline generally with negligible porosity, thus resulting in the rock's mottled character. Porosity is poor to fair overall. Due to pervasive dolomite, grains and porosity types are difficult to distinguish. Most porosity is thought to be biomoldic, however, areas are seen in thin section that appear to have biomoldic and intergranular porosity. Fractures are generally hairline and vugs are rare. Echinoderms are rarely visible on the slabbed core surface but, in thin section ghosts of echinoderms are significantly more numerous. The unit appears to have been an echinoderm wackestone/packstone.

V Gray to olive-gray, argillaceous dolomite with greenish gray, wispy, argillaceous laminae. Bioclasts are rare. Intercrystalline and fine moldic porosity may be present but are not readily visible on slabbed core surface. A domal shaped, compactional (?) feature is present in the upper part of the unit.

IV Light gray dolomite with negligible to poor porosity including biomoldic, intercrystalline, vuggy, and fracture. The unit was a lime mudstone with rare echinoderms and brachiopods. Sponge spicules are common in chert in the upper part of the unit.

III Gray, mottled, medium crystalline dolomite. Mottling is due to bioturbation; horizontal burrows resemble those in underlying units. As below, light-colored areas are coarser crystalline and more porous than darker areas giving the rocks their mottled character. Overall, porosity is poor to locally fair and predominantly biomoldic. There is minor intercrystalline porosity. The unit was a bioclast wackestone. Brachiopods (some silicified) and echinoderms are moderately common. Bryozoans are rare.

II Gray, mottled, medium crystalline dolomite. Mottling is due to bioturbation; horizontal burrows



		VC?	R			7.2	2.7	
						10.0	6.0	
	PS/WS	C?	R			10.0	36	
						10.3	12	
	MS					9.0	15	
	MS	R	R			8.2	1.8	
		R	R			5.0	1.6	
	MS	R	R			4.8	2.6	
		MC	C					
	WS		MC	R		7.5	2.6	
•		MC	C	R		9.5	0.6	
			C					
	WS					6.4	11	
	MS	R	R			4.8	6.5	
						4.9	5.4	
•						3.2	0.4	
	MS	R				4.5	3.4	
						3.7	1.3	
	WS/PS	C				7.0	26	
	MS	R	R			5.4	0.7	
	PS/GS		C	C		5.1	3.8	
	MS							
		R	R			5.3	21	
	WS	C	C			7.9	10	
	MS	R	R			5.1	3.0	
		R	R			6.4	17	
	WS/PS		MC			10.5		
	MS	S	S			5.1	4.1	

Dolomite, grains and pore types are difficult to distinguish. Most porosity is thought to be biomoldic, however, areas are seen in thin section that appear to have biomoldic and intergranular porosity. Fractures are generally hairline and vugs are rare. Echinoderms are rarely visible on the slabbed core surface but, in thin section ghosts of echinoderms are significantly more numerous. The unit appears to have been an echinoderm wackestone/packstone.

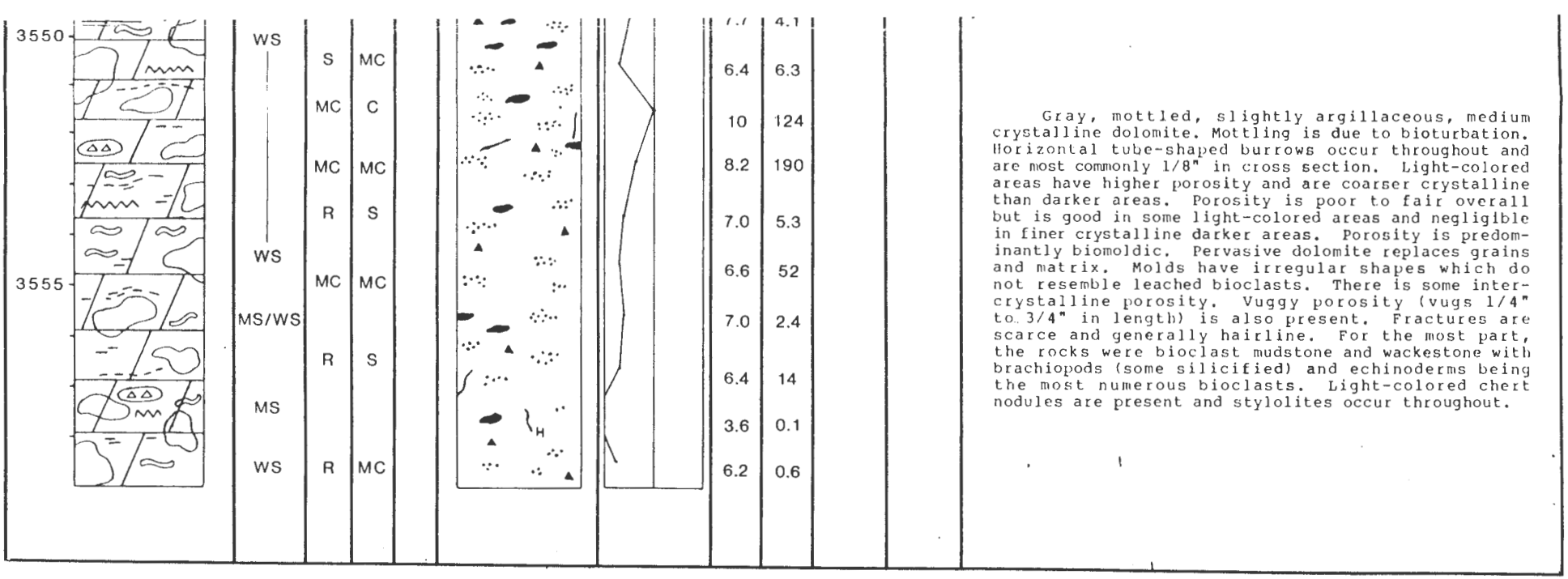
V Gray to olive-gray, argillaceous dolomite with greenish gray, wispy, argillaceous laminae. Bioclasts are rare. Intercrystalline and fine moldic porosity may be present but are not readily visible on slabbed core surface. A domal shaped, compactional (?) feature is present in the upper part of the unit.

IV Light gray dolomite with negligible to poor porosity including biomoldic, intercrystalline, vuggy, and fracture. The unit was a lime mudstone with rare echinoderms and brachiopods. Sponge spicules are common in chert in the upper part of the unit.

III Gray, mottled, medium crystalline dolomite. Mottling is due to bioturbation; horizontal burrows resemble those in underlying units. As below, light-colored areas are coarser crystalline and more porous than darker areas giving the rocks their mottled character. Overall, porosity is poor to locally fair and predominantly biomoldic. There is minor intercrystalline porosity. The unit was a bioclast wackestone. Brachiopods (some silicified) and echinoderms are moderately common. Bryozoans are rare.

II

Gray, mottled, medium crystalline dolomite. Mottling is due to bioturbation; horizontal burrows, resembling those in Unit I., are also present. This unit is similar to Unit I. but overall is finer crystalline, less fossiliferous, and less porous. As in Unit I., light-colored areas are coarser crystalline and more porous than darker areas. Overall, porosity is poor to negligible with the exception of a few thin beds with fair to good porosity. Porosity is thought to be predominantly biomoldic (molds are irregular-shaped) and minor intercrystalline. Fractures, generally hairline, and vugs (1/4" to 3/4" in length) are also present. The unit was a lime mudstone with a few thin bioclast packstone and/or grainstone beds. Echinoderms and brachiopods (some silicified) are the only recognizable bioclasts with the exception of common bryozoans in the grainstone/packstone bed at 3541.5'. Chert nodules are present locally.



• THIN SECTION

KEY

TYPES OF POROSITY

- MOLDIC
- INTERGRANULAR
- INTERCRYSTALLINE
- FRACTURE (H: HAIRLINE)
- VUGGY

SEDIMENTARY STRUCTURES AND LITHOLOGY

- LOW-ANGLE CROSS-STRAT.
- PLANAR (HORIZONTAL LAMINATION)
- STYLOLITES
- MOTTLED
- BURROWS
- UNDULOSE OR DEFORMED LAMINATION
- PARALLEL LAMINATION
- BRECCIA
- CHERT
- RED STAINING

CARBONATE LITHOLOGY

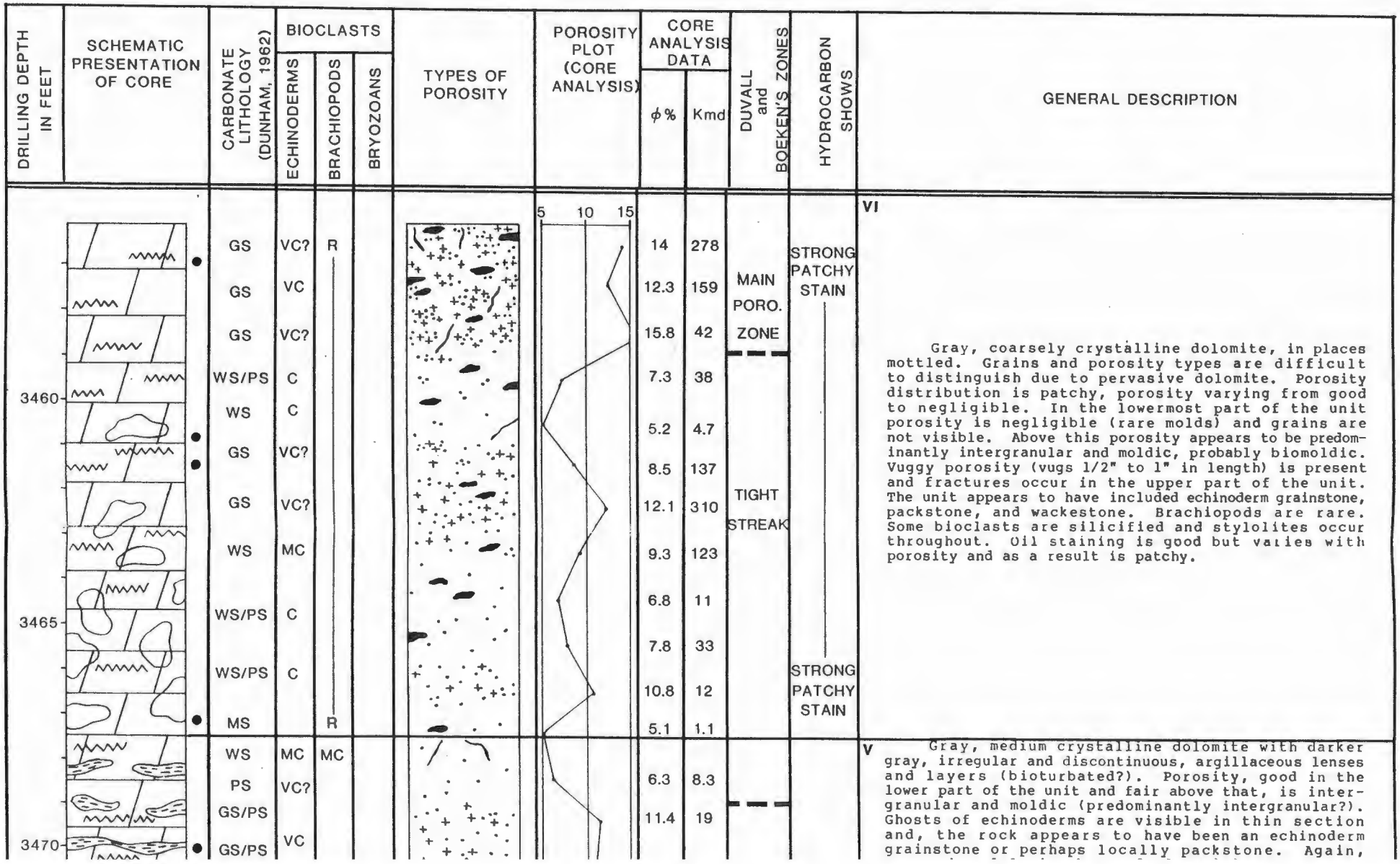
- GS- GRAINSTONE
- PS- PACKSTONE
- WS- WACKESTONE
- MS- MUDSTONE
- (BR)-(BRECCIA)

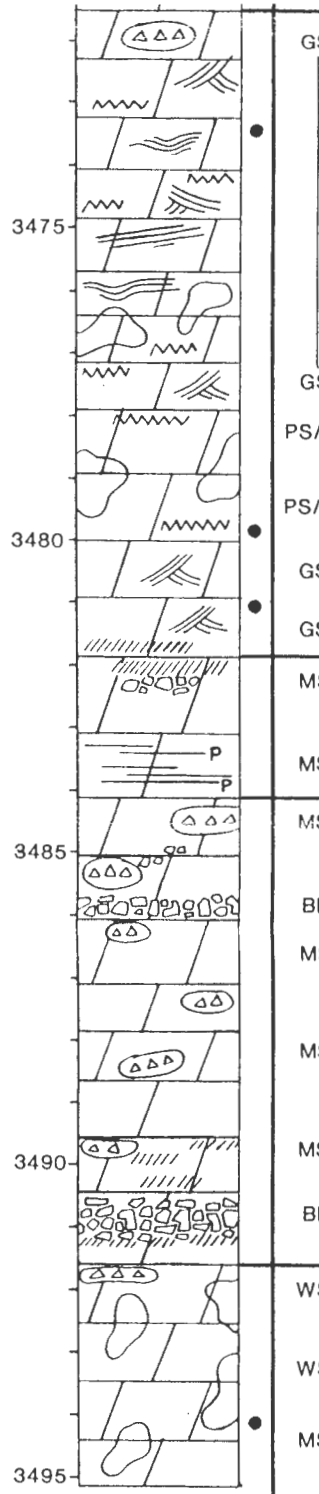
PRESENCE OF BIOCLASTS

- VC- VERY COMMON
- C- COMMON
- MC- MODERATELY COMMON
- S- SCARCE
- R- RARE

Figure 4. Schematic drawing and description of the Pendleton McClain #1, McClain field, Nemaha Co., Kansas.

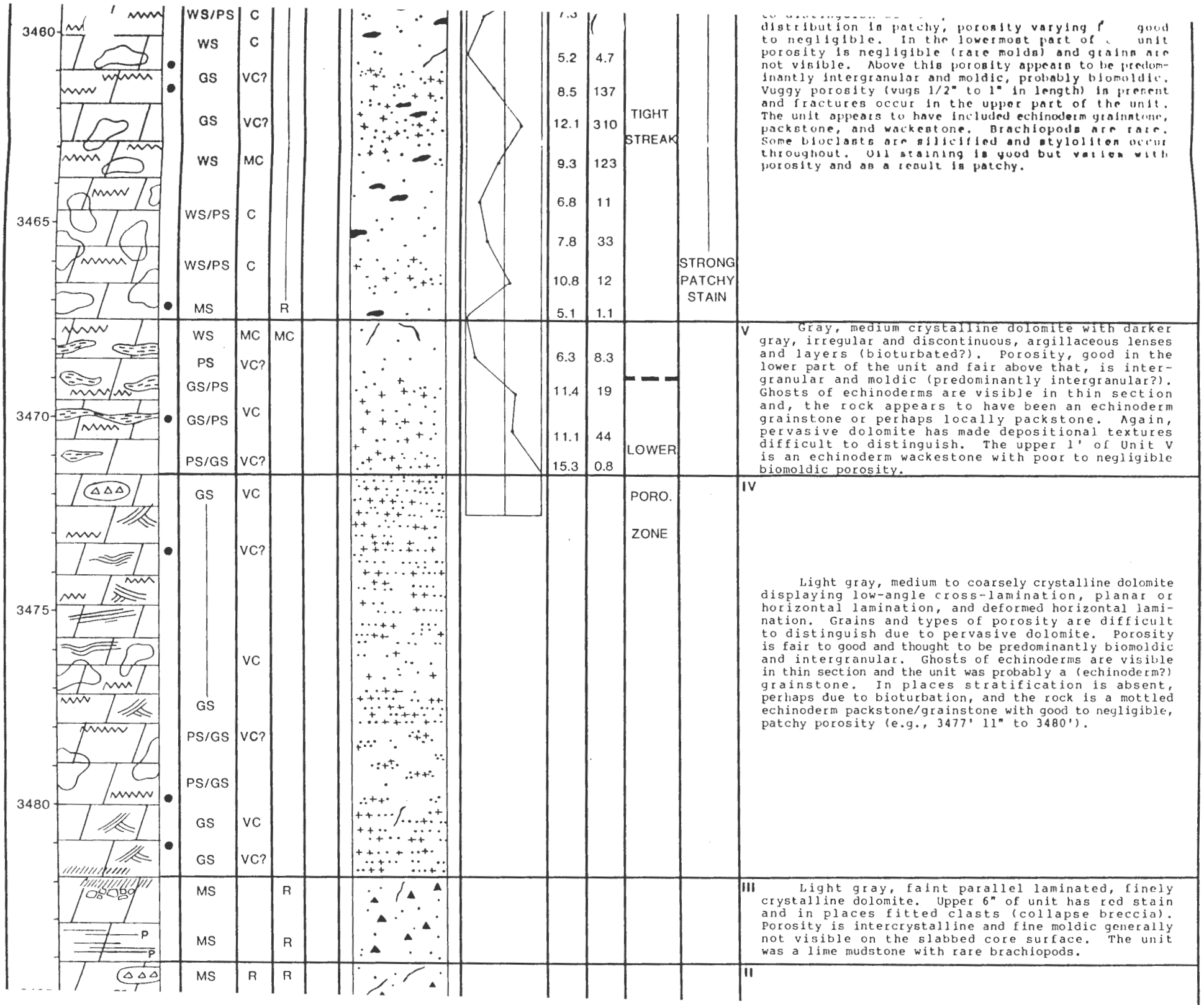
PETRO LEWIS, POTTS #1, McCLAIN FIELD, NEMAHA CO., KANSAS





											biomoldic porosity.
	GS	VC							PORO.	IV	
		VC?							ZONE		Light gray, medium to coarsely crystalline dolomite displaying low-angle cross-lamination, planar or horizontal lamination, and deformed horizontal lamination. Grains and types of porosity are difficult to distinguish due to pervasive dolomite. Porosity is fair to good and thought to be predominantly biomoldic and intergranular. Ghosts of echinoderms are visible in thin section and the unit was probably a (echinoderm?) grainstone. In places stratification is absent, perhaps due to bioturbation, and the rock is a mottled echinoderm packstone/grainstone with good to negligible, patchy porosity (e.g., 3477' 11" to 3480').
		VC									
	GS										
	PS/GS	VC?									
	PS/GS										
	GS	VC									
	GS	VC?									
	MS		R							III	Light gray, faint parallel laminated, finely crystalline dolomite. Upper 6" of unit has red stain and in places fitted clasts (collapse breccia). Porosity is intercrystalline and fine moldic generally not visible on the slabbed core surface. The unit was a lime mudstone with rare brachiopods.
	MS		R								
	MS	R	R							II	
	BR										Light gray, finely crystalline dolomite with large, white to light gray, chert nodules. Porosity appears poor to negligible on slabbed core surface, however, log porosity is fair to good suggesting significant intercrystalline and very fine moldic porosity are present. Fractures are common in the lower part of the unit. The unit was a lime mudstone. Red staining is present in the lower part of the unit. Echinoderms and small shell fragments, probably brachiopods, are rare. There are two collapse breccias with angular, unsorted, dolomite mudstone clasts, up to 2" in length, in a coarser crystalline dolomite matrix. In places clasts display a fitted fabric.
	MS		R								
	MS	R									
	BR										
	WS	R	MC							I	Mottled, medium crystalline dolomite. Mottling is probably due to bioturbation. Porosity is poor overall but, its distribution is patchy. Tan areas have fair to good porosity and gray finer crystalline areas poor to negligible porosity. For the most part, porosity is biomoldic. Molds are irregular-shaped, however, and no easily identified as leached bioclasts. Vuggy porosity is present locally and, there is minor fracture and intercrystalline porosity. Grains are generally indistinguishable due to dolomitization and leaching but, the unit was probably a bioclast mudstone and wackestone.
			MC								
	WS		S	R							
	MS		MC	R							

● THIN SECTION



distribution is patchy, porosity varying f good to negligible. In the lowermost part of unit porosity is negligible (rare molds) and grains are not visible. Above this porosity appears to be predominantly intergranular and moldic, probably biomoldic. Vuggy porosity (vugs 1/2" to 1" in length) is present and fractures occur in the upper part of the unit. The unit appears to have included echinoderm grainstone, packstone, and wackestone. Brachiopods are rare. Some bioclasts are silicified and stylolites occur throughout. Oil staining is good but varies with porosity and as a result is patchy.

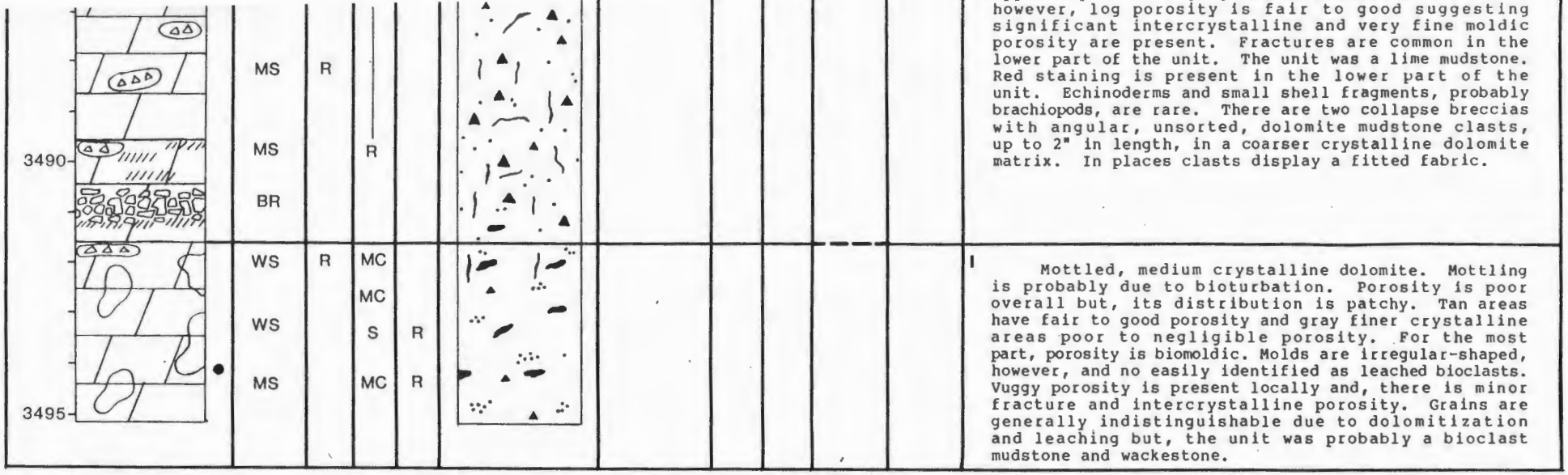
V Gray, medium crystalline dolomite with darker gray, irregular and discontinuous, argillaceous lenses and layers (bioturbated?). Porosity, good in the lower part of the unit and fair above that, is intergranular and moldic (predominantly intergranular?). Ghosts of echinoderms are visible in thin section and, the rock appears to have been an echinoderm grainstone or perhaps locally packstone. Again, pervasive dolomite has made depositional textures difficult to distinguish. The upper 1' of Unit V is an echinoderm wackestone with poor to negligible biomoldic porosity.

IV

Light gray, medium to coarsely crystalline dolomite displaying low-angle cross-lamination, planar or horizontal lamination, and deformed horizontal lamination. Grains and types of porosity are difficult to distinguish due to pervasive dolomite. Porosity is fair to good and thought to be predominantly biomoldic and intergranular. Ghosts of echinoderms are visible in thin section and the unit was probably a (echinoderm?) grainstone. In places stratification is absent, perhaps due to bioturbation, and the rock is a mottled echinoderm packstone/grainstone with good to negligible, patchy porosity (e.g., 3477' 11" to 3480').

III Light gray, faint parallel laminated, finely crystalline dolomite. Upper 6" of unit has red stain and in places fitted clasts (collapse breccia). Porosity is intercrystalline and fine moldic generally not visible on the slabbed core surface. The unit was a lime mudstone with rare brachiopods.

II



appears poor to negligible on slabbed core surface, however, log porosity is fair to good suggesting significant intercrystalline and very fine moldic porosity are present. Fractures are common in the lower part of the unit. The unit was a lime mudstone. Red staining is present in the lower part of the unit. Echinoderms and small shell fragments, probably brachiopods, are rare. There are two collapse breccias with angular, unsorted, dolomite mudstone clasts, up to 2" in length, in a coarser crystalline dolomite matrix. In places clasts display a fitted fabric.

Mottled, medium crystalline dolomite. Mottling is probably due to bioturbation. Porosity is poor overall but, its distribution is patchy. Tan areas have fair to good porosity and gray finer crystalline areas poor to negligible porosity. For the most part, porosity is biomoldic. Molds are irregular-shaped, however, and no easily identified as leached bioclasts. Vuggy porosity is present locally and, there is minor fracture and intercrystalline porosity. Grains are generally indistinguishable due to dolomitization and leaching but, the unit was probably a bioclast mudstone and wackestone.

• THIN SECTION

KEY

TYPES OF POROSITY

- MOLDIC
- INTERGRANULAR
- INTERCRYSTALLINE
- $\int\int_H$ FRACTURE (H: HAIRLINE)
- VUGGY

SEDIMENTARY STRUCTURES AND LITHOLOGY

- LOW-ANGLE CROSS-STRAT.
- PLANAR (HORIZONTAL LAMINATION)
- STYLOLITES
- MOTTLED
- BURROWS
- UNDULOSE OR DEFORMED LAMINATION
- PARALLEL LAMINATION
- BRECCIA
- CHERT
- RED STAINING

CARBONATE LITHOLOGY

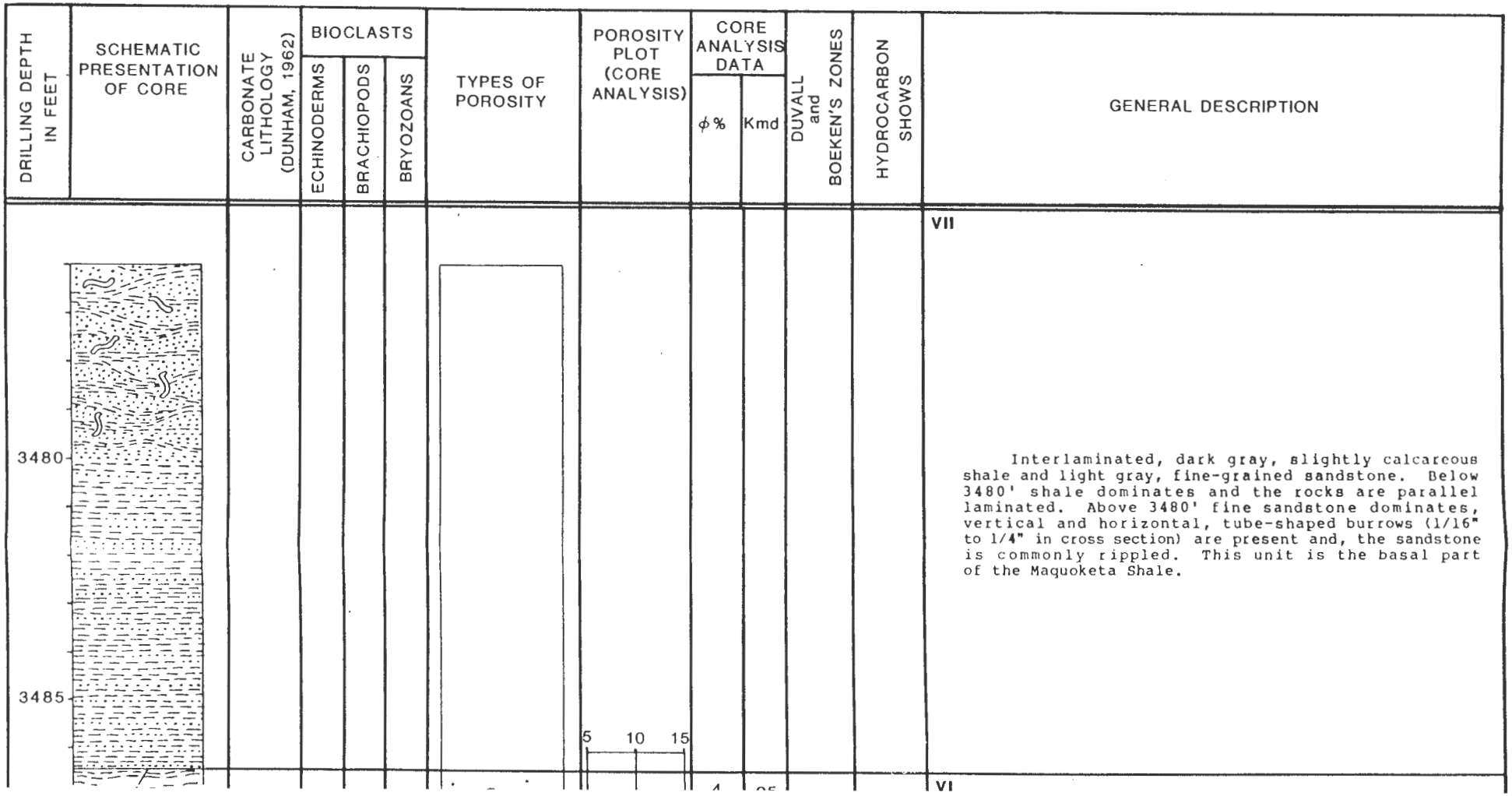
- GS- GRAINSTONE
- PS- PACKSTONE
- WS- WACKESTONE
- MS- MUDSTONE
- (BR)-(BRECCIA)

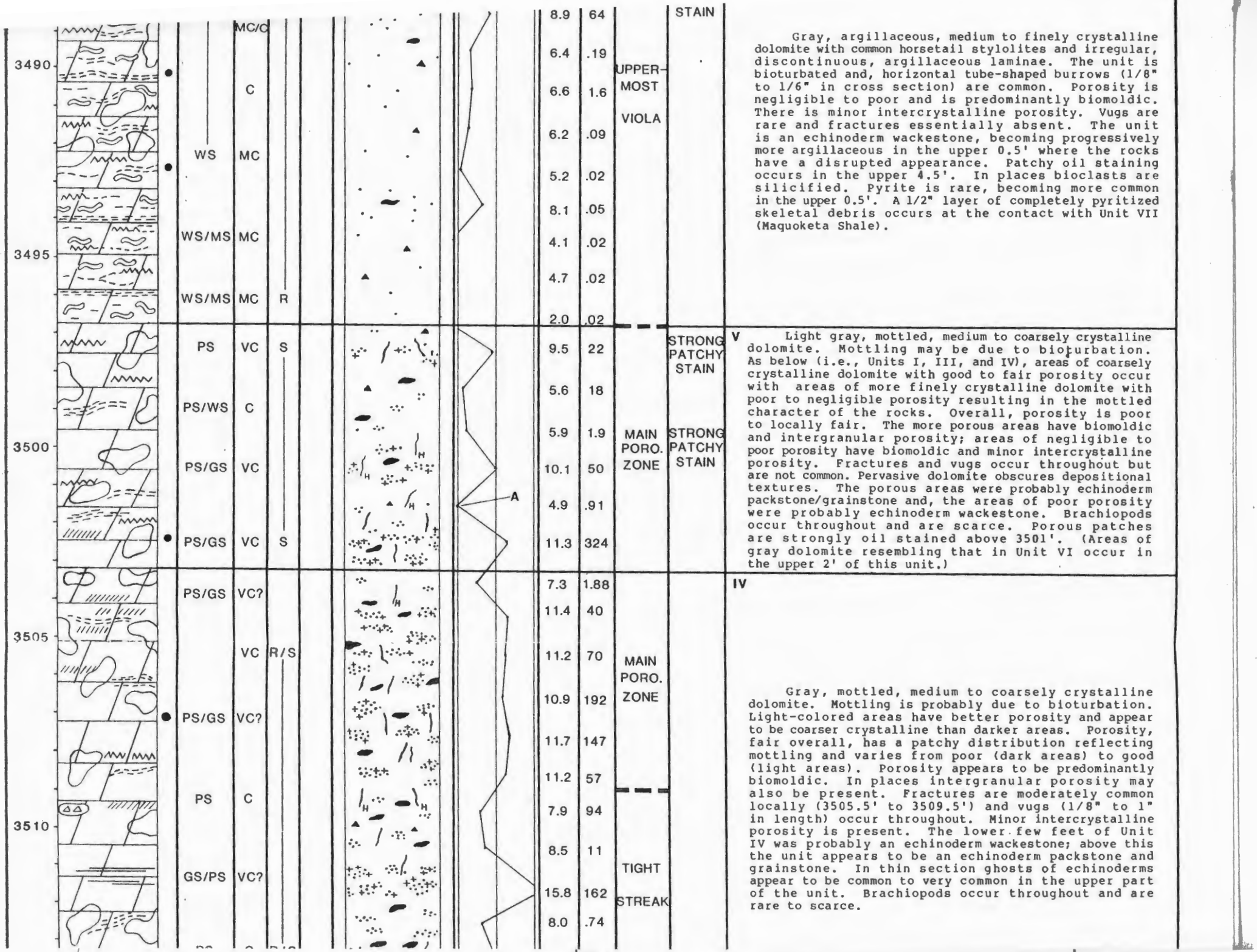
PRESENCE OF BIOCLASTS

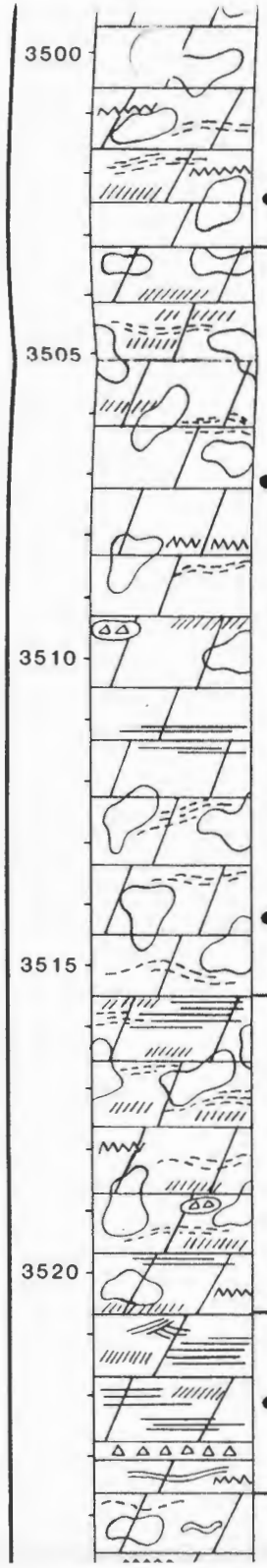
- VC- VERY COMMON
- C- COMMON
- MC- MODERATELY COMMON
- S- SCARCE
- R- RARE

Figure 5. Schematic drawing and description of the Petro Lewis Potts #1, McClain field, Nemaha Co., Kansas.

CITIES SERVICE, WESSEL "A" #1,
McCLAIN SW FIELD, NEMAHA CO., KANSAS




3490
3495
3500
3505
3510
MC/C
C
WS
MC
WS/MS
MC
WS/MS
MC
R
PS
VC
S
PS/WS
C
PS/GS
VC
PS/GS
VC
S
PS/GS
VC?
VC
R/S
PS/GS
VC?
PS
C
GS/PS
VC?
A
8.9 64
6.4 .19
6.6 1.6
6.2 .09
5.2 .02
8.1 .05
4.1 .02
4.7 .02
2.0 .02
9.5 22
5.6 18
5.9 1.9
10.1 50
4.9 .91
11.3 324
7.3 1.88
11.4 40
11.2 70
10.9 192
11.7 147
11.2 57
7.9 94
8.5 11
15.8 162
8.0 .74
UPPER-MOST VIOLA
MAIN PORO. ZONE
MAIN PORO. ZONE
TIGHT STREAK
STAIN
STRONG PATCHY STAIN
STRONG PATCHY STAIN
V
Light gray, mottled, medium to coarsely crystalline dolomite. Mottling may be due to bioturbation. As below (i.e., Units I, III, and IV), areas of coarsely crystalline dolomite with good to fair porosity occur with areas of more finely crystalline dolomite with poor to negligible porosity resulting in the mottled character of the rocks. Overall, porosity is poor to locally fair. The more porous areas have biomoldic and intergranular porosity; areas of negligible to poor porosity have biomoldic and minor intercrystalline porosity. Fractures and vugs occur throughout but are not common. Pervasive dolomite obscures depositional textures. The porous areas were probably echinoderm packstone/grainstone and, the areas of poor porosity were probably echinoderm wackestone. Brachiopods occur throughout and are scarce. Porous patches are strongly oil stained above 3501'. (Areas of gray dolomite resembling that in Unit VI occur in the upper 2' of this unit.)
IV
Gray, mottled, medium to coarsely crystalline dolomite. Mottling is probably due to bioturbation. Light-colored areas have better porosity and appear to be coarser crystalline than darker areas. Porosity, fair overall, has a patchy distribution reflecting mottling and varies from poor (dark areas) to good (light areas). Porosity appears to be predominantly biomoldic. In places intergranular porosity may also be present. Fractures are moderately common locally (3505.5' to 3509.5') and vugs (1/8" to 1" in length) occur throughout. Minor intercrystalline porosity is present. The lower few feet of Unit IV was probably an echinoderm wackestone; above this the unit appears to be an echinoderm packstone and grainstone. In thin section ghosts of echinoderms appear to be common to very common in the upper part of the unit. Brachiopods occur throughout and are rare to scarce.
Gray, argillaceous, medium to finely crystalline dolomite with common horsetail stylolites and irregular, discontinuous, argillaceous laminae. The unit is bioturbated and, horizontal tube-shaped burrows (1/8" to 1/6" in cross section) are common. Porosity is negligible to poor and is predominantly biomoldic. There is minor intercrystalline porosity. Vugs are rare and fractures essentially absent. The unit is an echinoderm wackestone, becoming progressively more argillaceous in the upper 0.5' where the rocks have a disrupted appearance. Patchy oil staining occurs in the upper 4.5'. In places bioclasts are silicified. Pyrite is rare, becoming more common in the upper 0.5'. A 1/2" layer of completely pyritized skeletal debris occurs at the contact with Unit VII (Maquoketa Shale).



	PS/GS	VC			5.9		MAIN PORO. ZONE	STRONG PATCHY STAIN
					10.1	50		
				A	4.9	.91		
	PS/GS	VC	S		11.3	324		
	PS/GS	VC?			7.3	1.88		
					11.4	40		
		VC	R/S		11.2	70		
	PS/GS	VC?			10.9	192		
					11.7	147		
	PS	C			11.2	57		
					7.9	94		
					8.5	11		
	GS/PS	VC?			15.8	162	TIGHT STREAK	
					8.0	.74		
	PS	C	R/S		9.9	23		
					5.2	1.1		
	WS	MC/C	S		4.4	.66		
	PS/GS	VC?	R					
					17.1	141	LOWER PORO. ZONE	
			MC		13.3	121		
			R/S		12.0	143		
					14.5	54		
	PS/GS	VC?	R/S		8.9	16		
	GS/PS	VC?	R		8.6	12		
	GS/PS	VC?	R		8.3	2007		
					8.6	1599		
	MS	S	R		6.3	20		

to locally fair. The more porous areas have biomoldic and intergranular porosity; areas of negli[illegible]le to poor porosity have biomoldic and minor interc[illegible]lline porosity. Fractures and vugs occur throug[illegible]t but are not common. Pervasive dolomite obscures depositional textures. The porous areas were probably echinoderm packstone/grainstone and, the areas of poor porosity were probably echinoderm wackestone. Brachiopods occur throughout and are scarce. Porous patches are strongly oil stained above 3501'. (Areas of gray dolomite resembling that in Unit VI occur in the upper 2' of this unit.)

IV

Gray, mottled, medium to coarsely crystalline dolomite. Mottling is probably due to bioturbation. Light-colored areas have better porosity and appear to be coarser crystalline than darker areas. Porosity, fair overall, has a patchy distribution reflecting mottling and varies from poor (dark areas) to good (light areas). Porosity appears to be predominantly biomoldic. In places intergranular porosity may also be present. Fractures are moderately common locally (3505.5' to 3509.5') and vugs (1/8" to 1" in length) occur throughout. Minor intercrystalline porosity is present. The lower few feet of Unit IV was probably an echinoderm wackestone; above this the unit appears to be an echinoderm packstone and grainstone. In thin section ghosts of echinoderms appear to be common to very common in the upper part of the unit. Brachiopods occur throughout and are rare to scarce.

III

Light gray, mottled, medium crystalline, argillaceous dolomite. Mottling is probably due to bioturbation. Porosity has a patchy distribution but is fair to good overall excluding the upper 8" of the unit where it is negligible. Porosity probably includes intergranular and biomoldic but, grains and types of porosity are difficult to distinguish due to pervasive dolomite. Numerous fractures occur in the upper 1.5' of the unit. Irregular-shaped, argillaceous lenses are present and often have a green, yellow, or red tint. The unit was probably a bioclast (echinoderm?) packstone and/or grainstone. There is rare white/light gray, irregular-shaped chert and stylolites occur throughout.

II

Light gray, planar to low-angle cross-stratified, medium to coarsely crystalline dolomite. Depositional textures are generally indistinguishable due to pervasive dolomite. Porosity is fair and includes moldic, intergranular, and fracture. Ghosts of echinoderms are visible in thin section suggesting the rock was an echinoderm grainstone or packstone. Red staining occurs in the upper part of the unit.

I

CITIES SERVICE, WESSEL "A" #1
NE-NW-SE SEC. 24 T4S R13E
NEMAHA CO., KS.