Wireline log zones and core description of upper part of the Middle Ordovician Viola Limestone, McClain and McClain SW fields, Nemaha County, Kansas

by *Craig D. Caldwell,* Cities Service Oil and Gas Corporation, Tulsa, Oklahoma, and *Roger Boeken,* Cities Service Oil and Gas Corporation, Oklahoma City, Oklahoma

Introduction

The Viola Limestone is productive in several fields in the Forest City Basin in northeast Kansas (e.g., the Davis Ranch, John Creek, McClain, McClain SW, Sebetha, and Straham). Core description of the Viola Limestone in the Forest City Basin has not, however, been available in the literature. In this study, cores of the upper part of the Middle Ordovician Viola Limestone from two wells in McClain field and one well in McClain SW field, Nemaha County, Kansas, are described and lithologic units are correlated with wireline log zones.

McClain and McClain SW fields are located on the western side of the Forest City Basin (fig. 1). Discovered in December 1981, McClain field is a structural trap (fig. 2) producing oil from the Viola Limestone and Middle Or-

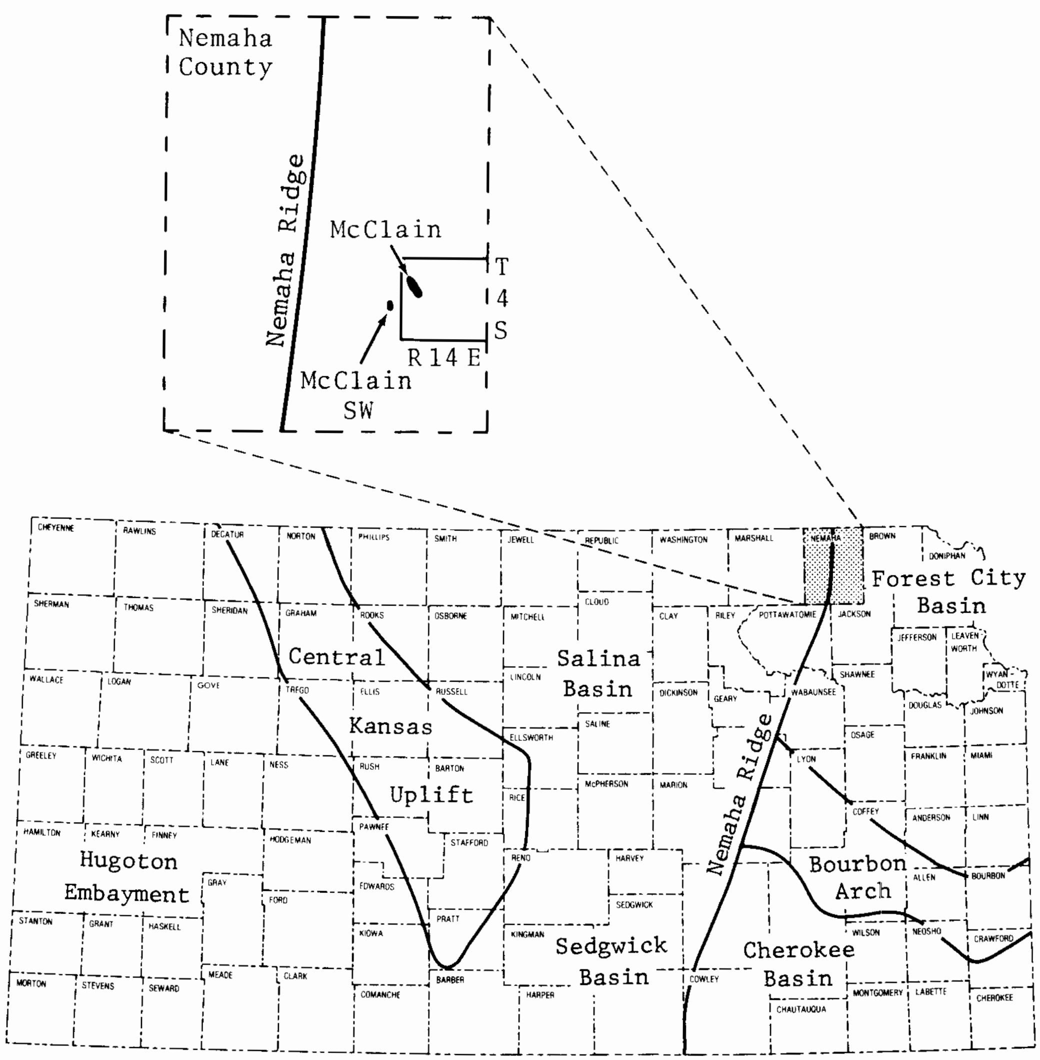


FIGURE 1—Location of McClain and McClain SW fields on the western side of the Forest City Basin, Nemaha County, Kansas.

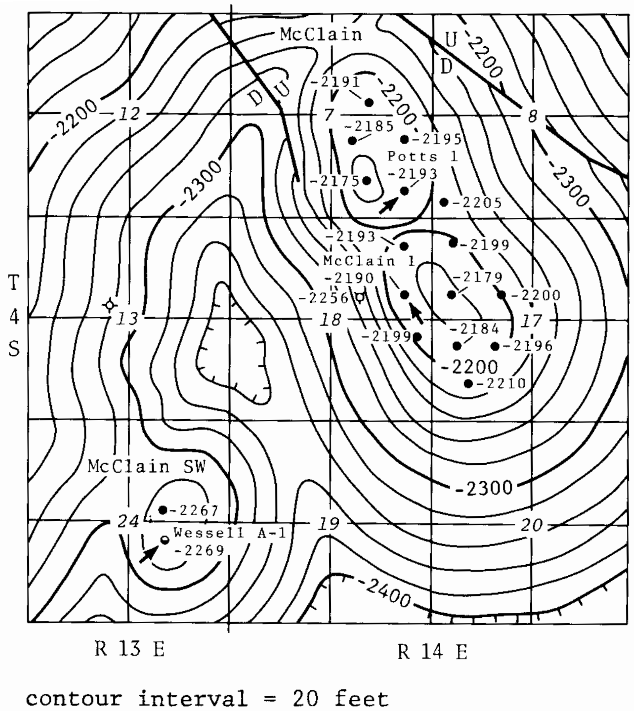


FIGURE 2—Viola structure McClain and McClain SW fields, Nemaha County, Kansas. Arrows indicate wells in which the upper part of the Viola Limestone was cored.

dovician, upper Simpson sandstone at depths of approximately 3,450 ft and 3,650 ft, respectively. As of June 1984, production was 290,453 BO from the Viola and 140,447 BO from the Simpson. June 1984 production was 8,127 BO from the Viola and 3,873 BO from the Simpson. McClain SW field has two wells, the Hermesen 1-24, which has produced 12,400 BO from the Viola with June production at 862 BO, and the Wessel "A" # 1, which is temporarily abandoned.

Wireline log zones and core description

Prior to core study, four wireline log zones were defined in the upper part of the Viola Limestone in McClain and McClain SW fields (fig. 3). In descending order, these zones are these: the "uppermost Viola" referring to the uppermost 10-12 ft of the Viola characterized by low log porosities, 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." The tight streak generally displays log porosities lower than those of the main or lower porosity area but is not uniformly tight in all wells. In places, the tight streak has fair log porosity. Core description of the wireline log zones is given below.

The uppermost Viola zone was cored only in the Cities Service Wessel "A" #1 where it corresponds to core unit VI (fig. 6). The zone is an argillaceous, medium to finely crystalline dolomite (echinoderm wackestone) with poor permeability and poor to negligible core porosity. Burrows are present throughout (plate I, A). Oil staining in the upper 4.5 ft of the zone suggests the uppermost Viola zone in the Wessel "A" #1, although having poor porosity and permeability, is in communication with the underlying, main porosity-zone reservoir.

The main porosity zone was cored, at least in part, in all three wells (figs. 4-6; see sheet 1 in back pocket). It is a medium to coarsely crystalline dolomite with fair to good core porosities 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, however, the zone seems to have been an echinoderm packstone and grainstone (plates II and III).

The tight streak is a mottled (bioturbated), medium crystalline dolomite and was probably an echinoderm wackestone, packstone, and in places grainstone dolomite. Porosity in this zone is generally poor, but a few grainstone/packstone beds are present with fair porosity (plate IV and figs. 4-6). Types of porosity include biomoldic, intercrystalline, and less commonly, vuggy and fracture. Intergranular porosity is present in a few porous grainstone beds. This zone does not form a vertical permeability barrier separating the main and lower porosity zones.

The upper part of the lower porosity zone is a medium to coarsely crystalline dolomite and has fair to very good porosity including intergranular, biomoldic, and fracture (plate V, C). This part of the zone seems to have been an echinoderm grainstone and packstone. Planar and low-angle cross-stratification are generally mottled, medium crystalline dolomite (echinoderm wackestone/packstone; plate VI, A and B) with fair porosity including biomoldic, intercrystalline (plate VI, C), fracture, vuggy, and in places intergranular. Also present is finely crystalline dolomite mudstone (plate VI, D) with intercrystalline, fracture, and fine moldic porosities. Collapse breccia is present and fractures are locally common in the lower part of the lower porosity zone in the Petro Lewis Potts #1 core (plate VII, A and C).

Below the lower porosity zone the Viola is a mottled (bioturbated), medium crystalline dolomite, predominantly bioclast wackestone and mudstone, with poor to negligible porosity (plate VII, B and D, and figs. 4 and 5). Brachiopods, rare in the overlying zones, are common in some beds. Echinoderm debris occurs throughout.

Because the wireline log zones were defined solely on 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 and porosity types, and argillaceous content (see figs. 4-6). Still, a general relationship exists between wireline log zones and lithology as described above and summarized in table 1.

Depositional environments

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 making up much of the tight streak reflect deposition below wave base

Wireline log zones	General core description
uppermost Viola	argillaceous, medium to coarsely crystalline dolomite (echninoderm wackestone) with poor porosity including biomoldic and rare vuggy
main porosity	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

FIGURE 3—Wireline log zones recognized in the upper part of the Viola Limestone in the Cities Service Wessel ''A'' #1, Pendleton McClain #1, and Petro Lewis Potts #1. Wireline log zones: U.V.—uppermost Viola, M.P.—main porosity, T.S.—tight streak, and L.P.—lower porosity.

in relatively quiet marine waters. Deposition in shallow, more agitated, marine waters 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, particularly those in the Petro Lewis Potts #1 core, may record very shallow, low-energy, restricted subtidal deposition.

The uppermost Viola zone in the Wessel "A" #1 records increased detrital influx, the upper 0.5 ft of the Viola becoming progressively more argillaceous upward toward an abrupt contact with overlying shale and fine sandstone of the Upper Ordovician Maquoketa Shale (fig. 6 and plate I, C). The upper 0.5 ft of the Viola has a disrupted (bioturbated?) appearance. Pyritized skeletal debris immediately above the Viola/Maquoketa contact reflects reducing conditions and perhaps slow deposition. Somewhat deeper water shelf deposition is suggested by parallel laminated fine sandstone and shale of the lowermost Maquoketa Shale (plate I, D).

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 occurs as void-filling intergranular cement. For the most part, this dolomite is thought to have formed relatively early, perhaps in the freshwater-marine phreatic mixing zone (fig. 7). Depositional textures (e.g., grains and types of porosity) are difficult to distinguish in many places due to pervasive dolomite.

Primary intergranular porosity is common in the main porosity zone (plate III) and upper part of the lower porosity zone (plate V, C) and occurs in scattered grainstone beds in the tight streak (plate IV, C). It is negligible in the uppermost Viola zone and in mudstones and wackestones of the tight streak, lower porosity zone, and interval below the lower porosity zone. Intergranular porosity in grainstones and packstones is partially filled in most beds by dolomite occurring as rhombs which have replaced echinoderm fragments and grown into the surrounding pore space (plates III, B, and V, C).

Biomoldic porosity occurs throughout the upper part of the Viola in all of the wireline log zones recognized in this study. Intercrystalline, vuggy, and fracture porosities, though significantly less important volumetrically, likewise occur throughout much of the upper part of the Viola. Biomoldic, intercrystalline, and vuggy porosities are thought to have formed shortly after the major phase of dolomite formation. These porosities record relatively early, freshwater dissolution of undolomitized grains (resulting in biomoldic porosity) and micrite matrix (resulting in intercrystalline porosity) in the freshwater phreatic zone. Collapse breccia and red stain in the lower porosity zone of the Petro Lewis Potts #1 core reflect freshwater diagenesis, perhaps relatively near the surface. Fractures in the cores are vertical, commonly hairline, and probably formed, for the most part, during structural deformation of the area. Fractures associated with collapse breccias and red-stained dolomite mudstones in the lower porosity zone of the Potts #1 core may, however, be related to early diagenesis.

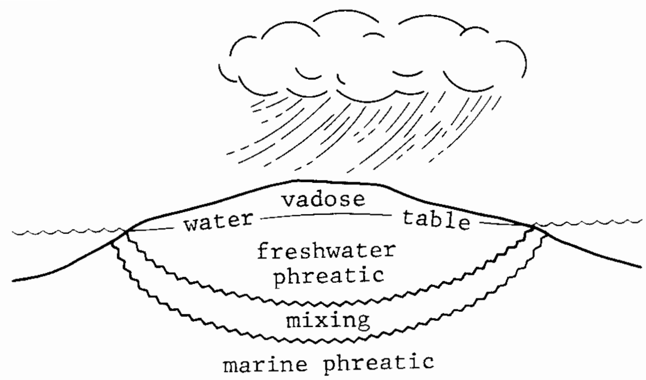


FIGURE 7—Idealized, shallow-subsurface, carbonate diagenetic environments, not to scale (after Longman, 1980).

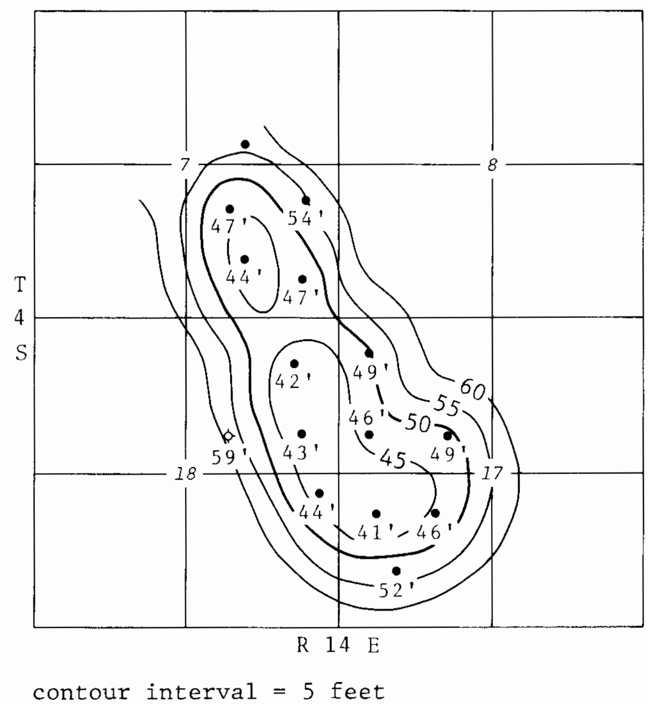


FIGURE 8—Lower Simpson Sandstone isopach, McClain field, Nemaha County, Kansas.

In the study area, higher porosities in the main porosity zone occur in the structurally higher wells. This may reflect greater freshwater dissolution of carbonate and/or better primary intergranular porosity on the upper part of an Ordovician high, the location of which approximates that of the present structure at McClain field. A Middle Ordovician high is suggested by thinning of the Lower Simpson sandstone over the crest of the present structure at McClain field (fig. 8, compare with fig. 2). The major period of structural deformation in the Forest City Basin is post-Mississippian (pre-Desmoinesian) and involves basement tectonic activity associated with uplift of the Nemaha Ridge.

References

Longman, M. W., 1980, Carbonate diagenetic textures from nearsurface diagenetic environments: American Association of Petroleum Geologists, Bulletin, v. 64, no. 4, p. 461–487.

Plates I–VII follow

PLATE I. Uppermost Viola zone and Maquoketa Shale

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

B. Finely crystalline dolomite (bioclast wackestone) of the uppermost Viola zone. Light-colored, medium crystalline dolomite areas are replaced bioclasts (RB). Microstylolites (S) are common (mag. 18.7x; Wessel "A" #1, 3492.6 ft).

C. Contact (C) of the Viola Limestone (uppermost Viola zone) and overlying Maquoketa Shale. The uppermost Viola has a disrupted appearance, and a thin layer of pyritized skeletal debris occurs just above the contact (Wessel "A" #1, 3486.5 ft).

D. Parallel laminated fine sandstone and shale of the lower part of the Maquoketa Shale (Wessel "A" #1, 3485.5 ft).

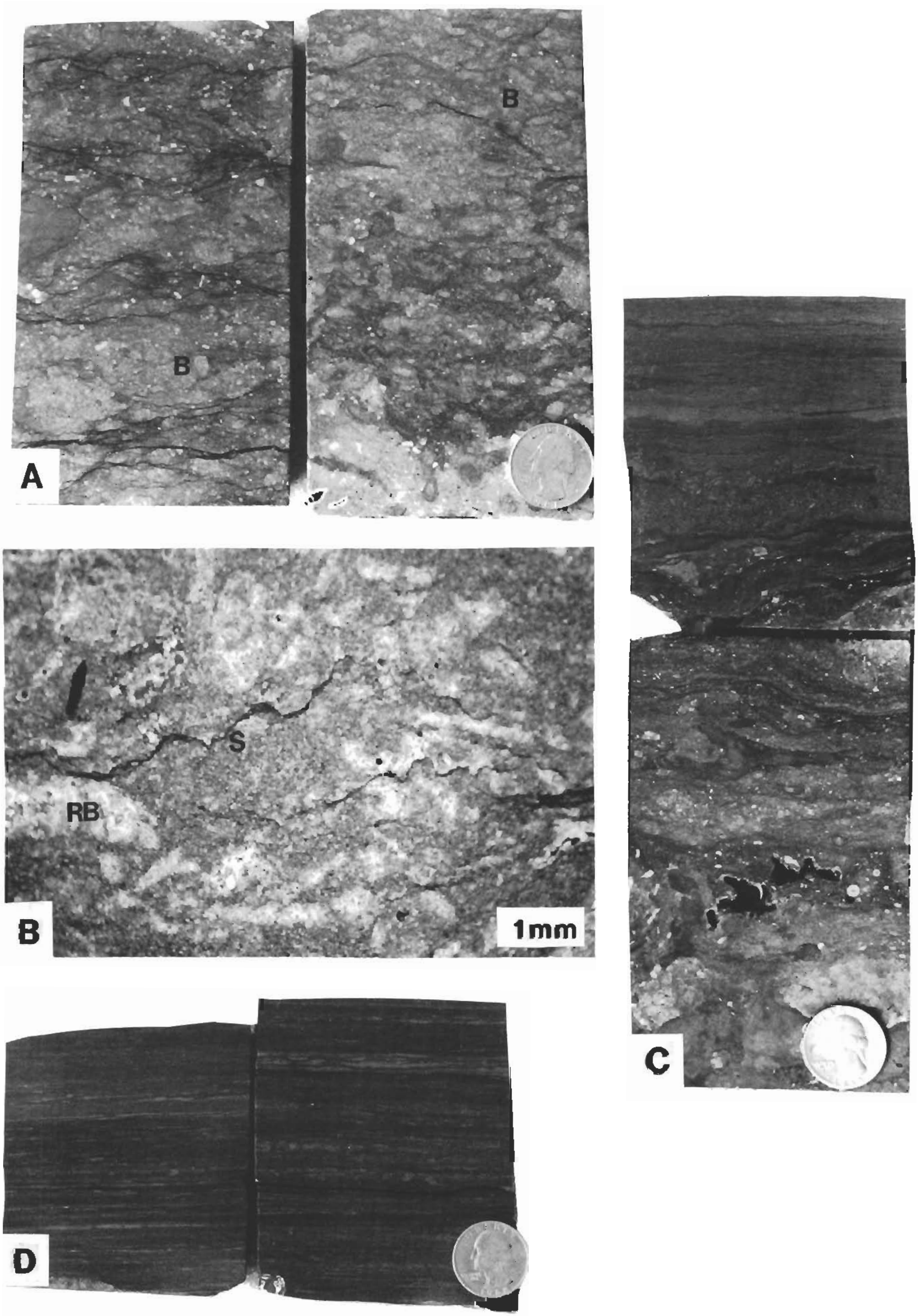
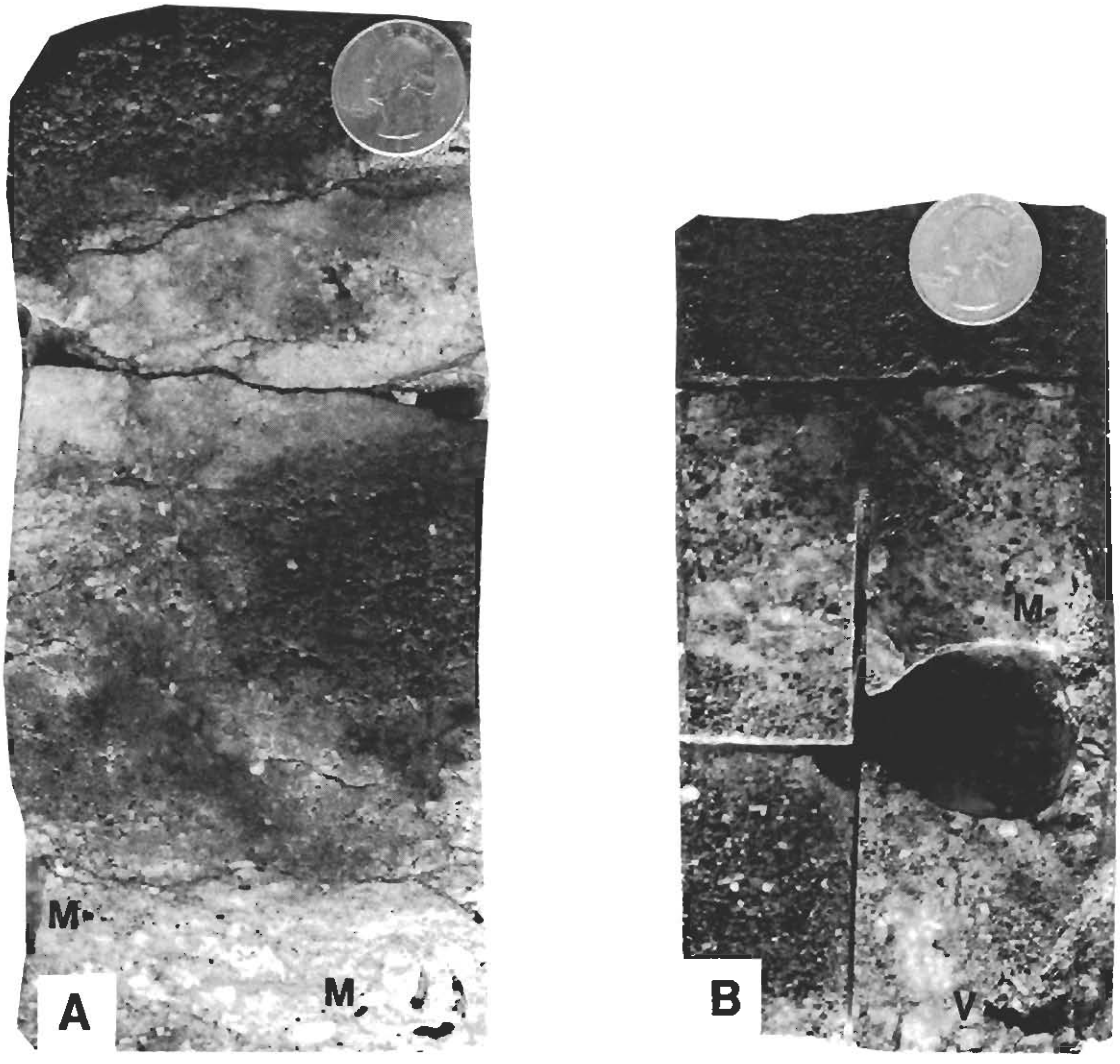

B
B
A
S
RB
B
1mm
C
D

PLATE II. Main porosity zone

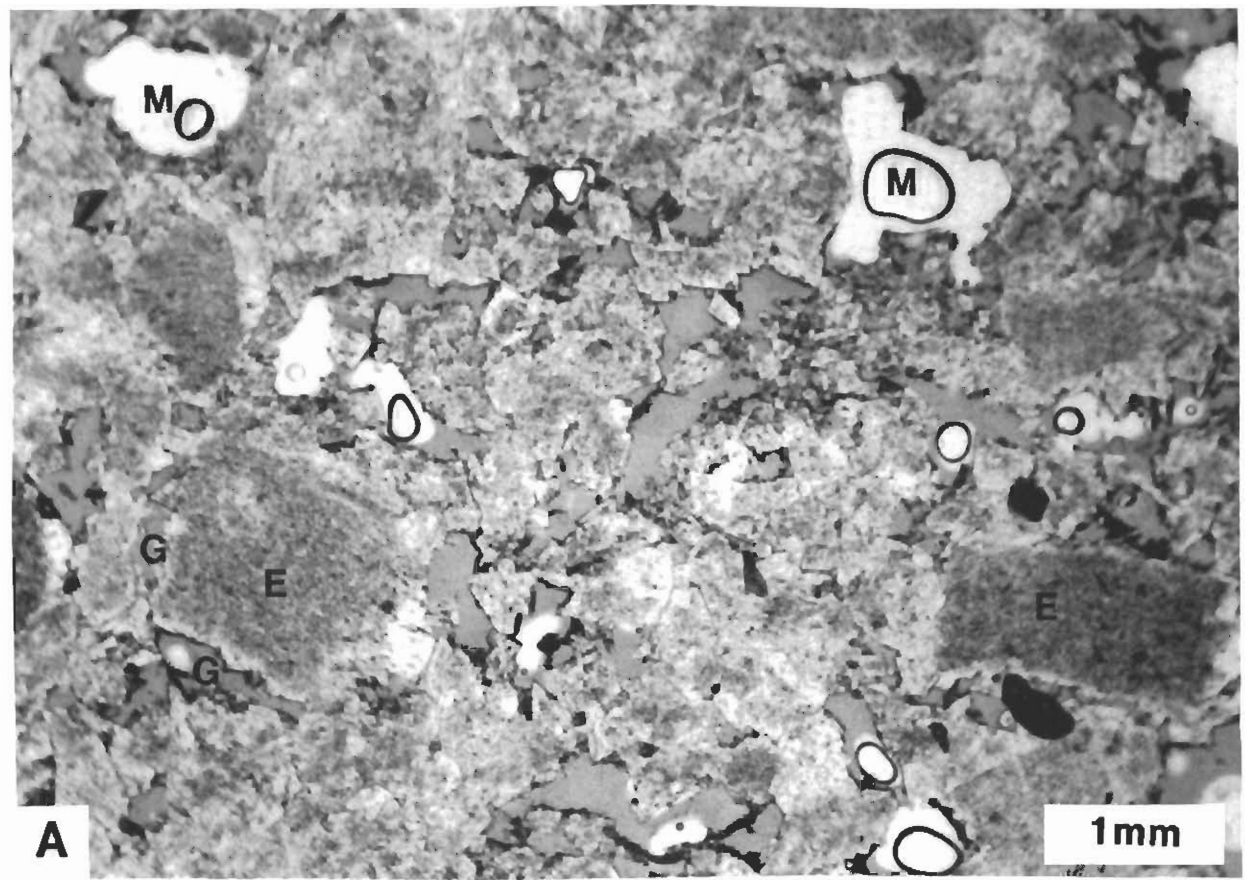
A–C. Oil stained, medium to coarsely crystalline dolomite (echinoderm grainstone, packstone, and in places wackestone) of the main porosity zone. Porosities include biomoldic (M), intergranular, vuggy (V), and fracture (F). A—Potts #1, 3457 ft; B—McClain #1, 3501.2 ft; and C—Wessel "A" #1, 3500 ft).



M
M
A
M
B
V
F
M
M
V
C

PLATE III. Main porosity zone

A and B. Coarsely crystalline dolomite (echinoderm (E) grainstone) of the main porosity zone. Both intergranular (G) and biomoldic (B) porosities are present, but it is often difficult to distinguish between the two (mag. 18.7x; A—McClain #1, 3501.8 ft, and B—Wessel "A" #1, 3502.4 ft).


M
M
G
E
E
G
A
1mm

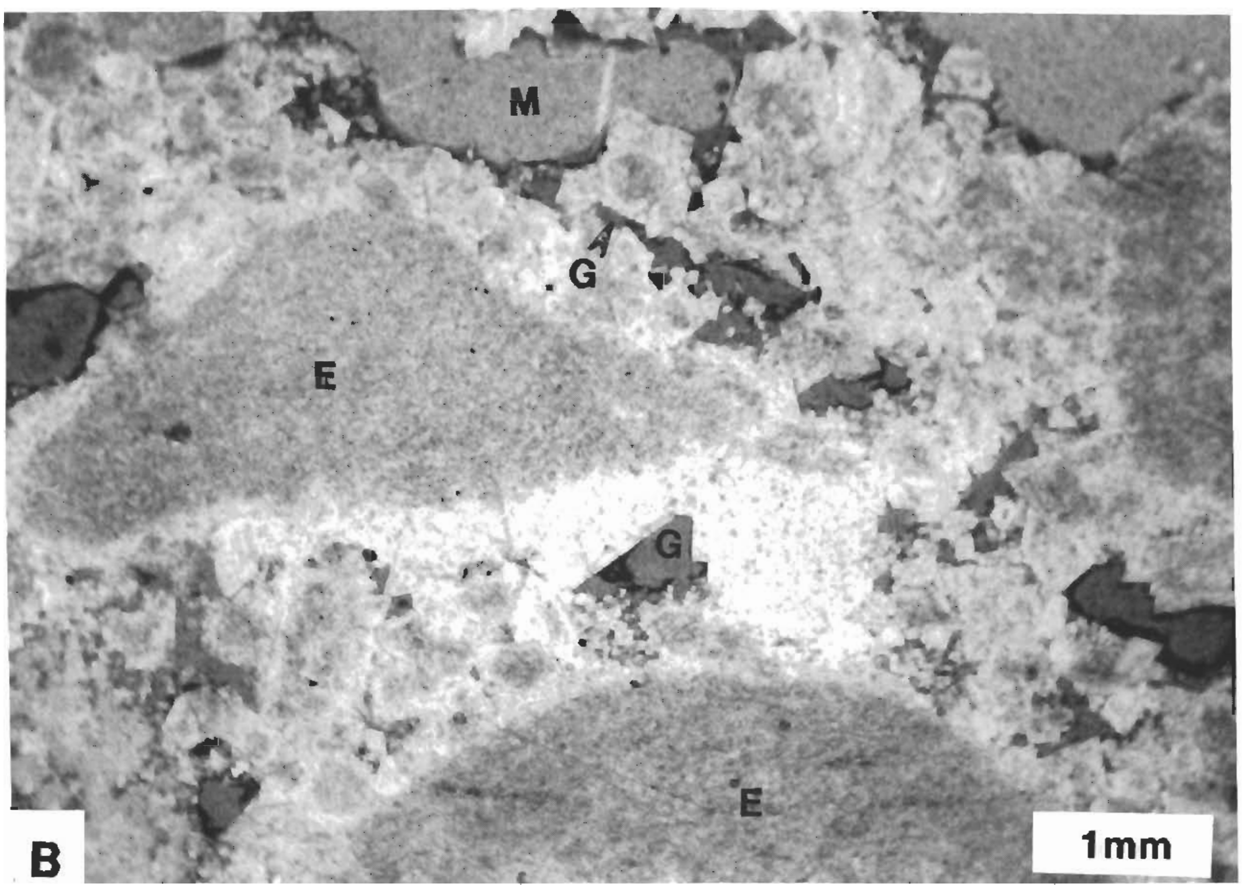

M
G
E
G
E
B
1mm

PLATE IV. Tight streak zone

A and B. Fine to medium crystalline dolomite of the tight streak. Porosity is negligible in dolomite mudstone of thin section photo A (mag. 18.7x) and negligible to poor in burrowed (B), echinoderm wackestone of photo B (A—McClain #1, 3507.6 ft, and B—Potts #1, 3463 ft).

C and D. Medium to coarsely crystalline dolomite (echinoderm (E) grainstone) of the tight streak. Thin section photo C (mag. 18.7x) shows intergranular (G) and biomoldic (M) porosities; photo D from the same bed shows oil staining in this grainstone (C and D—Potts #1, 3461.4 ft).

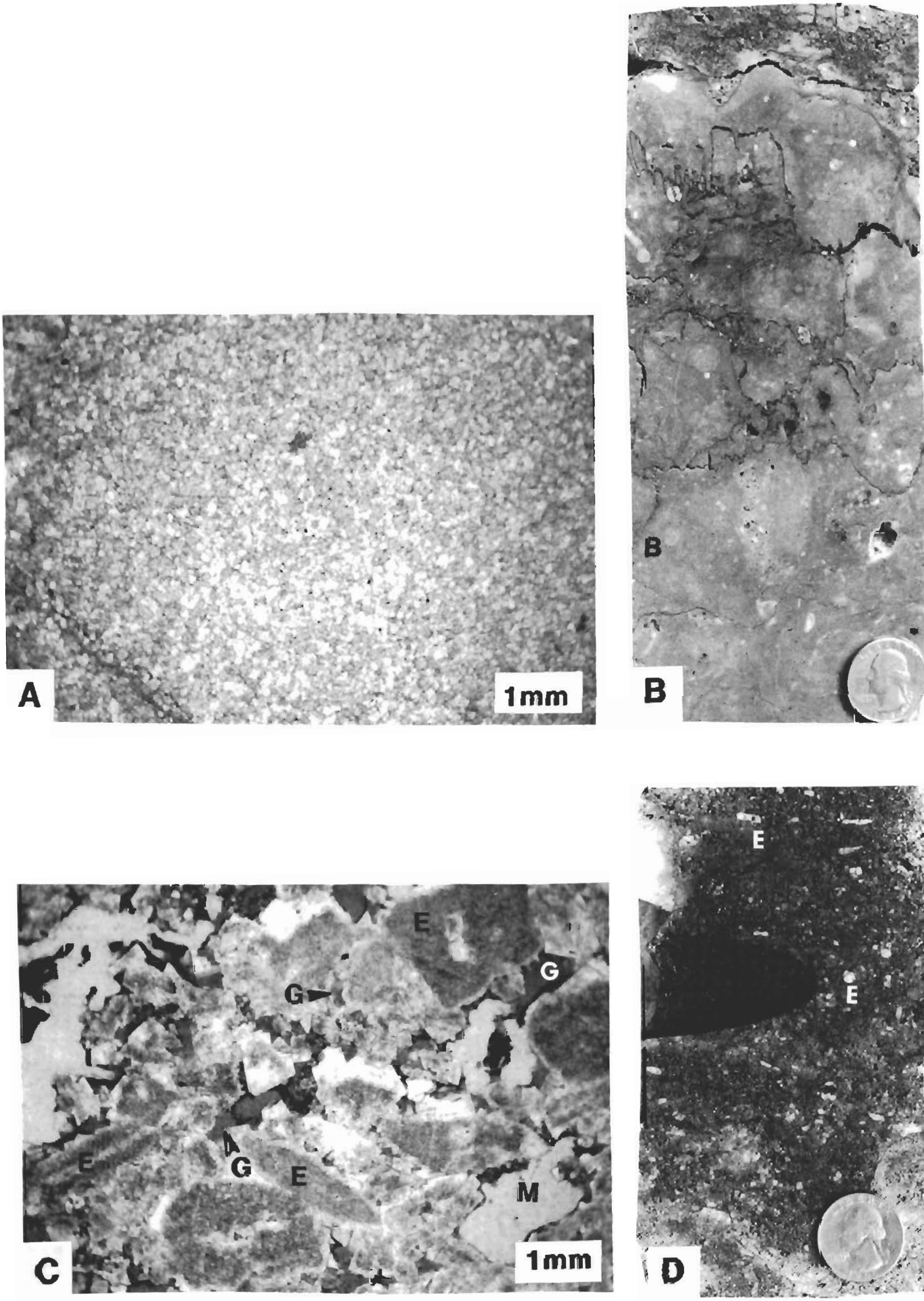

A
1mm
B
B
E
G
G
E
G
E
M
C
1mm
E
E
D

PLATE V. Lower porosity zone

A–C. Low-angle cross-stratified and planar-laminated, coarsely crystalline dolomite (echinoderm grainstone) of the upper and middle parts of the lower porosity zone. Intergranular (G) and biomoldic (M) porosities are indicated in thin section photo C (mag. 18.7x). As in the main porosity zone, it is often difficult to distinguish between intergranular and biomoldic porosities. Dolomite has replaced echinoderm debris (E) and grown into adjacent pore spaces (A—McClain #1, 3514.5 ft, B—Potts #1, 3481 ft, and C—Potts #1, 3470 ft).

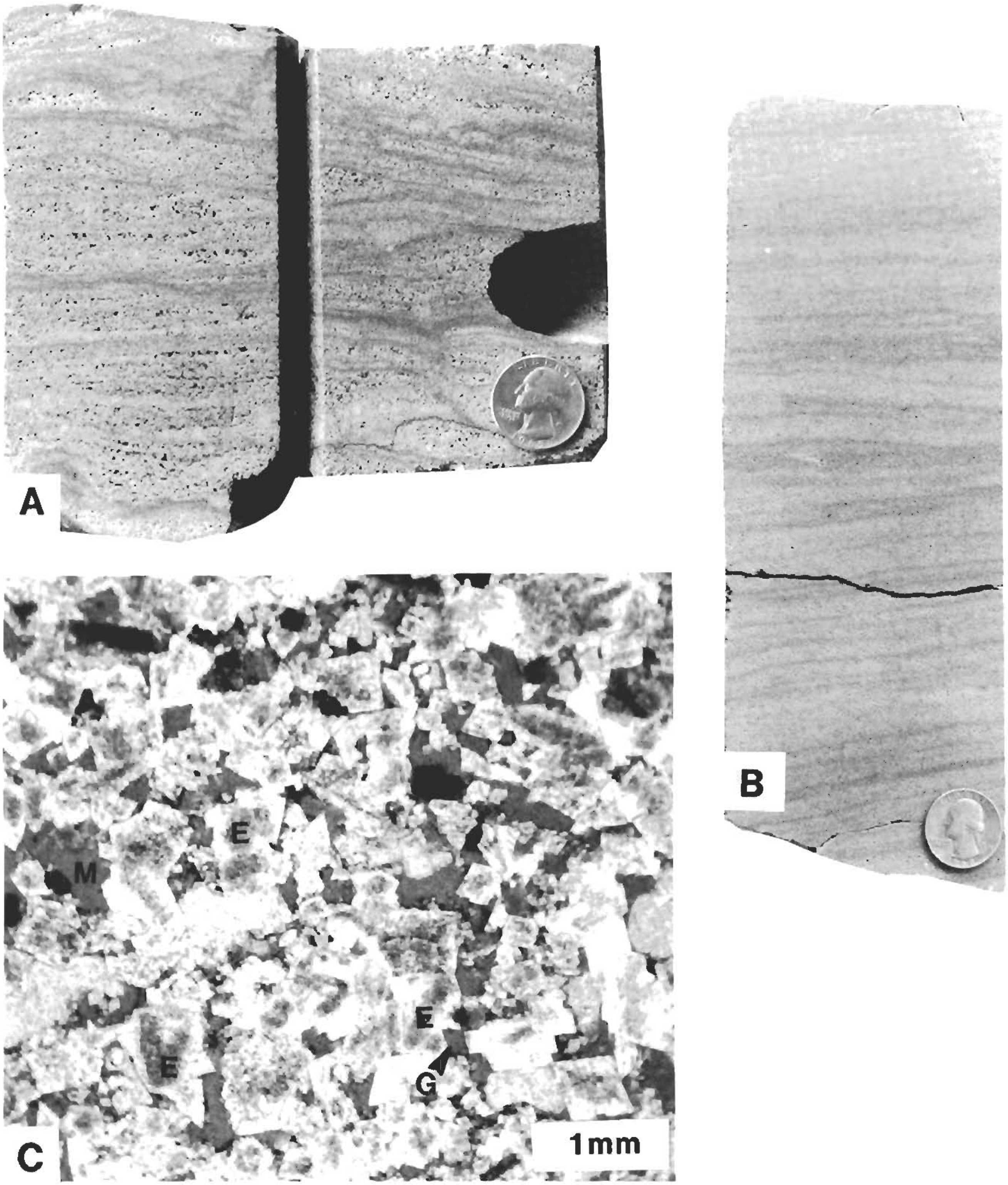
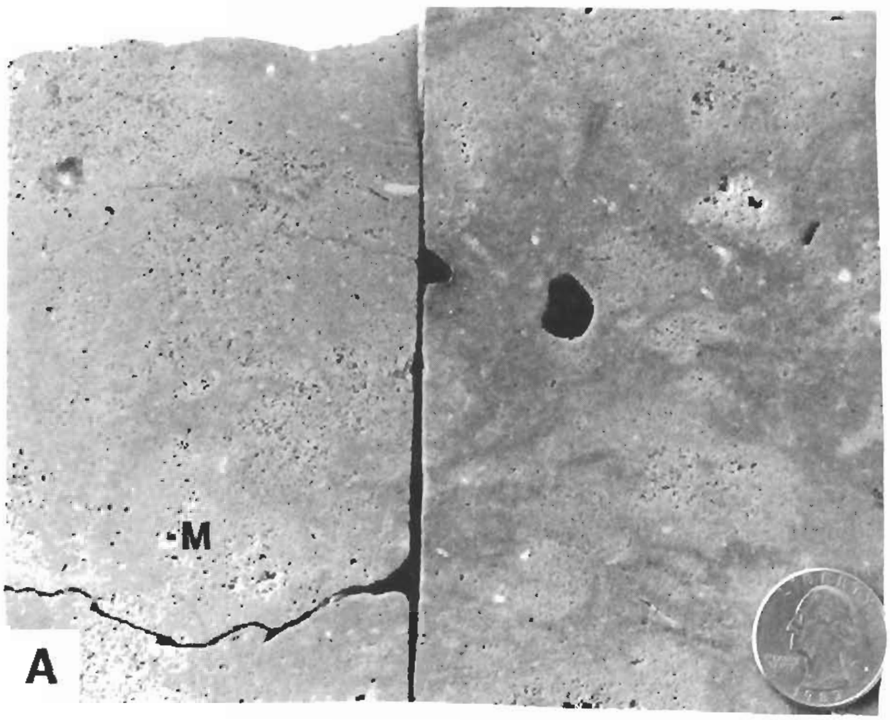
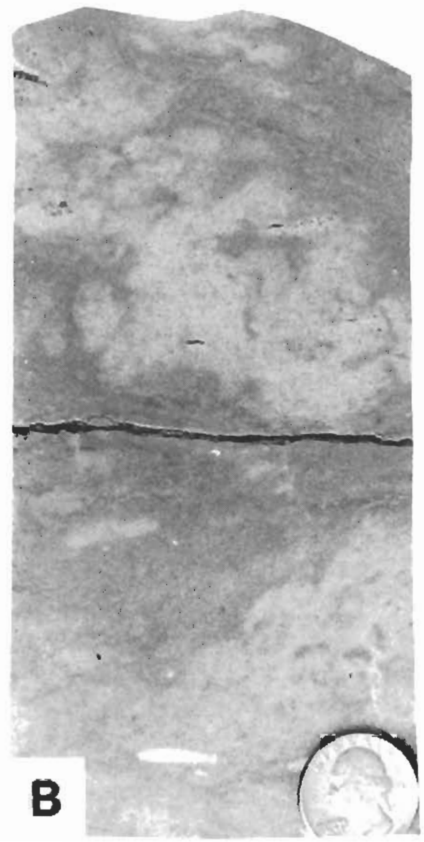
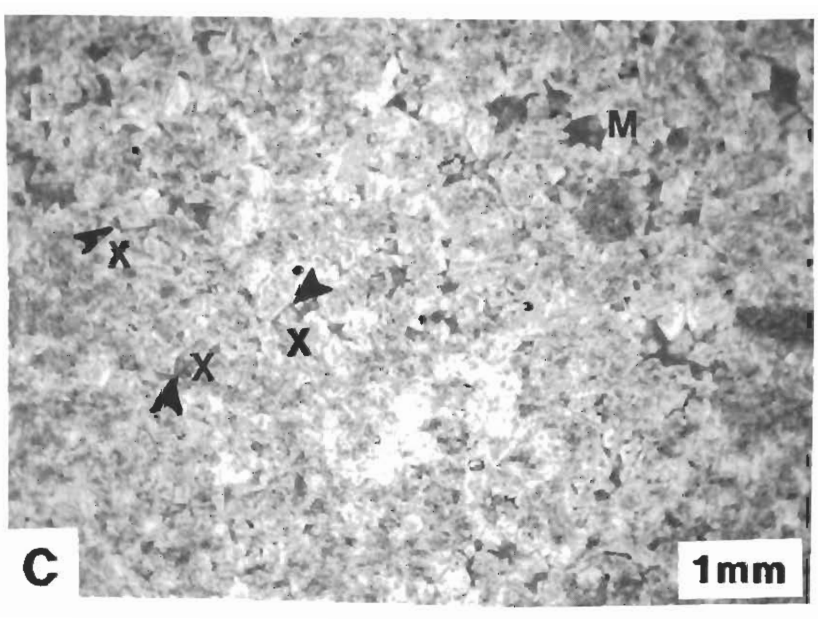

A
B
E
M
E
E
G
C
1mm

PLATE VI. Lower porosity zone

A–D. Fine to medium crystalline dolomite mudstone and wackestone of the lower part of the lower porosity zone. Photos A and B show burrow mottling, the light-colored areas being more coarsely crystalline and more porous. Fractures (F) are present in dolomite mudstone of photo D, and thin section photo C (mag. 18.7x) shows biomoldic (M) and intercrystalline (X) porosities. (A—McClain #1, left-3522 ft and right-3520.8 ft, B—Wessel "A" #1, 3529 ft, C—McClain #1, 3522.5 ft, and D—Potts #1, 3487.5 ft).


M
A


B


M
X
X
X
C
1mm

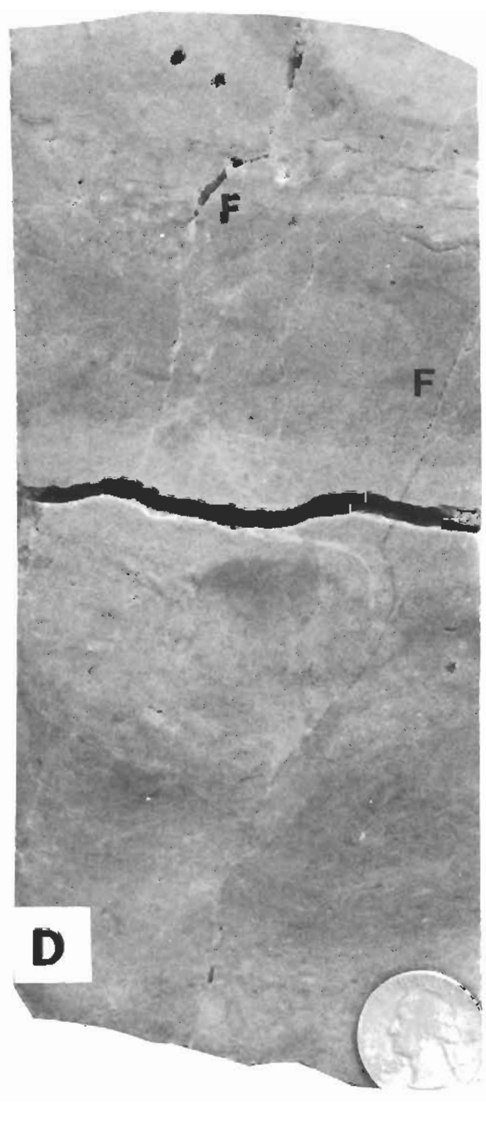
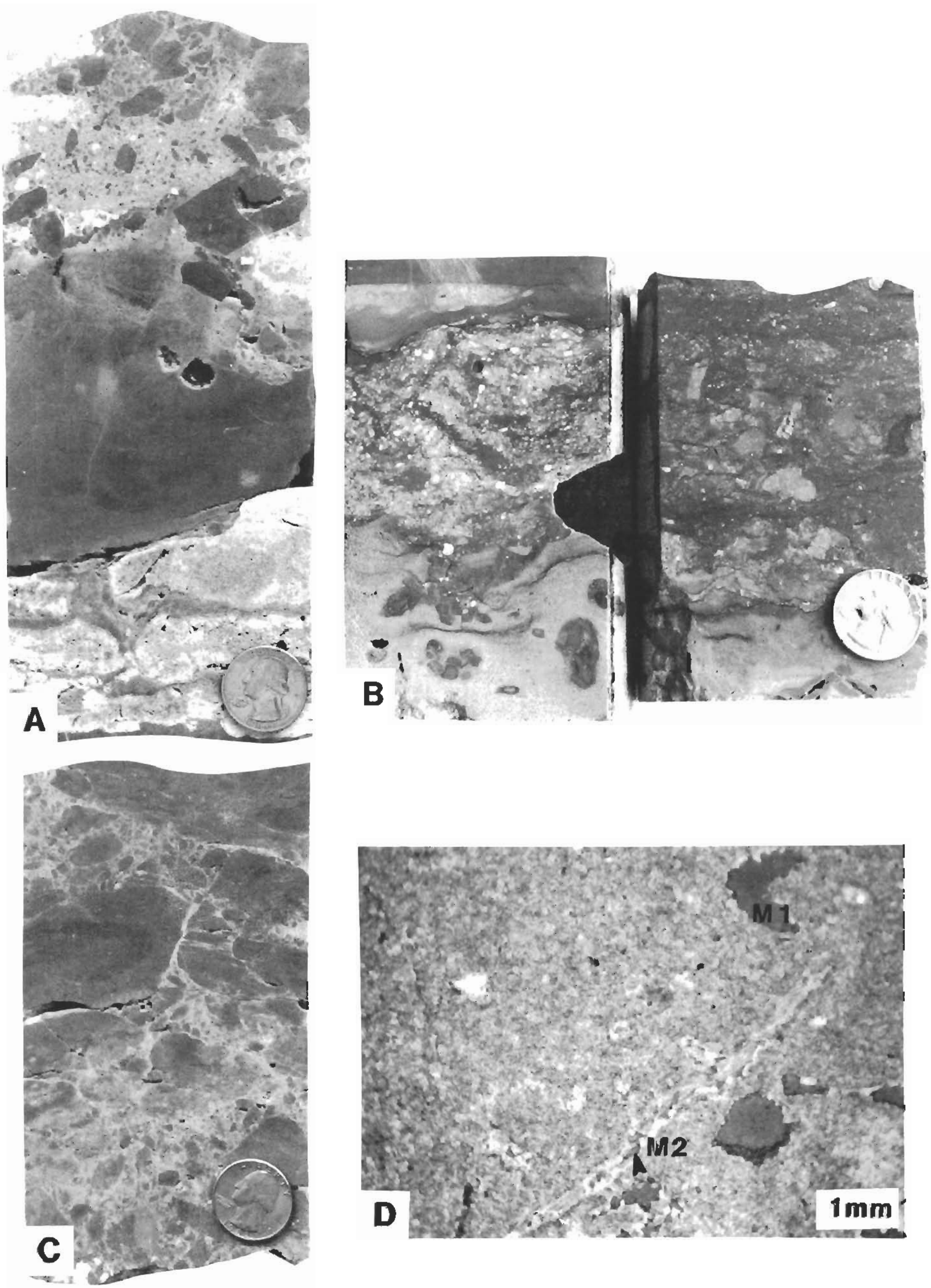

F
F
D

PLATE VII. Lower porosity zone and underlying interval

A and C. Collapse breccia of the lower part of the lower porosity zone. Red staining is common in these samples (A—Potts #1, 3491.5 ft, and C—Potts #1, 3491 ft).

B and D. Burrowed, fine to medium crystalline dolomite (bioclast wackestone) of the interval underlying the lower porosity zone. Thin section photo D (mag. 18.7x) shows biomoldic porosity; M1 is an echinoderm mold, and M2 is a partially leached brachiopod (B—McClain #1, 3543.5 ft, and D—Potts #1, 3494.1 ft).


A
B
C
M1
M2
D
1mm