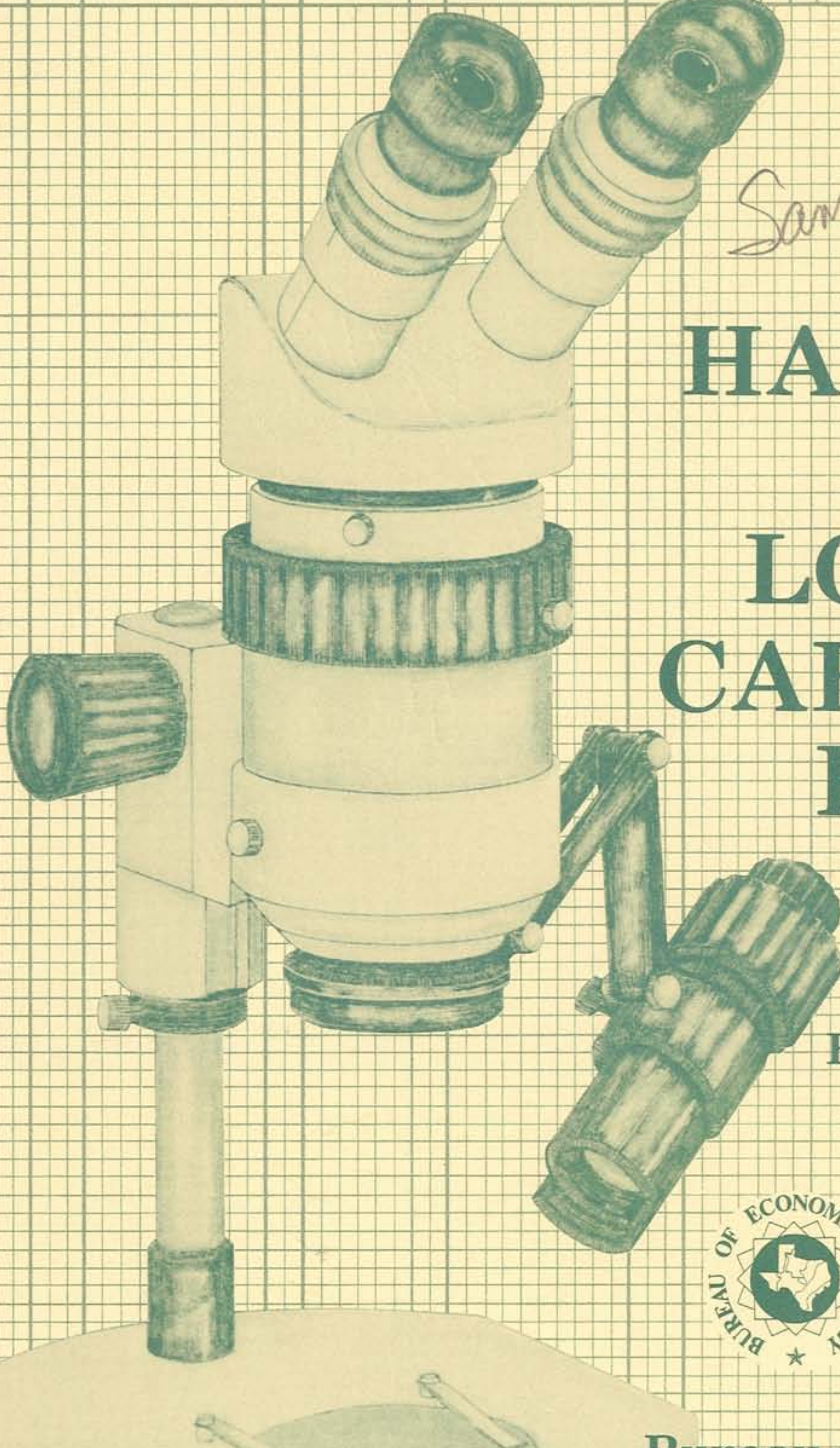
WELL ________________ **HANDBOOK 5**

STRATIGRAPHIC INTERVAL ________________ LOGGED BY ____________

	PORE TYPE	MINERAL COMPOSITION (INCL. POROSITY)	NATURE OF CONTACT	STRUCTURES		TEXTURE	FABRIC	GRAIN SIZE (DOLOMITE-CRYSTAL SIZE)	CRYSTAL SHAPE	COLOR	FOSSILS	CEMENT
				TYPE	SIZE			.01 .12 .5 1.0 2.0 4.0 6.4				



Sample Logging

HANDBOOK FOR LOGGING CARBONATE ROCKS

by

Don G. Bebout

and

Robert G. Loucks

1984

Bureau of Economic Geology

W. L. Fisher, Director

The University of Texas at Austin

Austin, Texas 78712

HANDBOOK 5

HANDBOOK FOR LOGGING CARBONATE ROCKS

by
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1984

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W. L. Fisher, Director
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INTRODUCTION

Core Logging Form

The procedure described here has been used successfully for logging carbonate cores for oil and gas exploration and production, geologic research, graduate-level courses, and industry short-courses. By design, the logging form discussed here is simple and flexible and can be readily altered to fit a specific project. However, this is only one of many logging styles used in industry and universities, and it should not be considered the only format applicable; personal preferences greatly influence the selection of a particular form.

We strongly recommend that some sort of graphic logging form be used when studying carbonate cores and samples. A logging form allows fast, accurate, and easy recording of data. Most important, the data presented on a logging form can be compared directly to associated geophysical logs and to core descriptions from other wells.

The logging form we devised is shown below (fig. 1), followed by a sample filled-out version (fig. 2). The rest of this Handbook contains charts and illustrations designed to facilitate logging carbonate cores using this logging form. We have also included photographs of slab surfaces and thin sections to illustrate some of the typical fossils and structures that may be encountered when logging core. Part of the filled-out logging form accompanies each example to serve as a guide in using the logging procedure described in this Handbook.

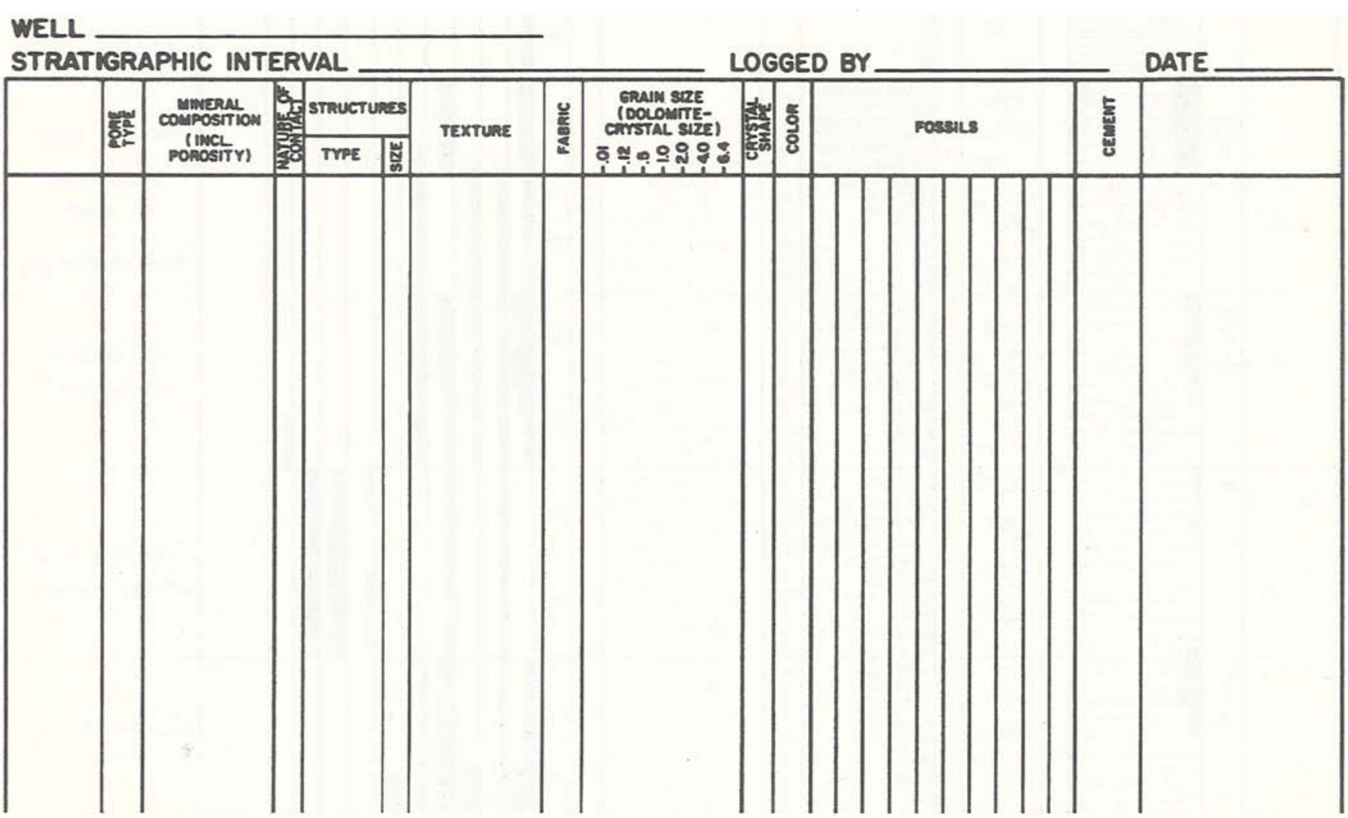


Figure 1. Logging form reduced 30 percent. See form in pocket at back for full-scale version.

Core Preparation

Proper core preparation before examination is essential for obtaining the maximum detail. Minimum preparation should include slabbing the core lengthwise, and limestone core should be etched with dilute (10 percent) hydrochloric acid to remove rock dust and some of the saw marks. Dolomite core is more easily examined after being dry sanded on a belt sander to remove the saw marks. The surface of the core should be kept wet at all times during study, except when estimating the amount and type of porosity, which are better observed on a dry surface.

All the features described in this Handbook can be observed by using a low-power (10X) binocular microscope.

Keywords: carbonate rocks, core and sample logging.

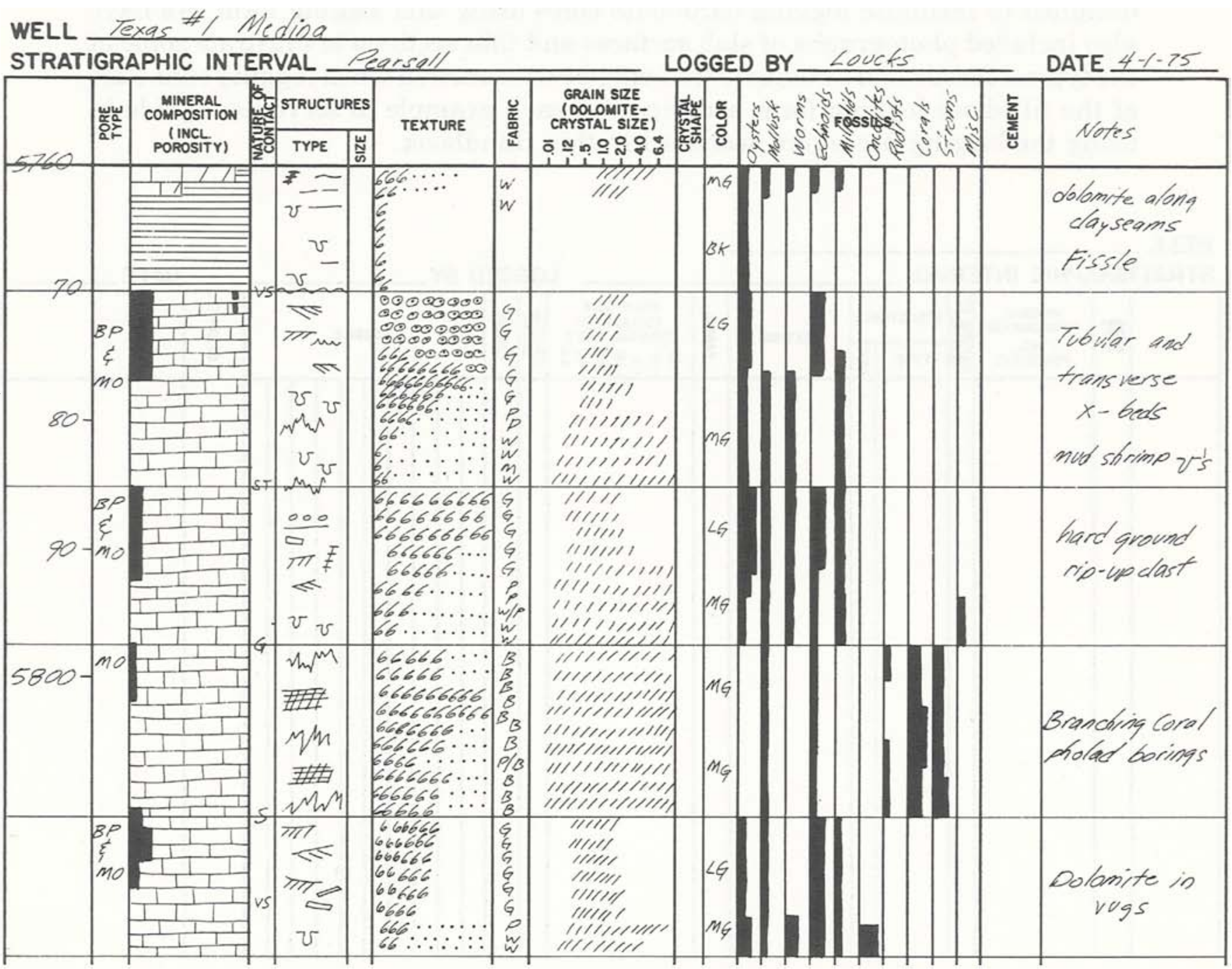


Figure 2. Completed logging form reduced 30 percent.

CARBONATE LOGGING GUIDE

Porosity

The percent porosity should be estimated as part of mineral composition. The type of porosity is recorded in the pore-type column according to the classification of Choquette and Pray (1970).

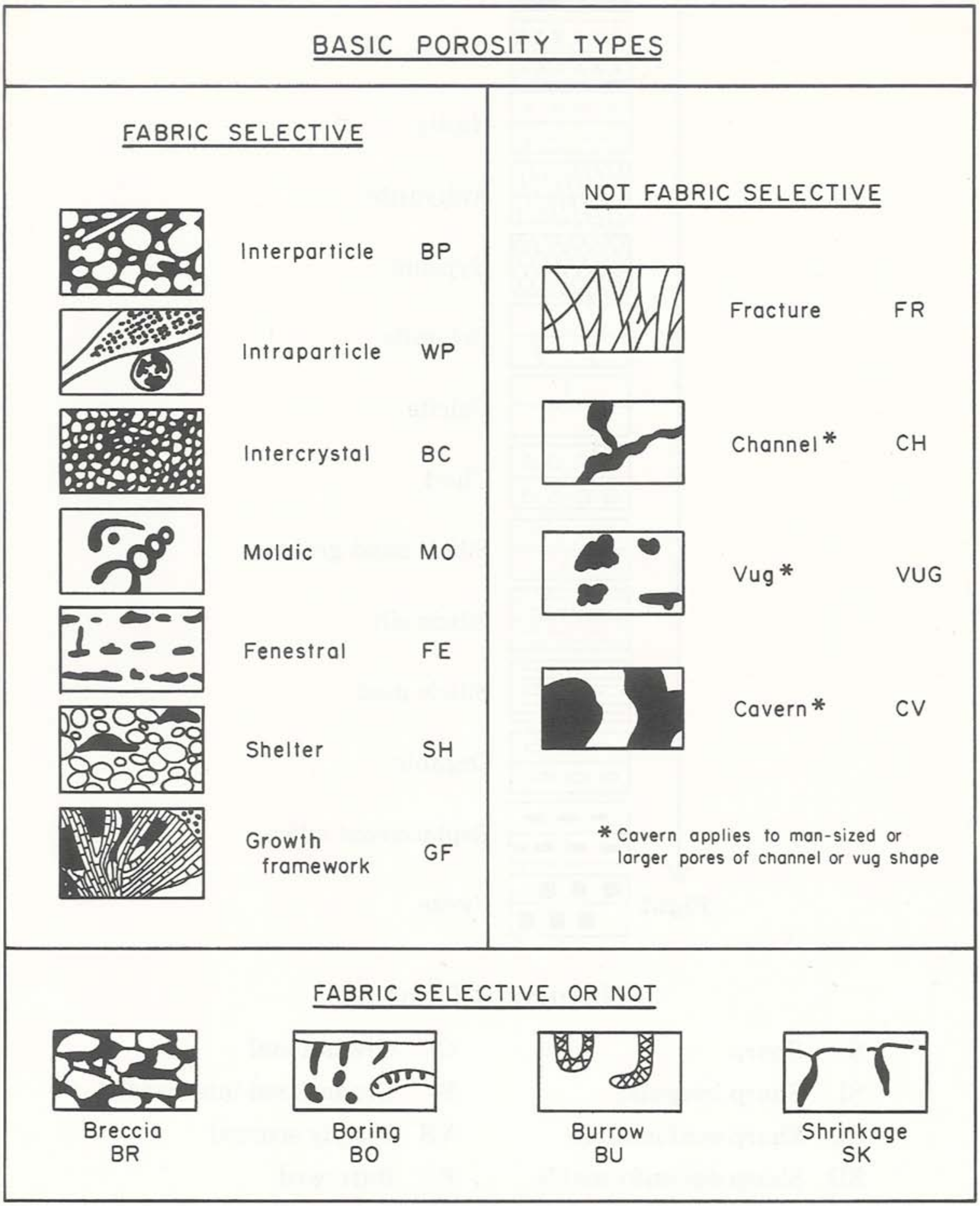
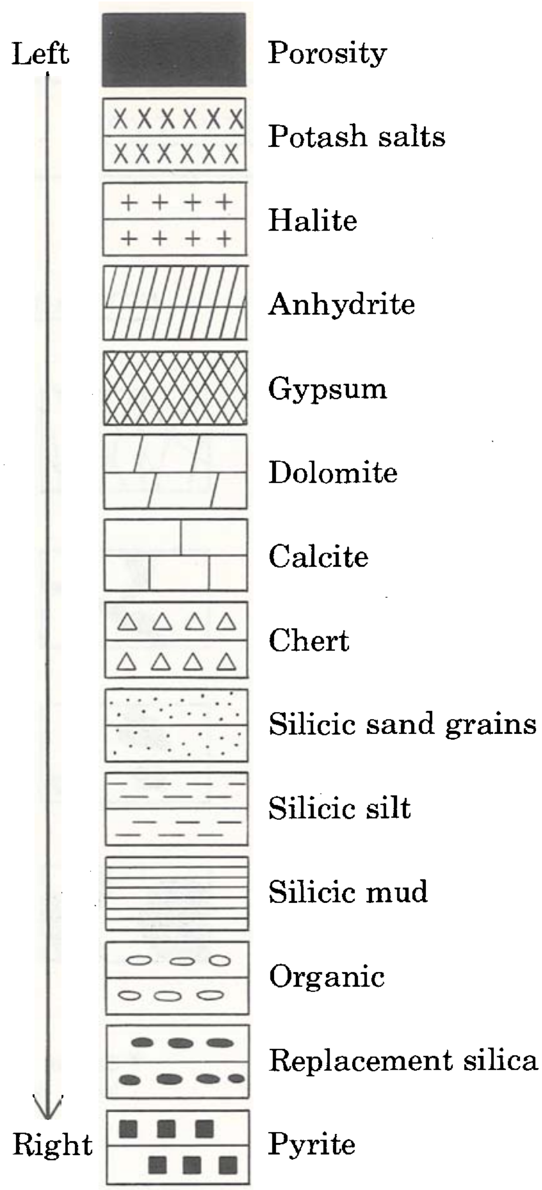


Figure 3. Basic porosity types, from Choquette and Pray (1970).

Mineral Composition

Log in percent. Column width on logging form represents 100 percent and is subdivided into 10-percent intervals. The items listed here should be entered on the mineral composition column in the order shown here, with porosity on the left and pyrite on the right. For example, on Figure 4C (p. 22) calcite is shown on the left and silicic sand, on the right.



Nature of Contact

S	Sharp	G	Gradational
SI	Sharp irregular	B	Gradational-interbedded
SC	Sharp conformable	VS	Visibly scoured
SD	Sharp disconformable	BU	Burrowed
ST	Stylolite		

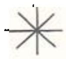
Structure

Carbonate Structures

- Streaky
- Streaky laminated
- Microstreaky
- Stylolites
- Fractures
- Cloudy
- Shale and bituminous partings
- Interbedded
- Truncated surface
- Scoured surface
- Convolute
- Graded beds
  - Fining up
  - Coarsening up
- Lamina types - sketch diagrammatically example - irregular laminations
- Ripple marks
- Cross bedding
- Brecciation types
  - Fracture
  - Mosaic
  - Chaotic

- Solution cavity with breccia
- Highly disturbed
- Hardground
- Boudinage
- Burrows
  - Vertical
  - Horizontal
  - Suggested
- Clasts
- Borings
- Keystone structures
- Mudcracks
- Birdseye
- Fenestral
- Organic framework
- Geopetal
- Roots
- Sheet cracks

Anhydrite Structures*

 Crystallotopic

 Gypsum pseudomorphs

 Nodular

 Nodular mosaic

 Mosaic

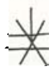
 Massive

 Bedded massive

Modifiers using mosaic as an example

 Distorted mosaic

 Bedded mosaic

 Distorted bedded mosaic

 Highly distorted

 Brecciated

Size of Anhydrite Structures

For nodular and mosaic and breccia

- Small (< 1/4 inch) - S
- Medium (1/4 to 1 inch) - M
- Large (>1 inch) - L

Beds or laminae

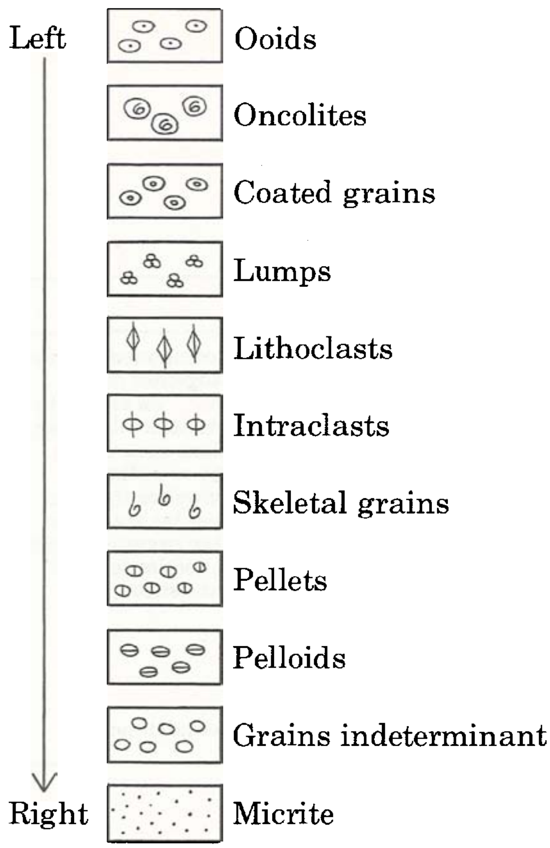
- Very thick (> 4.0 inches; 100 mm) - VTK
- Thick (1 to 4 inches; 30 to 100 mm) - TK
- Medium (0.4 to 1 inch; 10 to 30 mm) - ME
- Thin (0.1 to 0.4 inch; 3 to 10 mm) - TN
- Very thin (< 0.1 inch; 3 mm) - VTN

*From Maiklem, Bebout, and Glaister (1969).

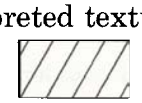
Texture

Log in percent. Column width on logging form represents 100 percent and is subdivided into 10-percent intervals. The items listed here should be entered on the texture column in the order shown here, with ooids on the left and micrite on the right. For example, on Figure 1B skeletal grains are shown on the left and micrite on the right.

Carbonate Textures



Highly altered. Superimpose over interpreted texture.



Anhydrite Textures*

Felted	Lathlike
Subfelted	Needles
Aligned felted	MX Microcrystalline
Blocky	A Anhedral

*From Maiklem, Bebout, and Glaister (1969).

Carbonate Fabrics

M - Mudstone
W - Wackestone
P - Packstone
G - Grainstone

B - Boundstone
Ba - Bafflestone
Bi - Bindstone
F - Framestone

<table>
<tr><td colspan="5">Depositional texture recognizable</td><td rowspan="6">Depositional texture not recognizable

Crystalline carbonate

(Subdivide according to classifications for physical texture or diagenesis.)</td></tr>
<tr><td colspan="4">Original components not bound together during depositions</td><td rowspan="4">Original components were bound together during deposition . . . as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.</td></tr>
<tr><td colspan="3">Contains mud (particles of clay and fine silt)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td></tr>
</table>

Carbonate classification by Dunham (1962).

<table>
<tr><td colspan="3">Autochthonous limestones; original components organically bound during deposition</td></tr>
<tr><td>By organisms that act as baffles</td><td>By organisms that encrust and bind</td><td>By organisms that build a rigid framework</td></tr>
<tr><td>Bafflestone</td><td>Bindstone</td><td>Framestone</td></tr>
</table>

Modification of Dunham "boundstone" by Embry and Klovan (1971).

Grain Size

Range of size of allochems, in millimeters.

In some dolomite, where allochems are unrecognizable, give size of dolomite crystals.

Crystal Shape (Dolomite)

A - Anhedral (no crystal faces)

S - Subhedral (some crystal faces)

E - Euhedral (most crystal faces)

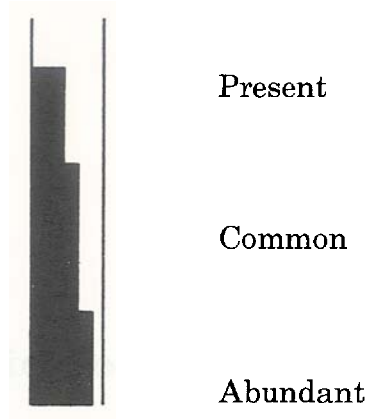
Color

L - Light	G - Gray	C - Cream
M - Medium	B - Brown	W - White
D - Dark	R - Red	Bk - Black
m - Mottled	O - Orange	Cl - Clear
	Y - Yellow	Tr - Transparent
	Gn - Green	T - Translucent
	Bl - Blue	

Example: LBG = light brownish gray

Fossils

Label fossil columns on logging form using name of appropriate organisms, and record relative fossil abundance as shown below.



Fossil	Reflected	Transmitted
Mollusks	250μ	125μ
Corals	250	250
Foraminifers	62	62
Bryozoans	250	125-250
Barnacles	500	125-250
Echinoids	125	62
Halimeda	125	62-125
Coralline algae	500	125
Spicules	<62	<62

Figure 4. Approximate lower size limits (microns) at which various skeletal components can be recognized in both reflected and transmitted light. Data from Milliman (1974).

Taxon	Arag.	Calcite %Mg (0 5 10 15 20 25 30 35)	Both Aragonite and Calcite
Calcareous Algae:			
Red		×————×	
Green	×		
Coccoliths		×	
Foraminifers:			
Benthonic	O	×———×- - -×	
Planktonic		××	
Sponges:	O	×—×	
Coelenterates:			
Stromatoporoids (A)	×	× ?	
Milleporoids	×		
Rugose (A)		×···	
Tabulate (A)		× ?	
Scleractinian	×		
Alcyonarian	O	×—×	
Bryozoans:	O	×—×	O
Brachiopods:		××	
Mollusks:			
Chitons	×		
Pelecypods	×	××	×
Gastropods	×	××	×
Pteropods	×		
Cephalopods (most)	×		
Belemnoids and Aptychi (A)		×	
Annelids (Serpulids):	×	×—×	×
Arthropods:			
Decapods		×—×	
Ostracodes		×—×	
Barnacles		××	
Trilobites (A)		×	
Echinoderms:		×——×	

× Common O Rare (A) Not based on modern forms

Figure 5. Original shell skeletal composition (from Scholle, 1978). Aragonite shells generally lose their microstructure during diagenesis, whereas calcite and Mg-calcite shells retain their microstructure.

Cement

C - Calcite

S - Silica

B - Bitumen

A - Anhydrite

H - Halite

D - Dolomite

G - Gypsum

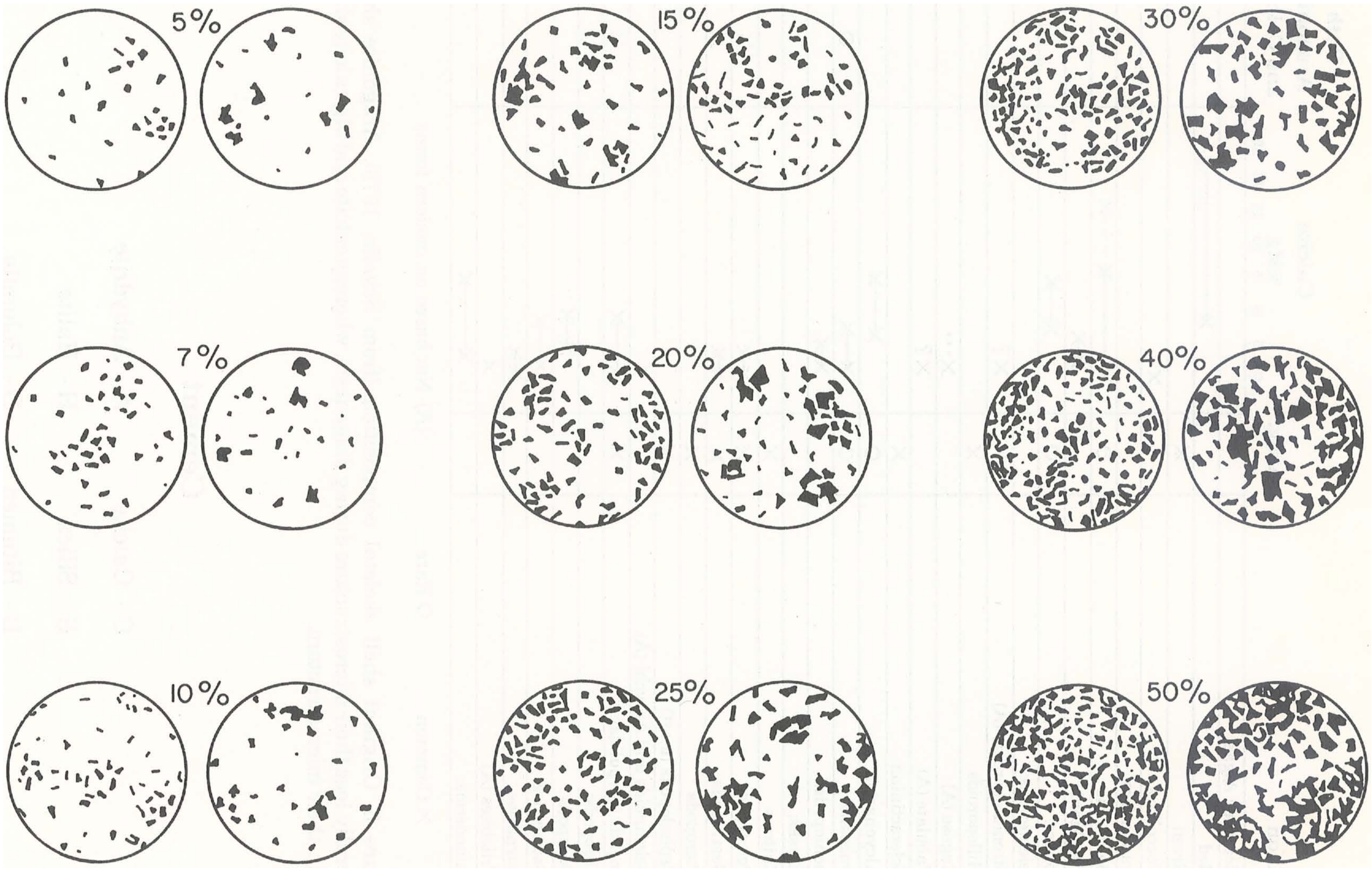


Figure 6. Charts for estimating percentages of angular grains in samples. From Terry and Chilingar (1955).

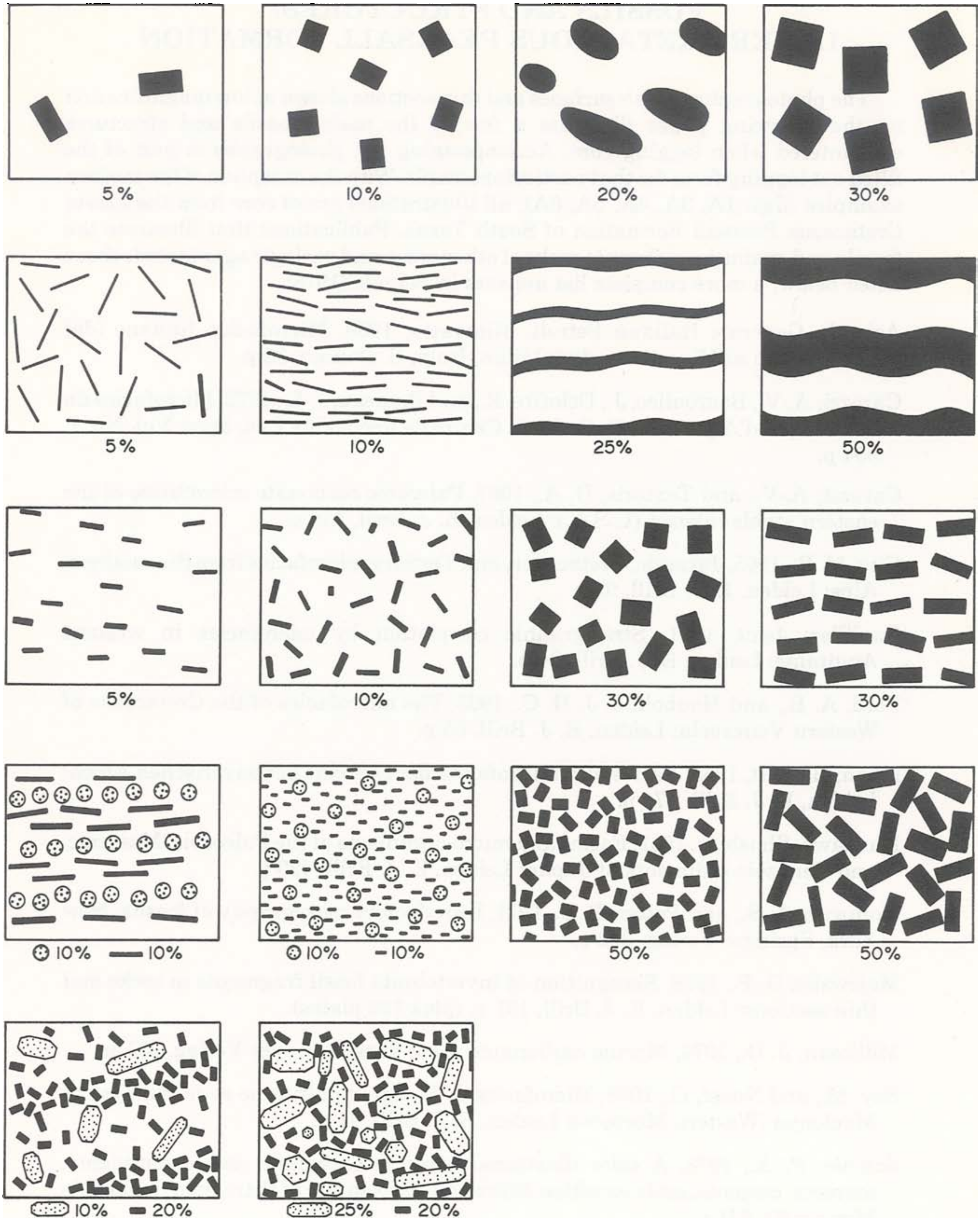


Figure 7. Charts for estimating percentages of irregularly shaped grains of various shapes.

FOSSILS AND STRUCTURES: LOWER CRETACEOUS PEARSALL FORMATION

The photographs of slab surfaces and thin sections shown at low magnification on the following pages illustrate a few of the major fossils and structures encountered when logging core. Accompanying the photographs is part of the filled-out logging form for that particular sample. With the exception of the modern examples (figs. 1A, 3A, 4A, 5A, 6A), all illustrations are of core from the Lower Cretaceous Pearsall Formation of South Texas. Publications that illustrate the fossils and grains in carbonate rocks of other areas and geologic ages include those listed below; a more complete list appears in Scholle (1978).

Azienda Generale Italiana Petroli, Mineraria, 1959, Microfacies Italiane (dal Carbonifero al Mioceno medio): Milan, Italy, S. Donato, 35 p.

Carozzi, A.-V., Bouroullec, J., Deloffre, R., and Rumeau, J.-L., 1972, Microfacies du Jurassique d'Aquitaine: Bulletin du Centre de Recherche Pau, Spec. Vol. No. 1, 594 p.

Carozzi, A.-V., and Textoris, D. A., 1967, Paleozoic carbonate microfacies of the eastern stable interior (U.S.A.): Leiden, E. J. Brill, 146 p.

Cita, M. B., 1965, Jurassic, Cretaceous, and Tertiary microfacies from the southern Alps: Leiden, E. J. Brill, 99 p.

Cuvillier, Jean, 1961, Stratigraphic correlation by microfacies in western Aquitaine: Leiden, E. J. Brill, 34 p.

Ford, A. B., and Houbolt, J. J. H. C., 1963, The microfacies of the Cretaceous of Western Venezuela: Leiden, E. J. Brill, 55 p.

Hagn, Herbert, 1955, Fazies und Mikrofauna der Gesteine der bayerischen Alpen: Leiden, E. J. Brill, 174 p.

Hanzawa, Shoshiro, 1961, Facies and micro-organisms of the Paleozoic, Mesozoic, and Cenozoic sediments of Japan: Leiden, E. J. Brill, 420 p.

Horowitz, A. S., and Potter, P. E., 1971, Introductory petrography of fossils: New York, Springer-Verlag, 302 p.

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Rey, M., and Nouet, G., 1958, Microfacies de la région prérifaine et de la moyenne Moulouya (Western Morocco): Leiden, E. J. Brill, 41 p.

Scholle, P. A., 1978, A color illustrated guide to carbonate rock constituents, textures, cements, and porosities: American Association of Petroleum Geologists Memoir 27, 241 p.

Wilson, J. L., 1975, Carbonate facies in geologic history: New York, Springer-Verlag, 471 p.

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Choquette, P. W., and Pray, L. C., 1970, Geologic nomenclature and classification of porosity in sedimentary carbonates: American Association of Petroleum Geologists Bulletin, v. 54, p. 207-250.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture, *in* Ham, W. E., ed., Classification of carbonate rocks: American Association of Petroleum Geologists Memoir 1, p. 108-121.

Embry, A. R., and Klovan, J. E., 1971, A Late Devonian reef tract on northeastern Banks Island, Northwest Territories: Canadian Petroleum Geologists Bulletin, v. 19, p. 730-781.

Maiklem, W. R., Bebout, D. G., and Glaister, R. P., 1969, Classification of anhydrite—a practical approach: Canadian Petroleum Geologists Bulletin, v. 17, p. 194-233.

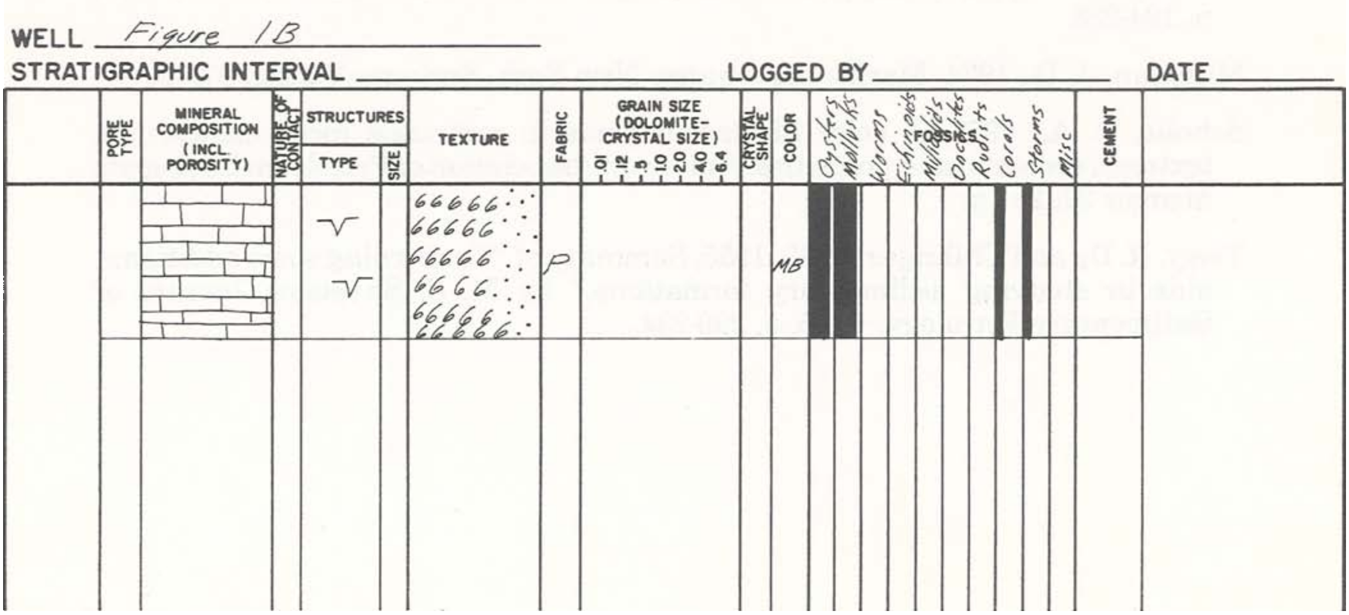
Milliman, J. D., 1974, Marine carbonates: New York, Springer-Verlag, 375 p.

Scholle, P. A., 1978, A color illustrated guide to carbonate rock constituents, textures, cements, and porosities: American Association of Petroleum Geologists Memoir 27, 241 p.

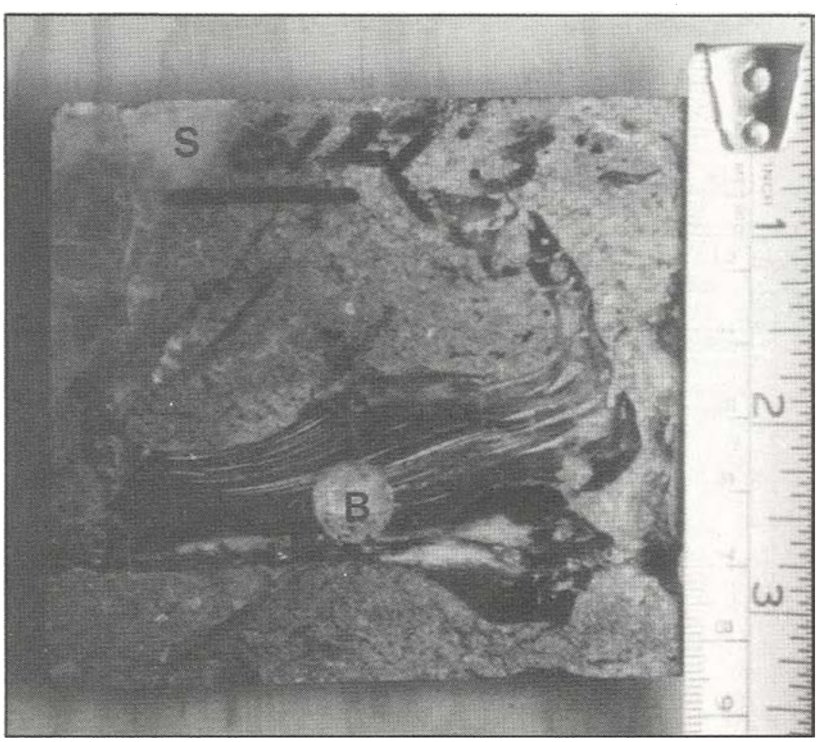
Terry, R. D., and Chilingar, G. V., 1955, Summary of "Concerning some additional aids in studying sedimentary formations," by M. S. Shvetsov: Journal of Sedimentary Petrology, v. 25, p. 229-234.

Figure 1A. Modern beach gravel showing whole mollusk shells. When these shells are studied in cores, they must be thought of in two dimensions or in a cross-section configuration. Photographed area is approximately three feet in width.

Figure 1B. Large oyster in coralgal-stromatoporoid-rudist packstone. Oyster shells were originally calcite and generally retain their fibrous structure after lithification and diagenesis. Note stromatoporoid (S) and boring (B) in oyster. Tenneco #1 Sirianni (6,127 ft), Frio County, Texas.



1A



1B

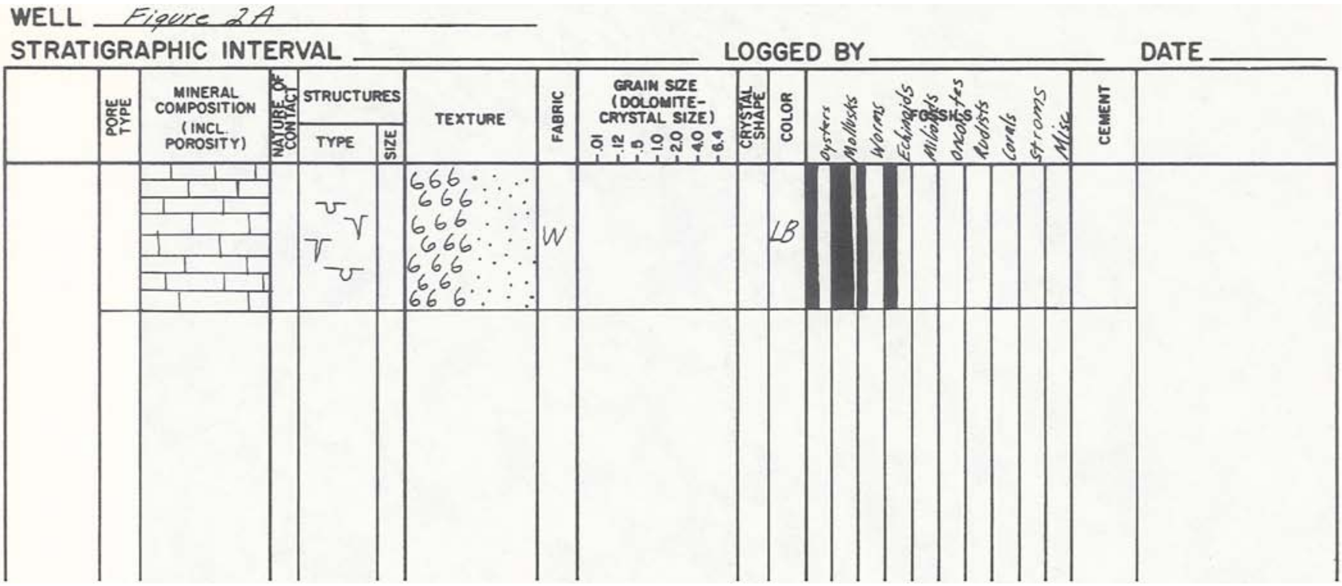
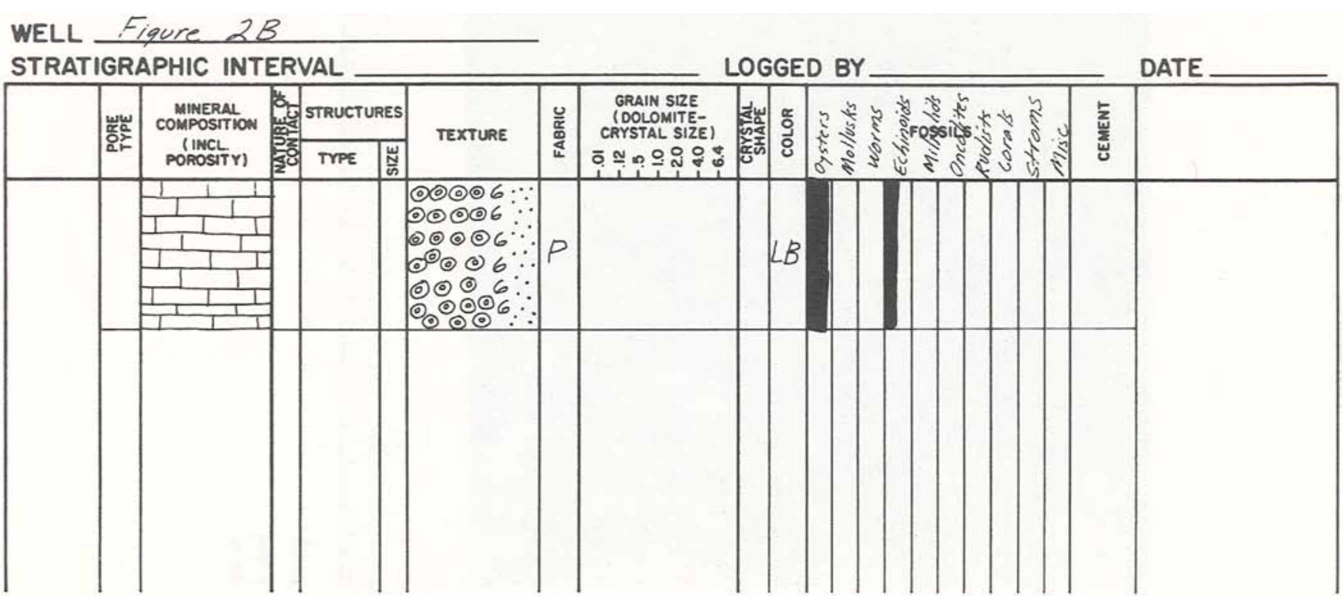
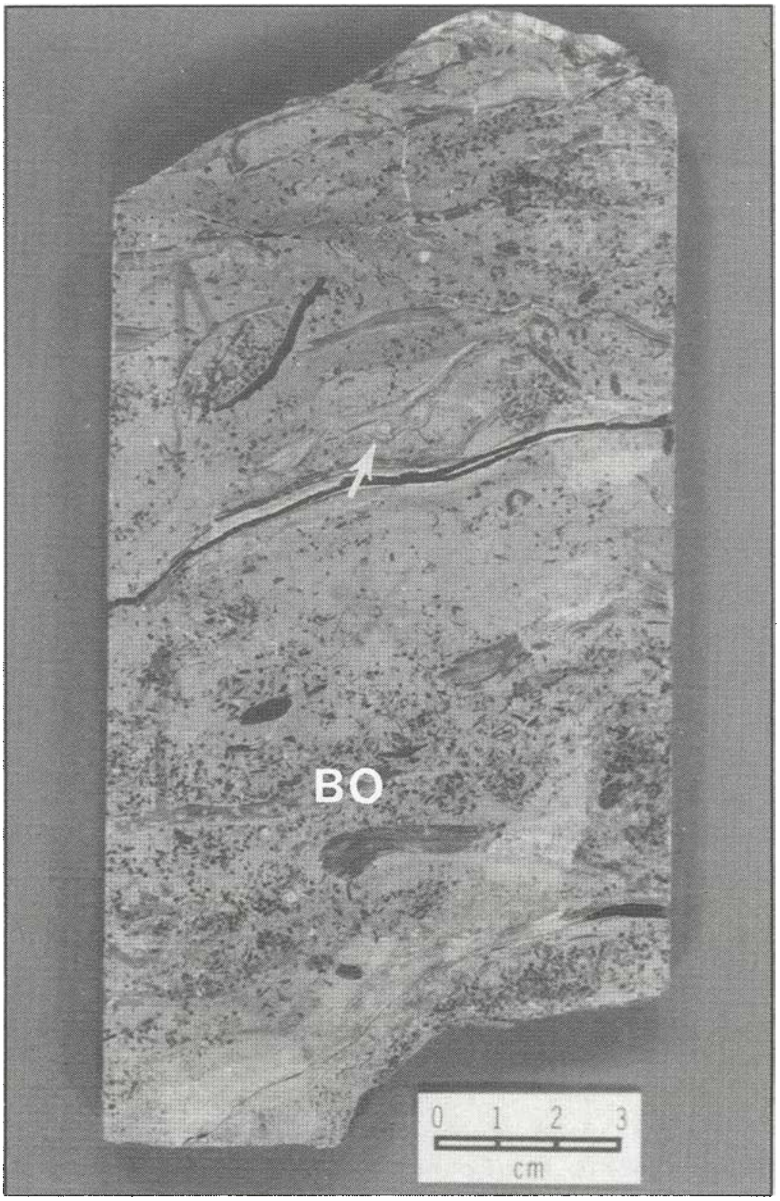


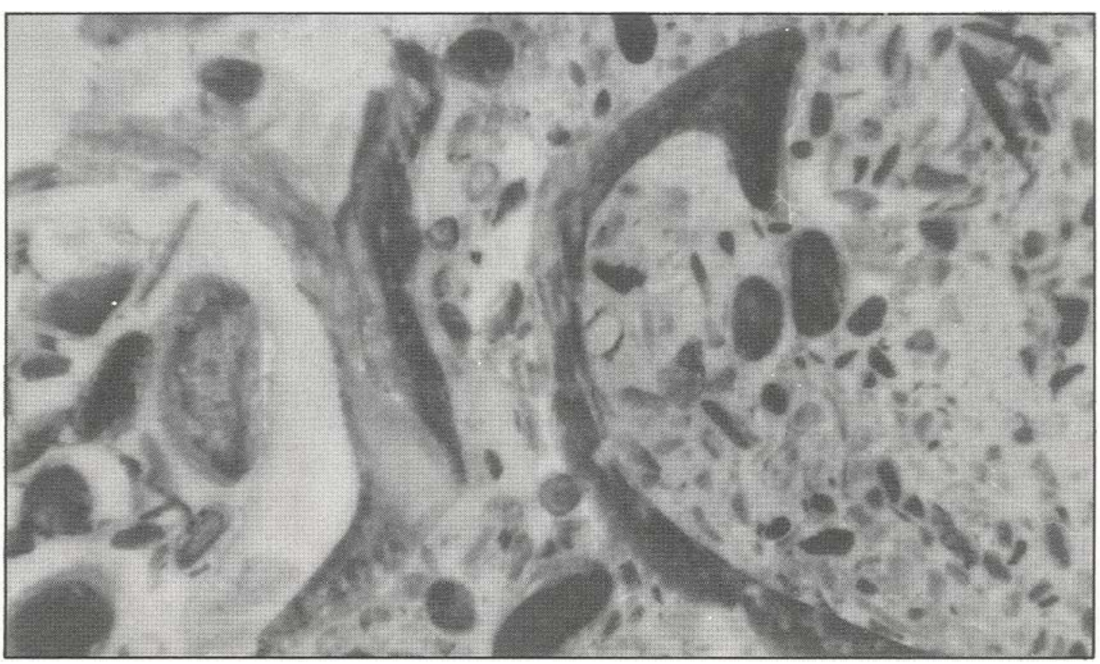
Figure 2A. Broken oyster and *Chondrodonta* shells in echinoid-mollusk wackestone. Note the fibrous structure of the mollusk shells. Some of the shells are bored (BO) and some have serpulid worm tubes attached (arrow). Tenneco #1 Ney (3,291 ft), Medina County, Texas.

Figure 2B. Whole and broken oyster and echinoid fragments in a coated-grain packstone. Note the different sizes and rounding of fragments. Slab surface, x10. Tenneco-Pennzoil #1 Edgar (5,964 ft), Frio County, Texas.





2A



2B

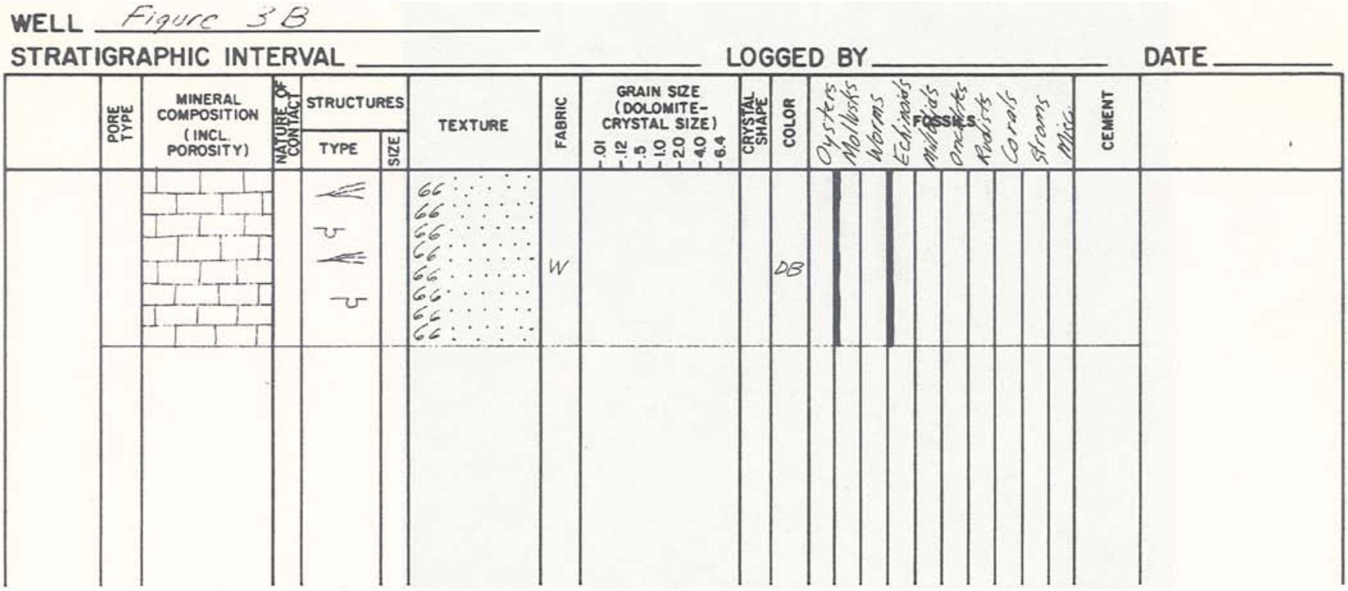
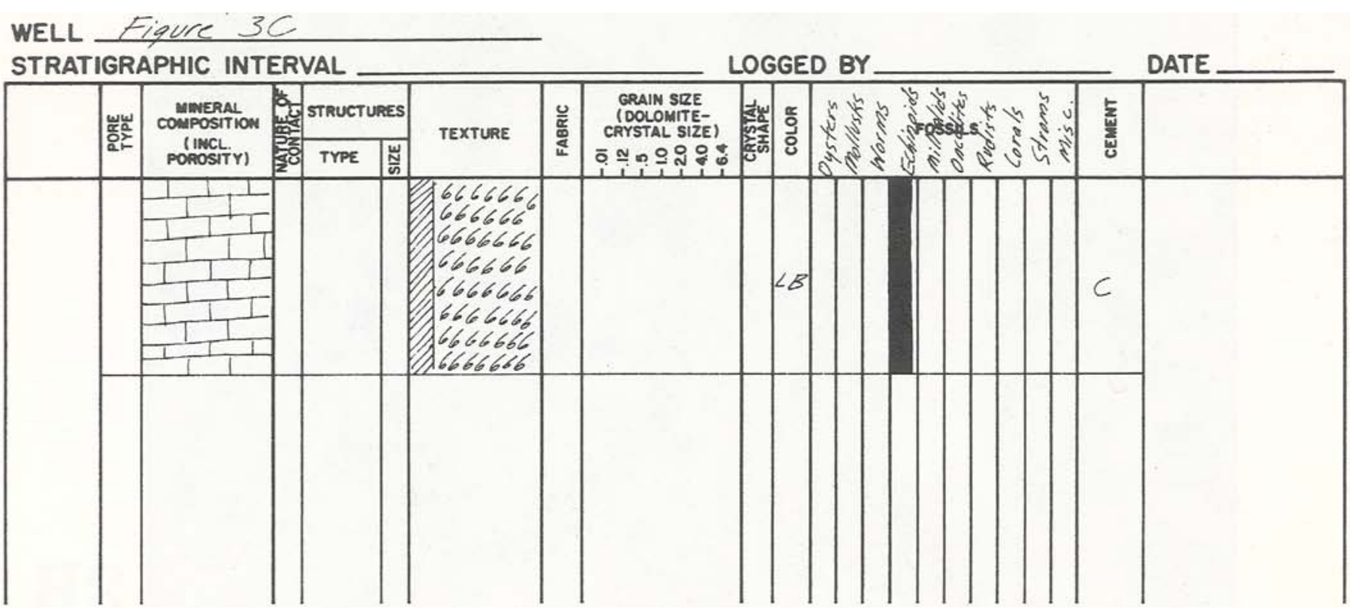


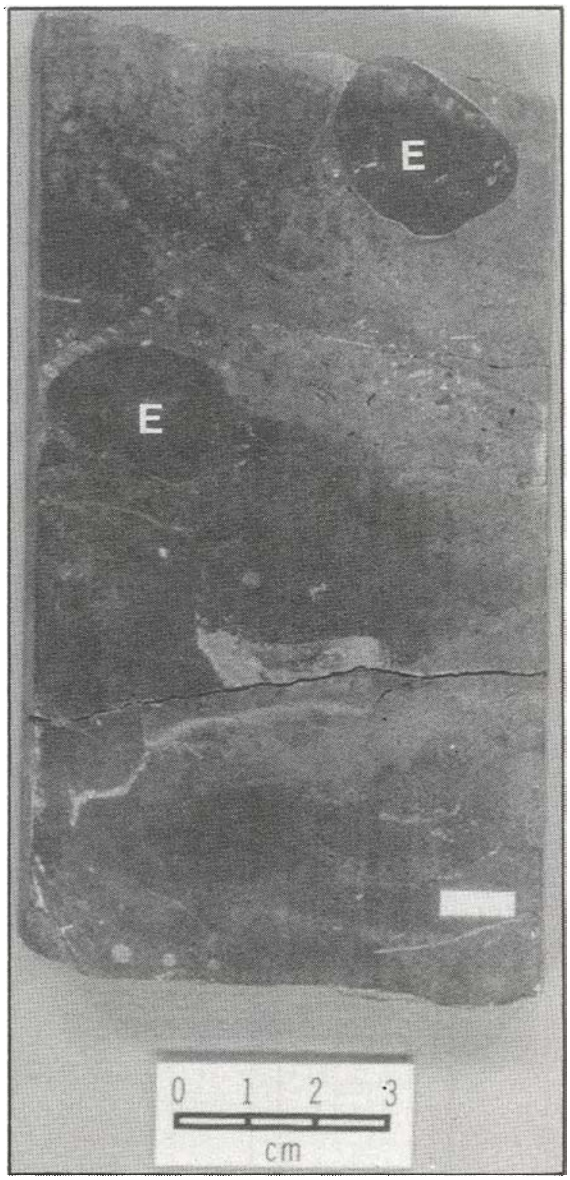
Figure 3A. Modern echinoid (sea urchin) from Florida Bay. After death, echinoids break up into individual plates and spines. Shells are originally Mg-calcite and retain their microstructure.

Figure 3B. Echinoid-mollusk wackestone with whole echinoids (E). Humble #1 Pruitt (9,648 ft), Atascosa County, Texas.

Figure 3C. Closeup of individual plates of echinoids in an echinoid grainstone. Slab surface, x10. Tenneco #1 Mack (7,457 ft), Frio County, Texas.



3A



3B

3C

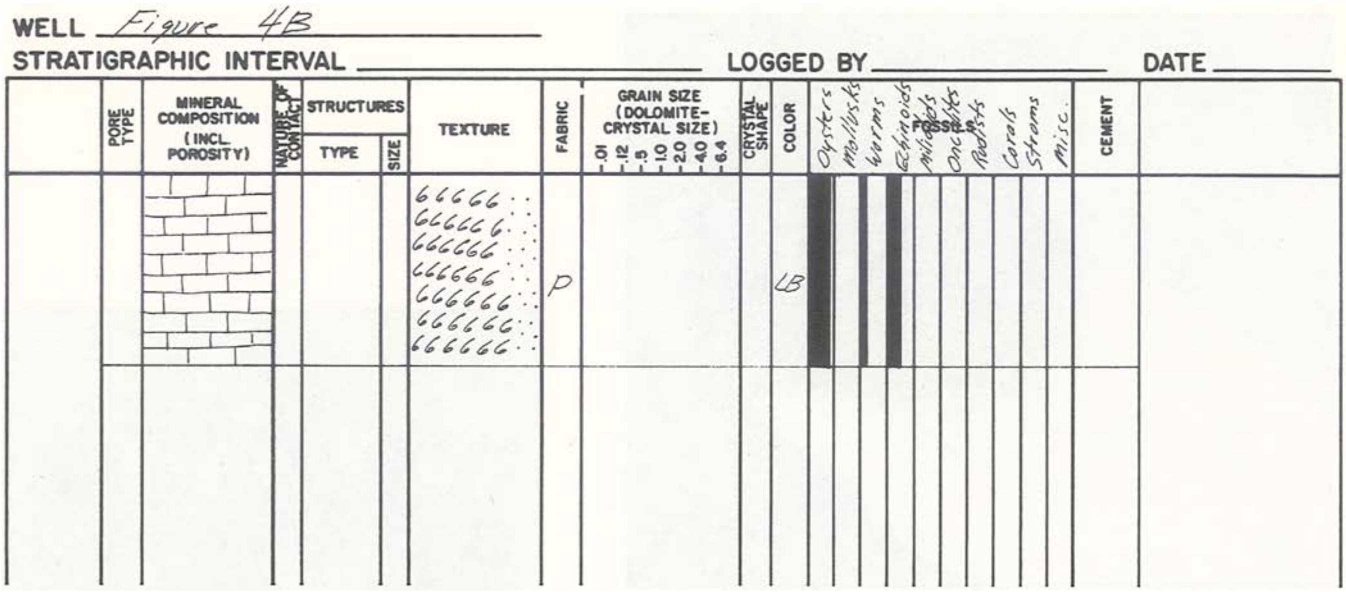
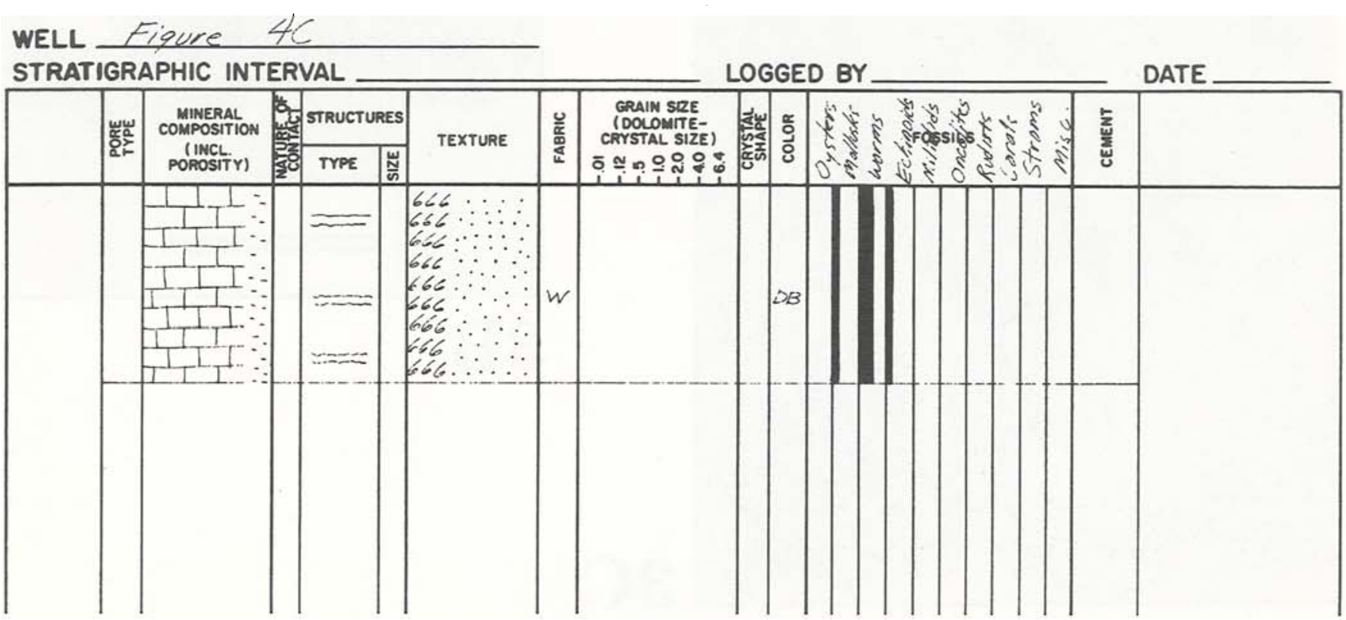
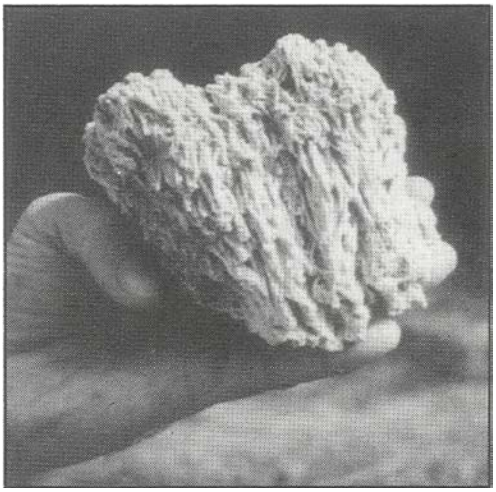


Figure 4A. Modern serpulid worm tubes from Baffin Bay, Texas. The original composition of the tubes was Mg-calcite, and the original microstructure is preserved.

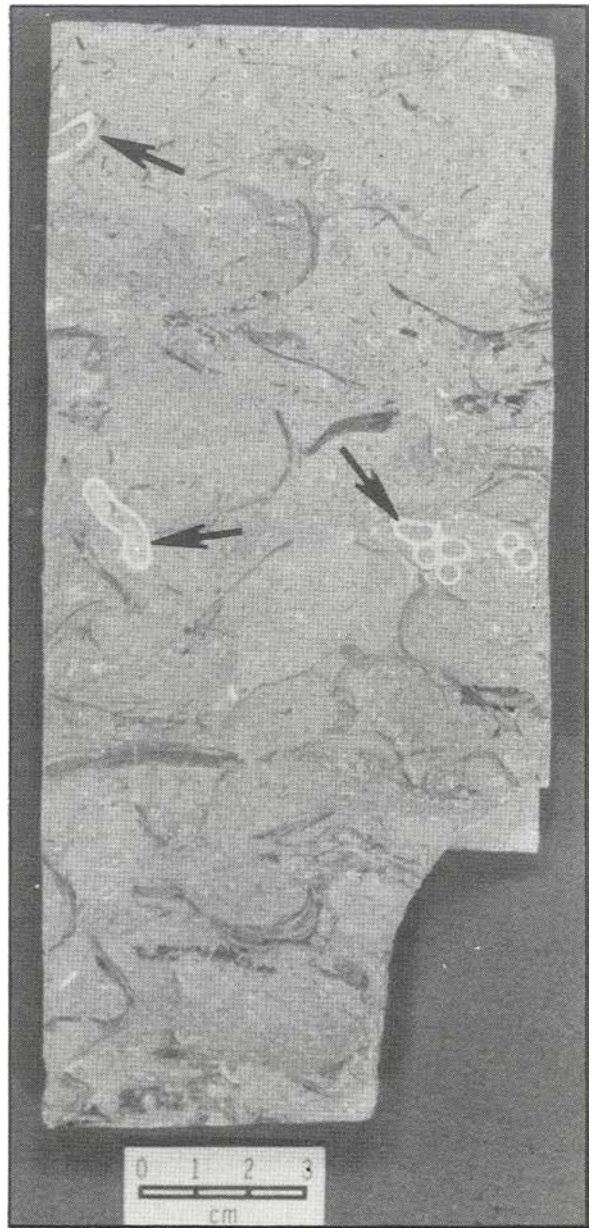
Figure 4B. Serpulid worm tubes (arrows) in an echinoid-oyster packstone. Note broken oyster shells (dark areas). Tenneco #1 Ney (3,491 ft), Medina County, Texas.

Figure 4C. Serpulid worm tubes in an argillaceous echinoid-mollusk wackestone. Slab surface, x5. Tenneco #2 Kiefer, Zavala County, Texas.

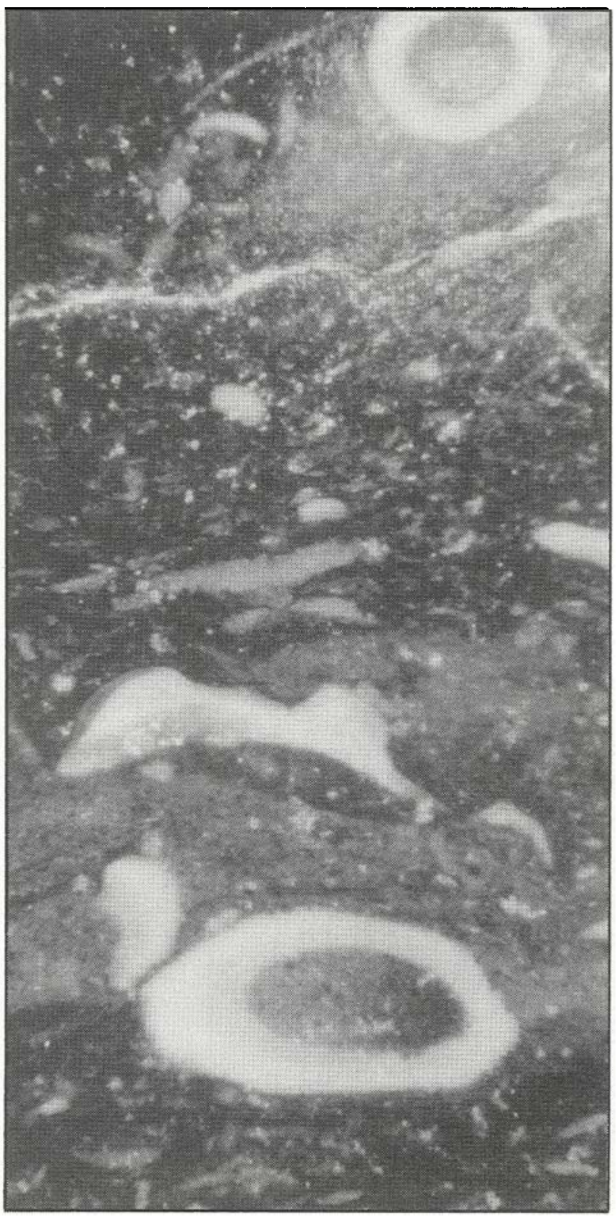




4A



4B

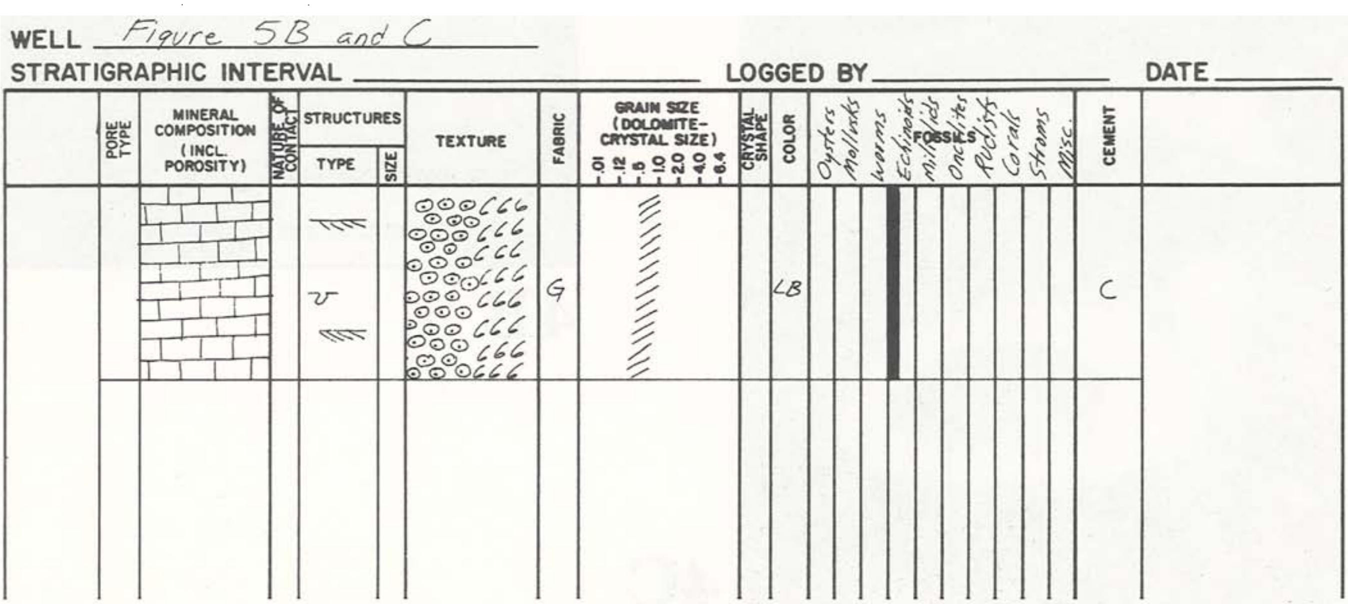


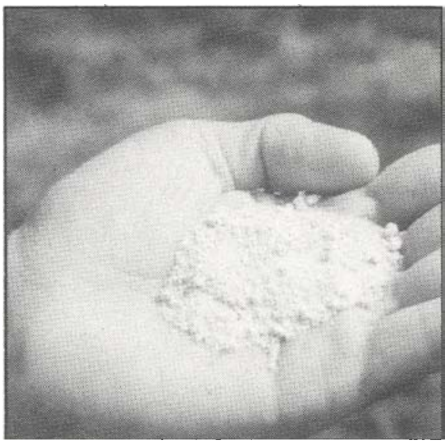
4C

Figure 5A. Modern ooid sand from Bermuda.

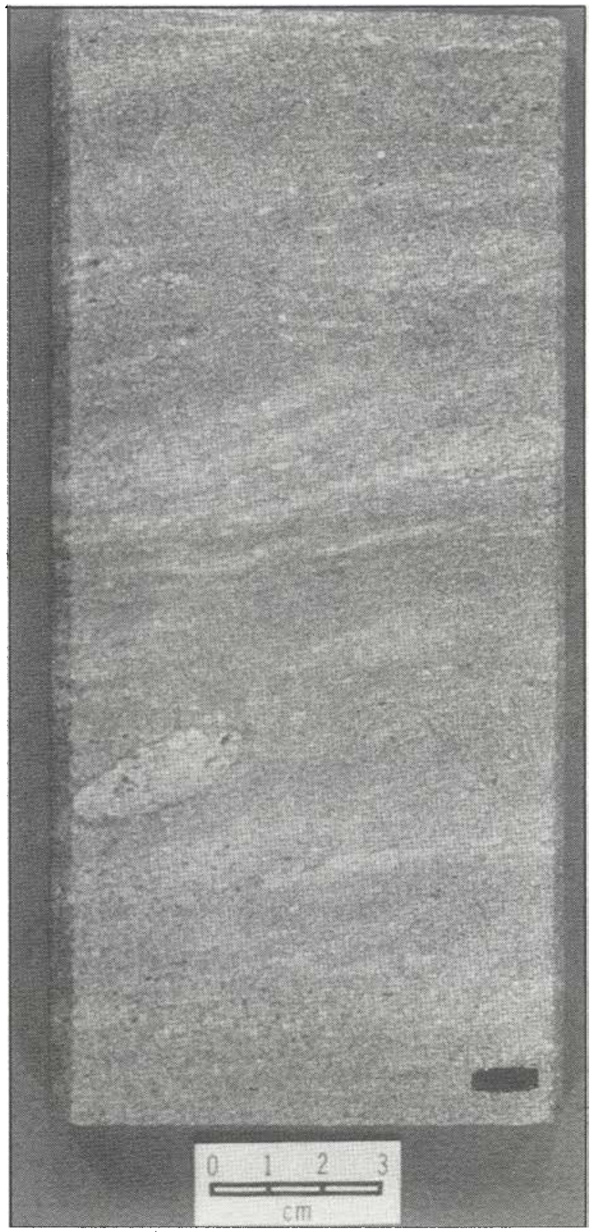
Figure 5B. Crossbedded, ooid-skeletal grainstone. Ooid grainstones are commonly crossbedded, reflecting high-energy environment of deposition. Tenneco #1 Mack (7,457 ft), Frio County, Texas.

Figure 5C. Ooid rims with nuclei of red-algae, echinoid, and mollusk grains. Thin section, x15.





5A

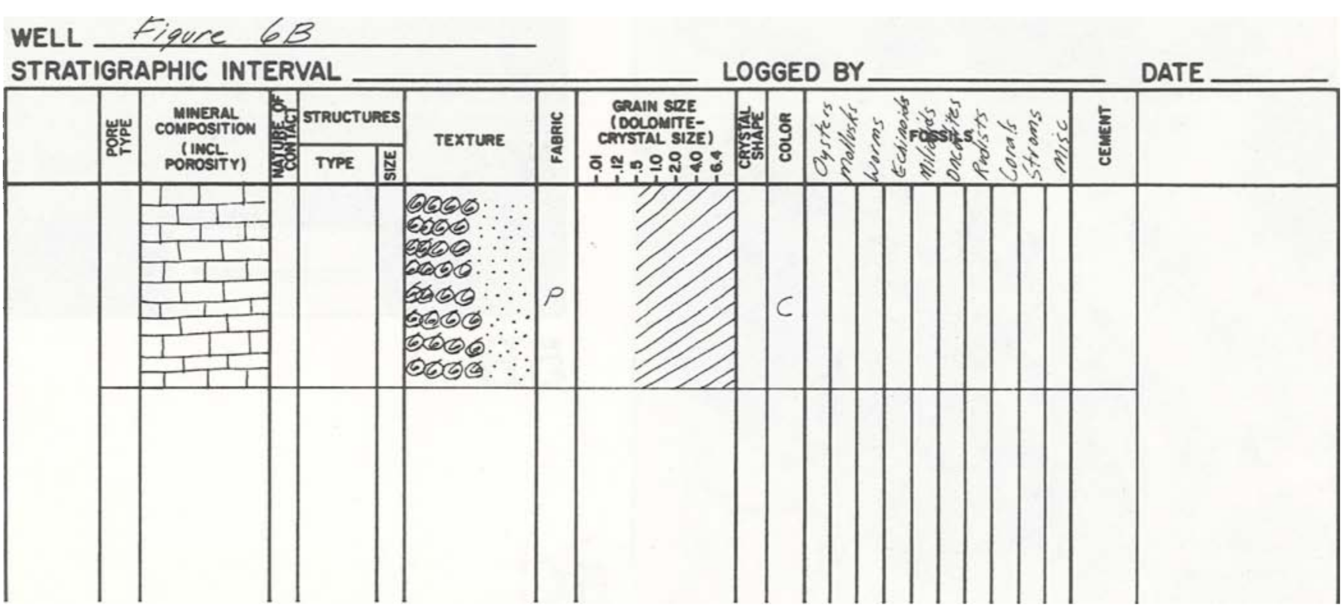


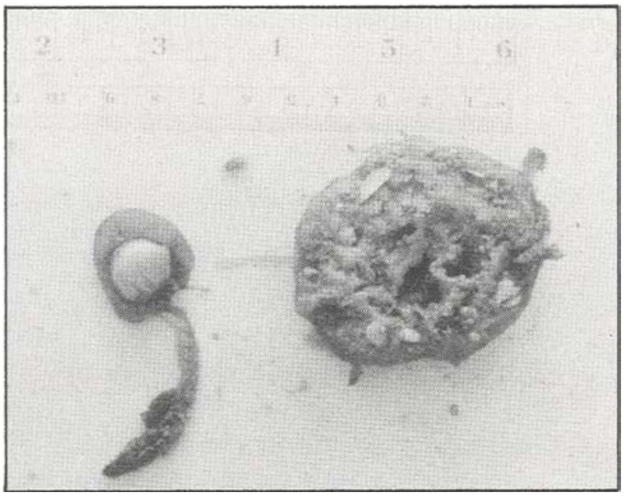
5B

5C

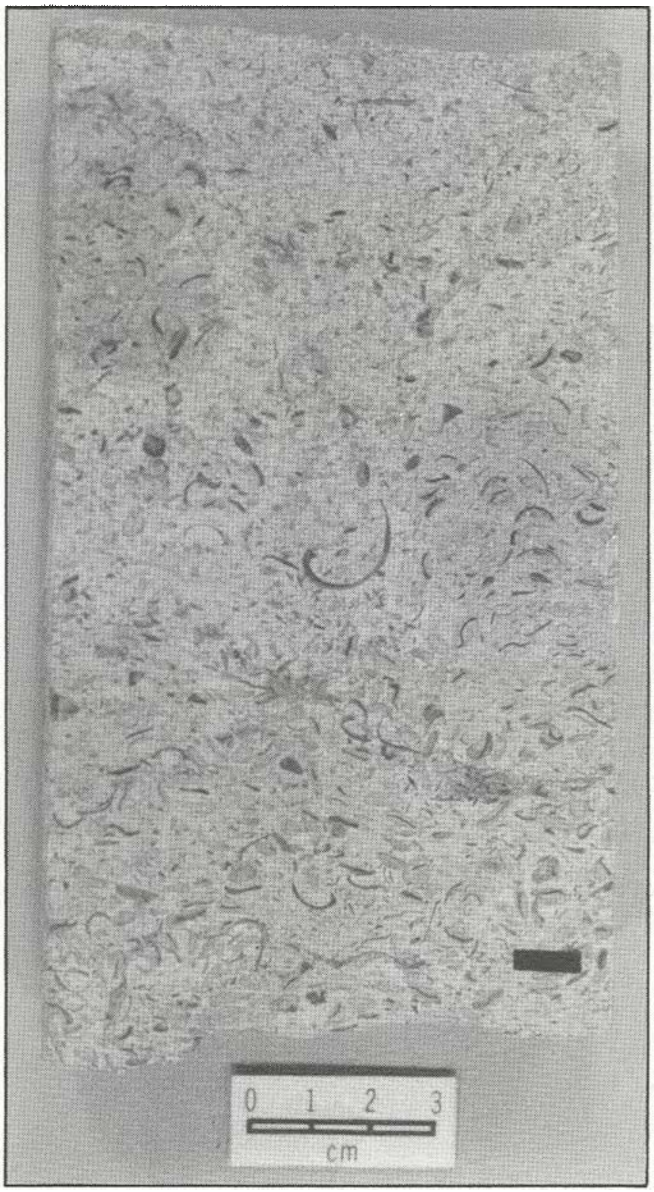
Figure 6A. Modern oncolites from a moderate-energy area in Florida Bay. The blue-green algae coat mollusk shells and trap carbonate mud, which is preserved as irregular laminae.

Figure 6B. Oncolite packstone. Most of the coated grains are mollusk fragments. Tenneco #1 Powell (4,771 ft), Medina County, Texas.





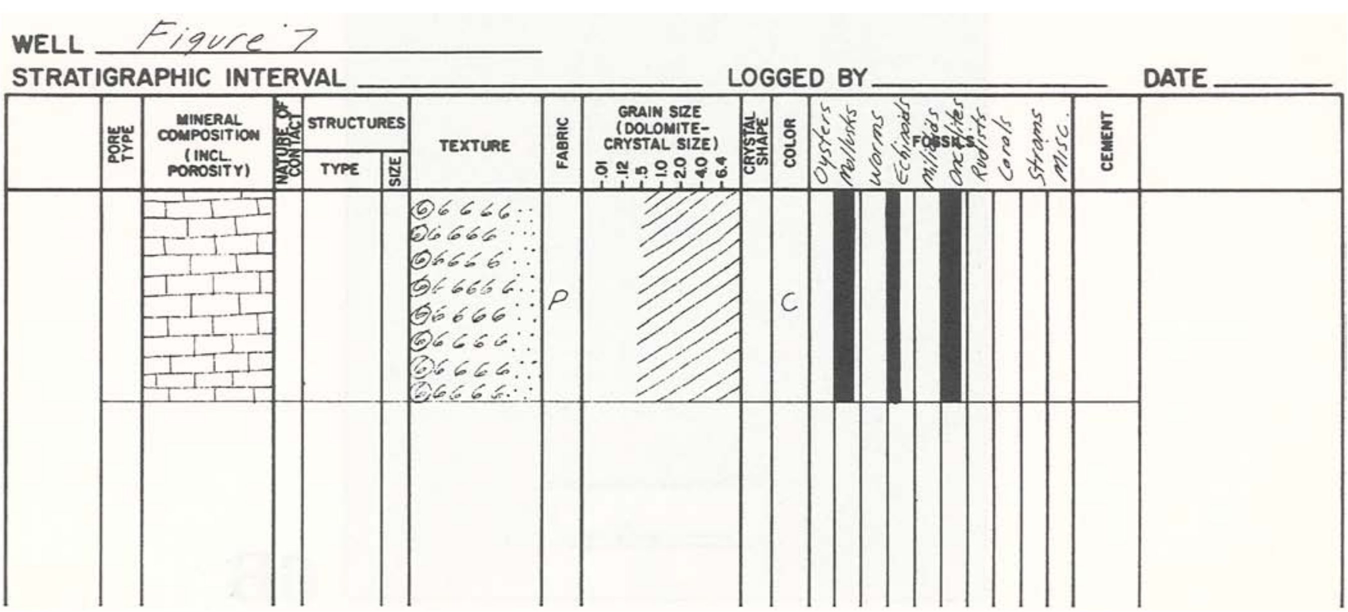
6A



6B

Figure 7A. Closeup of oncolites in oncolite packstone. Note the irregular laminae around grains. Thin section, x10. Tenneco #1 Powell (4,771 ft), Medina County, Texas.

Figure 7B. Closeup of oncolites. The light spots (arrows) are encrusting foraminifers. Slab surface, x15. Tenneco #1 Powell (4,771 ft), Medina County, Texas.

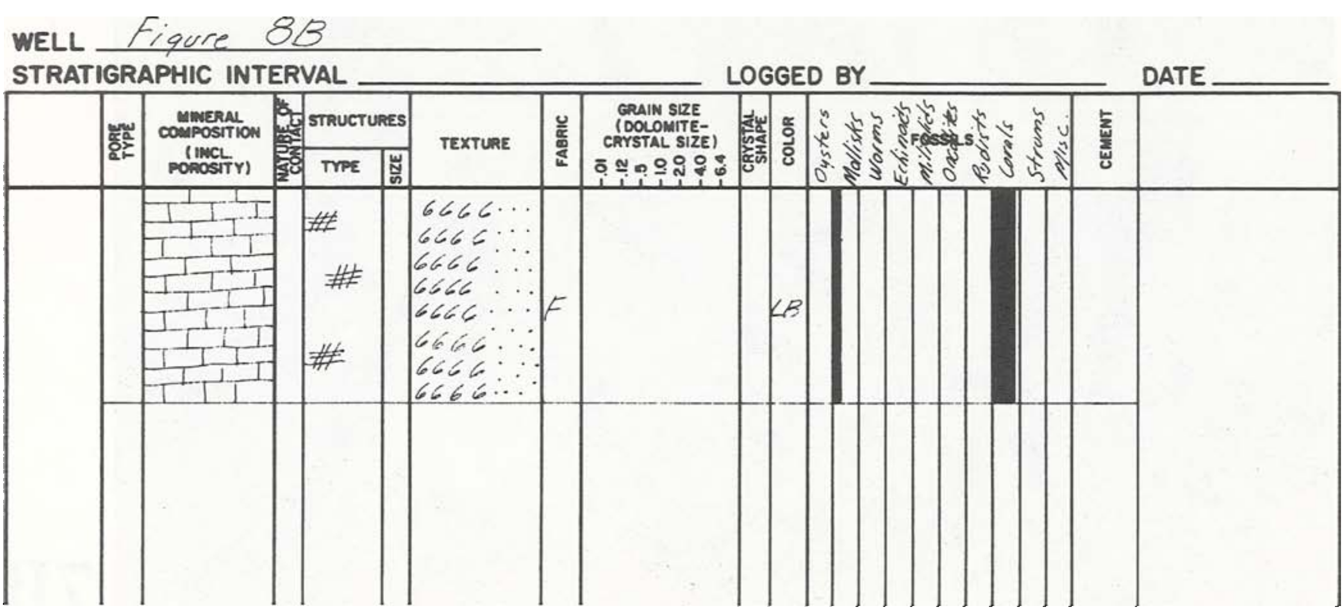


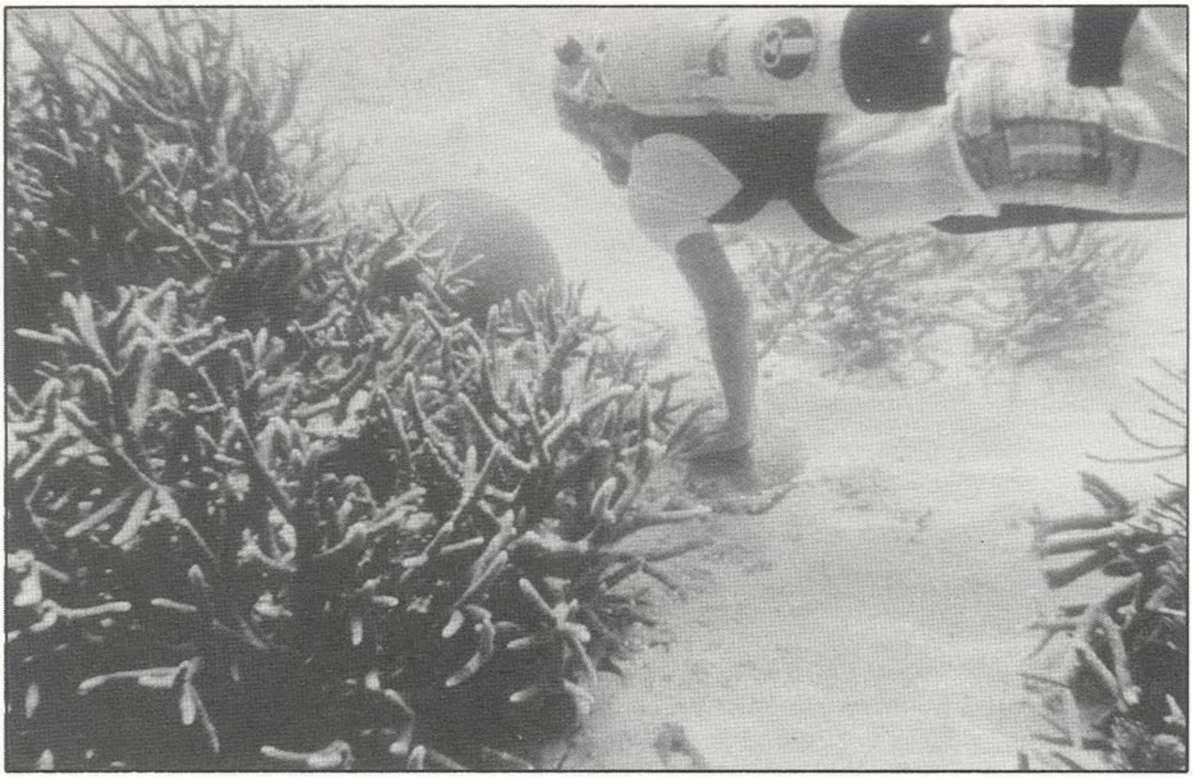

7A


7B

Figure 8A. Branching stick coral *(Acropora cervicornus)* from the Florida reef tract.

Figure 8B. Coral framestone. The corals shown on the slab are from a single branching colony. A wackestone matrix fills in between the branching coral. Tenneco #1 Sirianni (6,180 ft), Frio County, Texas.



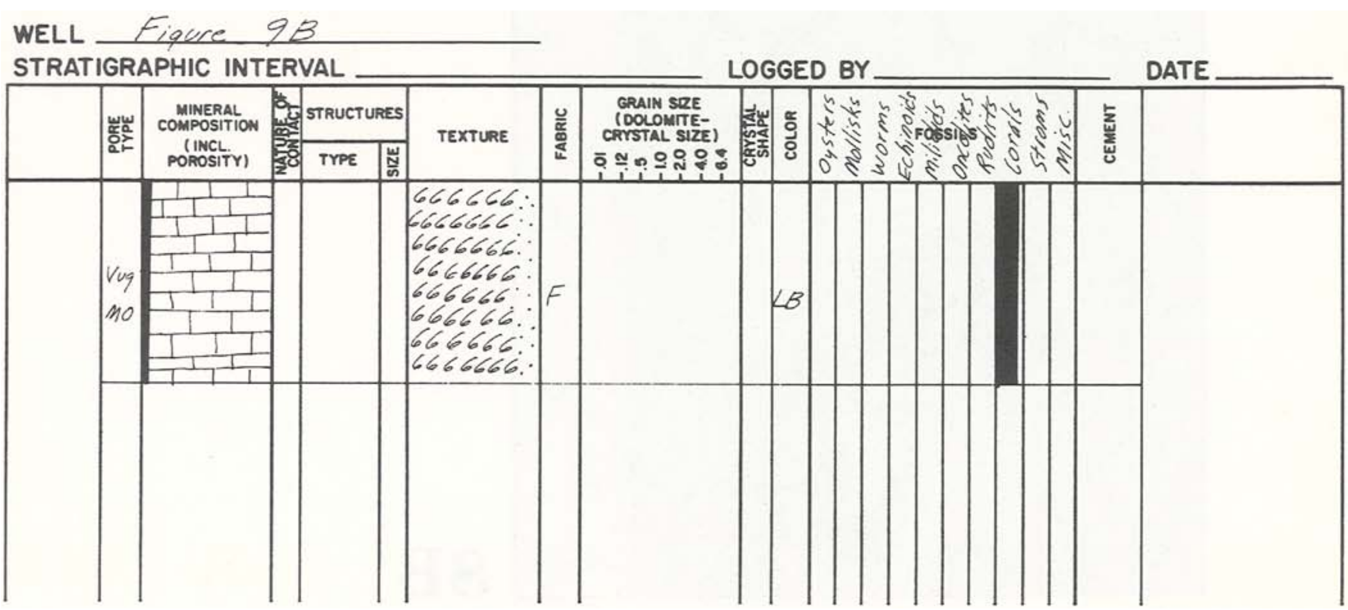


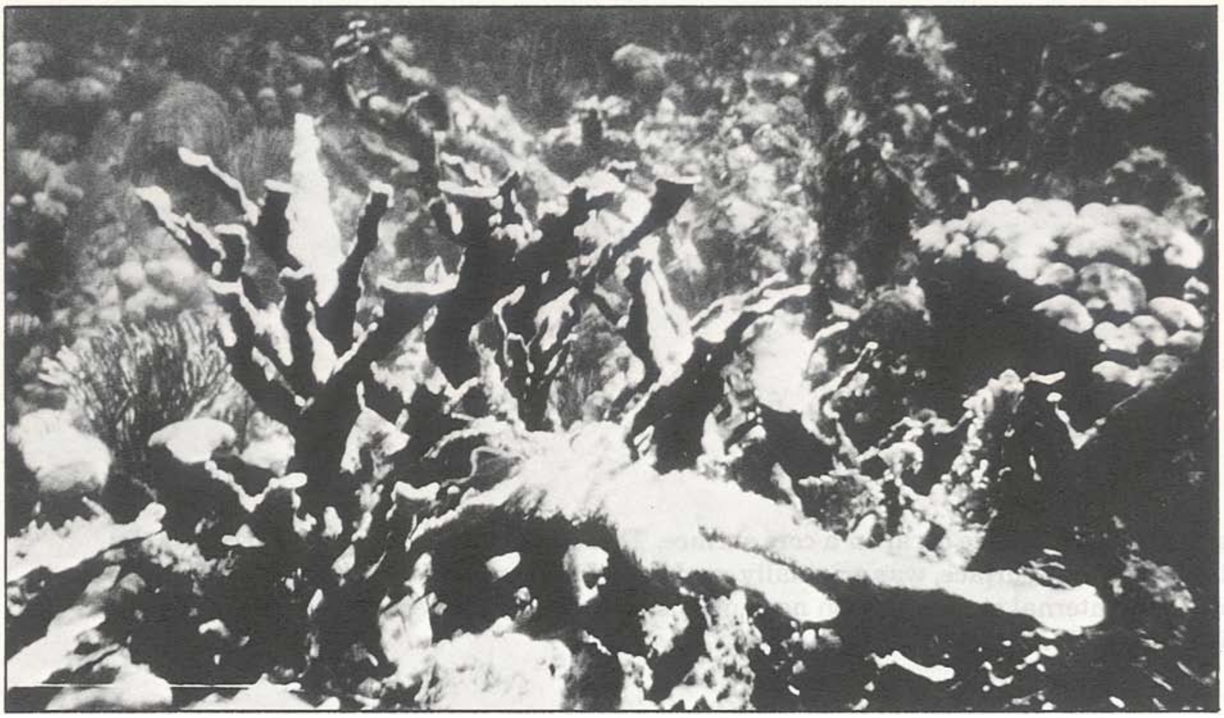
8A

8B

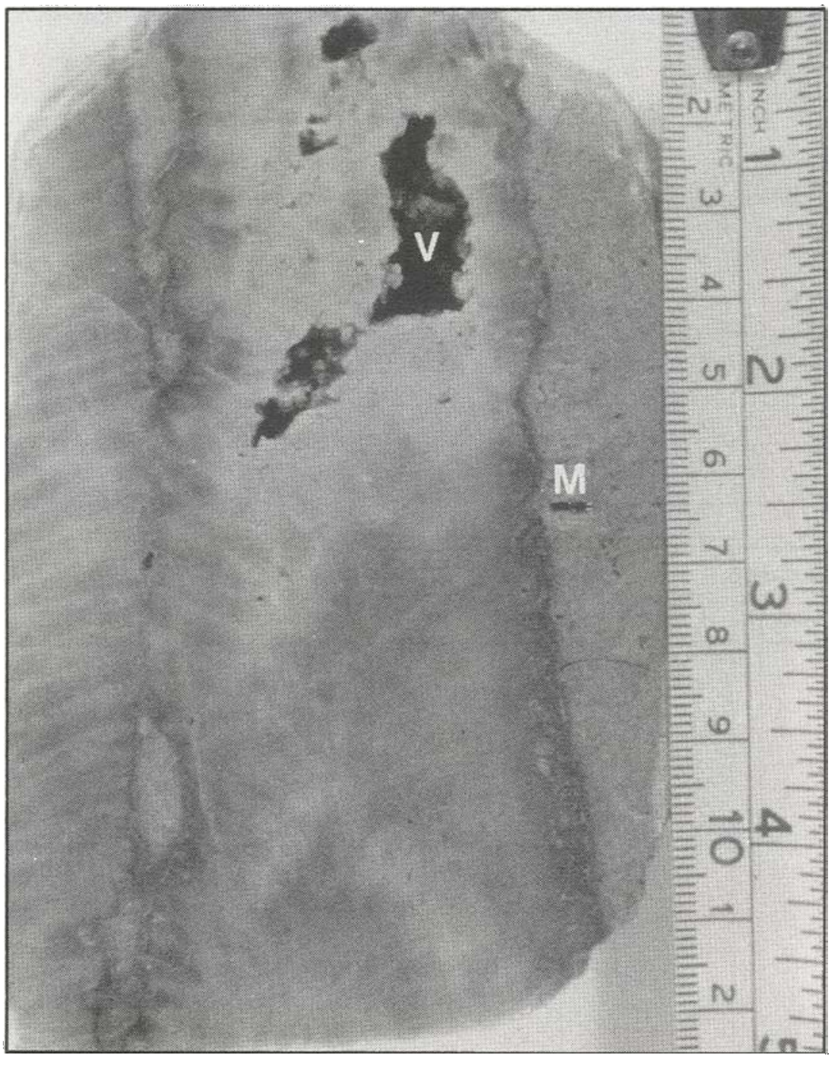
Figure 9A. Branching and massive corals from the reef tract on the east side of the Great Bahama Bank. The photographed area is approximately 10 ft in width.

Figure 9B. Part of a massive coral from a coralgal-stromatoporoid-rudist framestone. Coral contains vuggy porosity (V), and packstone matrix has minor moldic porosity (M). Tenneco #1 Wilson (4,323 ft), Medina County, Texas.





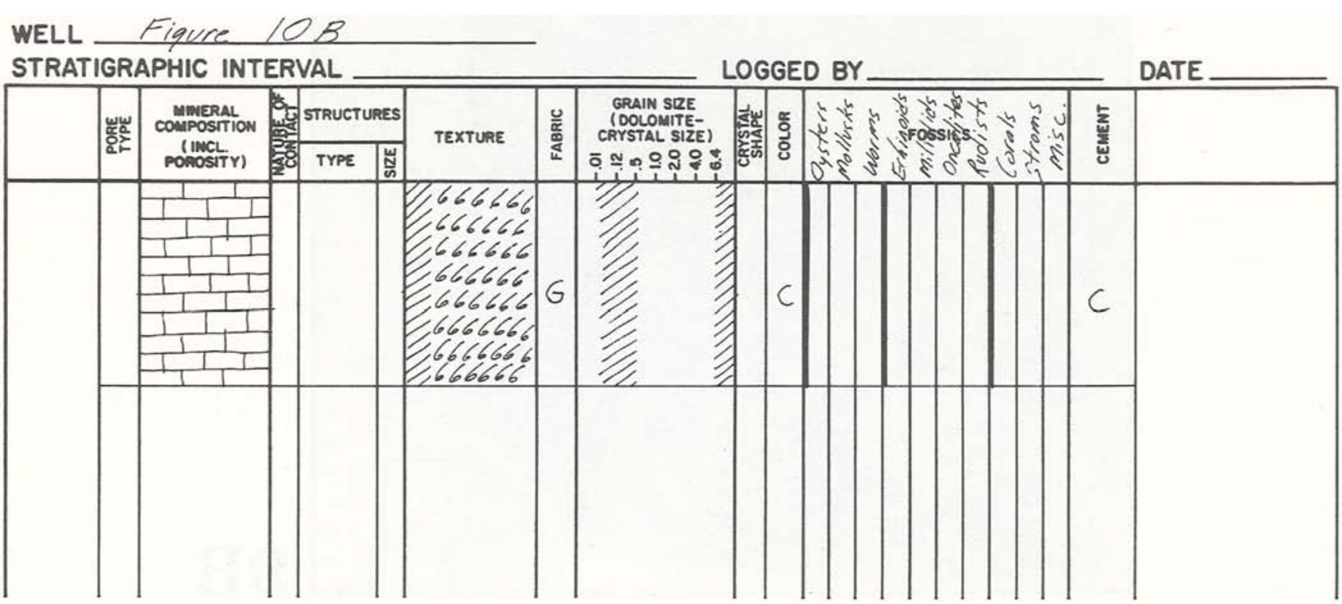
9A

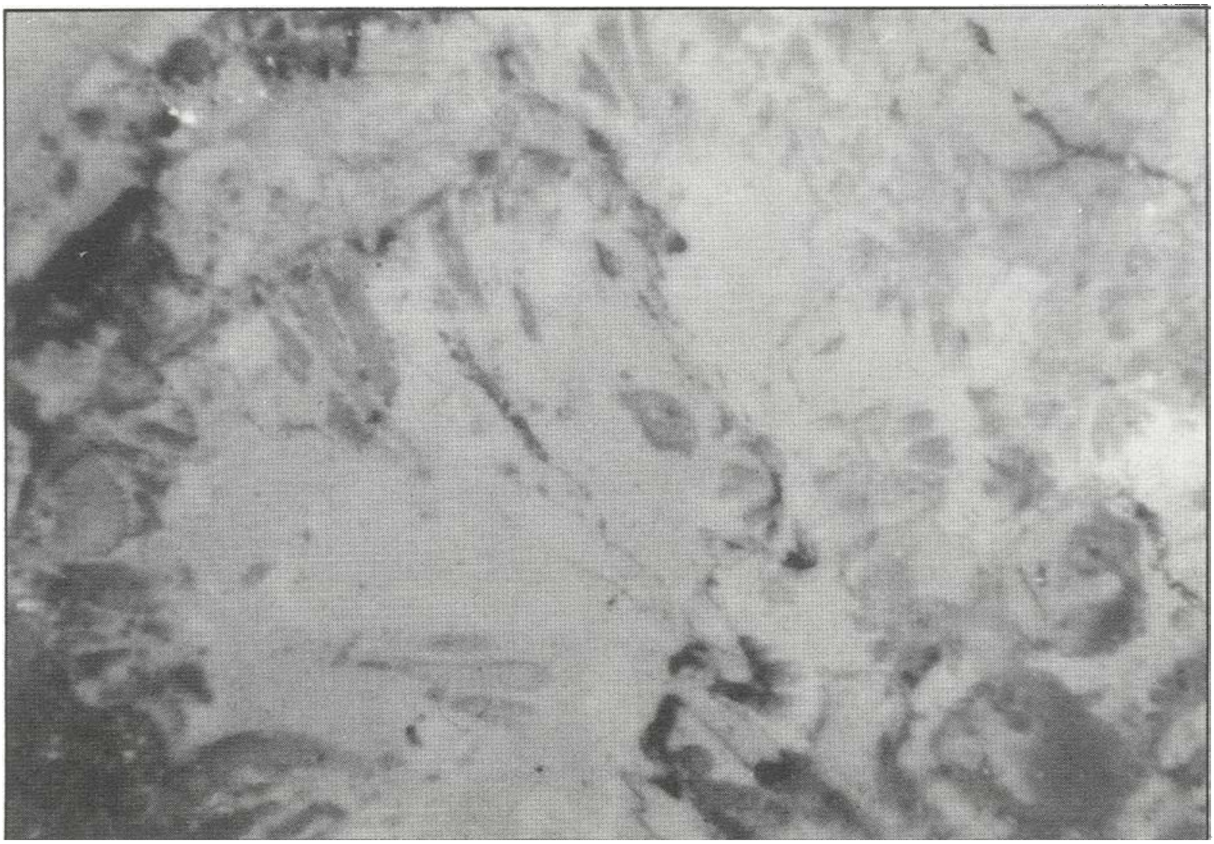


9B

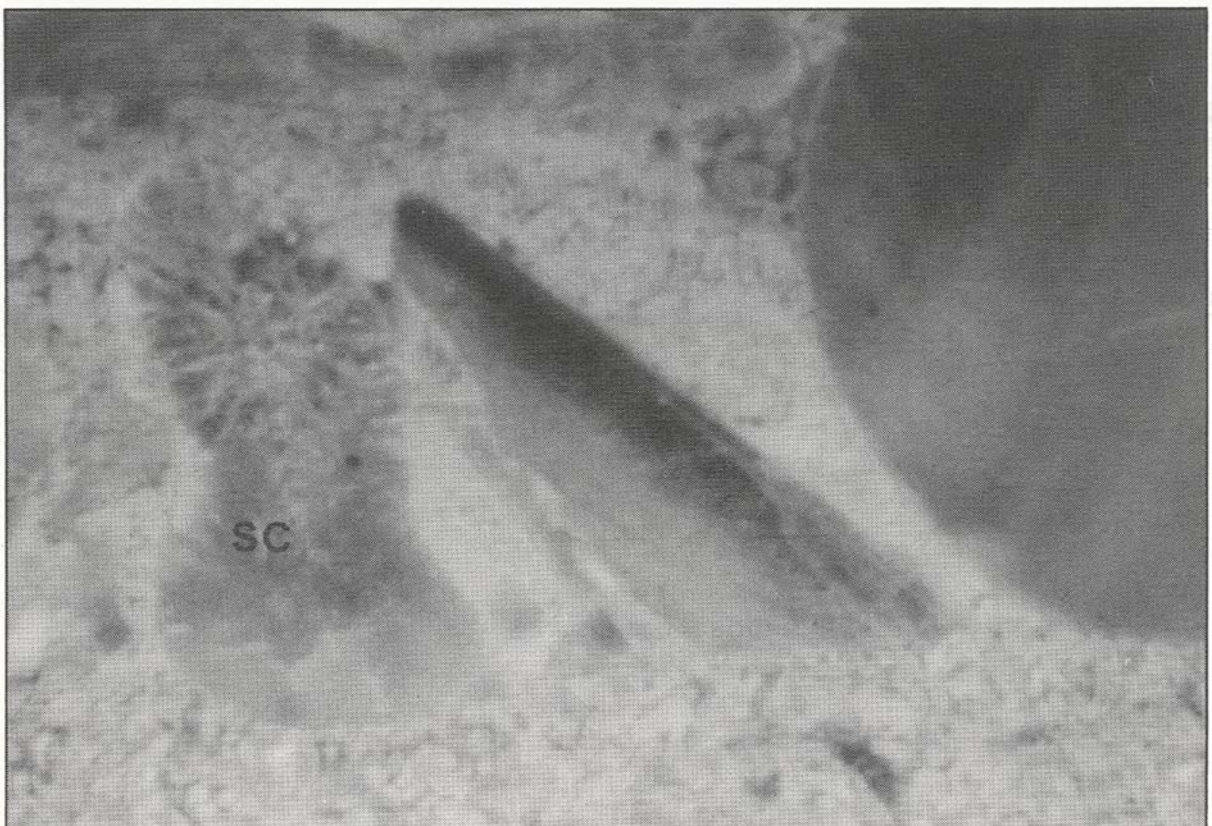
Figure 10A. Massive coral on a core surface. This scleractinian coral, which covers the entire illustrated surface, was originally made up of aragonite and during diagenesis lost most of its internal structure upon neomorphism to calcite. Tenneco #1 Sirianni (6,287 ft), Frio County, Texas. Slabbed surface, X2.

Figure 10B. Closeup of a small stick coral (SC) in core slab of coral-echinoid-mollusk grainstone. Tenneco #1 Ney (3,422 ft), Medina County, Texas. Slabbed surface, X5.





10A



10B

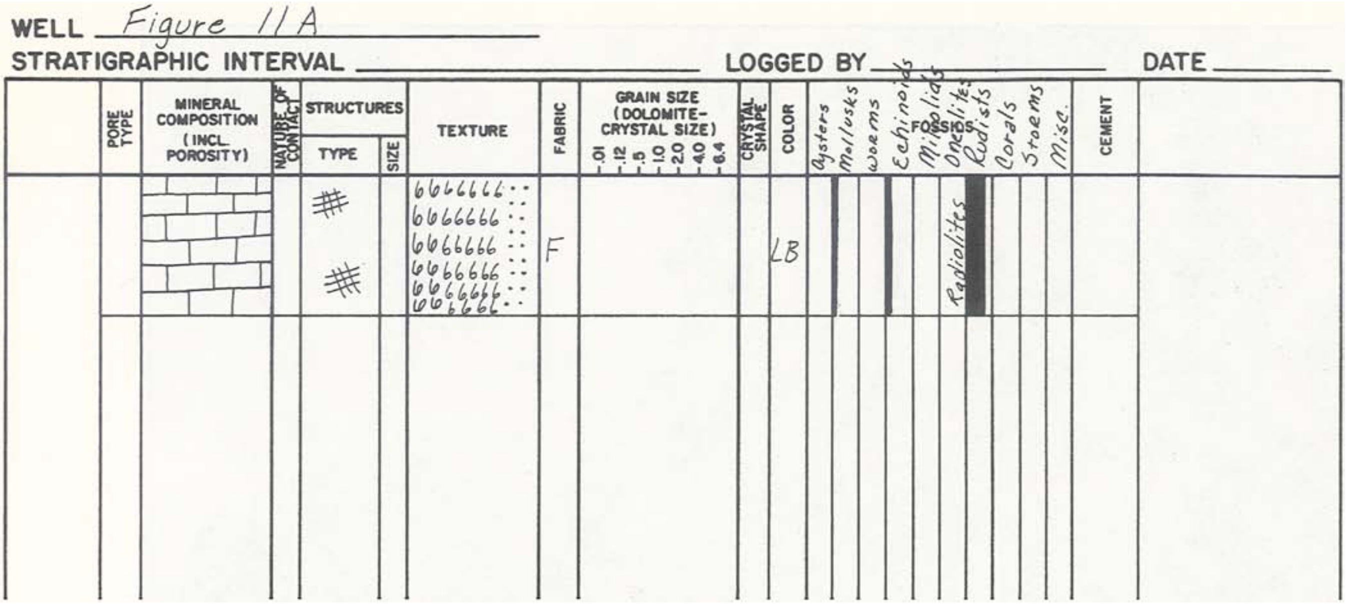
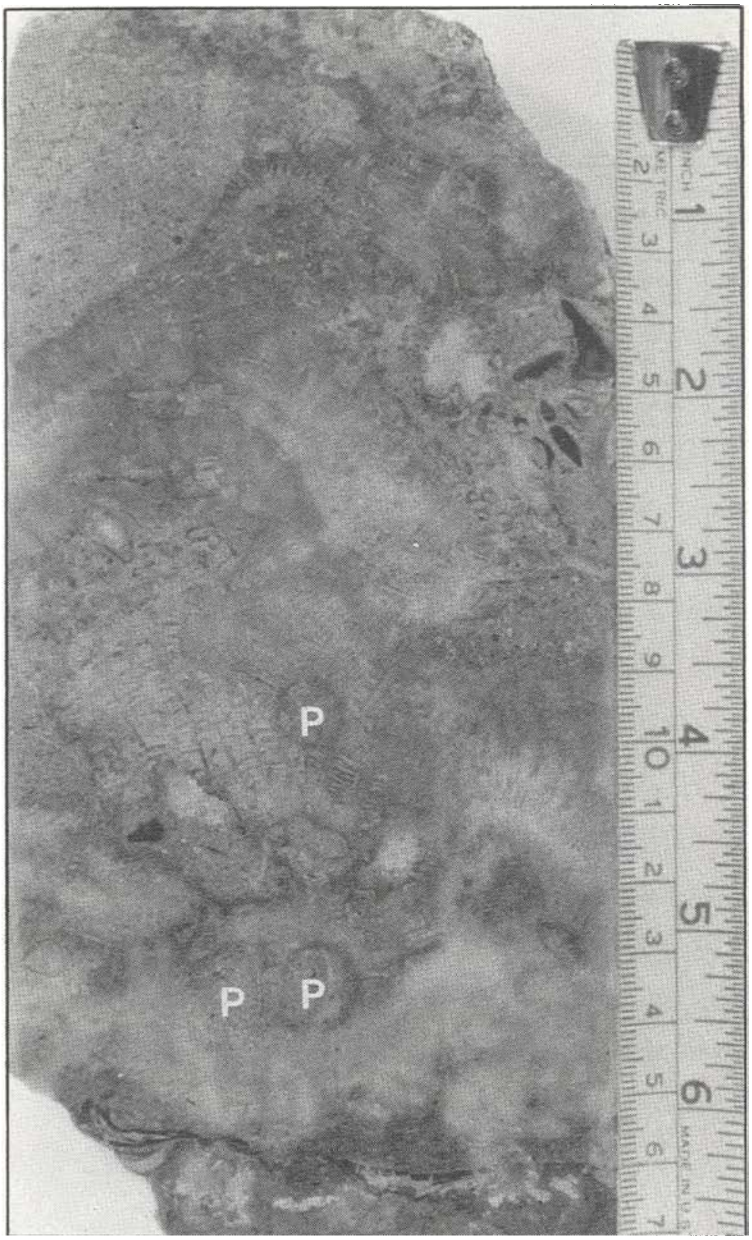
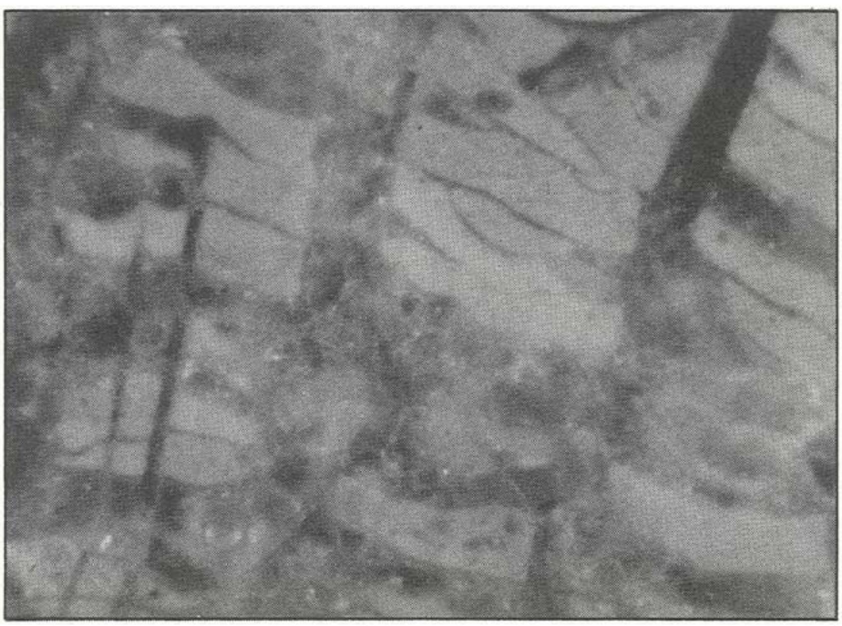


Figure 11A. *Radiolites* (a massive rudist characteristic of a high-energy environment) occurring in a coralgal-stromatoporoid-rudist framestone. The rudist is bored by pholad pelecypods (P). Tenneco #1 Sirianni (6,187 ft), Frio County, Texas.

Figure 11B. Closeup of the *Radiolites* in figure 11A showing irregular tabulate structure. Slabbed surface, X10.



11A



11B

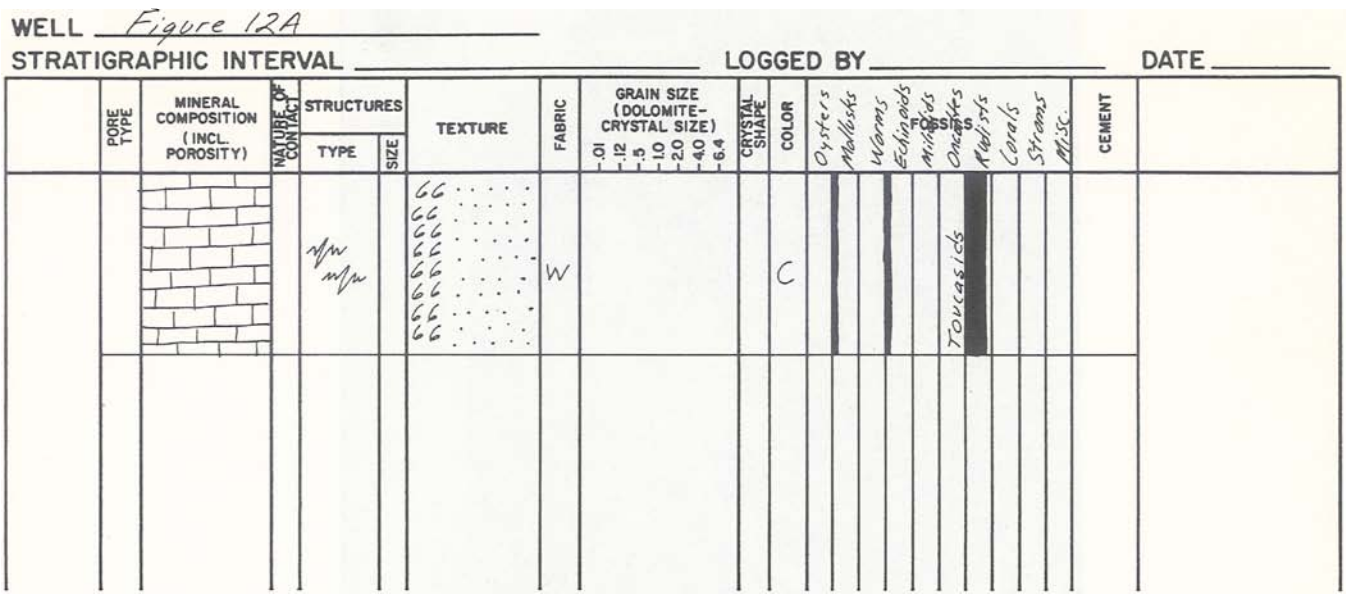
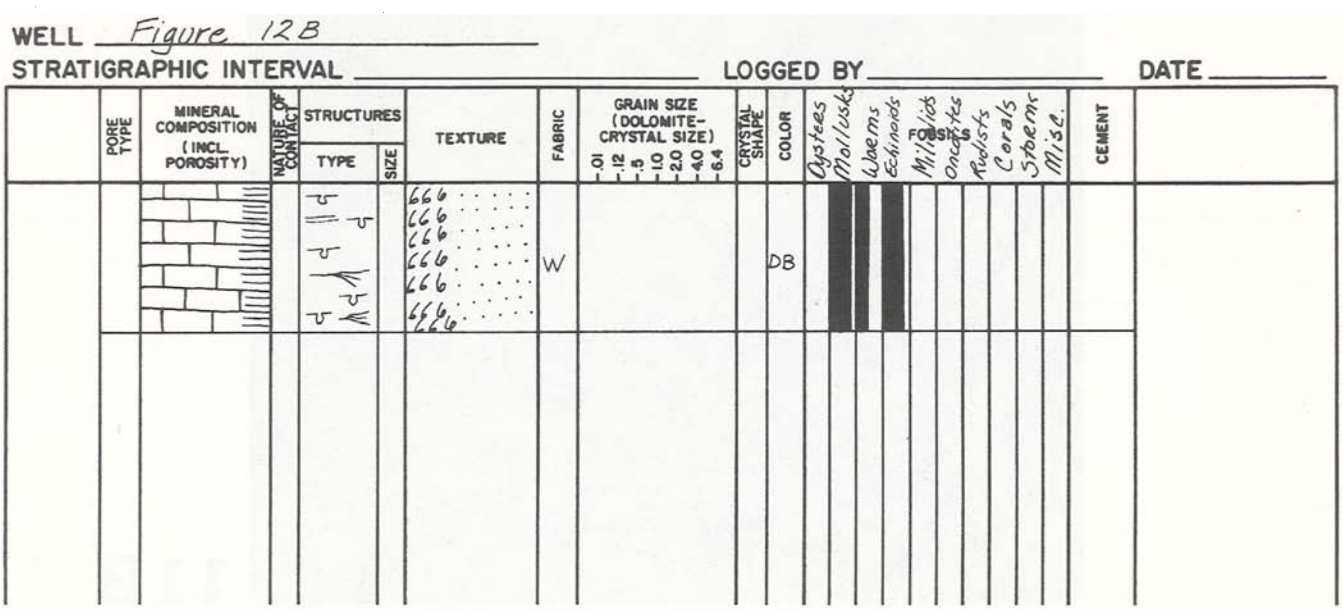
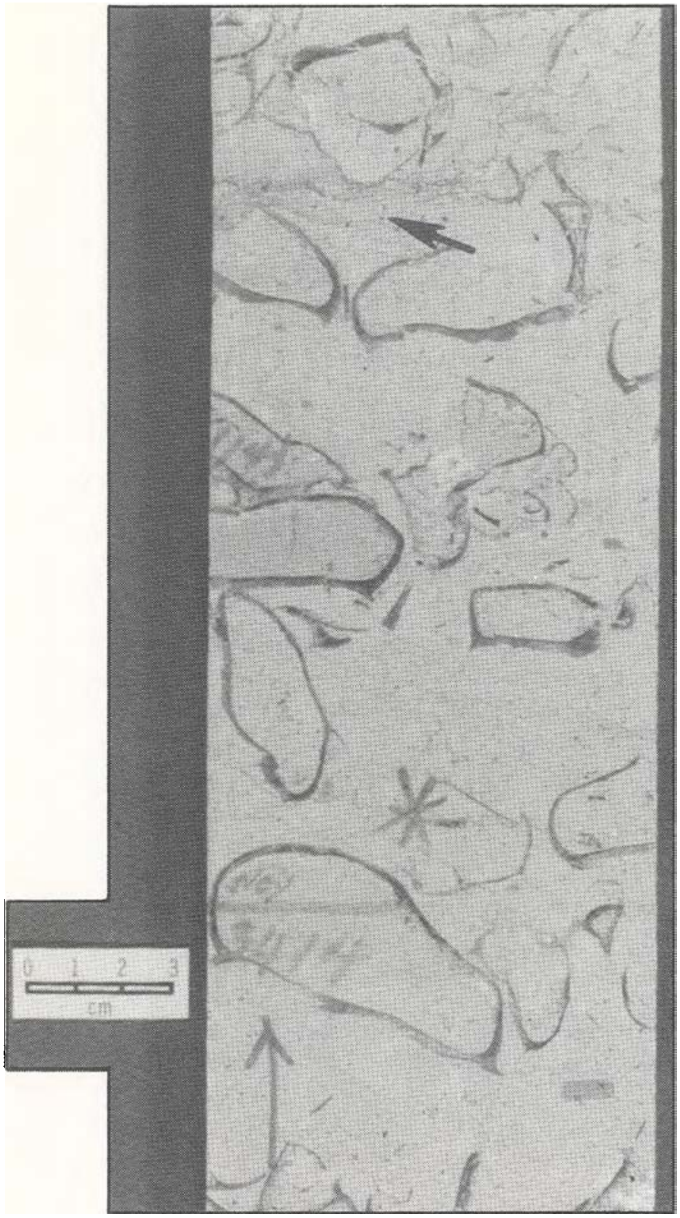


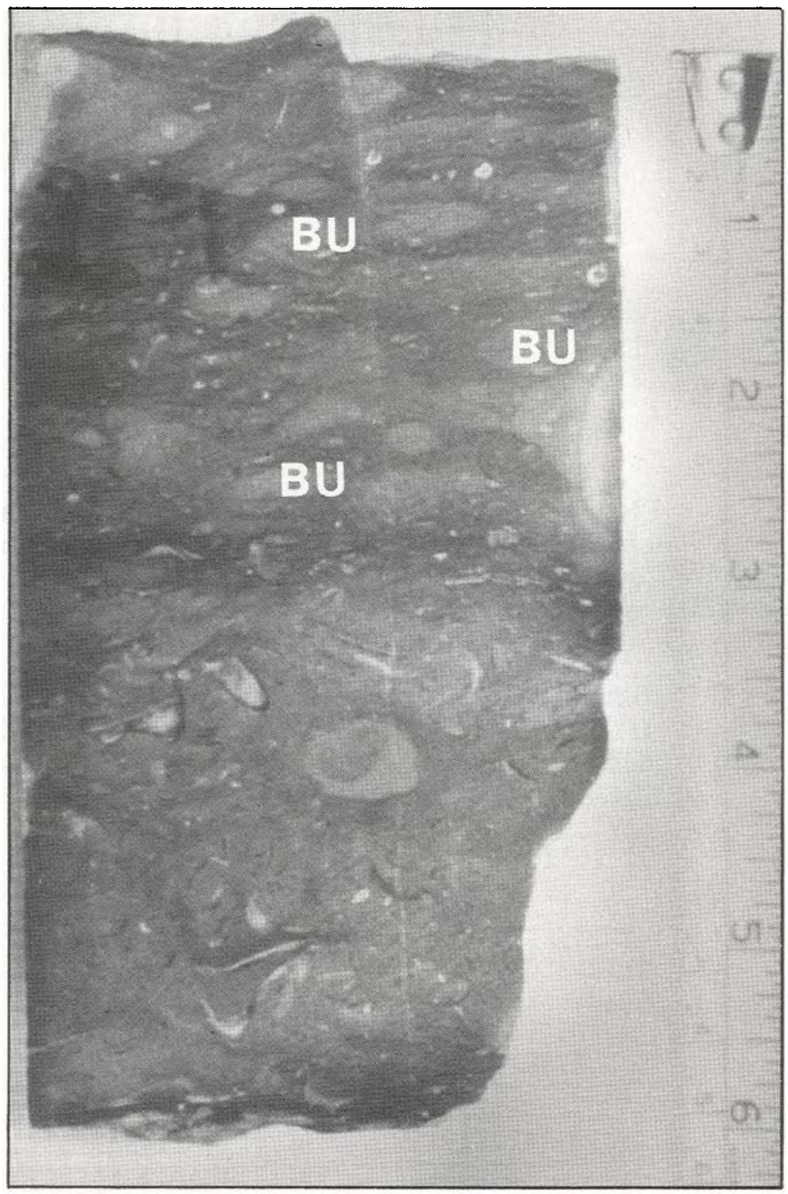
Figure 12A. Toucasiid wackestone. Whole and broken toucasiid shells occur in mud matrix cut by microstylolites (arrow). Tenneco #1 Ney (3,414 ft), Medina County, Texas.

Figure 12B. Burrowed (BU) argillaceous echinoid-mollusk wackestone.





12A



12B

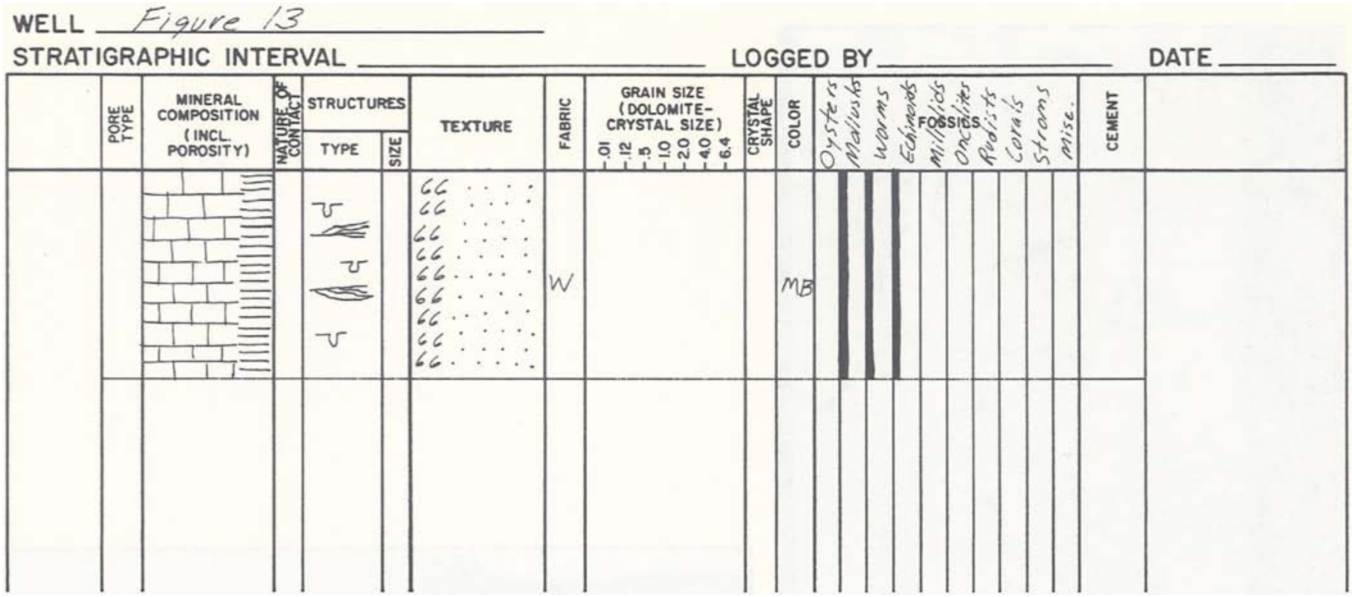
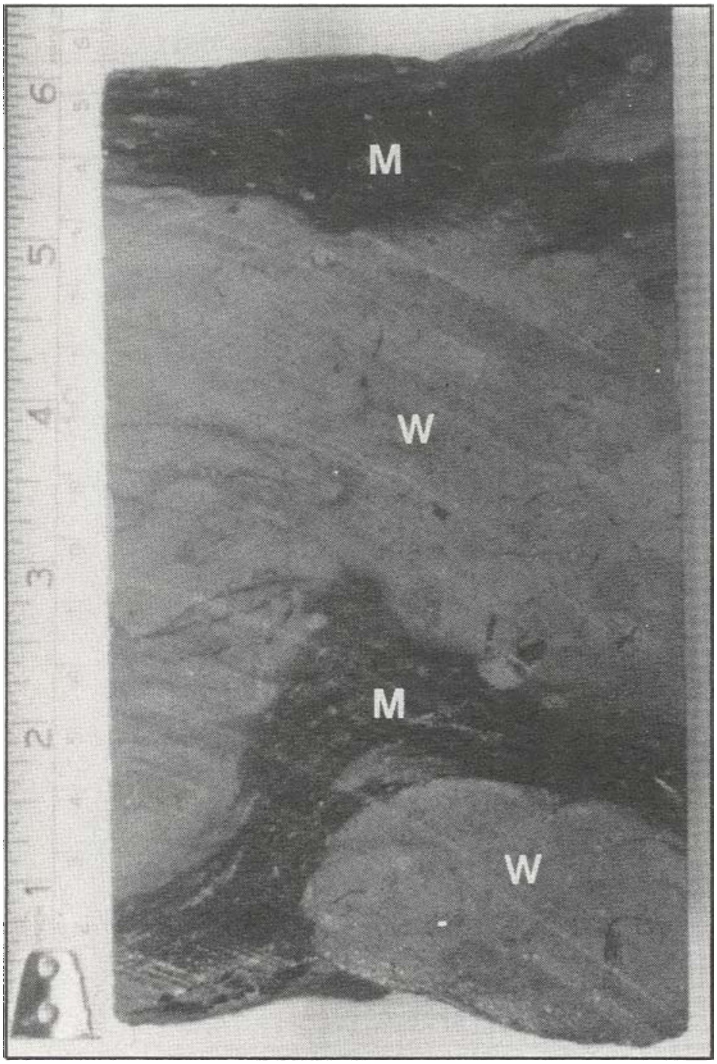
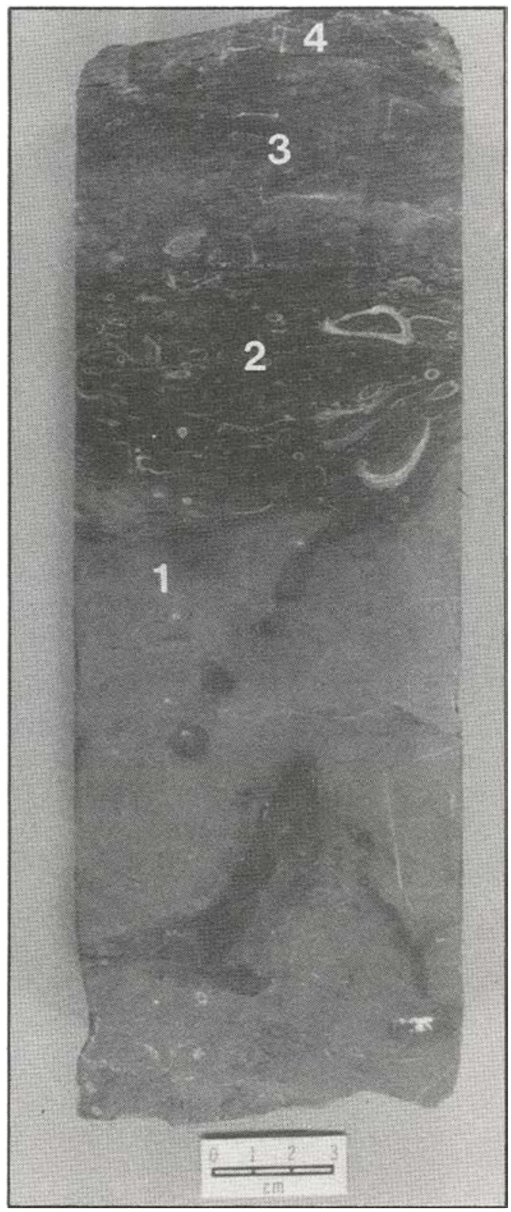


Figure 13A. Mixed terrigenous mudstone (M)/lime wackestone (W). Nodular bedding is mainly from differential compaction and burrowing. Tenneco #1 Kiefer (7,727 ft), Zavala County, Texas.

Figure 13B. Mixed terrigenous mudstone/lime wackestone. Sequence in slab shows (1) burrowed argillaceous echinoid-mollusk wackestone, (2) fossiliferous terrigenous mudstone, (3) argillaceous echinoid-mollusk wackestone, and (4) mudstone. Tenneco #1 Kiefer (7,727 ft), Zavala County, Texas.



13A



13B

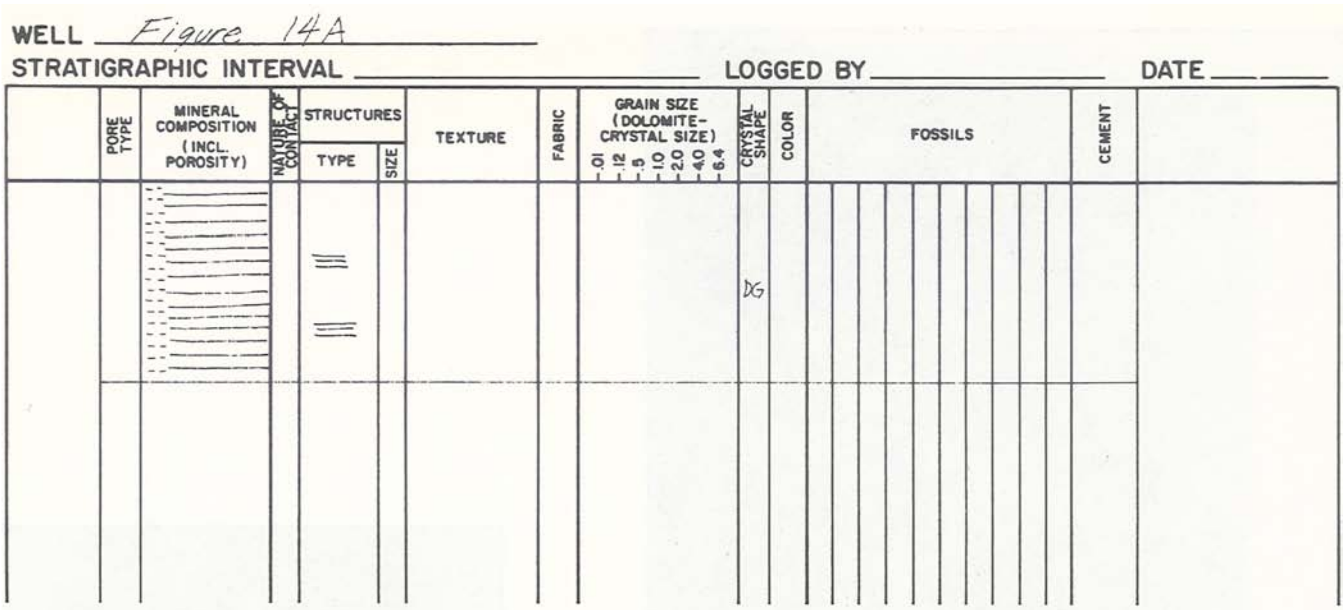
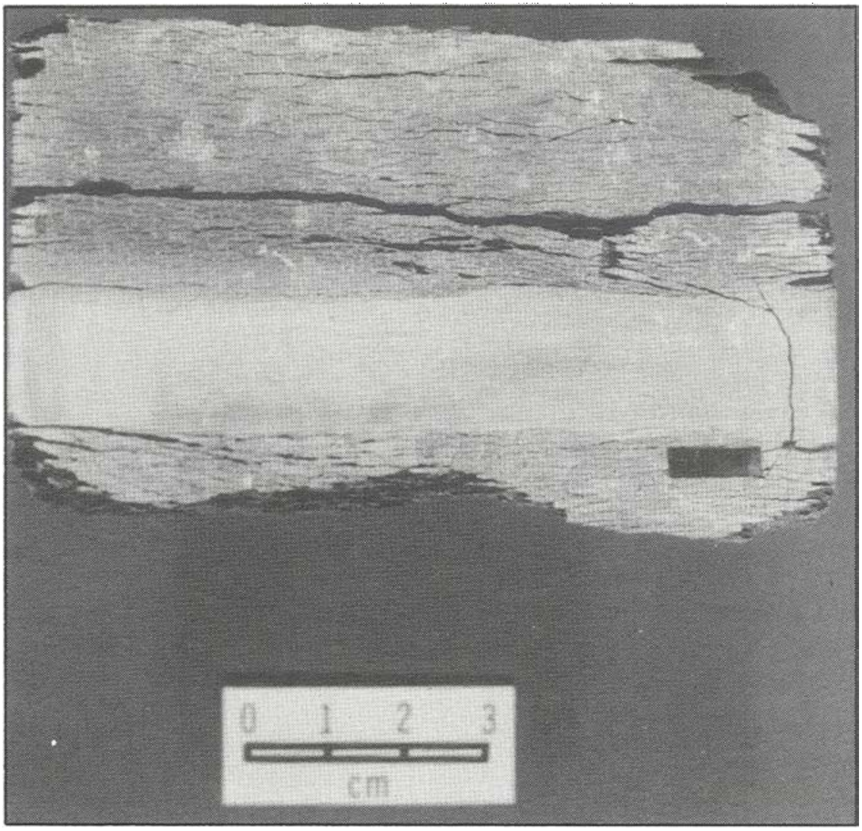
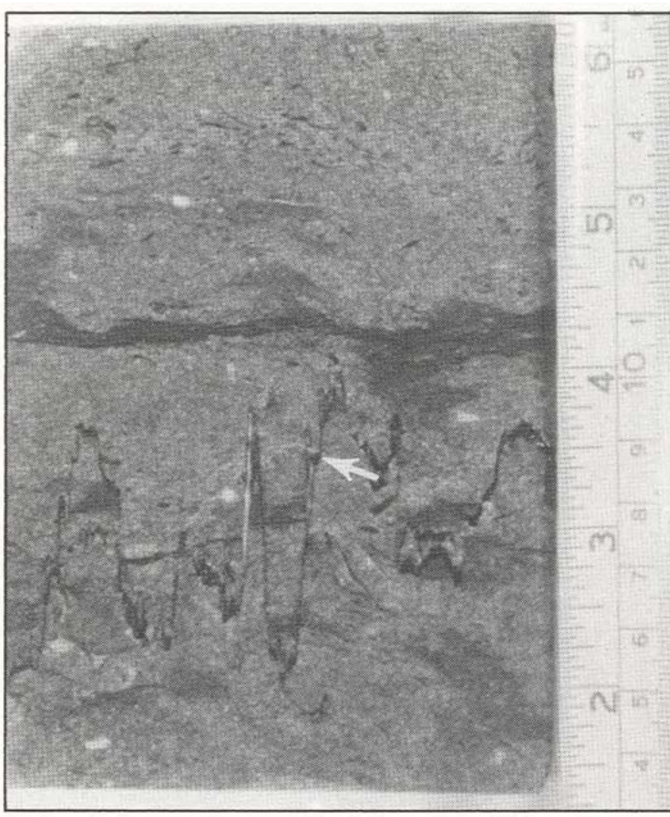


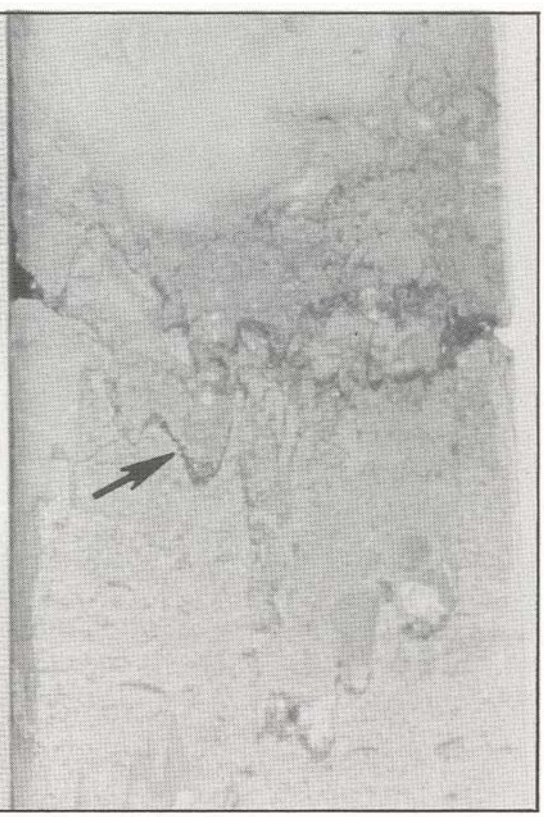
Figure 14A. Fissile clay-shale with thin siltstone layer. Tenneco-Pennzoil #1 Edgar (5,892 ft), Frio County, Texas.

Figure 14B and C. Stylolites (arrows). Stylolites are the result of pressure solution, which takes place after burial and lithification. B. Tenneco #1 Stoker (7,238 ft). C. Tenneco #1 Ney (3,422 ft), Medina County, Texas.



14A





14B **14C**

WELL ________________ COUNTY ______________ STATE ________

STRATIGRAPHIC INTERVAL ________________ LOGGED BY ___________ DATE ______

	PORE TYPE	MINERAL COMPOSITION (INCL. POROSITY)	NATURE OF CONTACT	STRUCTURES: TYPE	STRUCTURES: SIZE	TEXTURE	FABRIC	GRAIN SIZE (DOLOMITE-CRYSTAL SIZE) .01 .12 .5 1.0 2.0 4.0 6.4	CRYSTAL SHAPE	COLOR	FOSSILS	CEMENT	