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HANDBOOK 5

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HANDBOOK FOR LOGGING CARBONATE ROCKS

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In Pocket

Full-scale logging form

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 filledout 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.

	RATIGRAPHIC INTERVAL								LOGGED BY						
PONE	NIN A	MINERAL	P.C.P.	STRUCTL	RES	TEXTURE	BRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE)	SP4-	NON	FOSSILS	MENT			
	(INCL POROSITY)	NAT N	TYPE	SIZE		FA	0. 9. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	CRV	8	1111111	CE				
						-									
	4														
		COMPOSITION (INCL POROSITY)		COMPOSITION (INCL POROSITY)		COMPOSITION (INCL POROSITY)			EACOMPOSITION (INCL POROSITY) Image: Composition STYPE Image: Com						

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.

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760	PORE	MINERAL COMPOSITION (INCL. POROSITY)	NATUBE O	TYPE	S TEXTURE	FABRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE) 전 만 만 이 이 이 약 이	CRYSTAL	COLOR	Oysters Mallusk	WORMS	Echioids	Millo Mill	Rudists	Corals	Misc.	CEMENT	Notes
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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
- SI Sharp irregular
- SC Sharp conformable
- SD Sharp disconformable
- ST Stylolite

- G Gradational
- B Gradational-interbedded
- VS Visibly scoured
- BU Burrowed

Structure

Carbonate Structures

N	Streaky	700	Solution cavity with breccia				
~	Streaky laminated		Highly disturbed				
M	Microstreaky	~	Hardground				
mu	Stylolites	4	Daudinago				
xxx +++	Fractures		Bouumage				
5	Cloudy						
<u> </u>	Shale and bituminous partings		Horizontal				
	Interbedded		Suggested				
~	Truncated surface	1	Clasts				
VS	Scoured surface	~	Borings				
m	Convolute	Q	Keystone structures				
0000	Graded beds	y	Mudcracks				
	Fining up	В	Birdseye				
	Coarsening up	F	Fenestral				
	Lamina types -	Ħ	Organic framework				
	diagrammatically	0	Geopetal				
Æ	irregular laminations	K	Roots				
m	Ripple marks	_	Sheet cracks				
77777	Cross bedding						
	Brecciation types						
	Fracture						

🛛 Mosaic

~

🖉 Chaotic

Anhydrite Structures*

Crystallotopic
Gypsum pseudomorphs
Nodular
Nodular mosaic
Mosaic
Massive = Bedded massive
Modifiers using mosaic as an example
Distorted mosaic
Eedded mosaic

 \neq Distorted bedded mosaic

W 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

00 Left Ooids 666 Oncolites 000 Coated grains 8 8 8 8 Lumps 0 Lithoclasts 1 $\phi \phi \phi$ Intraclasts 6 **Skeletal** grains 6 Pellets Ð 000 Pelloids 000 Grains indeterminant Right Micrite

Highly altered. Superimpose over interpreted texture.



Anhydrite Textures*

// Lathlike
\varkappa Needles
MX Microcrystalline
Anhedral

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

Carbonate Fabrics

M - Mudstone	В	-	Boundstone
--------------	---	---	------------

- W Wackestone Ba Bafflestone
- P Packstone Bi Bindstone
- G Grainstone F Framestone

		Depositional texture not							
Origin	nal components during de	s not bound t positions	ogether	Origina bound	d component d together du	ts were iring	recognizable		
Contains mud (particles of clay and fine silt)				depositi intergro lamin grav	on as sho wn skeletal ation contra ity, or sedim	own by matter, ry to ent-	Crystalline carbonate		
Grain- Mud-supported supported			Lacks mud and is grain- supported	floored roofed question and a	l cavities tha over by orga ably organic are too large	at are inic or matter to be	(Subdivide according to classifications for physical		
Less than 10 percent grains	More than 10 percent grains				interstices.		texture or diagenesis.)		
Mudstone	Wackestone	Packstone	Grainstone		Boundstone				
		· · · · · · · · · · · · · · · · · · ·		Autoch original ce bound By organisms that act as baffles Baffle- stone	thonous lime omponents o during depo organisms that encrust and bind Bind- stone	estones; rganically osition By organisms that build a rigid frame- work Frame- stone	Carbonate classification by Dunham (1962).		

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.



Common

Abundant

Fossil	Reflected	Transmitted
Mollusks	250μ	125μ
Corals	250	250
Foraminifer	rs 62	62
Bryozoans	250	125-250
Barnacles	500	125-250
Echinoids	125	62
Halimeda	125	62-125
Coralline al	gae 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).

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

SKELETAL COMPOSITIONS

 \times Common \bigcirc 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 A Anhydrite
- S Silica H Halite
- B Bitumen D Dolomite
 - G Gypsum



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

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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.
- Majewske, O. P., 1969, Recognition of invertebrate fossil fragments in rocks and thin sections: Leiden, E. J. Brill, 101 p. (plus 106 plates).
- Milliman, J. D., 1974, Marine carbonates: New York, Springer-Verlag, 375 p.
- 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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- 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.
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- 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.

ORE YPE	MINERAL COMPOSITION	VPE OF	STRUCTU	RES	TEXTURE	BRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE)	YSTAL	DLOR	sters	Spio LFOSSIO	Prists	SIMIC	MENT	Martie
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			- 29		66666	P	eneral (55		MB						T ngga I
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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.

ww.	MINERAL	Acro	STRUCTU	RES		RIC	GRAIN SIZE	TAL	OR	rs sks	nus nids hots	sat to	Sun	ENT	
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	PE	MINERAL	RE OF	STRUCTU	IRES	TEXTURE	BRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE)	STAL	LOR	usks	em.	oss oss	the the	sials	Sun	ġ	MENT	÷.	
	a.	(INCL. POROSITY)	NATU	TYPE	SIZE		FA		S ^t	0	Noi V	ECh	milita	Pro Pros	Ś	Stre		CE		
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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.

PE	MINERAL COMPOSITION	PAC PF	STRUCTU	RES	TEXTURE	BRIC	GRAIN SIZE (DOLOMITE-	APE	theres there are the services and the services are the se	S C.	
di-	(INCL. POROSITY)	NATU	TYPE	SIZE		FA		5 5	Cyss Prove Prove Prove Prove Prove Cor Cor Cor	CE	
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					16666666					1	
					6666666			4	8	C	
					16666666					-	
					16666666			+			-
					1.0						





3A



3B

3C

YPE	MINERAL	PACP	STRUCTU	RES	TEXTURE	BRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE)	APE	ILOR	cters Wusks	spick	Sin s	els	oms Sc.	MENT	
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		-			66666											
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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.

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MIN	ERAL	AC. PF	STRUCTU	RES		RIC	GRAIN SIZE	STAL	NO.	ser.	Poks	S.	1	. D.	ENT	
(II PORC	ICL. SITY)	NATU	TYPE	SIZE	TEXTURE	FAB	0. 1. 0. 0. 0. 4. 0 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.	CRYS	CO	show of the	Echin Kills	Onco	con con	STra Mis	CEM	
	43				666								Π			
	<u> </u>				666											
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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.

WELL _	Figure	5B	and	C
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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.

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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.

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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.

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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.

PORE	MINERAL COMPOSITION (INCL.	JUBE OF	STRUCTU	RES	TEXTURE	FABRIC	GRAIN SIZE (DOLOMITE- CRYSTAL SIZE)	SHAPE	COLOR	ysters bullists orms hinoits hinoits bullists orals treans treans treans treans treans
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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.

WELL	Figure APHIC INT	<u>/C</u>	VAL_				L	.00	GE	D BY				DATE
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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

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			Mn m/n			W			С	Townscide				

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.

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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.

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13A



13B

ww	MINERAL	Acro	STRUCTU	JRES		RIC	GRAIN SIZE	TAL	N	FOREUR	ENT	
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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



14**B**

14C

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