PALEOKARSTIC FEATURES AND RESERVOIR CHARACTERISTICS OF THE HUNTON GROUP IN THE ANADARKO BASIN, OKLAHOMA

By

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The best rule is, search for anything and everything of geologic interest and record all you see . . . All earth features are but parts of a whole, and you can never tell when seemingly trivial things are going to furnish decisive evidence for the solution of important problems.

Field Geology, Lahee (1931)

CHAPTER I

INTRODUCTION

Objectives and Location

The one aspect of karst that is most commonly recognized in the geological record is extensive subsurface dissolution in the form of caves and associated cavities (Choquette & James, 1988). In a master's thesis written in 1939, Anderson wrote the following: "Occasionally in drilling, when the Hunton is reached, apparently cavities are encountered. It has been necessary to drop immense quantities of hay, cotton seed hulls, and other materials into some of the wells in order to stem the loss of drilling fluid."

The purpose of this study is to search for and to report paleokarst features and reservoir characteristics observed in subsurface rocks of the Hunton Group. These carbonate rocks have been important producers of oil and gas in Oklahoma for many years, and fields with Hunton production are located throughout the area of study. It is hoped that this investigation will shed more light upon the subject of paleokarst and on the intriguing economic possibilities that these sites may hold.

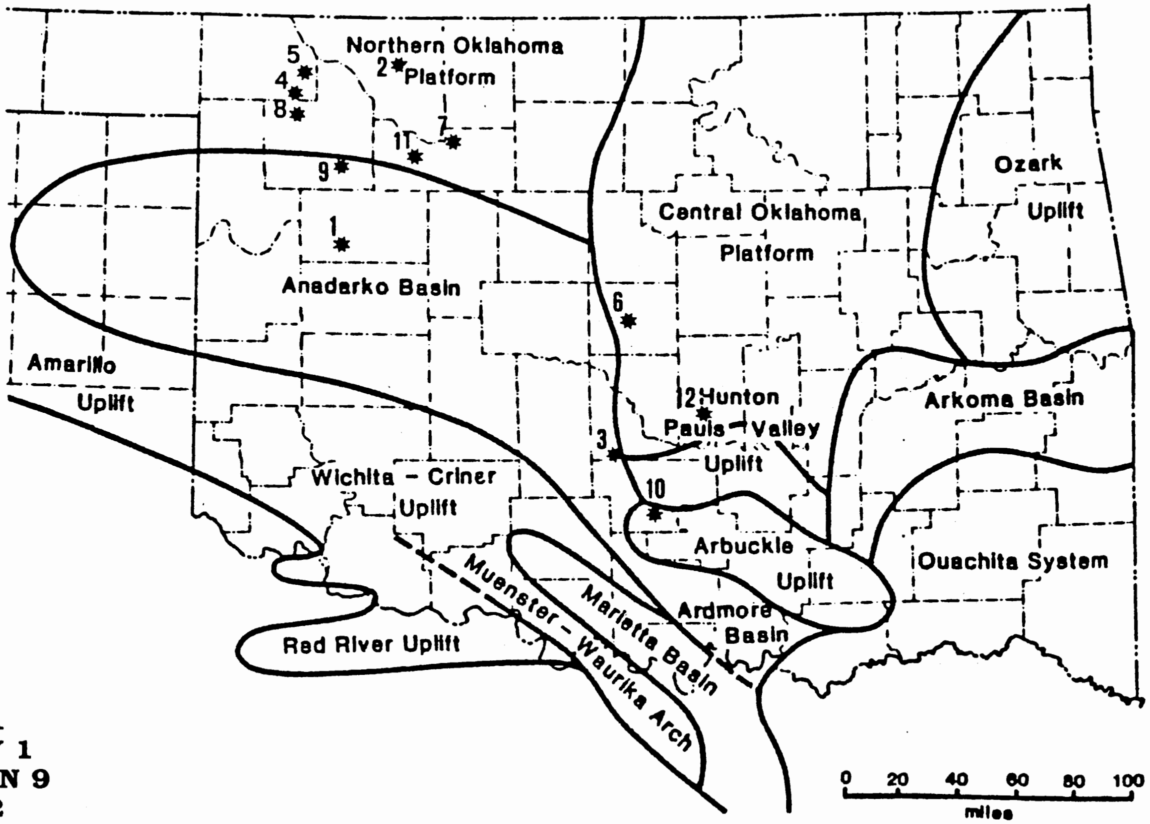
The organization of this paper will include a general review of the ideal karst profile and karst development in initial, middle, and late stages. This is followed by an inventory of paleokarst features observed in twelve Hunton cores from Oklahoma. During examination of the twelve cores, breccias, dissolution-enlarged fractures and channels, vuggy porosity, sediments in nondepositional cavities, and possible speleothems were discovered. The discussion of paleokarst features is accompanied by photographs and photomicrographs taken of the core samples. Also, the petrology of the rocks is described in the text and in core descriptions, core photographs and petrologs placed in the appendices. Finally, the reservoirs are catagorized by several criteria into Type One and Type Two Hunton Paleokarst Reservoirs. A precis regarding the presence of unconformities in the Hunton Group is given before the final chapter of summary and conclusions.

The location of the study area includes much of central and western Oklahoma. It encompasses the following tectonic provinces: Northern Oklahoma Platform, Anadarko Basin, Central Oklahoma Platform, and Hunton-Pauls Valley Uplift. It is limited to the north and east by the Hunton truncation, to the south by the Wichita and Arbuckle Uplifts, to the southeast by the Arkoma Basin, and to the west by the Texas state line (Figure 1).

Methods and Procedures

One hundred forty Hunton cores were examined for evidence of paleokarst. Most of the cores are housed at the Oklahoma Geological Survey Core Library in Norman, Oklahoma. A number of cores were transported to and from Stillwater. All of the cores were recorded; many of them showed that some type of dissolution had occurred. Eventually a dozen cores were chosen for futher intensive study. Each core was slabbed and samples of six cores were glued to 5" x 34" plywood strips. A seventh core had been previously affixed to 4" x 47" plywood strips. It is a teaching core and property of Oklahoma State University. Attaching the slabs to boards was done for convenience in handling and storing the cores. The wood may be noticed in the core photographs in Appendix A and in some of the core sample photographs in the figures. Tables I and II include core locations, intervals, and other pertinent information about each rock body.

Thin sections were prepared for petrofabric analysis using Alizarin Red-S to distinguish calcite and potassium ferricyanide stain to distinguish ferroan and nonferroan varieties of calcite and dolomite. Blue dye was used



1 AMAX HICKMAN 1-24
2 ARCO MARCUM 3
3 CARTER HESTER 1
4 CLEARY KINNEY 1-20
5 E. L. COX ANNIS A-1
6 GULF WRIGHT HEIRS 1
7 KIRKPATRICK SHEWEY 1
8 MACKELLAR FERGUSON 9
9 SHELL STOCKING 1-32
10 SAMSON WADE 1
11 TENNECO JORDAN A-1
12 WIL-Mc COSSEY 2

Figure 1. Location of Cores used in this Study Relative to the Tectonic Provinces of Oklahoma (After Arbenz, 1956; Al-Shaieb and Shelton, 1977).

TABLE I

HUNTON CORE AND INTERVAL INFORMATION

Core	Location	County/Field	Interval Cored (Ft. Depth)	Cored Formation	No. of Thin Sections
Amax Hickman 1-24	24-17N-18W NE SW NE	Dewey Putnam	-13,500 to -13,550	HH	0
Arco Marcum 3	20-27N-15W NE SW NW	Woods N.W. Avard	-6230 to -6263	W CH S	7
Carter Hester 1	27-5N-3W SW SE	McClain Golden Trend	-7770 to -7782	CH	6
Cleary Kinney 1-20	20-25N-21W C SW NE	Harper N.E. Ft. Supply	-8721 to -8760	CO	21
E.L. Cox Annis A-1	3-26N-21W C NW NW	Harper Lovedale	-7296 to -7364	W CH	20
Gulf Wright Heirs 1	5-12N-2W NW SW NW	Oklahoma Wicher	-6305 to -6338	M F HH	5
Kirkpatrick Shewey 1	28-22N-12W SW NE	Major Ringwood	-7895 to -7932	HH	13

TABLE I (Continued)

Core	Location	County/Field	Interval Cored (Ft. Depth)	Cored Formation	No. of Thin Sections
MacKellar Ferguson 9	35-24N-21W SW NE	Woodward NE Woodward (wildcat)	-9739 to -9776	Cl CO S	31
Samson Wade 1	33-2N-1W SE SW	Garvin Golden Trend	-6008 to -6051	HH	9
Shell Stocking 1-32	32-22N-19W SE NW	Woodward Moser area (wildcat)	-10,247 to -10,321	HH	24
Tenneco Jordan A-1	3-21N-14W SW NE	Major Cheyenne Valley	-8495 to -8613	HH	5
Wil-Mc Cossey 2	21-7N-2E E/2 NE NE	Pottawatomie W. Moral	-5060 to 5066	H/B	5

<u>LEGEND</u>

W = Woodford SH
M = Misener SS
F = Frisco
H/B = Haragan or Bois d'Arc

HH = Henryhouse
CH = Chimneyhill
Cl = Clarita
CO = Cochrane
S = Sylvan SH

TABLE II

HUNTON CORE AND RESERVOIR INFORMATION

Core	Type Core	Total Core feet	Total breccia feet	Total vuggy and/or dolomite feet	Depth Below Top Hunton	Scout Ticket & Completion Report
Amax Hickman 1-24	2	50	0	50	131	High Fluid Deliverability IPF: 15,661 MCFGPD
Arco Marcum 3	2	41	0	33	0 (at top)	High Fluid Del. IPF: 744 BOPD
Carter Hester 1	2	13	0	4	320	Show Hunton. Prod. Gibson No Test
Cleary Kinney 1-20	1	39	8	8	0 (at top)	D/A High Fluid Del. DST: Rec. 7000 Ft. SW.
E.L. Cox Annis A-1	1	69	15	10	0 (at top)	D/A Med. Fluid Del. IFT: 81 BOPD; Went to SW
Gulf Wright Heirs 1	2	32	2	13	0 (at top)	Low Fluid Del. IPF: 2BOPD
Kirkpatrick Shewey 1	2	37	3	34	9	High Fluid Del. IPF: 2,800 MCFPD

TABLE II (Continued)

Core	Type Core	Total Core feet	Total breccia feet	Total vuggy and/or dolomite feet	Depth Below Top Hunton	Scout Ticket & Completion Report
MacKellar Ferguson 9	1	37	14	10	0 (at top)	D/A High Fluid Del. DST: 3,000 MCFLPD + SW
Samson Wade 1	1	44	28	0	10	Low Fluid Del. IPP: 20 BOPD
Shell Stocking 1-32	1	74	21	0	0 (at top)	D/A Low Fluid Del. DST: Low Porosity
Tenneco Jordan A-1	2	118	0	75	0 (at top)	High Fluid Del. IPF: 20 BOPH
Wil-Mc Cossey 2	1	7	2.5	0	20	Low Fluid Del. IPP: 35 BOPD

to indicate porosity. The photographs and photomicrographs in the paper are taken from Hunton study cores and thin sections. In a few instances, samples were used from other Hunton cores which held unusually clear examples of a feature. All core photos and photomicrographs are identified by name, county, and depth, either in the text or with the picture. Photomicrographs marked "X.N." (crossed nicols) were taken with cross-polarized light. Absence of any symbol indicates that transmitted light with uncrossed polarizers was used.

Rock samples were selected for X-ray diffraction analysis to help determine the bulk mineralogy of the cave sediment within the rock. Petrologs especially designed at O.S.U. for karstic cores were used for descriptions of both depositional and diagenetic features. Three cross sections--A-A', B-B', C-C'--were constructed by using electric log signatures of the cores. The purpose of the cross sections is to show the extent of possible unconformities within the Group. Some of the formation boundaries have been dashed to infer uncertainty. The cross sections are located in the pocket inside the back cover of this volume. The map of Oklahoma shows the location of the study cores relative to the tectonic provinces of Oklahoma. Another map of Oklahoma displays the locations of fields with Hunton production in the study area.

Previous Investigations

Many workers have investigated Hunton rocks and, from the earliest times, the subject of unconformities and possible karst in the Group has been discussed in various publications. Hunton strata were first named by J.A. Taff (1902) in his work on the geology of the Atoka Quadrangle. However, the first paper pertaining to Hunton paleontology was published by Girty in 1899 (Amsden, 1956). In 1911, C.A. Reeds' doctoral dissertation, "The Stratigraphy of the Hunton Formation," was published. In the paper, he referred to stratigraphic "breaks"--the "times of no deposition as well as eroded sediments." Reeds places the word "Break" on his Table of Silurian Formations before and after the Chimneyhill, before and after the Henryhouse, and before the Haragan and Bois d'Arc. R.A. Maxwell (1936) writes in the conclusions of his doctoral dissertation that a Siluro-Devonian unconformity separates the Henryhouse from the Haragan formation. He also found three disconformities within the Hunton at the tops of the Cochrane, Dillard (Clarita), and Bois d'Arc limestones, respectively. Another early author, Anderson (1939), speaks of the Hunton surface as being similar to a "karst topography." He said, "oil produced from the Hunton is usually found accumulated in vugs, fissures, solution cavities, and brecciated zones." Bowles (1959) mentions "good shows in cavernous and vuggy cores of the Hunton." In his article about the Star-Lacey Field, Withrow (1971) concludes there is evidence that several unconformities exist within rocks of the Hunton Group.

Amsden has discussed the existence of unconformities in the Hunton in many articles (Amsden, 1960, and subsequent publications). In 1989, referring to the Henryhouse-Kirkidium biofacies, he states that "deposition was interrupted by areas of moderate uplift . . . exposing the sea floor to subaerial erosion and dissolution." The subject of Hunton unconformities is addressed by W.A. Morgan (1985) in "Silurian Reservoirs in Upward-Shoaling Cycles of the Hunton Group, Mt. Everette and Southwest Reeding Fields, Kingfisher County, Oklahoma," and by R.W. Maxwell (1959) in "Post-Hunton Pre-Woodford Unconformity in Southern Oklahoma." Manni (1985) writes that "the Chimneyhill exhibits karstification in the dolomites and in the pink crinoidal shoal packstones/wackestones." She believes that there is sufficient evidence for the presence of local unconformities in the Chimneyhill. Other investigators of the Hunton include Ballard (1930), Beardall (1983), Borak (1978), Decker (1935), England (1964), Harvey (1968), Hollrah (1977), Isom (1972), Kunsman (1967), Logsdon and Brown (1967), Medlock (1984), Menke (1986), G.D. Morgan (1922), Oxley (1958), Posey (1932), Shannon (1962), Swesnik (1948), Tarr (1955), Throckmorton and Al-Shaieb (1986), and Withrow (1971).

Hunton Stratigraphy

The Hunton Group in Oklahoma is a series of limestones and dolomites deposited over the areas of the Anadarko Basin, the central Arkoma Basin, and the Northern Oklahoma Platform during Late Ordovician, Silurian, and Early Devonian time. The rocks crop out in eastern Oklahoma near Marble City and in the Arbuckle Mountains.

Seven formations overlying the Sylvan Shale compose the Hunton Group in the study area of this report. In ascending order, the formations are the Keel, Cochrane, and Clarita (of the Chimneyhill Subgroup), Henryhouse, Haragan, Bois d'Arc, and Frisco. The Misener Sandstone and the Woodford Shale unconformably overlie the Hunton, making a distinctive shale, carbonate, shale sequence visible in electric-log signatures. The Woodford Shale may lie unconformably on any of the Hunton units and, in some areas, the Hunton Group was removed prior to Woodford deposition (Morgan, 1985).

Maximum thicknesses for each formation were assigned by Amsden as follows: Frisco, 60 ft; Haragan-Bois d'Arc, 325 ft; Henryhouse, 247 ft;

Clarita, 45 ft; Cochrane, 57 ft; Keel, 15 ft. The thickness of the Hunton in the Anadarko basin is greater than 1,600 feet; the thickness of the Group varies widely over the state due to pre-Woodford erosion and other periods of erosion during Hunton time (Amsden, 1975).

The stratigraphic columns have evolved to the present concept seen in Figure 2. The Hunton formation was first described by Taff in the Atoka Folio in 1902. He divided the Hunton into a lithological category of a basal limestone, a middle shale and upper limestone, and a paleontological category of Clinton, Niagara, Helderberg, and lower Oriskany. Taff's type area was located near the deserted village of Hunton, southwestern Coal County, at the foot of a prominent ridge of these sediments (Posey, 1932). Reeds (1911) renamed the subdivisions the Chimneyhill Limestone (Silurian), the Henryhouse Shale (Silurian), the Haragan Shale (Devonian), and the Bois d'Arc Limestone (Devonian). The difficulty in the stratigraphy was caused by the complete absence of the Henryhouse due to erosion in Taff's original area. Reeds recorded that no two of the 35 [cross?] sections he made across the Hunton were alike. The cause of the different thicknesses "is the unequal rate and time of deposition from place to place, and also to the differential erosion during and following sedimentation"

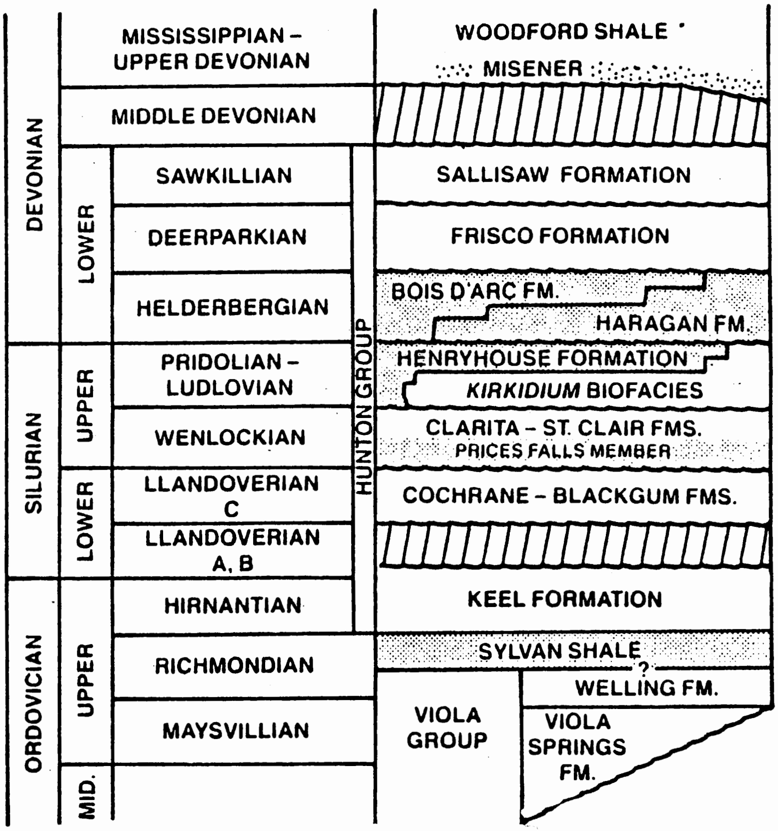


Figure 2. Stratigraphic Nomenclature of the Hunton Group in Oklahoma. Shaded formations are those containing moderate to heavy amounts of fine silt and clay-sized terrigenous detritus (Amsden, 1989).

(Reeds, 1911). In 1927, Reeds added a fifth formation, the Frisco Limestone (Devonian) that he declared rested upon the Bois d'Arc Limestone.

Major stratigraphic investigations were made by Maxwell (1936) and Amsden (1957, 1960, 1961, and subsequent publications) and Shannon (1962). Shannon proposed that the Cravatt member of the Bois d'Arc, the Haragan, and Henryhouse be lumped together as the Haragan-Henryhouse Formation. In practice, this has been done for more than forty years; the term "Haragan" on scout tickets implies all three members of the marlstone sequence (Kunsman, 1967). By 1967, the Hunton Group comprised in ascending order: the Chimneyhill Subgroup, composed of a basal Ideal Quarry Member of the Keel Formation, the Cochrane, a lower Prices Falls Member, and an upper Fitzhugh Limestone Member of the Clarita Formation, Henryhouse, Haragan, Bois d'Arc Formation, including the lower Cravatt Member and upper Fittstown Member, and the Frisco. In 1975, Amsden assigned the Keel Formation to the Late Ordovician. The Group was expanded to include Late Early Devonian strata: the Sallisaw Formation in eastern Oklahoma, the Turkey Creek Limestone in southern Oklahoma, and unnamed units in western Oklahoma and the Texas Panhandle (Amsden, 1975). However, Amsden (1980) sees no merit in further categorizing these strata into a Hunton megagroup.

CHAPTER II

A REVIEW OF KARST DEVELOPMENT

Introduction

The word "karst" is a German adaptation of the Slavic word "Kras" meaning "a bleak waterless place." The classical description of karst was derived from a high plateau area in Yugoslavia near the Adriatic Sea (Ritter, 1983). From its Eastern European roots in the last century, karst has become an essential concept for many geologists and other workers in the earth sciences. Geologists especially are interested in the possible occurrence of hydrocarbons that may be associated with subaerial exposure surfaces.

Esteban and Klappa (1983) state that karst is a diagenetic facies, an overprint in subaerially exposed carbonate bodies, produced and controlled by dissolution and migration of calcium carbonate in meteoric waters, occurring in a wide variety of climatic and tectonic settings, and generating a recognizable landscape. Karst differs from other carbonate environments in that it represents a diagenetic environment rather than a depositional one. In addition to carbonate surfaces true karst forms may develop upon gypsum, anhydrite and salt, as well as silicate and other "non-karst" rocks. Beck (1977) studied karren on granodiorites in Puerto Rico (Ford, 1980).

Paleokarst is karst that has been buried by younger sediments or sedimentary rocks or otherwise removed from the sphere of active meteoric diagenesis (Choquette and James, 1988). Therefore, paleokarst may include both relict paleokarst (present landscapes formed in the past) and buried paleokarst.

The Karst Profile

Input and output of ground water in a carbonate terrain is a function of several variables: the general lithology of the rock--matrix porosity, mineral composition, degree of fracturing, and thickness of beds. Other variables in karst development are climate and vegetation, position of the water table, and length of exposure to the meteoric water. The main agent in controlling the depth of karstic influences is the water flow pattern present in the rock itself. If the rock is porous, it will be characterized by diffuse flow and interparticle porosity. If the rock is tight, a fracture system or bedding permeability is essential.

In an idealized karst profile (Figure 3), the lithology of the host rock is massive, nonporous carbonate with water movement through bedding planes

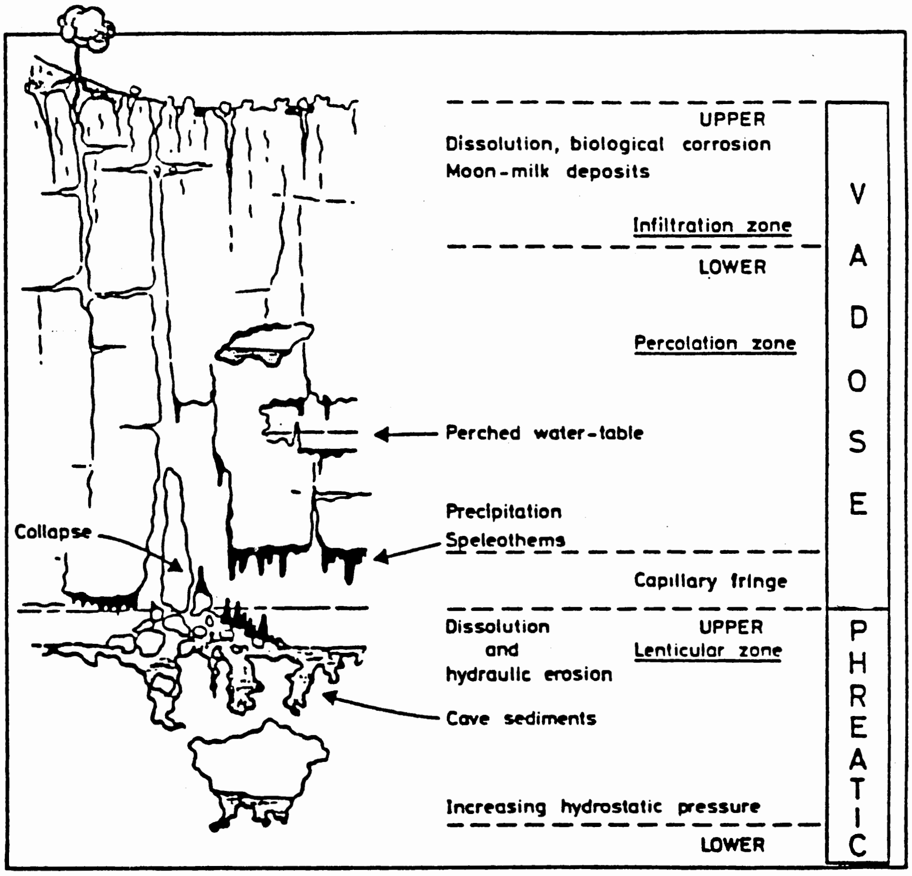


Figure 3. Idealized Karst Profile (from Esteban & Klappa, 1983).

and solution-enlarged channels. The area above the water table level is the Vadose Zone, which includes an upper Zone of Infiltration and a lower Zone of Percolation. The upper Vadose Zone is characterized by subvertical dissolution features with meniscoid and gravity-controlled dripstone cements. Speleothems--also known as cave calcite, travertine, or sinter (Ford, 1988)--of moon milk (low magnesian calcite needle fibers) and popcorn (globulites) may cover the carbonate host walls (Esteban & Klappa, 1983). Perched water tables, as shown in the ideal karst profile, inhabit the Zone of Percolation. The Phreatic, or Saturated, Zone lies below the water table. Fluctuation of the water table level causes subhorizontal dissolution and removal of carbonate rock. Cavern-sized pores may result, creating space for the growth of large speleothems such as stalactites and stalagmites. Isopachous, pore-lining and blocky, pore-filling cement morphologies typify phreatic conditions.

Stages of Karst Development

The mineralogy used in the following discussion was developed by Z. Al-Shaieb (personal communication, April, 1989). The chemical diagenesis which produces karst involves dissolution, remobilization, and precipitation of calcium carbonate. The ability of ground water to dissolve calcium carbonate is determined by its pH, which is a function of the amount of dissolved carbon dioxide, CO_2, in the water.

$$\begin{array}{c} CaCO_3 + H_2CO_3 \rightleftarrows 2HCO_3^- + Ca^{++} \\ \updownarrow \\ H_2O + CO_2 \end{array}$$

This equation shows that carbon dioxide combines with water to form carbonic acid. An increase in CO_2 content will drive the equation to the right resulting in the dissolution of calcium carbonate. Calcite precipitation is induced by driving the equation to the left, by the degassing of carbon dioxide. The main source of CO_2 is atmospheric CO_2 plus soil gas CO_2. Non-atmospheric CO_2, such as organic or sulfuric acid from the dissolution of pyrite, may contribute to the acidity of the water. In general, the dissolution process will continue since saturation would not be attained due to the continual recharge of ground water. The degree of dissolution will increase during turbulent flow.

In the initial stage drawing (Figure 4), the water table level is near the top of a carbonate sequence. A sinkhole has formed at the surface. The area below the water table, the Phreatic Zone, shows the consequences of subhorizontal water movement. The dissolving solution will flow initially as laminar flow. As the cavity enlarges, the flow will become turbulent, adding

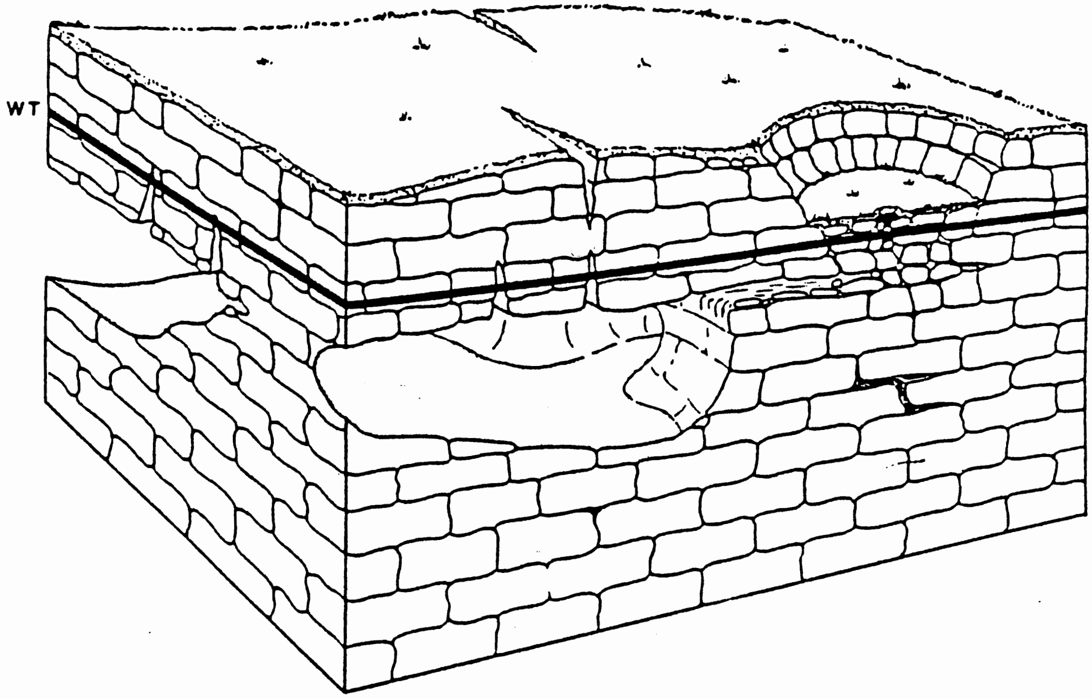


Figure 4. Initial Stage of Karst Development. Heavy black line represents the water table. No scale implied (Lynch, 1990).

a corrosive component to the dissolution. The initial cavity may stay intact or it may fill partially or completely with cave clay and other sediments.

The main stage of karstification is more complicated than the first stage because of the involvement of both vadose and phreatic zones (Figure 5). The model assumes that the carbonate terrain is being uplifted slowly, relative to base level. The oscillation and drop of the water table level have caused an increase in the size of the pipe or cavity. In the vadose zone, the cavity may change its geometry from pipe-like to a sinuous shape due to the passage of underground channel systems. Large volumes of carbonate have been excavated during vadose and phreatic dissolution. At ground level, the sinkhole has widened and deepened, as can be seen in the drawing. Fractures have become larger due to solution, allowing more meteoric water to infiltrate. Cave sediments commonly observed at this stage may range from channel sandstones to laminated clay material. The most spectacular features formed in the subterranean caverns are the speleothems, such as stalactites, stalagmites, and flowstone (Ford, 1988).

The late stage of karst development begins with the collapse of the cave roof. The entire profile has given way and extensive erosion is taking place as shown in Figure 6. The system is now totally above the water table level. The collapse of the cave roof complex leaves a large sinkhole; the remaining

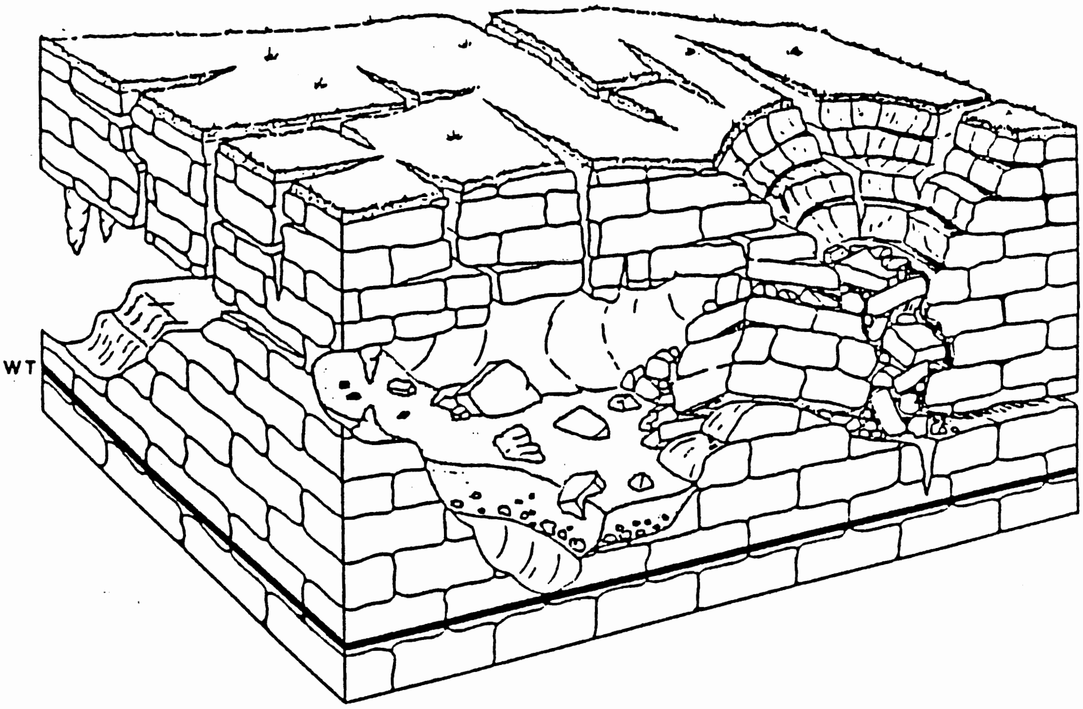


Figure 5. Main Stage of Karst Development. Heavy black line represents the water table. No scale implied (Lynch, 1990).

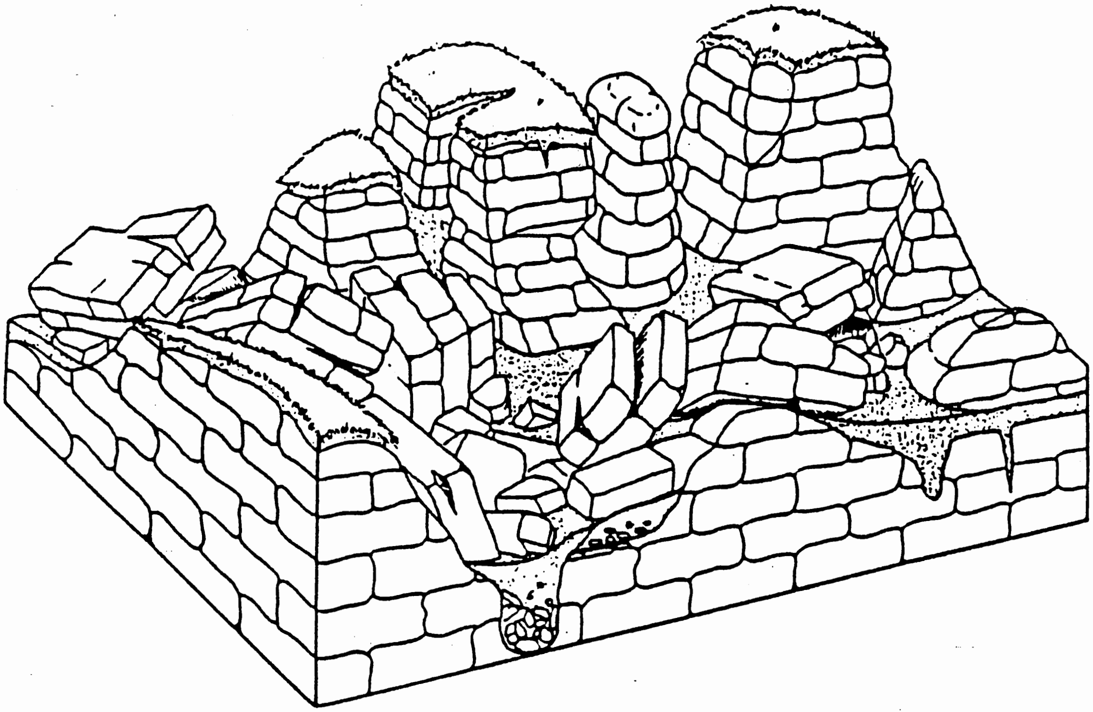


Figure 6. Late State of Karst Development. Entire system is above the water table. No scale implied (Lynch, 1990).

steep walls form distinctive tower karst landforms. Chaotic collapse breccias and water-laid deposits are abundant. Huge blocks of dolomite and fragments of broken speleothems are scattered over the area. Towers and karrens are filled with eluviated soils in wet regions whereas caliche zones develop in dry climates.

Rapid burial by a transgressive seal will help to preserve the karst facies. In this case, the facies will be covered by a marine sediment. If left exposed, the karst facies may be covered eventually by a continental sequence. The last exposure surface prior to renewed sedimentation is the only one preserved on most occasions. The best evidence of subaerial exposure is found at the base of a sequence of continental deposits (Esteban & Klappa, 1983).

Table III, Characteristic Features of Karst, lists those features that can be observed at the earth's surface, in the subsurface, and through a microscope. The table serves to emphasize the abundance and wide variety in size and shape of karstic traits.

TABLE III

CHARACTERISTIC FEATURES OF KARST

Stratigraphic

Karst landforms
• Unconformities
• Truncated shallowing-upward cycles

Macroscopic

Surface karst	**Subsurface karst**
Karren	• Caves and dissolution channels
• Paleosoils	• Stratiform breccias
• Caliches	• Collapse structures
• Nonsedimentary channels	• Dissolution-enlarged fractures
• Lichen structures	• Sediment in non-depositional cavities
• Boxwork structure	• Breccias in irregular bodies
• Mantling nonsedimentary breccias	• Speleothems

Microscopic

• Eluviated soil in small pores
• Etched carbonate cements
• Reddened and micritized grains
• Meniscus, pendant, and needle-fiber vadose cements
• Subisopachous columnar-calcite phreatic cement
• Extensive dissolution, or enlargment of fabric-selective pores

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Lynch, 1990 (modified after Choquette and James, 1988)

• Features discernable in core

CHAPTER III

PALEOKARST FEATURES OBSERVED IN CORE

Paleokarst features that are present in Hunton subsurface rocks include breccias, vugs and molds, solution-enlarged fractures and channels, infill sediment, possible speleothems and cavern porosity.

Breccias

Breccias are by far the most visible proof of paleokarst found in cores. However, the examination of breccias in cores is limited to a three- to four-inch width of slab. This provides only a narrow window through which to view the evidence. One pebble-sized fragment present in a collapse breccia sample may be, in fact, the edge of a boulder. Caution is required of the researcher. In his "A Classification of Breccias," Norton (1917) wrote,

> "Few geologic structures so lend themselves to diverse interpretations as the beds of broken rock called breccia...Diagnosis generally requires the use of multiple working hypotheses and may proceed chiefly by the process of elimination".

Four types of breccia were identified in the Hunton Group. They are crackle breccia, mosaic breccia, cavern-fill parabreccia, and collapse breccia. The location and length of the cored section from each study core determined how much of the paleokarst sequence was visible in the core. (For location and depth information of each core, refer to Table I in Chapter I.) Only two Hunton cores were taken high enough in their sequence to show crackle breccia. (In a complete and ideal paleokarst core sequence, the descending order of appearance of breccia types would be crackle breccia, at the top, followed by mosaic breccia, cavern-fill parabreccia, and collapse breccias, at the bottom).

Crackle Breccia

The term "crackle breccia" was described by Norton (1917) as incipient brecciation in extensively fractured rocks in which fragments have not been dislodged, rotated, or otherwise moved to any appreciable degree. The term "crackle breccia" is synonymous with the "fracture breccia" of Kerans (1989). In most cases, crackle breccia is indistinguishable from tectonically fractured rock. It is only through its spatial relation to other karst features in the core that this type of breccia has any use in karst diagnosis (Lynch, 1990).

Kerans (1989) addresses the problem of distinguishing between tectonic fractures and karst-related fractures in his article about paleokarst in the

West Texas Ellenburger Group. He writes that there are different origins for the fracture systems seen in Ellenburger carbonates, and suggests that it is possible to differentiate between fractures and breccias due to tectonic events and fractures and breccias related to karst activity. Tectonic fractures are the youngest features in his Ellenburger cores and clearly crosscut the earlier paleokarst breccias. Also, tectonic fractures and karst-related fractures have different distribution within the core sequence. Most karst-related fracture systems are restricted to upper portions of the sections, and the tectonic fractures occur at random throughout the sequences. While Kerans is dealing with a specific paleokarst location in West Texas, his observations may apply to other paleokarst situations as well.

The MacKellar Ferguson core, Woodward County, (Figure 7) and the Samson Wade, Garvin County, contain crackle breccia. In both cores, the inter-clast fracture porosity that is present in crackle breccia has been occluded by cement or by smaller grains. The Samson Wade core, (Figure 8), shows microbreccia filling the fractured chert crackle breccia at the top of the core.

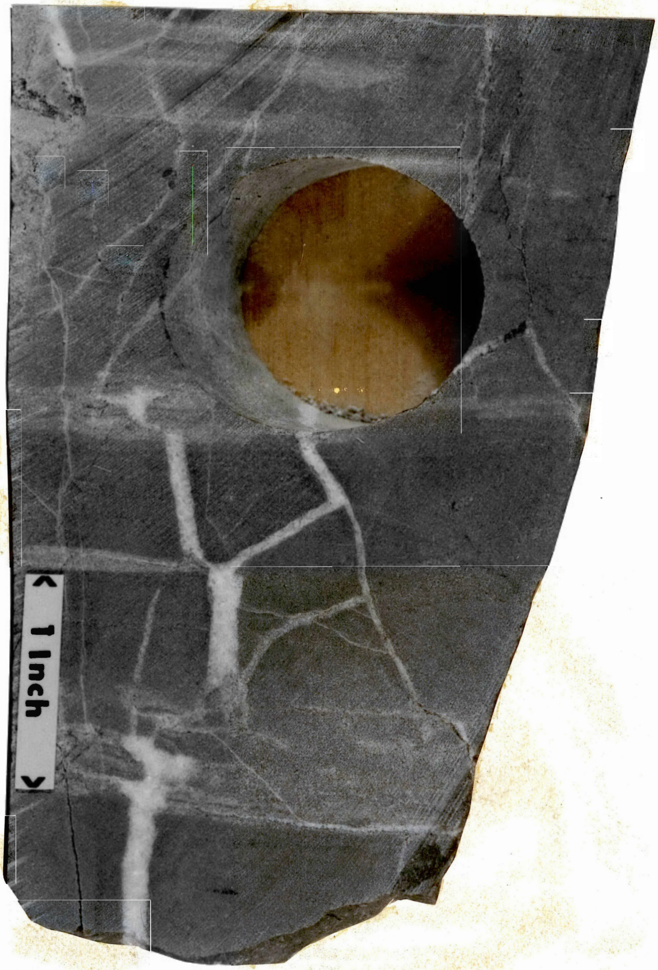


Figure 7. MacKellar Ferguson Core, -9,754 ft. Crackle breccia. Fractured gray, crystalline dolomite. Clasts cemented with baroque dolomite.

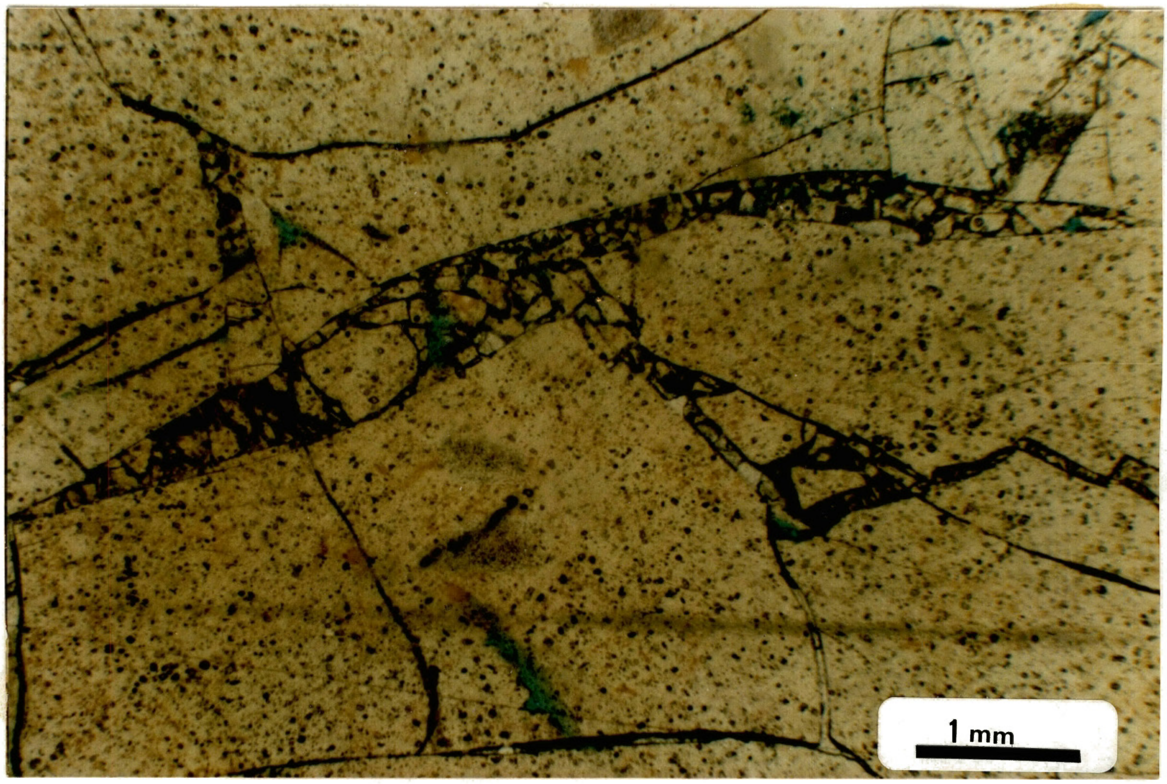


Figure 8. Samson Wade, Photomicrograph, - 6,008 ft. Crackle breccia in chert with microbreccia filling the fractures. Located at top of the core.

Mosaic Breccia

Crackle and mosaic breccias represent in-place brecciation. They correspond to the cave-roof facies of Kerans (1989) which he used in describing the karstified Ellenburger Group. There the crackle and mosaic breccias commonly contain the greatest porosity of all Ellenburger divisions--as much as fifteen percent where dolomite cement does not fill fractures (Kerans, 1989). Crackle and mosaic breccias in Hunton rocks tend to grade into one another and represent small areas of the core.

Mosaic breccia is composed of clasts which have been largely but not wholly disjointed and displaced. The clasts still match along adjacent surfaces and show that they are part of once unbroken stratum. Mosaic breccia is aptly described by Norton (1917), "these breccias may recall some ill-preserved mosaics of ancient ruins." In the samples from the Cox Annis core in Harper County, the seams are filled with cave sediment, part of which has been pyritized (Figure 9). Mosaic breccia is visible also in the Pelto Cheatwood core, Okfuskee County (Figure 10).

Cavern-Fill Parabreccia

The term "cavern-fill parabreccia" was proposed by Lynch (1990) for poorly sorted, matrix-supported breccias that form by subterranean

Figure 9. Cox Annis Core, -7,299 ft. Mosaic breccia. Chert clasts with dolomite and calcite cement. Pyritization a later event. Note interesting cross cutting relationships.

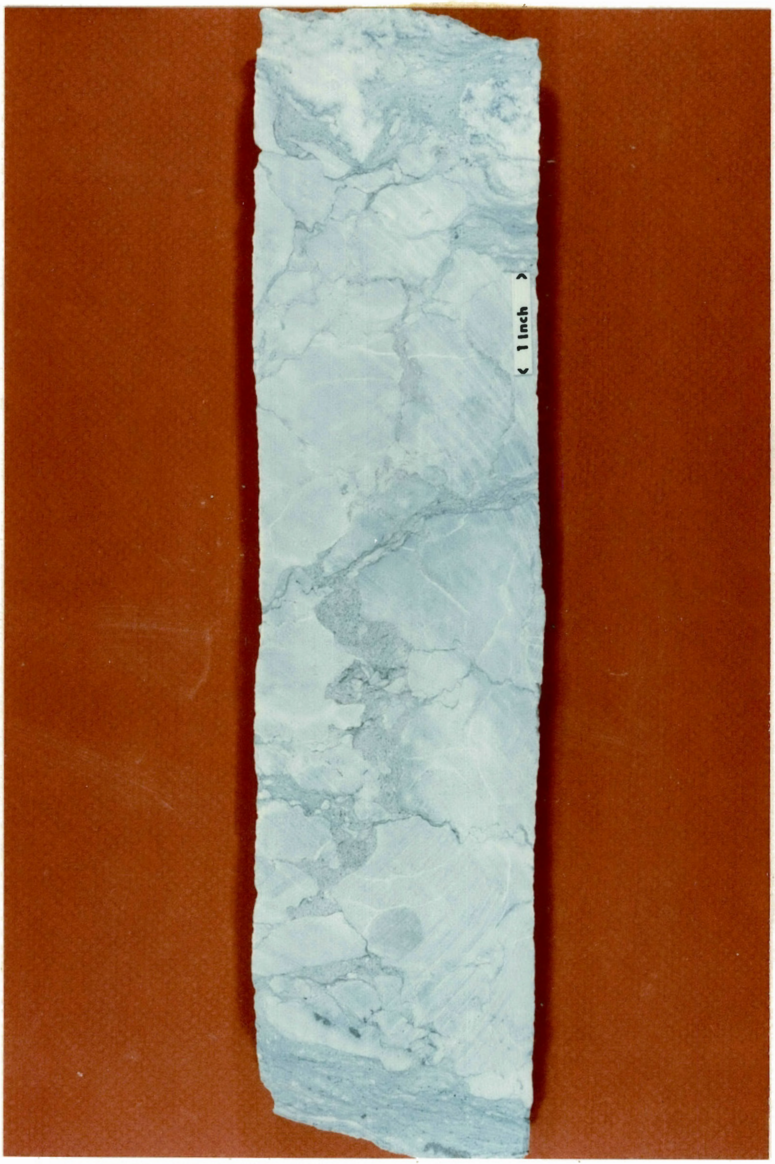


Figure 10. Pelto Cheatwood Core, -3,989 ft. Mosaic breccia, clast supported. Sediment between clasts contains glauconite, pyrite, quartz grains, and carbonate cement.

deposition within an open-cavern network. Cavern-fill parabreccia is used in this report to designate the material between the cave-roof facies (crackle and mosaic breccia) and the collapse-breccia facies covering the cave floor. This breccia is similar to terms used by other workers: "depositional breccia" of Blount and Moore (1969), "chaotic breccia, siliciclastic matrix-supported" of Kerans (1989), "breccia of sporadic fragments" of Norton (1917), and "paraconglomerate" of Pettijohn (1975).

The matrix-supported fragments may range in size from fine sand to boulder size. Norton (1917) points out that "fragments are embedded in a preponderant matrix like plums in a pudding." This type breccia may originate in the cavity itself, or clasts may calve from the cave roof and be transported by flow of water from other collapse locations within the system. It is possible that allochthonous fragments--those from other karst systems or from above ground--may be washed into the cavern during periods of flooding. In these instances, caves may function as giant sediment traps, accumulating samples of all clastics, chemical, and organic debris (Ford, 1988). Cave earth which consists of clay, silt, sand, or gravel--flooring or filling a cave passage--may be present in the cave-fill melange.

The Hunton study cores contain several examples of cavern-fill parabreccia. The clasts range from sand through pebble size and are angular to subrounded in shape. The Shell Stocking core of Woodward County and the Samson Wade core of Garvin County (Figures 11 and 12) both exhibit cavern-fill parabreccia.

Collapse Breccia

Collapse breccia is one of the main indications of subaerial karst facies (Esteban & Klappa, 1983). It is a result of structural collapse of a cave roof into a previously open cavern. The collapse may be the result of the dissolution of evaporites, or the cave roof may founder due to overburden. "Collapse breccia" in this paper encompasses the "founder" and "cavern" breccias of Norton (1917).

This type of breccia is characterized by diversity of clasts, poor sorting, and angularity of grains. It is possible that, following deposition of angular clasts in caves, some clasts may be subjected to rounding in situ as a result of solution by groundwater (Kahle, 1988). Clasts in the Hunton collapse breccia are angular to subrounded. Components which may be found in collapse breccia are broken speleothems, fossils, pieces of host rock, and infiltrated cavern-fill parabreccia.

Six of the twelve study cores contain significant amounts of collapse breccia, as noted in Table II in Chaper I and Table IV in Chapter IV. Two

Figure 11. Shell Stocking Core, -10,248 ft. Cavern-fill parabrecciaia. Matrix supported, heterolithic composition. Mineralogy includes chert, dolomite, calcite, ferroan dolomite, pyrite, collophane, feldspar, glauconite, anhydrite. Silicified fossils mainly crinoids and brachiopods. Possible speleothem fragment present.

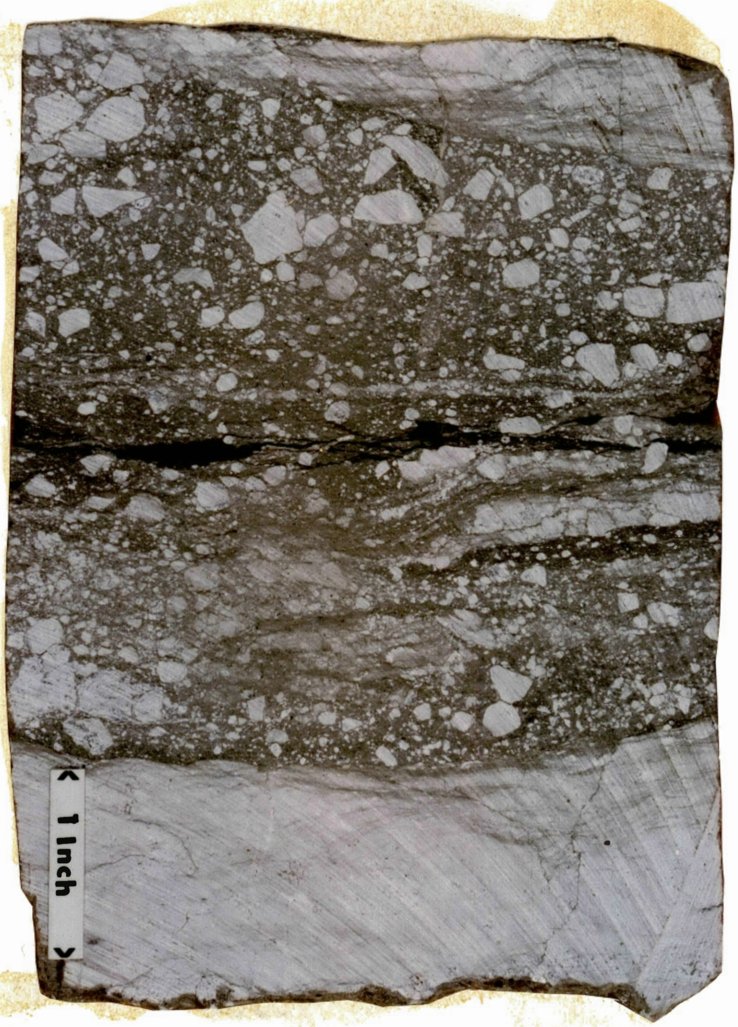


Figure 12. Samson Wade Core, -6,032 ft. Cavern-fill parabreccia. Clasts of packstone and mudstone with micrite matrix.

examples of this type breccia come from Harper County cores--the Cox Annis and the Cleary Kinney.

The Cox Annis core displays fifteen feet of dolomite and chert breccia with some visible porosity in the brecciated portion (Figure 13). The sample has a rubbly collapse texture with glauconite, some detrital quartz, and dolomite cement. A photomicrograph taken at -7,313 ft. in the Cox Annis illustrates the porosity present in the breccia (Figure 14). Three types of breccias--mosaic, cavern-fill parabreccia, and collapse--are represented in this core. Fifty feet deeper in the section a packstone shoal facies harbors solution-enlarged vugs which have been filled with dolomite and calcite cement (Figure 15).

The Cleary Kinney core is a pinkish gray limestone rock which includes two packstone intervals and a dolomite zone. The top eight feet of the core is a fine example of collapse breccia with some grains of chert and dolomite (Figure 16). The angular, poorly sorted grains show no evidence of transport. The fragments are grain supported. Stylolites are common. Several fragments, pebble to cobble size, appear to be coated with a cream-colored radiaxial fibrous calcite cement. This may indicate the presence of speleothems; in this case, it is the flowstone variety where calcite has accumulated against the walls of the host rock (Figure 17). Some

Figure 13. Cox Annis Core, -7,310 ft. Collapse breccia. Dolomite and chert with rubbly, chaotic texture. Some visible porosity in the top portion of the sample.

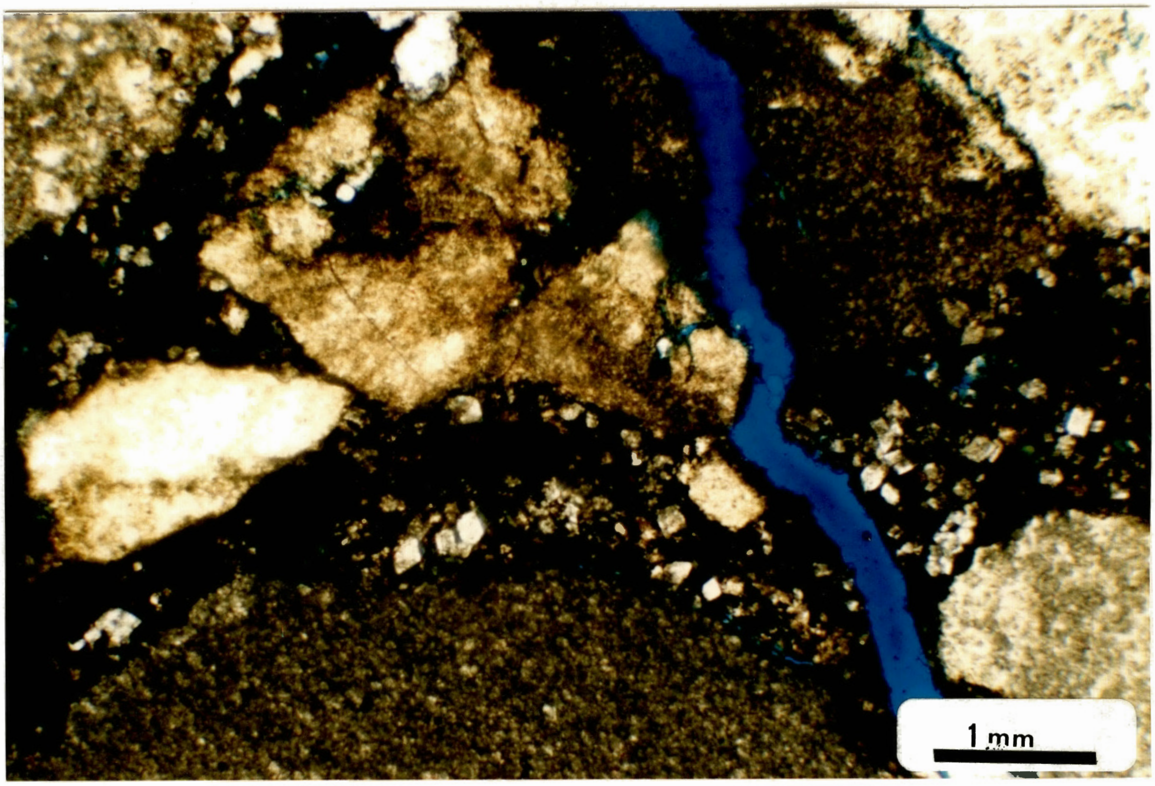


Figure 14. Cox Annis Photomicrograph, -7,313 ft. Collapse breccia showing porosity present between the fragments of chert, dolomite, glauconite. Smaller grains and pyrobitumen fill remaining pore space.

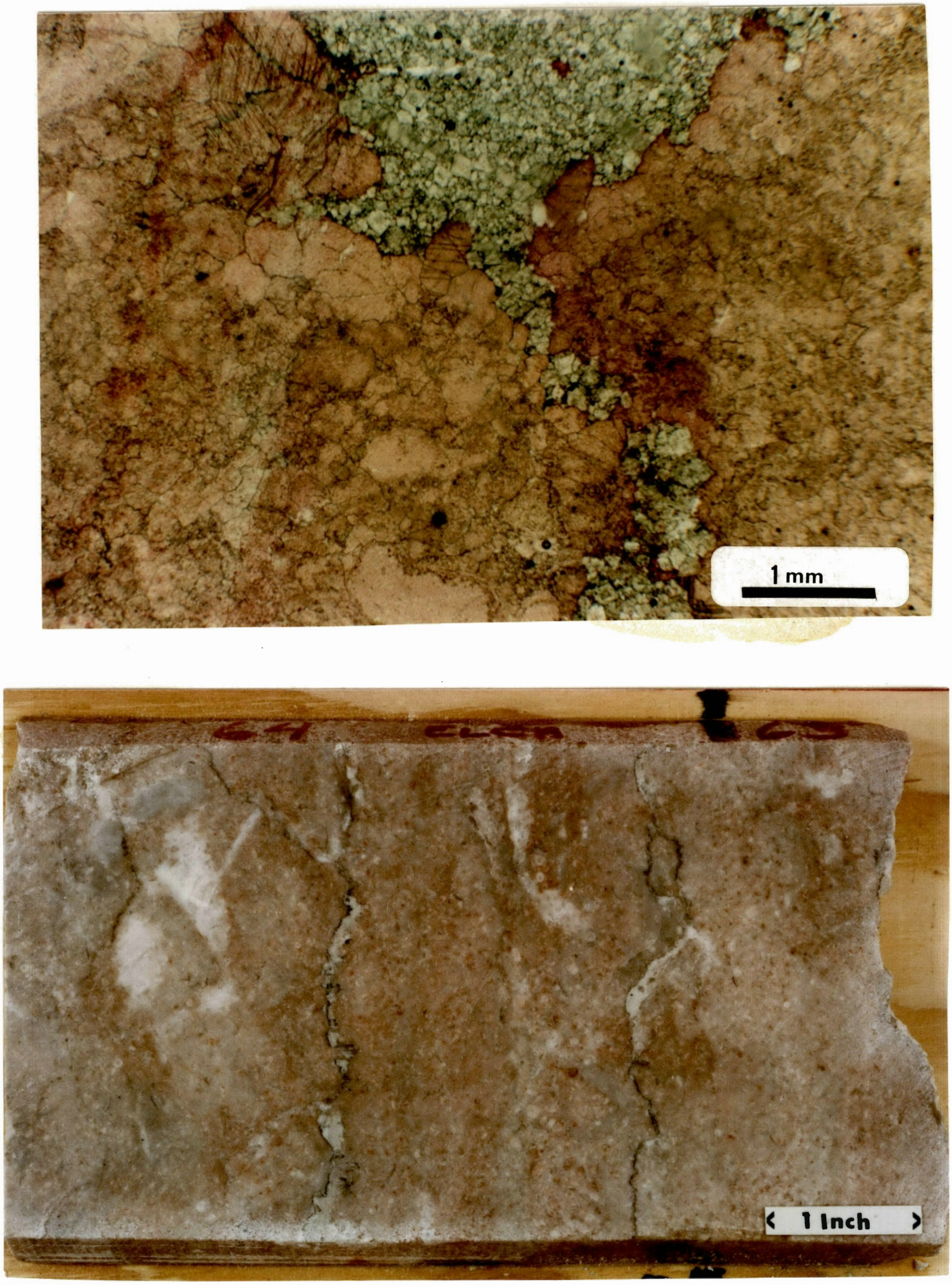


Figure 15. Cox Annis Core, -7,364 ft., and photomicrograph (X.N.), top of page. Packstone shoal facies with solution-enlarged vugs filled with clay-associated rhombic dolomite.

Figure 16. Cleary Kinney Core, -8,722 ft. Collapse breccia with fragments of dolomite and calcite. Note stylolite near bottom of sample.

Figure 17. Cleary Kinney Core, -8,723 ft. Collapse breccia. Contains some fragments coated with calcite cement which appears to be flowstone.

other clasts in the breccia contain cemented subvertical fractures which appear to be similar to the host rock lower in the section. These features can be seen in the core photograph in Appendix A.

Dissolution Features

The Hunton study cores display abundant paleokarstic dissolution features. This evidence of karst activity is small enough to be at least partially confined within the diameter of the core. Most features are millimeter or centimeter scale and include vugs, solution-enlarged fractures and channels.

Karstic Vugular Porosity

Vugular porosity was observed in at least forty Hunton cores examined at the Oklahoma Geological Survey Core Library in Norman. Vugular porosity is defined by Choquette and Pray (1970) as a nonfabric selective, relatively equidimensional pore space that is large enough to be visible with the naked eye. Five of the cores used for this report possess outstanding specimens of dissolution vugs, vugs partially or completely cemented, and vugs containing geopetal structure.

The Arco Marcum core, Woods County (Figure 18), and the Amax Hickman core of Dewey County (Figure 19) are prime examples of cores with highly visible vuggy porosity. The Arco Marcum photomicrograph shows a thoroughly bioturbated dolomite rock with remnant hydrocarbons in the pores (Figure 20). It contains vug- and mold-filling calcite with a small amount of silica and anhydrite.

Other fine specimens of vuggy porosity are present in the Kirkpatrick Shewey and Tenneco Jordan cores from Major County. The top thirty-two feet of the Tenneco Jordan core is a vuggy, brown, porous, oil-stained rock. This dark, stained portion of the Tenneco Jordan is apparent in the core photographs in Appendix A. Lower in this core, the molds and enlarged vugs have been filled with dolomite, chert, quartz, and anhydrite. At -8,514 ft., a 6-centimeter wide vug has been cemented with anhydrite.

Solution-Enlarged Fractures and Channels

Solution-enlarged fractures, joints, and channels are ubiquitous in the Hunton rocks. A typical solution-enlarged channel may be seen in the Pelto Cheatwood core from Okfuskee County (Figure 21). From McClain County, the Carter Hester core illustrates small-scale solution-enlarged fracture porosity. In this case, interstices have been filled geopetally with laminated

Figure 18. Arco Marcum Core, -6,244 ft.
Dolowackestone with visual
moldic and vuggy porosity.

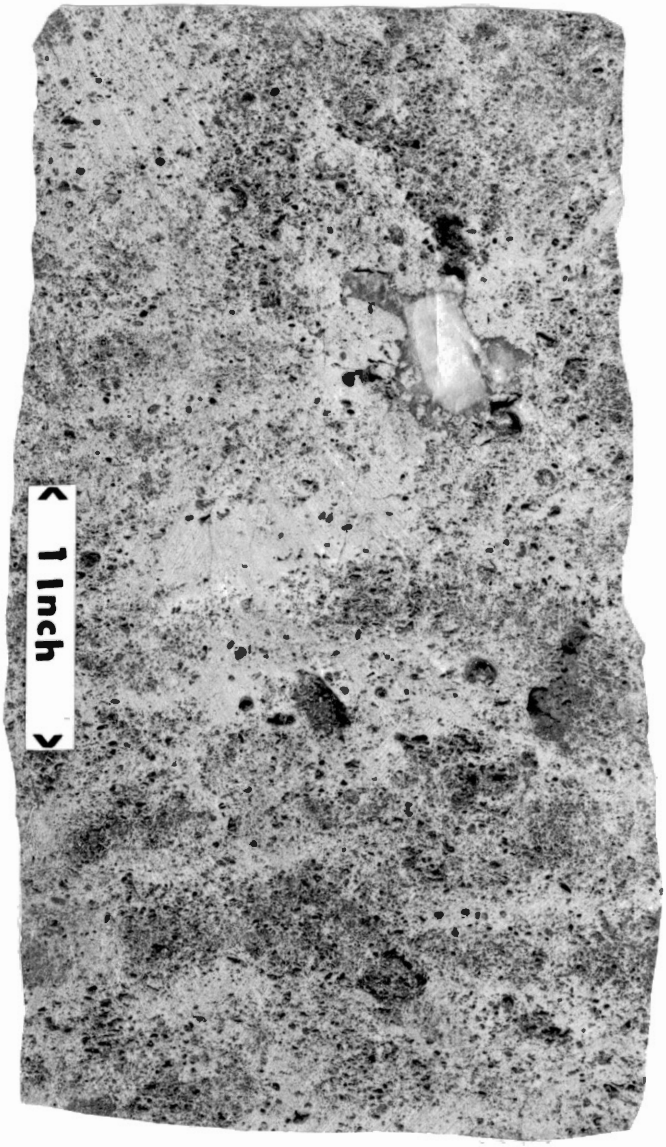


Figure 19. Amax Hickman Core, -13,525 ft. Sucrosic dolomite, bioturbated, vuggy porosity. Sample contains vug-filling calcite.

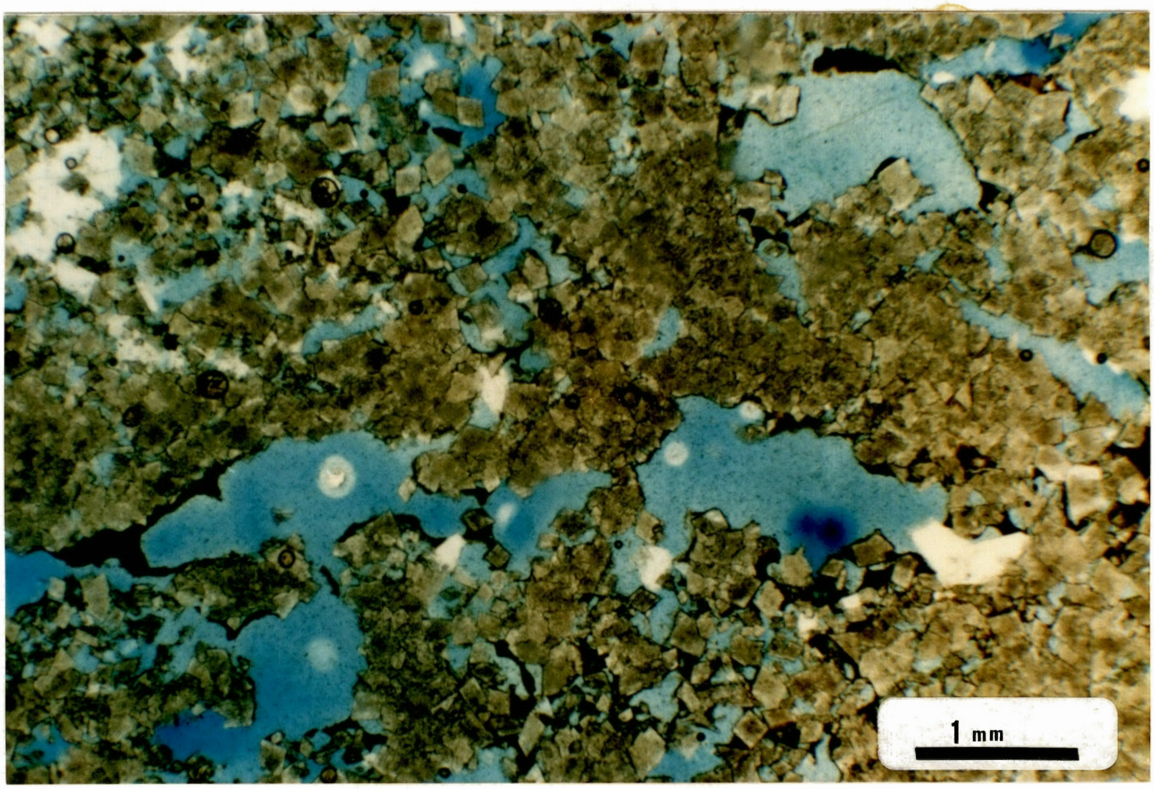


Figure 20. Arco Marcum Photomicrograph, -6,242 ft. Dolowackestone composed of sucrosic dolomite with intercrystalline porosity. Fossil molds are rimmed with dead oil.

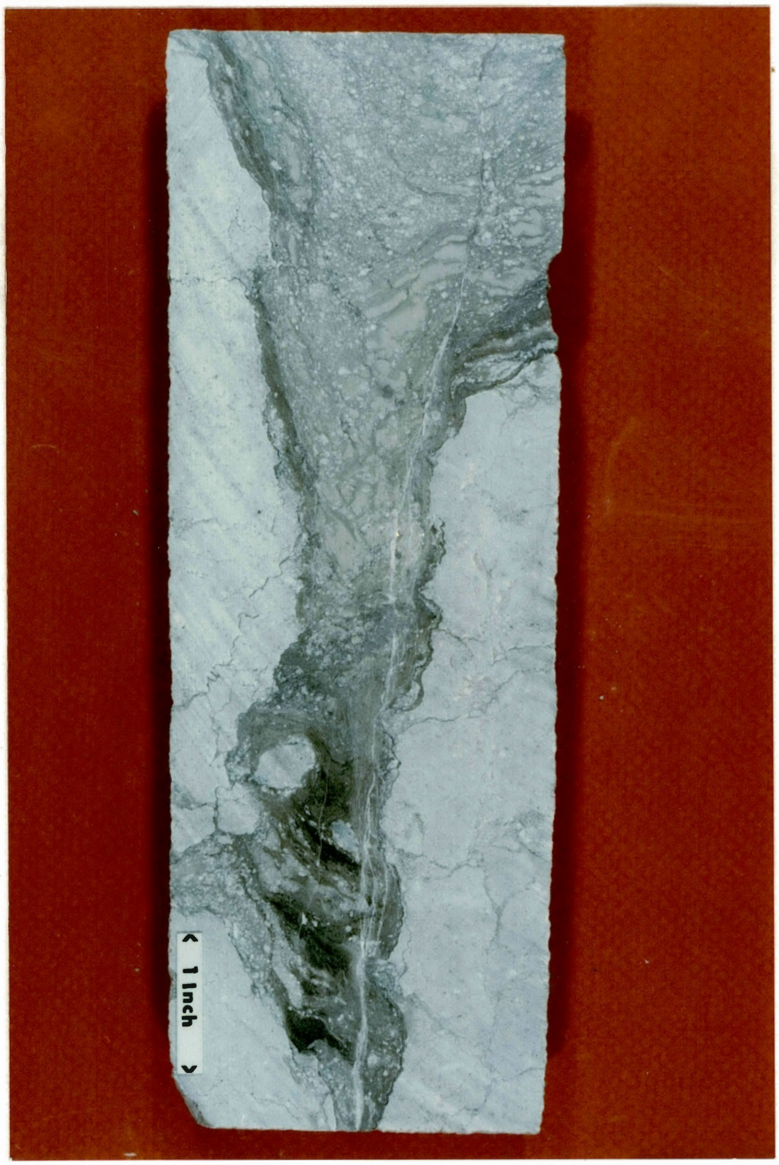


Figure 21. Pelto Cheatwood Core, -3,991 (?) ft.
Solution-enlarged channel.

cave muds, glauconite, and dolomite cement (Figure 22). The Samson Wade core, Garvin County, contains solution-enlarged channels filled with fragments of host rock, chert, and quartz grains. The channels are noticeable in the Samson Wade core photographs in Appendix A. Breccias within elongated channel pores are termed "channel breccias" and are formed by solution enlargement of joints and subsequent filling of the joints by breccia during karstification (Kahle, 1987). The Cleary Gilbert core, Kingfisher County, exhibits a sample of channel breccia (Figure 23).

Caverns

Cavern or cave porosity is defined by Choquette and Pray (1970) as the smallest opening that an adult human can enter; or if the rock is encountered in drilling, as any opening large enough to cause a noticeable drop of the drill bit. Craig (1988) defines cave size as one foot (0.3 m) minimum height, which is approximately the lower limit of detection by both density log caliper and the bulk density porosity log. Cavern porosity is the largest megapore designation and cannot be substantiated in a core study because of the limited size of the samples.

Figure 22. Carter Hester Core, -7,781 ft. Crinoidal packstone containing solution-enlarged fractures. Porosity has been occluded by cave muds, glauconite, and dolomite cement.

Figure 23. Cleary Gilbert Core, -7,562 ft.
Channel breccia.

Breccia has been found to occur in Hunton cores, much of it cavern-fill parabreccias and collapse breccias. In at least one core, the Cleary Kinney, what appears to be flowstone is also present in the collapse breccia. Therefore, the former presence of caves may be inferred by the existence of these breccias and possible speleothems. Even a few feet of heterolithic collapse breccia necessitates a precursor cavity of similar magnitude, into which roof rock could collapse.

Infill Sediment

Interesting examples of paleokarst infill sediment are present in Hunton cores. A core sample from the MacKellar Ferguson core, Woodward County, encompasses what may be vadose geopetal internal sediment (Vera et al., 1988). These laminated sediments can occur as partial fillings on floors of karst cavities or as matrix sediment in collapse breccias. In the MacKellar Ferguson case, the dolomitized sediment is brecciated and the clasts cemented with baroque pore-filling dolomite (Figure 24).

Many vugs and molds in these rocks hold infill sediment. The most outstanding example of this phenomenon is found in the Kirkpatrick Shewey, Major County, core. A 3 x 4 centimeter vug is geopetally filled with cave infill sediment. First, the cavity was lined with silica cement and

Figure 24. MacKellar Ferguson Core,
-9,757 ft. Vadose geopetal
internal sediment.

a light cream layer of sediment was then deposited. These events were followed by accumulation of a dark brown carbonate mudstone. Two layering sequences occurred, each with many laminations and each sequence a tannish-cream dolosiltite. The remnant pore space at the top of the vug is filled with deep burial baroque dolomite crystals. This geopetal structure is located at -8,720 feet (Figure 25). A brecciated dolomite and chert sample of the Cox Annis core, Harper County, reveals a cavity filled by cave sediment and a four-centimeter calcite crystal (Figure 26).

The Kirkpatrick Shewey core displays another intriguing infill sediment feature. Approximately forty feet from the top of the Hunton-Woodford Shale contact, a 12 x 2 centimeter Woodford Shale clast resides in a solution-enlarged channel of this Henryhouse section. It is probable that the shale would fill the existing crevasses that certainly existed on the unconformity surface between the Woodford Shale and the Hunton (Figure 27).

Smaller proof of infill sediment from above exists in the Gulf Wright core of Oklahoma County. The core has two feet of breccia at the top with cobbles of Frisco in the Misener Sandstone. Beneath this zone is sparry calcite Frisco grainstone with red, hematitic stain in solution cavities (Figure 28). The stain is evidence of downward infiltration of sediment and its

Figure 25. Kirkpatrick Shewey Core, -8,720 ft. Burrowed dolowackestone with vug filled by cave clay and dolomite crystals. Sample stained by machine oil during slabbing. Note vuggy porosity in the samples.

Figure 26. Cox Annis Core, -7,300 ft.
Calcite crystal and sediment
in dolomite and chert breccia.

Figure 27. Kirkpatrick Shewey Core, -7,929 ft. Woodford Shale clast in an eroded channel of Henryhouse.

Figure 28. Gulf Wright Core, -6,305 ft. (left) and -6,308 (right). Infill sediment from above. Core sample at left illustrates cobbles of Frisco in Misener Sandstone. Specimen rich in siderite cement. Core sample at right is grainstone with hematitic stain in solution cavities.

eventual accumulation in cavities in the Frisco Formation. The reddish discoloration of the sediment is due to oxidation, as discussed by Kahle (1988). Figure 29 is a photomicrograph of the Gulf Wright.

Speleothems

The term "speleothem" refers to every type of precipitated calcium carbonate deposit covering the walls, roofs, and floors of dissolved cavities (Vera, 1988). More than 100 minerals are known to occur in caves, but calcite is the chief precipitate (Ford, 1988). Speleothems can vary in size from a millimeter-thick coating on a cave wall to a multi-meter-long stalactite. Names of speleothems are descriptive of their habit: flowstone, rimstone, globulites, popcorn, cave pearls, lily pads, helictites, moon-milk, stalactites and stalagmites. Studies of calcite speleothems yield paleoenvironmental information pertaining to paleotemperature, humidity data, pollen grains, etc. (Ford, 1988).

Although not abundant, speleothems do occur in the fossil record. They may be corroded and partly replaced by argillaceous micrite, due to repeated cycles of exposure in the upper vadose zone of the karst profile. These reworked speleothem fragments within collapse breccia may be used as indications of karst (Esteban & Klappa, 1983). Lithologic evidence of fossil

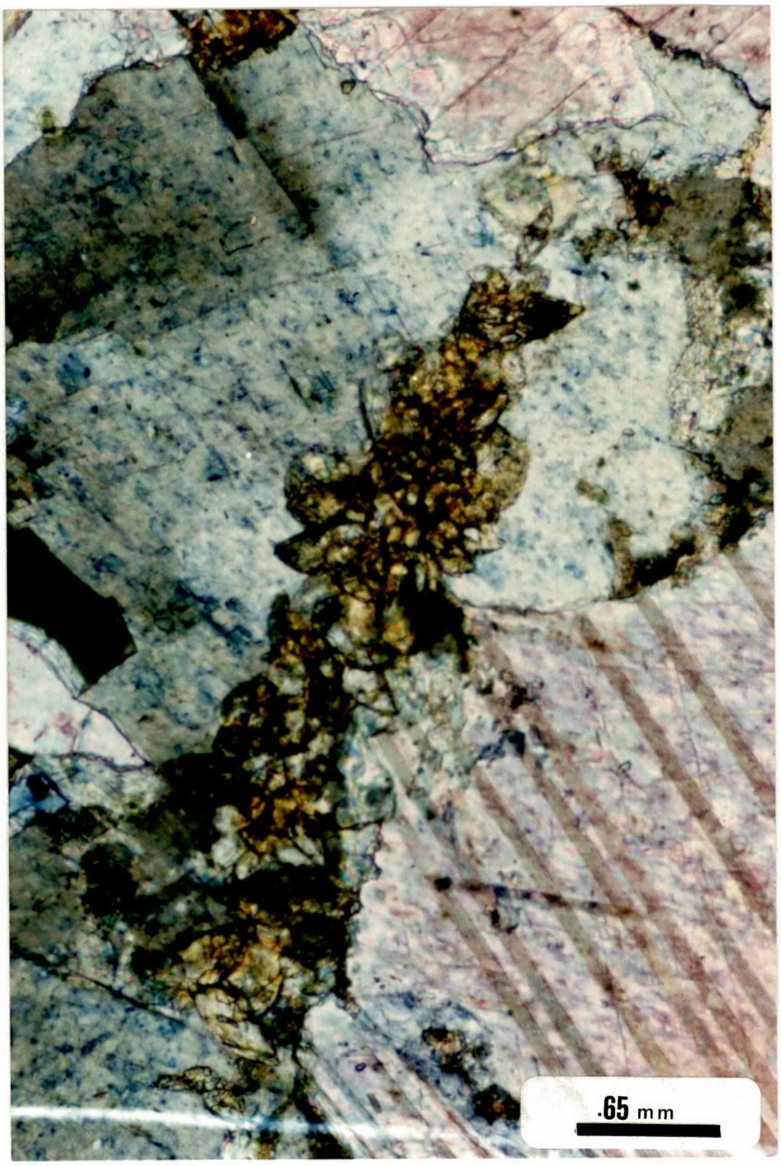


Figure 29. Gulf Wright Core, - 6,305 ft. Photomicrograph (X.N.) of Frisco clast with fibrous siderite cement, ferroan calcite and dolomite rhombs.

flowstone and dripstone in paleokarst are seen in photographs of slabbed cores from West Texas (Craig, 1988). Fossil speleothems, laminar flowstones and globulite, are visible also in the outcrop photographs accompanying Esteban and Klappa's paper (Esteban & Klappa, 1983).

Evidence of speleothems is uncommon in Hunton subsurface rocks. However, what appears to be flowstone-covered clasts are present within the collapse breccia samples from the Cleary Kinney core (Figures 16 and 17). The buff-colored, dolomitized parts in Figure 16 reveal the texture of flowstone. The white calcite coating, viewed in Figure 17, seems to "frost" a large part of one clast and the edges of some of the smaller shards. These examples of possible flowstone in the collapse breccia could be portions of a former cave wall which hosted patches of flowstone before the cave foundered. Millimeter-sized, silicified particles akin to broken pieces of flowstone are seen in thin sections from the Shell Stocking core. The cavern-fill parabreccia specimen from this core harbors pieces of suspect speleothems as well as other cave debris (Figure 11).

The Calvert Mid-America Bloyd core, Woods County, shows a contorted, laminated portion of rock (Figure 30). This enticing photograph may be a highly unlikely instance of a drill bit capturing a speleothem segment within the diameter of a core sample. Because of the "tremendous

Figure 30. Calvert Mid-America Bloyd
Core, -6,208 ft. Speleothem
or geophantasy?

improbability of actually coring one of these features" (Lynch, 1990), common sense dictates the interpretation of algal laminations from a supratidal depositional environment for this phenomenon. Nevertheless, the presence of speleothems in paleokarst cores is not an impossible event, only an improbable one.

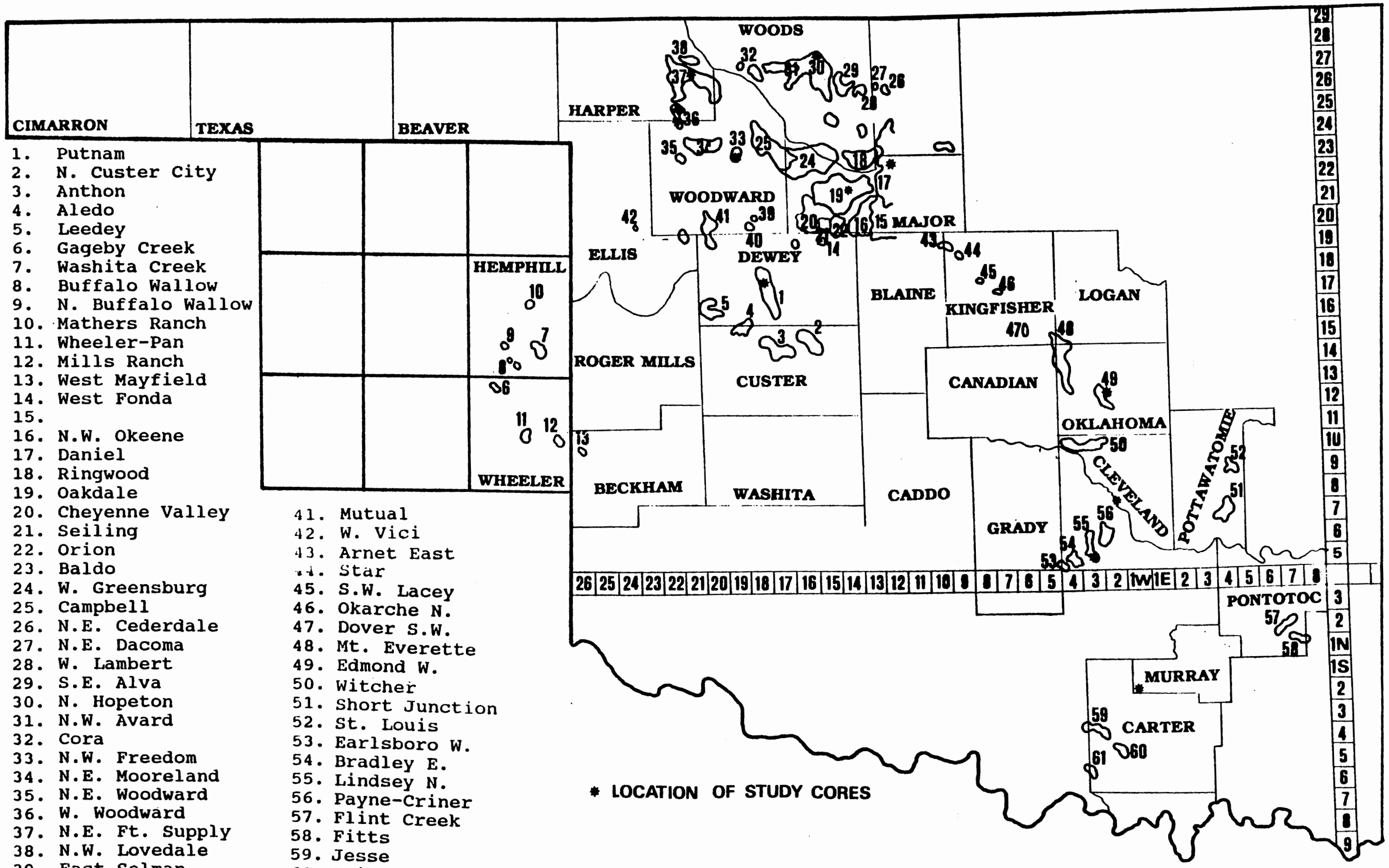
CHAPTER IV

HUNTON PALEOKARST RESERVOIRS

Introduction

The carbonate rocks of the Hunton Group have been important producers of oil and gas in Oklahoma for nearly seventy years. The first Hunton oil was discovered near Beebe in Pontotoc County in August, 1921. The St. Louis field was begun in 1926; in three years, over six and one half million barrels of oil had been recovered (Kunsman, 1967). Anderson wrote that the oil from the St. Louis field comes from the top of the weathered zone on differentially eroded, buried hills of thick Hunton (Anderson, 1939).

Today fields with Hunton production are established throughout the area of this report, and the map of Oklahoma shows the locations of the twelve study cores from various Hunton fields (Figure 31). Interval and reservoir information regarding the cores is available in Table I and Table II in Chapter I. The twelve study cores were classified into two types of reservoirs: Type One Hunton Paleokarst Reservoir and Type Two Hunton Paleokarst Reservoir.



1. Putnam
2. N. Custer City
3. Anthon
4. Aledo
5. Leedey
6. Gageby Creek
7. Washita Creek
8. Buffalo Wallow
9. N. Buffalo Wallow
10. Mathers Ranch
11. Wheeler-Pan
12. Mills Ranch
13. West Mayfield
14. West Fonda
15.
16. N.W. Okeene
17. Daniel
18. Ringwood
19. Oakdale
20. Cheyenne Valley
21. Seiling
22. Orion
23. Baldo
24. W. Greensburg
25. Campbell
26. N.E. Cederdale
27. N.E. Dacoma
28. W. Lambert
29. S.E. Alva
30. N. Hopeton
31. N.W. Avard
32. Cora
33. N.W. Freedom
34. N.E. Mooreland
35. N.E. Woodward
36. W. Woodward
37. N.E. Ft. Supply
38. N.W. Lovedale
39. East Selman
40. N.W. Seiling
41. Mutual
42. W. Vici
43. Arnet East
44. Star
45. S.W. Lacey
46. Okarche N.
47. Dover S.W.
48. Mt. Everette
49. Edmond W.
50. Witcher
51. Short Junction
52. St. Louis
53. Earlsboro W.
54. Bradley E.
55. Lindsey N.
56. Payne-Criner
57. Flint Creek
58. Fitts
59. Jesse
60. Joiner City
61. Joiner City S.E.

Figure 31. Location of Hunton Fields.

Type One Hunton Paleokarst Reservoir

Six cores were classified as representative of Type One Hunton Paleokarst Reservoir. The cores are the Cleary Kinney, Cox Annis, MacKellar Ferguson, Samson Wade, Shell Stocking, and Wil-Mc Cossey.

Type One paleokarst reservoirs consist of massive limestone host rocks, such as a mudstone or a tightly cemented grainstone. These rocks have low matrix or interparticle porosity. The flow of groundwater is forced to proceed along bedding planes and fractures, caves, and solution-widened joints due to the lack of interparticle porosity within the rock itself. Kerans (1989) employs the name "conduit-flow" karst for this type of system. White (1969) used the term "free-flow" karst hydrologic regime. In this report, the term "conduit-flow" paleokarst is adopted for the Type One reservoir.

Collapse breccia is the most distinctive feature of conduit-flow paleokarst. Collapse breccia is present as tabular bodies representing old phreatic cave systems or as thick, laterally restricted collapse-doline features (Kerans, 1989). The breccia may be stratiform; that is, composed of layers, indicating several episodes of karstic activity.

The Samson Wade core is an example of a stratiform breccia sequence. After a top interval of crackle and mosaic breccias, cavern-fill parabreccia and collapse breccias continue in stratiform manner for twenty-three feet. Another core, the MacKellar Ferguson, also exhibits stratiform brecciation in at least two portions of the core. The Clarita at the top of the core is unconformably overlain by the Woodford Shale due to the northward truncation of the Hunton. There is additional brecciation approximately fourteen feet lower in the sequence, suggesting a disconformable surface between the Clarita and the underlying Cochrane.

As noted in the previous chapter, the location and length of the cored portion from each study core determines to what extent a paleokarst sequence can be observed in each core. In an ideal situation, the cave roof facies of crackle and mosaic breccias would be followed, in descending order, by cavern-fill parabreccia and collapse breccia of the cave-fill facies. In Type One Hunton Paleokarst Reservoir, only two Hunton cores, the MacKellar Ferguson and the Samson Wade, were taken high enough from their sections to include crackle breccias. Three cores - the Cox Annis, MacKellar Ferguson, and the Samson Wade - show small amounts of mosaic breccias; and three cores - the Cox Annis, Samson Wade, and Shell Stocking - appear to contain cavern-fill parabreccia overlying the collapse breccia segments. All of the six cores of Type One reservoir category were found to contain collapse breccias.

An inventory of breccias discovered in Type One and Type Two Hunton Paleokarst Reservoirs is provided in Table IV. Other characteristics indicative of TYPE ONE, conduit-flow paleokarst, in addition to collapse breccias, include the presence of cave-fill sediment, speleothems (stalactites, stalagmites, and flowstone), and a surface topography that may have several feet to several hundred feet of relief (Kerans, 1989). The existence of cave-fill sediment and speleothems in the Hunton rocks is addressed in sections of Chapter III regarding cavern-fill parabreccia and speleothems. However, the presence of sinkholes, towers, and other karst surface landforms cannot be substantiated by a core study and is beyond the scope of this paper.

Porosity in cores of Type One reservoirs is sparse but not altogether absent. The Cox Annis, Harper County, and Wil-Mc Cossey, Pottawatomie County, do contain some visible interparticle porosity between the clasts in the collapse breccia portions of their cores. This type of porosity is noticeable in the photographs of the Cox Annis sample in Figure 13, Chapter III, and in the Wil-Mc Cossey sample. Type One lithologies generally are tight because the fractures and solution-widened joints and vugs have been filled by cave sediments and cements.

TABLE IV

BRECCIAS REPRESENTED IN HUNTON CORES

CORES	Crackle Breccia	Mosaic Breccia	Cavern-Fill Parabreccia	Collapse Breccia
TYPE ONE HUNTON RESERVOIRS				
Cleary Kinney 1-20	O	O	O	X
E. L. Cox Annis A-1	O	X	X	X
MacKellar Ferguson 9	X	X	O	X
Samson Wade 1	X	X	X	X
Shell Stocking 1-32	O	O	X	X
Wil-Mc Cossey 2	O	O	O	X
TYPE TWO HUNTON RESERVOIRS				
Amax Hickman 1-24	O	O	O	O
Arco Marcum 3	O	O	O	O
Carter Hester 1	O	O	O	O
Gulf Wright Heirs 1	O	O	O	O
Kirkpatrick Shewey 1	O	O	O	X
Tenneco Jordan A-1	O	O	O	O

Two examples of Type One reservoir rocks are illustrated in Figures 32 and 33. The Shell Stocking core of Woodward County holds twenty-one feet of cavern-fill parabreccia and collapse breccia in its exposed core. Figure 32 displays a slab from the Shell Stocking which is typical of Type One reservoirs. The clasts are angular and poorly-sorted dolomudstone in a matrix of dolomite rhombs, detrital grains of glauconite, collophane, pyrite, chert and feldspar. There is sparse intercrystalline and moldic porosity in this sample. Another Type One reservoir specimen is given in Figure 33. Here, the Wil-Mc Cossey core reveals tightly packed, heterolithic clasts of mudstone, packstone, and grainstone. Cave clay fills the seams between the clasts.

Most of the rocks of Type One Hunton Paleokarst Reservoir were not producers of oil or gas, according to the production records as seen in Table II in Chapter I.

Type Two Hunton Paleokarst Reservoir

Six study cores have been placed in the Type Two Hunton Paleokarst Reservoir category. These cores are the Amax Hickman, Arco Marcum, Carter Hester, Gulf Wright, Kirkpatrick Shewey, and the Tenneco Jordan. These cores contain features which are different from the Type One group.

Figure 32. Shell Stocking Core, -10,264 ft.
Core sample of Type One Hunton Paleokarst Reservoir. Collapse breccia.

Figure 33. Wil-Mc Cossey Core, -5,060 ft. Core sample of Type One Hunton Paleokarst Reservoir. Collapse breccia with heterolithic cobbles in cave clay sediment.

Type Two reservoirs are composed of lithologies which allow groundwater to flow through the rock. Kerans (1989) has named this type of karst "interparticle flow"; White (1969) proposed the term "diffuse flow" for this karst hydrologic regime. "Diffuse flow" is the term which is used in this report. Kerans' term, "interparticle flow" is based on pore geometry; whereas, White's "diffuse flow" emphasizes flow characteristics. Both terms adequately describe the manner of flow through these Hunton subsurface rocks.

Rocks with diffuse flow of groundwater are thought to have been deposited in an intertidal zone where they underwent intense bioturbation and dolomitization. Beardall's (1983) study of the Henryhouse suggests several features which are characteristic of intertidal facies. These features comprise burrow mottling, dissolution of grains which results in moldic and vuggy porosity, and a dolowackestone lithology. Karstification further enhanced the porosity of these rocks by the enlargement of already existing pores. Four of the study cores in Type Two category contain these intertidal facies characteristics. They are dolowackestones or dolomudstones with excellent visible vuggy and moldic porosity. The cores are the Amax Hickman, Arco Marcum, Kirkpatrick Shewey, and the Tenneco Jordan. The dissolution traits of these rock bodies have been described in the vugular porosity and solution-enlarged fractures portions of Chapter III, and may be seen in Figures 18, 19, 20, 25, and 27 in Chapter III.

Two other study cores listed in Type Two Hunton Paleokarst Reservoir category are the Carter Hester and the Gulf Wright cores. The Carter Hester, McClain County, is a wackestone/dolomudstone with some vuggy porosity. It is mentioned in the solution-enlarged fractures section in Chapter III, and a sample is shown in Figure 22 in Chapter III. The Gulf Wright core of Oklahoma County is a dolograinstone with low intraparticle porosity and is described in the infill sediment portion of Chapter III. Two samples from this core illustrating infill sediment is shown in Figure 28. An example of Type Two Hunton Paleokarst Reservoir rock is given in Figure 34. The photograph clearly shows the excellent porosity to be found in the Amax Hickman, Dewey County, core.

The disparity in the composition of Type One conduit-flow lithology and the Type Two diffuse-flow lithology results in an absence of caves in the Type Two reservoirs. Meteoric fluids move through Type One reservoir rocks in solution-enlarged channels or bedding planes, removing carbonate and causing cavern-sized pores to exist. In Type Two reservoir lithology, however, waters can pass through the interparticle pore space with little or no additional removal of carbonate rock. As a consequence, cavern-fill

Figure 34. Amax Hickman Core, -13,510 ft. Example of Type Two Hunton Paleokarst Reservoir. Outstanding moldic and vuggy porosity.

parabreccias and collapse breccias are rare or nonexistent in Type Two reservoirs. It is possible that there may be small-scale breccia present in Type Two lithologies. This could occur as a result of near-surface karstification during a subaerial exposure event.

One study core in Type Two category displays breccia. The Kirkpatrick Shewey of Major County holds two and one-half feet of collapse breccia. Figure 35 shows a sample of the dolowackestone core containing baroque pore-filling dolomite cement. The darker rock on the left side of the photograph is believed to be the host rock. The collapse breccia portion of the core has the semblance of a cavity which has at its base the enclosed Woodford Shale debris. Perhaps this is an indication of the surficial weathering of the Hunton which occurred during the time of the pre-Woodford unconformity.

Most of the reservoirs of the Type Two groups were producers of oil or gas according to the production records as seen in Table II in Chapter I. This is a consequence of the porous lithology inherent of the Type Two Hunton Paleokarst Reservoirs.

Additional information concerning the lithologies and porosities of Type One or Type Two Hunton Paleokarst Reservoir cores may be obtained in core descriptions, photographs, and petrologs located in the Appendices.

Figure 35. Kirkpatrick Shewey Core, -7,927 ft. Type Two Hunton Paleokarst Reservoir. Only instance of breccia in Type Two category.

Unconformities

Introduction

Unconformities, or subaerial exposure surfaces, are areas where upper bounding surfaces of rock show the effect of being exposed at the Earth's surface. In order to be recognized, the rocks need to be exposed long enough to allow diagenetic processes to modify or obliterate their fabrics (Esteban & Klappa, 1983). This process will record a break in the sedimentary sequence. Other terms used to describe this condition are hiatus, diastem, break, disconformity, unconformity, hardground, or discontinuity surface (Estaban & Klappa, 1983).

Because of the close ties between unconformities and oil fields, these areas hold great interest for geologists. Levorsen (1967) declares that crossing an unconformity with a drill for the first time means discovering a whole new geologic environment, which often means the discovery of new oil and gas production. The more unconformities present in a region, the better chances that it will be productive of petroleum.

The carbonate rocks of the Hunton are believed to have experienced subaerial weathering at various times throughout their history. In Chapter I of this paper it was noted that many Hunton workers have described evidence of subaerial exposure events; the reader is referred to these reports. Amsden (1975) asserts that the Hunton represents an incomplete depositional sequence with significant time-stratigraphic gaps developed over substantial areas in the Arbuckle Mountains - Criner Hills outcrop area. Local unconformities probably existed during pre-Cochrane, pre-Clarita, pre-Henryhouse, pre-Haragan/Bois d' Arc, and pre-Frisco times (Amsden, 1980). Of these unconformities, Amsden writes that the pre-Frisco and pre-Woodford truncations are of regional scope and are the result of subaerial erosion. Amsden states that he does not imply that other unconformities are not represented in the subsurface but that, if present, they affect relatively small areas (Amsden, 1980).

Types of Unconformities

The Stratigraphy of Paleokarst in Figure 36 is a diagram which illustrates the types of unconformities which may be found in subsurface carbonate rocks, such as the Hunton Group. "Interregional karst" is related to major tectonic events and is identified by large-scale collapse breccias and caverns. It represents the occurrence of subaerial exposure for long periods of time over a vast terrain. "Depositional karst" forms by sediment accretion to sea level, a shallowing-upward sequence, in the evolution of a carbonate

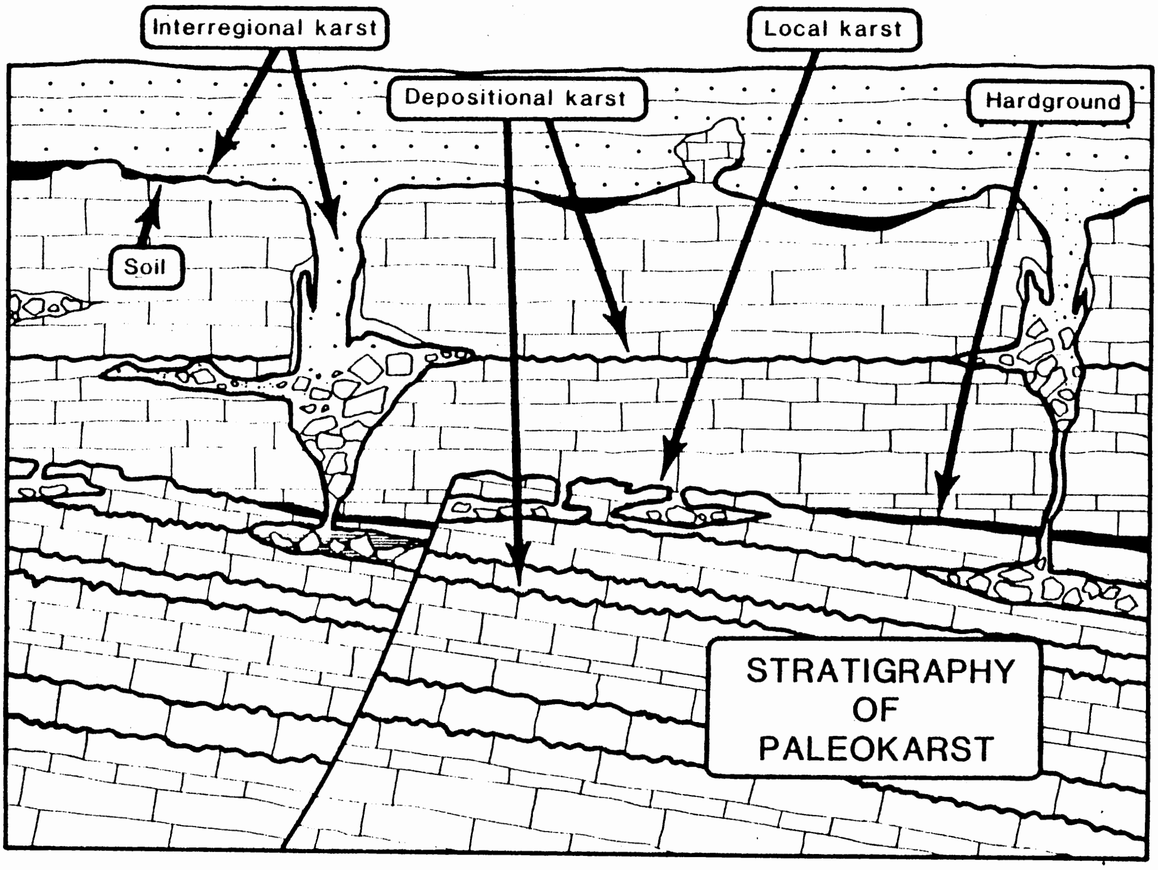


Figure 36. A diagram summarizing the different levels of karst to be expected within carbonate terranes (Choquette & James, 1988).

platform. Hardgrounds and planar truncation surfaces may result; topographic relief could be measured in centimeters. "Local karst" develops when a portion of the carbonate shelf is exposed by a drop in sea level, or by local uplift. The amount of dissolution of carbonate which occurs depends on the length of exposure time and the degree of displacement. Local unconformities or intraformational disconformities may be formed. If the subaerial exposure is prolonged, interformational unconformities could be the result.

The Pre-Woodford Unconformity

The pre-Woodford unconformity in Oklahoma has been recognized for a long time (Tarr, 1955). The unconformity is described as a fairly uniform regional beveling of the Hunton toward the north; and along the northern margin of the state these rocks have been entirely stripped away (Amsden, 1975). Within the outcrop area of the Arbuckle Mountains, pre-Woodford erosion locally truncates the Hunton completely, allowing the Woodford to rest on the Sylvan Shale (Amsden, 1975). The scope of the pre-Woodford unconformity corresponds to the level of karst called "interregional karst" as illustrated in the drawing in Figure 36.

The presence of the pre-Woodford unconformity above the Hunton rocks is confirmed in three study cores, the Arco Marcum, Woods County; the Cox Annis, Harper County; and the MacKellar Ferguson, Woodward County. These cores are found along the northern extent of the Hunton and consist of Chimneyhill rocks. The rest of the Hunton Group above the Chimneyhill has been removed by erosion in this location. The Arco Marcum and the Cox Annis cores show samples of Woodford Shale which directly overlie the dolomite of the Chimneyhill. In the MacKellar Ferguson, cobbles of the Clarita are found in the gray-black rock at the top of the core which is thought to be the lower Woodford Shale. The location of the Woodford directly over the Chimneyhill records the loss of the Henryhouse, Haragan, Bois d'Arc, and Frisco Formations of the Hunton Group. There is a sudden change of lithology with no facies gradation represented in these three cores.

Criteria to Recognize Unconformities

Abrupt changes in lithology can be used as a criterion for the identification of unconformities. Other criteria used to identify unconformities in carbonate reservoirs may include the occurrence of karst features, the presence of dedolomitization, and characteristic electric log signatures.

Karst

Karst and collapse breccia features are believed to represent unconformity surfaces (Esteban & Klappa, 1983). Six of the study cores of Type One Hunton Paleokarst Reservoirs encompass collapse breccia. All of the twelve study cores contain certain elements of paleokarst which have been previously addressed in the paper (see Table II in Chapter I, Chapter III, and Table IV). Three cross sections, A-A', B-B', C-C', are enclosed in the pocket attached to the back cover of this report. These cross sections graphically portray the existence and location of paleokarst as related to the pre-Woodford and other possible unconformities. It is believed that the majority of the cores were influenced by the pre-Woodford event. As stated earlier, three cores are in direct contact with the Woodford. Other study cores - Tenneco Jordan, Samson Wade, Cleary Kinney, Shell Stocking, Gulf Wright, Kirkpatrick Shewey - reside within a few feet or few tens of feet below the unconformity. The position of one study core, the Wil-Mc Cossey, relative to the pre-Woodford erosion has not been determined. Two cores are located a considerable distance from the pre-Woodford unconformity: the Amax Hickman lies 125 feet below and the Carter Hester approximatley 300 feet below. Each core contains paleokarstic features. It may be that these cores represent "local karst" or "depositional karst" episodes. Intraformational disconformities may have formed in the rocks due to periods of erosion or local nondeposition.

Dedolomitization

The presence of dedolomitization is considered to be another criterion for the recognition of unconformities. Dedolomitization is the process which results in corrosion, dissolution, and/or calcitization of dolomite rhombs. It occurs when calcium-rich waters flow through the dolomite, rendering it unstable and resulting in its dissolution or replacement (Manni, 1985). Petrographic evidence of the presence of dedolomitization is in the cores that are directly overlain by the Woodford. This coincides with the findings of Munn and Jackson (1980) that nearly all reported dedolomitization is associated with subaerial weathering, either at ancient unconformities, or at the Earth's surface. Experimental work by de Groot (1967) also concluded that dedolomitization is most likely a near-surface phenomenon. This aids in the confirmation that dedolomitization is associated with unconformities (Manni, 1985).

Electric Well Log Signatures

Electric well log signatures with kickbacks are traits which help identify unconformity surfaces. The contact between the Hunton and the Woodford is noticeable in the well log signatures in the cross sections. The gamma ray curve and resistivity curve show "notches" or kickbacks at the unconformity boundary. The well log signatures help to confirm the changes in lithology present in the study cores.

Dolomite

It is the purpose of this discussion to present an inventory of the types of dolomite present in the Hunton study cores. Seven types of dolomite were identified in Hunton rocks. The nomenclature in this inventory is based on that employed by Lynch in his report about the Arbuckle Group dolomite (Lynch, 1990).

Dolomite in the Hunton consists of an early, eogenetic type and a later, epigenetic type. The eogenetic zone extends from the surface of newly deposited carbonate to depths where processes genetically related to the surface become ineffective (Scholle, 1983). Epigenetic dolomite is formed after the deposition of the sediment. Figure 37 is a diagram which furnishes a paragenetic "map" to help trace the development of different types of

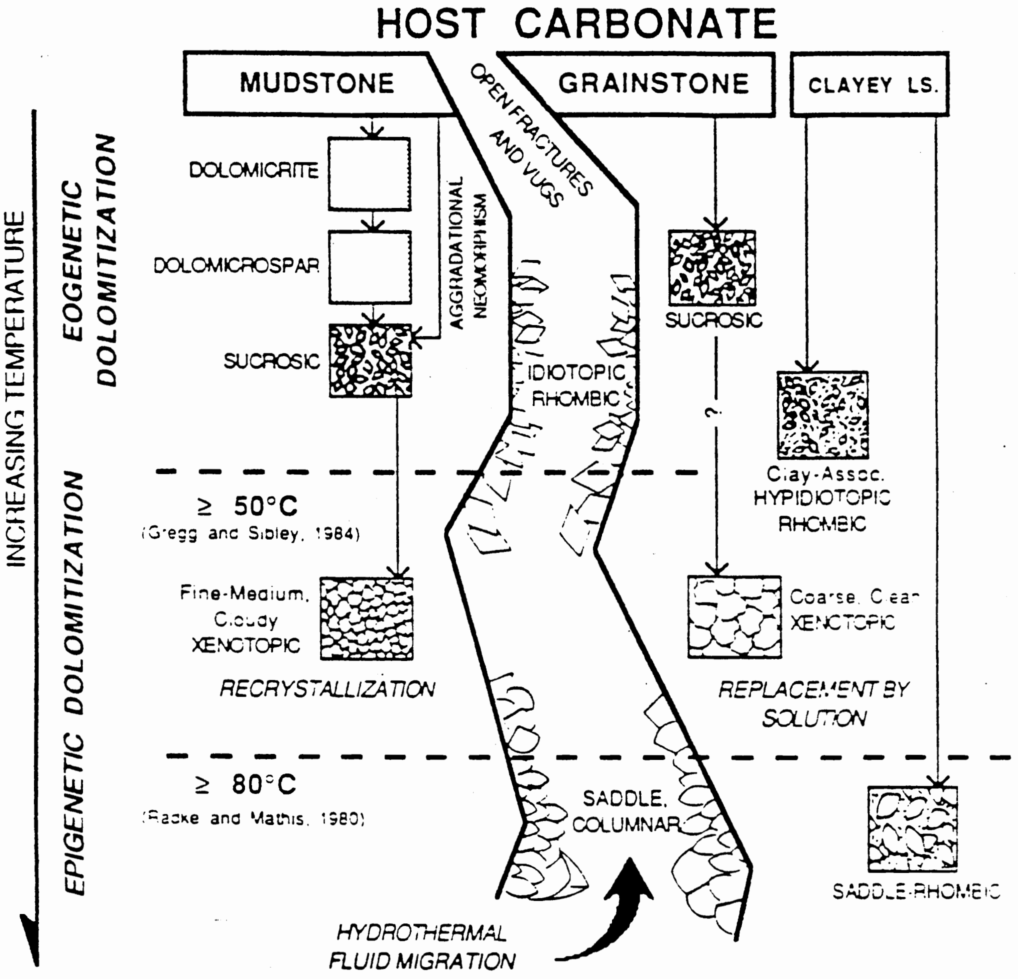


Figure 37. Diagram of dolomite types and probable paragenesis in relation to types of host rock present and temperature. Initiation temperatures for xenotopic and saddle dolomite are from Gregg and Sibley (1984) and Radke and Mathis (1980), respectively (Lynch, 1990).

dolomite. The main catagories of dolomite are the matrix-replacive dolomites and the pore-filling dolomites.

Matrix-Replacive Dolomicrite/Dolomicrospar

This type of matrix replacive dolomite, or recrystallized host rock, is an early-forming, syndepositional dolomite. Crystal size ranges from 0.01 - 0.05 mm, has anhedral shape, and appears "dirty looking" in thin section. Figure 38 shows dolomicrospar from the MacKellar Ferguson, Woodward County, which exhibits dedolomitizaton due to its proximity to the pre-Woodford unconformity.

Matrix-Replacive Sucrosic Dolomite

Figure 39 illustrates the porous fabric of this type dolomite. Note dead oil lining some pores. Sucrosic dolomite is typically found in Type Two Hunton Paleokarst Reservoirs. This example is from the Arco Marcum core in Woods County. Crystals are loosely interlocking, hypidiotopic to idiotopic, rhombohedral shape. The highest porosities in the Hunton are found in this type of dolomite. The crystal size ranges from 0.1-0.3 mm; the rhombs often have dirty, inclusion-rich cores with a limpid outer rim.

Figure 38. MacKellar Ferguson, -9,754 ft. Photomicrograph of matrix-replacive, dolomicrospar. Red stain indicates dedolomitization (X.N.).

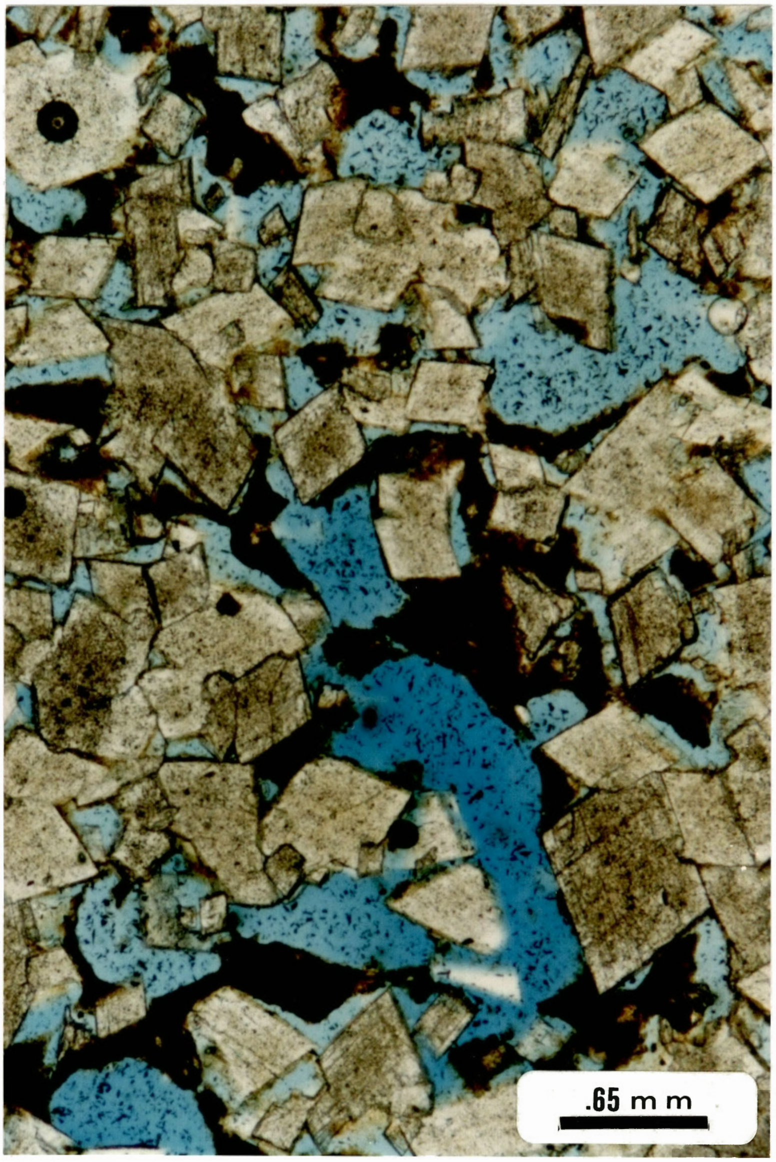


Figure 39. Arco Marcum, -6,242 ft.
Photomicrograph of matrix-replacive, hypidiotopic-rhombic (sucrosic) dolomite.

Matrix-Replacive Clay-Associated Rhombic Dolomite

This catagory dolomite is seen in at least ten of the study cores. Crystals are smaller than the sucrosic dolomite rhombs, averaging 0.05-0.2 mm. The rhombs may be clean and free of inclusions, or they may have inclusion-rich centers. This type of dolomite is formed in terrigenous-clastic clay seams. Figure 40 shows the rhombs in a matrix of micrite and quartz. This sample is from the Shell Stocking core, Woodward County.

Matrix-Replacive Xenotopic Dolomite

Xenotopic dolomite has anhedral crystals ranging in size from 0.1-0.5 mm. This replacement type dolomite is usually arranged in a tightly interlocking, nonporous, fabric. Faint "ghosts" of former grains which have been replaced by the dolomite may be noticed. The sample in Figure 41 is from the Arco Marcum core, Chimneyhill Subgroup, Cochrane Formation. Glauconite grains typically are found in the Cochrane. Xenotopic dolomite is found in a deeper location with temperatures over 50° C.

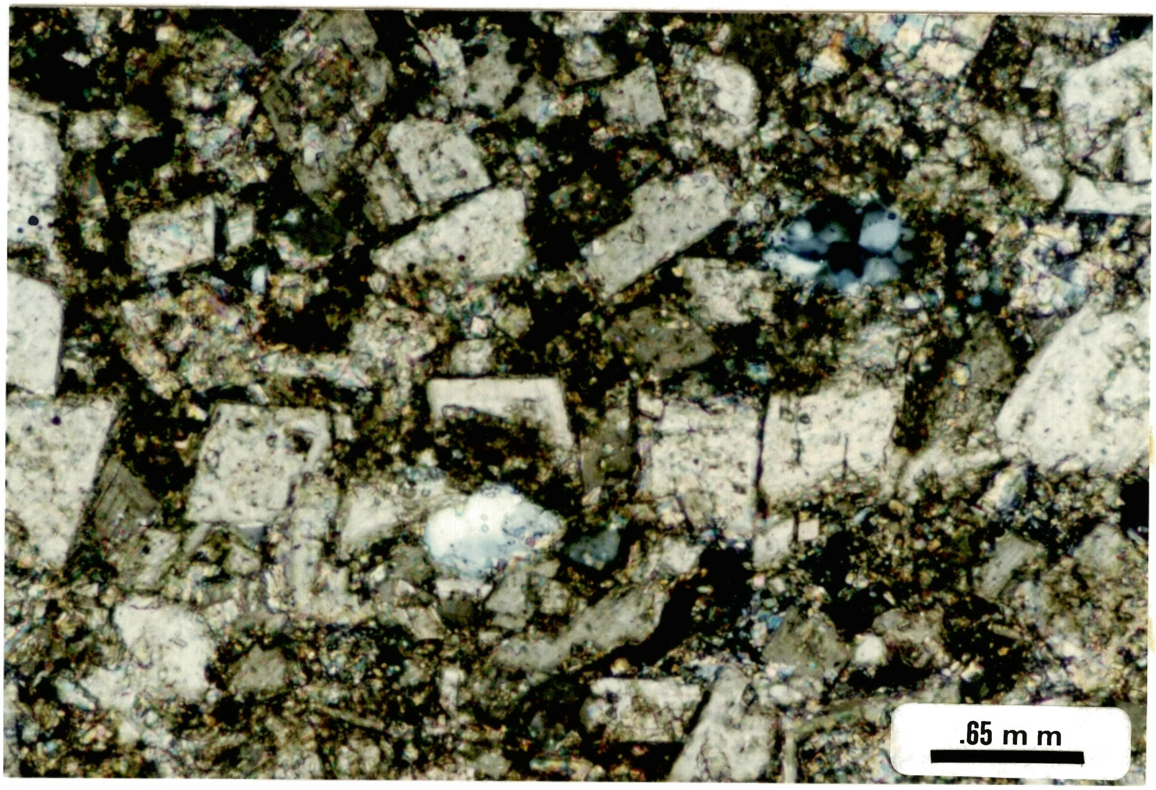


Figure 40. Shell Stocking, -10,257 ft. Photomicro-graph (X.N.). Matrix-replacive, clay associated hypidiotopic-rhombic dolomite.

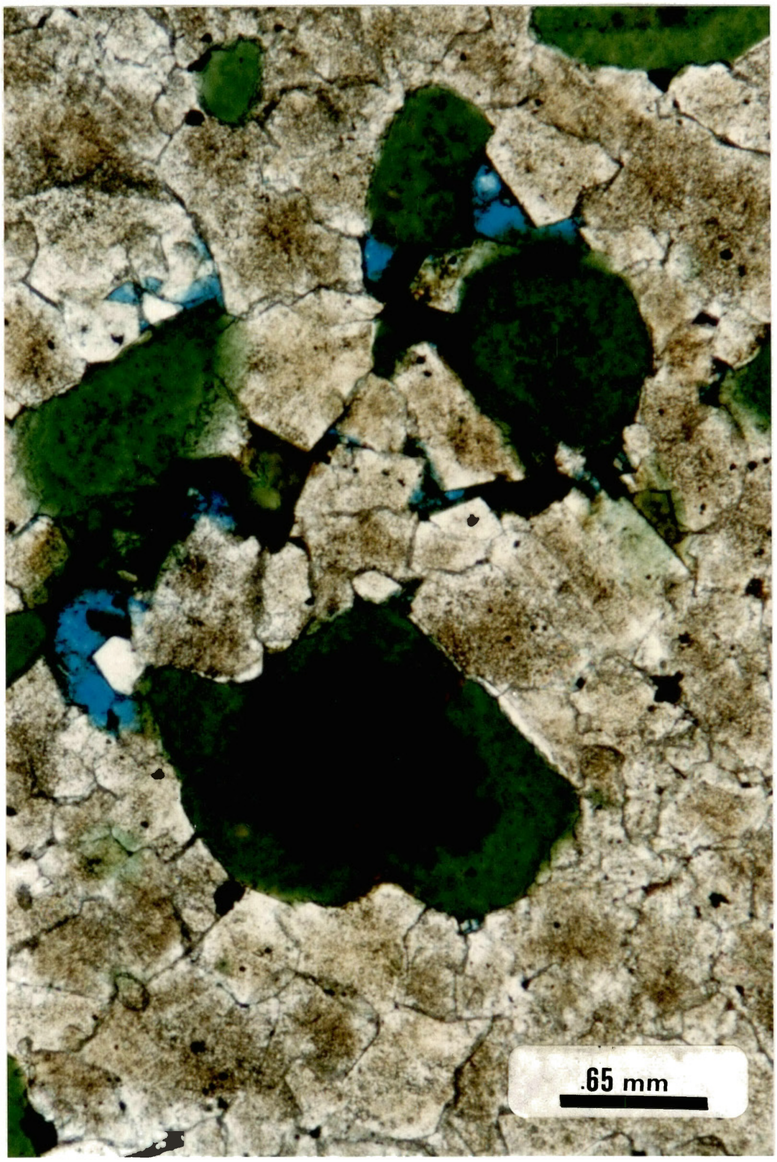


Figure 41. Arco Marcum, -6,240 ft.
Photomicrograph of
matrix-replacive,
xenotopic dolomite
containing glauconite.

Pore-Filling Idiotopic-Rhombic Dolomite

These clear rhombs of dolomite inhabit pore spaces in three Type One reservoirs. The size of the crystals are not interlocked to the extent seen in saddle dolomites. They have straight to slightly undulose extinction. Figure 42 displays several rhombs from the brecciated section of the Cox Annis core.

Pore-Filling Saddle Dolomite

Saddle, or baroque, dolomites fill fractures and vugs in at least eight Hunton cores of Type One and Type Two reservoirs. This type of dolomite is considered to be deep burial or hydrothermal dolomite. The hypidiotopic curved crystals are oriented normal to pore walls or grain boundaries. Typical pronounced undulose extinction is shown in Figure 43. Crystal size is 0.5-5.0 mm. Baroque dolomite may be seen also in Figure 29, Chapter III.

Pore-Filling Columnar Dolomite

This type of dolomite is similar to saddle dolomite except that there is a greater length-to-width ratio. It has strong, sweeping undulose extinction. Only two occurrences of this type dolomite were recognized in study cores.

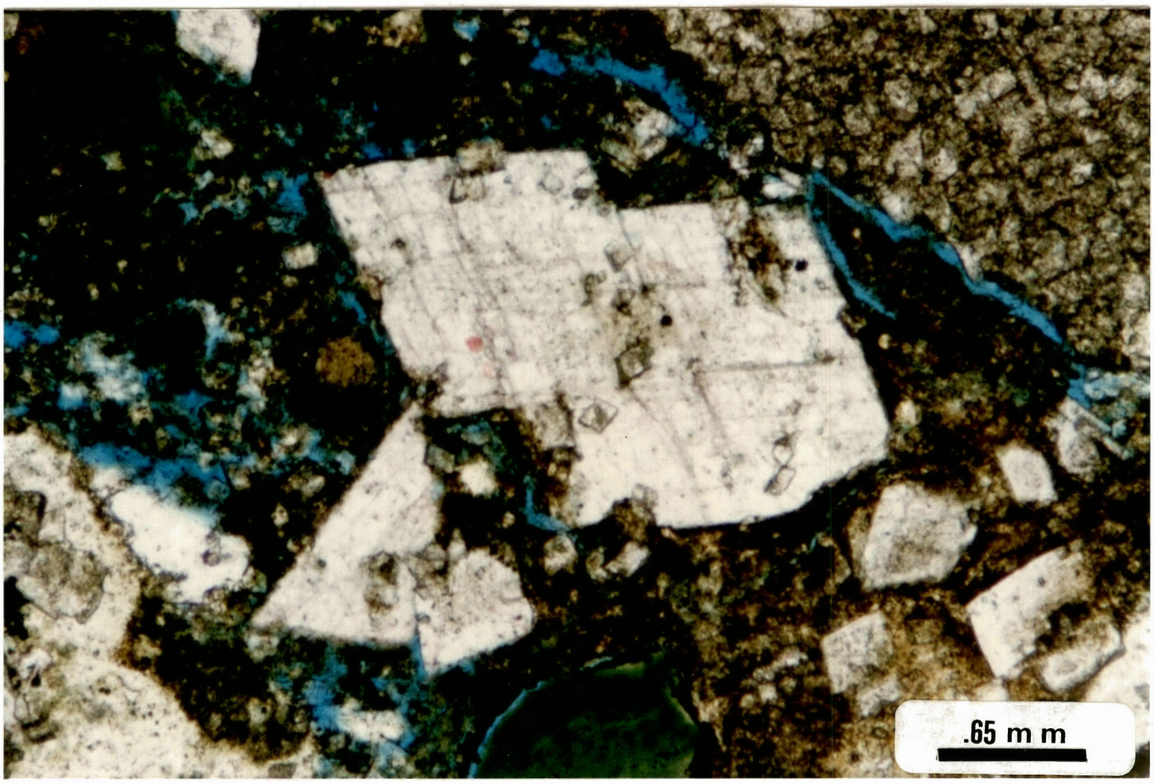


Figure 42. Cox Annis, -7,313 ft. Photomicrograph (X.N.) of pore-filling, idiotopic-rhombic dolomite. Glauconite grains are present; blue stain shows porosity. Top right corner contains a clast of dolomicrospar.

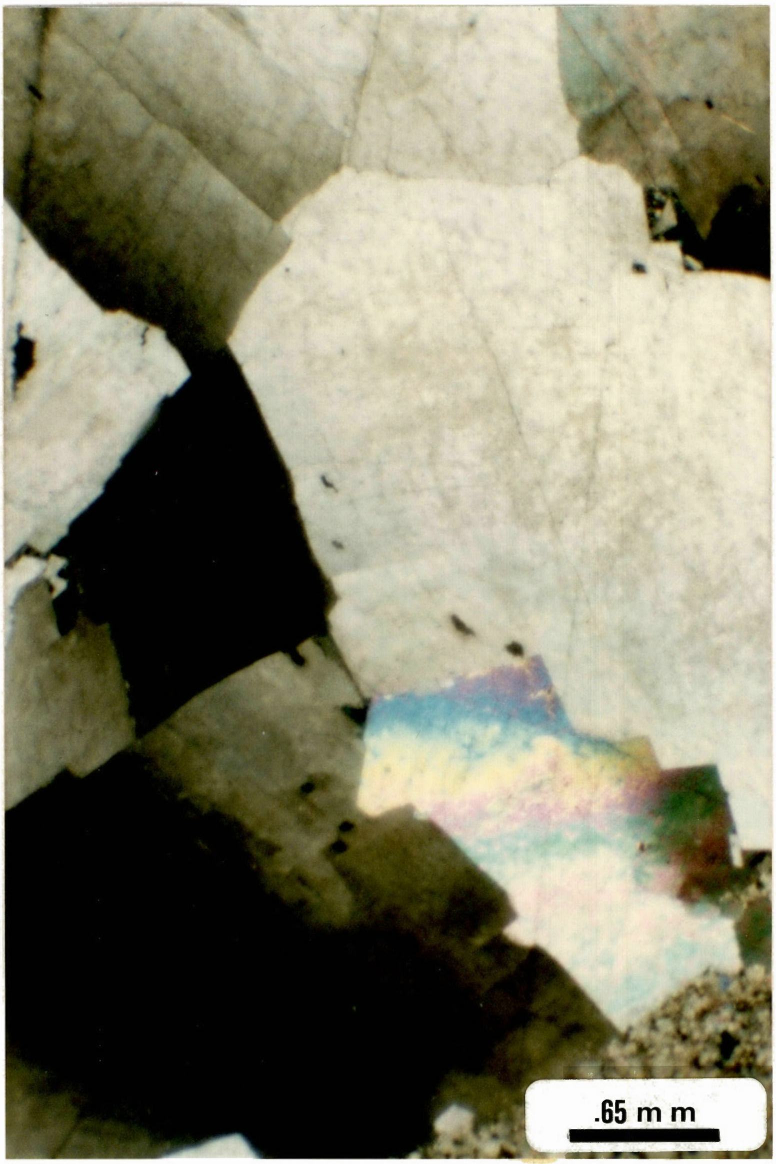


Figure 43. Kirkpatrick Shewey, -7,926 ft. Photomicrograph (X.N.) of pore-filling, saddle (baroque) dolomite.

Columnar dolomite crystals are shown in Figure 44 from the MacKellar Ferguson.

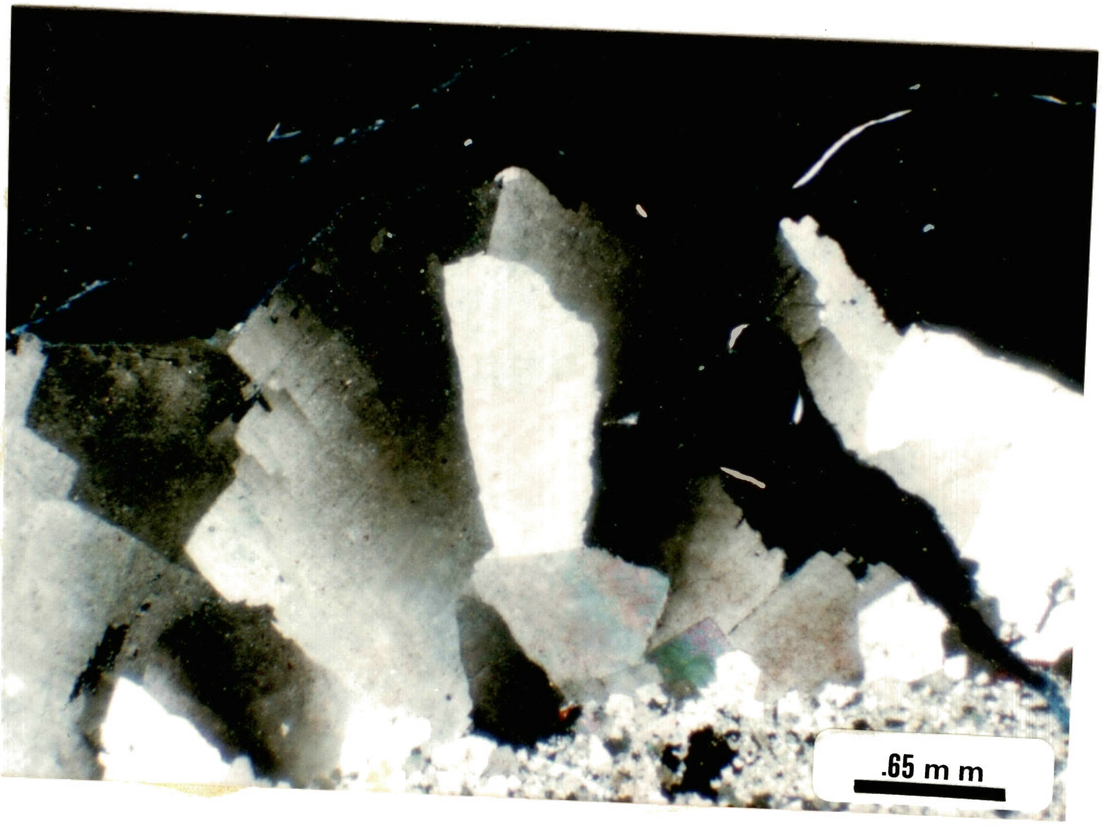


Figure 44. MacKellar Ferguson, -9,755 ft. Photomicrograph (X.N.) of pore-filling, columnar dolomite.

CHAPTER V

SUMMARY AND CONCLUSIONS

1. Many workers have investigated Hunton rocks. Several have commented on the possibility of the existence of paleokarst in the Group.

2. Porosity in Hunton cores is related to the depositional environment and is found in the intertidal facies. Karstification enhances this porosity.

3. One hundred forty cores were examined. Six cores exhibited significant amounts of breccia. Twelve cores were chosen for extensive study. More than 30% of the Hunton cores had vugular porosity.

4. Karst develops during three stages. The Initial Stage starts with the dissolution of carbonates in the phreatic zone. The Main Stage involves processes in the vadose as well as phreatic zone. Large volumes of rock are dissolved away, leaving microscopic- to cavern-sized pores. The Final Stage comprehends the collapse of the cave roof which creates definitive karst landforms. Cementation and sedimentation inhibits and finally destroys the flow of ground water.

5. Paleokarst is ancient karst which commonly is buried by younger sediments.

6. Diagnostic indicators of paleokarst are present in Hunton study cores. The paleokarstic traits are breccia facies, dissolution features, infill sediments, and possible speleothems.

7. Four categories of breccias were identified in Hunton rocks: crackle breccia, mosaic breccia, cavern-fill parabreccia, and collapse breccia.

8. Based on information and data observed in the cores, Hunton Paleokarst Reservoirs were classified into two groups:

Type One Hunton Paleokarst Reservoir

- It contains one or all four examples of breccia.
- Groundwater has conduit flow along fractures, caverns and bedding planes.
- Lithology is massive, nonporous limestone.
- Reservoirs are less productive based on examination of production records.

Type Two Hunton Paleokarst Reservoir

- Has insignificant or no breccias.

- Lithology has moldic/vuggy porosity.
- There is diffuse, interparticle flow of groundwater.
- Reservoirs produce some oil and gas based on examination of production records.

9. Three cross sections were constructed to show the extent of the pre-Woodford unconformity and possible existence of other types of unconformities. One core exposed a possible disconformity surface 300 feet below the Hunton-Woodford contact.

10. Basically, the timing of the karstification of the other cores appears to have been associated with the pre-Woodford unconformity.

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APPENDICES

APPENDIX A

CORE DESCRIPTIONS AND PHOTOGRAPHS

CORE: AMAX HICKMAN #1-24

LOCATION: 24-17N-18W, DEWEY COUNTY, OKLAHOMA

CORED INTERVAL: -13,500 FT TO -13,550 FT

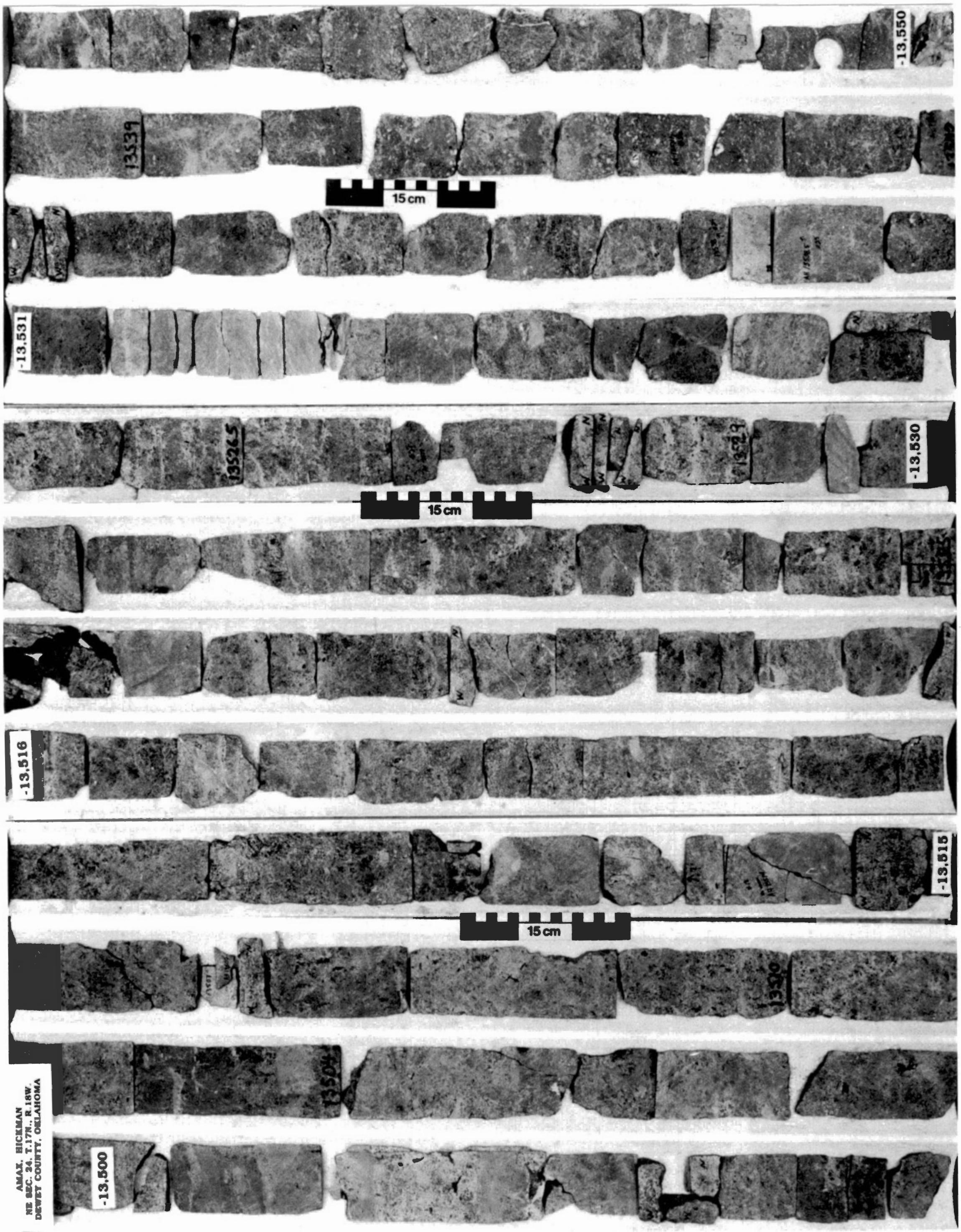
STRATIGRAPHIC INTERVAL: HENRYHOUSE

CORE DESCRIPTION:

The following description is given in reference to the core photograph that immediately follows this text, and to the core petrolog (Appendix B).

-13,500 ft to -13,550 ft

This core is medium bluish-gray dolowackestone with excellent moldic and vuggy porosity. The rock is oil stained and bioturbated throughout. Other sedimentary structures are faint algal laminations and sparse stylolites. In the lower portion, vugs may be filled with calcite. Porosity developed from 7 to 17% in the burrowed host rock. The environment is thought to be intertidal. Thin section information from Beardall (1983).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-13,516
-13,515
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-13,500
AMAX. HICKMAN
NE SEC. 24. T.17N., R.18W.
DEWEY COUNTY, OKLAHOMA

CORE: ARCO MARCUM #3

LOCATION: 20-27N-15W, WOODS COUNTY

CORE INTERVAL: -6,230 FT TO -6,263 FT

STRATIGRAPHIC INTERVAL: CHIMNEYHILL

CORE DESCRIPTION:

The following description is given in reference to the core photograph that immediately follows this text, and to the core petrolog (Appendix B).

-6,230 ft to -6,244 ft

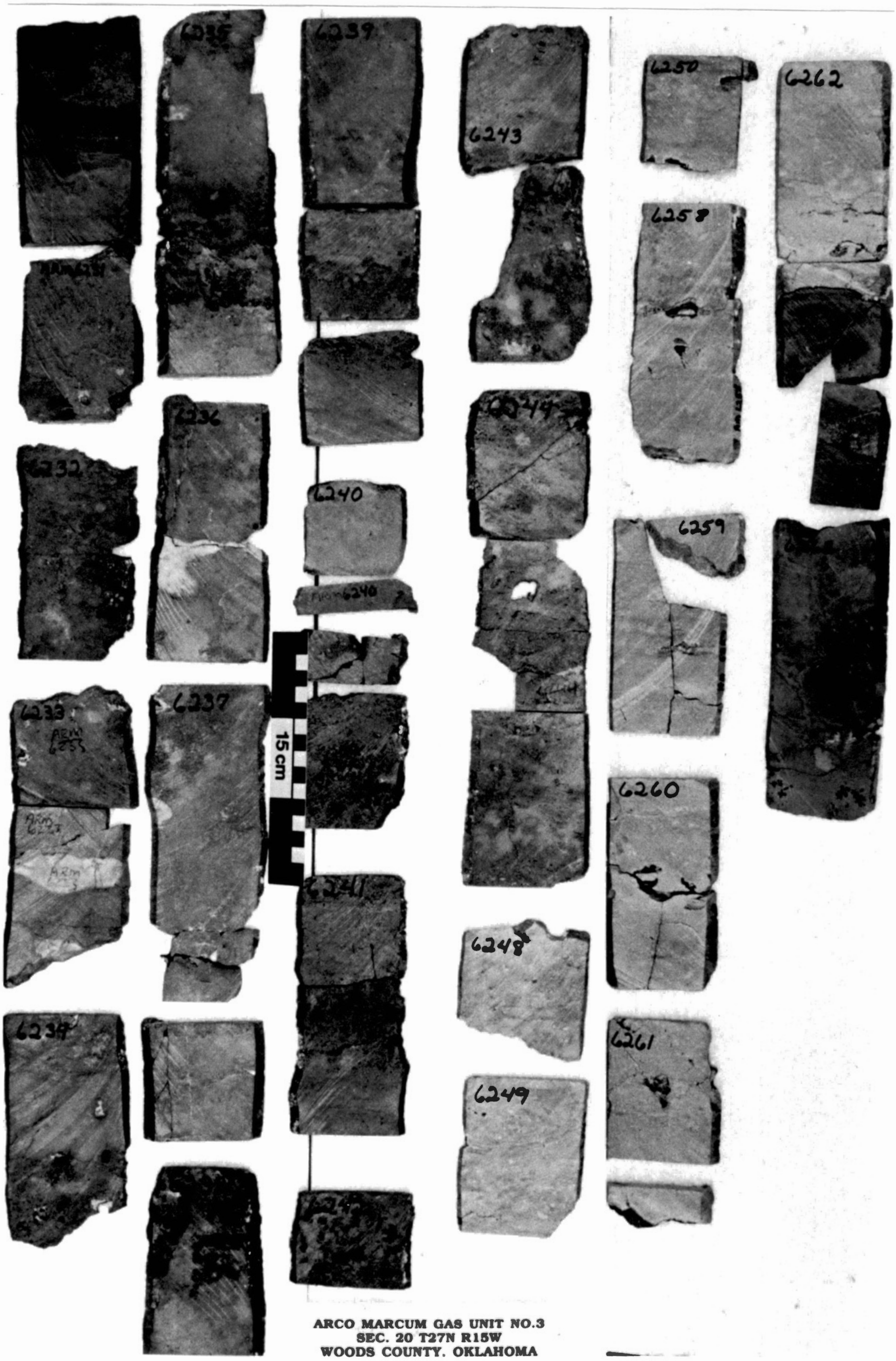
The Woodford Shale lies unconformably upon the Chimneyhill dolomite at -6,230 ft. This portion of the core is a medium dark-gray dolomite with good visible vuggy porosity. The sucrosic dolowackestone is burrowed and contains algal laminations, a 2.5-cm uncemented vug, chert nodules, glauconite, and dead oil. Porosity ranges from 10-15%. Dedolomitization is present. This was probably an intertidal environment.

-6,244 to -6,262 ft

The lower interval is a crinoidal grainstone/packstone which is a lighter, pinkish gray. Several open vugs appear. Most of the rock's porosity has been closed by calcite spar. Ferroan calcite is present. This is a subtidal shoal environment.

<u>-6,263 ft</u>

The bottom rock is a dark gray-green Sylvan Shale, rich in pyrite and dolomite. There is pore-filling saddle dolomite and ferroan dolomite. The shale holds a thin dolograinstone stringer.



ARCO MARCUM GAS UNIT NO.3
SEC. 20 T27N R15W
WOODS COUNTY. OKLAHOMA

CORE: CARTER HESTER 1

LOCATION: 27-5N-3W, McCLAIN COUNTY, OKLAHOMA

CORE INTERVAL: -7,771 FT TO -7,782 FT

STRATIGRAPHIC INTERVAL: CLARITA AND COCHRANE

CORE DESCRIPTION:

The following description is given in reference to the core photograph that immediately follows this text, and to the core petrolog (Appendix B).

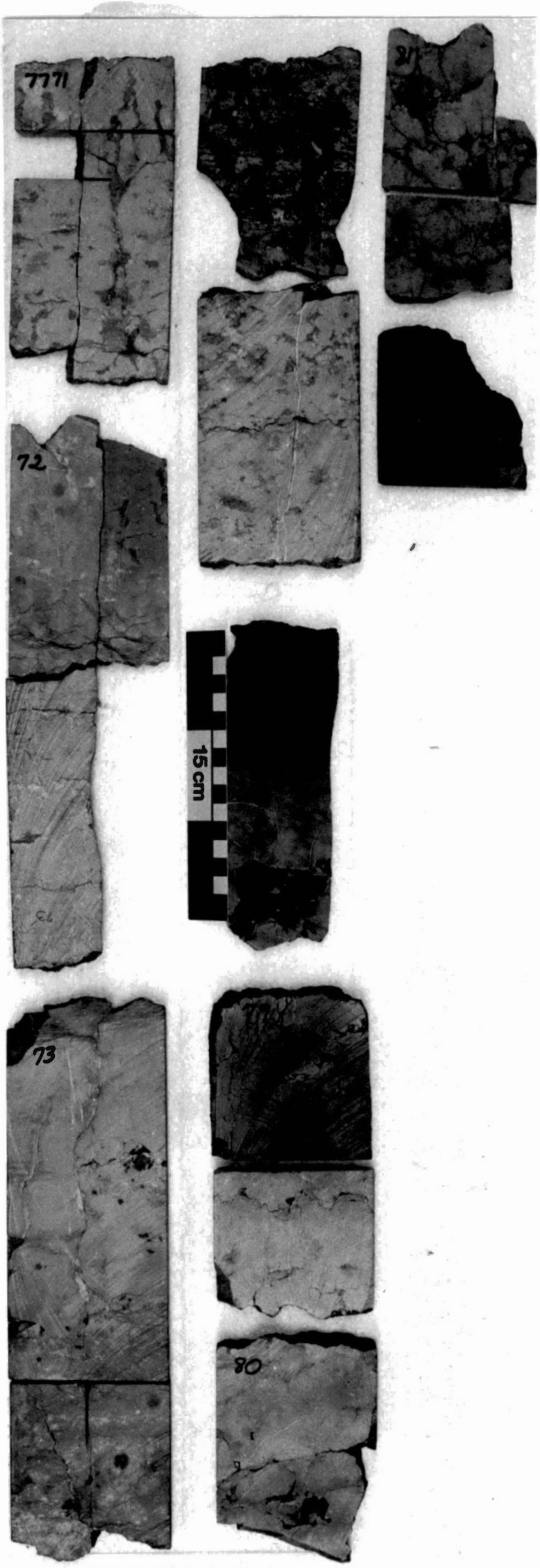
-7,771 ft to -7,778 ft

The Carter Hester core contains much evidence of solution. The upper interval is a medium gray wackestone with ferroan calcite spar. Fossils are thin and unbroken ostracods, brachiopods, crinoids, trilobites. Solution-widened fractures, burrows, and incipient stylolites are present. Dead oil is seen at -7,774 ft. This portion is labeled a subtidal environment.

-7,778 ft to -7,782 ft

The middle interval is a pelmatazoan packstone with vuggy porosity and pinkish-gray color. Minerals present in solution seams are glauconite grains, ferroan dolomite rhombs, ferroan and nonferroan calcite, pyrite, dolomicrospar. Dedolomitization is present. This interval was probably a subtidal shoal in the Cochrane Formation. The porosity is 2-4%. Porosity at -7,781 is 10%.

The lowest sample at -7,782 ft is an oil-stained dolomitic mudstone with few fossils in a subtidal environment.



CARTER HESTER NO. 1
SEC. 27 T5N R3W
McCLAIN COUNTY, OKLAHOMA

CORE: CLEARY KINNEY 1-20

LOCATION: 20-25N-21W, HARPER COUNTY, OKLAHOMA

CORE INTERVAL: -8,721 FT TO -8,760 FT

STRATIGRAPHIC INTERVAL: COCHRANE

CORE DESCRIPTION:

The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-8,721 ft to -8,730 ft

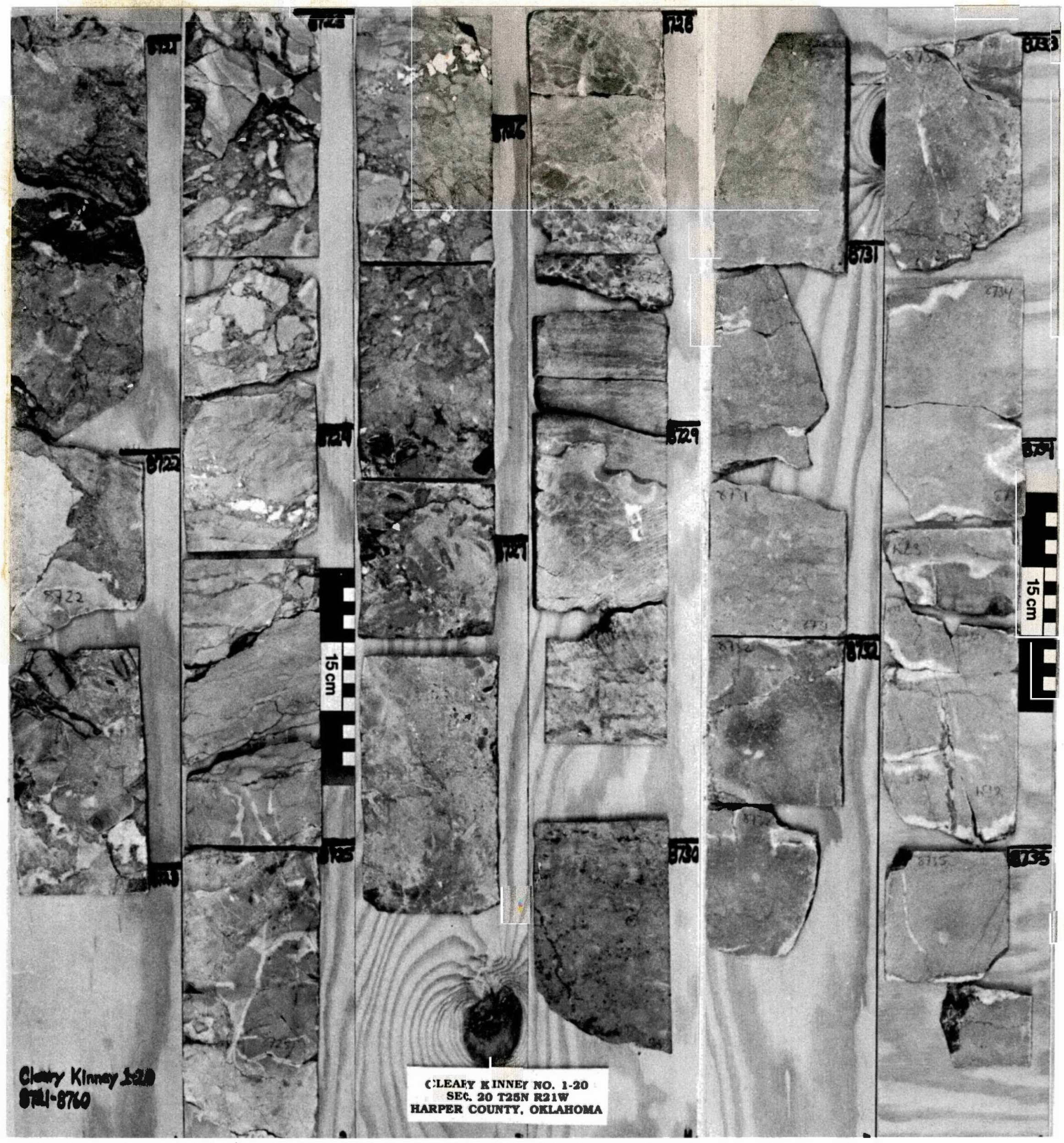
The upper facies is a medium gray wackestone. The first eight feet are collapse breccia with granular-to-cobble size, angular, clast-supported fragments. Some of the clasts are partially and randomly covered by what appears to be flowstone. Other clasts contain cemented fractures, a feature of the host rock seen again lower in the core. Stylolites are common. At -8,728 ft, glauconitic, laminated dolomite, perhaps indicating a supratidal environment, overlies a packstone unit with sharp contact. The packstone contains glauconite and pyrite in solution seams. Porosity is trace to 1/2%. Ferroan calcite cement is present.

-8,730 ft to -8,749 ft

This interval is a pale pinkish-gray packstone with abundant glauconite and crinoids. Vugs of several centimeter size have been filled with glauconite and dolomitic cave mud. Subvertical fractures filled with ferroan calcite cement are prominent. Porosity is in trace amount except for 5% at 8,744 ft. This portion of the core appears to be an intertidal zone.

-8,749 ft to -8,760 ft

The lowest interval is a friable pink crinoidal pack/grainstone with ferroan sparry cement and some dolomite. Stylolites and solution-enlarged fractures may be seen at -8,752 ft. Porosity is in trace amount. This facies represents a subtidal shoal.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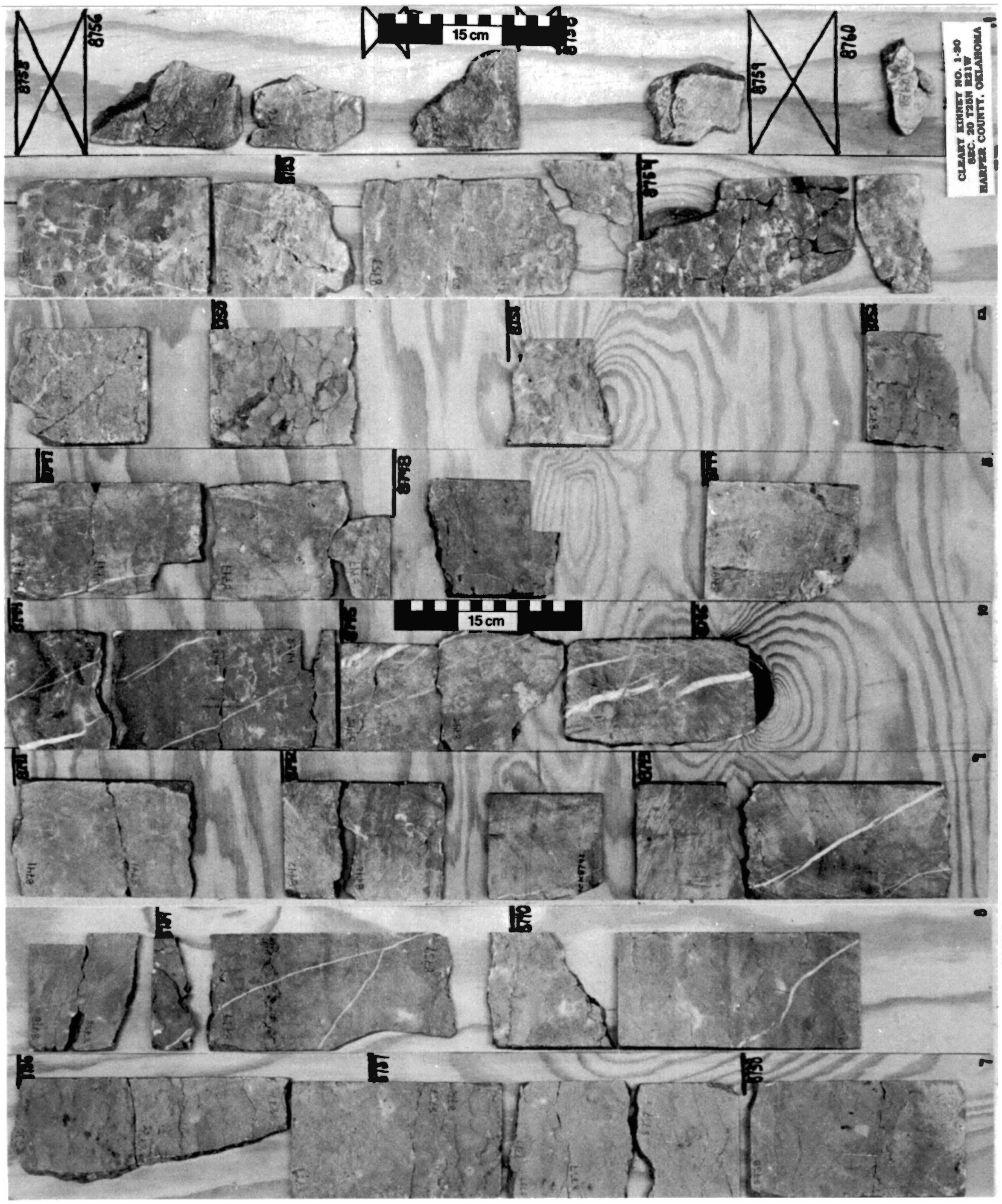
CLEARY KINNEY NO. 1-20
SEC. 20 T25N R21W
HARPER COUNTY, OKLAHOMA


CLEARY KINNEY NO. 1-20
SEC. 20 T25N R21W
HARPER COUNTY, OKLAHOMA
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CORE: E.L. COX ANNIS A-1

LOCATION: 3-26N-21W, HARPER COUNTY, OKLAHOMA

CORE INTERVAL: -7,296 FT to -7,364 FT

STRATIGRAPHIC INTERVAL: CHIMNEYHILL

CORE DESCRIPTION:

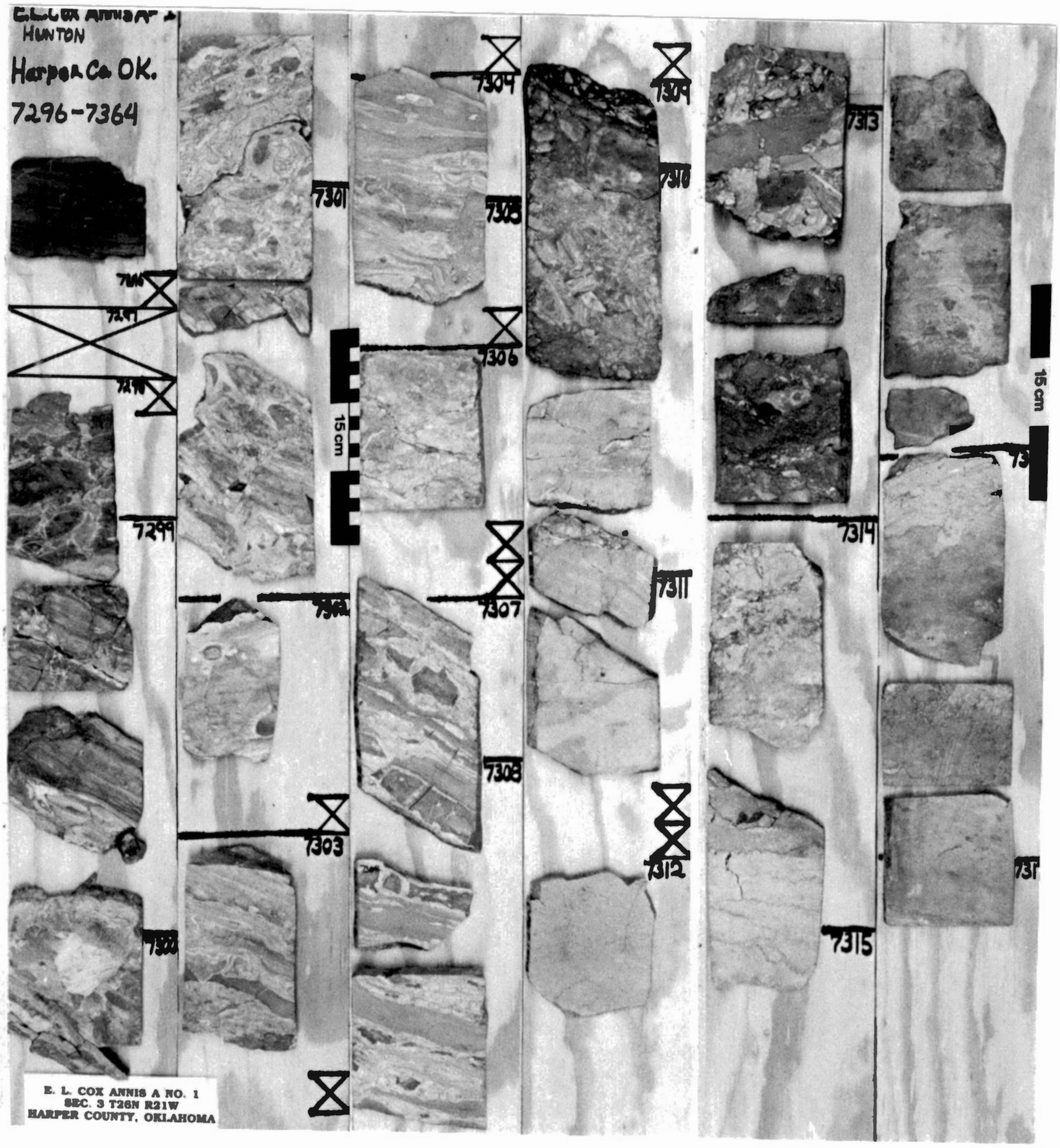
The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-7,269 ft to -7,323 ft

At the top of this interval is dark gray Woodford Shale, which unconformably overlies the Chimneyhill. The Chimneyhill unit has fifteen feet of medium dark gray dolomite with white and gray-blue chert breccia. The first foot is a mosaic breccia with pyritized matrix between the grains. The following ten feet of rock has cavern-fill parabreccia displaying a steep dip. At -7,300 ft, a 5-cm calcite nodule is seen. Collapse breccia exists at -7,310 ft, with an interval of dolomite between the rubbly collapse breccia. Some visible interclast porosity is present--from 2 to 10%. Silica--in megaquartz or microquartz or chalcedonic types--is prominent. Dedolomitization is present. The matrix in the collapse breccia also includes calcite, dolomite, and zebroid chalcedony cements, glauconite, terrigenous quartz grains, and pyrite.

-7,323 ft to -7,364 ft

This portion of the core is a pink crinoidal packstone with stylolites and sparse vugs. It is believed to have been a subtidal shoal. The porosity in solution-enlarged molds and vugs has been occluded by dolomite and calcite cement. Porosity is trace to 1.5%. The sample at -7,323 ft holds stylolites, and a solution-widened vertical fracture which has been filled with core sediment. From -7,330 ft to -7,364 ft the main constituents are micrite or microspar and calcite spar. Minor amounts of clay-associated dolomite rhombs, glauconite, pyrite, collophane are found. Dedolomitization and small-scale stylolites are present at -7,364 ft.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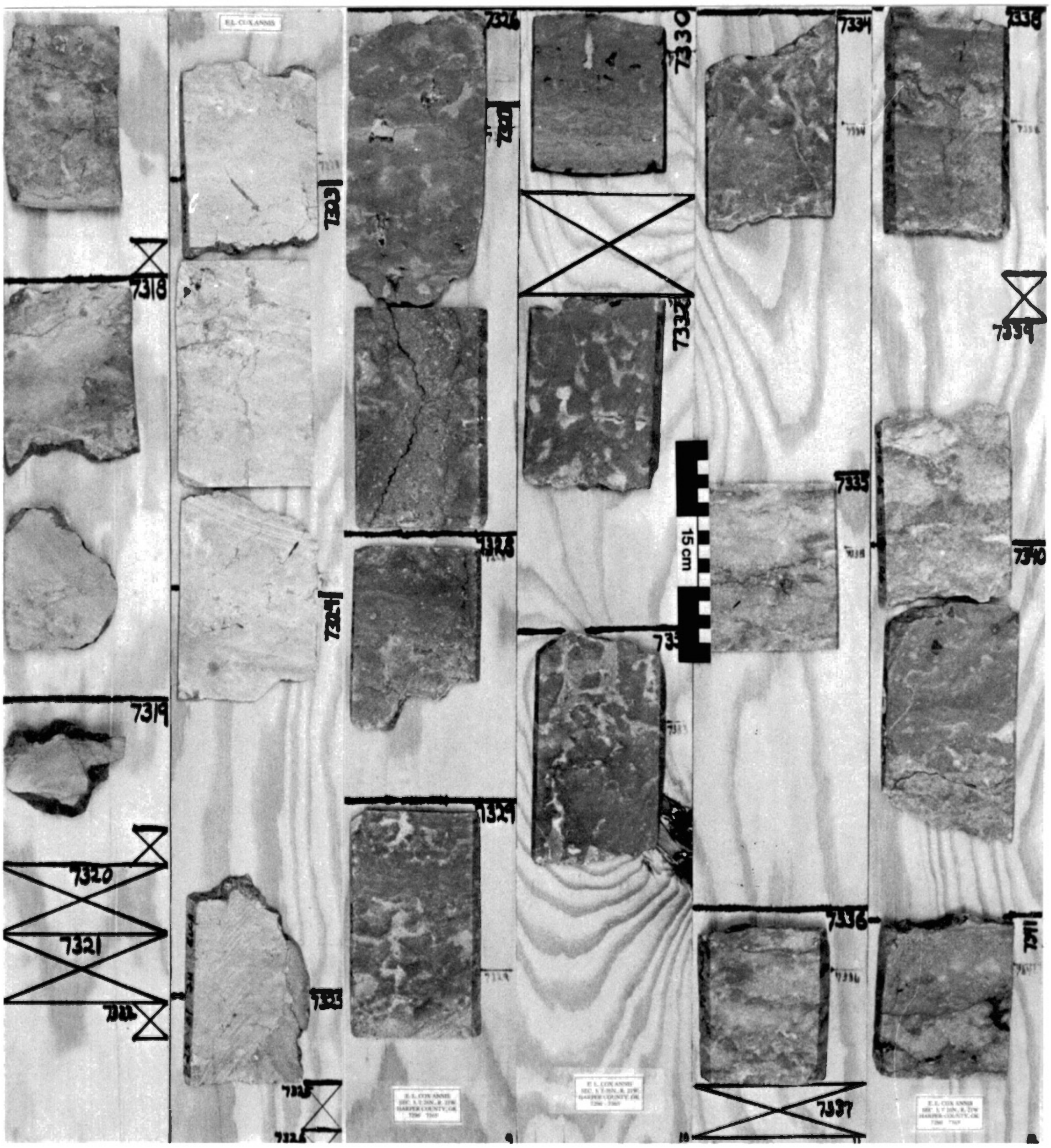
SEC. 3 T26N R21W
HARPER COUNTY, OKLAHOMA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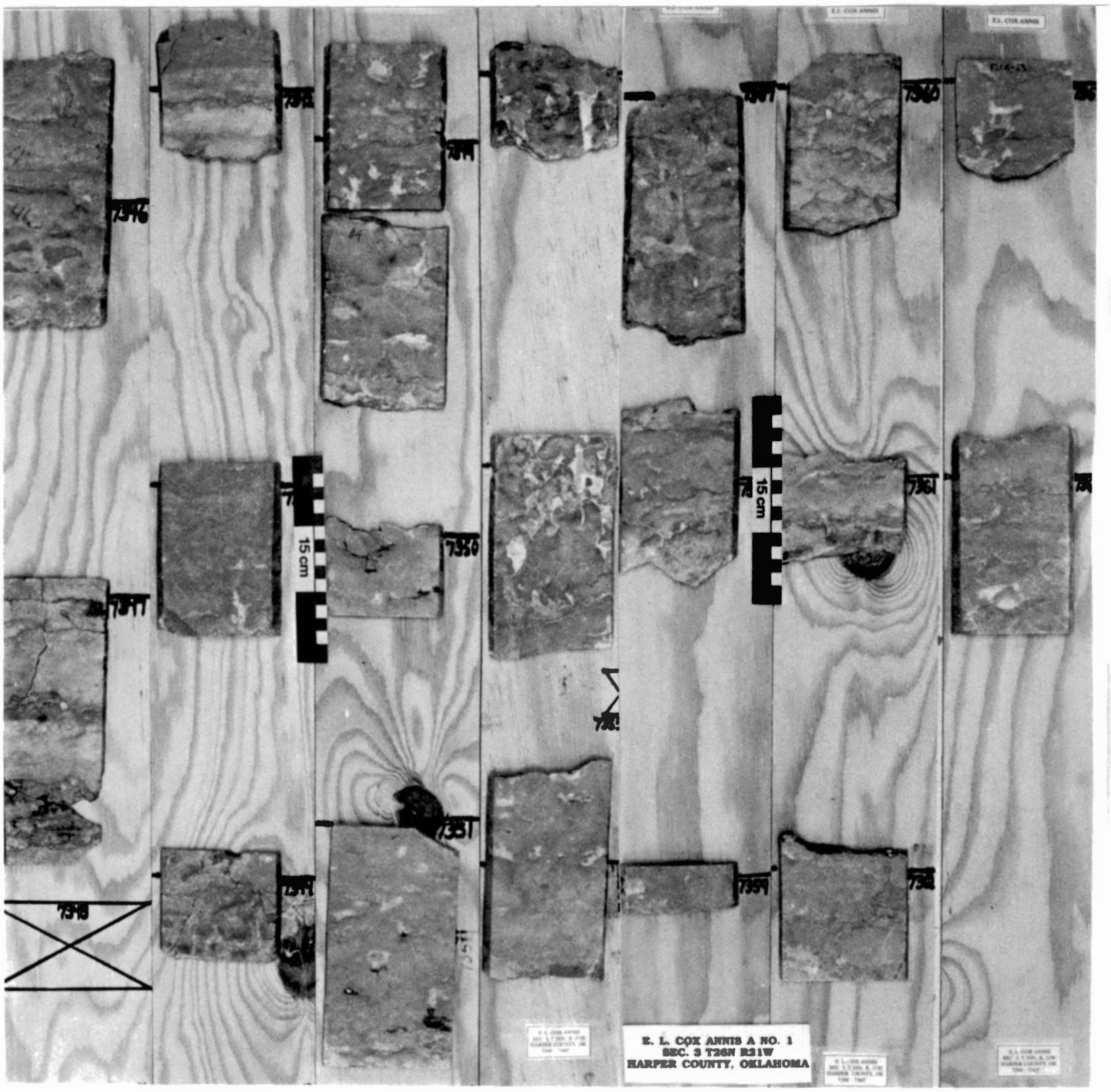
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E. L. COX ANNIS A NO. 1
SEC. 3 T26N R21W
HARPER COUNTY, OKLAHOMA

CORE: GULF WRIGHT HEIRS 1

LOCATION: 5-12N-2W, OKLAHOMA COUNTY, OKLAHOMA

CORE INTERVAL: -6,305 FT TO -6,338 FT

STRATIGRAPHIC INTERVAL: MISENER, FRISCO, HENRYHOUSE

CORE DESCRIPTION:

The following description is given in reference to the core photograph that immediately follows this text, and to the core petrolog (Appendix B).

-6,305 ft to -6,306 ft

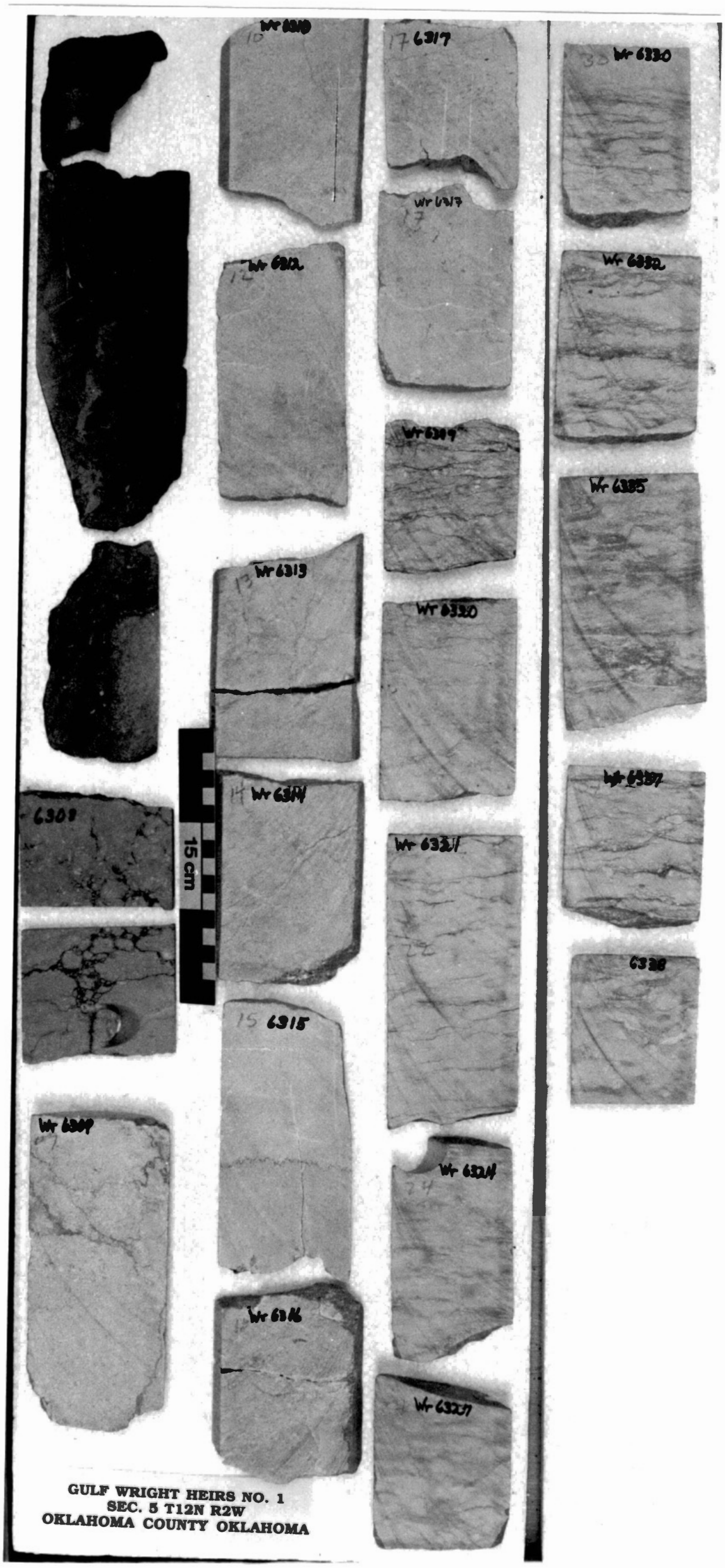
The top portion of the core is a dark red-greenish, gray sandstone and grainstone breccia. It consists of Frisco clasts in the Misener, which had been deposited over the eroded unconformable Frisco surface. The Frisco clasts are dolograinstone, pebble to cobble size, with ferroan dolomite and calcite cements, along with siderite cement. The sandstone host rock contains quartz grains with overgrowths and collophane-replaced fossils. Porosity is zero.

-6,308 ft to -6,316 ft

The Frisco is a light tannish-gray dolograinstone containing brachiopods, corals, trilobites, echinoderms. Cements are calcite spar and baroque dolomite. A red hematitic stain has infiltrated from the unconformity above into the fractures at -6308 ft to -6310 ft. Increasing amounts of lime mud and fossils suggest a subtidal mud mound environment. Intra-particle porosity is 1% in this section.

-6,316 ft to -6,338 ft

The lowest portion of the core is Henryhouse. It is a medium gray dolowackestone with darker gray laminations, incipient stylolites. Terrigenous quartz grains and ferroan sparite in fossil cavities are present. Fossils are fewer in number. This represents a nonporous, subtidal environment.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15 cm
GULF WRIGHT HEIRS NO. 1
SEC. 5 T12N R2W
OKLAHOMA COUNTY OKLAHOMA

CORE: KIRKPATRICK SHEWEY #1

LOCATION: 28-22N-12W, MAJOR COUNTY, OKLAHOMA

CORED INTERVAL: -7,895 FT TO -7,932 FT

STRATIGRAPHIC INTERVAL: HENRYHOUSE

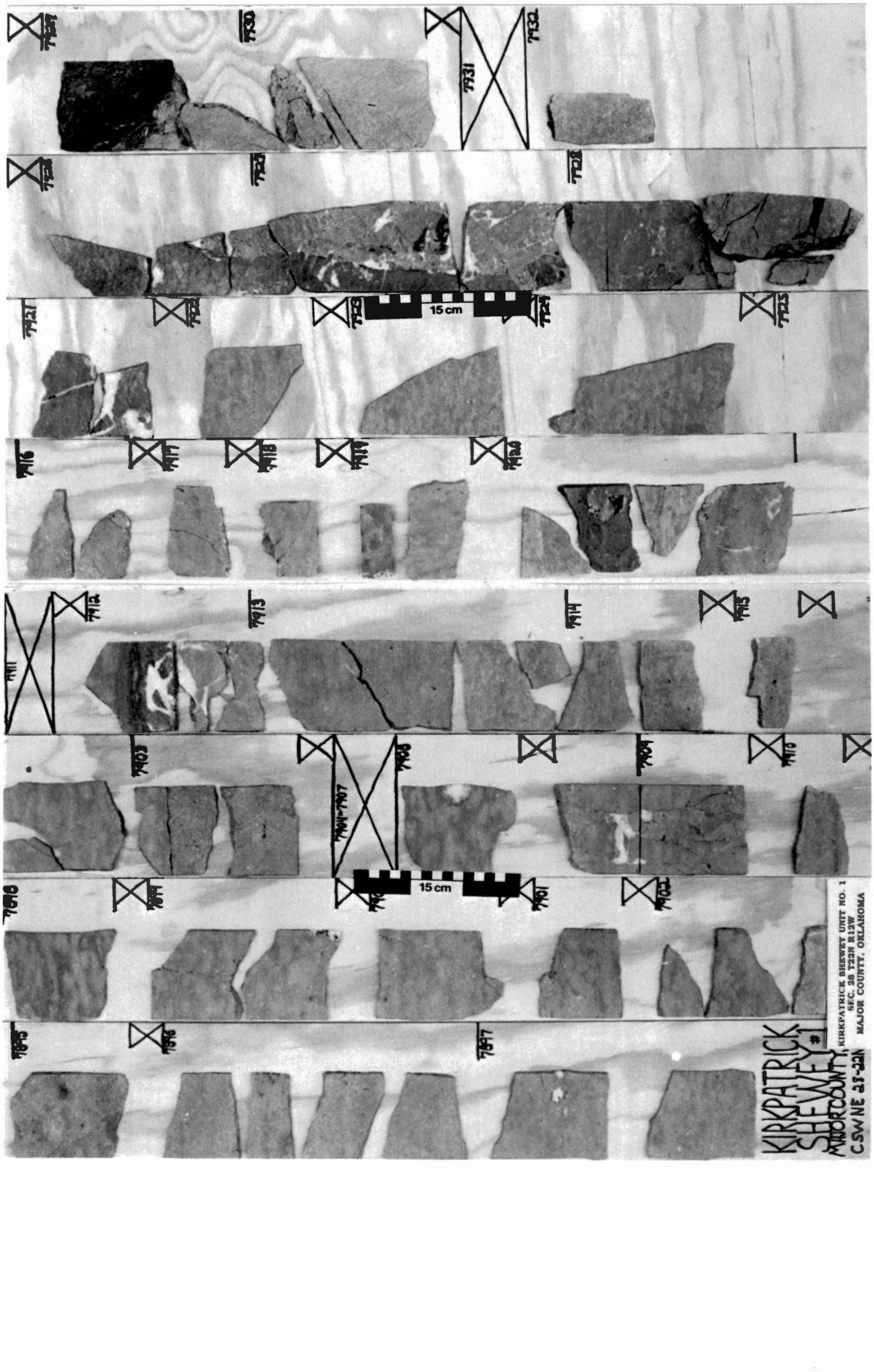
CORE DESCRIPTION:

The following description is given in reference to the core photograph that immediately follows this text, and to the core petrolog (Appendix B).

-7,895 ft to -7,932 ft

This core is a light gray, burrowed, dolomudstone/wackestone with visible vuggy porosity. Porosity types are fracture, intercrystalline, and moldic. Porosity averages 3-4%. Quartz cement and baroque fracture-filling cement are commonly seen. A 4-cm geopetal structure in a vug contains 29 laminations of cave clay; silica and baroque dolomite fill the remaining pore space.

Small-scale breccia is cemented by baroque dolomite and sparse ferroan calcite. Black shale appears to have been deposited at -7,929 ft. Perhaps it is an infiltration of Woodford Shale into a karstic cavity formed during the pre-Woodford unconformity. Fossil existence is represented by moldic porosity. The core is probably from an intertidal location.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KIRKPATRICK
SHEWEY #1
MAJOR COUNTY,
C SW NE 28-22N
KIRKPATRICK SHEWEY UNIT NO. 1
SEC. 28 T22N R12W
MAJOR COUNTY, OKLAHOMA

CORE: MACKELLAR FERGUSON #9

LOCATION: 35-24N-21W, WOODWARD COUNTY, OKLAHOMA

CORED INTERVAL: -9,739 FT TO -9,822 FT

STRATIGRAPHIC INTERVAL: CHIMNEYHILL

CORE DESCRIPTION:

The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-9,739 ft to -9,750 ft

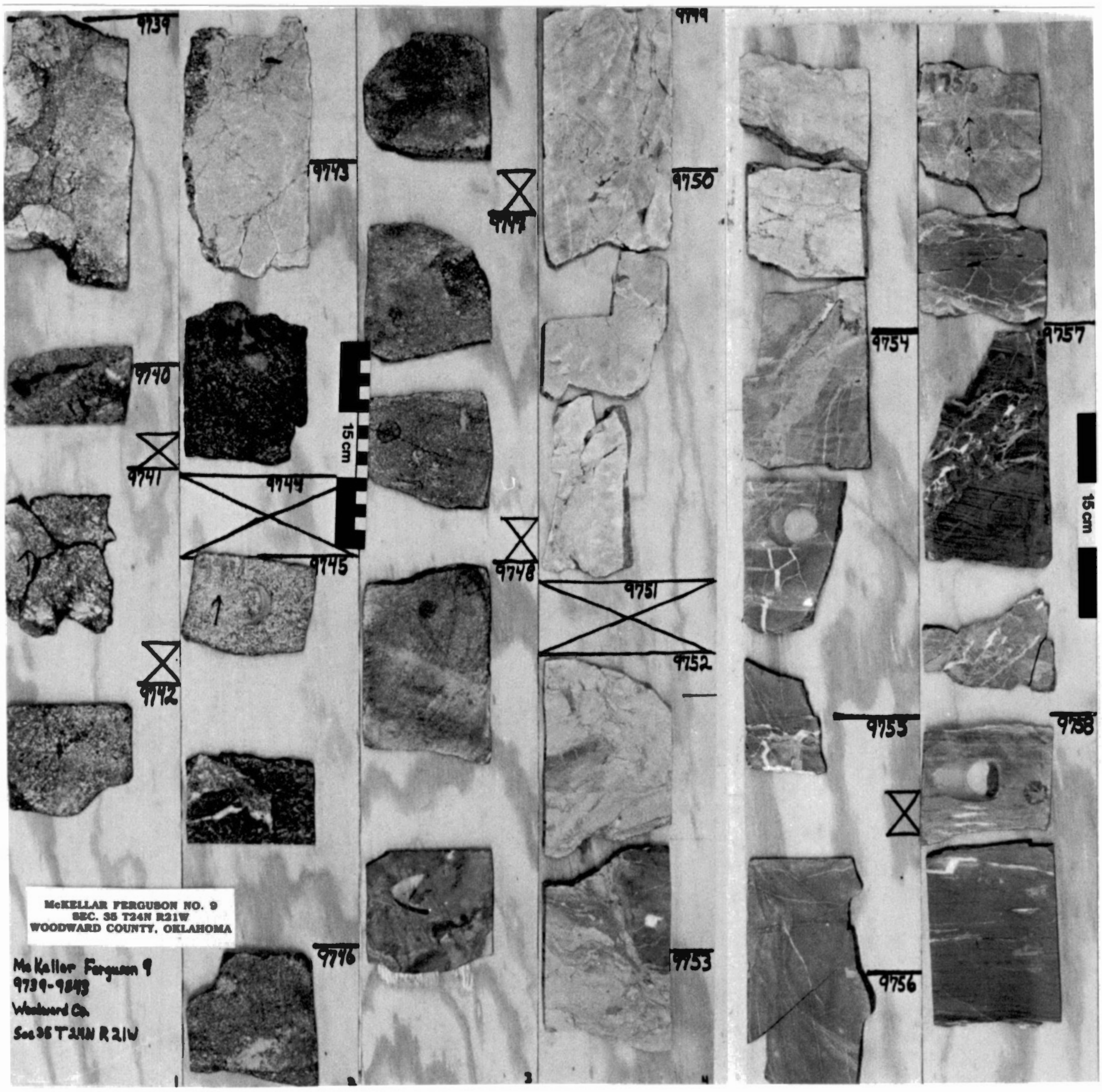
This interval is a dark gray crinoidal dolopackstone, cemented by baroque dolomite and sparite. The top five feet show cobbles of Clarita, possibly a consequence of the pre-Woodford unconformity. This is the first occurrence of several layers of breccia, or stratiform breccia. Fossils include, in addition to the crinoids, brachiopods, corals and bryozoans. Vug and solution-widened fractures provide porosity of 2-6%. Pyrobitumin is present. At -9,749 ft there is a 5-foot sequence of lighter gray wackestone and calcite-filled fractures. Some of the cement may be flowstone. Dedolomitization is found in this section.

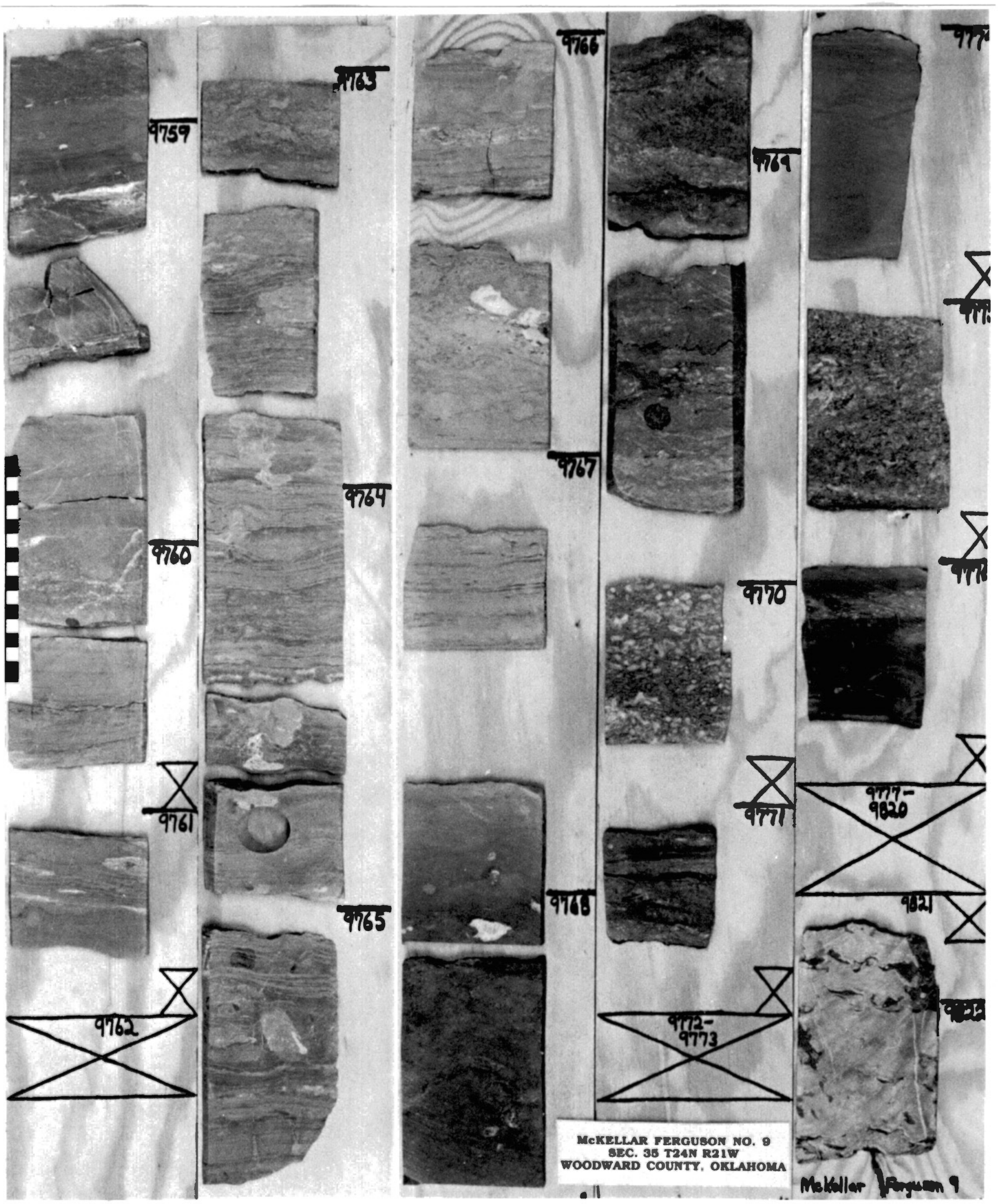
-9,752 ft to -9,768 ft

Clasts of dark gray dolomite in a gray-green dolomite matrix have increased dolomite content. At -9,754 ft the rock is a medium dark gray, glauconitic, pyritic, dolomudstone. Breccias--crackle, mosaic, and small-scale collapse--are in this sequence which is thought to be the Cochrane. Fractures are cemented by baroque dolomite. Stylolites and chert are present. Laminations of dolomite at this location resemble the vadose geopetal internal sediments of Vera et al. (1988). The laminations may point to a supratidal environment. Dedolomitization appears in this portion.

-9,768 ft to -9,776 ft

The lower segment is a dark gray, siliceous, dolowackestone/grainstone with bryozoan-rich beds. Stylolites, calcite and chert nodules are displayed. The abundance of fossils may indicate an intertidal zone. -9,776 ft appears to be a dark, pyritic shale. The sample at -9,822 may be Viola Limestone (Amsden, 1980).


9739
9740
9741
9742
9743
9744
9745
9746
15 cm
9747
9748
9749
9750
9751
9752
9753
9754
9755
9756
9757
9758
15 cm
McKELLAR FERGUSON NO. 9
SEC. 35 T24N R21W
WOODWARD COUNTY, OKLAHOMA
McKellar Ferguson 9
9739-9843
Woodward Co.
Sec 35 T24N R21W



McKELLAR FERGUSON NO. 9
SEC. 35 T24N R21W
WOODWARD COUNTY, OKLAHOMA

CORE: SAMSON WADE 1

LOCATION: 33-2N-1W, GARVIN COUNTY, OKLAHOMA

CORE INTERVAL: -6,008 FT TO -6,051 FT

STRATIGRAPHIC INTERVAL: HENRYHOUSE

CORE DESCRIPTION:

The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-6,008 ft to -6,021 ft

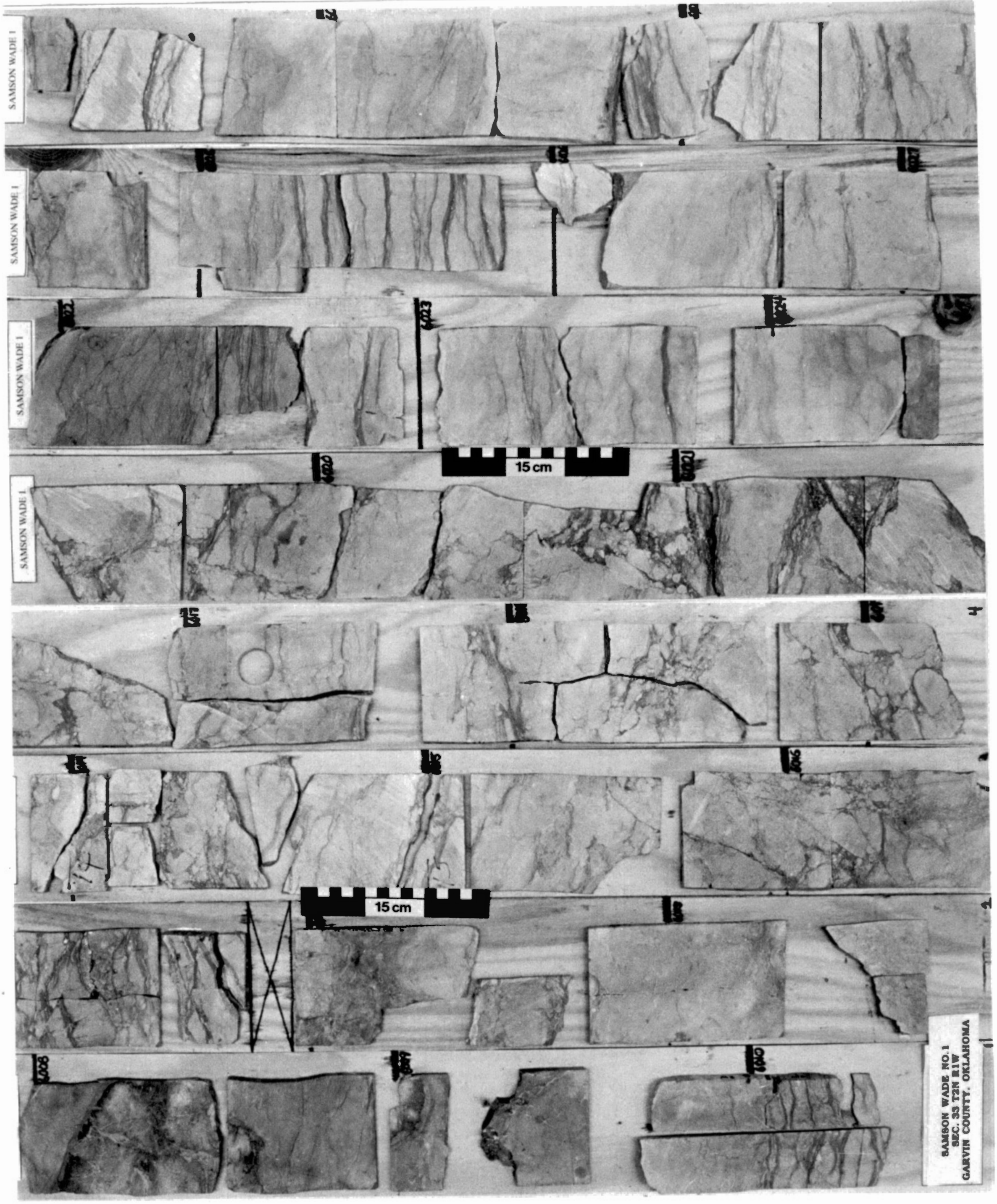
The uppermost five feet of the core is a tan-gray, dolomite and chert mosaic breccia and cavern-fill parabreccia. The first few feet are mosaic breccia with matrix between the clasts. The fractured blue-gray chert cobbles display microbreccia in thin sections. Fossil molds are filled with zebraic chalcedony; zebraic chalcedony is sometimes associated with evaporitic minerals. Cavern-fill parabreccia clasts are disjointed and matrix supported. Collapse breccia occurs from -6,012 ft to -6,013 ft. Clasts are subrounded to angular shape, sand to cobble size and clast supported with only trace porosity. Sediment between clasts and in fractures contain abundant silt-sized terrigenous quartz grains, dolomite rhombs, chert, and small amounts of pyrite, collophane, and anhydrite.

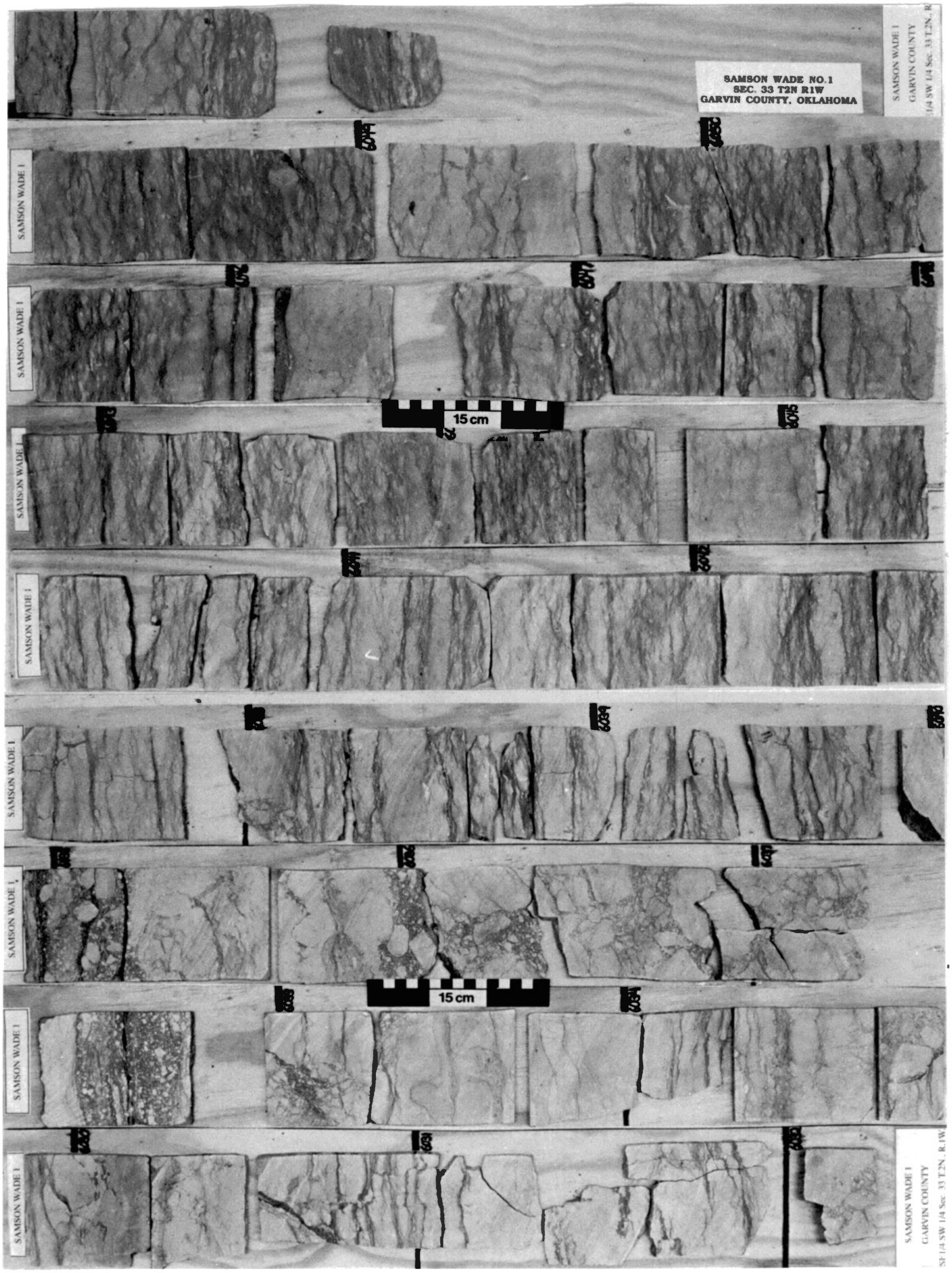
-6,021 ft to -6,029 ft

This medium gray, slightly dolomitic packestone interval has wavy bedding with dark gray incipient stylolites. Fossil components of the packstone include ostracods, bryozoans, crinoids, and trilobites. It may have been deposited in a lower intertidal zone.

-6,029 ft to -6,051 ft

This portion features another brecciated section which may represent stratiform breccia. Crackle/mosaic type breccias are followed by matrix-supported, cavern-fill parabreccia. Four feet of collapse breccia are composed of granule- to cobble-size fragments. The host rock and clasts are packstone with sparse pore-filling silica. Fossils present at -6,032 ft are bryozoans, crinoids, brachiopods, with small amounts of replacive dolomite rhombs and chert in the matrix. At -6,038 ft, paleokarst is indicated by the small-size channel breccia and solution-enlarged fractures. The rock is medium gray, with dark gray incipient stylolites. These seams contain visible fossils; a 6-cm crinoid resides at -6,039 ft. The remainder of the core is crinoidal packstone and includes ostracods commonly filled with sparite and corals. Bedding is mottled; pyrite nodules are common. Porosity is zero to trace throughout the core. The environment may have been subtidal.


SAMSON WADE 1
SAMSON WADE 1
SAMSON WADE 1
SAMSON WADE 1
15 cm
15 cm
SAMSON WADE NO.1
SEC. 33 T2N R1W
GARVIN COUNTY, OKLAHOMA


SAMSON WADE NO.1
SEC. 33 T2N R1W
GARVIN COUNTY, OKLAHOMA
SAMSON WADE I
GARVIN COUNTY
SE1/4 SW 1/4 Sec. 33 T2N, R1W
15 cm
15 cm

CORE: SHELL STOCKING 1-32

LOCATION: 32-22N-19W, WOODWARD COUNTY, OKLAHOMA

CORED INTERVAL: -10,247 FT TO -10,321 FT

STRATIGRAPHIC INTERVAL: HENRYHOUSE

CORE DESCRIPTION:

The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-10,247 ft to -10,256.5 ft

The Shell Stocking rocks exhibit stratiform, or layered, breccia. This interval is a medium dark gray dolomite and chert cavern-fill parabreccia. It is the topmost portion of a 21-foot brecciated section of the core. The sample at 10,248 ft may reveal fragments of speleothems. The first 9 1/2 feet contain poorly-sorted, sand-to-pebble size chert fragments and silicified fossils. Fossils include Halysites and other corals, crinoids, and bryozoans. These grains are subrounded to subangular and are matrix supported. Other minerals in the cavern-fill parabreccia are glauconite, pyrite, collophane fossils. Terrigenous silt-size quartz and feldspar grains may be part of the Misener which filled the eroded Hunton surface. Baroque dolomite and ferroan calcite cements are present.

-10,256.5 ft to -10,275 ft

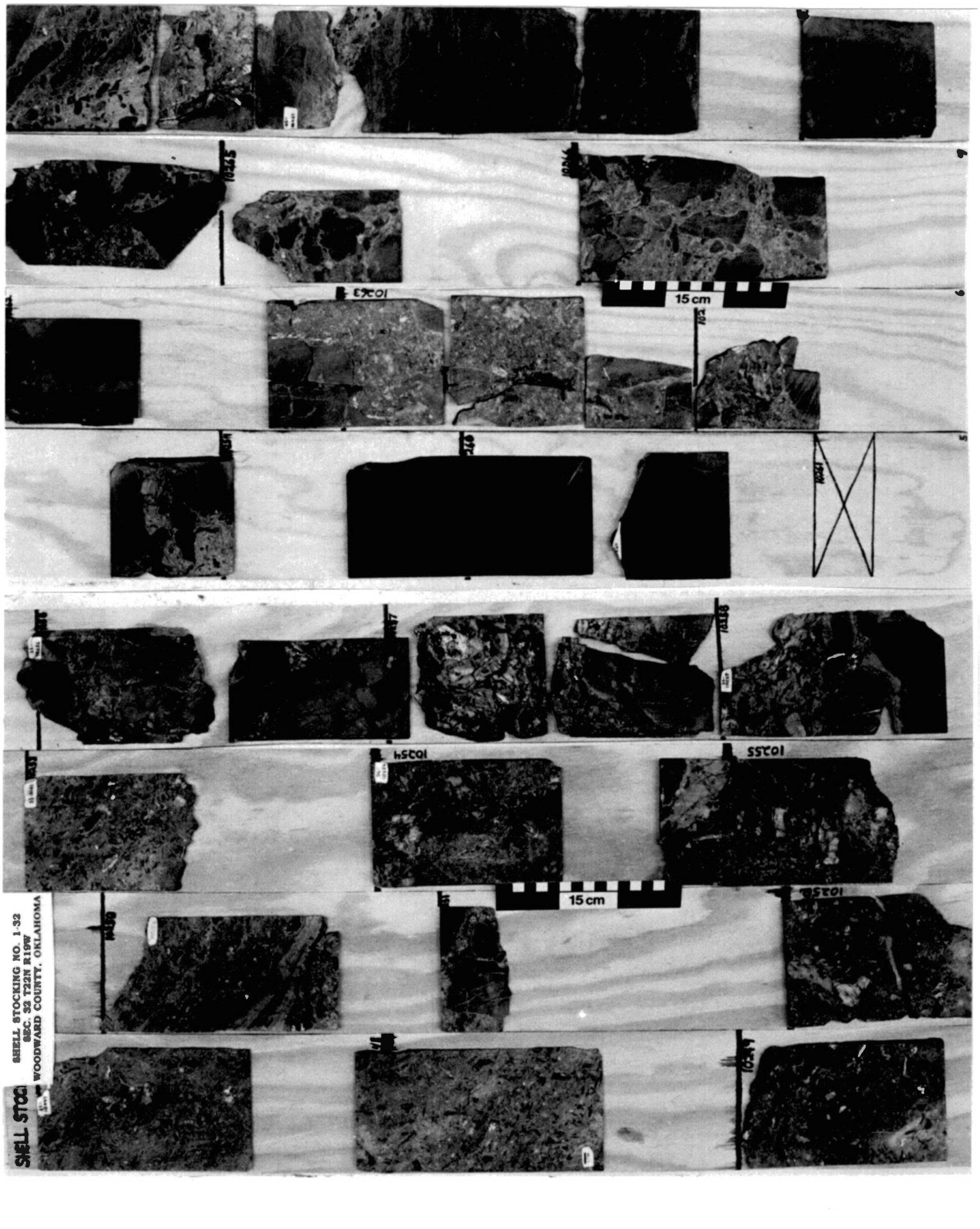
The core is a dark, brownish-gray dolomite and chert collapse breccia, with 6 feet of dolomitic, burrowed, wackestone/mudstone. Clasts are pebble to cobble size, subangular to angular, and clast supported. Fossils have been replaced by calcite and silica. Anhydrite remnants are in authigenic quartz. Ferroan calcite and pyrobitumen are present. Large amplitude stylolites appear at -10,266 ft, -10,267 ft, and -10, 272 ft. At -10,260 ft, intercrystalline porosity is approximately 9%. This interval may be an intertidal deposit.

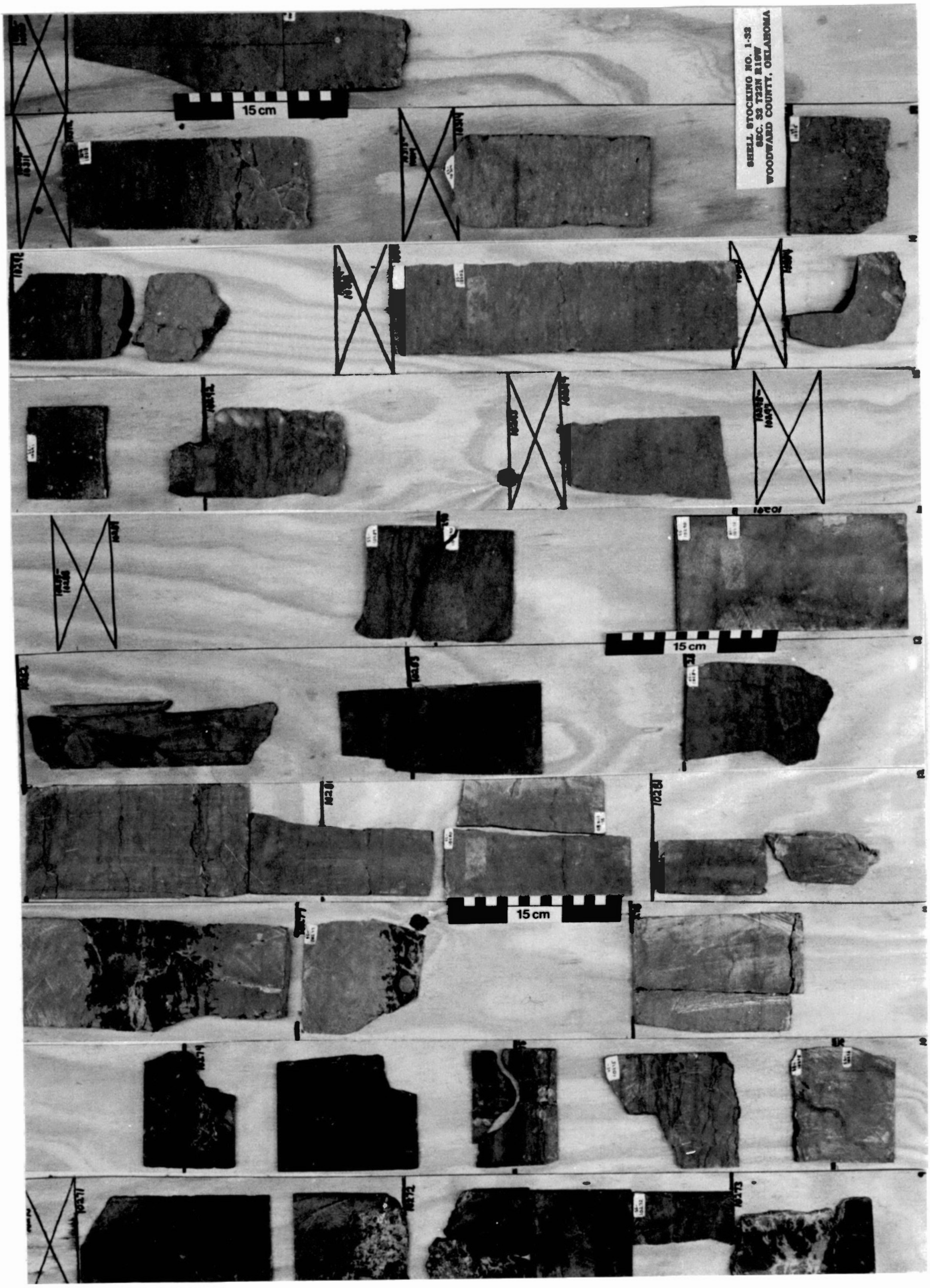
-10,275 ft to -10,294 ft

This portion is a medium-gray dolomudstone with 0-2% porosity. Calcite is increasingly abundant. Pyrobitumen is seen at -10,276 ft. Solution-enlarged fracture is exhibited at -10,282 ft. Burrows and a paucity of fossils indicate a subtidal facies.

-10,294 ft to -10,321 ft

The lowest portion of the core is a slightly pinkish-gray dolowackestone/packstone. Fossils, mostly crinoids, are abundant and point to the existence of a subtidal shoal.


15 cm
15 cm
10263
10254
10255
SHELL STOCKING NO. 1-32
SEC. 32 T22N R19W
WOODWARD COUNTY, OKLAHOMA
SHELL STOC


SHELL STOCKING NO. 1-32
SEC. 32 T22N R19W
WOODWARD COUNTY, OKLAHOMA
15 cm
15 cm
15 cm

CORE: TENNECO JORDAN A-1

LOCATION: 3-21N-14W, MAJOR COUNTY, OKLAHOMA

CORE INTERVAL: -8,495 FT TO -8,612 FT

STRATIGRAPHIC INTERVAL: HENRYHOUSE

CORE DESCRIPTION:

The following description is given in reference to the core photographs that immediately follow this text, and to the core petrolog (Appendix B).

-8,495 ft to -8,579 ft

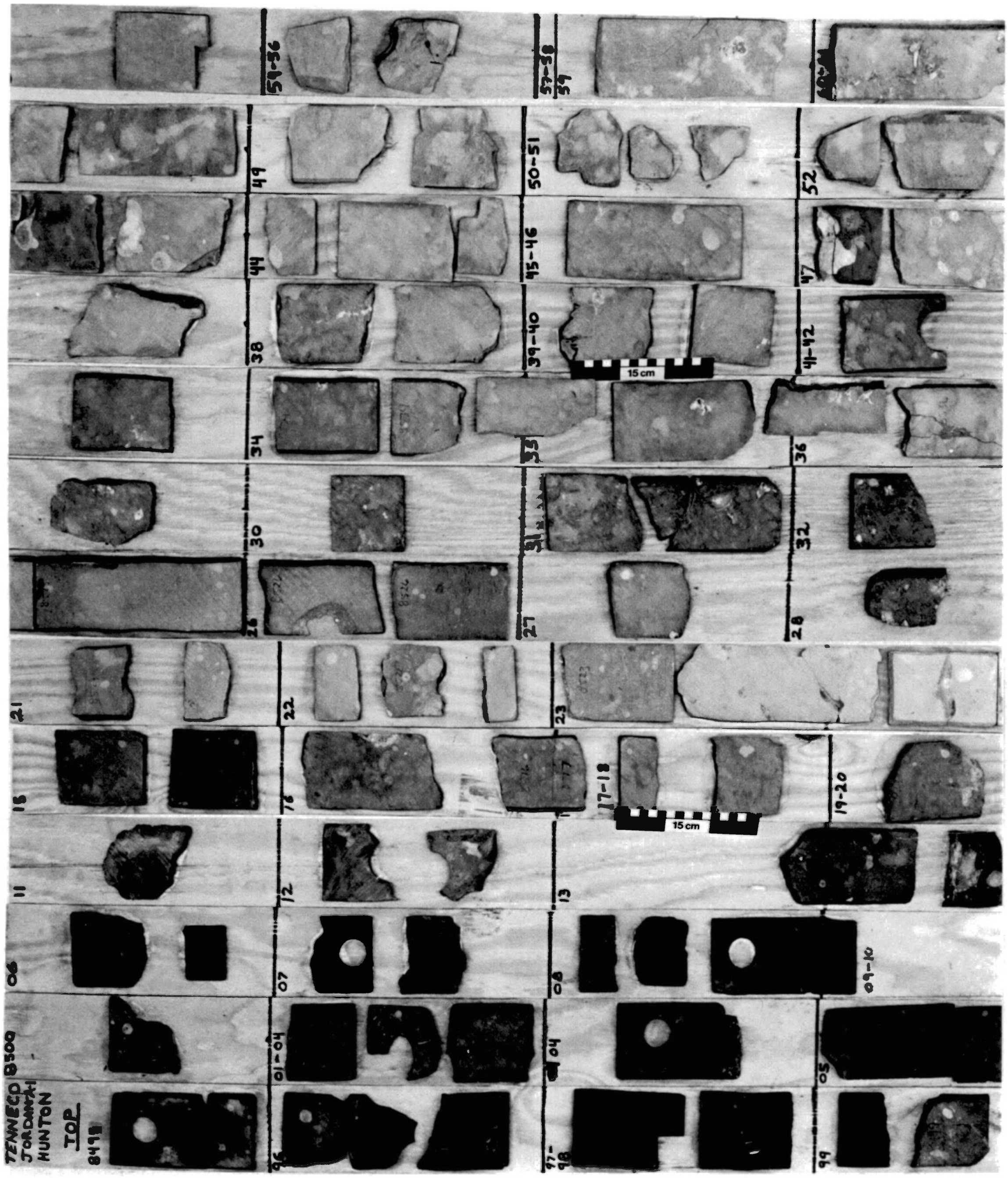
The Tenneco Jordan A-1 core is a teaching core at the OSU Geology Department. The noticeable "blotches" on the slabs in the photograph are caused by drops of dilute hydrochloric acid used during students' examinations of the core.

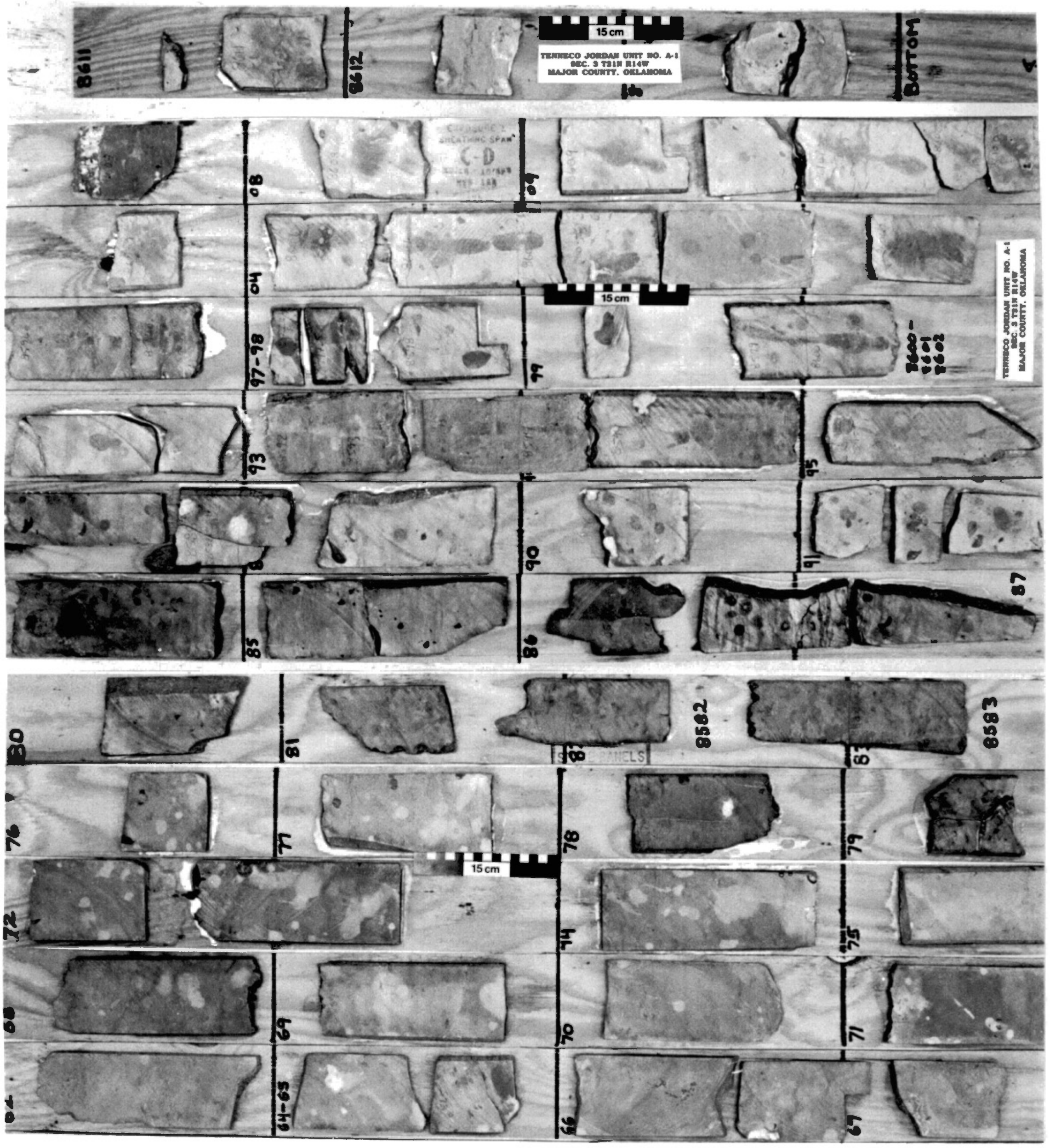
The core contains two major facies. The upper interval encompasses a dark oil-stained brown-gray, burrowed/mottled, dolomudstone/wackestone. Fossil existence is indicated by molds of crinoid shape. Dolomite is sucroisic matrix-replacive rhombs providing 5% to 18% porosity. The porosity is due also to fractures, enlarged pores, interpartical pores, and moldic pores. At -8,514 ft a vug-filling, 7-cm anhydrite nodule is exposed. Other smaller nodules contain chert, quartz, dolomite. Stylolites are rare.

The lower part of the interval has fewer burrows. The color is lighter and grayer. This interval is believed to be an intertidal facies.

-8,579 ft to -8,612 ft

This segment of the core is a medium gray, dolomite mudstone/wackestone to packstone. The dolomudstone/wackestone contains some moldic porosity and horizontal and vertical burrows. Fossils include crinoids, trilobites, brachiopods, bryozoans, and corals. Molds of fossils are filled with sparite. Stylolites are common. Porosity ranges from zero to 5%. This interval is thought to represent a subtidal environment with a subtidal shoal.


TENNECO 8500 JORDAN #1
HUNTON
TOP
8498
96
97-98
99
01-04
04
05
06
07
08
09-10
11
12
13
18
17-18
19-20
21
22
23
26
27
28
30
31
32
34
33
36
38
39-40
41-42
44
45-46
47
49
50-51
52
54-56
57-58
59
15 cm
15 cm


TENNECO JORDAN UNIT NO. A-1
SEC. 3 T21N R14W
MAJOR COUNTY, OKLAHOMA
15 cm
8611
8612
BOTTOM
8582
8583
8600-
8601
8602

CORE: WIL-Mc COSSEY 2

LOCATION: 21-7N-2E, POTTAWATOMIE COUNTY, OKLAHOMA

CORE INTERVAL: -5,060 FT TO -5,066 FT

STRATIGRAPHIC INTERVAL: BOIS d'ARC/HARAGAN

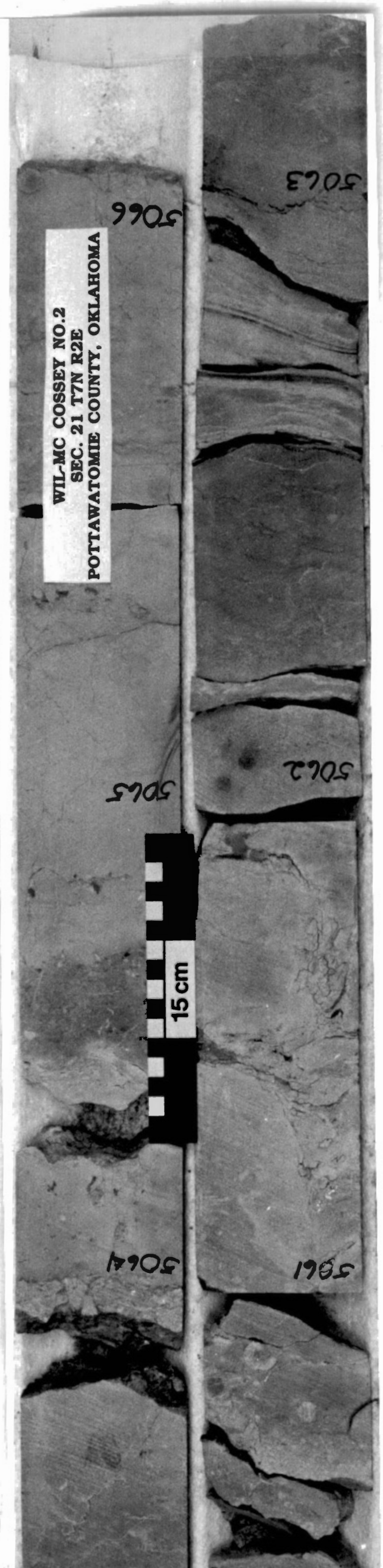
CORE DESCRIPTION:

The following description is given in reference to the core photographs that follow this text, and to the core petrolog (Appendix B).

-5,060 ft to -5,066 ft

There are 2.5 feet of collapse breccia at the top of this core. The clasts are subrounded, pebble to possibly boulder size, and are made of three lithologies: mudstone, packstone, and grainstone. The sediment between the clasts is a dolomitic gray-green cave clay which swells when wet. The mineralogy of the segment includes dolomite rhombs, terrigenous quartz grains, glauconite, clay, pyrite, packstone fragments, and fossils. Fossils represented are brachiopods, corals, bryozoans, echinoderms, trilobites, ostrocods, and Girvanella. Some fossil pores are filled with chalcedony. The lower half of the core contains features such as solution-enlarged fractures, geopetal structures, and a 6-cm wide debris flow in the host rock. Cements in the core consist of ferroan calcite, chalcedony, and dolomite.

Porosity ranges from 0 to 20% in the brecciated area. The depositional environment is possibly lower intertidal. Stratigraphic interval was chosen because of well log signature.


WIL-MC COSSEY NO.2
SEC. 21 T7N R2E
POTTAWATOMIE COUNTY, OKLAHOMA
15 cm
5063
5066
5062
5065
5064
5061
5060

APPENDIX B

PETROLOGS

PETROLOG

WELL ______________________________

SEC.______T______R______ ______COTTON______ COUNTY, OKLAHOMA

LITHOLOGY

- SANDSTONE
- SHALE
- LIMESTONE
- DOLOMITIC LIMESTONE
- DOLOMITE
- CLAYEY DOLOMITE
- BRECCIA
- CRACKLE BRECCIA
- ▲ CHERT

SED STRUCTURES/ CONSTITUENTS

- MOTTLED BEDDING
- STROMATOLITE
- INTRACLASTS
- TRILOBITE
- GASTROPODS
- ALGAE
- VUGS, CHANNELS
- CEMENT VEIN
- G GLAUCONITE
- ■ PYRITE
- CORALS
- BRACH
- ECHINODERM
- BURROWS
- ⬭ OSTRACOD
- BRYOZOAN
- ～ UNCONFORMITY

POROSITY TYPES

F	FRACTURE
SEF	SOLUTION-ENLARGED FRACTURE
V	VUGULAR
M	MOLDIC
IG	INTERGRANULAR
IX	INTERCRYSTALLINE

CLAST SHAPE

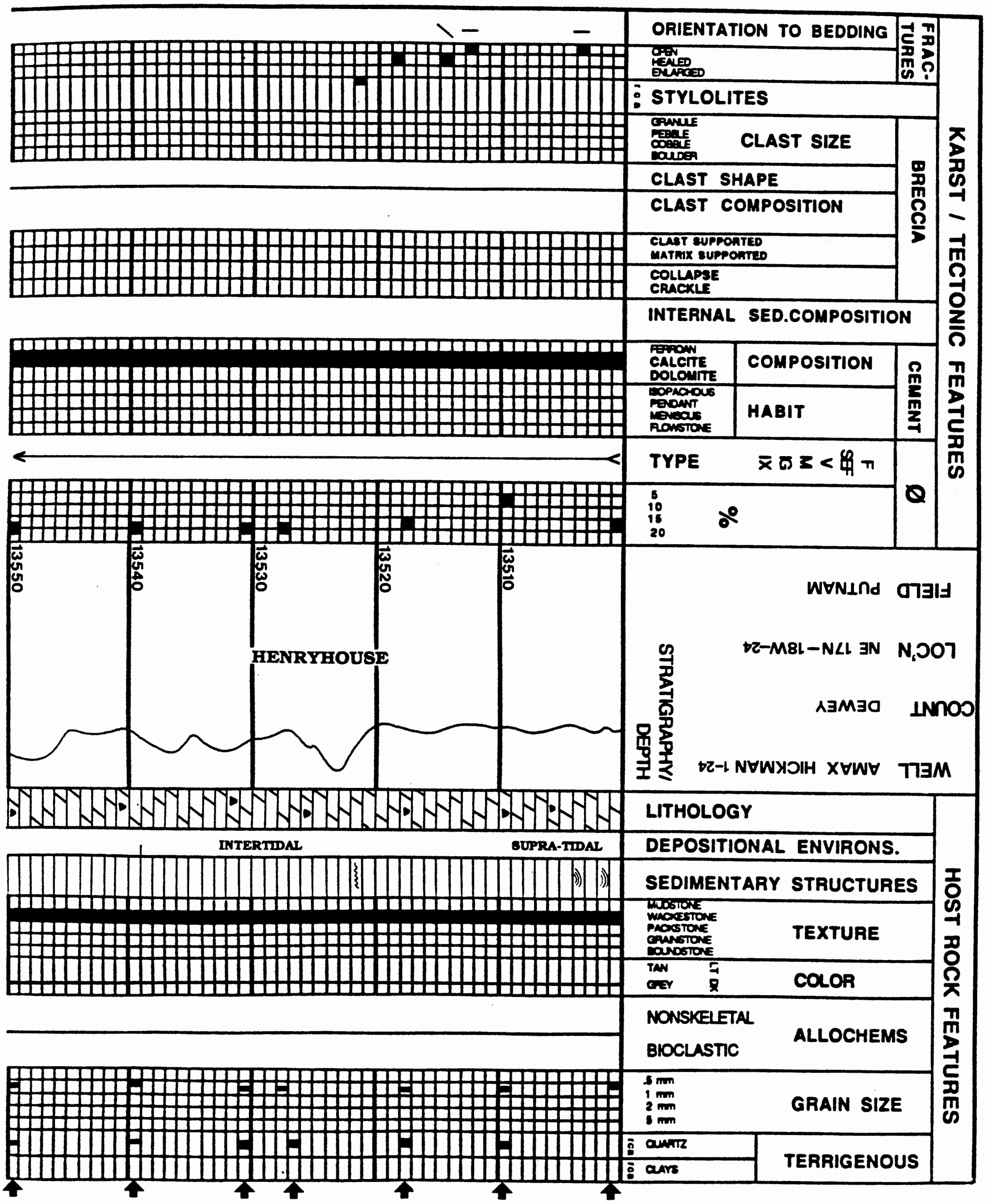
A	ANGULAR
SA	SUBANGULAR
SR	SUBROUNDED
R	ROUNDED

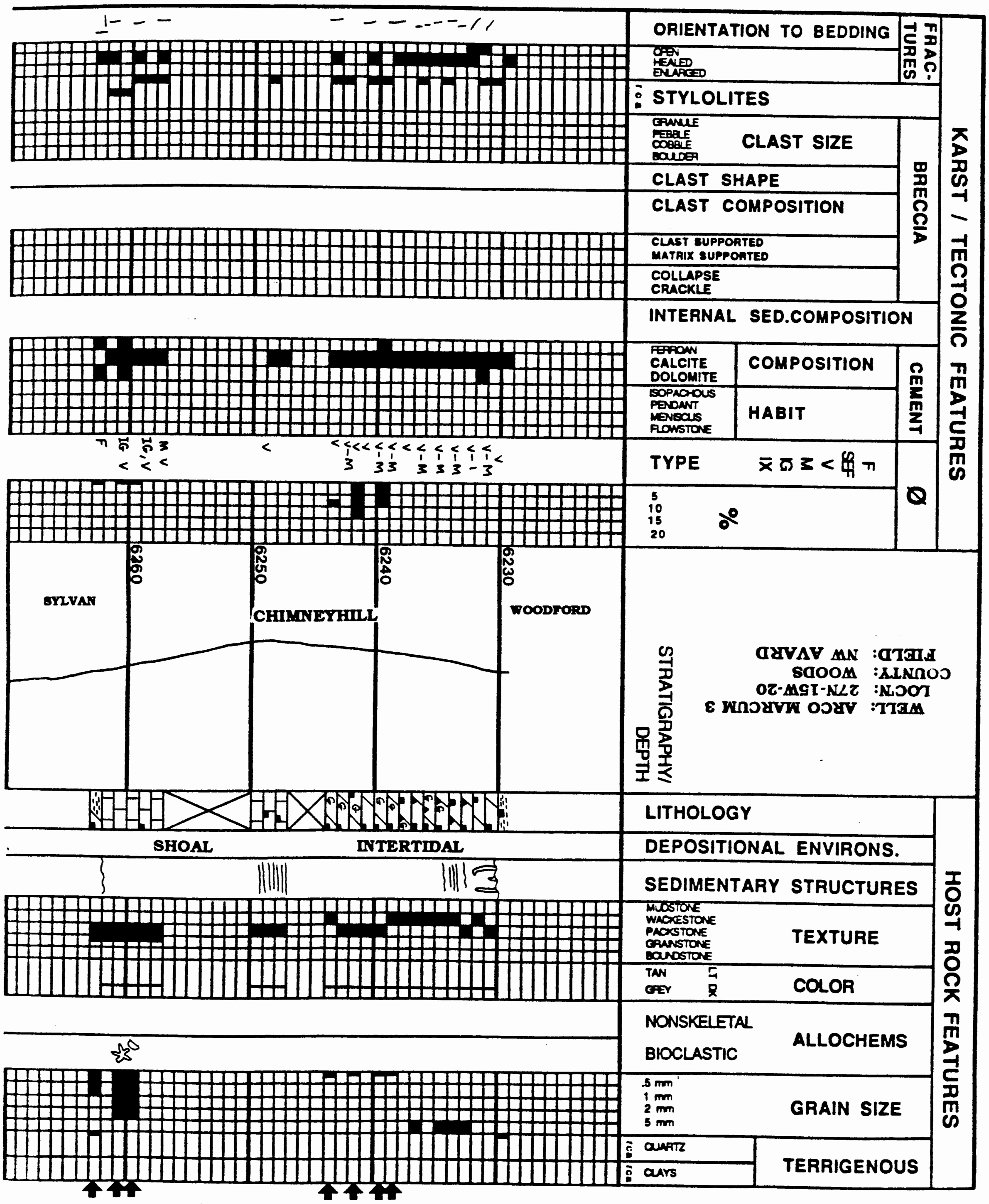
MISCELLANEOUS

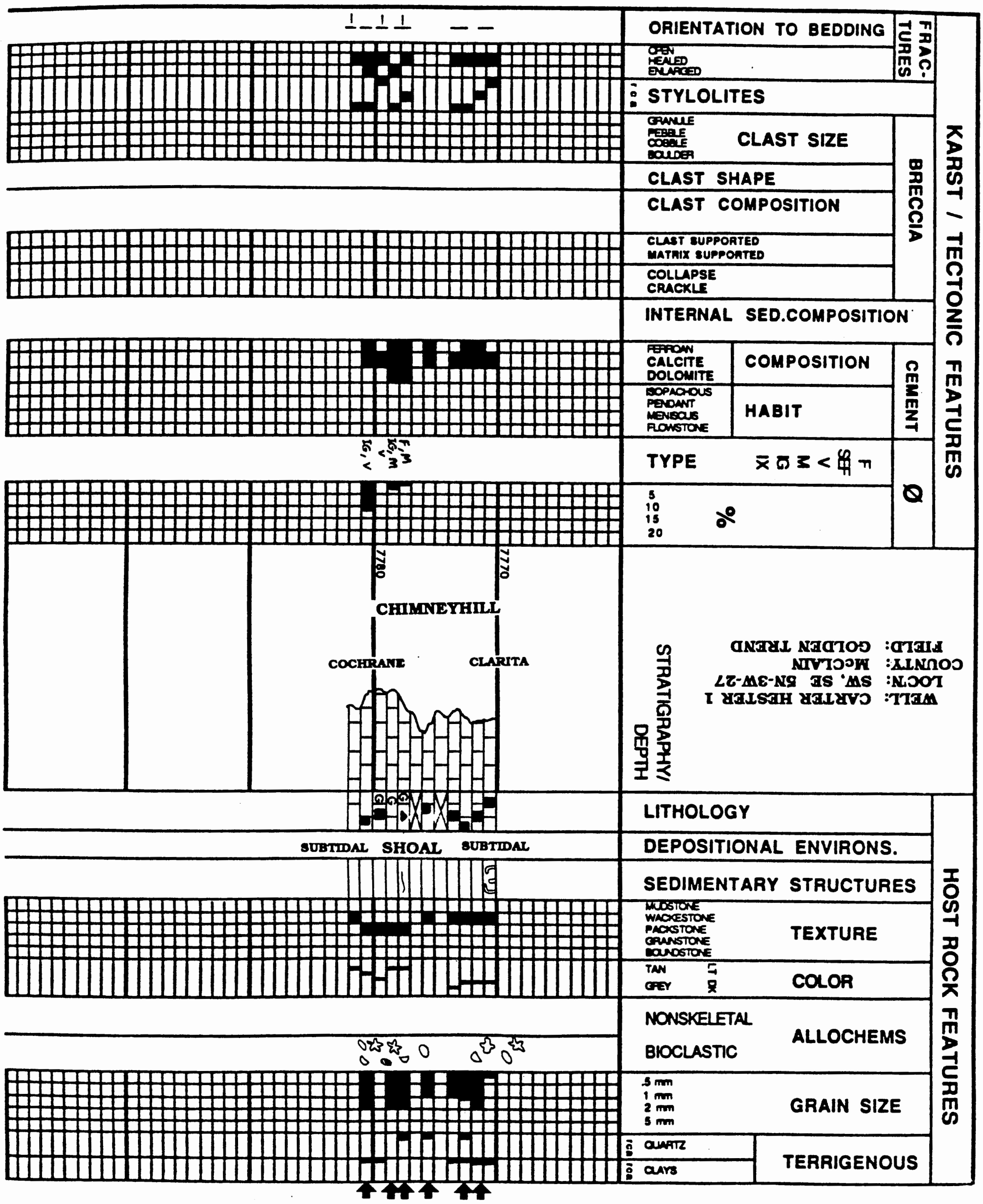
▮	DOMINANT FEATURE, TEXTURE
┆	LESS COMMONLY OCCURRING
cmt.	CEMENT
☒	MISSING CORE

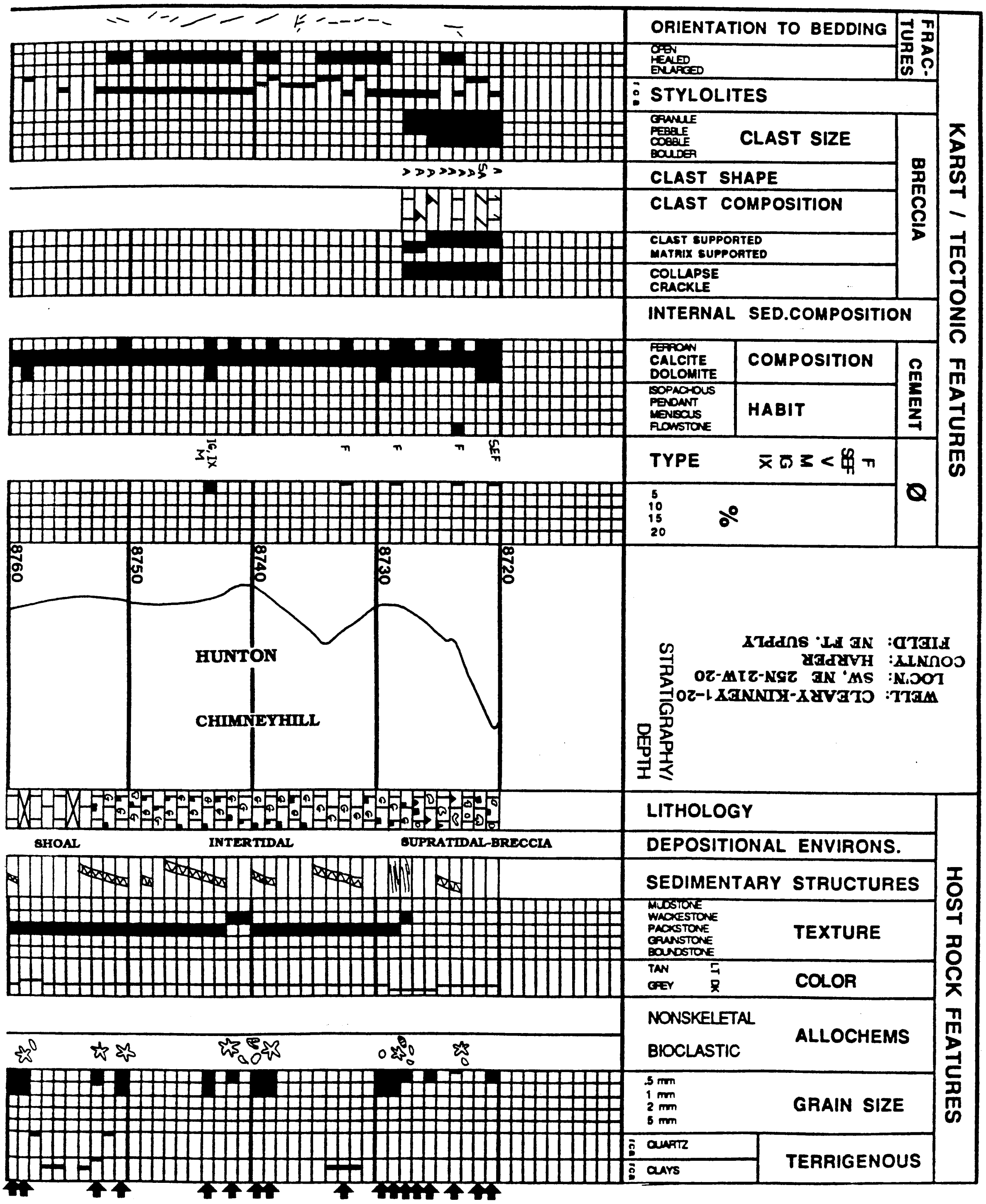
r RARE c COMMON a ABUNDANT

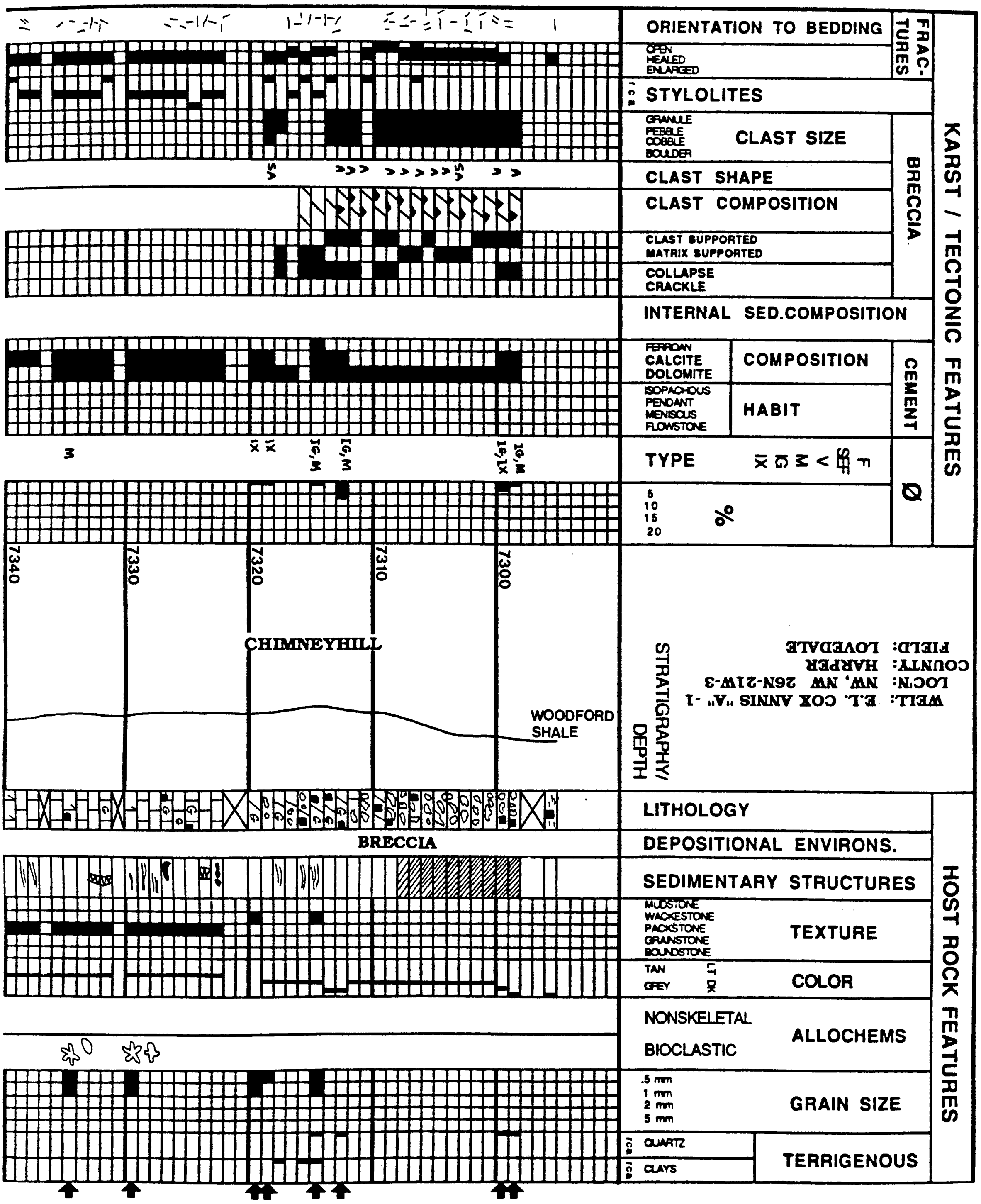
← THIN SECTION

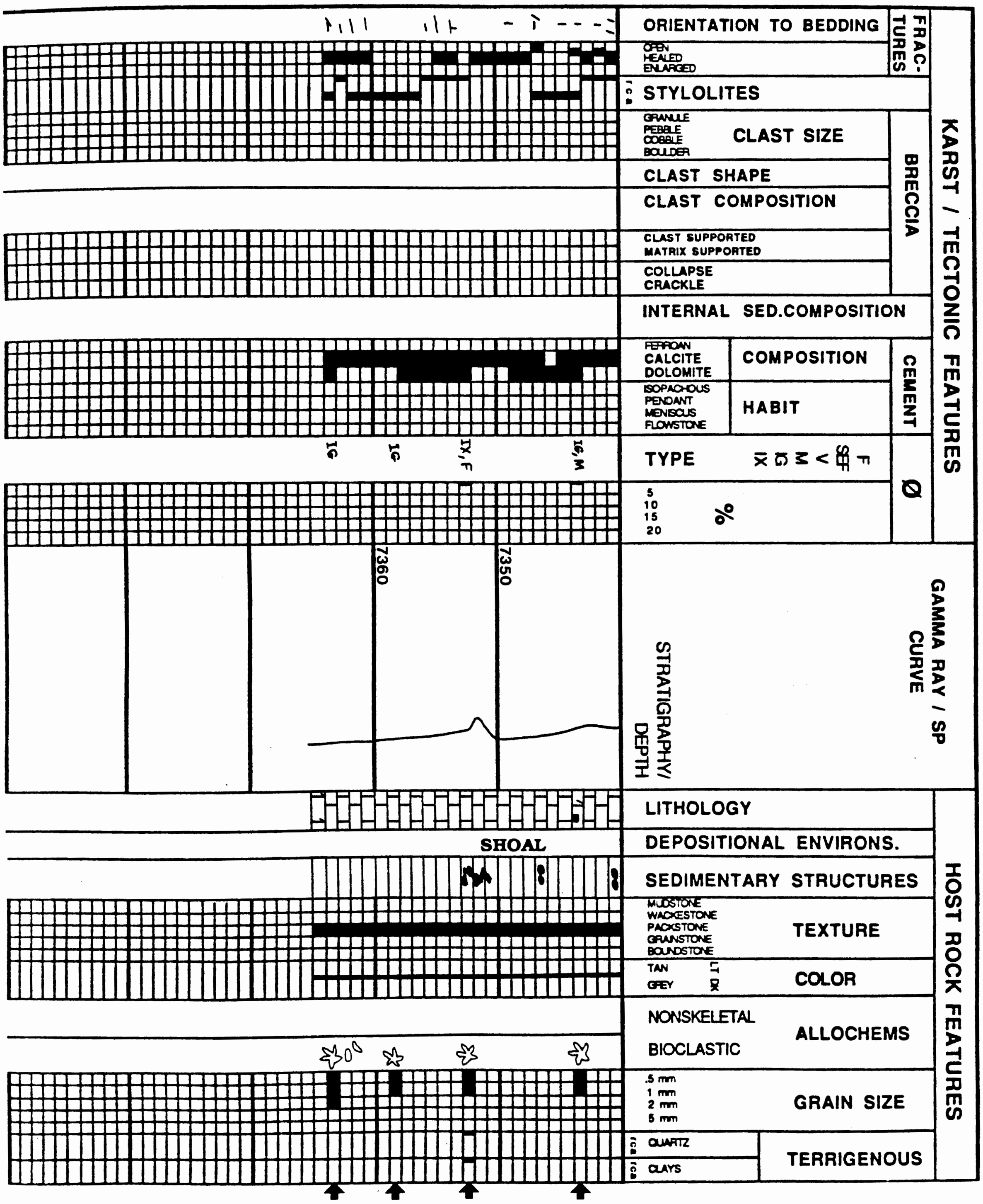

ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
KARST / TECTONIC FEATURES
FERROAN
CALCITE
DOLOMITE
COMPOSITION
BIOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
F
SEF
V
M
G
IX
Ø
5
10
15
20
%
13550
13540
13530
13520
13510
HENRYHOUSE
STRATIGRAPHY/ DEPTH
FIELD PUTNAM
LOC'N NE 17N-18W-24
COUNT DEWEY
WELL AMAX HICKMAN 1-24
LITHOLOGY
INTERTIDAL
SUPRA-TIDAL
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES


ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
5
10
15
20
%
Ø
KARST / TECTONIC FEATURES
6260
6250
6240
6230
SYLVAN
CHIMNEYHILL
WOODFORD
STRATIGRAPHY/ DEPTH
WELL: ARCO MARCUM 3
LOC'N: 27N-15W-20
COUNTY: WOODS
FIELD: NW AVARD
LITHOLOGY
SHOAL
INTERTIDAL
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES

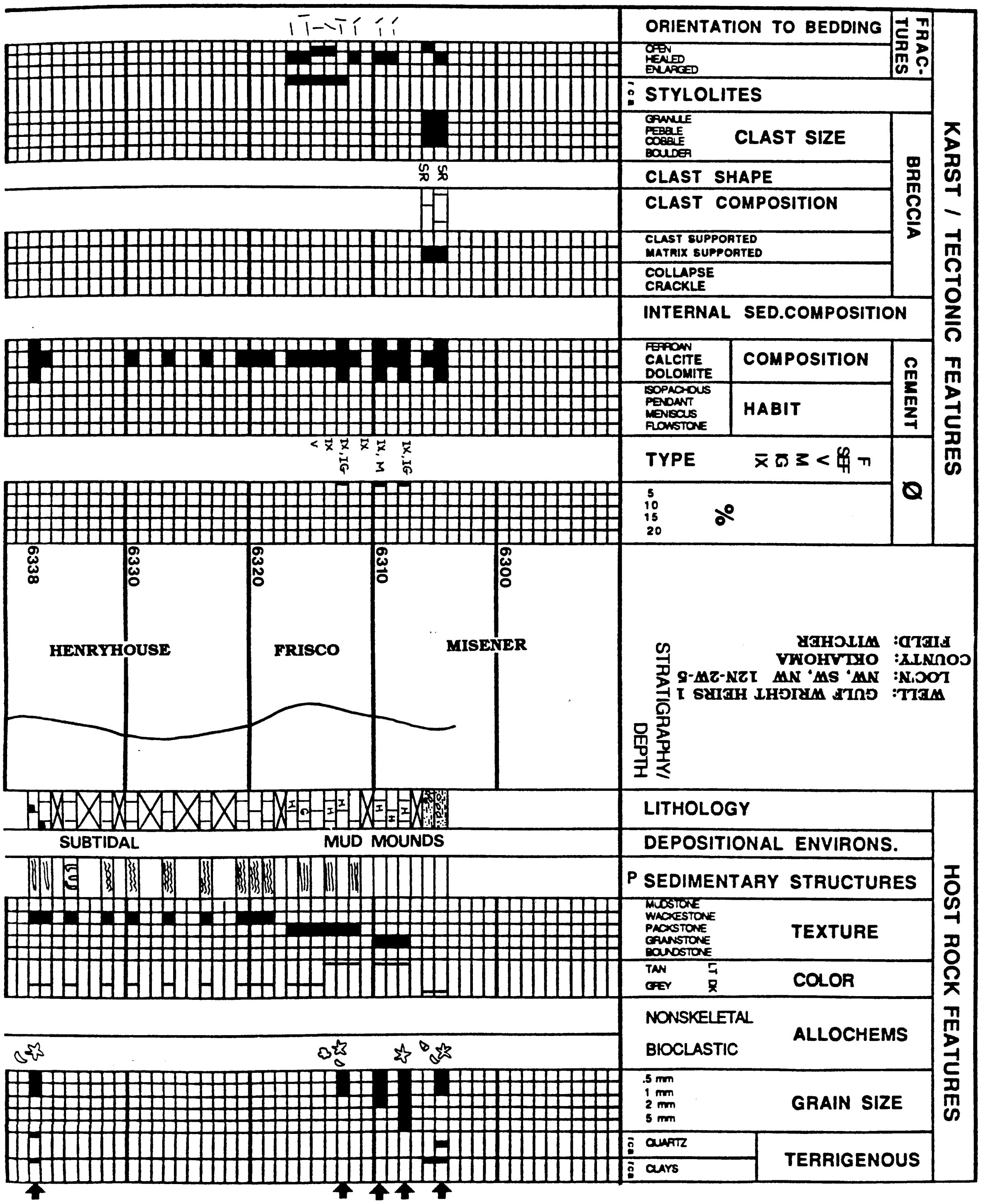

WELL: CARTER HESTER 1
LOC'N: SW, SE 5N-3W-27
COUNTY: McCLAIN
FIELD: GOLDEN TREND
KARST / TECTONIC FEATURES
FRAC-TURES
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
STYLOLITES
BRECCIA
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
INTERNAL SED.COMPOSITION
CEMENT
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
Ø
TYPE
F
SEF
V
M
G
IX
5
10
15
20
%
F,M
IG,M
V
IG,V
7780
7770
CHIMNEYHILL
COCHRANE
CLARITA
STRATIGRAPHY/ DEPTH
HOST ROCK FEATURES
LITHOLOGY
G
G
G
SUBTIDAL
SHOAL
SUBTIDAL
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS


ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
IX
IG
M
V
SEF
F
5
10
15
20
%
Ø
KARST / TECTONIC FEATURES
8760
8750
8740
8730
8720
HUNTON
CHIMNEYHILL
STRATIGRAPHY/ DEPTH
WELL: CLEARY-KINNEY 1-20
LOC'N: SW, NE 25N-21W-20
COUNTY: HARPER
FIELD: NE FT. SUPPLY
LITHOLOGY
SHOAL
INTERTIDAL
SUPRATIDAL-BRECCIA
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES


ORIENTATION TO BEDDING
FRAC-TURES
OPEN
HEALED
ENLARGED
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
IX
G
M
V
SEF
F
5
10
15
20
%
Ø
KARST / TECTONIC FEATURES
7340
7330
7320
7310
7300
CHIMNEYHILL
WOODFORD SHALE
STRATIGRAPHY/ DEPTH
WELL: E.L. COX ANNIS "A" -1
LOC'N: NW, NW 26N-21W-3
COUNTY: HARPER
FIELD: LOVEDALE
LITHOLOGY
BRECCIA
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES
1X
1X
1G,M
1G,M
1G,1X
1G,M
SA
SA



KARST / TECTONIC FEATURES
FRAC-TURES
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
STYLOLITES
BRECCIA
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
INTERNAL SED.COMPOSITION
CEMENT
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
Ø
TYPE
F
SEF
V
M
G
IX
5
10
15
20
%
1G
1G
IX,F
1G,M
GAMMA RAY / SP CURVE
STRATIGRAPHY/ DEPTH
7360
7350
HOST ROCK FEATURES
LITHOLOGY
DEPOSITIONAL ENVIRONS.
SHOAL
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS



ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
SR
SR
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
F
SFF
V
M
IG
IX
IX, IG
IX, M
IX
IX, IG
IX
V
5
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15
20
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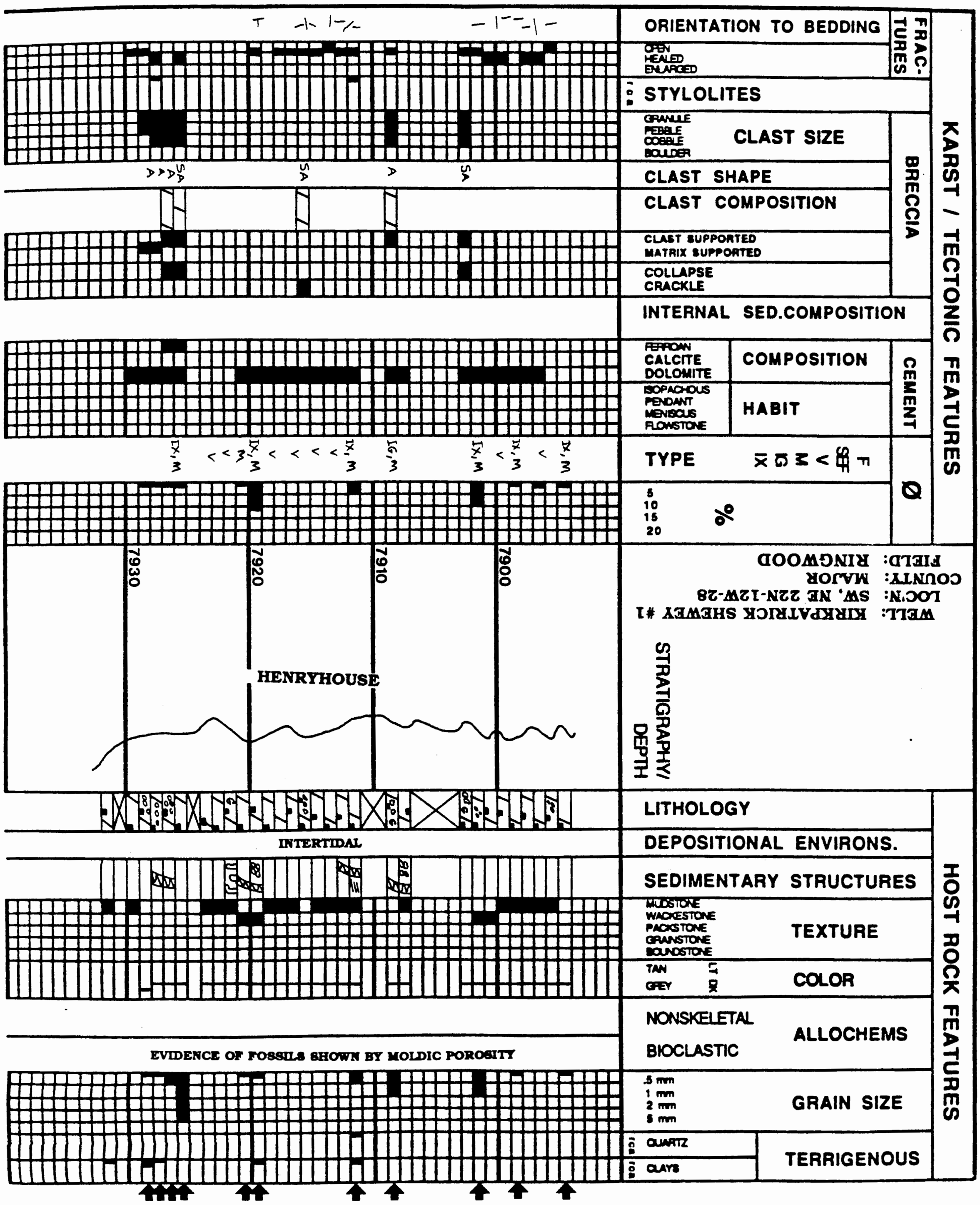
KARST / TECTONIC FEATURES
6338
6330
6320
6310
6300
HENRYHOUSE
FRISCO
MISENER
STRATIGRAPHY/ DEPTH
WELL: GULF WRIGHT HEIRS 1
LOC'N: NW, SW, NW 12N-2W-5
COUNTY: OKLAHOMA
FIELD: WITCHER
LITHOLOGY
SUBTIDAL
MUD MOUNDS
DEPOSITIONAL ENVIRONS.
P
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES


KARST / TECTONIC FEATURES
FRAC-TURES
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
STYLOLITES
BRECCIA
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
INTERNAL SED.COMPOSITION
CEMENT
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
Ø
TYPE
5
10
15
20
%
WELL: KIRKPATRICK SHEWEY #1
LOC'N: SW, NE 22N-12W-28
COUNTY: MAJOR
FIELD: RINGWOOD
STRATIGRAPHY/ DEPTH
7930
7920
7910
7900
HENRYHOUSE
HOST ROCK FEATURES
LITHOLOGY
DEPOSITIONAL ENVIRONS.
INTERTIDAL
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
EVIDENCE OF FOSSILS SHOWN BY MOLDIC POROSITY
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
SA
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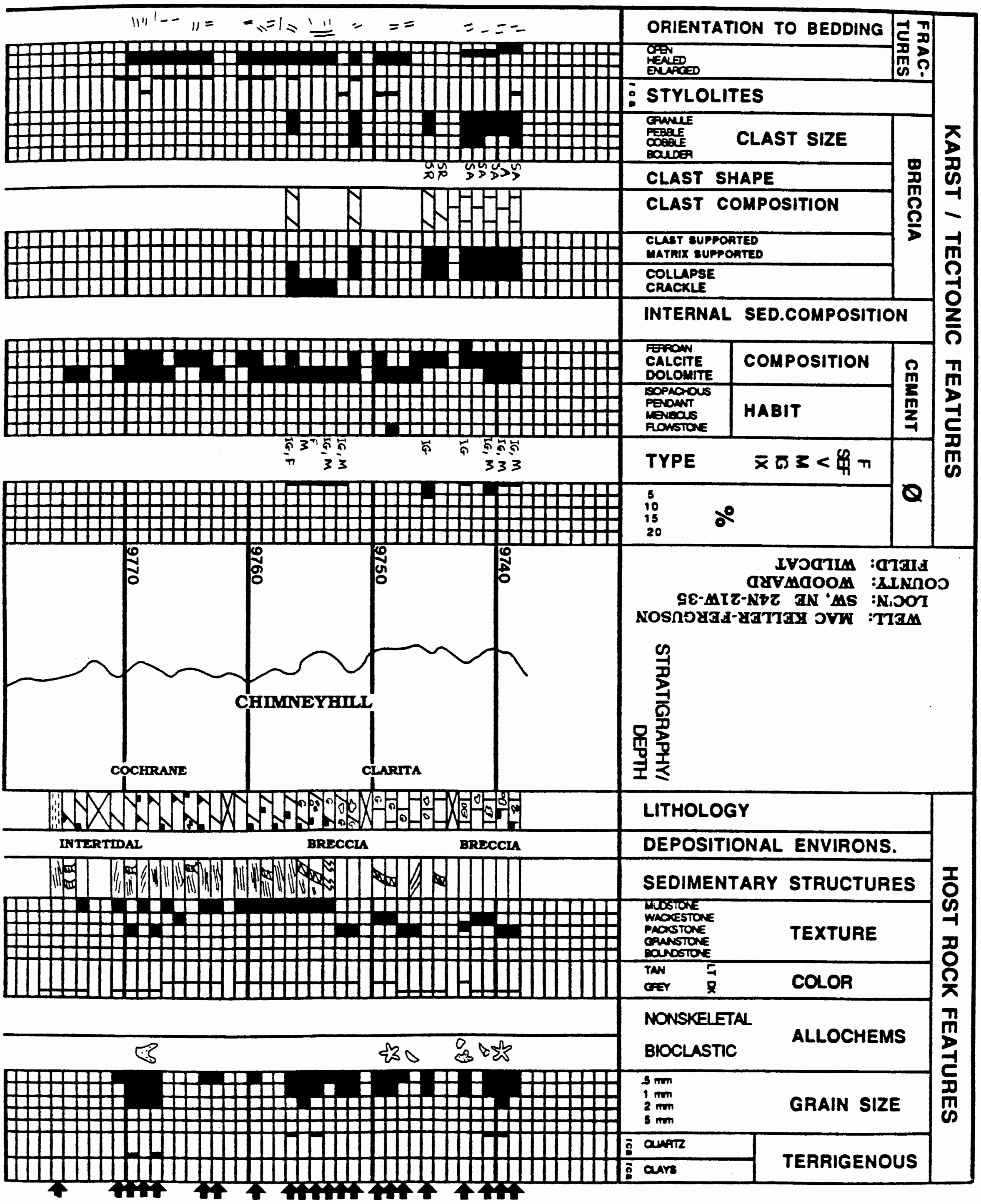
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
5
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15
20
%
Ø
KARST / TECTONIC FEATURES
WELL: MAC KELLER-FERGUSON
LOC'N: SW, NE 24N-21W-35
COUNTY: WOODWARD
FIELD: WILDCAT
STRATIGRAPHY/ DEPTH
9770
9760
9750
9740
CHIMNEYHILL
COCHRANE
CLARITA
LITHOLOGY
DEPOSITIONAL ENVIRONS.
INTERTIDAL
BRECCIA
BRECCIA
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
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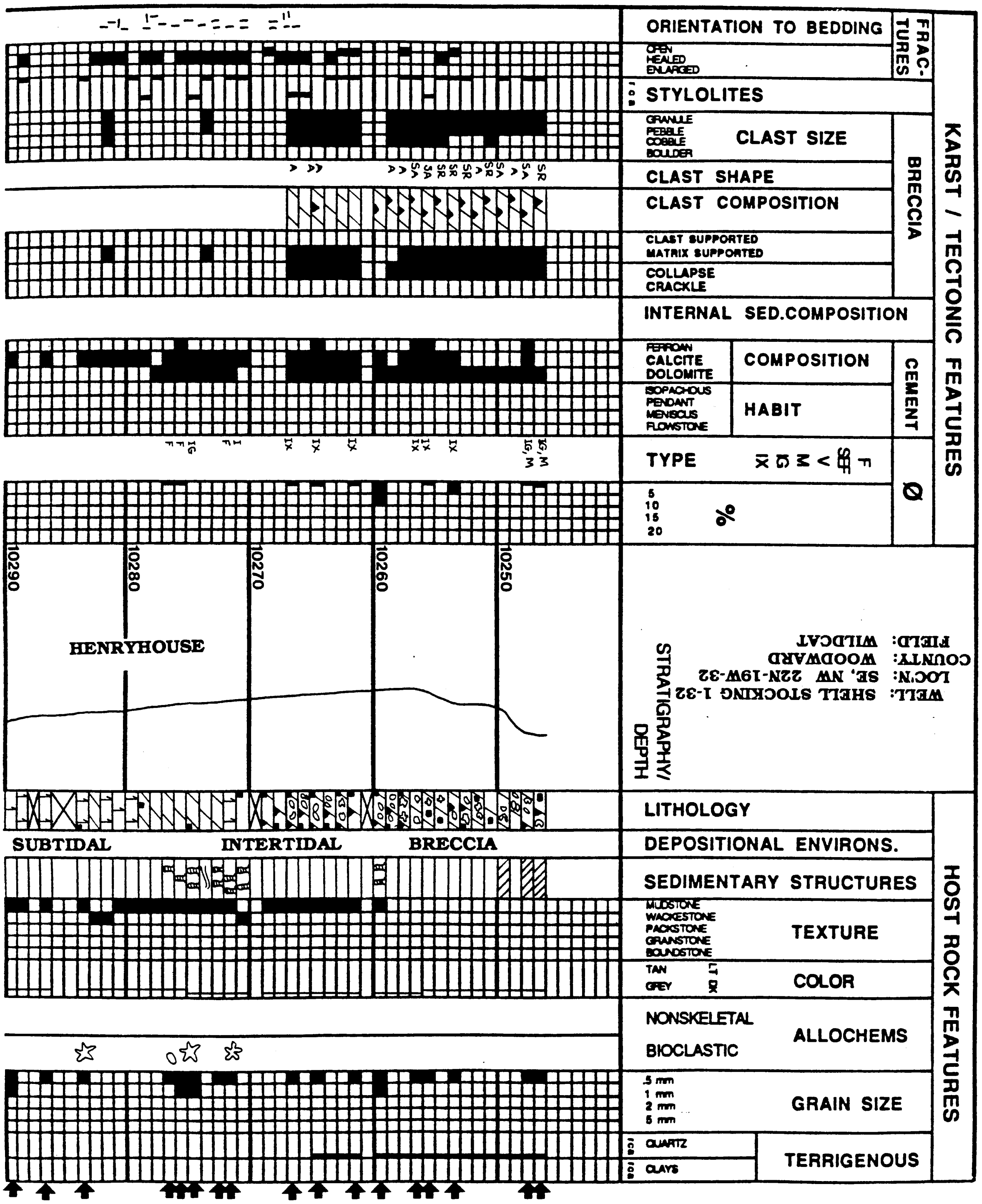
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES



ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
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%
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KARST / TECTONIC FEATURES
10290
10280
10270
10260
10250
HENRYHOUSE
STRATIGRAPHY/ DEPTH
WELL: SHELL STOCKING 1-32
LOC'N: SE, NW 22N-19W-32
COUNTY: WOODWARD
FIELD: WILDCAT
LITHOLOGY
SUBTIDAL
INTERTIDAL
BRECCIA
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
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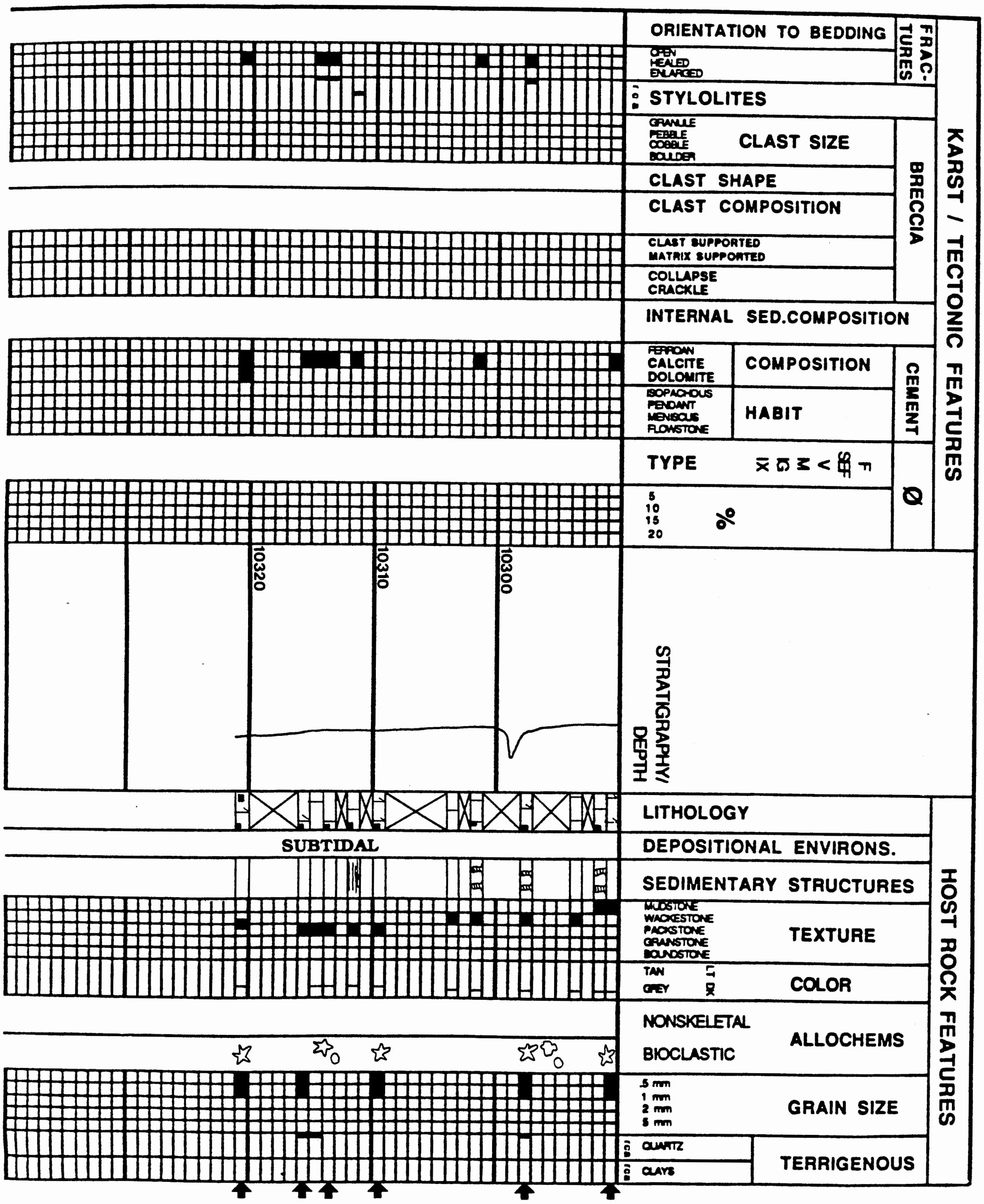
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES


ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
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KARST / TECTONIC FEATURES
10320
10310
10300
STRATIGRAPHY/ DEPTH
LITHOLOGY
SUBTIDAL
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
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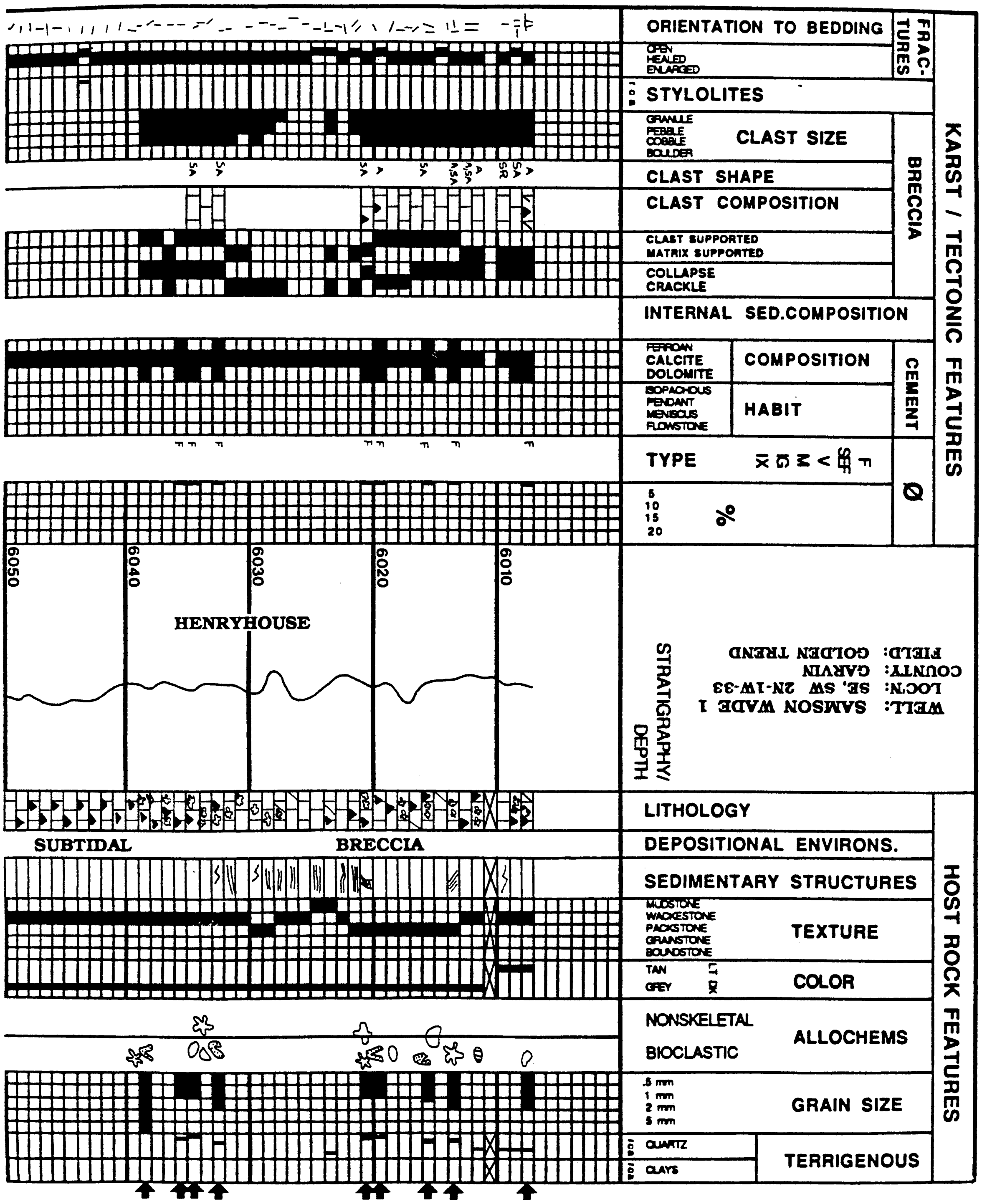
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES


ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
FRAC-TURES
STYLOLITES
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
BRECCIA
INTERNAL SED.COMPOSITION
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
HABIT
CEMENT
TYPE
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KARST / TECTONIC FEATURES
6050
6040
6030
6020
6010
HENRYHOUSE
STRATIGRAPHY/ DEPTH
WELL: SAMSON WADE 1
LOC'N: SE, SW 2N-1W-33
COUNTY: GARVIN
FIELD: GOLDEN TREND
LITHOLOGY
SUBTIDAL
BRECCIA
DEPOSITIONAL ENVIRONS.
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
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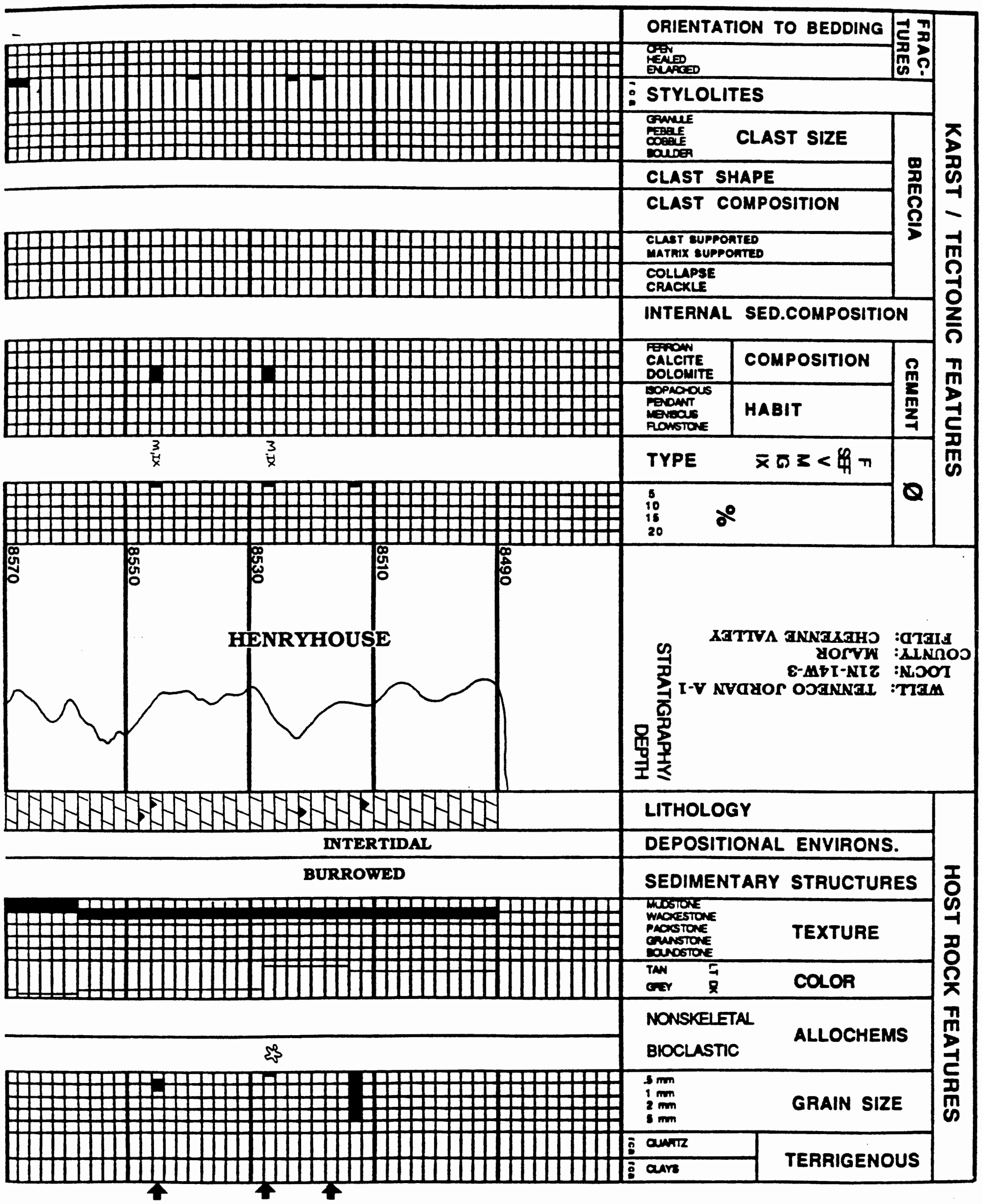
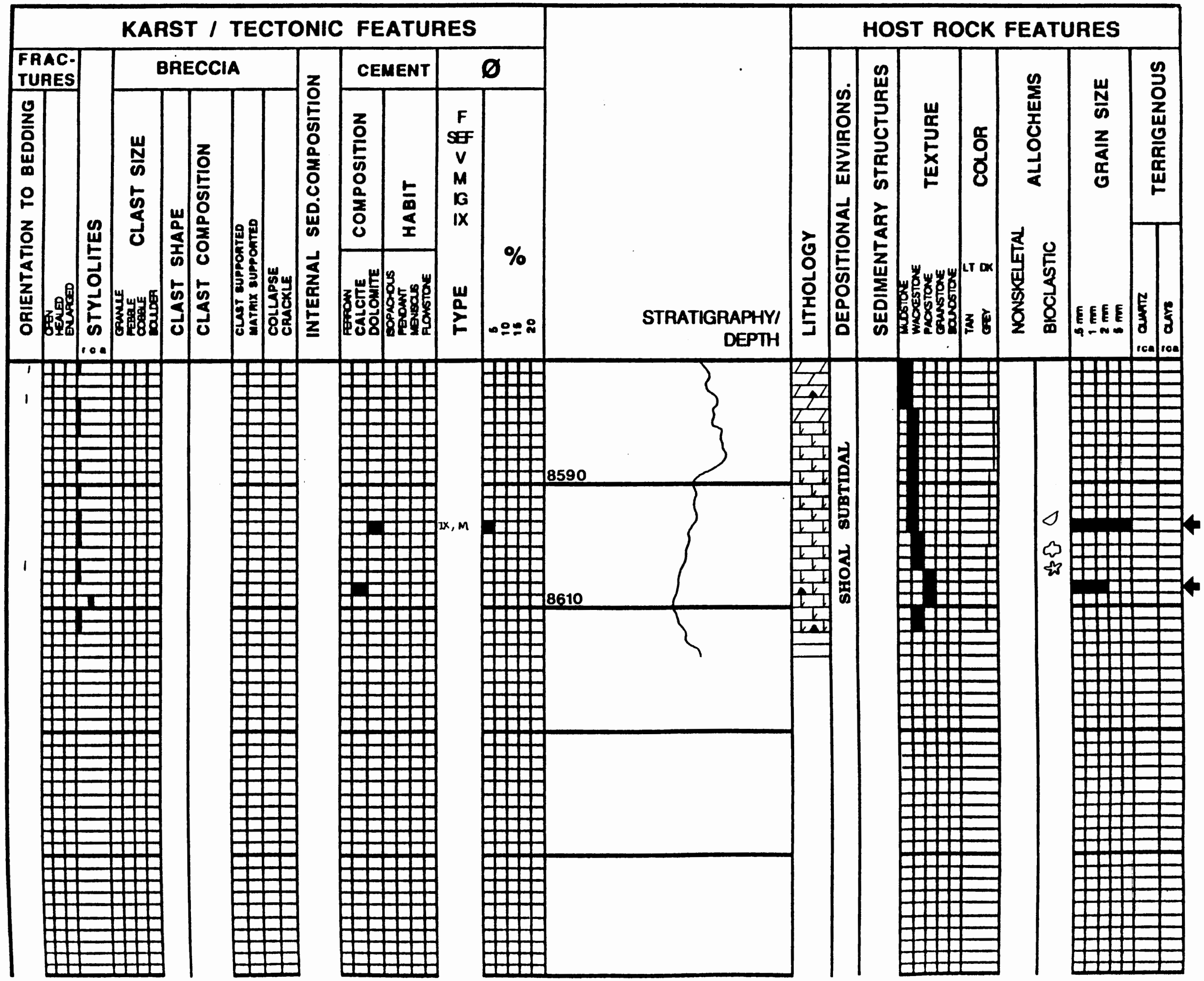
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES



WELL: TENNECO JORDAN A-1
LOC'N: 21N-14W-3
COUNTY: MAJOR
FIELD: CHEYENNE VALLEY


KARST / TECTONIC FEATURES
FRAC-TURES
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
STYLOLITES
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CLAST SIZE
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
INTERNAL SED.COMPOSITION
CEMENT
COMPOSITION
FERROAN
CALCITE
DOLOMITE
HABIT
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
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SEF
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M
G
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IX, M
STRATIGRAPHY/
DEPTH
8590
8610
HOST ROCK FEATURES
LITHOLOGY
DEPOSITIONAL ENVIRONS.
SHOAL SUBTIDAL
SEDIMENTARY STRUCTURES
TEXTURE
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
COLOR
TAN
GREY
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ALLOCHEMS
NONSKELETAL
BIOCLASTIC
GRAIN SIZE
.5 mm
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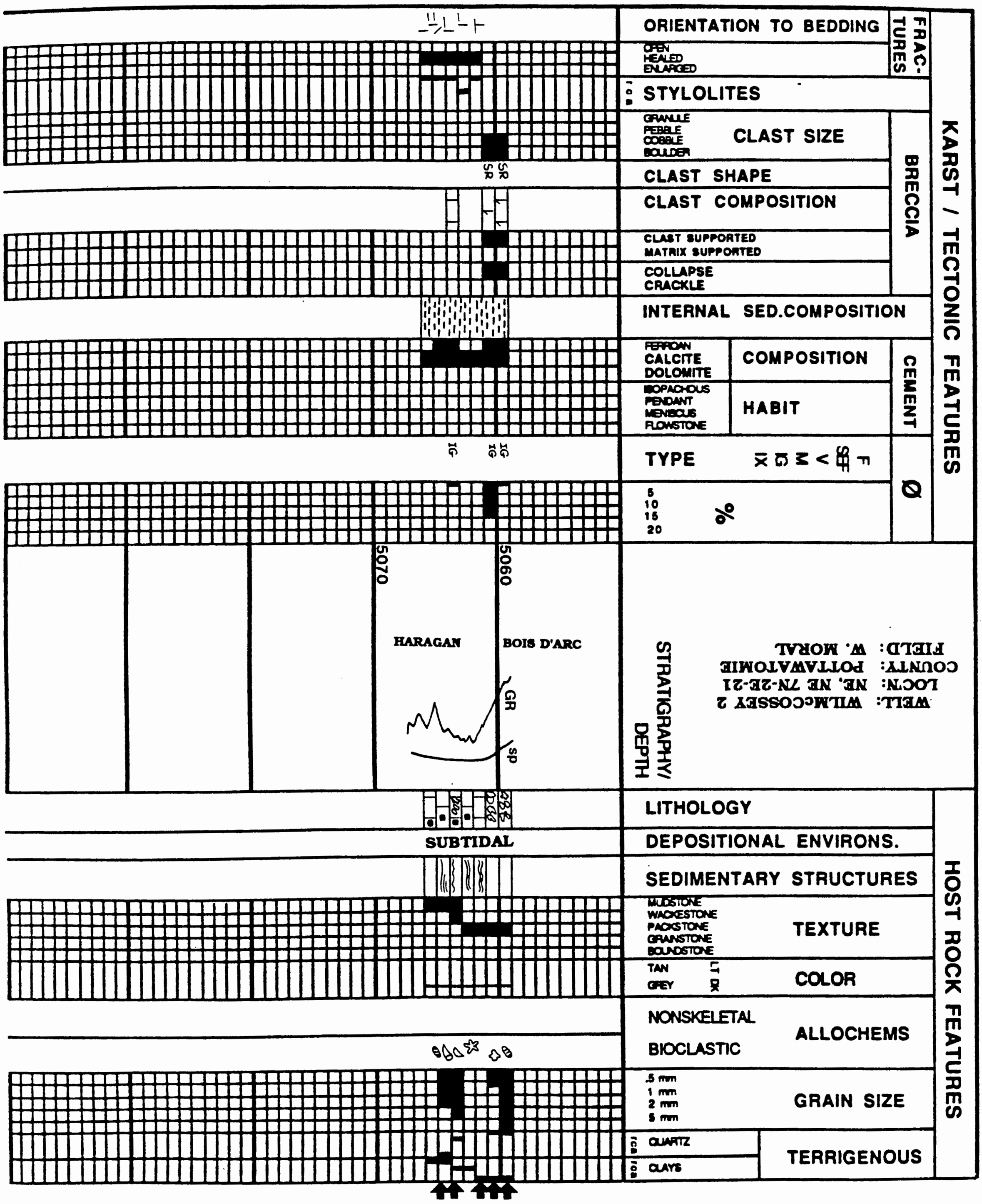
TERRIGENOUS
QUARTZ
CLAYS
rca rca



KARST / TECTONIC FEATURES
FRAC-TURES
ORIENTATION TO BEDDING
OPEN
HEALED
ENLARGED
STYLOLITES
BRECCIA
GRANULE
PEBBLE
COBBLE
BOULDER
CLAST SIZE
CLAST SHAPE
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SR
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLAPSE
CRACKLE
INTERNAL SED.COMPOSITION
CEMENT
FERROAN
CALCITE
DOLOMITE
COMPOSITION
ISOPACHOUS
PENDANT
MENISCUS
FLOWSTONE
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TYPE
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15
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%
STRATIGRAPHY/ DEPTH
5070
5060
HARAGAN
BOIS D'ARC
GR
SP
WELL: WILMcCOSSEY 2
LOC'N: NE, NE 7N-2E-21
COUNTY: POTTAWATOMIE
FIELD: W. MORAL
HOST ROCK FEATURES
LITHOLOGY
DEPOSITIONAL ENVIRONS.
SUBTIDAL
SEDIMENTARY STRUCTURES
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN
GREY
LT
DK
COLOR
NONSKELETAL
BIOCLASTIC
ALLOCHEMS
.5 mm
1 mm
2 mm
5 mm
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS

VITA

Felicia Danuser Matthews

Candidate for the Degree of

Master of Science

Thesis: PALEOKARSTIC FEATURES AND RESERVOIR CHARACTERISTICS OF THE HUNTON GROUP IN THE ANADARKO-BASIN, OKLAHOMA

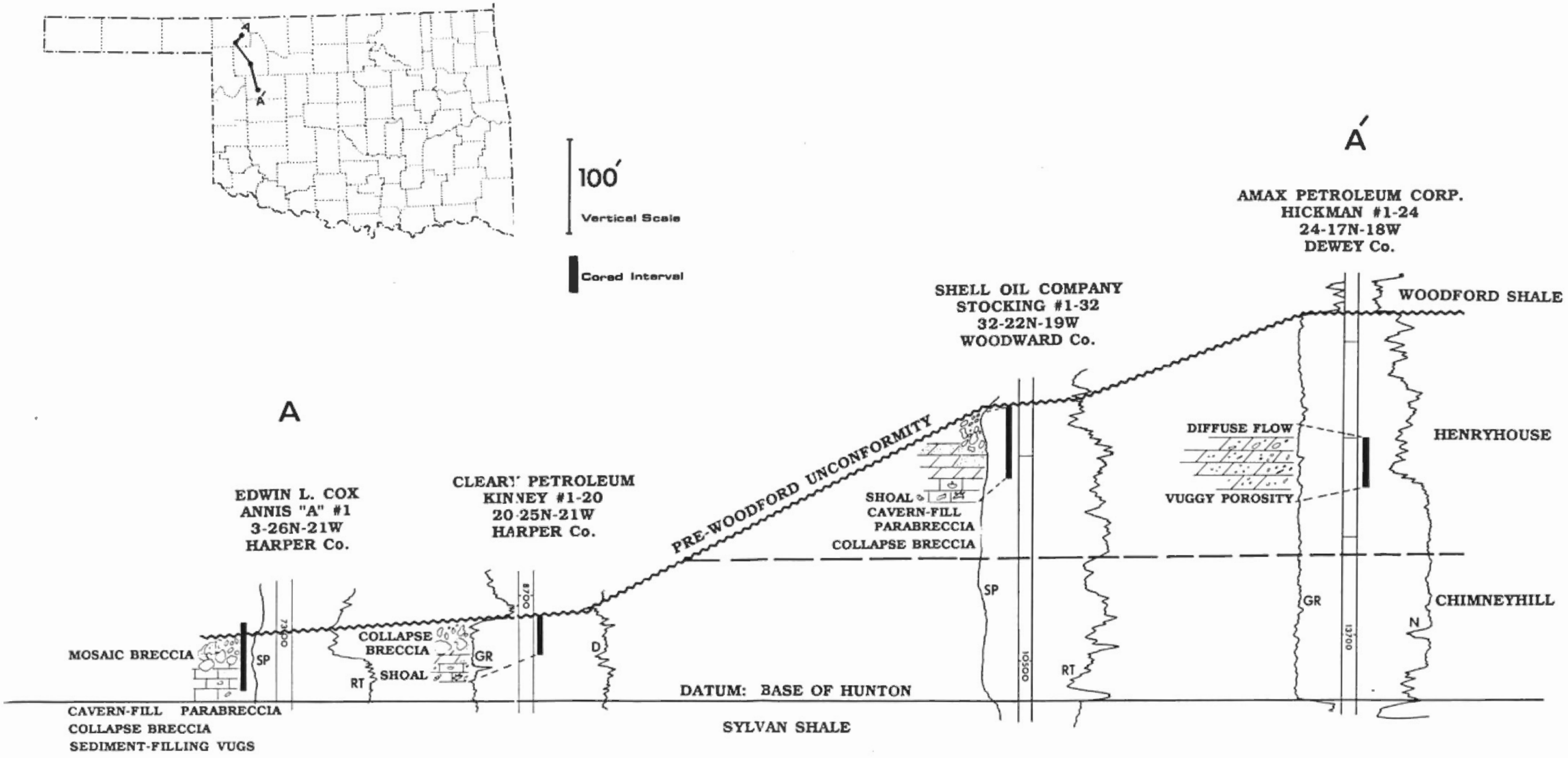
Major Field: Geology

Biographical:

Personal Data: Born in St. Louis, Missouri, August 1, 1937, the daughter of Walter W. and Hallie Ebersole Danuser. Married to Robert R. Matthews, Jr. One son, Robert D. Matthews.

Education: Graduated from Will Rogers High School, Tulsa, Oklahoma, 1955. Received Associate of Arts from William Woods College, Fulton, Missouri, 1957; received Bachelor of Arts from the University of Tulsa, Tulsa, Oklahoma, 1959; received Bachelor of Science from Oklahoma State University, December, 1984; completed requirements for Master of Science Degree at Oklahoma State University in May,1992.

Professional Experience: Teaching Assistant, School of Geology, Oklahoma State University, 1988-1990. Member, American Association of Petroleum Geologists.


A
A′
100′
Vertical Scale
Cored Interval
A
A′
EDWIN L. COX
ANNIS "A" #1
3-26N-21W
HARPER Co.
CLEARY PETROLEUM
KINNEY #1-20
20-25N-21W
HARPER Co.
SHELL OIL COMPANY
STOCKING #1-32
32-22N-19W
WOODWARD Co.
AMAX PETROLEUM CORP.
HICKMAN #1-24
24-17N-18W
DEWEY Co.
WOODFORD SHALE
HENRYHOUSE
CHIMNEYHILL
PRE-WOODFORD UNCONFORMITY
DIFFUSE FLOW
VUGGY POROSITY
SHOAL
CAVERN-FILL
PARABRECCIA
COLLAPSE BRECCIA
MOSAIC BRECCIA
CAVERN-FILL PARABRECCIA
COLLAPSE BRECCIA
SEDIMENT-FILLING VUGS
COLLAPSE
BRECCIA
SHOAL
SP
RT
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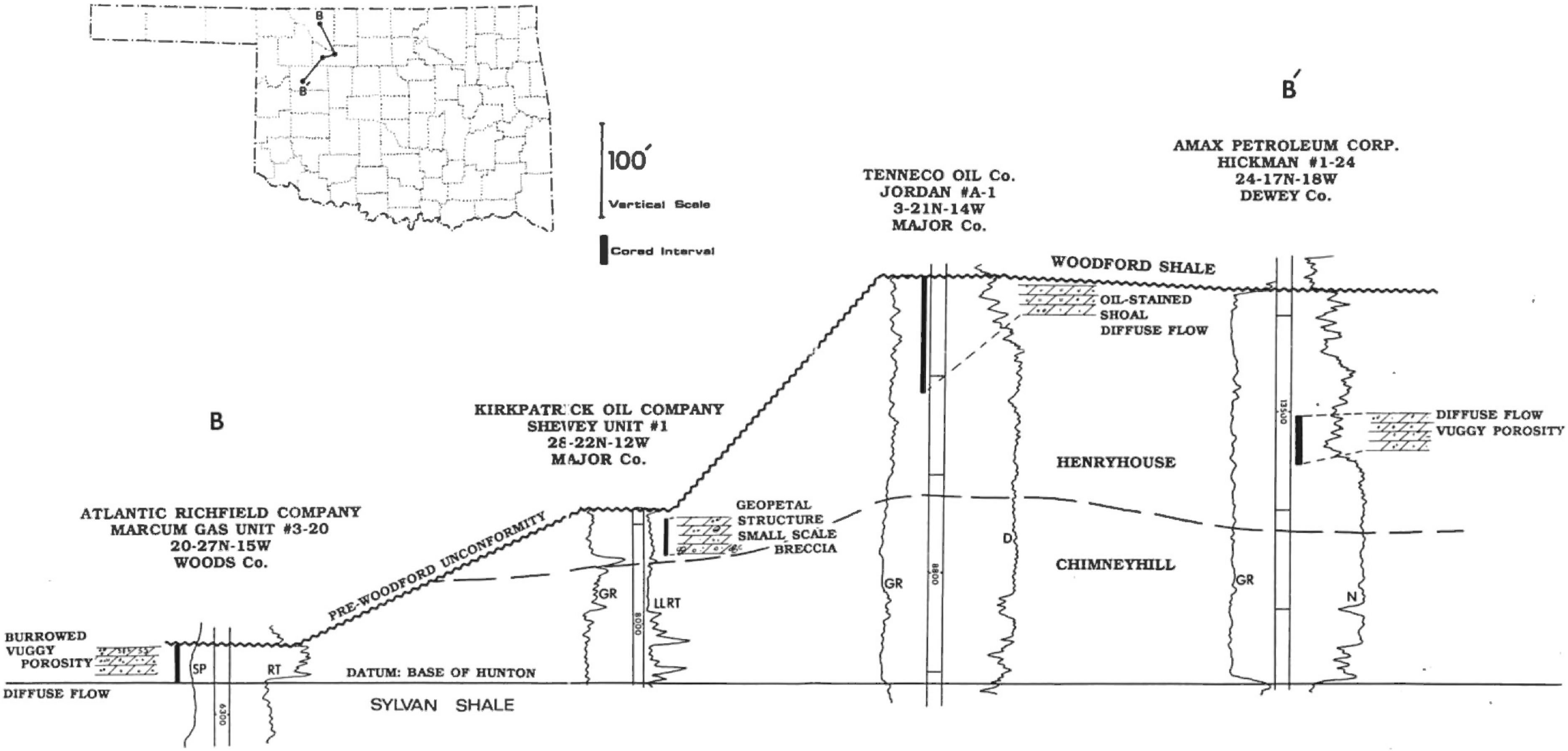
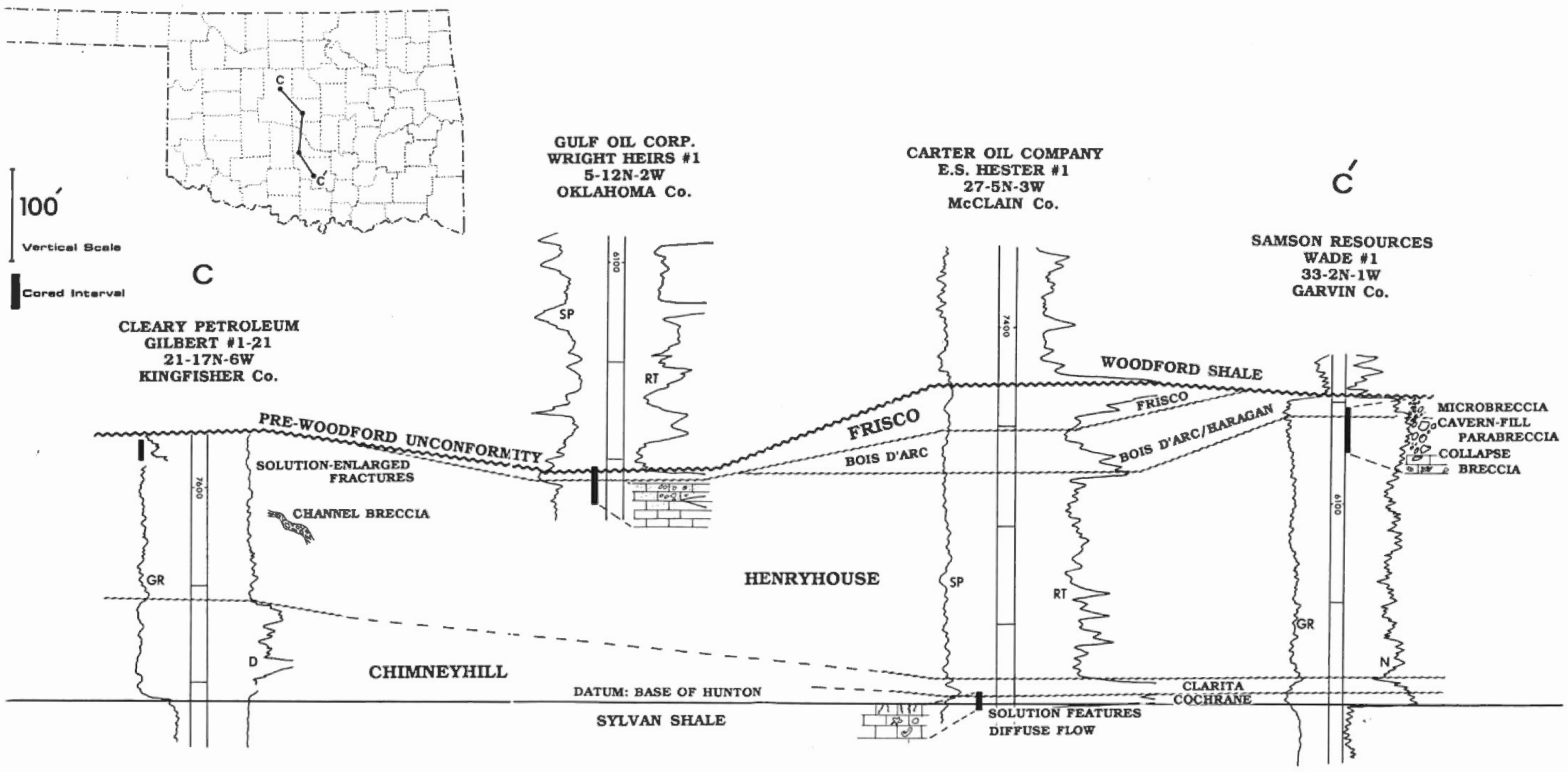
D
N
7300
8700
10500
13700
DATUM: BASE OF HUNTON
SYLVAN SHALE


B
B
B´
100´
Vertical Scale
Cored Interval
B
B´
ATLANTIC RICHFIELD COMPANY
MARCUM GAS UNIT #3-20
20-27N-15W
WOODS Co.
KIRKPATRICK OIL COMPANY
SHEWEY UNIT #1
28-22N-12W
MAJOR Co.
TENNECO OIL Co.
JORDAN #A-1
3-21N-14W
MAJOR Co.
AMAX PETROLEUM CORP.
HICKMAN #1-24
24-17N-18W
DEWEY Co.
WOODFORD SHALE
OIL-STAINED
SHOAL
DIFFUSE FLOW
DIFFUSE FLOW
VUGGY POROSITY
HENRYHOUSE
CHIMNEYHILL
GEOPETAL
STRUCTURE
SMALL SCALE
BRECCIA
PRE-WOODFORD UNCONFORMITY
BURROWED
VUGGY
POROSITY
DIFFUSE FLOW
SP
RT
6300
GR
LLRT
8000
GR
8800
D
GR
13500
N
DATUM: BASE OF HUNTON
SYLVAN SHALE


C
C′
100′
Vertical Scale
Cored Interval
C
CLEARY PETROLEUM
GILBERT #1-21
21-17N-6W
KINGFISHER Co.
GULF OIL CORP.
WRIGHT HEIRS #1
5-12N-2W
OKLAHOMA Co.
CARTER OIL COMPANY
E.S. HESTER #1
27-5N-3W
McCLAIN Co.
C′
SAMSON RESOURCES
WADE #1
33-2N-1W
GARVIN Co.
SP
RT
6100
7400
7600
6100
GR
D
SP
RT
GR
N
WOODFORD SHALE
PRE-WOODFORD UNCONFORMITY
FRISCO
BOIS D'ARC
FRISCO
BOIS D'ARC/HARAGAN
SOLUTION-ENLARGED
FRACTURES
CHANNEL BRECCIA
HENRYHOUSE
CHIMNEYHILL
DATUM: BASE OF HUNTON
SYLVAN SHALE
CLARITA
COCHRANE
SOLUTION FEATURES
DIFFUSE FLOW
MICROBRECCIA
CAVERN-FILL
PARABRECCIA
COLLAPSE
BRECCIA