

KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 96-7

Improved Oil Recovery in Mississippian
Carbonate Reservoirs of Kansas--
Near Term--Class 2

Annual Report

by

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KANSAS GEOLOGICAL SURVEY
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**IMPROVED OIL RECOVERY IN
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RESERVOIRS OF KANSAS --
NEAR TERM -- CLASS 2**

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**TITLE: IMPROVED OIL RECOVERY IN
MISSISSIPPIAN CARBONATE
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NEAR TERM -- CLASS 2**

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FOREWORD

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ABSTRACT

This report represents a summary of the progress during the first year of Budget period 1 of the near term Class 2 project entitled "Improved Oil Recovery in Mississippian Carbonate Reservoirs of Kansas". Two examples of advanced technologies developed as part of this project are highlighted along with the use of the Internet to transfer these technologies. The two advanced technologies are a spread-sheet petrophysical analysis and reservoir evaluation (PfeFFER), and a petrophysical/seismic approach to well logs (*pseudoseismic*). Work continues on multi-disciplinary reservoir characterization at the demonstration site. The potential for incremental primary recovery is being evaluated using the improved reservoir characterization to target infill drilling and evaluate the potential of a horizontal well. The impact of successful incremental primary recovery from sub-Pennsylvanian unconformity Mississippian reservoirs such as are present at the Schaben demonstration site would be significant for Kansas and the US

EXECUTIVE SUMMARY

The Mississippian Class 2 project introduces Kansas producers to potentially useful technologies and demonstrates these technologies in actual oil field operations. In addition, advanced technology will be tailored specifically to the scale appropriate to the operations of Kansas producers. The majority of Kansas production is operated by small independent producers that do not have resources to develop and test advanced technologies (90% of the 3,000 Kansas producers have less than 20 employees). For Kansas producer's, access to new technology is important for sustaining production and increasing viability. A major emphasis of the project is collaboration of university scientists and engineers with the independent producers and service companies operating in the state to accelerate adaptation and evaluation of new technologies. Examples of advanced technologies developed as part of this project are a spread-sheet petrophysical analysis and reservoir evaluation (PfeFFER), and a petrophysical/seismic approach to well logs (*pseudoseismic*).

An extensive technology transfer effort is being undertaken to inform other operators of the project results. In addition to traditional technology transfer methods (for example, reports;

trade, professional, and technical publications; workshops; and seminars) a public domain relational database and computerized display package are being made available through the Internet and other means of digital access. The goal is literally to provide access to data and technology to independent producers in their office.

At the end of year 1 acquisition and consolidation of geologic, digital log, and production data are complete and all data have been entered into a database management and analysis system. Two of three wells to gather modern data for reservoir characterization have been drilled, cored, logged and tested. Basic geologic maps and cross-sections have been generated on the computer workstation.

On the basis of present geologic analysis, a multi-tiered karst reservoir model has been developed for Schaben Field. If this model is valid numerous vertically and laterally segregated reservoir compartments would be expected. Engineering analysis and simulation is in progress, and should provide insight to more refined geologic model. Plans call for developing recommendations to test the accuracy of the model and the adequacy of the technology during budget period 2 of the project.

INTRODUCTION

The Mississippian Class 2 project is an effort to introduce Kansas producers to potentially useful technologies and to demonstrate these technologies in actual oil field operations. In addition advanced technology will be tailored specifically to the scale appropriate to the operations of Kansas producers. The majority of Kansas production is operated by small independent producers that do not have resources to develop and test advanced technologies (90% of the 3,000 Kansas producers have less than 20 employees). For Kansas producer's, access to new technology is important for sustaining production and increasing viability. A major emphasis of the project is collaboration of university scientists and engineers with the independent producers and service companies operating in the state to accelerate adaptation and evaluation of new technologies. An extensive technology transfer effort is being undertaken to inform other operators of the project results. In addition to traditional technology transfer methods (for example, reports; trade, professional, and technical publications; workshops; and seminars) a public domain relational database and computerized display package will be made available through the

Internet and other means of digital access. The goal is literally to provide access to data and technology to independent producers in their office.

The majority of Mississippian production in Kansas occurs at or near the top of the Mississippian section just below the sub-Pennsylvanian unconformity. These reservoirs are a major source of Kansas oil production and account for approximately 43% (21 million barrels in 1994) of total annual production (Carr et al., 1995a). This project addresses producibility problems in fields such as the Schaben field in Ness County, Kansas and Bindley field in Hodgeman County that produce from Meramecian and Osagian dolomites beneath the sub-Pennsylvanian unconformity. Producibility problems in these reservoirs include inadequate reservoir characterization, drilling and completion design problems, and non-optimal primary recovery. Tools and techniques will facilitate integrated, multi-disciplinary reservoir characterization. Additional incremental primary recovery is expected from deepening and recompletion of existing wells and targeted infill drilling.

Project design, methodologies, data, and results will be disseminated through focused technology transfer activities. These activities include open-file reports, publication in trade, professional, and technical publications, workshops and seminars, and the establishment of a public domain relational database and computerized display package. The target audience includes other operators in the demonstration fields, operators of other Mississippian sub-unconformity dolomite reservoirs in Kansas, operators of analogous shallow shelf carbonate reservoirs in the Mid-continent, and technical personnel involved in reservoir development and management.

Site Description

The Schaben demonstration site consists of 1,720 contiguous acres within Schaben field, located in Township 19 South--Range 21 West, Township 20 South--Range 21 West, and Township 19 South--Range 22 West, Ness County, Kansas (Figure 1). The leases comprising the demonstration sites are highlighted in Figure 1. This site is located in the upper shelf of the Hugoton Embayment of the Anadarko Basin and produces oil from dolostones and limestones of the lower Meramecian Warsaw Limestone and Osagian Keokuk Limestone (Mississippian) at depths of 4,350-4,410 feet.

Schaben field, discovered in 1963, consists of 75 completed oil wells spaced primarily on 40-acre locations (Figure 1). Cumulative field production as of September, 1995 was

8,481,592 barrels of oil (BO), and daily field production was 326 BOPD from 63 wells (Figure 2). Wells in the Schaben demonstration site have cumulatively produced 3,593,609 BO, with current (June 1993) daily production totaling 141 BOPD from 29 wells. In addition to production from the Mississippian, one well produces oil from the Cherokee Group and the Fort Scott Limestone, however, the relative volume of oil produced from these secondary zones is small. The Schaben demonstration site contains 6 plugged and abandoned oil wells, 24 actively producing oil wells, and 2 water disposal wells.

The Schaben Field demonstration site is located on the western flank of the Central Kansas uplift at the western edge of the Mississippian Osagean subcrop beneath the sub-Pennsylvanian unconformity (figures 3 - 5).

Participating Organizations

University of Kansas Center for Research Inc., the University of Kansas Energy Research Center of Lawrence Kansas, and Ritchie Exploration Inc. of Wichita, Kansas are participating in the project. Total cost sharing in the project is 50 percent.

Schaben Field Study Area

Top Mississippian Structure Map

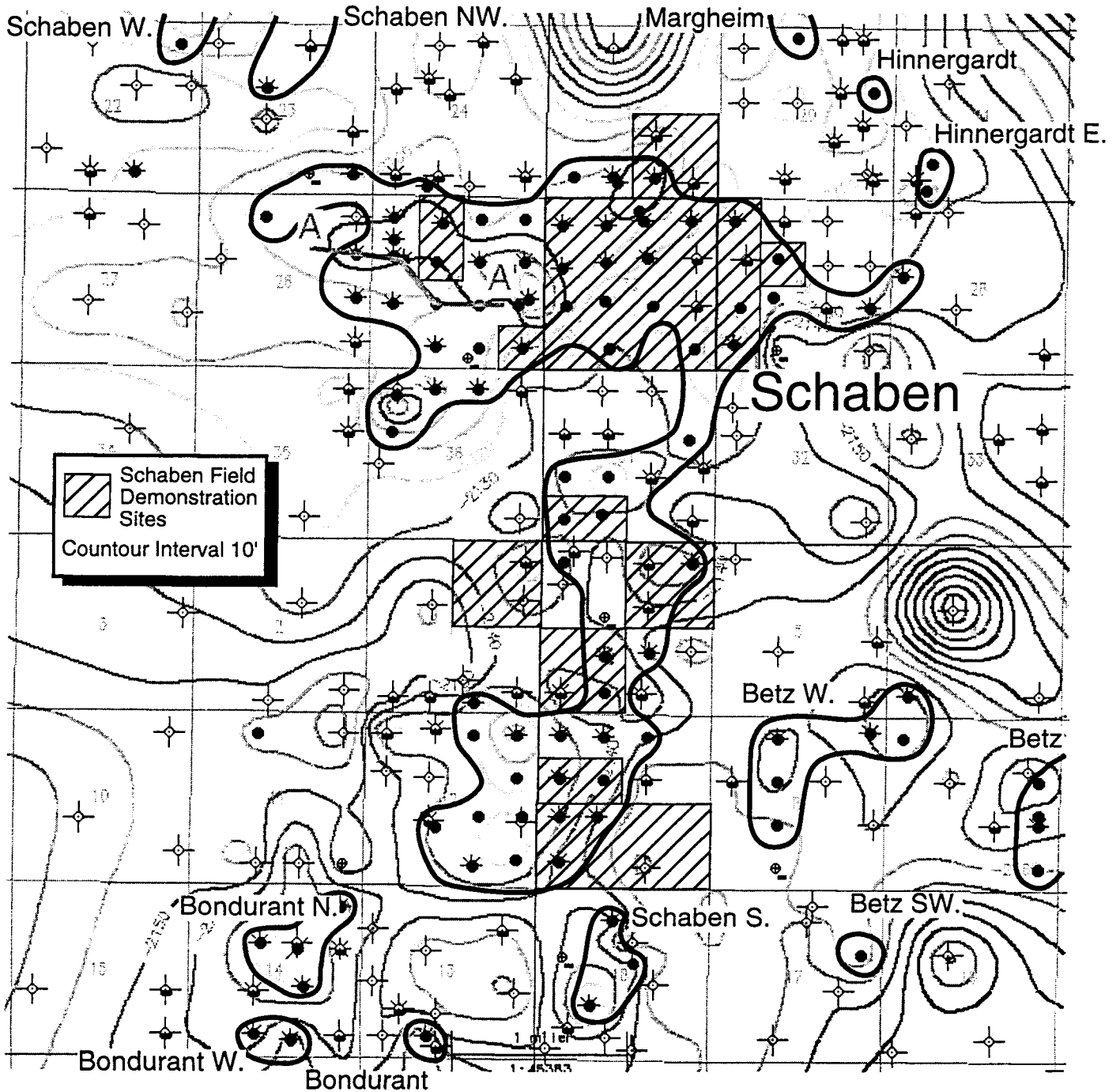


FIGURE 1. Schaben Field demonstration site with structure on top of the Mississippian Limestone. The Schaben Field outline and location of leases involved in demonstration are indicated.

Schaben Field Annual Production

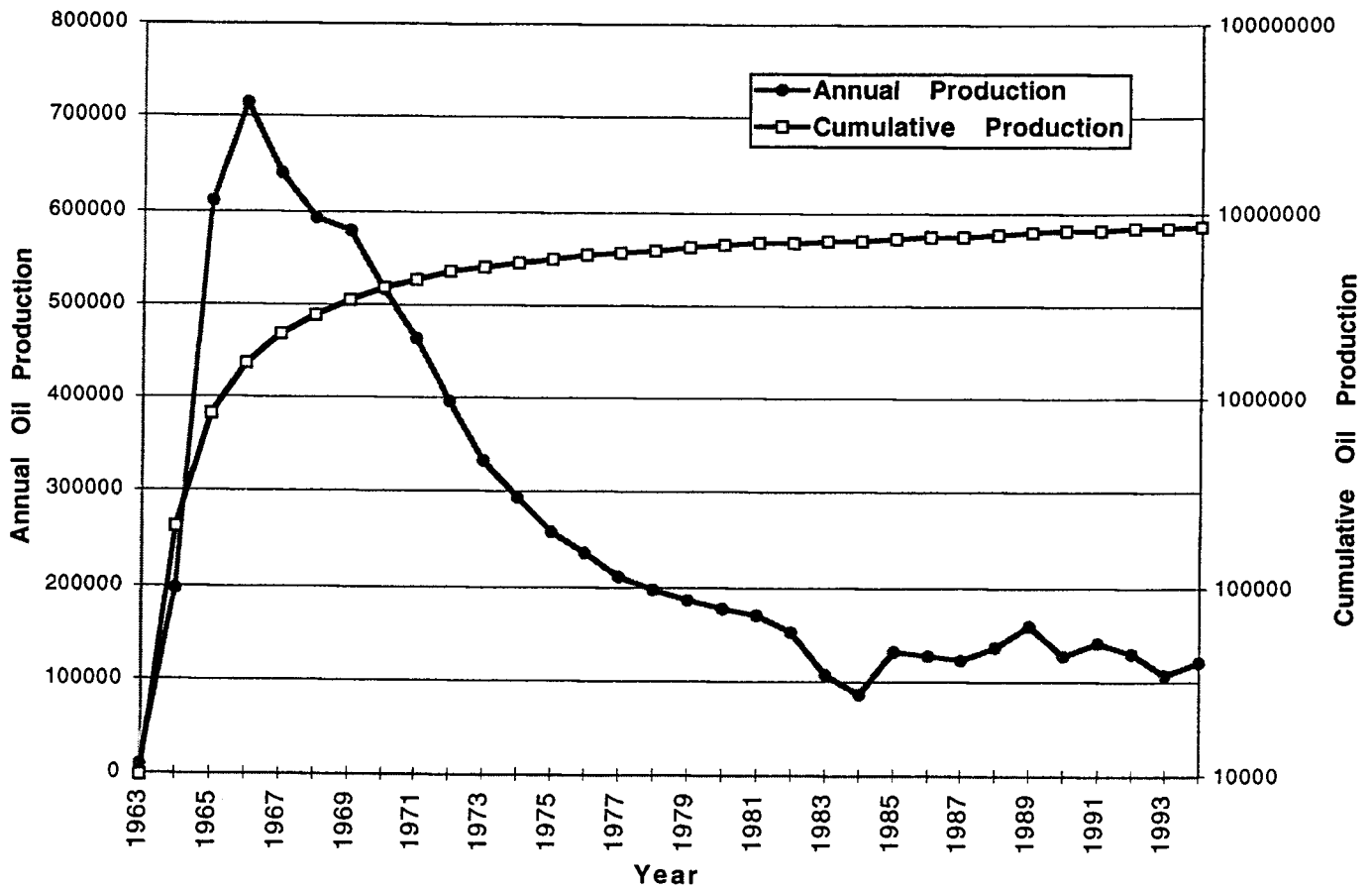


FIGURE 2. Annual and cumulative field production for the Schaben Field Ness County, Kansas.

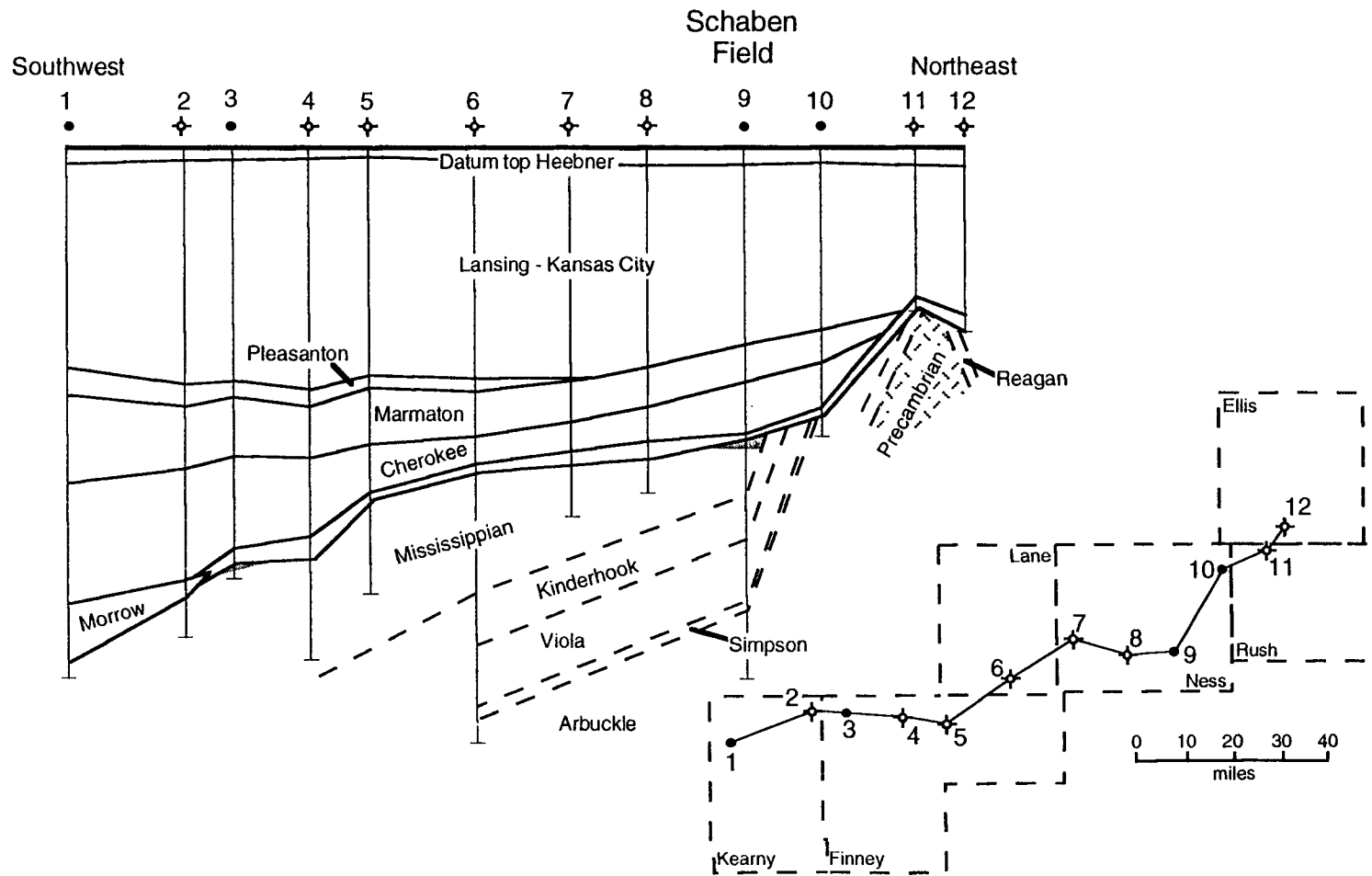


Figure 3. Regional southwest-northeast cross-section showing relation of Mississippian and older rocks to the pre-Pennsylvanian unconformity. Location of the Schaben Field demonstration site is indicated by the shaded area at the top of the Mississippian at well 9. Modified from Goebel and Merriam (1957).

Subcrop Map of Mississippian Rocks

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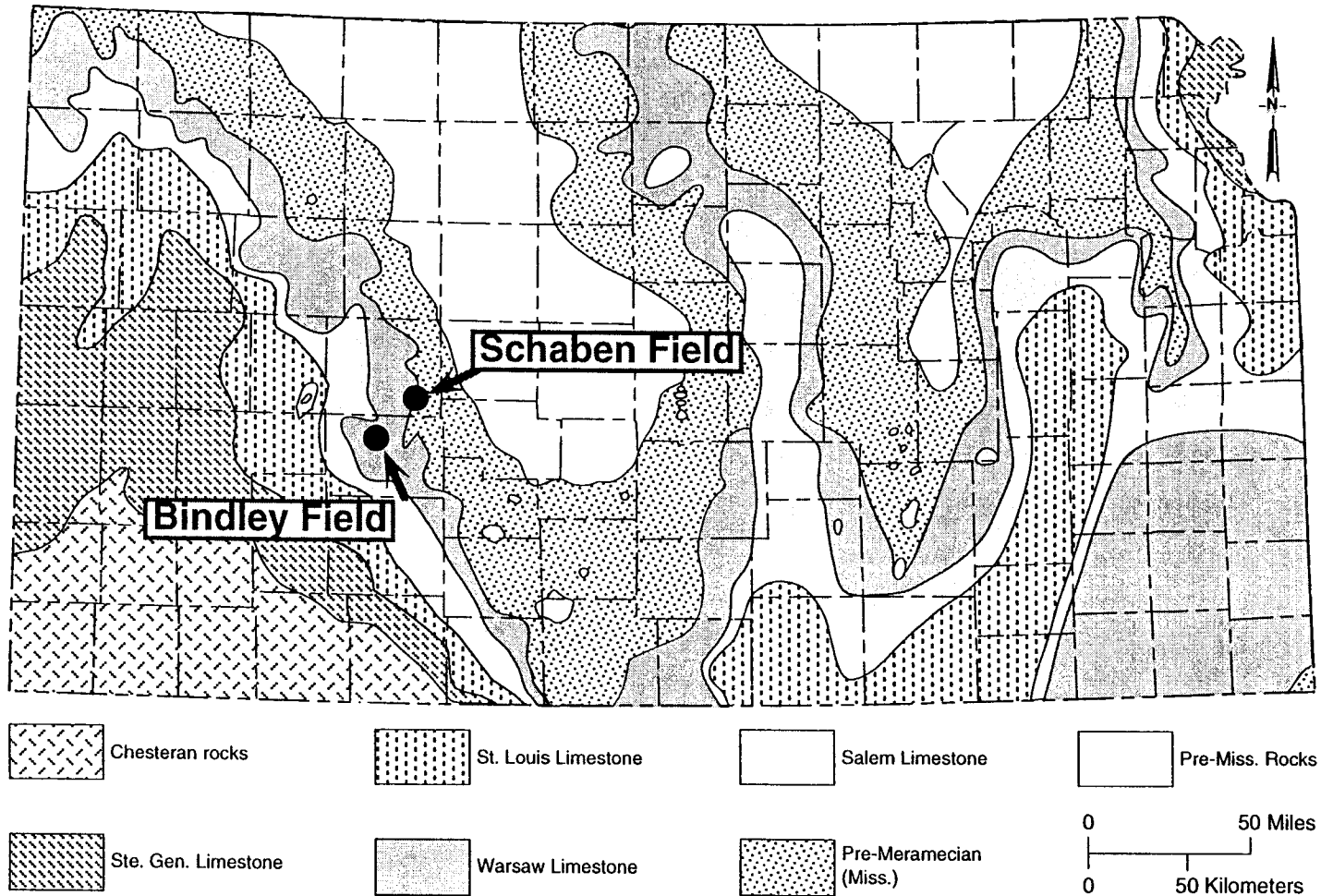
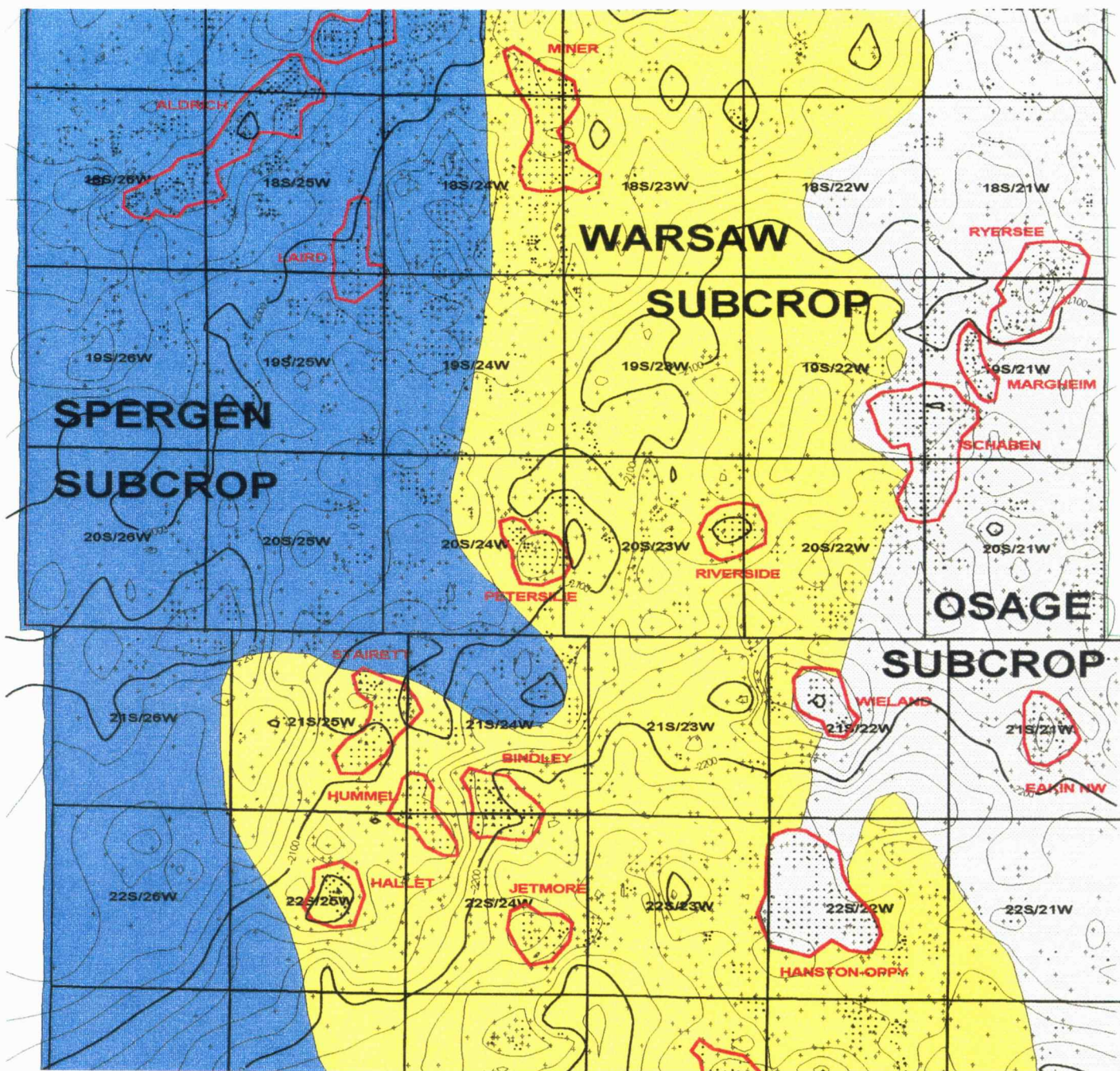


FIGURE 4. Mississippian subcrop map beneath the Pennsylvanian unconformity showing location of Schaben Field. Mississippian units beneath the unconformity become progressively older and are absent on the Central Kansas uplift.



SCHABEN FIELD		
Regional Geology Mississippian Structure Mississippian Subcrop		
Paul Gerlach		2/13/96
Scale 1:322932.19		

FIGURE 5. Mississippian subcrop map and structure on top of the Mississippian for Ness County Kansas. Field outlines for Mississippian production are shown. Schaben Field is located in the southeast corner of the county.

DISCUSSION

The general goal of the project is the application of existing recovery technologies to extend the economic life of selected fields producing from shallow shelf carbonate reservoirs, and the innovative dissemination of the data, methodologies, and results for the purpose of fostering wider application of demonstrated technologies to other fields. The specific goal is to identify areas of unrecovered mobile oil in Osagian and Meramecian (Mississippian) dolostone reservoirs in western Kansas through integrated, multi-disciplinary reservoir characterization, and the demonstration of incremental primary recovery through deepening and recompletion of existing wells and targeted infill drilling.

At the Schaben site, integrated, descriptive reservoir characterization will provide the basis for development of a descriptive reservoir model. Descriptive reservoir characterization will entail integration of existing data, drilling and coring up to four new wells through the reservoir interval. Descriptive core analysis, petrophysical and petrographic analysis, calibration of logs and core data, and integration of existing well data into a computerized three dimensional visualization/simulation will be used to develop a descriptive reservoir model for the Osagian and Meramecian rocks at the Schaben site. This model will be compared to the existing model at the Bindley site to provide a broad foundation of modern geologic and engineering analysis for demonstration of incremental primary recovery through deepening and recompletion of existing wells and targeted infill drilling in this major producing trend.

Advanced reservoir characterization at the Schaben site will be used to identify areas of uncontacted mobile oil, and to select optimal sites for infill drilling. Advanced reservoir characterization techniques will include high-resolution core description, petrophysical analysis of pore system attributes, geostatistical analysis of interwell heterogeneity, and reservoir simulation. Incremental reserves will be identified and demonstrated through targeted infill drilling.

Description of Project Work Accomplished

Acquisition and consolidation of geologic, digital log, and production data are complete and all data have been entered into a database management and analysis system. Data for 267 wells distributed of 36 sections in and surrounding the Schaben project area were collected,

Well Data Management		
Units Modify Create Delete Cancel Save Exit		
Well Name : #3 SCHNEIDER	Unique Well ID : 99000000790000	Viewing Well: 1 Active Wells: 1
Second Well ID :		Prev Next
General Well Data		
Operator : MOBILE OIL	Platform Name :	Well List
Lease : SCHNEIDER	Well No : #3	Clear List
Country : UNITED STATES OF AMERICA	Initial Class :	General
State : KANSAS	Final Class : oil	Elev & Depths
County : NESS	Current Class :	Curves
Field Name : Schaben	Formation At TD : Usagean	Picks
Location Data		
Area Name :	OCS# :	State/Federal : n/a
Survey :	Block : 22	Section : 12
	Abstract : 0	
Twn : 20	Twn Dir : S	Rge : 22
	Rge Dir : W	Spot : C SE NE
Loc. Desc. :		
Latitude : 038°19'45.41"N	X : 1656535.390000	
Longitude : 099°41'50.39"W	Y : 607597.420000	
Well Dates		
Spud Date : 4/22/64	Date Drilling Finished :	Rig Release Date :
Completion Date : 5/25/64	Date On Production :	
Shut-in Date :	Abandonment Date :	
Current Unit: Feet	Mode: Report	

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Figure 6.-- Sample screen from Schaben Field computer database of well data and logs. Additional data is accessed through buttons on left side of screen

edited and loaded into a computer database. Digital well logs for 209 of the 267 wells were obtained and loaded into the database. All digital data is available through a common computer database for use in construction geologic maps and cross-sections and reservoir analysis (Figure 6).

Log analyses, core analyses and descriptions are underway to better understand the pore geometry of the carbonate reservoir in the Schaben Field. All of the complexities existing in an evaluation of an extremely heterogeneous reservoir, are present in the producing reservoir in the Schaben Field. Determination of pore size, throat size, irreducible water saturation, permeability, effective porosity, and movable oil should be possible with the techniques being used in the Schaben Field project.

Summary of Drilling of New Wells

Two of three planned wells were drilled, cored, logged and tested to gather modern data for reservoir characterization. The well history for each of the two wells is summarized below.

Ritchie 4 Moore "B-P" Twin
NW NE Sec. 30-T19S-R21W
Ness County, Kansas

Spudded 4/25/95. Reached TD of 4450' (log) 5/5/95. Cored Pennsylvanian conglomerate-Mississippian limestone from 4370-82' and 4390-4443. Ran Halliburton Dual Introduction Laterolog Log before running 5 1/2" casing to 4452'. Ran BPB Neutron 2, sonic, and spectral logs through casing. Final perfs 4412-17' (top Mississippian 4385'). Last one hour swab test before running tubing recovered 14.2 barrels of fluid (23% oil). Current production is 265 barrels of fluid (3% oil) or 7.95 barrels of oil per day.

The core from the 4 Moore was analyzed from 4390.4-4399.4', 4410.3-4411.9, 4418.5-4442.8', and of 4443.2' for air and Klickenberg permeability, helium porosity, grain density, water saturation and oil saturation. Eight whole core samples were also analyzed. The core was slabbed, photographed, and described in detail. Thin sections have been made of selected reservoir lithologies. Six core plugs have been sent out for magnetic resonance and oil-brine capillary measurements. The core was measured on a 1/4 foot spacing for permeability attributes using a mini-permeameter.

Ritchie 1 Foos "A-P" Twin
NE SW SW Sec. 31-T19S-R21W
Ness County, Kansas

Spudded 8/4/95. Reached TD of 4445' (log) 8/12/95. Cored Mississippian limestone from 4387-4441.5'. Ran BPB Induction Shallow Focused, Neutron-Photo Density, sonic, micro-resistivity, and spectral logs. Ran drill stem test from 4412-24'. Recovered 160' very slightly oil specked water. Ran 5 1/2" casing to 4444'. Final perfs 4394-95.5' (top Mississippian 4388'). Last one hour swab test before running tubing recovered 25.46 barrels of fluid (8% oil). Current production is 508 barrels of fluid (1.5% oil) or 7.75 barrels of oil per day.

The core from the 1 Foos was analyzed from 4393.3-4431.6' for air and Klickenberg permeability, helium porosity, grain density, water saturation and oil saturation. Nine whole core samples were also analyzed. The core was slabbed, photographed, and described in detail. Thin sections are being made of selected reservoir lithologies. A few selected core plugs will be sent out for magnetic resonance and oil-brine capillary measurements. The core was measured on a 1/4 foot spacing for permeability attributes using a mini-permeameter.

Petrophysical Analysis (PfeFFER)

Petrophysical analysis and reservoir evaluation are making use of a new computer package (PfeFFER) that was developed in conjunction with this project. Prototype software was tested and successfully applied in Schaben Field, and grew out of the "Super-Pickett" crossplot that was initially developed and applied as part of other DOE funding (DOE/BC/14434-13). PfeFFER stands for "Petrofacies Evaluation of Formations for Engineering Reservoirs" (Doveton et al., 1995). PfeFFER v. 1 was released January 2, 1996 as a commercial spreadsheet-based well-log analysis program developed and distributed through the Kansas Geological Survey. PfeFFER v. 1 software was developed as a separate project with one year of additional funding provided by twelve major and small independent companies. Additional funding for development of an enhanced PfeFFER has been requested from industry and BDM. PfeFFER was designed as a means to obtain timely, inexpensive, but reliable and consistent reservoir characterization using the limited available information, staff, and technical resources (a major problem identified by independent producers).

PfEFFER is an interactive spreadsheet-based program that is designed to run as an add-in to Excel version 5.0 or later and is written in Visual Basic. The minimum logs required are a porosity log and a resistivity log. The focal point of the analytical routines and graphical displays is the "Super Pickett" crossplot, an extension of the standard log-log porosity/resistivity plot. The special features in this crossplot include: tracking the pattern of data points by depth, and annotation of the crossplot with bulk volume water and permeability lines in addition to the standard water saturation lines. Color is used in the data shown on the "Super Pickett" crossplot to display attributes such as well log data, completion information, and other derived data. Color ranges are automatically or manually selected to highlight and emphasize reservoir components, adding new perspectives to the reservoir. Proportions of complex lithologies can be solved with the "RU" option, Rhomaa Umaa plot, if neutron/density porosity and PEF logs are available. A variety of lithologies can be selected and easily changed through menu choices to modify the matrix coefficients. Explicit lithological information can be displayed as attributes on the Pickett crossplot or shown as compositional profiles keyed to depth. Lithology solutions can be presented as attribute colors on the crossplot or the information can be presented along with other depth-related information as a vertical depth display by activating the "LOG" button and corresponding dialog boxes and menus. Log traces can be combined on single or multiple tracks. Additional details can be found in Doveton et al. (1995, 1996).

Well log analyses of the Schaben Field uses the PfEFFER Version 1.0 computer program. Logging suites in the Schaben Field are as diverse as the reservoir. There are about 41 wells that have only the Microlateralog to use in determining porosity, 46 wells have only the uncalibrated neutron for determining porosity, 56 wells with sonic porosity logs, and 23 wells with a combination density neutron porosity. Using the PfEFFER program, we have been able to determine reservoir parameters that are reasonably accurate and comparable, no matter which porosity tools were run. Petrophysical results indicate that the reservoir is highly stratified vertically, of variable lithology (limestone, dolomite, and chert), and has high BVW (Bulk Volume Water). Examples of PfEFFER plots and preliminary petrophysical interpretations for the new wells drilled as part of the project are attached (Appendices A & B). The petrophysical results from the PfEFFER analyses are being tied into advanced core analysis (for example, Minipermeability, Capillary Pressure and NMR).

Pseudoseismic Analysis

Additional petrophysical/seismic procedures have been developed to modify, load, and display well log data from Schaben Field as a 3D "pseudoseismic" volume (figures 7 - 9). The pseudoseismic volume can be displayed and interpreted on a commercial geophysical workstation. At Schaben the "pseudoseismic" approach is used to recognize and map previously unknown small faults and subtle stratigraphic heterogeneities within the reservoir units. All these techniques adapt technologies and leverage previously existing data. The pseudoseismic approach developed at Schaben has been presented and published as a newsletter (Carr et al. 1995b). Future plans call for presentation at several technical conferences (see attached abstracts in Appendix C) during the first half of 1996 and for formal publication in the last half of the year (Gulf Coast SEPM Proceedings). Numerous producing companies have inquired concerning software and assistance in using the 3D pseudoseismic approach in their projects.

Genesis of a seismic approach to wireline logs arose from efforts to use the computer workstation to integrate geologic and geophysical approaches to subsurface analysis, and the challenge of trying to apply computer-aided exploration and development techniques to mature producing areas that are dominated by well data such as the Schaben demonstration site. Wireline well logs resemble seismic traces in many respects. Fundamentally, both wireline log data and seismic data are simple x-y series. The wireline log records amplitude in the depth domain, and the seismic trace records amplitude in the time domain. Wireline well logging tools record various rock properties and output these data as a depth series. Ultimately, the goal of seismic processing is to approach on a trace-by-trace basis the resolution of geophysical well logs. If wireline logs can be transformed to more closely resemble the seismic trace one can interpret wireline logs within existing seismic interpretation software. This change in approach is labeled *pseudoseismic*. The pseudoseismic approach significantly increases the scope, power, and resolution of the interpretation.

In a series of papers during the 1980's John Doveton and Dave Collins of the Kansas Geological Survey proposed a color image transformation that achieves a significant improvement in the stratigraphic interpretation of wireline log data (Collins and Doveton, 1986, 1989). When well designed, such a transformation of wireline log data from multiple wells can maximize both spatial and compositional information contents, and

provide a readily interpretable image of the subsurface geology. They introduced the concept of a color cube subdivided into a series of discrete cells to represent the log data. The planes between cells were selected to coincide with coordinate values that discriminate between lithologies, porosity levels, or shale mineralogy. The transformation operates as an automatic classification device that provides visual meaning. The color image transformation was used to construct single well displays and a single cross-section across western Kansas. The cross-section was constructed on a well-by-well basis, and resembles in many ways a standard 2D seismic display (See: Doveton, 1994, p. 43).

The pseudoseismic approach uses a similar transform of a single curve or combination from multiple tools (e.g., gamma ray, density and neutron) to generate a color coded "crossplot log" for each well as the single trace input to the pseudo-seismic approach. The key is to take the transformed log data and treat it as either 2D or 3D "seismic" data. The actual conversion of digitized well data to pseudo-seismic data is accomplished by a conversion program to transform wire-line or transformed wireline log data into a binary SEG Y file.

LAS and SEG Y formats are "standard" formats for digital well log and seismic data, respectively. SEG Y was designed primarily as a format for recording and processing seismic data. This format consists of a 3600 byte reel header containing general information about the seismic line or survey. The first 3200 bytes of the SEG Y reel header are in ASCII and the remaining 400 bytes are binary. Following the reel header are the binary trace data. Each trace also has its own header (240 bytes binary) and is followed by the seismic trace data (Barry, Cavers, and Kneale, 1975). The data are arranged serially. A common starting point (the seismic datum) and time increment (sample interval) are assigned to all traces. The data appear as a listing of numbers, time increasing at an equal interval from left to right across rows and downwards between rows. The data one encounters within a seismic trace are normally seismic reflection amplitudes, or, loosely, waves.

LAS formatted well log data contrast strongly in appearance with SEG Y seismic data. LAS was developed to insure that there was a standard digital well log format that anyone with a computer could read (Canadian Well Logging Society's LAS Committee, 1993). The entire well log data set is in ASCII and can be opened like any ASCII file. The data structure is relatively straight forward. The well header contains LAS version, general well, logging parameter, and curve information. The curve data following the header is set

up much like a spread sheet. Depth values appear in the far left column followed by one or more data points for that depth, corresponding to the various well logging tools run in that well.

The pseudo-seismic transform "maps" LAS header and curve data onto corresponding SEGY data fields creating a file formatted like seismic reflection data. Coding of the pseudo-seismic transform uses a "C" program (pers. comm. Alan Feltz of the Kansas Geological Survey). The transform reads LAS files containing one curve (depth-value pairs) plus the well header. For instance, if it was desired to transform neutron-porosity readings from LAS to SEGY, files must exist which contain only the well log header and depth-porosity pairs. It is also required that all the digital well logs have the same sample interval. The transform program reads the LAS files, writes portions of the curve header to specific locations in the SEGY trace header, and writes the log data to the SEGY trace data field (Table 1). Data from the well header that are used in the trace header are location (X, Y or latitude and longitude) and kelly bushing elevation. Many of the fields in the reel and trace headers are filled with null values because they have little relevance to well log data. For instance, there are SEGY fields set aside for filter parameters and vibrator sweep characteristics. Data handling and loading are made somewhat easier by using SEGY data fields in the standard manner.

The pseudo-seismic transform combines data from many individual wells and creates a 2-D or 3-D data set. In doing so, the program also assigns a datum for the data set (the largest K. B. value), pads the tops and bottoms of well logs to ensure the "traces" are of equal length and writes this information to a binary SEGY file. Trace spacing is determined from well spacing based on the nearest neighbors to an arbitrary spacing unit (e.g., an 80 acre bin or a 330 foot spacing). Transformation of well locations to trace spacing can be computed rounding to the nearest whole spacing unit or bin. Areas without wells can be represented by empty bins or blank traces. The net result is that the SEGY file contains a structural volume created from geophysical well logs.

After the transform, the ASCII well log data looks like a binary seismic data set. This allows the data set to be loaded into a seismic workstation for display, manipulation, and interpretation purposes. It also facilitates the compiling of very large digital well log data bases, which eases data handling burdens. For example, a cross-section containing 300 gamma-ray traces (one well per mile) was constructed for a project at the Kansas Geological Survey (Figure 7). If this cross-section had been constructed using 4 inch wide

paper logs, at a scale of 4 inches per mile, the section would have been a 100 feet long. A section of this monumental proportions would be unwieldy and impractical. However, as a pseudo-seismic line it contains only 300 traces, about as many traces as a 3 mile seismic reflection line shot with 55 foot C. D. P. spacing, and is readily manipulated or interpreted.

Using a seismic approach to well data can significantly ease the data handling burdens through use of computerized techniques designed for interpretation and display of seismic data. The use of interpretation and processing packages developed for seismic data offers flexibility in displaying and picking horizons, and opens new opportunities for increasing the efficiency of stratigraphic interpretation. The change in approach from the traditional well-by-well examination to treating the wireline logs in a field or basin as a data volume permits comprehensive study and cost-effective analysis of data sets that were previously considered intractable.

The examples from the Schaben demonstration site uses gamma ray logs to map small faults and subtle stratigraphic geometries in the Pennsylvanian rocks overlying the Mississippian reservoirs. Data was "binned" at a 40 acre spacing resulting in a volume that covers approximately six square miles with a trace every 1330 feet (Figure 8). The "hot" Pennsylvanian core shale make excellent markers that can be traced using the gamma-ray log across the demonstration site (Figure 9). The pseudoseismic technique is being used to map these small faults.

WELL LOG HEADER & OTHER INFORMATION	SEGY BYTE NUMBERS FOR REEL HEADER	DESCRIPTION
1	3213-3214	Number of traces per record, always 1 for curve data
1000, 2000, ...	3217-3218	Sample interval in feet *1000
XXX	3221-3222	Number of samples per curve
1	3225-3226	Data format: 4 byte floating point
1	3227-3228	Number of traces per record or C. D. P.
1 or 2 ...	3255-3256	Measurement system: 1 = metres 2 = feet
WELL HEADER & OTHER INFORMATION	SEGY BYTE NUMBERS IN TRACE HEADER	DESCRIPTION
1, 2, 3, ...	1-4	Trace sequence number, numbers increase for each curve.
K. B. elevation	41-44	Elevation of well, used to place wells in correct relative vertical position.
Max K. B. elevation	53-56	elevation used as datum
X coordinate or Longitude	81-84	Survey coordinates
Y coordinate or Latitude	85-88	Survey coordinates
1 or 2	89-90	Coordinate units: 1 = length (metres or feet) 2 = seconds of arc
XXX	115-116	Maximum number of samples
1000, 2000 ...	117-118	Sample interval in feet *1000

Table 1: Data field and header information and the corresponding SEG Y reel and trace header byte numbers. Not all SEG Y fields are used in the transform. The unused fields are filled with null values.

Figure 7.-- Following page. Pseudoseismic profile of gamma-ray logs detailing the regional stratigraphic geometries across western Kansas. This profile was constructed using gamma-ray logs from over 200 wells and mimics in part the east-west regional cross-section constructed on a well-by-well basis by Collins and Doveton (1989). The Permian Stone Corral Formation is used as a stratigraphic datum (yellow horizon). The pseudoseismic profile shows the stratigraphic geometries, especially truncation across western Kansas of Permian units (red and orange horizons) and the Jurassic unit (purple horizon) against the Cretaceous unconformity (green horizon). Individual beds can be correlated between wells and across 10's of miles. Individual traces are at 1 mile spacings and logs are sampled a 1 foot verical intervals.

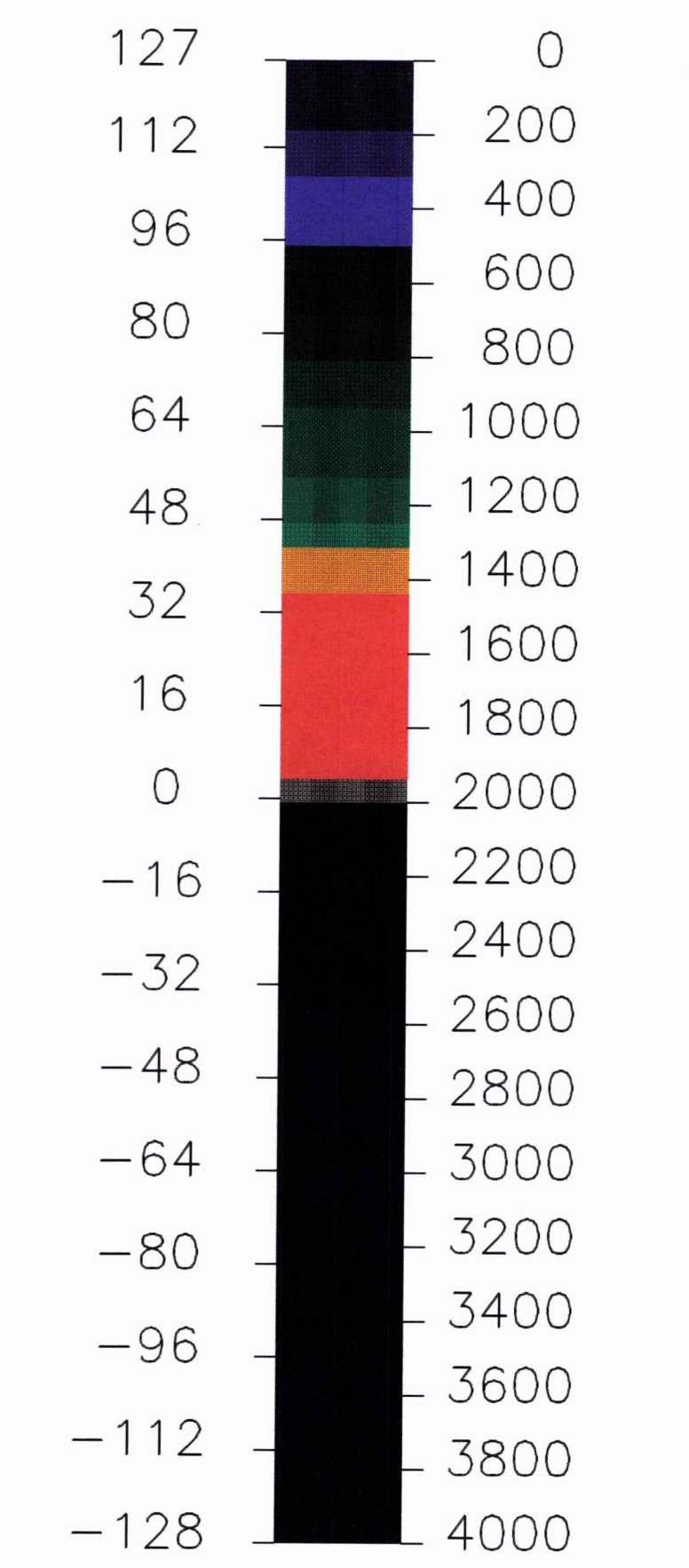
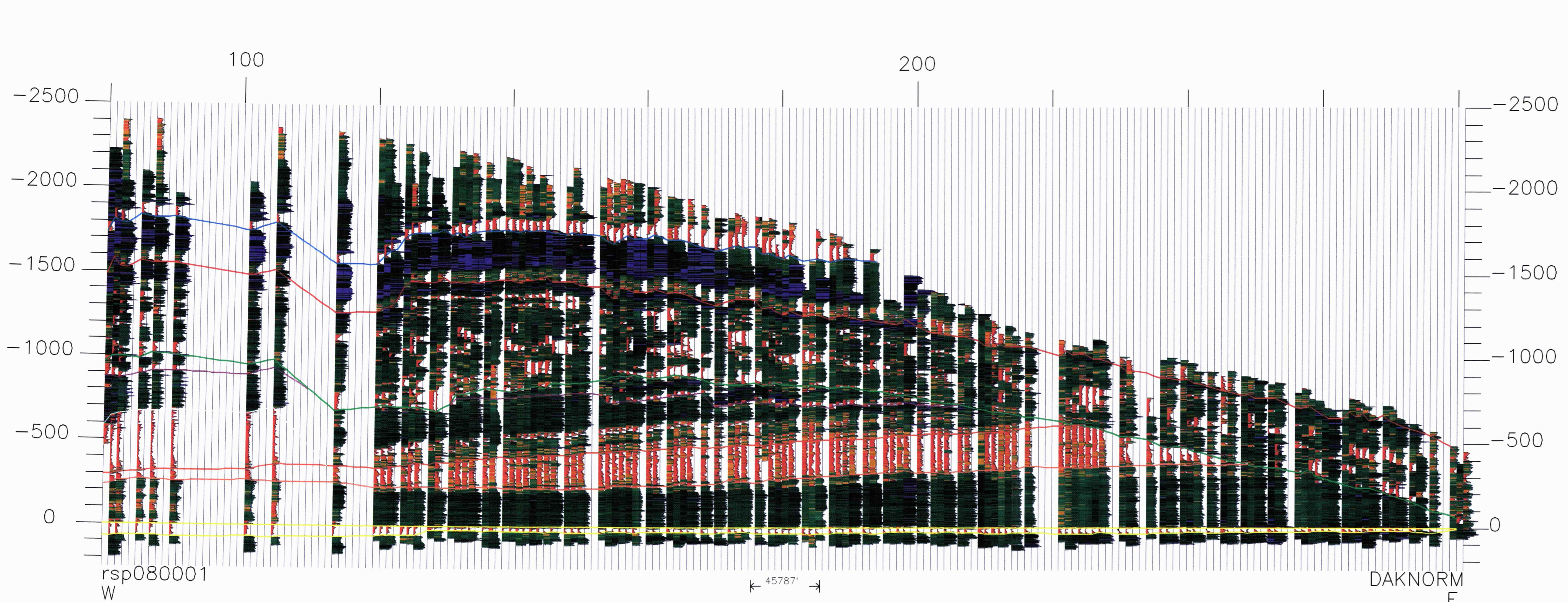


Figure 8.-- Following page. A group of four east-west pseudoseismic profiles of gamma-ray across Schaben Field. These individual profiles was extracted from the Schaben demonstration site 3D volume. Volume contains data from over 200 wells and is "binned" at forty-acre spacings. Note consistent east to west offset of shale markers on all four profiles across the demonstration site.

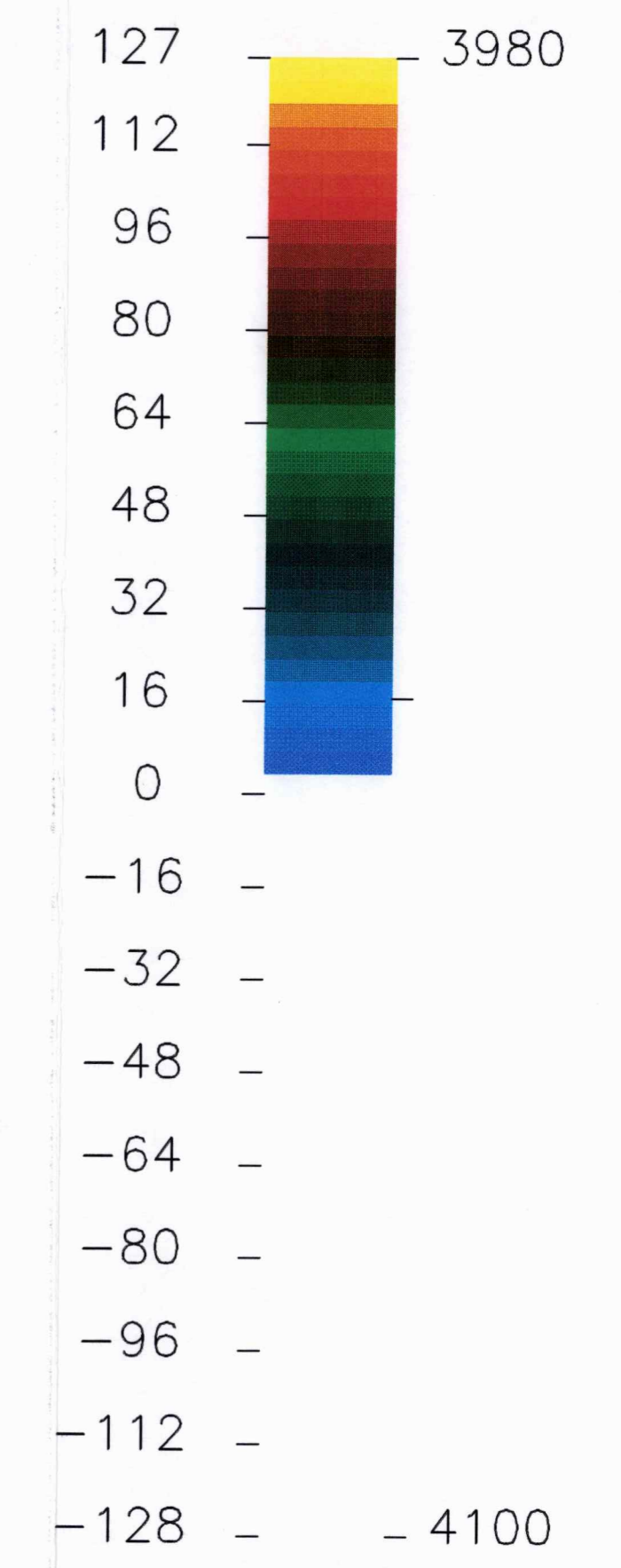
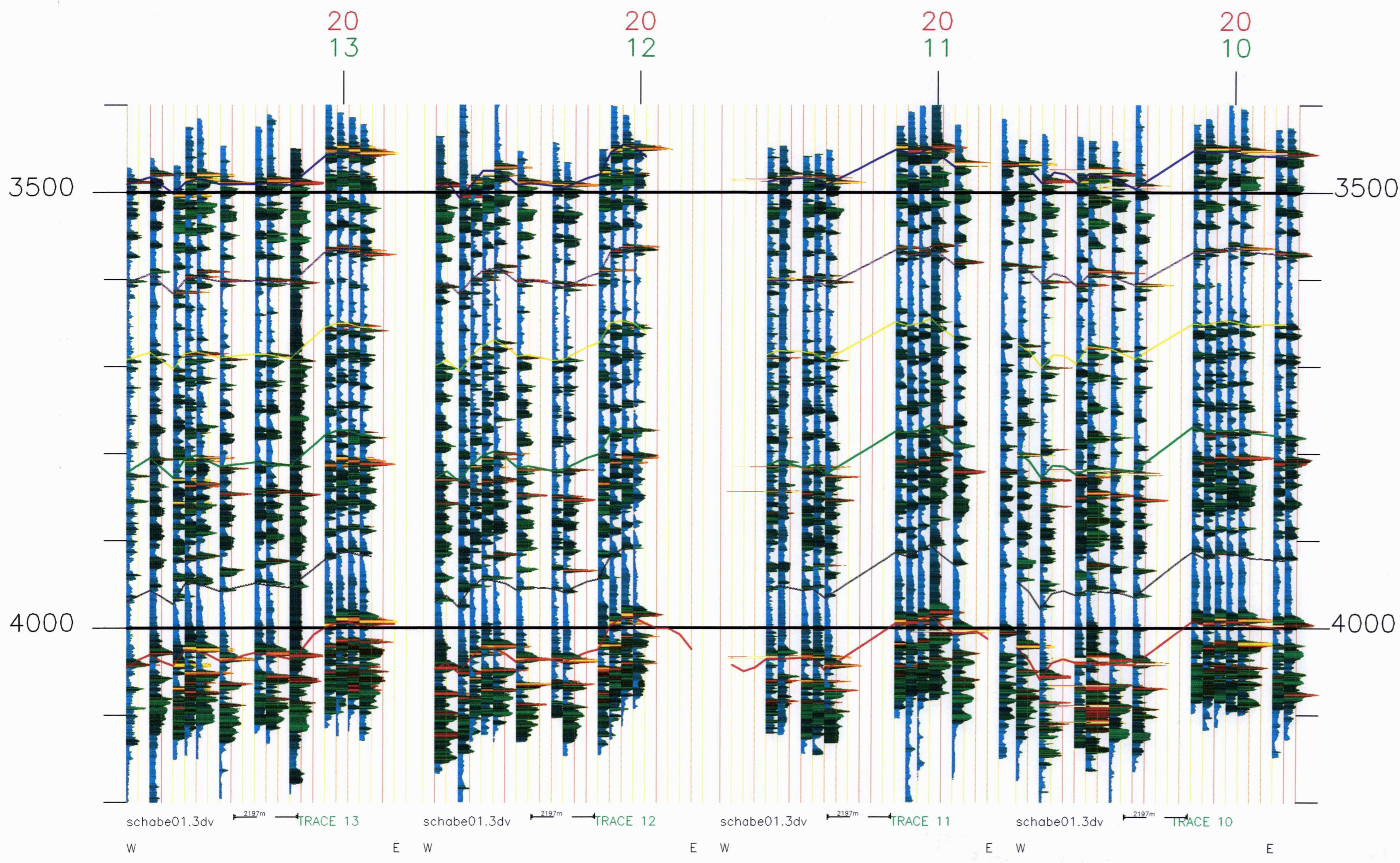
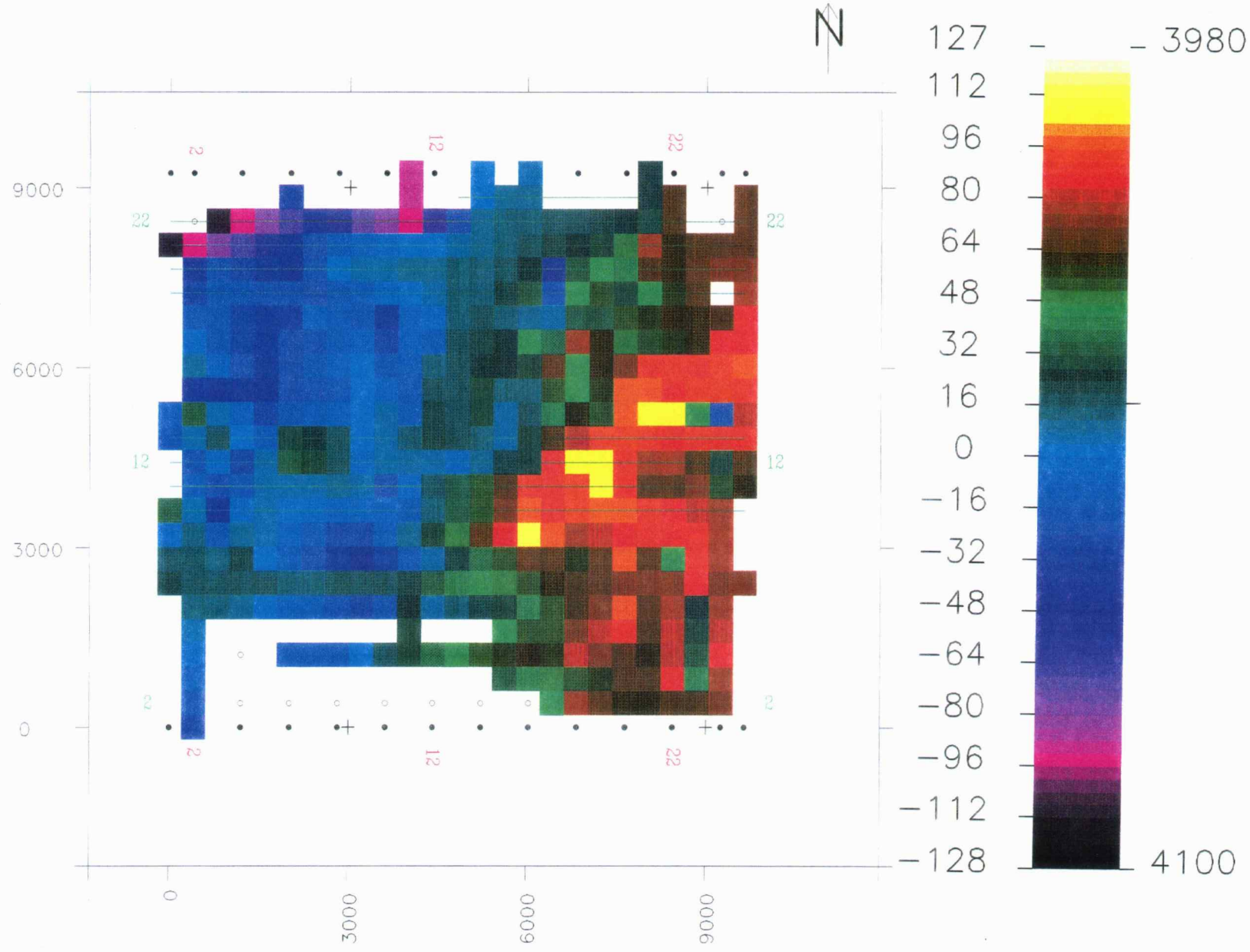


Figure 9.-- Following page. Map of selected pseudoseismic surface (Bethany Falls) from the Schaben demonstration site 3D *pseudoseismic* volume. Note uplifted wedge shaped block on east side of demonstration site. Hotter colors represent higher subsea depths.



Initial Results of Core Analysis

Two cores from Ness County have been described in detail to determine original depositional facies, visible diagenetic features including porosity types and features associated with karst overprinting. Approximately 30 samples from each core were selected for thin section preparation for petrographic examination. In addition, minipermeameter measurements were collected at an interval spacing of 0.25 feet to determine vertical variation in permeability. These variations in permeability are being related to variations in lithologic features.

One core (#1 Foos AP Twin: Sect. 31, T.19S, R.21W) is approximately 53' long (~4387' - ~4440') extending downward from the top of the Mississippian(?). The other core (Ritchie Moore #4 BP Twin: Sect. 30, T.19S, R.21W) is approximately 80' long (~4370' - ~4450') extending downward from the top of the Mississippian.

Description of Facies

Although the rocks in the core have been extensively altered in areas by fracturing and brecciation associated with karst and locally by diagenetic processes including dolomitization and chert and chalcedony replacement, some original depositional facies were discernible.

Dolomite and/or lime mudstone-wackestone.--This facies is typically light gray to olive green in color; locally dark gray to brown. Locally it is massive but more commonly is laminated, or wavy to wispy laminated. Laminations are imparted locally by interbedded green shale-siltstone and by horsetail stylolites. A mottled texture occurs locally due to burrowing, microscopic fracturing, or a combination of both. Other features include rare soft sediment deformation. Identifiable skeletal grains are rare; sponge spicules and their molds are locally identifiable. This facies is typically very tight with rare moldic, intercrystalline, and vuggy porosity locally developed. This facies is particularly abundant and tight in the #1 Foos AP Twin core where it occurs predominantly as a lime mudstone or dolomitic lime mudstone.

Dolomitic wackestone-packstone.--This facies is the most abundant depositional facies in both cores. It is characteristically tan to dark brown in color and typically has a wispy

laminated or somewhat mottled texture; locally it has a massive texture. Rarely, horizontal to low-angle laminations are preserved. Skeletal grains (locally preserved as molds or by silica replacement) include echinoderm fragments, bryozoans, sponge spicules, brachiopod fragments, and other unidentifiable skeletal fragments. Very fine to fine grained detrital quartz grains occur locally. This facies is typically the most porous of the original depositional facies. Oil staining occurs most commonly in this facies (Figure 9). Common porosity types include moldic, intercrystalline, and vuggy porosity. Locally, interbedded skeletal rich layers (more porous) and skeletal poor layers (tighter) result in an alternating porous and tight layering within this facies.

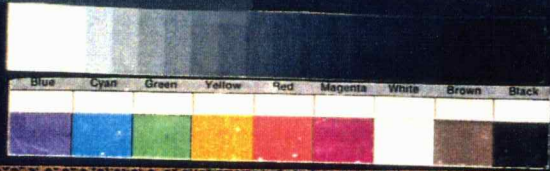
Packstone-grainstone.--This facies is preserved by pervasive chert and chalcedony replacement of original textures and grains. In the absence of chert preserving this facies, original texture may have been similar to that for the above described dolomitic wackestone-packstone facies. This facies is dominated by skeletal grains, which include echinoderm fragments, sponge spicules, bryozoan fragments, brachiopods, and other skeletal debris. Horizontal laminations and low-angle cross laminations are locally preserved. Some intervals show sorting of grains into fine grained layers and coarser-grained layers. Other intervals show possible normal grading of grains. This facies is typically very tight. Only locally are vugs developed. These vugs range from mostly open to partially or fully occluded by silica cement. Likely early developed fenestral and vuggy porosity, now completely filled with silica cement (locally with early geopetal fill), was identified in this facies in several locations.

Discussion of Depositional Facies Trends

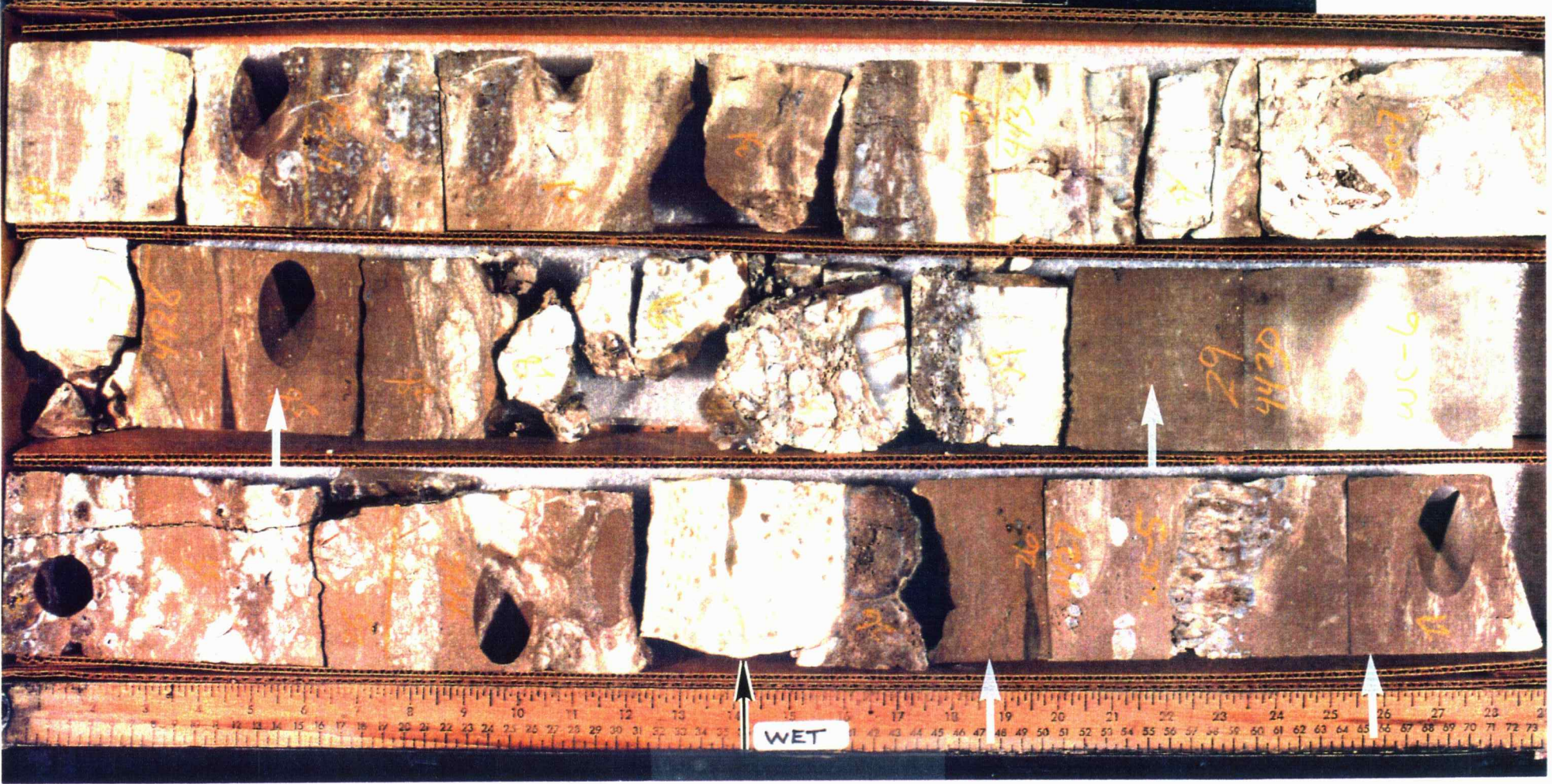
A general upward facies pattern is repeated several times in both cores with finer grained facies (dolo(lime) mudstone/wackestone) at the base going to coarser grained facies (dolowackestone-packstone and locally packstone-grainstone facies) at the top. This coarsening upward typically occurs on the scale of less than 1 meter to over 5 meters. This pattern appears to reflect cyclic development. However, due to the incomplete preservation of these facies and karstic overprints, determining if real cycles exist is problematic. Several of the coarsening upward trends are capped by chert preserved packstone-grainstone facies with fenestral fabric likely indicating subaerial exposure on top of a shoaling upward unit. Some chert nodules and layers (see below) in dolomitic mudstone wackestone or dolomitic wackestone-packstone immediately underlying the fenestral packstone-grainstone facies are likely the result of replacement of original evaporite

Figure 10.-- Folowing page. Photograph of a section of the #4 Moore BP Twin (4425' to 4432'). White arrows indicate dolomitic wackestone-packstone facies horizons that are oil stained. The black arrow indicates a horizon of packstone-grainstone facies, characterized by pervasive chert and chalcedony replacement of original textures and grains, that caps the dolomitic wackestone-packstone. This is a characteristic upwards facies change (occurring on a scale of less than 1 meter to over 5 meters) that is repeated several times in both cores. These repeated facies changes likely have implications for internal reservoir characteristics of these strata. Fracturing and brecciation of facies, likely karst associated, occur at several horizons in the core (e.g. ~4428'9"; ~4432'7"). The best production is likely to occur where favorable karst features (open fracture systems or fractures and breccias with relatively homogeneous and coarse-grained matrix) intersect the wackestone-packstone reservoir units.

RITCHIE EXPL. - #4 MOORE BP TWIN
Sec. 30 T. 19s R. 21w
NESS CO., KANSAS



4425 TO 4432
Box 6 of 9



DE-FC22-93BC14987

WET

minerals and are supportive of a shallow water setting and exposure as indicated by the fenestral fabric. These repetitive facies relationships have implications for reservoir characteristics of these strata in both cores (discussed later).

Description of Facies Other Lithologies and Features

Chert/Chalcedony.--Chert is abundant throughout both cores. One type of chert occurs either as pervasive replacement of whole layers, typically preserving original fabrics (e.g. packstone-grainstone facies) or as isolated replacement blebs or patches within other facies that commonly imparts a mottled texture. This chert is typically very light (white-gray) in color and very tight, except for isolated vugs. Where the chert replaces whole facies, it likely forms impermeable layers that could be important barriers between reservoir flow units.

The other type of chert/chalcedony occurs as nodules. These types of nodules are darker gray in color and have more associated vuggy porosity. The nodules occur either as isolated nodules, horizontal layers of isolated or laterally coalescing nodules, or as horizontal layers of vertically elongate nodules. These nodules are interpreted to represent replacement of original evaporite minerals. Some of these nodules preserve a bladed or radiating bladed crystal morphology when viewed with a petrographic microscope, further indicating replacement of an original evaporite mineral. The morphology and alignment of the nodules likely indicates formation in a subaqueous setting at or just below the sediment/water interface (Warren, 1989).

Siltstone/shale.--This facies is typically green to gray in color. It is wavy to wispy laminated and locally displays low-angle lamination. This facies occurs as late stage fracture (and cave?) fill associated with karst fracturing and brecciation.

Karst.--Fracturing and brecciation features associated with the karst event at the top of the Mississippian are complex and ubiquitous throughout both cores. Fracturing and brecciation results in fracture and mosaic breccias, with little to no rotation on clasts (indicating in-situ brecciation), and matrix-supported and clast-supported chaotic breccias, which represent mixtures of autochthonous and allochthonous materials resedimented by gravitationally driven processes.

Fracturing and brecciation occurs on a macroscopic and microscopic scale. Fracture filling material and breccia matrix includes shale, siltstone, carbonate mudstone, and only locally, some dark gray to black shale. Grains and clasts (ranging from rounded to angular) include chert/chalcedony fragments, detrital quartz, individual skeletal fragments, clasts of original carbonate facies, and locally (mostly near the upper Mississippian unconformity) rubble of red and greenish limy clay with some features likely indicative of soil development. Porosity associated with fracturing and brecciation is quite variable, ranging from tight to very porous, and depends on amount of fracturing and brecciation, “openness” of fractures, types and grain size of fracture fill, and types and grain size of breccia clasts and matrix.

Comparison of Minipermeameter Measurements With Facies and Karst Features

In order to analyze the degree of vertical stratification present in Schaben Field, permeability values were measured in two cores using a portable field permeameter (minipermeameter). The values obtained using the minipermeameter were compared with permeability analyses of plugs taken from the core at the same interval. Core plug measurements were collected at an interval spacing of approximately 1.0 foot whereas the minipermeameter measurements were collected at an interval spacing of 0.25 feet (3 inches). Because a larger volume of the rock was tested, core plug permeability values were thought to be more accurate than minipermeameter results. Regression analysis allowed us to establish a correlation line between the minipermeameter and core plug permeability results and minipermeameter values were corrected to the equation of this line.

Vertical profiles of minipermeameter and core plug permeability values from the reservoir interval of the Ritchie Exploration, #1 Foos AP Twin are shown in Figure 10. The minipermeameter profile demonstrates that a high degree of vertical stratification is present in the reservoir interval. Comparison of the minipermeameter profile to the core plug profile indicates that core plug permeability values were sampled at a spacing insufficient for representing the vertical stratification present in the Mississippian reservoir at Schaben Field. The same type of vertical stratification of flow units is present in the reservoir interval of the Ritchie Exploration, #4 Moore BP Twin (Figure 11).

A plot of minipermeameter values, simplified depiction's of facies and karst features as related to these values and locations of oil staining is shown for the Ritchie Exploration, #1 Foos AP Twin (Figure 12).

The Foos core shows that there is a striking amount of vertical variation that has evident implications for internal reservoir heterogeneity and compartmentalization (note for the Moore core that there are more missing intervals or rubble zones but the same variations occur). Although some of the fractured and brecciated areas locally show relatively high permeabilities, in both cores the dolomitic wackestone-packstone facies (commonly lacking macroscopic evidence of much, if any, karstic overprint) was consistently observed to have the highest permeabilities. Well developed oil staining also appears to be associated with this facies (Figure 12). The lowest permeability readings are associated with chert or the dolomite and/or lime mudstone-wackestone facies. Not surprisingly, fractured and brecciated areas show quite a variation in permeability measurements, likely due to the heterogeneous nature of the fracture fills and breccia matrix, as well as to the size of fractures, and tightness versus openness of the fracture systems. This emphasizes that not all karst related features are conducive to favorable reservoir development and production conditions.

Based on the core observations coarsening, upward trends appear to be potential important factors in internal reservoir compartmentalization within the Schaben reservoir (Figure 12). At several horizons in both cores, the upward trend from mudstone-wackestone to wackestone-packstone to packstone-grainstone is nicely illustrated (e.g. from ~4434' to ~4431', from ~4422.5' to ~4420', and from ~4408' to ~4403' in the Foos core; from ~4437' to ~4434', and ~4425' to ~4422.5" in the Moore core). In these locations, the more porous and permeable wackestone-packstone facies (commonly oil stained) is underlain by relatively non-porous and non-permeable mudstone facies and overlain by the packstone-grainstone facies (pervasively replaced by chert) which is also nonporous and impermeable. Several other intervals in both cores show similar facies trends but are missing the underlying tight mudstone-wackestone or overlying chertified packstone-grainstone (either they weren't deposited, or they are masked or were removed by karst processes). Depending on lateral extent of each of these units, the wackestone-packstone intervals have good potential as individual, or a group of several, compartmentalized reservoir units. The best production results are likely to occur where favorable karst features (open fracture systems or fractures and breccias with relatively homogeneous and coarse-grained matrix) intersect these wackestone-packstone reservoir units or compartments.

A final feature to note is that the permeability measurements for the Moore core are consistently much lower than the measurements for the Foos core, even though similar facies and karst features occur and were measured in both cores. The reasons for the significant difference in values is currently poorly understood. Speculatively, some of the difference may be attributed to less dolomitization of facies, more silt and clay in the fractures and breccia matrix, and possibly more late stage cementation in the Moore core. Interestingly, at first inspection, the wackestone-packstone facies (which shows the highest permeability values for both cores) looks very similar for both cores, but the permeability measurements in the Moore core are generally lower than in the Foos core. This may be attributable to differences in original lime mudstone content, amount, type and interconnectability of skeletal molds, amount of dolomitization, amount and interconnectability of intercrystalline porosity, and amount of later stage dissolution and cementation. Initial petrographic studies show that the dolomite in the wackestone-packstone facies of the Moore core is very finely crystalline to micrite size. Dolomite crystals are euhedral to anhedral. Textures range from tightly packed with no intercrystalline porosity to looser packed with moderate amounts of intercrystalline porosity. Moldic porosity is variable throughout. This wide range in textures and porosity sometimes occurs within the same thin section. Future studies will aim at gaining a better understanding for the differences in permeability measurements between the two cores.

Ritchie Exploration, #1 Foos AP Twin

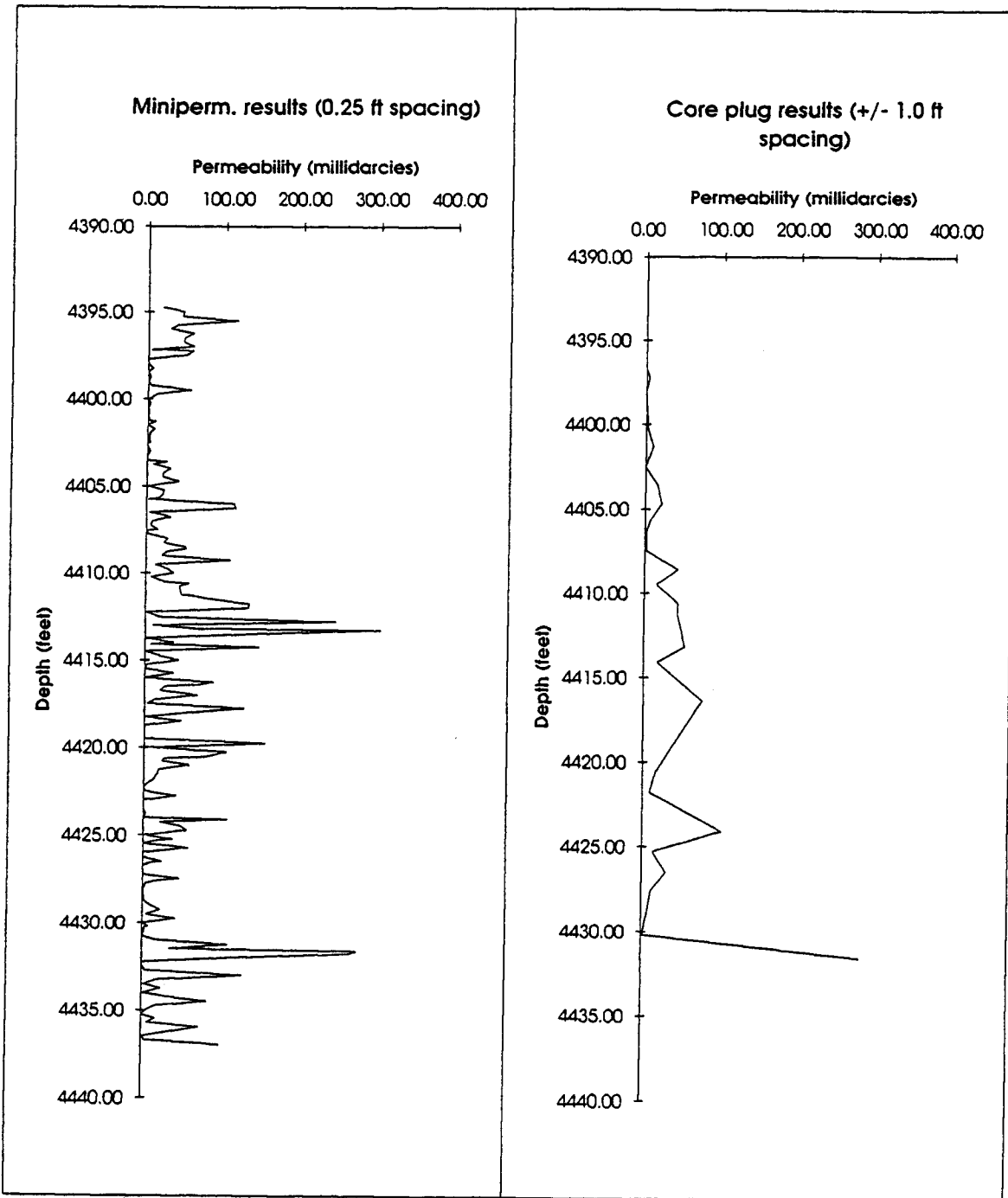


Figure 11.-- Vertical profiles of minipermeameter and core plug permeability values from the reservoir interval of the Ritchie Exploration, #1 Foos AP Twin. The minipermeameter profile demonstrates that a high degree of vertical stratification is present in the reservoir. Comparison of the minipermeameter profile to the core plug profile indicates that core plug permeability values were sampled at a spacing insufficient for representing the vertical stratification present in the Mississippian reservoir at Schaben Field

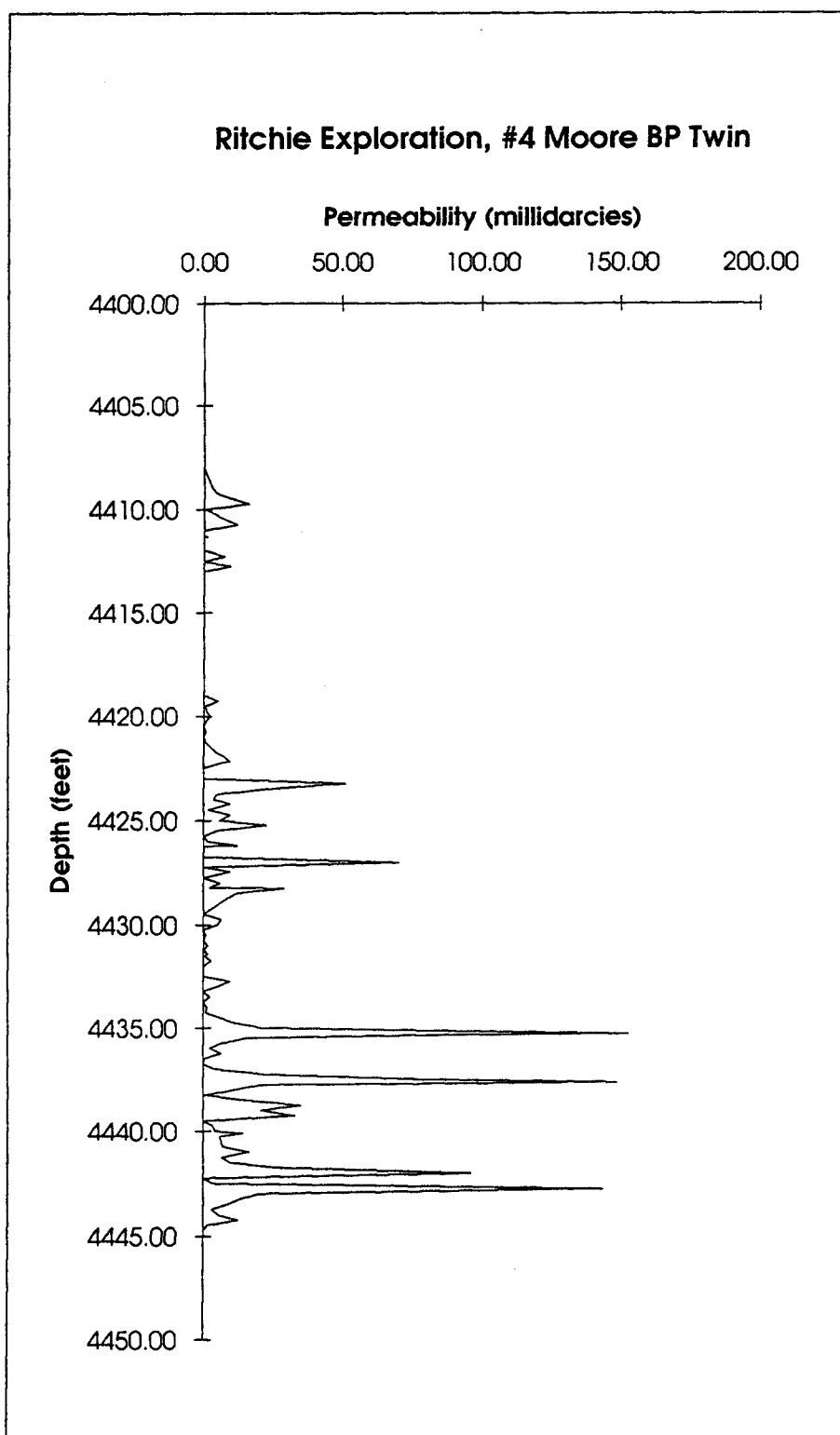


Figure 12.-- Vertical profiles of minipermeameter and core plug permeability values from the reservoir interval of the Ritchie Exploration, #4 Moore BP Twin. The minipermeameter profile demonstrates that a high degree of vertical stratification is present in the reservoir. Comparison of the minipermeameter profile to the core plug profile indicates that core plug permeability values were sampled at a spacing insufficient for representing the vertical stratification present in the Mississippian reservoir at Schaben Field.

Ritchie Exploration1 Foos "A-P" Twin
 NE SW SW Sec. 31-T19S-R21W
 Ness County, Kansas

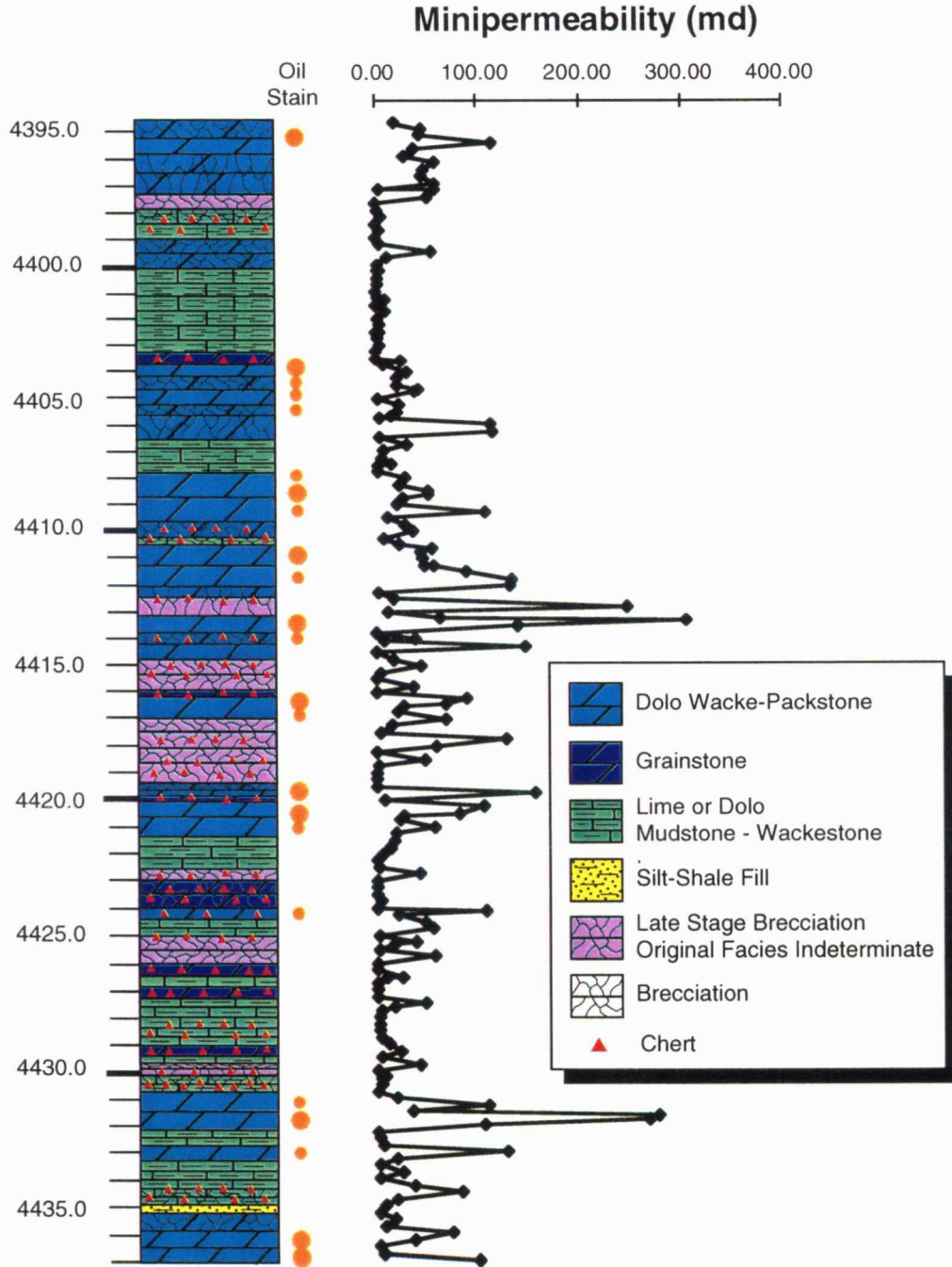


Figure 13.-- Graphical core description showing facies discussed in text for the Ritchie Exploration, #1 Foos AP Twin compared with the vertical profile of minipermeameter values. Depositional facies appear to influence permeability development and the reservoir is very vertically heterogeneous. Individual facies are discussed in text.

Reservoir Model

On the basis of present geologic analysis, a multi-tiered karst reservoir model has been developed at the field scale for Schaben demonstration site. This karst reservoir model is being supplemented by the core scale observations that original depositional facies and subsequent diagenesis have a significant control on development and preservation of effective porosity. Osagean reservoirs such as present at Schaben are extremely heterogeneous and if this model is valid numerous vertically and laterally segregated reservoir compartments would be expected. Engineering analysis and simulation is in progress, and should provide insight to more refined geologic model. Plans call for developing recommendations to test the accuracy of the model and the adequacy of the technology during budget period 2 of the project.

The Internet: A New Model and Method for Technology Transfer

The data and results of the Schaben project are being added to a world-wide-web server. The Internet protocol provides independent operators with on-line access to digital information, digital data bases, results of the field study, related regional geologic and production data, and purposeful transfer of technology. Access is through the Ness County page of the Digital Petroleum Atlas prototype (Figure 14; the uniform resource locator [URL] is <http://crude2.kgs.ukans.edu:80/DPA/County/ness.html>). It should be emphasized that the Schaben Project is an additional play/field to the Digital Petroleum Atlas and is not a substitute. The Internet provides just-in-time accessibility to fundamental well, reservoir, and geographic data (such as e-logs, production volumes, and digital map data), to petroleum related data compilations (such as the Schaben field study, regional maps [see Ness County page] and bibliographies), and to the latest research ideas. The virtual resource center provides a flexible and efficient method to disseminate data and technology to a geographically dispersed high technology industry.

We will provide on-line access to independent operators an evaluation of the technologies best suited for additional petroleum at Schaben and other Mississippian sub-unconformity fields. Information will be available when and where operators need it (literally on the operator's desk). The digital structure permits the operator to access comprehensive reservoir data and customize the interpretative products (for example, maps and cross-sections) to their needs. Schaben Field and regional data sets along with technical studies

Ness County

Click on the name of the field you are interested in to go to pages about that field. Only the Arroyo and Big Bow fields have been added to the atlas at this time. Clicking on the other field names will take you to pages showing the historical production for those fields.

Clicking on the small circles on the stratigraphic column will take you to pages showing structure or isopach maps. You can also use the "Next" and "Previous" buttons at the bottom of the page to investigate Ness County.

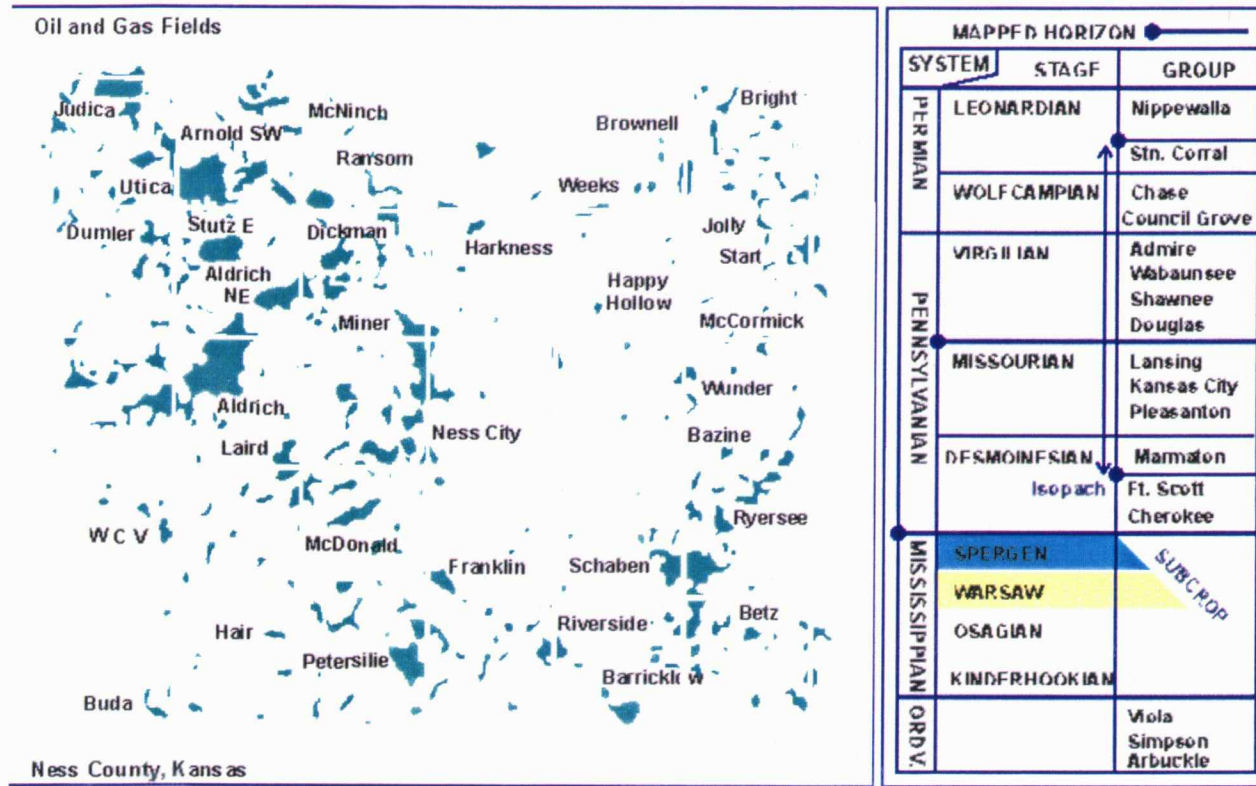


Figure 14.-- Ness County page of the Digital Petroleum Atlas prototype showing location of Schaben Field in southeast corner of county. Information on the Schaben Demonstration site can be accessed by clicking on the field name. Regional information and maps can be accessed by clicking on the stratigraphic column. The uniform resource locator [URL] for the page is <http://crude2.kgs.ukans.edu:80/DPA/County/ness.html>.

will be free-standing, but linked, entities that will be made available on-line through the Internet to users as they are completed.

Data sets will have relational links to provide opportunity for history-matching, feasibility, and risk analysis tests on the Schaben demonstration site. The flexible "web-like" design provides ready access to data, and technology at a variety of scales from regional, to field, to lease, and finally to the individual bore. The digital structure permits the operator to access comprehensive reservoir data and customize the interpretative products (for example, maps and cross-sections) to their needs. The results of the Schaben study will be accessible in digital form on-line and through CD-ROM using a World-Wide-Web browser as the graphical user interface.

Problems Encountered

Geologic reservoir characterization is nearly complete and the results will be presented at industry related conferences during the first half of 1996 (See attached for examples). Data developed to date is being used by several Kansas operators to evaluate targeted infill and even horizontal drilling at other analog fields in Kansas. Permitting problems have delayed the third well, but have not had a significant impact on project results. The project is well within budget and present cost sharing is in excess of 50%.

Recommendations for Future Work

Technology transfer activities are well underway. Results from the project during budget period 1 have met expectations. PFEFFER and the *pseudoseismic* approach have had a positive impact on exploration and development efforts in Kansas and other parts of the United States. Schaben and Bindley fields have the potential to become analog models that can be easily accessed and used throughout Kansas. We are currently comparing the Osagean reservoirs of Kansas with similar Mississippian reservoirs in the Williston Basin of Canada. The Canadian reservoirs have been successful horizontal well targets. The goal is to evaluate the potential of horizontal wells at the Schaben demonstration site.

Technology transfer continues to increase and is well underway. Abstracts have been prepared and presentations are scheduled for a number of professional meetings and workshops (Appendix C). These include: the Platform Carbonates Workshop to be held in Norman, Oklahoma (3/96); SIPES National Meeting in Dallas, Texas (3/96); the

AAPG/SEPM Carbonate Reservoir Session at the National AAPG meeting (5/96); BDM Class II workshop in Midland Texas (5/96); and the GCSEPM conference on Advanced Wireline and Geophysical Technology in Houston, Texas (12/96). Planned papers to be published will be associated with the Oklahoma Geological Survey Platform Carbonates Workshop and the GCSEPM Advanced Wireline and Geophysical Technology conference.

This project will continue our work with Kansas operators on application of the technologies developed as part of the Class II project. We are working to provide BDM with access to the digital data from the project, and to place the data into an on-line (Internet) accessible format.

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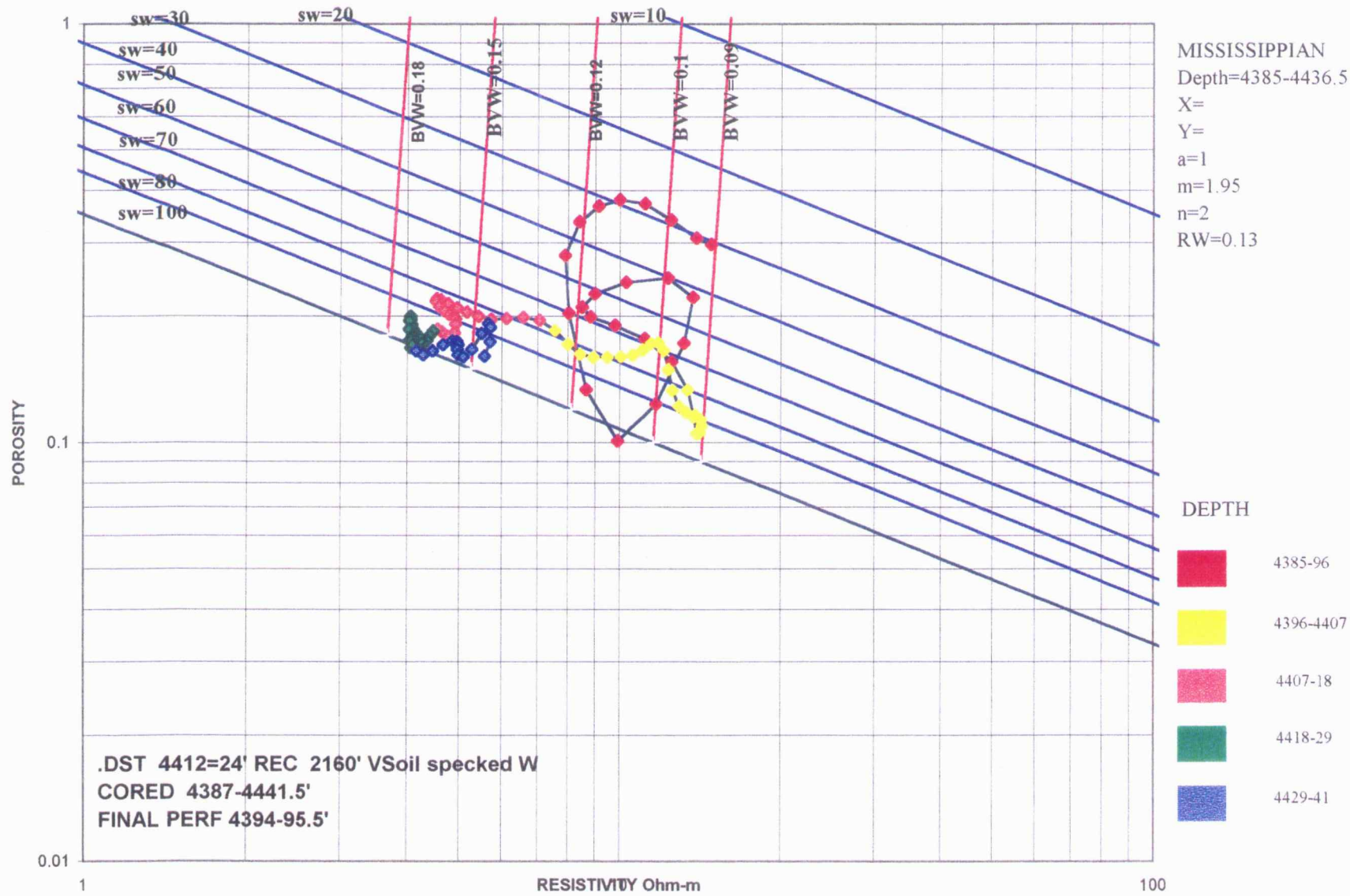
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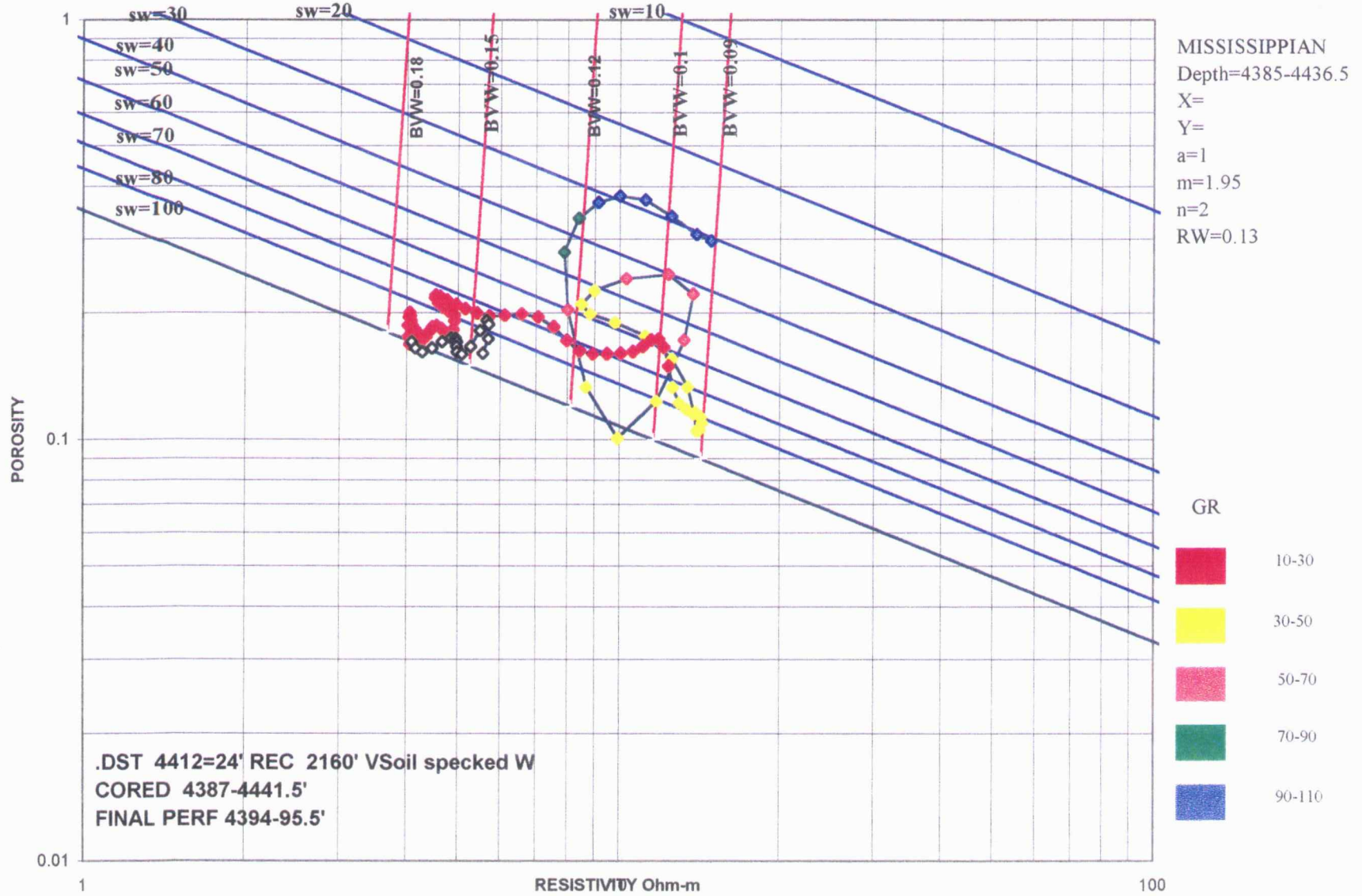
APPENDIX A
PFEFFER "Super Pickett" PLOTS
from
Ritchie 1 Foos "A-P" Twin
NE SW SW Sec. 31-T19S-R21W
Ness County, Kansas

Resistivity-porosity cross plots on depth attributes of computed Gamma Ray and Photo-Electric effect indicate a reservoir that is very heterogeneous of the top with a high bulk volume water (.09-.12), varying porosity (10-30%), and a varying water saturation (30-100%). The lower section indicates a more constant porosity (17-20%), an increasingly high BVW with depth (0.1 to 0.17), a increasing water saturation with depth (60%-100%). This indicates that the reservoir is in a long transition zone from oil to water. The Photo-Electric effect readings of 2.5-3 indicates a dolomite and chert reservoir. The Rhomaa-Umaa plot indicates that the reservoir is a mixture of chert and dolomite. The multi-coarsening upward cycles are indicated by the plots cyclically changing direction.

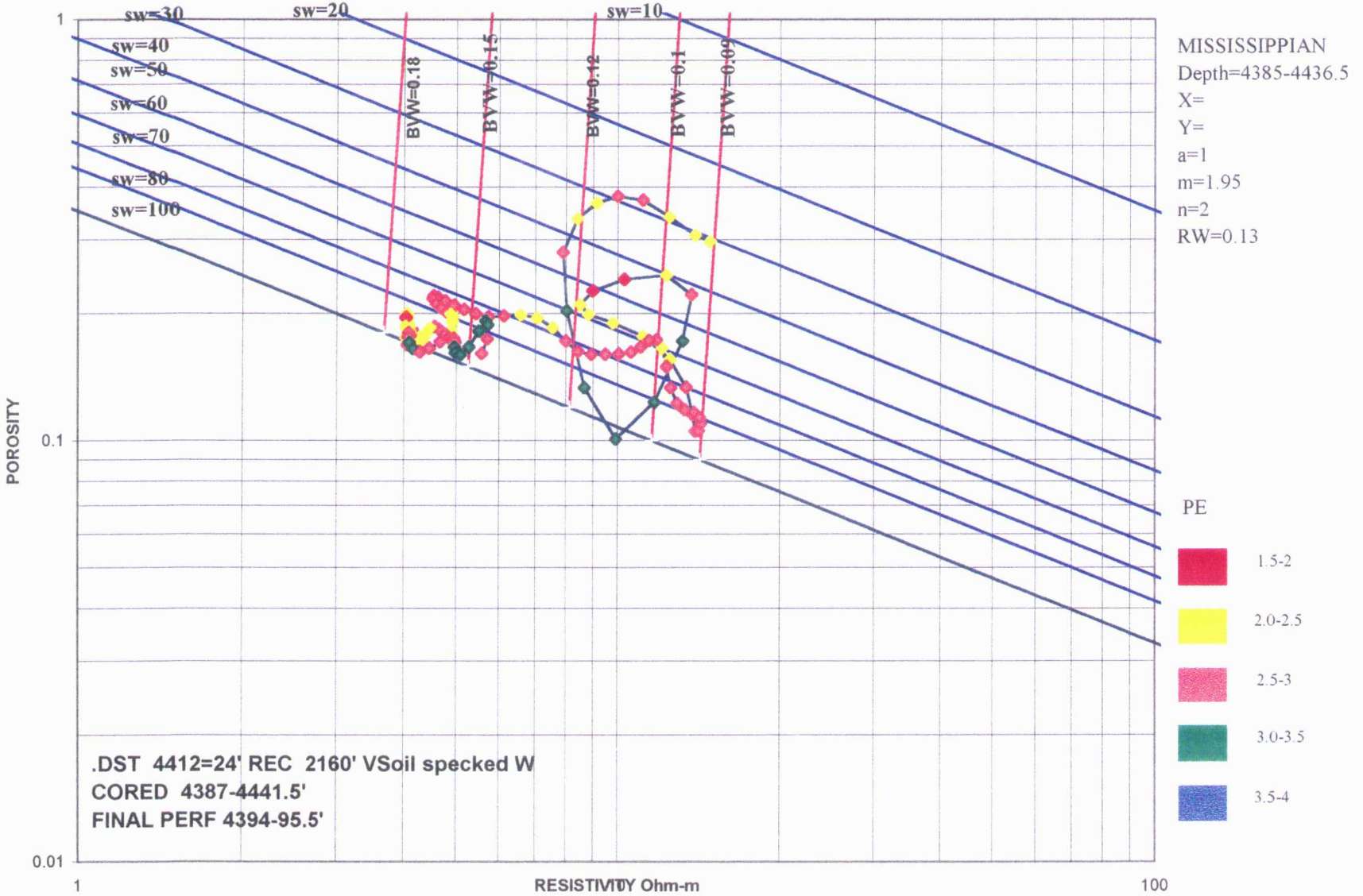
RITCHIE 1 A-P FOOS TWIN



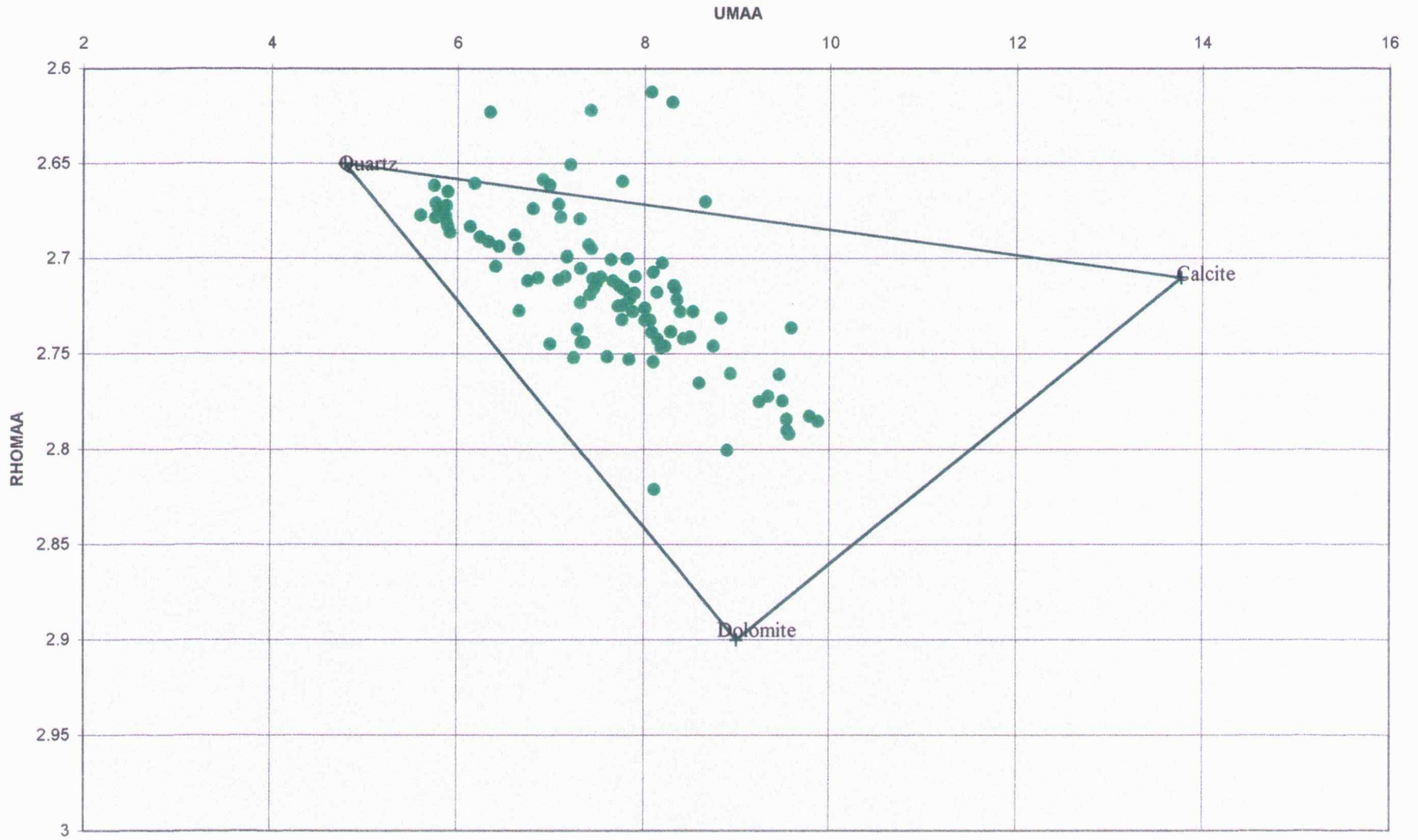
RITCHIE 1 A-P FOOS TWIN



RITCHIE 1 A-P FOOS TWIN

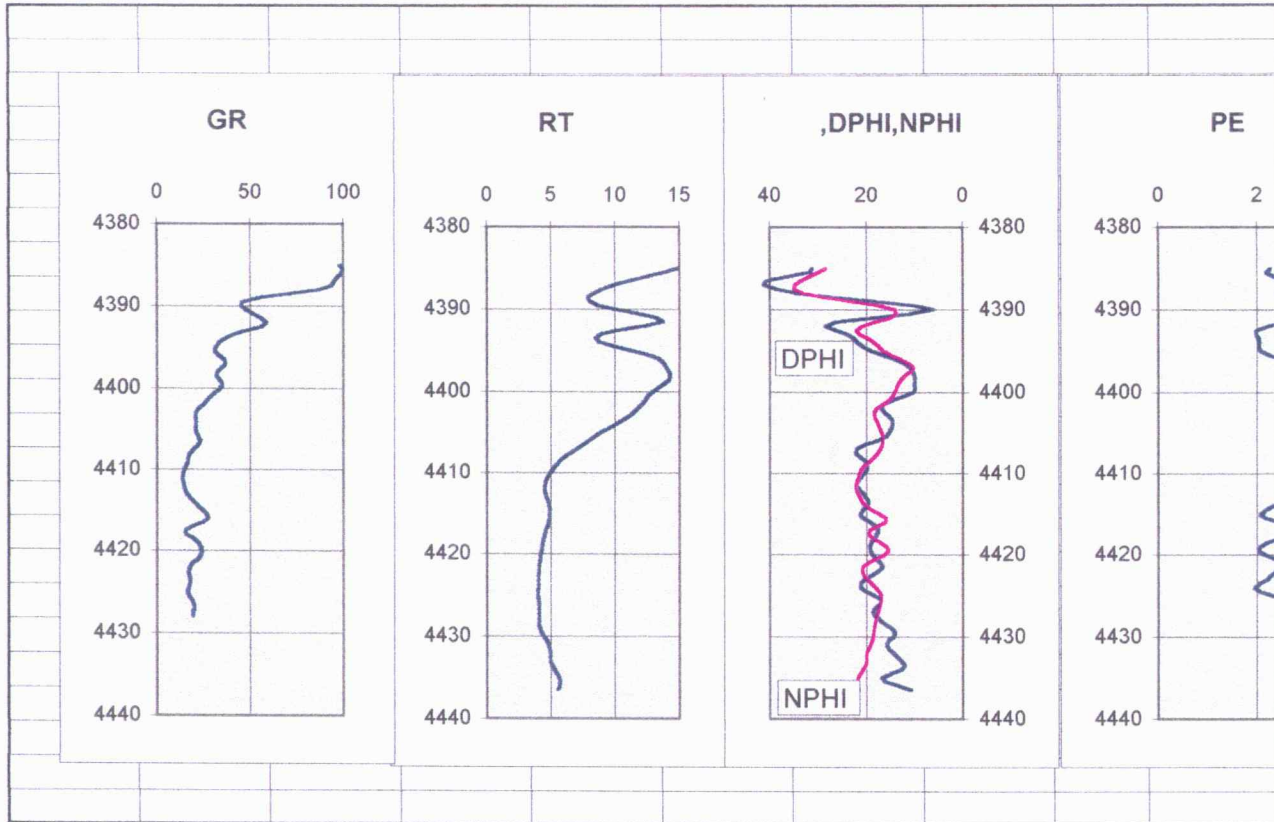


RITCHIE 1 A-P FOOS TWIN--MISSISSIPPIAN



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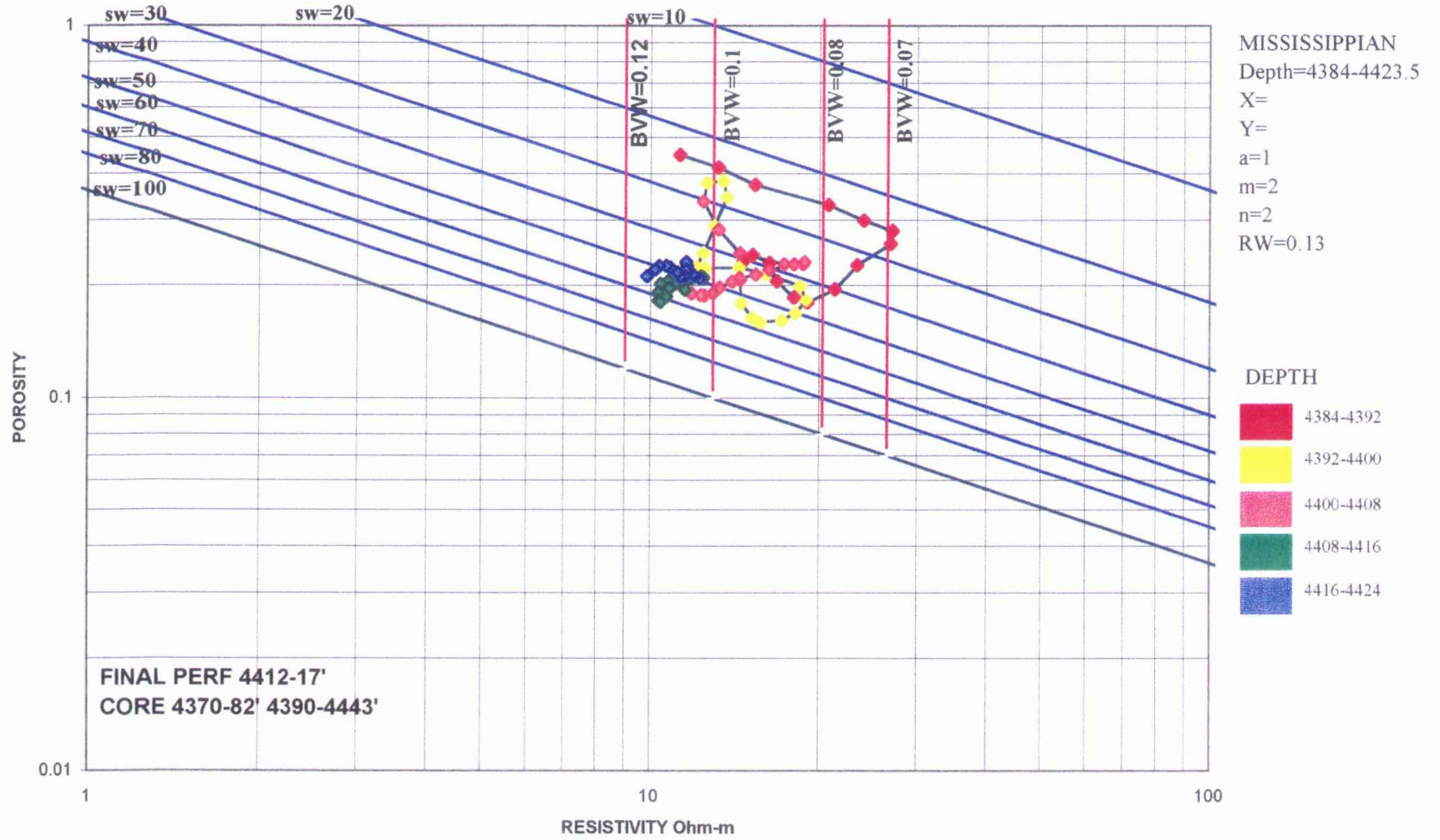


APPENDIX B
PFEFFER "Super Pickett" PLOTS
from
Ritchie 4 Moore "B-P" Twin
NW NE Sec. 30-T19S-R21W
Ness County, Kansas

Resistivity-porosity plots on depth with an attribute of computed Gamma Ray indicate a reservoir with a high bulk volume water (.08-.11), a relatively constant porosity (20%), and a medium high water saturation (up to 60%). This would agree with Franseen's core description of the reservoir as a very fine-to-fine crystalline dolomite. The reservoir presently open by perforations has a BVW of 0.11 and a SW of 50-60%. The upper section is more heterogeneous. The multi-coarsening upward cycles are indicated by the plots cyclically changing direction.

MISSISSIPPIAN Chart 1

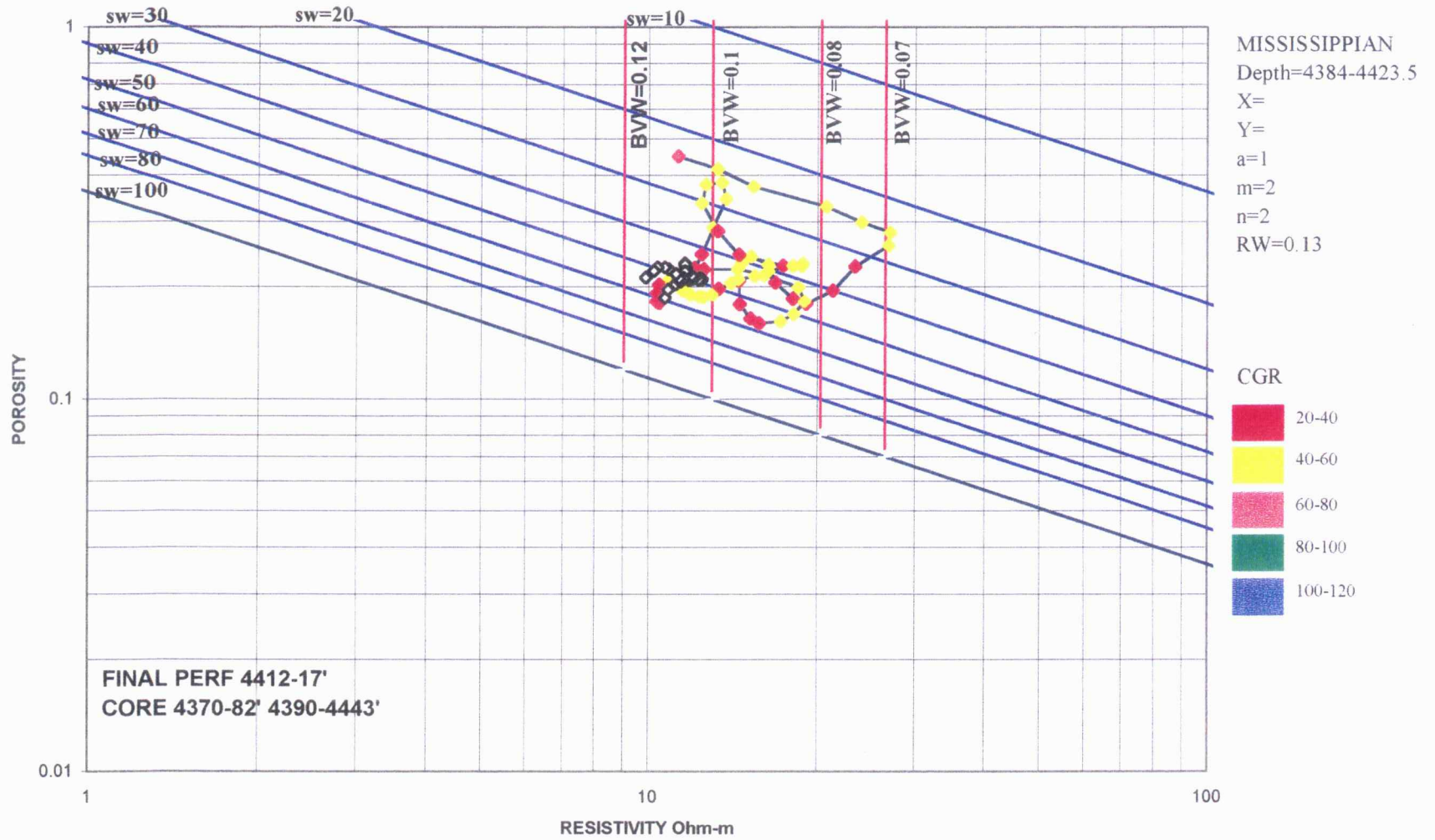
RITCHIE 4 MOORE "B-P" TWIN



DE-FC22-93BC14987

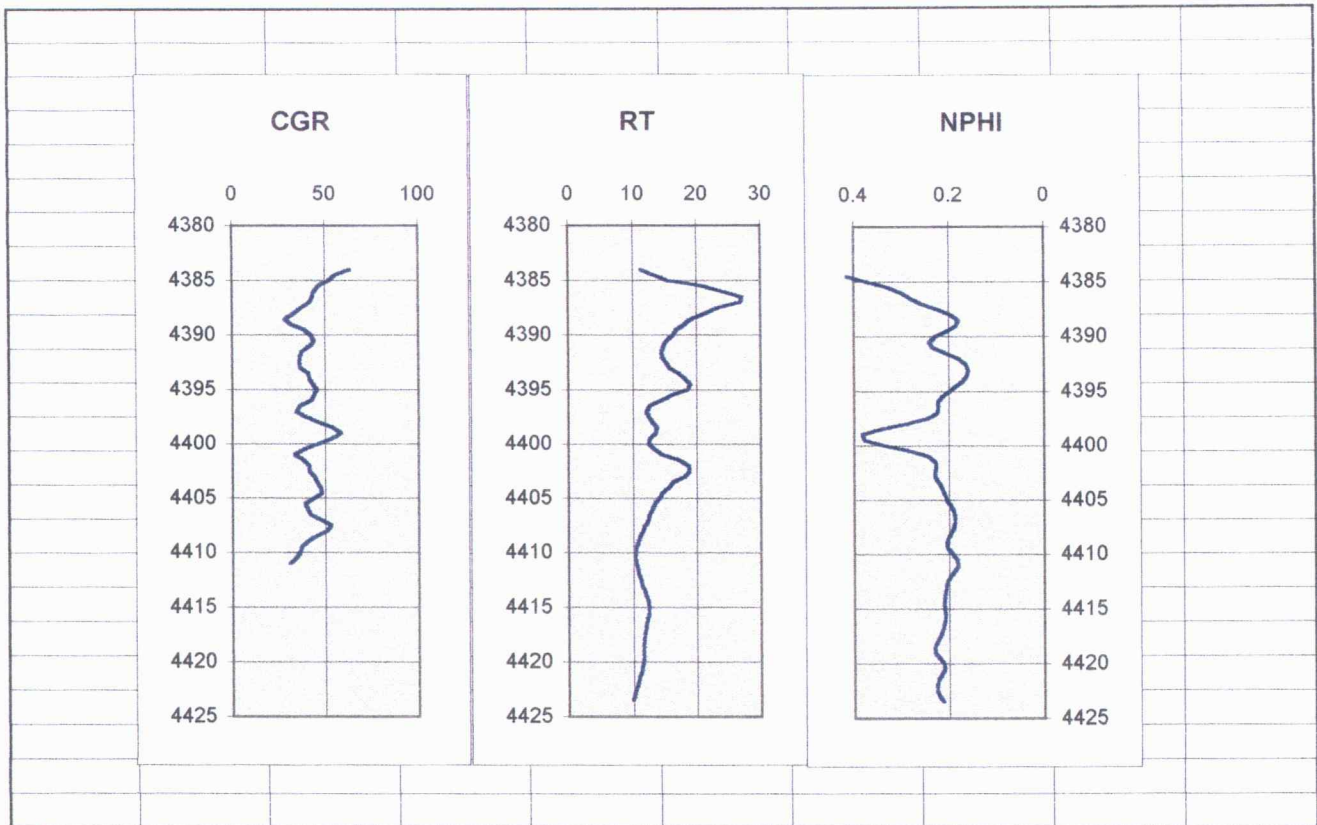
MISSISSIPPIAN Chart 1

RITCHIE 4 MOORE "B-P" TWIN



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MISSISSIPPIAN



**APPENDIX C
SELECTED ABSTRACTS**

Abstract for Invited Talk/Panel Discussion at Society of Independent Petroleum Earth Scientists (SIPES) National Convention, March 20 -- 23, Dallas, TX

The Role of the Public Sector in Providing Cost-Effective Technology to the Petroleum Independent: A Kansas Example

CARR, TIMOTHY R., Kansas Geological Survey, University of Kansas, Lawrence, KS

To remain competitive, independent oil operators require the highest level of appropriate technology, and the highest quality data. Major technical challenges to independent operators are; geologic and engineering uncertainty, lack of knowledge of existing technology, lack of high quality data, and the lack of confidence that existing technologies can improve operations. In the last few years, the University of Kansas and the Kansas Geological Survey have attempted to address these technical challenges by a renewed commitment to improve technology and data transfer. Improvements include changes both in organizational structure, research directions, and in the process of technology transfer.

Research efforts in Kansas have focused on developing tools that leverage existing data through cost-effective application of technology. Examples include: use of well logs within interpretation systems designed for analysis of 3D seismic data ("Pseudoseismic"); a spreadsheet computer program to implement traditional and innovative log analysis (Pfeffer); and techniques for acquisition of high-resolution seismic data.

Changes in the technology transfer process are moving away from the one-on-one consultations, paper publications and dusty files, and toward providing high-speed large-volume conduits for digital data and technology among operating companies, service companies, consultants and public sector entities. The Internet has provided just-in-time accessibility to fundamental well, reservoir, and geographic data (such as e-logs, production volumes, and digital map data), to petroleum related data compilations (such as field studies, regional maps and bibliographies), and to the latest research ideas. The virtual resource center provides a flexible and efficient method to disseminate data and technology to a geographically dispersed high technology industry.

Abstract for National AAPG Convention AAPG/SEPM Session on Carbonate, May 19 -- 22, 1996, San Diego, CA

Enhanced Carbonate Reservoir Model for an Old Reservoir Utilizing New Techniques: The Schaben Field (Mississippian), Ness County , Kansas

CARR, TIMOTHY R., WILLARD J. GUY, EVAN K. FRANSEEN, and SAIBAL BHATTACHARYA, Kansas Geological Survey, University of Kansas, Lawrence, KS

The Pennsylvanian-Mississippian unconformity is a major stratigraphic event in Kansas that truncates rocks ranging from Precambrian to Mississippian. Many of the 6,000 fields in Kansas are located immediately beneath this unconformity. One example, Schaben Field located in Ness County, Kansas, has produced approximately 9 million barrels since it was discovered in 1963. Production is from the Mississippian (Osagian) cherty dolomites beneath the unconformity. The field was initially developed on a regular forty-acre spacing, but recent drilling has demonstrated the potential for additional targeted infill drilling.

To develop an enhanced reservoir model for the Schaben field modern core, log, and well data were integrated with the existing data. New techniques such as "Pseudoseismic" and the "Super" Pickett plot were used to leverage the existing data and provide tools for analysis and 3D visualization. The pseudoseismic approach uses well-logs within a standard 3D seismic visualization system to provide a detailed macroscale view of karst patterns. The petrophysical analyses using the "Super" Pickett plot were used to recognize subtle trends and patterns for each of multiple reservoir intervals. Visual and petrographic examination of core from the field confirms karst development and indicates multiple stages of fracturing, brecciation, and dissolution features that were important in controlling and modifying development of reservoirs. The resulting multiple stage karst reservoir model for the Schaben Field emphasizes the opportunities provided by both vertical and lateral reservoir compartments due to well-developed karst. The understanding of the reservoir heterogeneities resulting from the paleokarst model at Schaben field emphasizes the importance of integrating available data with new techniques to provide a predictive tool for discovery of additional pay within existing subunconformity fields in Kansas.

Abstract for 1996 GCSEPM Research Conference on Stratigraphic Analysis using Advanced Geophysical, Wireline and Borehole Technology for Petroleum Exploration and Production, December 8 -- 11, 1996, Houston, Texas. Paper to be submitted.

**PSEUDO-SEISMIC TRANSFORMS OF WIRELINE LOGS:
A SEISMIC APPROACH TO PETROPHYSICAL
SEQUENCE STRATIGRAPHY**

John F. Hopkins, and Timothy R. Carr

Stratigraphic interpretation from wireline logs is typically drawn from multiple log traces or from crossplots of log data. Both techniques can readily depict vertical changes in lithology or reservoir quality, but lateral relationships are not readily visualized. Significant improvement in the geologic interpretation of wireline log data can be achieved through transformation and treatment of the transformed data as "seismic" traces for the purposes of processing, interpretation and display. This combination of wireline logs with a seismic interpretive approach is labeled pseudo-seismic. The pseudo-seismic transform can combine data from multiple logging tools generating a convolved 'crossplot log' for each well. A well-designed transformation of wireline log data across multiple wells maximizes both spatial and compositional information contents, and provides a readily interpretable image of the subsurface geology. Various filters and transformations can be applied to emphasize different aspects of the subsurface geology.

The transformed wireline log data are loaded into a computer workstation and interpreted as a set of 2D pseudo-seismic traces or as a 3D pseudo-seismic volume. Use of interpretation and visualization packages developed for seismic data offers flexibility in displaying and picking horizons, and increased efficiency of sequence stratigraphic interpretation. The treatment of wireline logs as a data volume permits comprehensive and cost effective sequence stratigraphic analysis of data sets that were previously considered intractable.

Examples from western Kansas, at both the regional and field scale, illustrate the utility and efficiency of sequence stratigraphic interpretation using the pseudo-seismic approach. The pseudo-seismic approach to the analysis of wireline log data from multiple wells opens new dimensions in log interpretation and provides significant insight into complex stratigraphic geometries associated with lithology, reservoir quality, and fluids.

Abstract for Workshop on Platform Carbonates in the Southern Midcontinent, March 26 -- 27, Oklahoma City, Oklahoma. Paper to be submitted.

**A NEW LOOK AT THE RESERVOIR GEOLOGY OF THE MISSISSIPPIAN
SCHABEN FIELD, NESS COUNTY, KANSAS**

CARR, Timothy R., GUY, Willard J., FRANSEEN, Evan K., BHATTACHARYA, Saibal, BEATY, Scott D., and FELDMAN, Howard R.; Kansas Geological Survey, University of Kansas, Lawrence, KS

As part of US Department of Energy funded reservoir studies, research units at the University of Kansas have expanded their commitment to address the technical challenges faced by independent oil and gas operators. Our efforts focus on Kansas reservoirs and developing tools that leverage existing data through cost-effective application of advanced technology. An example of this approach to reservoir studies is Schaben Field, Ness County, Kansas. Since discovery in 1963, Schaben Field has produced approximately 9 million barrels from the Mississippian (Osagian) cherty dolomites beneath the Pennsylvanian-Mississippian unconformity. This unconformity is a major stratigraphic event in Kansas truncating rocks ranging from Precambrian to Mississippian. The field was initially developed on a regular forty-acre spacing, but recent drilling has demonstrated the potential for additional infill drilling. However, a detailed reservoir model is required to efficiently target infill drilling and evaluate the potential for other advanced recovery methods.

An enhanced reservoir model for the Schaben field is based on integrating modern core, log, and well data with the existing data of variable quality. New techniques such as "Pseudoseismic" and the "Super" Pickett plot leverage existing data and provide tools for analysis and 3D visualization. Pseudoseismic uses well-logs within a standard 3D seismic visualization system to provide a detailed macroscale view of reservoir patterns. At Schaben the "pseudoseismic" approach was used to recognize and map previously unknown small faults and subtle stratigraphic heterogeneities within reservoir units. The "Super" Pickett plots were used to recognize subtle trends and patterns for each of multiple reservoir intervals. Petrophysical analyses indicate that the reservoir is vertically stratified, of variable lithology (limestone, dolomite, and chert), and has high BVW (Bulk Volume Water). Petrophysical results were tied into newly acquired core data to provide the detailed documentation of reservoir heterogeneity. Original depositional facies exerts an important control on later dissolution, cementation and dolomitization patterns. Highest quality reservoir units are associated with dolowackestone-packstones with abundant moldic, vuggy and intercrystalline porosity. Carbonate mudstones and chert horizons contribute to complex vertical and lateral compartmentalization within the Schaben Field. Karst associated with the overlying unconformity results in a fracture and breccia overprint that variably producibility of individual horizons.

The resulting multiple stage reservoir model for the Schaben Field emphasizes the opportunities provided by both vertical and lateral reservoir compartments. Compartmentalization is the result of a complex depositional and diagenetic history overprinted by a well-developed karst. The understanding of the reservoir heterogeneities resulting from the paleokarst model at Schaben field emphasizes the importance of integrating available data with new techniques to provide a predictive tool for discovery of additional pay within existing subunconformity fields in Kansas.