DOE/BC/14983--7

QUARTERLY REPORT

MICHIGAN TECHNOLOGICAL UNIVERSITY

OCTOBER, 1995

Recovery of Bypassed Oil in the Dundee Formation Using Horizontal Drains

Contract Number: DE-FC22-94BC14983

University: Michigan Technological University

Budget Period: 04-28-94 to 10-27-95

Project Period: 04-28-94 to 04-27-97

Cumulative DOE Obligation: $800,000

Program Manager: James R. Wood (906) 487-2894

Principal Investigator: James R. Wood

Contracting Officer's Representative (COR): Chandra Nautiyal (918) 337-4409

Reporting Period: 4th Quarter FY 1995

DISCLAIMER

EXECUTIVE SUMMARY

The TOW No. 1-3 HD-1 well in Crystal Field (our DOE project well) was spudded on September 20, 1995, cored through the upper 60 ft of the Dundee Formation, drilled to the base of the Dundee, and logged from the base of the Dundee to the base of the glacial till.

59.3 ft of core was recovered from the top of the Dundee. Dolomite extends almost to the top of the Dundee, and the nonporous cap limestone, which is normally 10-15 ft thick in much of Crystal Field, is only 2 ft thick in the well. The upper 15 ft of the Dundee is heavily fractured in core and contains centimeter-sized vugs. Twelve to fourteen feet of oil staining at the top of the Dundee reservoir in the core indicate significant unrecovered oil.

Haliburton ran 3 consecutive log suites, which included: 1) a gamma ray and dual laterolog with microresistivity, 2) a lithodensity log (compensated formation density plus photoelectric factor), and 3) a compensated neutron log. The logs were then correlated with a high degree of confidence and combined. The top 12-14 ft of the Dundee displayed good oil staining in the core. Therefore, the log suite has good coverage of both the oil leg and the water leg in the Dundee Formation.

During drilling through the Dundee, several lost-circulation events were experienced. After drilling, coring, and logging of the vertical leg was completed, the well was cemented and plugged back to the top of the Traverse Lime and a 10 in. directional wellbore was drilled on the curve to convert the vertical well to a horizontal one. The curve was lined with 8 5/8 in. casing and drilling of the 7 7/8 in. horizontal leg commenced. A Measurement While Drilling (MWD) gamma ray log was run to monitor orientation of the horizontal leg.

After 90 ft of horizontal leg was drilled, the well encountered a pocket of high porosity (probably vugs and fractures), a major lost-circulation event ensued, and the well blew out. Oil blew out around the drill string in a column that cascaded 15-20 ft above the drill floor. The well was quickly brought under control. At the time of the blowout, the well was being drilled with a mud capable of holding 1500 psi. Because the Dundee reservoir is maintained at hydrostatic pressure by a very active water drive, it is believed that the well will produce at about 1400 psi.

Because of the high reservoir porosity, permeability, and pressure and the propensity to lost circulation in the area penetrated by the horizontal wellbore, it was decided to suspend horizontal drilling and to complete the well in the Dundee. Although the well is capable of much higher production rates, initially it will be produced at 30-50 BOPD to prevent water coning. If expectations are met, the well will pay out in 2-3 years and continue on production for 10-15 years.

Thus, the play concept we chose to test, that bypassed attic oil remained in the Dundee reservoir between wells that had been produced at excessively high flow rates and had coned water during primary production, appears to be correct, and the TOW No. 1-3 HD-1 well is now a scientific, and appears destined to become an economic, success.

Several people joined the project this quarter. A. Wylie entered the Ph.D. program in Geology at MTU. He will be working under the direction of J. Huntoon on problems related to the Michigan Basin. Mr. Wylie has extensive experience in the oil industry and is expert in the use of the GeoGraphix Exploration System. C. Asiala was hired as a part-time database programmer, and M. Sivek was hired as an undergraduate assistant to help in the programming.

Well-log analysis using TerraSciences TerraStation software is underway. Lithologies and water saturations continue to be calculated for selected wells in the 30 fields in our seven-county study area using density/porosity and Pickett crossplots. QLA2, GeoGraphix's well-log package, was acquired this summer, along with other modules in the GeoGraphix Exploration System. Digitized logs were loaded into QLA2 this summer and a few trial log cross sections were constructed.

FTIR spectral analyses and ICP chemical analyses were completed on a suite of mineral standards by graduate student N. Popko. Data reduction is now beginning. When the FTIR technique is perfected, it will be used to analyze Dundee core samples

A data set containing over 77,000 geochemical analyses of brines from wells throughout the United States, was acquired from a commercial database vendor. The database is currently being input to and organized in Microsoft Access. The well locations for all Michigan wells which contain brine analyses were plotted on a basemap using GeoGraphix.

C. Asiala is developing Microsoft Access databases to archive analytical data and digitized log traces. Once in Access, this data can be transferred easily to a variety of applications programs.

The GeoGraphix Exploration System software package was acquired last quarter and installed on a PC in the Subsurface Laboratory at MTU. Graduate student S. Chittick worked all summer loading logs, formation tops, and other data into the program. Dundee tops and initial production (IP) data for Winterfield Field were input and 3D surface visualizations of structure and production data were constructed for the Dundee reservoir.

The USGS Digital Land Grid was also acquired. This data set contains surface data, such as the locations of roads, rivers, towns, etc., for the entire United States. All data for Michigan was input to GeoGraphix and is now available for use.

The National Geophysical Data Center's Gravity Data CD ROM was acquired and the Michigan portion of the data set was input to GeoGraphix. Bouguer anomaly and second-derivative contour maps were constructed and displayed at several scales, including the state, seven-county study area, and field levels.

B. Watkins continues to develop the Multimedia Database Manager shell/interface for data archiving and presentation using Microsoft Visual Basic 3.0. At present, it takes an experienced programmer to input information to the Database Manager. Watkins is developing an input interface which will make it possible for anyone in the project to input any type of data or graphics to the Database Manager archive. Data input will consist of calling up a List Box of Files and a

List Box of Destinations, then simply clicking and dragging the files to their desired destinations. The input interface will be completed and ready for testing in a few weeks.

The Dundee Project now has its own Homepage on the Internet, which is networked to the Geology Department at WMU. It can be reached at:
http://www.wmich.edu/geology/corelab/coreres.htm

A. Wylie and J. Huntoon are editing a volume entitled "Practical Reservoir Characterization", which is to be published as a volume in the AAPG Computer Applications in Geology series. Wylie is writing the first six chapters, which constitute a "how-to" guide to computerized reservoir characterization. Seven authors have committed to contribute case studies in reservoir characterization. Each of these will be a separate chapter. One of these case studies will be a paper on the Dundee reservoir in Winterfield Field, co-authored by Chittick, et al.

In September, W. Harrison presented a talk on the Dundee project to the Ontario Petroleum Institute in London, Ontario. In October, S. Chittick presented a talk entitled "Characterization of the Dundee Formation, Winterfield Field, Clare County, Michigan", co-authored by S. Chittick, C. Salotti, J. Wood, W. Pennington, S. McDowell, J. Huntoon, and W. Harrison, at the AAPG Northeast Section Meeting in Schenectedy, NY.

A Project Evaluation Report describing in detail the current project status was prepared and submitted to DOE in August in accordance with the Reporting Requirements. A Topical Report summarizing data for Crystal Field was also prepared and submitted.

The GeoGraphix Exploration System was acquired early this summer and installed on a PC in the Subsurface Laboratory at MTU. S. Chittick has been working all summer on system installation and data input and has used GeoGraphix to analyze gravity data in the vicinity of Winterfield Field.

A data set containing information on >10,000 Michigan wells was acquired from Angstrom. The data set includes well locations, formation tops, lithologies, etc., in a form that can be read directly into our GeoGraphix Exploration System software. S. Chittick is currently in the process of inputting the data to GeoGraphix.

Other software developments include the following: BasinMod was acquired and installed on a PC in the Subsurface Laboratory at MTU and test runs will be made later this fall. Earlier this summer, Access.basin was acquired and installed on the Sun Workstation in the Subsurface Laboratory at MTU. An older 3D version is now running. The latest upgrade was recently received, but requires debugging before it can be used. We purchased the numerical computation and visualization software package MATLAB and subsequently input gamma-ray logs from wells in Winterfield Field to it. A "pseudoseismic" cross section was generated and the results were encouraging.

SUMMARY OF TECHNICAL PROGRESS BY TASK

BUDGET PERIOD 1

TASK 1.1 PROJECT MANAGEMENT

The management tasks have gone smoothly this quarter. Various subgroups met and worked on specific tasks and subtasks throughout the quarter. Several people joined the project this quarter. A. Wylie entered the Ph.D. program in Geology at MTU. He will be working under the direction of J. Huntoon on problems related to the Michigan Basin. Mr. Wylie has extensive experience in the oil industry and is expert in the use of the GeoGraphix Exploration System. C. Asiala was hired as a part-time database programmer, and M. Sivek was hired as an undergraduate assistant to help in the programming.

1.1.2 BUDGET MANAGEMENT AND QUARTERLY REPORTS

M. Gruener and A. Hein are responsible for daily management of the budget and expenditures. A. Hein is responsible for preparation of quarterly financial reports and for distribution of all reports to DOE. J. Allan is responsible for quarterly and annual technical reports.

TASK 1.2 RESERVOIR CHARACTERIZATION

Well and log data sets and production data sets for all 30 fields are now complete. Tops have been picked on all formations in all wells. The well location and formation tops data sets are also now complete.

1.2.1 WELL LOG ACQUISITION, DIGITIZATION, ANALYSIS

The TOW No. 1-3 HD-1 well in Crystal Field (our DOE project well) was spudded on September 20, 1995 and cored and logged through the Dundee one and one half weeks later (see Fig. 1). 59.3 ft of core was recovered from the top of the Dundee and the well was then drilled 150 ft below the base of the core to TD at the top of the Detroit River anhydrite. The vertical well was then logged from TD at the base of the Dundee (3334 ft) to the base of casing (683 ft), which corresponds approximately to the base of the glacial till. Haliburton ran 3 consecutive log suites, which included: 1) a gamma ray and dual laterolog with microresistivity, 2) a lithodensity log (compensated formation density plus photoelectric factor), and 3) a compensated neutron log. The logs were then correlated with a high degree of confidence and combined. The top 12-14 ft of the Dundee displayed good oil staining in the core (see Subtask 1.2.2). Therefore, the log suite has good coverage of both the oil leg and the water leg in the Dundee Formation. Log evaluation has begun, but has not progressed far enough to report any results at this time.

Well-log analysis and regional geological studies are being carried out by W. Harrison and his graduate students at WMU. Well data, including drillers' logs and wireline logs for 8526 wells, including 4785 wells that penetrate the Dundee, are now in our oil and gas well data set. Maps and cross sections have been completed for Crystal Field and 30 other Dundee oil fields in the

Michigan basin. All these maps have been plotted on 81/2x11 pages and have been compiled by field into single "folio" sized poster sheets.

Well-log analysis using TerraSciences TerraStation software is underway. Lithologies and water saturations continue to be calculated for selected wells in the 30 fields in our seven-county study area using density/porosity and Pickett crossplots.

QLA2, GeoGraphix's well-log package, was acquired this summer, along with other modules in the GeoGraphix Exploration System. Although its analytical capabilities are perhaps less sophisticated than TerraSciences, it appears that it may be used to produce more polished log displays and cross sections. Digitized logs were loaded into QLA2 this summer and a few trial log cross sections were constructed.

1.2.2 CORE ACQUISITION AND ANALYSIS

The uppermost Dundee reservoir was cored in the TOW No. 1-3 HD-1 well. The coring point was in the lowermost Bell Shale, immediately above the Dundee. 59.3 ft of core were recovered out of a possible 60 ft.

Dolomite extends almost to the top of the Dundee, and the nonporous cap limestone, which is normally 10-15 ft thick in much of Crystal Field, is only 2 ft thick in the TOW No. 1-3 well (Fig. 1). The upper 15 ft of the Dundee is heavily fractured in core and contains centimeter-sized vugs. Most fractures are subvertical with highly variable azimuths, but some fractures are developed at lower angles. Most fractures and vugs are lined with white, sparry dolomite. The top of the Dundee in the well was encountered 8 ft lower than projected. Together, these observations suggest that a top-down solution process (karst?) led to fracturing and collapse of the uppermost Dundee, which resulted in development of enhanced porosity.

Twelve to fourteen feet of oil staining at the top of the Dundee in the core indicate significant unrecovered oil. A change in the appearance of the lower 4-5 ft of the oil-stained interval may indicate either a transition zone or a swept zone where the oil-water contact moved up as a result of primary oil production. Log evaluation may help to differentiate between these two alternatives.

As of mid-October, the core was housed at Western Michigan University where a detailed core description is being made. After samples are collected for thin section and SEM work, the core will be shipped to Omni in Houston where a core gamma ray log will be run and the core will be photographed under plane and ultraviolet light to reveal sedimentary structures and heterogeneities in oil saturation. Finally, porosity and permeability analyses and Dean Stark extractions will be performed by Omni on whole-core samples taken at 1 ft intervals.

About 50 cores of the Dundee Formation from throughout the state of Michigan have been identified and are currently available in public repositories (i.e., the Western Michigan University Core Research Lab, the University of Michigan Subsurface Lab, the Wayne State University core facility, the Central Michigan University core facility, and the Michigan Geological Survey core repository in Lansing). Many of these cores will be described and samples will be taken for thin

section, Xray diffraction, and SEM analyses to determine mineralogy and porosity characteristics. Cuttings samples from 60 to 100 Michigan wells are also available.

Rock work has begun at WMU and will continue into Phase II. SEM analyses of selected samples from the nearest cored well to Crystal Field (Leonard Oil Co., Lee #1, Montcalm County, MI) were performed by W. Harrison and his graduate students at WMU to investigate microtextures in the Dundee reservoir, including intercrystalline porosity and fractures.

1.2.3 FTIR SPECTROSCOPY

FTIR spectral analyses and ICP chemical analyses were completed on a suite of mineral standards by graduate student N. Popko. Data reduction is now beginning. Spectral data from standards will be input to MATLAB, a numerical computation and visualization software package, which will generate non-negative least-squares (NNLS) fits to the data. ICP elemental analyses will be converted to oxides, and mineralogies will be calculated and used to cross-check the FTIR results. When the FTIR technique is perfected, it will be used to analyze Dundee core samples. Popko is doing this work as his Master's research under the direction of W. Pennington.

1.2.4 FLUID SAMPLES

Hydrocarbon and produced-water samples will soon be collected from the research well in Crystal Field. If possible, arrangements will be made to sample fluids from other Dundee fields as well. Inorganic geochemical analyses of produced brines will be used in conjunction with isotope and fluid inclusion analyses of core and cuttings to determine the origin and history of the porosity-producing dolomitizing fluid.

A data set containing over 77,000 geochemical analyses of brines from wells throughout the United States, was acquired from a commercial database vendor. The database is currently being input to and organized in Microsoft Access. The well locations for all Michigan wells which contain brine analyses were plotted on a basemap using GeoGraphix (Fig. 2).

TASK 1.3 DATABASE MANAGEMENT

Currently, project personnel at WMU are using TerraSciences' TerraStation software to analyze and archive project data, while the MTU group is using GeoGraphix to analyze project data. C. Asiala is developing Microsoft Access databases to archive analytical data and digitized log traces. Once in Access, this data can then be transferred easily to a variety of applications software packages.

Thirty Dundee fields are being studied in this project. Well data (drillers' logs and scout tickets), log data, and production data sets for all 30 fields are now complete. The data are currently stored in the TerraSciences' database at WMU. Digitized well logs from selected wells were read into the WMU database and many intervals were evaluated for S_w and other calculated parameters

during the last quarter. These calculations are continuing and will be made for the Dundee reservoir interval in most wells in the seven-county study area which contain modern log suites.

The GeoGraphix Exploration System software package was acquired last quarter and installed on a PC in the Subsurface Laboratory at MTU. Graduate student S. Chittick worked all summer loading logs, formation tops, and other data into the program and getting the system operational. Well location data was input from the 10,000-well database that we acquired from Angstrom this summer (see Subtask 2.3.2). Dundee tops and initial production (IP) data for Winterfield Field were input and 3D surface visualizations of structure and production data were constructed for the Dundee reservoir. Tops for the other 30 fields in the study are currently being loaded into GeoGraphix.

The USGS Digital Land Grid was also acquired. This data set contains surface data, such as the locations of roads, rivers, towns, etc., for the entire United States. All data for Michigan was input to GeoGraphix and is now available for use.

Chittick has begun working on a doctoral dissertation under the direction of W. Pennington. An important component of his doctoral study will be to determine whether structural deformation in the area is reflected in the gravity maps. In pursuit of this study, he acquired the National Geophysical Data Center's Gravity Data CD ROM and loaded the Michigan portion of the data set into GeoGraphix. Bouguer anomaly and second-derivative contour maps were constructed and displayed at several scales, including the state, seven-county study area, and field levels.

B. Watkins continues to develop the Multimedia Database Manager shell/interface for data archiving and presentation using Microsoft Visual Basic 3.0. The Database Manager has been used extensively to-date in our other DOE project "Visual Display of Reservoir Parameters Affecting Enhanced Oil Recovery", which is centered on Pioneer Field in California. Interim results were recently written to CD ROM for internal distribution.

At present, it takes an experienced programmer to input information to the Database Manager. Watkins is developing an input interface called PioneerBuilder which will make it possible for anyone in the project to input any type of data or graphics to the Database Manager. With PioneerBuilder, data input will consist of calling up a List Box of Files and a List Box of Destinations, then simply clicking and dragging the files to their desired destinations. PioneerBuilder will be completed and ready for testing in a few weeks. When it is working to our satisfaction, C. Asiala will define any special needs and changes necessary for handling the Michigan data, the Multimedia shell will be replicated, modified if necessary, and a second input interface called CrystalBuilder will be written to handle to Michigan data. When complete, all Dundee data, maps, cross sections, photomicrographs, etc., will be loaded into the Michigan Multimedia Database Manager, where they can be easily archived and accessed.

TASK 1.4 DRILLING

W. Pennington constructed a new cross section of the Dundee Formation using an improved technique for projecting wells onto the section plane. It provided new detail and insights into the

structure of the dolomite/cap-limestone contact at the top of the Dundee, a surface that has a profound effect on attic oil distribution in the field (Fig. 1). It proved useful in planning the final trajectory for the horizontal leg of the TOW No. 1-3 HD-1 research well in Crystal Field.

The TOW No. 1-3 well was spudded on September 20, 1995, cored through the upper 60 ft of the Dundee Formation, drilled to the base of the Dundee, and logged from the base of the Dundee to the base of the glacial till (see Subtasks 1.2.1 and 1.2.2). During drilling through the Dundee, several lost-circulation events were experienced. The well was then cemented and plugged back to the top of the Traverse Lime and a 10 in. directional wellbore was drilled on the curve to convert the vertical well to a horizontal one. It took three days and 600 vertical feet to drill the curve and when the horizontal leg entered the Dundee, it was 400 ft laterally distant from the original intercept of the vertical well with the top of the Dundee. The curve was then lined with 8 5/8 in. casing and drilling of the 7 7/8 in. horizontal leg commenced. A Measurement While Drilling (MWD) gamma ray log was run to monitor orientation of the horizontal leg.

After 90 ft of horizontal leg was drilled, the well encountered a pocket of high porosity (probably vugs and fractures), a major lost-circulation event ensued, and the well blew out. Oil blew out around the drill string in a column that cascaded 15-20 ft above the drill floor. The well was quickly brought under control. At the time of the blowout, the well was being drilled with a mud capable of holding 1500 psi. Because the Dundee reservoir is maintained at hydrostatic pressure by a very active water drive, it is believed that the well will produce at about 1400 psi.

Because of the high reservoir porosity, permeability, and pressure and the propensity to lost circulation in the area penetrated by the horizontal wellbore, it was decided to suspend horizontal drilling and to complete the well in the Dundee. Although the well is capable of much higher production rates, initially it will be produced at 30-50 BOPD to prevent water coning. If expectations are met, the well will pay out in 2-3 years and continue on production for 10-15 years.'

Thus, the play concept we chose to test, that bypassed attic oil remained in the Dundee reservoir between wells that had been produced at excessively high flow rates and had coned water during primary production, appears to be correct, and the TOW No. 1-3 HD-1 well is now a scientific, and appears destined to become an economic, success.

TASK 1.5 TECHNOLOGY TRANSFER

This task focuses on technology transfer of information derived in this study through academic, technical, and commercial channels.

Internet Homepage

The Dundee Project now has its own Homepage on the Internet, which is networked to the Geology Department at WMU. It can be reached at:
http://www.wmich.edu/geology/corelab/coreres.htm

1.5.1 MEETINGS

In September, Wood, Harrison, Huntoon, Pennington, Gruener, Chittick, and several WMU students traveled to the Crystal Field drill site to be present for drilling, coring, logging, and testing of the Crystal Field test well. E. Taylor of Terra Energy acted as the well-site geologist on the well. Allan traveled to MTU to work on the project.

1.5.2 REPORTS

Multimedia Presentations on CD-ROM

During this period, work continued on the Visual Basic programming for the Multimedia Database Manager (see Task 1.3).

AAPG Computer Applications in Geology Volume

A. Wylie and J. Huntoon are editing a volume entitled "Practical Reservoir Characterization", which is to be published as a volume in the AAPG Computer Applications in Geology series. Wylie is writing the first six chapters, which constitute a "how-to" guide to computerized reservoir characterization (Attachment 1). Seven authors have committed to contribute case studies in reservoir characterization. Each of these will be a separate chapter. One of these case studies will be a paper on the Dundee reservoir in Winterfield Field, co-authored by S. Chittick and others.

1.5.3 PROFESSIONAL MEETINGS AND PUBLICATIONS

Presentations by W. Harrison

W. Harrison presented a talk entitled "Recovery of Bypassed Oil in the Dundee Formation Using Horizontal Drains", which described the project's activities and accomplishments to date, to the Geology Department at the University of Illinois-Chicago during the week of September 25, to the Geology Department at Western Michigan University during the week of October 2, and to the Ontario Petroleum Institute in London, Ontario, Canada on October 19, 1995.

Presentations by S. Chittick

In October, S. Chittick presented a talk entitled "Characterization of the Dundee Formation, Winterfield Field, Clare County, Michigan", co-authored by S. Chittick, C. Salotti, J. Wood, W. Pennington, S. McDowell, J. Huntoon, and W. Harrison, at the AAPG Northeast Section Meeting in Schenectedy, NY (Attachment 2). He recently submitted an abstract for a poster session to be presented at the AAPG National Meeting in San Diego in May, 1996 (Attachment 3).

1.5.4 WORKSHOPS

No workshops were held during this quarter.

TASK 1.6 PROJECT CONTINUATION

A Project Evaluation Report describing in detail the current project status was prepared and submitted to DOE in August in accordance with the Reporting Requirements. A Topical Report summarizing data for Crystal Field was also prepared and submitted.

TASK 2.3 MODELING

2.3.2 BASIN MODELING

Although the Modeling Task is not scheduled to begin until the Budget Period 2, software has been acquired and installation is underway. J. Huntoon is directing the modeling effort. During the last quarter, the following progress was made:

1) Michigan well data set: A data set containing information on >10,000 Michigan wells was acquired from Angstrom. The data set includes well locations, formation tops, lithologies, etc., in a form that can be read directly into our GeoGraphix Exploration System software. S. Chittick is currently in the process of inputting the data to GeoGraphix.

2) HP650C - Color Plotter: An HP650C color plotter was installed and is now in use. It was first used to prepare the poster displays for the SEG Development and Production Forum in June and has seen extensive use this summer in the preparation of maps and cross sections.

3) GeoGraphix - Data Management and Visualization Software: The GeoGraphix Exploration System was acquired early this summer and installed on a PC in the Subsurface Laboratory at MTU (see Task 1.3). GeoGraphix is designed to facilitate data management and visualization. It uses the same type of Geographic Information System technology that is common in more expensive types of software (e.g. ArcInfo, Intergraph), but is tailored to the needs of oil companies working with subsurface, rather than surface, data. It runs on PCs which makes it attractive to smaller, independent oil companies. S. Chittick has been working all summer on system installation and data input and has used GeoGraphix to analyze gravity data in the vicinity of Winterfield Field.

4) BasinMod - 1-D Basin Modeling Software: The BasinMod system provides users with a relatively simple, user-friendly method for modeling the evolution of single wells. Multiple well histories can also be modeled to investigate variations in basin evolution that occur from one geographic locality to another. BasinMod allows modeling of burial histories, compaction, temperature histories, lithology, heat flow, hydrocarbon maturities, and pressures, and allows for multiwell mapping of variables. BasinMod was acquired and installed on a PC in the Subsurface Laboratory at MTU. Test runs will be made later this fall.

5) Akcess.basin - 2-D, 3-D Basin Modeling Software: Earlier this summer, Access.basin was acquired and installed on the Sun Workstation in the Subsurface Laboratory at MTU. This software uses a finite-element formulation to examine the effects of thermal processes (conduction, convection, advection), fluid flow processes (compaction-driven, hydraulic-head

driven), sealing mechanisms, and sedimentation/erosion during the development of a sedimentary basin. The program also predicts hydrocarbon generation (timing, location, and rate) and migration patterns. An older 3D version is now running. The latest upgrade was recently received, but requires debugging before it can be used.

6) MATLAB: At the 1995 DOE Review Meeting for Fossil Energy Contractors in Oklahoma, T. Carr (U. Kansas) presented a "pseudoseismic" model that is based on the precept that well logs can be substituted for seismic traces in visualization software and then analyzed as if they were regular seismic data. We purchased the numerical computation and visualization software package MATLAB and input gamma-ray logs from wells in Winterfield Field. A "pseudoseismic" cross section was generated and the results were encouraging.

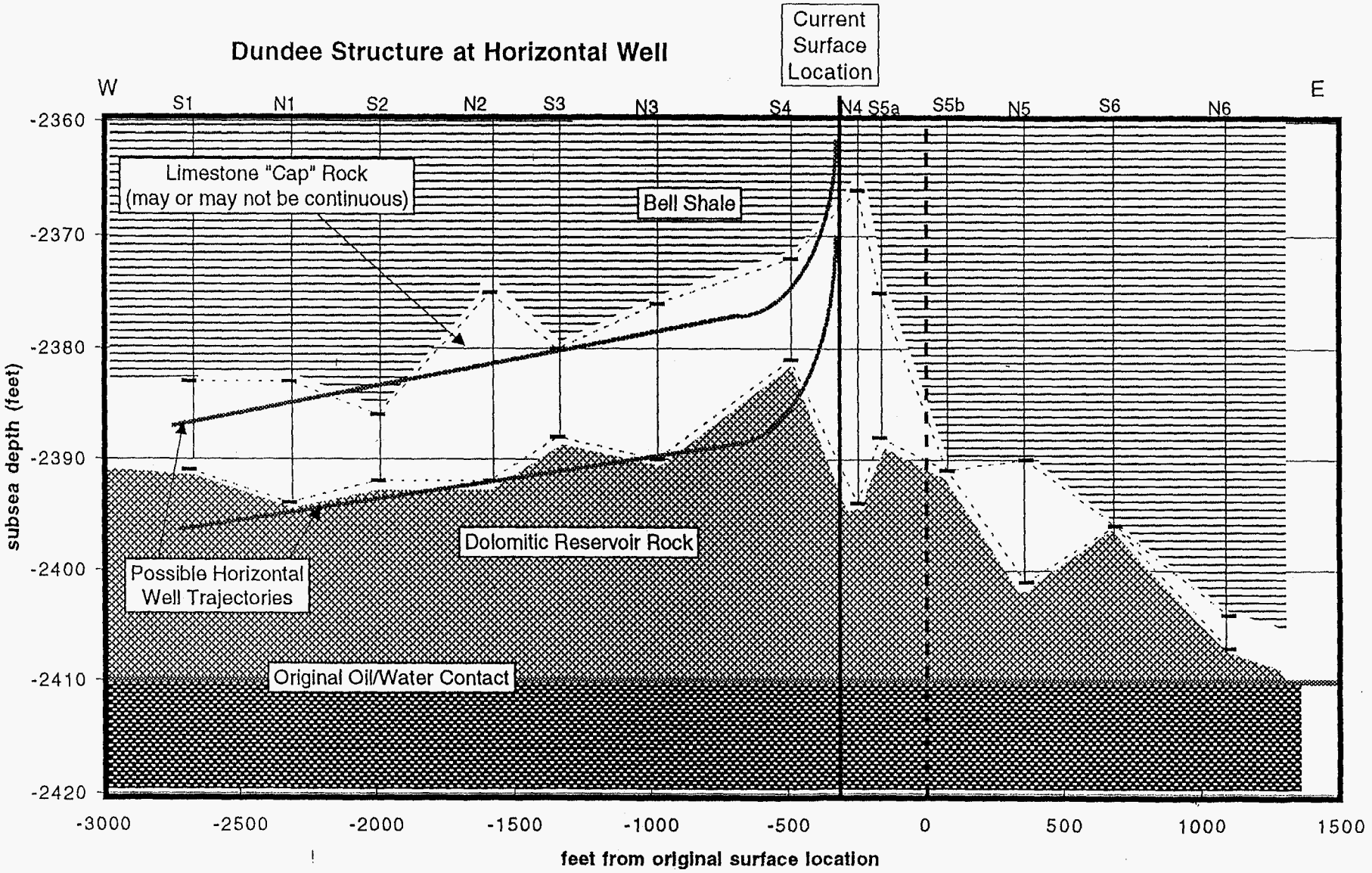
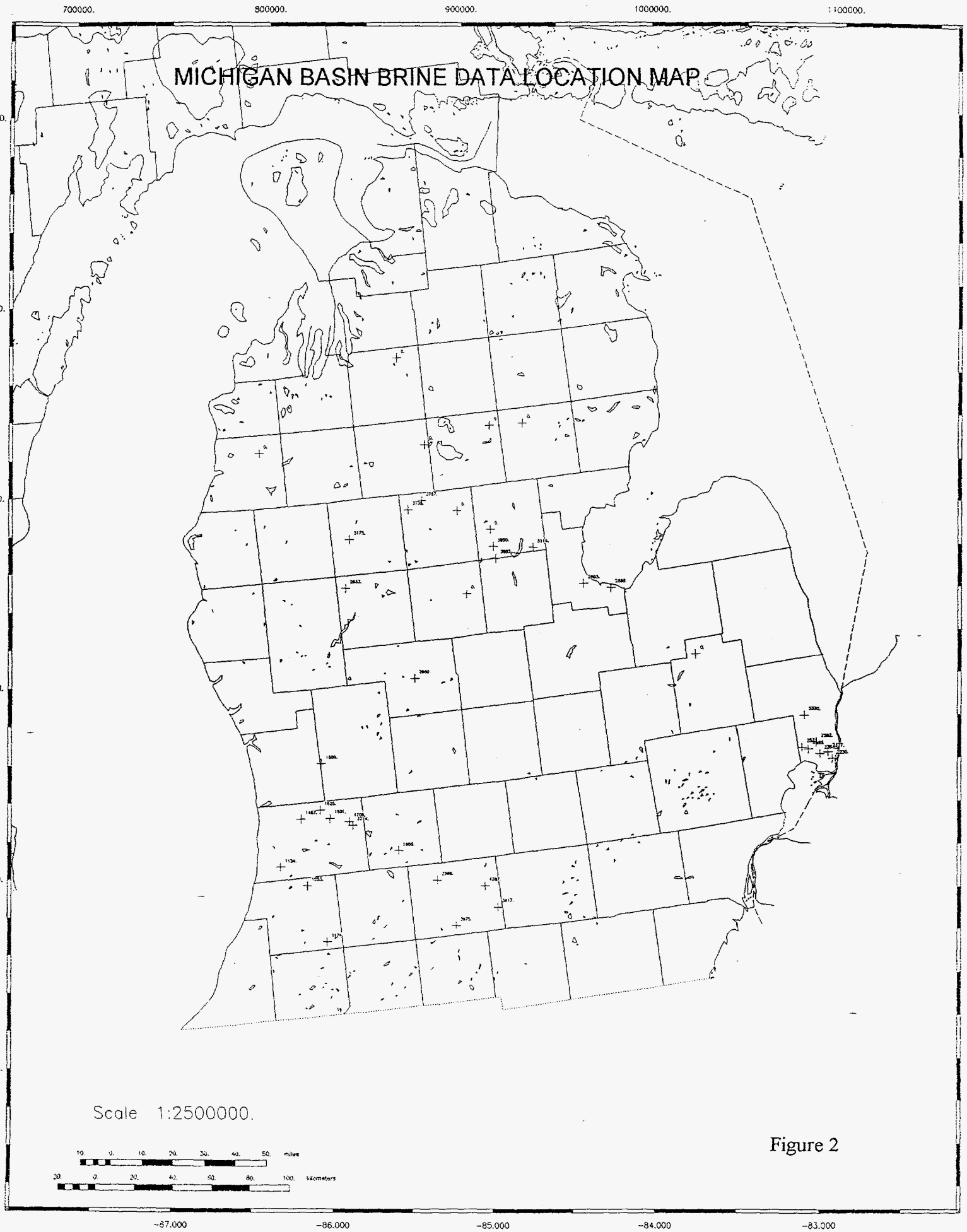


Figure 1

Prepared by wayne pennington 8/8/95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MICHIGAN BASIN BRINE DATA LOCATION MAP
Scale 1:2500000.
-87.000
-86.000
-85.000
-84.000
-83.000

Figure 2

Attachment 1

To: Richard Steinmetz **Date: October 10,1994**
Science Director, AAPG

From: A.S. Wylie, Jr. and J.E. Huntoon

Re: Practical Reservoir Characterization
A Nonjournal publication proposal to AAPG

Title of publication: PRACTICAL RESERVOIR CHARACTERIZATION

Compilation Authors: A.S. 'Buddy' Wylie, Jr. and Jackie Huntoon
Resumes attached

Format: Book, Computer Applications in Geology Series

Electronic Media Availability: WordPerfect 5.1

Table of Contents: Attached

Estimated number of Pages: 150-175

Numbers and Types of Descriptive Figures: Anticipate all b/w figures at 81/2" x 11" or smaller
b/w Line Drawings (garphs, maps, tables) - 50-75
b/w Photos - 5-15
color subjects - 5 (possible)

Sample Chapter Sections: Attached
Chapter 3, Log Data - Uniform log Curve Formats
Chapter 4, Log Normalization

Target Audience: Independent oil company geologists, goephysicists, engineers, and managers as well as major oil company technical information specialists involved in reservoir characterization at the field, exploration and exploration scale; university and government faculty, students and researchers involved in reservoir characterization and data mangement in petroleum related fields.

PRACTICAL RESERVOIR CHARACTERIZATION

Techniques for database construction and analysis
to find and produce more oil and gas.

A Nonjournal publication proposal to AAPG

Purpose

To provide a present-day cutting-edge guidebook to help the practicing explorationist, technical manager, and independent oil & gas company understand the steps requirted in building a working, productive, bottom-line oriented, technical computer database. The use of this book will enable these individuals to significantly increase the value of their company's asset bases through the practical application of computer-based technical data mangement. Finally, it will aid them in recognizing the person-power, time, money, and management commitments needed to ensure a successful and productive reservoir characterization project.

A.S. 'Buddy' Wylie, Jr.
and
Jackie E. Huntoon

October 10, 1994

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Chapter 4

Chapter 5

Characterization of the Dundee Formation, Winterfield Field, Clare County, Michigan

Steve Chittick, Charles Salotti, James R. Wood, Wayne Pennington, S. Douglas McDowell, Jacqueline Huntoon: Michigan Technological University, William Harrison III: Western Michigan University

ABSTRACT

The Devonian Dundee Formation of the Winterfield field was originally developed in the late 1930's and early 1940's and rapid production helped support the U.S. war effort. Poor completion and production practices may have caused the field to have been inefficiently developed, and wells prematurely watered out due to water coning. There were several competing producing companies on the western side of the field, which may have influenced rapid production.

Production occurs in porous dolomitized "chimneys" where they extend above the oil-water contact within the otherwise "tight" limestone. Cross plots of the PEF (Photoelectric) log and the LLD (deep lateral) log separate the porous, oil-saturated dolomite from water-saturated dolomites and the "tight" limestone. The PEF distinguishes the lithologies (dolomite and limestone) and the LLD separates the fluids (water and oil); other useful logs are the CNL and GR to indicate porous and shale zones respectively. The dolomite "chimneys" are small in scale, less than 60' high and can be laterally discontinuous between wells on 40 acre spacings. The dolomite zones tend to have good porosity and permeability; the API gravity of the oil is 44.2 and the reservoir is produced by a strong, constant water drive. Initial production tests on some wells indicate the ability to produce up to nearly 2000 barrels per day (BOPD).

Wells drilled in the 1980's to the deeper Richfield intercepted an isolated oil pocket in the Dundee off structure, prompting further drilling activity; subsequent production has significantly added to the cumulative production in the field. We believe that due to the heterogeneity of the reservoir, the strong water drive, the low density of the oil and the relatively high permeabilities, this reservoir and others like it are ideal candidates for horizontal drain technology. The horizontal wells could link "chimneys" that have previously been untapped, significantly adding to the total production of these Dundee fields.

Attachment 3

THE DUNDEE FORMATION IN THE CENTRAL MICHIGAN BASIN: RELATIONSHIPS BETWEEN STRUCTURE, STRATIGRAPHY, PRODUCTION, AND THE MID-MICHIGAN GRAVITY HIGH

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The Devonian Dundee Formation has been the most prolific hydrocarbon producer within the central Michigan Basin accounting for more than 352 million barrels of oil and 42 billion cubic feet of gas. Recent studies focus on characterizing thirty Dundee fields to identify areas that potentially may produce more oil using horizontal drains. Characterization of the Dundee fields has led to interpretations about how the Dundee fields were formed. The association of favorable structure and stratigraphy within the anomalous regions of the Mid-Michigan Gravity High suggests that basement structure influences production.

A base map of the Michigan Basin including political boundaries, Dundee oil fields, and contoured Bouguer gravity data was created using data from several governmental and private sources. Initial display of the data seems to indicate a visual correlation of field trends and position with the southern extension of the Mid-Michigan Gravity High. The Mid-Michigan Gravity High may represent Keweenawan basement rocks associated with a failed rifting event. It is speculated that movement along old basement faults between Ordovician and Mississippian times facilitated fracturing of brittle basin rocks in zones of highest flexure; core from the Crystal field's Cronus Development Corporation Tow #1-3 indicates fractured carbonate rocks and shales with slickensides above and within the Dundee interval. Second derivative plots of gravity data and structure surface data were created in an attempt to correlate gravity with structure.

It is anticipated that the results of this work will aid in selecting current Dundee fields for further development using horizontal drain technology and as an aid to exploration for new Dundee fields.