DOE Award no.: DE-FE0002111

Final Report

July 17, 2014

Title: Recovery Act: Develop a modular Curriculum for Training University Students in Industry Standard CO2 Sequestration and enhanced Oil recovery Methodologies

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Abstract

CO_2 Enhanced Oil Recovery, Sequestration, & Monitoring Measuring & Verification are topics that are not typically covered in Geoscience, Land Management, and Petroleum Engineering curriculum. Students are not typically exposed to the level of training that would prepare them for CO_2 reservoir and aquifer sequestration related projects when they begin assignments in industry. As a result, industry training, schools & conferences are essential training venues for new & experienced personnel working on CO_2 projects for the first time. This project collected and/or generated industry level CO_2 training to create modules which faculties can utilize as presentations, projects, field trips and site visits for undergrad and grad students and prepare them to "hit the ground running" & be contributing participants in CO_2 projects with minimal additional training.

In order to create the modules, UTPB/CEED utilized a variety of sources. Data & presentations from industry CO_2 Flooding Schools & Conferences, Carbon Management Workshops, UTPB Classes, and other venues was tailored to provide introductory reservoir & aquifer training, state-of-the-art methodologies, field seminars and road logs, site visits, and case studies for students. After discussions with faculty at UTPB, Sul Ross, Midland College, other universities, and petroleum industry professionals, it was decided to base the module sets on a series of road logs from Midland to, and through, a number of Permian Basin CO_2 Enhanced Oil Recovery (EOR) projects, CO2 Carbon Capture and Storage (CCUS) projects and outcrop equivalents of the formations where CO2 is being utilized or will be utilized, in EOR projects in the Permian Basin. Although road logs to and through these projects exist, none of them included CO2 specific information. Over 1400 miles of road logs were created, or revised specifically to highlight CO_2 EOR projects. After testing a number of different entry points into the data set with students and faculty form a number of different universities, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student modules.

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Executive Summary

CO_2 Enhanced Oil Recovery, Sequestration, & Monitoring Measuring & Verification are topics that are not typically covered in Geoscience, Land Management, and Petroleum Engineering curriculum. Students are not typically exposed to the level of training that would prepare them for CO_2 reservoir and aquifer sequestration related projects when they begin assignments in industry. As a result, industry training, schools & conferences are essential training venues for new & experienced personnel working on CO_2 projects for the first time. This project collected and/or generated industry level CO_2 training to create modules which faculties can utilize as presentations, projects, field trips and site visits for undergrad and grad students and prepare them to "hit the ground running" & be contributing participants in CO_2 projects with minimal additional training.

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After testing a number of different entry points into the data set with students and faculty form a number of different universities, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student modules. As a result of the 3 Young Professional Field Trip run in 2011, 2012, and 2013, and discussions with faculty at Midland College, Sul Ross State University, and UTPB and industry professionals following presentations at society meetings, it became clear that in order to make the modules accessible and "user friendly" that associating the modules with the 1400+ miles of Field Trip/Road Logs was the most logical presentation format. STARS are located at specific CO2 related locations on the road logs. These Stars are points where a number of related Engineering, Geologic, and Land Management powerpoints, PDF's of DOE sponsored CO2 related projects, Core Descriptions and Analyses, Water Chemistry excel spreadsheets, and well top *files* provide an opportunity for team and cross-training.

The modules were developed, tested and presented to audiences at Univ. Texas Permian Basin, Midland College, and Sul Ross State University, and presented to industry interns, representing a number of regional and national universities, and new hire professionals on a number of occasions to check their veracity, obtain feedback on clarity, usefulness and content. The modules have been made available to other regional universities.

With a rapidly graying workforce, the CO_2, EOR and Sequestration industries are hard pressed to maintain adequate numbers of skilled workers. If the universities do not participate with industry in preparing students for entry into the CO_2 industry, time will be wasted till "on the job" training & in-house & industry schools come available. UTPB, partnering with industry professionals makes it the most logical site to develop CO_2 related training for students. Industry agreed to donate data for this project.

1.0 PROJECT OBJECTIVES

The project goal was to develop, test and disseminate a modular curriculum to interested universities. Provide modules to faculty to allow them, with a minimum of effort to provide this training to the students. UTPB has develop a working relationships with industry partners which allows the university to maintain knowledge of CO_2 related state-of-the-art technologies and methodologies and be capable of periodically updating the modules.

The primary objective of this project was to create a modular CO_2 Brine Aquifer and EOR Sequestration curriculum for university level use. This curriculum can be utilized in Petroleum Geoscience, Engineering and Land Management senior undergraduate and graduate level classes, symposia, and field seminars to develop critical skill sets which will be utilized once the students have graduated and begun careers in CO_2 related positions in pertinent industries. Where possible, previous DOE sponsored CCUS related research project outcomes were utilized in this study.

The expected outcome of the project was to provide students with a CO_2 relevant skill set prior to employment in the EOR, Carbon Capture Utilization and Storage (CCUS) or Carbon Capture and Storage (CCS)/Sequestration industry. The field trip based modules allow faculty to bring students to the Permian Basin of West Texas and Southeastern New Mexico and spatially place the CO_2 EOR and CCUS industry in context. These skill sets enable them to reduce the time, training and effort necessary to reach the point where they can be effective contributors and independently manage CO_2 projects with a minimum of supervision.

The ultimate objective of the effort was to develop training modules and best practices to assist students and others with characterizing CO_2 Sequestration and EOR recovery projects. It was also intended to assist with helping student understand the importance of maximizing the use of ROZs for storage volumes, providing clues of upward leakage paths (e.g., sulfur deposits) and estimating lateral connectivity of reservoirs.

The Field Trip/Road Log based Modules were developed as a result of the 3 Young Professional Field Trip run in 2011, 2012, and 2013, and discussions with faculty at Midland College, Sul Ross State University, and UTPB and industry professionals following presentations at society meetings. It became clear that in order to make the modules accessible and "user friendly" that associating the modules with the Field Trip/Road Logs was the most logical presentation format. STARS are located at specific CO2 related locations on a base map entry point to the modules and on the road logs as a reference point for the modules. These Stars are points where a number of related Engineering, Geologic, and Land Management powerpoints, PDF's of DOE sponsored CO2 related projects, Core Descriptions and Analyses, Water Chemistry excel spreadsheets, and well top *files* provide an opportunity for team and cross-training.

There are 6 field trips/road logs, totaling over 1400 miles in length which form the basis for the curriculum. Each road log either ends at a CO_2 EOR project (North Ward Estes and Seminole Fields) or passes through/by a significant CO_2 EOR Project or CCUS project (Goldsmith Field, Summit's Texas Clean Energy Project). A base map with the road log routes, Figure 1, is the primary entrance to the modules. In addition to introductory information about CO_2 utilization in the Permian Basin at the

beginning of each road log, sets of geologic, engineering, and land power point modules, articles, and other data sets are linked at specific CO_2 related points.

Included in a complete module (Star) is access to engineering, geology and land PowerPoints, core descriptions, logs, excel spreadsheets of data, references, and other data. These are tied to the Road Logs and serve as both standalone data sets for classroom presentations and projects related to important CO2 related projects in the Permian Basin, and as introductory presentations for the Road Logs.

One important realization from the multiple "dry runs" with students is that some students are not going to be attentive and reading the road logs during the trip. Some students rest, some text (although there are places in the Permian Basin where there is no cell phone service) or be unable to read in a vehicle due to car sickness issues. Therefore, we stress presenting a summary of the road log prior to leaving for the field. Also, we stress orienting the students to their physical location, north orientation, and field or formation in outcrop. Especially in the Guadalupe Mountains it is easy for students to get "turned around" and become disoriented with respect to shelf to basin relationships and therefore reservoir geometries.

In an effort to determine levels of understanding and interest, presentations were made to faculty and students at Sul Ross University, Midland College, and the University of Texas of the Permian Basin. In addition, presentations were made to students from Texas Tech, New Mexico Tech, University of Oklahoma, Oklahoma State and the University of Texas at Austin in mixed group settings. The feedback from these presentations was sued to tailor the modules.

Approach / Results Discussion

Task 1. Development of Classroom Modules.

Field Trip/Road Log based Modules.

Testing of the geologic modules with students began during the 1st quarter of 2011, during the 3rd quarter of 2011, and the 2nd quarter of 2012, during the summer and fall semester. Feedback questionnaires (see Questionnaire, Appendix 1, 4th quarter 2010) on the "History of Production in the Permian Basin" presentation indicated more background on the Permian Basin was necessary to introduce geology and engineering students to Permian Basin Regional field development history, this module was tested with junior Petroleum Engineering students at UTPB and senior Geology students at UTPB and Sul Ross State University and results indicated a mixed reaction based on the level of engineering and geologic understanding. The data sets were adjusted and more introductory information added.

Presentations of many of the PowerPoints, and core/log analysis exercises were made to Petroleum Engineering students at UTPB during 2012 and 2013, and based on feedback, changes made to the presentations. General Engineering PowerPoints on CO2 Surface Facilities, CO2 Well Bore Management Issues, Facilities Engineering, CO2 Transportation, and CO2 Gas Lift are included. PowerPoints covering the different aspects of Reservoirs Engineering and the relationship of Engineering to Geology in a successful CO2 EOR projects are included for Foster

South Cowden, Goldsmith, and Vacuum Fields. A glossary of common engineering terms students will need to be familiar was updated and included. PDF's of DOE sponsored CO2 related projects are included as is a reference list of pertinent articles.

After testing a number of different entry points into the data set, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student modules.

As a result of the 3 Young Professional Field Trip to Carlsbad, New Mexico, run in 2011, 2012, and 2013, and discussions with faculty at Midland College, Sul Ross State University, and UTPB and industry professionals following presentations at society meetings, it became clear that in order to make the modules accessible and "user friendly" that associating the modules with the Field Trip/Road Logs was the most logical presentation format

There are 6 field trips/road logs, Table 1, which therefore form the basis for the curriculum. Each road log either ends at a CO_2 EOR project (e.g. North Ward Estes and Seminole) or passes through/by CO_2 EOR or CCUS project (e.g. Goldsmith, Summit's Texas Clean Energy Project). A base map with the road log routes is the primary entrance point to the modules. In addition to introductory information

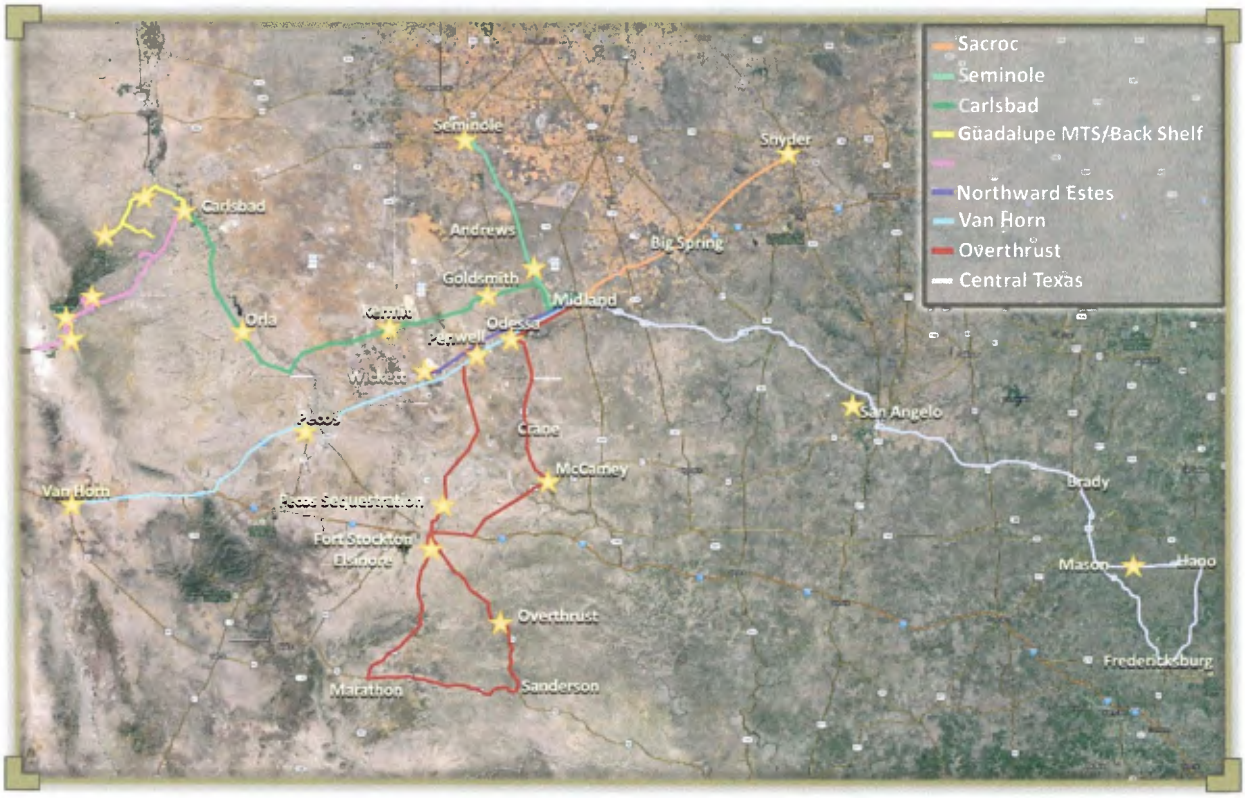

Figure 1. Base Map for Road Logs and the location of the STARS where the data sets are identified. The field trip road logs cover >1400 miles (one way). The Snyder road log is proposed to be added at a later date. See table 1 below for distances.

about CO_2 utilization in the Permian Basin at the beginning of each road log, sets of geologic, engineering, and land power point modules, articles, and other data sets are linked at specific CO_2 related points.

The entry "port" into the data set that made the best impression, and led the best potential use, was based on the map showing each of the field trip routes with strategically placed "**STARS**", Figure 1, with associated CO2 related features. Since some road logs follow the same path for a portion of the route, the Stars will be active for all the routes that cross them. For instance the Foster South Cowden Star is the same for The Wickett, Van Horn, and Sanderson routes. In some cases, material is projected in from some distance away, for example, the Orla Star materials on the Carlsbad Road log will also be available at the Pecos Star of the Van Horn Road Log. Since each of the routes begins in the Midland area, there is a write up of pertinent Permian Basin, and CO2, information at the beginning of each road log that introduces the user to CO2 in the Permian Basin. In addition, there is a set of power points, an Excel Spreadsheet, and a Word document that provides all the basic information that could be used in the classroom setting to introduce the students to general knowledge about the Permian Basin oil industry, and specific knowledge of CO2 Utilization and Storage. By linking the data sets to the road logs, faculty at other universities could use the road logs to lead field trips to the Permian Basin and have PowerPoints, core descriptions, excel spreadsheets, word and pdf documents available for classroom presentations and projects. For an example of how the module STARS work, consider the road log for the route from Midland to the North Ward Estes Field at Wickett in Ward Country. There is a STAR where the route crosses the Foster-South Cowden Field just west of Odessa in Ector County. By scrolling across the star a drop down menu appears with links to:

- "An integrated Study of an Old Oil Field, Foster South Cowden", a power point, reviewing a small producer team approach with a Reservoir and Production Engineers, Geologist and Geophysicist, and field personnel, to enhancing oil production in a 60 year old field with a >30 year waterflood, while maintaining access to old well bores and better preparing the field for potential CO2 flooding in the future.
- 4 core descriptions of the Grayburg and San Andres reservoirs in the Laguna #11 Foster, Laguna #11 Foster Pegues, Laguna #12 Witcher and Sun #6 Witcher presented in Adobe Illustrator format, for use in a cycle/cycle set/flow unit correlation exercise. The cycles and cycle set data can then be imported into a reservoir simulator as flow units.
- A spreadsheet of all the available Foster Field Core Analyses for parsing the data set by field, flow units, or variations in porosities and permeabilities in the units and access the effectiveness of the waterflood.
- A spread sheet of produced and injected water chemistry data and a companion excel spreadsheet for creating Stiff Diagrams which plots the water chemistry data and allows of comparison of the data to see how the flood sweep has changed thru time.
- In addition, there are pdf versions of DOE final reports on Foster-South Cowden and South Foster Fields.

Information for faculty at other universities on how to acquire the Modules was delayed until the Road Log Base Map and associated STAR locations was refined. Recently an upgrade of the UTPB Website in response to changes in ADA statues resulted in the changes to the http://www.utpb.edu/ceed/student_modules website. An initial draft of the website layout was

discussed the UTPB, MC, and SRSU faculty and staff. The original design was not based on the Field Trip/Road Logs, rather a summary of the Modules with examples of the type of material they contained. This was deemed to be lacking in a "hook" for faculty and students at other universities to want to go deeper into the website to view the modules. It was not until June of 2013 following the final Young Professionals Field Trip that the concept of using the Field Trip/Road Logs as the base for accessing the Modules was developed. The rational for this being the base for identifying modules with significance to faculty and students was that potential users could immediately see the spatial relationship of the Road Logs, fields where CO2 is being utilized in EOR, pipelines, sources, and CCUS projects.

Presentations made in Midland Texas, Bakersfield California, Lawrence Kansas and Denver Colorado to industry groups as part of the RPSEA Program included information on the Modules being developed for this grant. Several suggestion were incorporated into the project design. As the result of a presentation made in the 3rd quarter 2011, staff from New Mexico Tech indicated interest in using our modules, however, those staff have since left New Mexico Tech. This is a common occurrence with the significant increase in drilling activity in the Permian Basin and elsewhere. Faculty and staff from UTPB, MC, and New Mexico Tech have all left for industry positions during the duration of the project, reducing the effectiveness of discussions with, and presentations to these contacts.

Task 2. Sequestration Related Modules.

The shift in Department of Energy philosophy away from simple CCS, and toward Carbon Capture, Utilization and Storage (CCUS) during the 3rd and 4th quarters of 2011 was duly noted and modules on: Key Elements of Reservoir Geology as it Applies to CO2 Floods (see the Midland Star); Seismic Techniques for Monitoring CO2 Flood Response Through Time (See West Pearl Queen (Carlsbad Star, and Geophysical Techniques, Midland Star); and Geologic Reasons Why CO2 Floods Fail, were identified, modified and developed for the project. A module on Residual Oil Zones (ROZ's) as a major CCUS target was presented at Sul Ross during the 2nd quarter 2010 and again during the 4th quarter 2010 at UTPB. As a result of student responses a revised version of the module was presented during the 2nd quarter 2011, and again during the 4th quarter of 2011 at UTPB with favorable comments. A module on the presently available natural occurring sources of CO2 for EOR projects was also added (see Midland Star).

Each Star contains modules, that stress the need for integrated Geological, Engineering, Land and field management cooperation to avoid subsurface problem that are common to Enhanced Oil Recovery projects and Brine Aquifer Storage projects (see Key Elements PowerPoint in Midland Star). These problems typically center on a lack of complete understanding of the heterogeneities of the reservoir/aquifer (see the Foster South Cowden Star Foster Field Waters PowerPoint). A series of PowerPoints and a PDF of the FutureGen Environmental Information is the best source for evaluating the potential for CCUS in the Permian Basin and is available in both the Penwell FutureGen Star and the Pecos Sequestration Star. A module documenting the development of Residual Oil Zones (ROZ's) as a CO2 EOR target (see ROZ's Team Concept PowerPoint in the Midland Star) is also an excellent entry into CO2 in the Permian Basin. This module includes a review of the proposed models for the creation of ROZ's, a "size of the prize" estimate of potential reserves in the Permian and the

potential impact this will have on the potential to store CO2 beneath existing and potential oil fields. A presentation on "the Potential for long term uses of Anthropogenic CO2 in the Permian Basin (See Midland Star), made at the South Central Geological Society of America in Alpine, Texas in March 2011 introduces the concept of Potential for long term uses of Anthropogenic CO2 in the Permian Basin and elsewhere. An updated module based on this presentation is in progress.

At the Core Workshop during the West Texas Geological Society Fall Symposium in September 2012. Symposium, 3 wells, the Goldsmith Landreth San Andres Unit (GLSAU) #204R, GLSAU #190, and GLSAU #58,that had been described as part of this project were presented. The field is a small producer CO2 project in the Goldsmith Landreth San Andres Unit of the Goldsmith Field, Ector County, Texas. This field is described in the CEED to Carlsbad Road Log (Goldsmith Star) and the road log and core descriptions can be utilized together as a class room module and field trip road log set. A total of 7 cores in the GLSAU portion of the Goldsmith Field have been described and included in Goldsmith Star.

The RPSEA ROZ Modeling Project was successful in testing the model for "Mother Nature's Waterflood" of ROZ Zones in the Permian Basin. Although the modeling results are for meteoric waters, the parameters can be applied to CO2 moving through the system. The modeling resulted in the development of parameters for the movement of meteorically derived waters of the Artesia-Western Central Basin Platform Trend. These parameters included: Number of pore volumes of fluid moved through the system range from 19 to 51 based on a porosity that ranges from 6% to 16%; The time frame is 15,000,0000 years; The low flow portions of the San Andres had flow rates that ranged from 0.8 to 2.1'/thousand years; The core of the high flow zone had a flow rate that ranged from 317 to 847'/thousand years; the total flow volume is 6.54683E+12 cubic feet; Flow rate through the high K zone was 6.21 GPM, the total flow through the San Andres section was 7.23 GPM; From the perspective of the movement of groundwater mass or sweeping action that portion of the San Andres represented by conditions of high porosity and High Conductivity (relatively speaking) were significantly dominant. This is important work which can also be used to advance the understanding of the potential for CO2 to remain in the reservoirs where it is sequestered. Essentially, groundwater in this San Andres reservoir in the Permian Basin will move less than 1' per year over 1,000 years. CO2 is proposed to have similar velocities.

Task 3. Engineering and Geoscience Reservoir Studies Modules.

Field specific and general engineering PowerPoints, and spreadsheets were created and an attempt made to coordinate them with the geologic PowerPoints and core descriptions wherever possible. The Core based Reservoir Studies for McCamey, Foster South Cowden, Vacuum, Goldsmith, South Leonard, and Ford Geraldine have associated core analyses (where available), and produced water chemistry data that allow for coordinated exercised between engineering and geology. The Vacuum Field Team project was specifically designed to create a "real world" example of how the three disciplines work together on projects. A list of the engineering, geology, and land management PowerPoints, spreadsheets, word Doc's pdf are found in Appendix 1. PDF version of a number of DOE sponsored project Technical and Final Reports and other reports are found in Appendix 2. The DOE sponsored, and other projects

(Tenaska Trailblazer) are included, see Appendix 2 for complete list, as they are excellent references for the powerpoints and other data associated with the Foster South Cowden, Orla, San Angelo, and Carlsbad Stars.

A number of modules include information on "Green Field" ROZ targets and their potential includes documentation on the types and range of information required (DST's, core analyses, log analyses, royalty and legal questions) A Module on the Causes and Solutions for Marginally Successful Projects cannot be completed unless and until additional data on reservoir parameters (oil saturate ranges, porosity and permeability, salinity of lateral flushing fluids) is collected. From the data collected and included in the Goldsmith module, it apparent that the minimum oil saturation in the ROZ's will need to be in the range of 20% to be economic. Additional data from research presently underway at the Enhanced Oil Recovery Institute (EORI) in Wyoming will be used to better quantify this value.

Task 4. Field Seminars.

It is important to stress that although the road logs lead to each of the fields, permission to leave the hiway and enter the field MUST be obtained each and every time a group wants to enter the field or facilities. This must be done far enough in advance to allow the request to pass through the "Chain of Command". Due to the nature of the oil fields today, giving a list of contacts names and phone numbers is almost out of date before it is published. Therefore, we recommend that anyone wanting to gain access should go thru the local public relations person for the company to begin the process of gaining access for a tour.

"Dry Runs" for CO2 EOR Field Trips to all the major CO2 EOR projects covered in the modules: Seminole, North Ward Estes Goldsmith, and Vacuum Fields were completed. The Seminole Field is the "Cadillac" of field operations. The field has been in CO2 flood for more than 30 years and their surface facilities are considered to be the industry "gold standard". The Goldsmith Field CO2 flood is less than four years old and is an example of a small operator using lower cost CO2 flood processes (there has been a change in operator recently). Whereas the Seminole Field injects >240 MMCF CO2 per day, and has a large CO2/Methane/NGL separation facility costing $300,000,000 to build over 30 years, Goldsmith injects ~45 MMCF CO2 per day (up from 25 MM in the 4th quarter of 2010) and has built their separation facility for considerably less.

A Road Log to the southern portion of the Permian Basin where sources of CO2 was developed. and included crossing a proposed CO2 Sequestration Site for the FutureGen site in Pecos County, and pass an area where an attempt was made in the 1970's to tap CO2 from the lower Ordovician Ellenburger. The road log also pass Oxy's new "Century Plant" which is separating CO2 from produced natural gas. and through the Marathon Overthrust there multiple horizons produce a mix of natural gas up to 70% CO2. The road log also passed through the McElroy CO2 EOR Project in Crane County. Due to the rapid pace of work in the oil industry, some materials that were expected to be made available to the project have been delayed. "mud logs" for producing formations crossed in the Overthrust, and Central Texas road logs are not yet available for insertion.

Task 5. Field Trips to Analogs of CO2 Sequestration, EOR, and ROZ EOR Targets.

As discussed above in Task 1. Development of Modules, after testing a number of different entry points into the data set, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student modules.

As a result of the 3 Young Professional Field Trip run in 2011, 2012, and 2013, and discussions with faculty at Midland College, Sul Ross State University, and UTPB and industry professionals following presentations at society meetings, it became clear that in order to make the modules accessible and "user friendly" that associating the modules with the Field Trip/Road Logs was the most logical presentation format

Field Trip Road Log Name	Distance
Midland to Wickett North Ward Estes	66.9 miles, one way
Midland to Seminole	61.8 miles, one way
Midland to Van Horn	184.2 miles, one way
Midland to Carlsbad	149.3 miles, one way
Carlsbad to Salt flat	133.8 miles, round trip
Carlsbad to Rocky Arroyo, Sitting Bull Falls, Dark Canyon	88.8 miles round trip
Overthrust	394.3 miles, round trip
Mason	330.7 miles, one way

Table 1. Field Trip Road Logs and distances.

There are 6 field trips/road logs, two examples from those road logs are shown in Figure 2, which therefore form the basis for the curriculum. Each road log either ends at a CO_2 EOR project (e.g. North Ward Estes and Seminole) or passes through/by CO_2 EOR or CCUS project (e.g. Goldsmith, Summit's Texas Clean Energy Project). A base map with the road log routes is the primary entrance point to the modules. In addition to introductory information about CO_2 utilization in the Permian Basin at the beginning of each road log, sets of geologic, engineering, and land power point modules, articles, and other data sets are linked at specific CO_2 related points. See Appendix 3 for the complete Carlsbad Road Log with figures.

A

Interval Mileage	Cumulative Mileage	Description
		Welcome to the Carbon Capture and Storage Field Trip to the Guadalupe Mountains. Today, we will leave the Center for Energy and Economic Diversification located at the intersection of SH 191 and FM 1788 in western Midland County between Midland and Odessa and head west on SH 191 through Odessa. We will then be driving west on SH 302 thru Notrees, Kermit and Mentone. Turn north on US 285 to Orla and west on FM 652 to US 62 /180, west/south on US 62/180 to Pine Spring and the Salt Flat Graben. Then backtrack to Carlsbad. On this trip we will be reviewing the Permian Guadalupian basin and shelf deposits in the Delaware and Guadalupe Mountains and the utilization of CO2 in Enhanced Oil Recovery project in the Permian Basin. CO2 has been utilized in Enhanced Oil Recovery projects in the basin for the past 40 years. Today, 4 billion cubic feet of CO2 is "handled" daily in over 60 producing oil fields. Over 200,000 barrels of oil per day is recovered as a direct result of injecting CO2 into the oil reservoirs. To date, over 1 Billion barrels of oil has been produced from field as a result of CO2 flooding. We will be crossing a number of fields and pipelines where CO2 is transported, injected, produced, and separated on a daily basis.

B

Interval Mileage	Cumulative Mileage	Description
3.5	19.2	Town of Goldsmith and Refinery to north. A CO2 flood of a portion of the Goldsmith Landreth San Andres Unit producing zone was initiated in 2009. In a "pilot" project in the field approximately ½ north of SH 158, there is 1 producing well and 6 injectors, as of December, 2010, Legado Resources was injecting 27.7 MMCF CO2 a day. Over the next few years, CO2 injection will commence in a major portion of the field. This enhanced oil recovery project was initiated by a small producing company proving that CO2 EOR is not restricted to major oil companies. The company is flooding the Residual Oil Zone where the original oil saturation at discovery was ~30%. This is compared to the "main pay" where original oil saturations were 70-80%. The efficiency of CO2 in "sweeping" oil out of the reservoirs is so high that even at these low saturations, the ability of CO2 to recover high percentages of the remaining oil makes this process economic.

Figure 2. ROAD LOGS include information on the oil & gas reservoirs as well as CO2 Utilization/Sequestration Targets. A. Portion of introduction to Road Log to Carlsbad. B. Portion of Road Log to Carlsbad discussing the Goldsmith CO2 Flood.

ROAD LOGS STARS

After testing a number of different entry points into the data set, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student modules.

After many discussions with faculty and students from UTPB, Sul Ross, Midland College and other universities, and with fellow CO2 EOR workers, it was decided that the best method to present the assembled data was to link all the presentations and work products to a map of the

Permian Basin with the road logs prominently displayed. The entry "port" into the data set that made the best impression, and led the best potential use, was based on the map showing each of the field trip routes with strategically placed "Stars" with associated CO2 related features. Since some road logs follow the same path for a portion of the route, the Stars will be active for all the routes that cross them. For instance the Foster South Cowden Star is the same for The Wickett, Van Horn, and Sanderson routes. In some cases, material is projected in from some distance away, for example, the Orla Star materials on the Carlsbad Road log will also be available at the Pecos Star of the Van Horn Road Log. Since each of the routes begins in the Midland area, there is a write up of pertinent Permian Basin, and CO2, information at the beginning of each road log that introduces the user to CO2 in the Permian Basin. In addition, there is a set of power points, an Excel Spreadsheet, and a Word document that provides all the basic information that could be used in the classroom setting to introduce the students to general knowledge about the Permian Basin oil industry, and specific knowledge of CO2 Utilization and Storage.

By linking the data sets to the road logs, faculty at other universities could use the road logs to lead field trips to the Permian Basin and have power points, core descriptions, excel spreadsheets, word and pdf documents available for classroom presentations and projects. For an example of how the module STARS work, consider the road log for the route from Midland to the North Ward Estes Field at Wickett in Ward Country. There is a STAR where the route crosses the Foster-South Cowden Field just west of Odessa in Ector County. By scrolling across the star a drop down menu appears with links to:

- "An integrated Study of an Old Oil Field, Foster South Cowden", a power point, reviewing a small producer team approach with a Reservoir and Production Engineers, Geologist and Geophysicist, and field personnel, to enhancing oil production in a 60 year old field with a >30 year waterflood, while maintaining access to old well bores and better preparing the field for potential CO2 flooding in the future.
- 4 core descriptions of the Grayburg and San Andres reservoirs in the Laguna #11 Foster, Laguna #11 Foster Pegues, Laguna #12 Witcher and Sun #6 Witcher presented in Adobe Illustrator format, for use in a cycle/cycle set/flow unit correlation exercise. The cycles and cycle set data can then be imported into a reservoir simulator as flow units.
- A spreadsheet of all the available Foster Field Core Analyses for parsing the data set by field, flow units, or variations in porosities and permeabilities in the units and access the effectiveness of the waterflood.
- A spread sheet of produced and injected water chemistry data and a companion excel spreadsheet for creating Stiff Diagrams which plots the water chemistry data and allows of comparison of the data to see how the flood sweep has changed thru time.
- In addition, there are pdf versions of DOE final reports on Foster-South Cowden and South Foster Fields.

A Summary of the "STARS"

Midland Star

As the jumping off point for all the road logs/field trips, the Midland Star, includes a number of review power points, spreadsheets and a glossary, Table 2, that can/will be used in conjunction with each Road Log, including:

- The review of the Student Modules Training program (power point)

- BEG Hovorka CO2 Capacity fairways
- The History of the Oil and Gas in the Permian Basin (power point),
- History of Land in the Permian Basin (power point),
- Review of CO2 sources, both natural and Anthropogenic (power point),
- Introduction to CO2 Enhanced Oil Recovery Industry in the Permian Basin (power point),
- The Long Term Future of the Permian Basin (power point),
- The potential for long term uses of Anthropogenic CO2 in the Permian Basin (power point),
- Team Concept of Residual Oil Zones
- How to access the 3 primary sources of free log, production, and completion data: the Texas Railroad Commission (TRRC), University Lands (Texas), and the EMNRD (New Mexico) Oil Conservation Division (power point),
- There is information on downloading and using the 2 freeware log manipulation tools from Schlumberger, Blue View and Data View which permit users to create logs in different presentation formats for use in different software packages. BlueView log image manipulation software displays, annotates, edits, splices, and prints log images, and DataView software displays digital data on the screen with conventional log formats (power point),
- The Long Term Future of the Permian Basin
- A CO2 flood scoping spreadsheet from Kinder Morgan (excel)
- Booking EOR project reserves
- CO2 Wellbore Management Issues
- CO2 Surface Facilities
- Geophysical and Geochemical Techniques for Monitoring CO2 Floods
- A CO2 Glossary of Terms (word).

Midland Star	
BEG Hovorka CO2 Capacity fairways	PPT
Booking EOR project reserves	PPT
CO2 Wellbore Management Issues	PPT
CO2 Surface Facilities	PPT
EOR Industry Permian Basin Overview	PPT
Glossary	DOC
Pipeline Construction – Centerline Case History	PPT
CO2 Sources - Natural and Anthropogenic	PPT
Developing a Modular Curriculum for training University Students	PPT
Kinder Morgan CO2 Scoping CO2 projects San Andres 2008	Excel
Land in the Permian Basin	PPT
Potential for Long Term Use of Anthropogenic CO2	PPT
The History of Oil And Gas in the Permian Basin	PPT
The Long Term Future of the Permian Basin	PPT
Use of TX Railroad Comm, UTexas Lands and NM Oil Conservation Div well logs and Data	PPT
Team Concept of Residual Oil zones	PPT

Table 2. Midland Star including all available files.

Foster-South Cowden (Odessa) Star

By utilizing the Well Log Access power point, and the directions for accessing the Schlumberger Blue View and Data View free Software found at the Midland STAR, the user can view and work with the numerous logs for recently drilled wells in the Foster-South Cowden area. Although the Foster-South Cowden is not presently under CO2 Flood, the data set was utilized to evaluate the potential for a CO2 flood. The conclusion drawn from the data was that the Laguna Foster-South Cowden leases were not ready for a CO2 Flood. The review of data in the pdf of the DOE funded project, shows that the waterflood in this small producer operated, 880 acre lease was not optimized and need additional work before implementing a CO2 Flood. A summary of the data sets available for the Foster South Cowden Star shows the variety of data:

- "An integrated Study of an Old Oil Field, Foster South Cowden", a power point, reviewing a small producer team approach with a Reservoir and Production Engineers, Geologist and Geophysicist, and field personnel, to enhancing oil production in a 60 year old field with a >30 year waterflood, while maintaining access to old well bores and better preparing the field for potential CO2 flooding in the future.
- 4 core descriptions of the Grayburg and San Andres reservoirs in the Laguna #11 Foster, Laguna #11 Foster Pegues, Laguna #12 Witcher and Sun #6 Witcher presented in Adobe Illustrator format, for use in a cycle/cycle set/flow unit correlation exercise. The cycles and cycle set data can then be imported into a reservoir simulator as flow units.
- A spreadsheet of all the available Foster Field Core Analyses for parsing the data set by field, flow units, or variations in porosities and permeabilities in the units and access the effectiveness of the waterflood.
- A spread sheet of produced and injected water chemistry data and a companion excel spreadsheet for creating Stiff Diagrams which plots the water chemistry data and allows of comparison of the data to see how the flood sweep has changed thru time.
- In addition, there are pdf versions of DOE final reports on Foster-South Cowden and South Foster Fields.

The complete list of available data is seen in Table 3. The DOE Class II, Shallow Shelf Carbonate Foster-South Cowden Field study was originally designed to demonstrate that a small producer can utilize an integrated team approach to extend the access to wellbores in an old waterflood, see DOE Final Report pdf. It was originally estimated, in 1994, that the field would become uneconomic by the year 2012. The field, discovered in the 1930's, Herald, (1957), was on a steady decline and wells, on the 880 acre lease, and were expected to be producing less than 1 BOPD on average by 2012 if nothing was done to improve production. In addition, the effort was to include an attempt to maintain access to wellbores in the belief that at some point in the future (post 1994) the leases would be placed under CO2 Flood. Thru the integrated use of core, logs, well data, a history match and simulation, and 3D seismic, the production was vastly improved and access to the well bores extended well beyond to original 2012 deadline. During the study, however, it was discovered that the "size of the prize" of a CO2 flood was much smaller than originally estimated.

The South Cowden Field pdf is the final report of the DOE Class II, Shallow Shelf Carbonate effort to utilize horizontal wells as injectors in a CO2 flood by a major oil company. This project too had less than desirable results. It is important to stress that not all

Foster South Cowden Star	
Foster Field Case History of Water	PPT
Foster Oil Field Waters	PPT
Foster South Cowden Cores	PPT
Foster South Cowden Engineering	PPT
Foster South Cowden Summary	PPT
Foster Waters	Excel
Laguna #11 Foster Logs	TIF
Laguna #11 Foster Pegues Logs	TIF
Laguna #12 Witcher Logs	TIF
Laguna #2 Witcher Logs	TIF
Laguna All Core Analyses Data	Excel
Laguna #11 Foster Core Description	JPG
Laguna #11 Foster Pegues Core Description	JPG
Laguna #6 Witcher Core Description	JPG
Laguna #12 Witcher Core Description	JPG
Laguna Foster South Cowden Technical Report	Adobe PDF
Phillips South Cowden Technical Report	Adobe PDF
Stiff Plot Generator	Excel
Stiff Plot Generator with Data	Excel

Table 3. Foster South Cowden Star including all available files.

fields/waterfloods are ready for CO2 flooding as they exist, and that although not all projects are going to be economic successes (See North Ward Estes below), North Ward Estes is an example of a CO2 project that had less than desirable results during the initial flood, but has achieved success almost 20 years after the original project was initiated.

Penwell Star

The Penwell Star centers on the original FutureGen Integrated Gasification Combined Cycle (IGCC) coal fired, near zero emission, combined cycle power plant concept, jointly supported by government and industry. The Permian Basin FutureGen proposal was one of 4 finalists for the Integrated Gasification Combined Cycle facility site. However, the Penwell site was not chosen as the location for the plant. Instead, Mattoon, Illinois was chosen, however the plant was never constructed. The final presentation documents for the Permian Basin proposal are included as a pdf for this Star. A study of the CO2 Sequestration Site, 50 miles to the south in Pecos County and how and why this area so far from the plant site was chosen. A study of the potential water sources for the IGCC plant is included.

It is important to note that although the Penwell site was not chosen for FutureGen development, Summit Power chose the Permian Basin FutureGen site proposal an a base line for a commercial project. The Texas Clean Energy Project (TCEP) is a "NowGen" Integrated Gasification Combined Cycle (IGCC) facility that will incorporate Carbon Capture and Storage (CCS) technology in a first-of-its-kind commercial clean coal power plant. TCEP will be a 400MW power/poly-gen project that will also produce urea for the U.S. fertilizer market and capture 90 percent of its carbon dioxide (CO2) – approximately 3 million tons per year (120 MMCFCO2/day) – which will be used for enhanced oil recovery (EOR) in the West Texas Permian Basin. It is anticipated that construction of the plant will begin in 2014.

Penwell / Pecos Storage Star	
CO2 Pipeline Maps	PPT
Energy Bill 2005 FutureGen Coal Gasification	Word
FutureGen Penwell Environmental Information	PDF
FutureGen Multiple Potential Water Sources	PPT
FutureGen Penwell CO2 Capture	PPT
FutureGen Road Trip 8-21-06	PPT
BEG FutureGen CCS Texas Tinker	PPT
Insoluble Residues Pecos Sequestration Site Geology	PPT
CO2 Sequestration Site-Defining a Target	PPT
Pecos Sequestration - Sul Ross Presentation	PPT
Pecos CO2 Sequestration	PPT
Pecos Sequestration Delaware Mountain Group	PPT
Santa Rosa Schuyler Wight Ranch	PPT
FutureGen Proposal	PPT

Table 4. Penwell/Pecos Storage Star including all available files.

For the Midland to North Ward Estes, and Midland to Van Horn Road Logs, this is the point where the files for the CO2 Sequestration site in Pecos County will be included. The module includes these files also although the field trip does not pass the Pecos sequestration site, it is important to have this data available. This set of files will also be presented at the "Pecos Sequestration Site". The complete list of available data is seen in Table 4.

Wickett Star

There have been 2 CO2 EOR projects in the upper Guadalupian Yates Sands of North Ward Estes. The original 6 section (3,800 acre) project on the Hutchins Stock Association (H. S. A.) lease was initiated by Chevron in 1989, and completed in 1998. See Winzinger, et.al., (1991), and Chou, et.al. (1992). A power point on why the Chevron CO2 EOR project did not meet expectations is included. The second project was initiated by Whiting Petroleum in 2007 on the G. W. O'Brien lease and has expanded to include both the G. W. O'Brien leases in Ward and Winkler county and parts of the H. S. A. Leases in Ward County. In addition, Whiting has expanded the CO2 flood to the middle Guadalupian Queen Formation, which is 300 – 500'

below the Yates. A major new method for simultaneous gas lift and chemical treatment in producing CO2 flood wells has been presented at a number of CO2 EOR conferences and schools and been the focal point of a number of industry field trips including foreign nationals from China, Japan, and Indonesia. The Gas Lift and Scale Inhibition program that has been successfully developed at N. W. E. is being duplicated in other CO2 floods in the basin, and elsewhere. CO2 is being used to "lighten" the produced fluid in the producing wells by injecting ~100MCFCO2/day. This process reduces costs by eliminating the need for a pump, rods, and pump jack during the initial phase of production and the need to workover the well and remove the pump and rods when the well begins to flow. At the point when the wells begin to flow from the injection support, the Gas Lift injection is ceased. A power point documenting this new technology is included. The complete list of available data is seen in Table 5.

Whiting is currently injecting approximately 390MMcf/d of CO2 into the field, of which about 32% new CO2 and 68% recycled gas. Net production from North Ward Estes averaged 9.6 MBOE/d for the third quarter of 2013. It is apparent that a significant fraction of the injected CO2 is retained in the reservoir.

Geologically, the Yates and Queen Formations are a series of shelf sands that are reworked during succeeding seal level rises and separated by thin shallow marine dolomites that serve as corelatable barriers to flow), Andreason (1992), Borer and Harris (1991), and Johnson (1982). The reservoir sands transition into updip sabkha seals. To the north in the New Mexico portion of the Queen trend along the west side of the Central Basin Platform, are two fields that can demonstrate the complex nature of the shelf sand reservoirs. The West Pearl Queen powerpoint is modified from is a presentation of the results of the Sandia National Labs injection test in the West Pearl Queen Field and the study of the outcrop equivalent in Rocky Arroyo.

Two Leonard South Field powerpoints are included to provide log and core analyses of a queen reservoir that demonstrates the complex relationships in a field that at first blush appears to be simple but has a more complex geometry which suggests potential for CO2 CCUS.

There is a power point which reviews the creation of Residual Oil Zones (ROZ's) which are large Enhanced Oil Recovery (EOR) Carbon Capture and Utilization and Storage (CCUS) targets. The power point discusses the origin of the ROZ that occur throughout the basin as the result of a meteoric derived "Mother Nature's Waterflood". It is believed that there is >30 billion barrels of recoverable reserves and an associated storage capacity in the ROZ CO2 floods for 6000cf CO2 for every barrel of oil produced. There is a pdf of the final report on the modeling of the Meteoric Derived flushing that has created the large potential ROZ target in the Permian Basin. Although the modeling focuses on the San Andres formation, there are a number of potential ROZ CO2 EOR targets in the basin. Beneath the North Ward Estes Field are 5 documented ROZ CCUS targets. Although there is only minor established primary production in these targets, there is believed to be 600' of ROZ targets in a 3000' think interval at North Ward Estes. The RPSEA sponsored ROZ Modeling Project was completed in 2012, and a PowerPoint included in the Wickett/North Ward Estes and Kermit Stars. This is important work which can also be used to advance the understanding of the potential for CO2 to remain in the reservoirs where it is sequestered. Essentially, groundwater in this San Andres reservoir in the Permian

Basin will move less than 1' per year over 1,000 years. CO2 is proposed to have similar velocities.

Wickett Star	
Artificial Lift with CO2 and Chemical Treatment	PPT
Gascoyne River - North Ward Estes Analog	PPT
North Ward Estes Overview - Hagist	PPT
Mother Nature's Waterflood - Artesia Trend	PPT
North Ward Estes Correlation Exercise	PPT
North Ward Estes Yates Facies	PPT
North Ward Estes - Why CO2 Floods Fail	PPT
South Leonard Queen Complex Geology Part 1	PPT
South Leonard Queen Complex Geology Part 2	PPT
Tenneco #9 and #28 Core Description	PPT
West Pearl Queen CO2 Flood - Pawar	PPT
Rocky Arroyo West Pearl Queen	PPT
West Pearl Queen DOE Report	Adobe PDF
West Pearl Queen Environmental Report	Adobe PDF
West Pearl Queen Sequestration Technical Report	Adobe PDF

Table 5. Wickett/North Ward Estes Star including all available files.

The RPSEA ROZ Modeling Project was successful in testing the theory that oil had been swept of portions of San Andres reservoirs by meteoric derived sweep (referred to as Mother Nature's Waterflood) during the uplift of the western part of the basin as a result of Basin and range Uplift. Although the modeling results are for meteoric water and oil, the parameters can be applied to CO2 moving through the system. The modeling resulted in the development of parameters for the movement of meteorically derived waters of the Artesia-Western Central Basin Platform Trend. These parameters included: Number of pore volumes of fluid moved through the system range from 19 to 51 based on a porosity that ranges from 6% to 16%; The time frame is 15,000,000 years; The low flow portions of the San Andres had flow rates that ranged from 0.8 to 2.1'/thousand years; The core of the high flow zone had a flow rate that ranged from 317 to 847'/thousand years; the total flow volume is 6.54683E+12 cubic feet; Flow rate through the high K zone was 6.21 GPM, the total flow through the San Andres section was 7.23 GPM; From the perspective of the movement of groundwater mass or sweeping action that portion of the San Andres represented by conditions of high porosity and High Conductivity (relatively speaking) were significantly dominant. This is important work which can also be used to advance the understanding of the potential for CO2 to remain in the reservoirs where it is sequestered. Essentially, groundwater in this San Andres reservoir in the Permian Basin will move less than 1' per year over 1,000 years. CO2 is proposed to have similar velocities.

Pecos Star

Although there are no CO2 projects in the immediate vicinity of the Pecos Star, going 45 miles north on U. S. 285, will lead to Orla. The Ford Geraldine and East Ford, Ramsey Sand, (Delaware Mountain Group) fields Where Conoco, the Texas Bureau of Economic Geology and Orla-Petco evaluated the potential for CO2 flooding in these submarine fan channel complex reservoirs. After the phase 1 evaluation of the Ford Geraldine potential. Conoco declined to continue into Phase 2 and the BEG and Orla-Petco completed the study in the East Ford Field. The objective of this Class 3 project was demonstrate that detailed reservoir characterization of slope and basin clastic reservoirs in sandstones of the Delaware Mountain Group in the Delaware Basin of West Texas and New Mexico is a cost effective way to recover a higher percentage of the original oil in place through strategic placement of infill wells and geologically based field development. Project objectives are divided into two main phases. The original objectives of the reservoir-characterization phase of the project were (1) to provide a detailed understanding of the architecture and heterogeneity of two representative fields of the Delaware Mountain Group, Geraldine Ford and Ford West, which produce from the Bell Canyon and Cherry Canyon Formations, respectively, (2) to choose a demonstration area in one of the fields, and (3) to simulate a CO 2 flood in the demonstration area. Other Delaware Mountain Group CO2 projects are: El Mar, 40 miles to the north on the Texas/New Mexico border, and Two Freds fifteen miles to the north. The complete list of available data is seen in Table 6.

The 4 core descriptions in Adobe Illustrator format, for the Tenneco Bateman #3-31 TXL, Continental #2-4 Russell, Continental #6-26 Ramsey and the Penrose Bateman, are Cherry Canyon age (the formation below the Bell Canyon studied in the Ford Geraldine Field)

Pecos Star	
Tenneco #3-31 TXL Core Description	JPG
Continental #2-4 Russell Core Description	JPG
Continental #6-26 Ramsey Core Description	JPG
Penrose #1 Bateman Core Description	JPG
East Ford Geraldine Geology Topical Report	Adobe PDF
East Ford Geraldine Reservoir Characterization	Adobe PDF
East Ford Geraldine Topical Using Old Electric Logs	Adobe PDF
East Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ouachita Tectonism	PPT
South Wells Cherry Canyon Cross Section	PPT
Cherry Canyon Isopachs	PPT

Table 6. Pecos Star including all available files.

provide an excellent example of the complexity of the submarine channel sands in the Delaware portion of the Permian Basin. These sands are good CO2 EOR targets, and have the potential as ROZ targets as well. The CCUS potential of the Delaware Mountain Group (Bell, Cherry, and

Brushy Canyon Formations) is enormous and as the group sits above the rapidly developing WolfBone unconventional resource play in the basin, there is an ever expanding data base for this interval. There is also a power point which describes the relationship of the 4 cored wells.

Since the 1950's it has been known that the lower Paleozoic rocks in the southwestern and southern Delaware Basin contains from 25 -100% naturally occurring CO2 in the Ellenburger, Fusselman and Montoya. This is the result of heating the margins of the basin during the Ouachita overthrust and Cenozoic Volcanism. Reference is made to the CO2 source in the southern overthrust as the high values of CO2 in gas produced from the Lower Paleozoic carbonate reservoir in this area. Conoco CO2 well.

Van Horn Star

The Apache Mountains are composed of Guadalupian age rocks that are equivalent to the producing formations on the Central Basin Platform: Grayburg, Queen, Seven Rivers, and Yates. The Yates and Queen are equivalent to the CO2 EOR projects at North Ward Estes. Additionally, rocks of Bone Spring and Cutoff (Unconventional Resources) are also present in the western portion of the range. To the north, in the southern Delaware Mountains, the Bell Canyon formation, including Ramsey Sand, Lamar Lime, and an upper Bell Canyon carbonate debris flow are present. The complete list of available data is seen in Table 7.

In the Beach Mountains to the northwest of Van Horn are the highly complex, PreCambrian, and lower Paleozoic rocks (including El Paso, Montoya, Fusselman, and SiluroDevonian) that are equivalent to the producing formations that already are (Devonian in North Cross and Mid Cross Fields, Crane & Upton Counties; Cordona Lake, Crane Co.; and Dollarhide and North Dollarhide Fields, Andrews County) or may become CO2 EOR targets (Ellenburger, Montoya, and Fusselman). The Hueco Formation and PowWow Conglomerate of the lower Wolfcamp are also present in outcrop. In the Sierra Diablo Range to the northwest, are outcrops of Clearfork and Abo, which are equivalent to the T Star (Abo) in Hockley County, and Dollarhide and Anton Irish (Clearfork) in Andrews and Hale Counties respectively. Unfortunately, access to the Sierra Diablo range has become difficult due to a change in ownership.

Van Horn Star	
Apache Delaware Mountains	PPT
Surface to Subsurface in the Permian Basin	PPT
Van Horn Sandstone Red Rocks Ranch	PPT

Table 7. Van Horn Star including all available files.

Pecos Sequestration Star

Although the FutureGen Request For Proposals had specified injecting the CO2 into two "Brine Aquifers" in a >10 section (6400 acres) area with a minimum of existing well bores and oil or Gas production on, or near, the power plant site, that was deemed impossible in West Texas. As a result of a search was initiated for: a township size area (36 sections) with one surface and subsurface owner, with a minimum of well bores and oil/gas production. It was determined that the best location was on University of Texas Lands Block 23 and 24 (each with 36 sections, equal to a Township) in northern Pecos county. There was no production, a minimal number of wells (all plugged and abandoned with multiple casing strings thru the "Brine Aquifer" intervals. As important is the presence of two Aquifers, the Queen and Cherry Canyon, with traps and seals. The complete list of available data is seen in Table 8.

A geologic reservoir characterization was completed to document the presence of 2 thick, porous, and permeable sands that would be capable of storing large volumes of CO2 for >1,000 years (a proposal requirement).

As there was a requirement to capture the CO2 and Store it, it would be necessary to transport the CO2 from the plant site 50 miles to the Sequestration Site. A compromise was proposed. CO2 was being transported north from the Overthrust and CO2 would be taken from one of the pipelines which crossed the University Lands Blocks could be substitute for the CO2 captured at the plant. CO2 captured at the plant would then be sent to the Central Basin Pipeline, which was only one mile east of the plant. This "trade" was acceptable to the DOE.

Pecos Sequestration Site Star	
CO2 Pipeline Maps	PPT
Energy Bill 2005 FutureGen Coal Gasification	Word
FutureGen Multiple Potential Water Sources	PPT
FutureGen Penwell CO2 Capture	PPT
FutureGen Road Trip 8-21-06	PPT
Insoluble Residues Pecos Sequestration Site Geology	PPT
CO2 Sequestration Site-Defining a Target	PPT
Pecos Sequestration - Sul Ross Presentation	PPT
Pecos CO2 Sequestration	PPT
Pecos Sequestration Delware Mountain Group	PPT
Santa Rosa Schuyler Wight Ranch	PPT

Table 8. Pecos Sequestration Site Star including all available files.

During the discussion phase of the proposal, the issue was raised if, after the four years testing phase of injecting the CO2 into the Brine Aquifers, the CO2 could be pumped back out

and used in a CO2 EOR project. This was not acceptable to the DOE as this was a research project where a waste product would be injected into a storage site.

Ft Stockton/Elsinore Star

The lower Paleozoic groups and formations in the deep Delaware Basin south of Ft Stockton have been known for decades to produce high percentages of CO2 in association with methane, and in the southern and westernmost areas, pure CO2. The deep Delaware Basin south and east of Ft Stockton was the source for CO2 for the original Permian Basin CO2 Floods at SACROC Field in Scurry County and the North Cross (Devonian) Field in Crane and Upton Counties. The complete list of available data is seen in Table 9.

Conoco drilled an Ellenburger wells south of Ft Stockton specifically to provide a source of CO2 for the Ford Geraldine Ramsey Sand CO2 project in 1983, Skopak and Phillips (1984). This wells tested flowing 11.5 MMCFPD of saturated CO2 at a pressure above the critical and produced 4 to 5 Million Cubic Feet of pure CO2 a day. However because the Ellenburger is karsted and faulted an effort to produce larger volumes of CO2 resulted in coning water for below the gas/water contact. The highly saline brine caused mechanical issues and the wells were abandoned.

The Skopak and Phillips (1984) paper details the design and operation of the Elsinore "73" No. 1 CO2 dehydration facility. Specific topics that will be discussed are pipelining and dehydration alternatives, molecular pipelining and dehydration alternatives, molecular sieve (mol sieve) bed design, equipment and piping, metallurgy, fuel options, automation and startup.

The carbon dioxide source for the Ford Geraldine Unit CO2 Project is the vent gas off Lone Star's Pikes Peak Plant, Pecos County, Texas. The CO2 concentration of the vent gas varies between 93-98% depending on the volumes being processed through the plant. Water content was less than 8 pounds per MMCF of CO2 and the H2S content about 125 ppm. The CO2 was compressed at the plant and moved through a 112-mile bare steel pipeline to the Ford Geraldine Unit. Carbon dioxide deliverability has been a major concern. During the first two years of CO2 injection, the available CO2 volumes have been half of the expected 20 MMCFPD desired rate. The supply had also been very erratic with many zero delivery days. The unreliable daily supply rate and questionable reserves from the Lone Star Pikes Peak Plant lead to the search for additional CO2 supplies. Numerous CO2 sources along the pipeline route were investigated as possible supplemental supplies. The investigation revealed a well drilled by Hunt Oil Company in 1961 on Elsinore Cattle Company acreage. The Elsinore Royalty Company No. 57, located in Section 72, drill stem tested 18.9 MMCFPD of 97.5% CO2 at a flowing surface pressure of 1200 psig. There was no demand for the CO2 at that time so the well was not completed. Conoco obtained the CO2 rights for four sections offsetting this well. The favorable location, 9 miles from the Lone Star Pikes Peak Plant, and the excellent DST made this area ideal for the development of CO2 for the Ford Geraldine Unit. (Figure 2).

The Elsinore "73" No. 1 was drilled and completed in September, 1983. The well flowed 11.5 MMCFPD of 95.89% CO2, 3.85% Methane, 0.16% Nitrogen, and 42 ppm H2S from the Ellenburger formation at a depth of 14,894 - 15,217'. The well flowed at 1500 psig with a

wellhead temperature of 110F (very low considering the depth). Water production was 150 barrels per day. Table 2 shows a typical water composition after the well had been on production.

Ft Stockton/Elsinore Star	
Elsinore CO2	PPT
Conoco #1 73 Elsinore DLL Log	TIF
Hunt #57 Elsinore DLL Log	TIF
Hunt #57 Elsinore Sonic Log	TIF
Sandridge 6046 West Ranch Pinon DLL Log	TIF

Table 9. Ft Stockton Elsinore Star including all available files.

Overthrust Star

Canyon Reef Carriers pipeline Carbon dioxide is collected from five facilities the Mitchell, Gray Ranch, Puckett, Pikes Peak and Terrell gas plants. at low pressure, compressed, and transported at a rate of approximately one million pounds per hour to a large oil field where injection occurs for secondary and tertiary recovery of oil. The SACROC carbon dioxide pipeline system consisted of 40 miles of 12-inch pipeline, 180 miles of 16-inch pipeline, and six large reciprocating compressor stations with a total of 84,500 HP. The 150-mile Canyon Reef Carriers Pipeline connects with Kinder Morgan CO2 Company's Central Basin Pipeline in McCamey, Tex. and provides over 200 MMcf/day of transportation capacity to the eastern Permian Basin region. Anthropogenically produced CO2 daily (4.4 Mt yr-1) from Shell Oil Company gas processing plants in the Texas Val Verde basin. The complete list of available data is seen in Table 10.

Overthrust Star	
Ouachita Orogeny	PPT
CO2 Sources Natural and Anthropogenic	PPT
Potential Long Term Use of Anthropogenic CO2	PPT

Table 10. Overthrust Star including all available files.

McCamey Star

The McCamey Field is one of the oldest San Andres and Grayburg fields in the Permian Basin. Although it is not under CO2 flood, it is a close analog to the Yates field which is one of the largest CO2 floods in the Permian Basin, having similar heavy karstification in the San Andres portion of the reservoir. There is: A Field History power point, Core reports in an excel spreadsheet format with charts of porosity vs. permeability for the #19 A. A. Reese, #51R J. F. Lane, #1087 McCamey Unit, #353 McCamey Unit, #549W McCamey Unit, and #9R "A" Baker,

and Core Descriptions presented in Adobe Illustrator format, for use in a cycle/cycle set/flow unit correlation exercise. The cycles and cycle set data can then be imported into a reservoir simulator as flow units. The complete list of available data is seen in Table 11.

The North Cross (Devonian) Unit CO2 Flood, Mizenko, 1992, Shell's first, began in 1972, soon after the initiation of the SACROC project is Scurry County. While fairly small by West Texas standards, the project provides an example of a successful, mature CO2 flood. Seventy-eight billion cubic feet (BCF) of pipeline CO2 have been injected into the reservoir. Recycled produced gas has augmented this to bring cumulative CO2 injection to 128 BCF or nearly 70% of the hydrocarbon pore volume. Production performance has been excellent. Unit oil production increased from approximately 1400 barrels per day (BOPD) when CO2 injection began to its peak of over 2600 BOPD in late 1978 before declining gradually to approximately 1900 BOPD by the end of 1991. An estimated 11 million barrels of enhanced oil had been recovered through 1991 and ultimate EOR is expected to double to over 22 million barrels. The

McCamey Star	
Core analysis McCamey field	PPT
Kinder Morgan CO2 Projects North Cross and South Wasson	PPT
McCamey core data Interpretation	PPT
McCamey core data Interpretation 2	PPT
McCamey Field	PPT
	Adobe
Strat framework and Reservoir Delineation McCamey field	PDF
What can core data tell without the core McCamey	PPT
Yates field Merchant	PPT
Burlington #3R 3622 Lane core description	JPG
Burlington #353 McCamey Unit core description	JPG
Burlington #549 McCamey Unit core description	JPG
Burlington #1087 McCamey Unit core description	JPG
Meridian #51R Lane A Core description	JPG
Meridian #9R Baker Core description	JPG
Meridian #19 Reese A Core description	JPG
Gulf #16 Shirk Core description	JPG

Table 11. McCamey Star including all available files.

North Cross CO2 flood was designed as a secondary (pre-waterflood) rather than a tertiary (post-waterflood) displacement process. Waterflooding, which in West Texas typically precedes CO2 flooding,was not performed in the Devonian Main Pay reservoir due to low anticipated water infectivity. The large EOR target at North Cross and the Unit's proximity to the Canyon Reef Carrier pipeline, which was being installed to supply CO2 to the SACROC CO2 Project, made it an attractive CO2 flood candidate. The major producing horizon is the Devonian "Main Pay," a classical Archie Type II-A rock composed of microscopic, tripolitic chert grains bound by limestone cement. Average porosity is 22 % and permeability averages 5 mD.

Goldsmith Star

Goldsmith Field is the subject of one of the first Residual Oil Zone (ROZ) CO2 Enhanced Oil Recovery (EOR) projects undertaken by a non-major oil company. The Laguna Resources Goldsmith Landreth San Andres Unit (GLSAU) project included 10 sections (6400 acres). The initial 5 spot pilot (4 injectors and 1 producer) was successful and later expanded. By the time Legado sold the property in 2013, they had increased production from ~150 BOPD to ~1400 BOPD from the CO2 flood of both the main pay and ROZ. PowerPoints describing the engineering and geologic understanding of the GLSAU are included. The complete list of available data is seen in Table 11.

Goldsmith Star	
Legado #26 Core Description	JPG
Legado #58 Core Description	JPG
Legado #126R Core Description	JPG
Legado #142A Core Description	JPG
Legado #190 Core Description	JPG
Legado #203RW Core Description	JPG
Legado #204R Core Description	JPG
Legado #222W Core Description	JPG
Legado #313R Core Description	JPG
Legado #58 Core Report	excel
Legado #126R Core Report	excel
Legado #190 Core Report	excel
Legado #204R Core Report	excel
Legado #222W Core Report	excel
GLSAU Formation Tops	excel
NGL Recovery Options in CO2Floods - Prim	PPT
Managing a CO2 Project Goldsmith Landreth Pilot - Thurmond	PPT
203RW a CO2 Bank Caught in the Act	PPT
GLSAU Core Description Corss Section	PPT
GLSAU Geology and Volumetrics- Adrian	PPT
Goldsmith Geologic Review	PPT
San Andres Platform Potential	PPT
Chevron Goldsmith CO2 Pilot - Jasek SPE	Doc

Table 11. Goldsmith Star including all available files.

Seven (7) core descriptions and 4 core analyses of cores taken by Legado to evaluate the ROZ EOR potential are included in this Star. The cores are spread across the field and provide a

"Top to Bottom" look at the geologic reservoir facies distribution, flow units, and diagenetic overprint in the Gas Cap, Main Pay, ROZ and the interval below the ROZ.

The first booking EOR Reserves in a Residual Oil Zone CO2 project was presented by Mike Stell of Ryder Scott. This represents a significant step forward in the economic evaluation of ROZ projects. That PowerPoint is included in the Goldsmith Star.

Jasek et. Al., (1998) reviewed the success of the Goldsmith San Andres Unit (GSAU) pilot to the south of the GLSAU which consisted of nine inverted (injector-centered) 5-spot patterns covering approximately 320 acres and located in a mature area of the field where the majority of the wells had been plugged due to high water cuts. The pilot location was selected based on geology and reservoir performance during waterflood. A CO2 pilot was chosen, rather than full- field implementation, to investigate uncertainties associated with the CO2 target oil saturation, the feasibility of re-entering abandoned wellbores, and overall CO2 flood performance. CO2 injection in the pilot commenced in December of 1996.

Approximately 45 miles to the northeast, Seminole Field in Gaines County, is one of the most successful CO2 EOR floods in the ROZ. Operated by Hess Corp., the main pay CO2 flood has been producing oil for almost 30 years. In 1999 and in 2004, two ROZ test phases were run to evaluate the potential for CO2 EOR in the in ROZ. Based on the success of these two studies, the first of 4 stages of full field ROZ development was initiated in 2007.

Kermit Star

There have been 2 CO2 EOR projects in the Yates Sands of North Ward Estes. The original 6 section (3,800 acre) project on the Hutchins Stock Association (H. S. A.) lease was initiated by Chevron in 1989, and completed in 1998. A power point on why the Chevron CO2 EOR project did not meet/exceed expectations is included. The second project was initiated by Whiting Petroleum in 2007 on the G. W. O'Brien lease and has expanded to include both the G. W. O'Brien leases in Ward and Winkler county and parts of the H. S. A. Leases in Ward County. In addition, Whiting has expanded the CO2 flood to the Queen Formation 300 – 500' below the Yates. A major new method for simultaneous chemical treatment and gas lift in producing CO2 flood wells has been presented at a number of CO2 EOR conferences and Schools and been the focal point of a number of industry field trips including foreign nationals from China, Japan, and Indonesia. The Gas Lift and Scale Inhibition program that has been successfully developed at N. W. E. is being duplicated in other CO2 floods in the basin, and elsewhere. This process reduces costs by eliminating the need for a pump, rods, and pump jack during the initial phase of production and the need to workover the well and remove the pump and rods when the well begins to flow. At the point when the wells begin to flow from the injection support, the Gas Lift injection is ceased. A power point documenting this new technology is included. Whiting is currently injecting approximately 390MMcf/d of CO2 into the field, of which about 68% is recycled gas. Net production from North Ward Estes averaged 9.6 MBOE/d for the third quarter of 2013.

There is a power point which reviews the creation of Residual Oil Zones (ROZ's) which are large Enhanced Oil Recovery (EOR) Carbon Capture and Utilization and Storage (CCUS)

targets. Beneath the N. W. E. field are a number of ROZ CCUS targets. Although there is only minor established primary production in these targets, there is believed to be 600' of ROZ targets in a 3000' think interval. The power point discusses the origin of the ROZ that occur thru out the basin as the result of a meteoric derived "Mother Nature's Waterflood". It is believed that there is >30 billion barrels of recoverable reserves and an associated storage capacity in the ROZ CO2 floods for 6000cf CO2 for every barrel of oil produced. The complete list of available data is seen in Table 13.

The RPSEA ROZ Modeling Project was successful in testing the theory that oil had been swept of portions of San Andres reservoirs by meteoric derived sweep (referred to as Mother Nature's Waterflood) during the uplift of the western part of the basin as a result of Basin and range Uplift. The parameters determined for this sweep included: Number of pore volumes of fluid moved through the system range from 19 to 51 based on a porosity that ranges from 6% to 16%; The time frame is 15,000,000 years; The low flow portions of the San Andres had flow rates that ranged from 0.8 to 2.1'/thousand years; The core of the high flow zone had a flow rate that ranged from 317 to 847'/thousand years; the total flow volume is 6.54683E+12 cubic feet; Flow rate through the high K zone was 6.21 GPM, the total flow through the San Andres section was 7.23 GPM; From the perspective of the movement of groundwater mass or sweeping action that portion of the San Andres represented by conditions of high porosity and High Conductivity (relatively speaking) were significantly dominant. This is important work which can also be used to advance the understanding of the potential for CO2 to remain in the reservoirs where it is sequestered. Essentially, groundwater in this San Andres reservoir in the Permian Basin will move less than 1' per year over 1,000 years. CO2 is proposed to have similar velocities.

Kermit Star	
Atrifical Lift with CO2 and Chemical Treatment	PPT
Gascoyne River - North Ward Estes Analog	PPT
North Ward Estes Overview - Hagist	PPT
Mother Nature's Waterflood - Artesia Trend	PPT
North Ward Estes Correlation Exercise	PPT
North Ward Estes Yates Facies	PPT
North Ward Estes - Why CO2 Floods Fail	PPT

Table 13. Kermit Star including all available files.

The 3 core Vacuum Field Exercise in also inserted at this point (See Carlsbad Star) in the possibility that a shorter field trip may end here.

Orla Star

The Ford Geraldine and East Ford, Ramsey Sand, (Delaware Mountain Group) fields, Galloway and Hobday (1996), Makik (1998), Silver and Todd (1969), and Williamson (1978), where Conoco, the Texas Bureau of Economic Geology, and Orla-Petco evaluated the potential

for CO2 flooding in these submarine fan channel complex reservoirs (see . After the phase 1 evaluation of the Ford Geraldine potential. Conoco declined to continue into Phase 2 and the BEG and Orla-Petro completed the study in the East Ford Field, Asquith, et. Al., (1997), Barton, (1997), Dutton et. Al., (1999a), Dutton et. Al., (1999b). The objective of this Class 3 project (see Topical Reports as PDF's in Orla Star) was demonstrate that detailed reservoir characterization of slope and basin clastic reservoirs in sandstones of the Delaware Mountain Group in the Delaware Basin of West Texas and New Mexico is a cost effective way to recover a higher percentage of the original oil in place through strategic placement of infill wells and geologically based field development. Project objectives are divided into two main phases. The original objectives of the reservoir-characterization phase of the project were (1) to provide a detailed understanding of the architecture and heterogeneity of two representative fields of the Delaware Mountain Group, Geraldine Ford and Ford West, which produce from the Bell Canyon and Cherry Canyon Formations, respectively, (2) to choose a demonstration area in one of the fields, and (3) to simulate a CO 2 flood in the demonstration area. The complete list of available data is seen in Table 14.

The 4 core descriptions, in Adobe Illustrator format, for the Tenneco Bateman #3-31 TXL, Continental #2-4 Russell, Continental #6-26 Ramsey and the Penrose Bateman, are Cherry Canyon age (the formation below the Bell Canyon studied in the Ford Geraldine Field) bur provide an excellent example of the complexity of the submarine channel sands in the Delaware portion of the Permian Basin. These sands are good CO2 EOR targets, and have the potential as ROZ targets as well. The CCUS potential of the Delaware Mountain Group (Bell, Cherry, and

Orla Star	
Tenneco #3-31 TXL Core Description	JPG
Continental #2-4 Russell Core Description	JPG
Continental #6-26 Ramsey Core Description	JPG
Penrose #1 Bateman Core Description	JPG
East Ford Geraldine Geology Topical Report	Adobe PDF
East Ford Geraldine Reservoir Characterization	Adobe PDF
East Ford Geraldine Topical Using Old Electric Logs	Adobe PDF
East Ford Geraldine Topical Tilted Oil/Water Contact	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ford Geraldine Topical	Adobe PDF
Ouachita Tectonism	PPT
South Wells Cherry Canyon Cross Section	PPT
Cherry Canyon Isopachs	PPT

Table 14. Orla Star including all available files.

Brushy Canyon Formations) is enormous and as the group sits above the rapidly developing WolfBone unconventional resource play in the basin, there is an ever expanding data base for this interval. There is also a power point which describes the relationship of the 4 cored wells.

Four (4) Cherry Canyon submarine fan cores in Adobe Illustrator format from the Ford Geraldine area and an associated power point are available. These 4 cores demonstrate the variability of the pay sands in the fan complex. There are 4 channels separated by correlatable Organic Rich Sequences (ORS).An exercise in the isopaching of one of these submarine fan sands in available.

Carlsbad Star

The Carlsbad Star has 3 modules: the Basin Transect, The Shelf Transect and the Vacuum Core Exercise.

Carlsbad is the jumping-off point for the Guadalupe and Delaware Mountains. These two ranges contain the outcrop equivalents of the upper Permian (Leonardian and Guadalupian) producing formations. The Road Log for the "basinal" formations extends from the salt Flat Graben back to Carlsbad the Delaware Basin and includes the Delaware Mountain Group: Brushy Canyon, Cherry Canyon, and Bell Canyon, the Bone Spring Formation, the Cutoff Formation, and the Pipeline Shale. Stops can include an overview of the western Escarpment of the Guadalupe Mountains which shows the shelf to basin transition, the Cherry Canyon (Manzanita Marker), Cutoff Formation (formally referred to as the Bone Spring), Brushy Canyon channel, Overview of El Capitan – the reef talus of the Capitan Reef and the Salt Flat Bench – a Brushy Canyon slope channel with multiple sands, other Brushy, Cherry, and Bell Canyon outcrops, the shelf-slope-basin transition at Pine Springs and McKittrick Canyon, intro to the Geology Reef trail at McKittrick Canyon, the Radar Slide – a Capitan Reef shelf margin collapse and debris flow encased in basinal sand, the Lamar Lime – the uppermost member of the Delaware Mountain Group, and the basin filling Castile Evaporites just north of the state line. Thetransect also highlights the shelf to basin depositional topography seen during the Guadalupian.

The Road Log for the shelf begins in Carlsbad and includes a series of stops in the middle to upper Guadalupian. Stops include the Seven Rivers back shelf – tidal flat carbonates, the Queen fluvial/deltaic sandstones and overlying collapse in the Sabkha where evaporates (halite) had been dissolved out, and shelf interbedded sandstones and carbonates of the Yates Formation. Other stops include the aggrading upper Guadalupian reef crest with large Teepee structures and the deeper water reef. The second part of this road log includes stops in Last chance Canyon. Here the canyon has downcut into the uplifted western portion of the Gauadalupe Mountains and exposed the Grayburg, San Andres, and Cherry Canyon tongue. Work by Mark Sonnenfeld measuring sections in the canyon provide an excellent transect thru the prograding San Andres ramp to shelf. The Grayburg cycles are also seen in outcrop in the portion of the road log.

The Vacuum "project" is an integrated Engineering-Geology-Land exercise. The engineers can work on the logs for the 3 wells, the geologists on the core descriptions, Stoudt and Raines, (2004), and the land personnel can attempt to acquire the private, federal, and state

leases, and an interest in the HBP acreage for their team. Each team will be given a base map with the different types of leases identified. Each faculty can determine how to In the exercise, each team is given $1,000,000 in chips to drill one well ($50,000), to purchase additional well logs, and purchase as much "high quality" reservoir as possible. The faculty can give the teams an opportunity to earn additional cash by answering questions related to the project. The game can be used to create a team environment among students in the 3 programs. Each discipline begins by discussing their data separately: logs (Engineering), core (Geologists), and land (Land Management), see Appendix 4 for Land map and Appendix 5 for condensed geologic core description answer powerpoint. The engineers will determine the pay in each well, Asquith and Krygowski, (2006), and the geologists will determine the cycles and cycle sets (using the Gualdalupe Mountains geology power points) in each well. As this data is being evaluated, the Land Management students are reviewing the types of leases available, and the ownership of the HBP and private leases, and becoming familiar with the lease forms available for this state (New Mexico). Once the students have been given sufficient time to evaluate the data sets, the Engineering, Geology, and Land students will be formed into teams (typically with 2-3 engineering, geology, and land students to each team). To make the game more fun, let the students pick a Company Name for their team. After having some time together (to be determined by their level of understanding), the students will determine their strategy. They will be given an opportunity to talk to the "Private Ranch" owner and attempt to make a deal, then more time to determine their bids for the "Sealed Bid" state sale tracts. After the sealed bids are opened and the leases assigned, be given time to review their land position, and their remaining

Carlsbad Star	
Identifying the Formations we will be discussing	Word DOC
Field Trip Well Logs	PPT
Mosley Canyon Well Logs	PPT
Cycles-Sequence Stratigraphy and Reservoirs - Stoudt	PPT
Permian Overview - Stoudt	PPT
Vacuum Project - Land Map	PPT
Vacuum Project -Core and Log Cross Sections	PPT
Vacuum Project -Core and Log Cross Sections with Correlations	PPT
Vacuum Project - Chevron - Sagnak	PPT
Vacuum Project - CO2 Potential	PPT
Vacuum Project -Vacuum-Slaughter Field Comparison - Saller	Adobe PDF
Vacuum Project - Land Map	PPT
West Pearl Queen Environmental Report	Adobe PDF
West Pearl Queen Sequestration Technical Report	Adobe PDF
Tenneco #9 and #28 Core Description	Excel
Rocky Arroyo West Pearl Queen	PPT
West Pearl Queen CO2 Flood - Pawar	PPT
Rocky Arroyo West Pearl Queen	PPT
West Pearl Queen DOE Report	Adobe PDF

Table 15. Carlsbad Star including all available files.

cash position After the "State Sale", there will be a "Federal Open Bid Lease Sale" with teams orally bidding on the remaining tracts. After the bidding is complete, the two PhiH maps (porosity thickness) from Chevron, which can be used to determine which team had the best strategy for acquiring the highest quality leases, are displayed and a determination of which of the Teams has acquired the most high quality leases. It is often the case that there is two teams that have both acquired larger block of high quality acreage. This is to be expected as each team is on a level footing, with each team having access to the same data. This is a point to stress, with equal access to the same data, teams should arrive at the same conclusions. In real life, access to data is often very unequal and this tends to skew and the interpretation and results of the bidding, and therefore the outcome of the "Game".

The West Pearl Queen powerpoint modified from is a presentation made of the results of the Sandia National Labs injection test in the West Pearl Queen Field and the study of the outcrop equivalent in Rocky Arroyo. Leonard South Field powerpoints are included to provide log and core analyses of a queen reservoir that demonstrates the complex relationships in a field that at first blush appears to be simple but has a more complex geometry which suggests potential for CO2 CCUS potential. The complete list of available data is seen in Table 15.

Seminole Star

Seminole Field is the "Gold Standard" of CO2 Main Pay and ROZ EOR projects in the Permian Basin'. The Main Pay in the field was discovered in 1936, and was unitized and placed under waterflood in 1969. The MPZ has been under CO2 flood since 1983. It was during the 1980's that the potential for an ROZ was evaluated. Hess, the operator of the field, recovered Conventional core, "Sponge Core" and "Pressure Core" The reason for taking the three types of is to evaluate the S_o (oil saturation). The range of oil saturation in the cores was from the high teens to low 30's, with the pressure core being the highest and the conventional the lowest. It has been postulated that oil saturations higher than 25% is necessary for successful, economic ROZ flood potential. The ROZ Phase 1 (Pilot) was initiated in 1996. This was a comingled MPZ and

Seminole Star	
Seminole CO2 Plant Carmody	ppt
Seminole SSAU ROZ Status Biagiotti	ppt
ROZ Model History Characteristics	ppt
Sable Field Land Issues on ROZ	ppt
Summary Field Trip Seminole	Adobe PDF
Hugh Value of ROZ at Seminole	PPT
USGS Pub 2012	Adobe PDF
Welcome to Seminole CO2 field Trip	Word DOC

*Table 16. **Seminole Star including all available files.***

ROZ study and it was difficult to determine the precise percentage of contribution from the MPZ and the ROZ. In 2004, a second ROZ only Phase 2 (Pilot) study was initiated. This pilot proved that the CO2 ROZ was successfully being swept. In 2007 Stage 1 of a full field development of the ROZ is coordination with the MPZ was initiated.

The Goldsmith Core Description exercise is included here as the original core evaluations for Seminole, done in-house by Hess and their contractors, has never been publically released. The "Mother Nature's Waterflood", ROZ Regional work is also included here. Although the modeling was done on the Artesia Trend on the west side of the Central Basin Platform, the model also applies to Seminole. The complete list of available data is seen in Table 16.

San Angelo Star

Until recently, there were no CO2 projects on the Eastern Shelf of the Permian Basin (Katz, Strawn, Field in King County is now on line) in large part due to the lack of infrastructure. Kinder Morgan's CO2 project at SACROC Field in Scurry County was the first large scale CO2 project in the Basin (1971) and there are a number of other Pennsylvanian carbonate CO2 floods on the Horseshoe Atoll, but no upper Paleozoic floods exist on the Eastern Shelf. The first pipeline converted to CO2 transportation, the Canyon Reef Carriers Pipeline from south of Ft Stockton to Snyder, has also been in use since 1971. The Star included a status report on the SACROC Field CO2 injection and the one major environmental study of the 42 year old SACROC Field surface and near surface to determine if there was any evidence of CO2 leakage. None was detected.

Tenaska Inc., proposed to build a Post-Combustion Coal Fired Power plant at Sweetwater with the captured CO2 e being used in lower Paleozoic (Ellenburger) CO2 floods. The project was shelved primarily due to a lack of a large, consistent water source. A pdf on Tenaska's project is included. A summary of the production from, and geology of the Ellenburger Group on the Eastern Shelf is also included. The complete list of available data is seen in Table 17.

San Angelo Star	
Tenaska Trailblazer Structure Model	Adobe PDF
Tenaska Trailblazer Agreement for Geologic StudtStructure Model	Adobe PDF
Tenaska Trailblazer Geologic Methodology	Adobe PDF
SACROC Carbon Balance	PPT
SACROC Rejuvinating Miscible Flood	PPT
SACROC Near Surface Environmental Study	PPT
Lower Paleozoic Tabosa Basin	PPT
SACROC Conformance	PPT
Tenaska Trailblazer SOPO	Word DOC
Trailblazer News Release	Word DOC

Table 17. San Angelo Star including all available files.

Mason Star

The Ellenburger outcrops in Central Texas and has been studied there for over 100 years. The nearest outcrops to the Central Texas area are the Ellenburger equivalent El Paso Group found in the ranges around Van Horn and discussed in the Van Horn Star power points. There are two mineral cores, the Johanson and the Glaze, included in the Mason Star with an associated

Mason Star	
Glaze Core Description	JPG
Johanson Core Description	JPG
Mason Field Trip	PPT
Lower Paleozoic Tobosa Basin	PPT
Mason Ellenburger	PPT

Table 18. Mason Star including all available files.

power point. This is the one lower Paleozoic core set included in the modules. The amount of karstification seen in the core reflects long term exposure at or near the surface, this is similar to the long term exposure of the Ellenburger thru out the eastern half of the Permian Basin. The Ellenburger would only be considered a CO2 there is a documented seal (as where the Ellenburger is productive). Although the Ellenburger is not as yet, a target for CCUS, there is potential for this in the future. The complete list of available data is seen in Table 18.

Task 6. Sequestration Core Study Sets.

Sets of cores for existing main pay and ROZ CO2 floods were identified, operators contacted, and the cores made available to the project, see complete list in Appendix 6. There are 38 complete Core Descriptions, 2 Excel Short Core Descriptions (South Leonard), and 1 field Tops data set (Goldsmith) The complete Adobe Illustrator format core descriptions are:

- 3 cores from the Vacuum Field (San Andres carbonate Main Pay),
- 8 Cores from the McCamey Field (San Andres and Grayburg carbonate, and Queen siliciclastics Main Pay and ROZ),
- 9 from Goldsmith Field (San Andres carbonate Main Pay and ROZ),
- 2 from the Central Texas (Mason) area (Ellenburger dolomite),
- 4 from Foster South Cowden (San Andres and Grayburg carbonate Main Pay) and
- 4 cores from the Ford Geraldine basinal siliclastics area.

It was decided at the beginning of the project to have all the Core Descriptions available in the same format. Some of the cores had previously been described in other, older, pencil on paper formats but would need to be updated in newer, digital friendly formats. Adobe Illustrator was chosen as the program in which to present the data. The original format used symbols to identify the fossils and textures. However, after the format was utilized during the first Vacuum Field Team Project in 2011, it was determined that the symbols caused confusion and slowed the

interpretation. At that point, a series of columns was designed and the presence of a fossil or texture noted by a vertical bar, the width of which denoted the amount present This proved to be very successful, but required additional work to create the Core Descriptions. Additional minor changes were made to the more academic friendly Adobe Illustrator presentation format as suggestions were made. Cores that had been described previously using different formats were re-formatted.

The core descriptions are typically presented in Excel format at 24" or 36" tall as the amount of detail in the descriptions make it very difficult to work at standard powerpoint presentation scale. (8 1/2" x 11"). 24" tall by 36" wide is typically used for correlation of 3 or more descriptions.

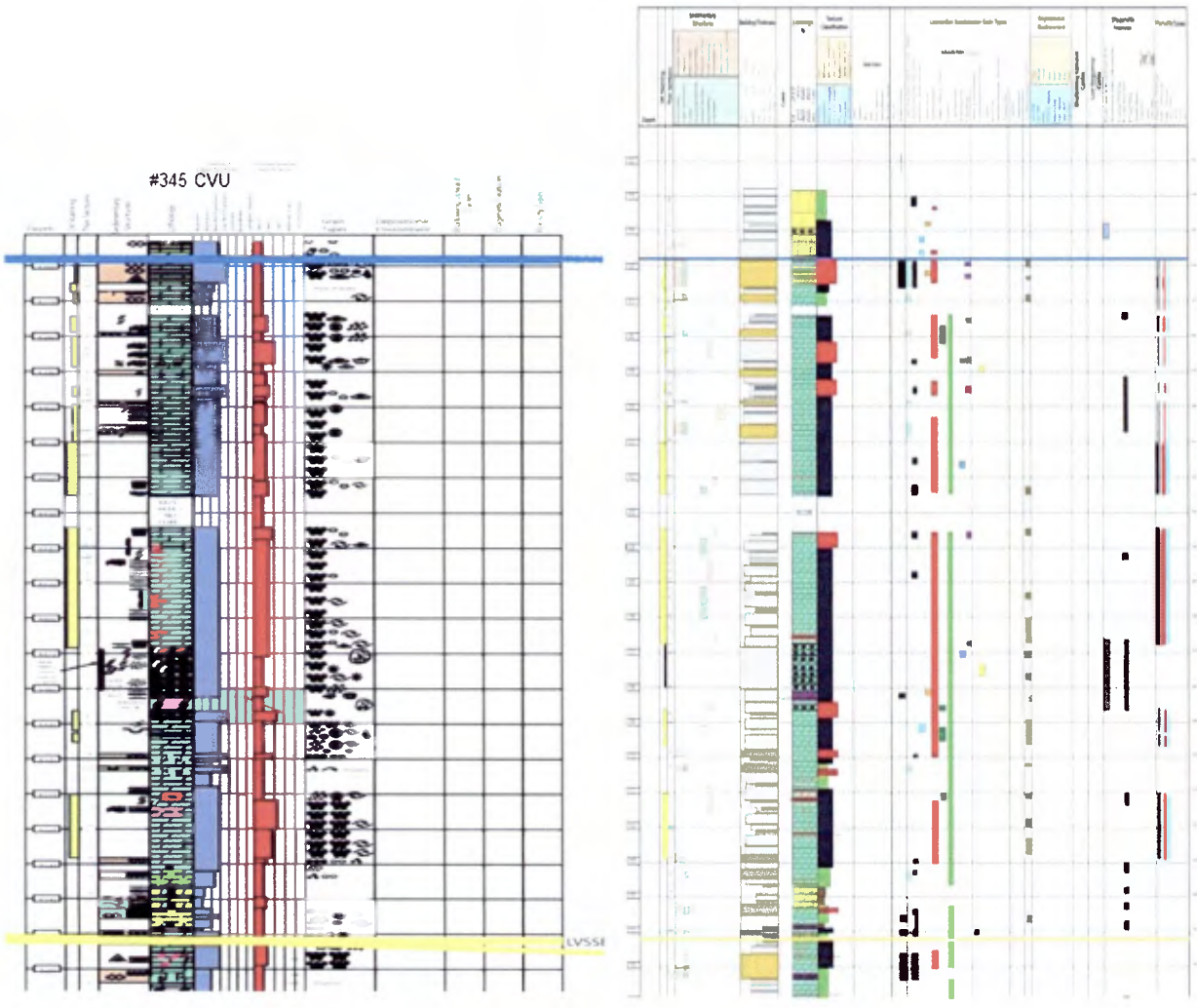

Figure 3. Comparison of older core descriptions with symbol.

Presentations

Presentation at the annual DOE meeting in Pittsburg was made in August, 2012 and 2013 via Webinar. Presentations were made at the Fall WTGS Symposium in 2011, 2012 and 2013. A presentation was made at the Southwest Section of the AAPG in Ruidoso in 2011 and the Geological Society of America in Alpine in March 2012. PowerPoint presentations on the Vacuum Team Project, and the Field Trip Road Logs utilized, at the PBS-SEPM Young Professionals Field Trip in 2011, 2012, and 2013. Presentations were made to Geology majors at Sul Ross in 2011 and 2012. Each semester from 2010 thru 2013, presentations were made to undergraduate and/or graduate Geology majors and to undergraduate Petroleum Engineering majors. Presentations that were made as part of the annual CO2 Flooding School were used in whole or part in the Student Modules.

Conclusion

In order to create the modules, UTPB/CEED utilized a variety of sources. Data & presentations from industry CO_2 Flooding Schools & Conferences, Carbon Management Workshops, UTPB Classes, and other venues was tailored to provide introductory reservoir & aquifer training, state-of-the-art methodologies, field seminars and road logs, site visits, and case studies for students. After discussions with faculty at UTPB, Sul Ross, Midland College, other universities, and petroleum industry professionals, it was decided to base the module sets on a series of road logs from Midland to, and through, a number of Permian Basin CO_2 Enhanced Oil Recovery (EOR) projects, CO2 Carbon Capture and Storage (CCUS) projects and outcrop equivalents of the formations where CO2 is being utilized or will be utilized, in EOR projects in the Permian Basin. Although road logs to and through these projects exist, none of them included CO2 specific information. Over 1400 miles of road logs were created, or revised specifically to highlight CO_2 EOR projects.

After testing a number of different entry points into the data set, it was clear that a standard website presentation with a list of available power point presentations, excel spreadsheets, word documents and pdf's would not entice faculty, staff, and students at universities to delve deeper into the website http://www.utpb.edu/ceed/student_modules. As a result of the 3 Young Professional Field Trip run in 2011, 2012, and 2013, and discussions with faculty at Midland College, Sul Ross State University, and UTPB and industry professionals following presentations at society meetings, it became clear that in order to make the modules accessible and "user friendly" that associating the modules with the 1400+ miles of Field Trip/Road Logs was the most logical presentation format. STARS are located at specific CO2 related locations on the road logs. These Stars are points where a number of related Engineering, Geologic, and Land Management powerpoints, PDF's of DOE sponsored CO2 related projects, Core Descriptions and Analyses, Water Chemistry excel spreadsheets, and well top *files* provide an opportunity for team and cross-training.

The modules were developed, tested and presented to audiences at Univ. Texas Permian Basin, Midland College, and Sul Ross State University, and presented to industry interns, representing a number of regional and national universities, and new hire professionals on a number of occasions to check their veracity, obtain feedback on clarity, usefulness and content. The modules have been made available to other regional universities.

With a rapidly graying workforce, the CO_2, EOR and Sequestration industries are hard pressed to maintain adequate numbers of skilled workers. If the universities do not participate with industry in preparing students for entry into the CO_2 industry, time will be wasted till "on the job" training & in-house & industry schools come available. UTPB, partnering with industry professionals makes it the most logical site to develop CO_2 related training for students. Industry agreed to donate data for this project.

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Acronym/Definitions

Anthropogenic CO2. CO2 that has been "captured" from a manufacturing facility. Potential sources include: Petroleum Refineries, Post Combustion Coal-fired Power Plants, Coal Gasification Power Plants, Ethanol Plants, Cement Plants.

CCUS – Carbon Capture Utilization and Storage. Capture of anthropogenic CO2 derived from natural or industrial sources, utilized in CO2 Enhanced Oil Recovery projects in existing fields and Residual Oil Zone floods, and eventually d stored permanently in a geologic medium.

EOR - Enhanced Oil Recovery. Any methodology for enhancing oil recovery beyond basic primary and secondary (waterflood) methods. These include CO2, chemical (surfactants or caustic), or fire flooding.

EORI – Enhanced Oil Recovery Institute at the University of Wyoming in Laramie, Wyoming is tasked with assisting Wyoming operators with their EOR projects by applying existing technologies and creating new knowledge when necessary. They have been in communication with us and we find they are pursuing similar avenues of study into ROZ's.

Green Field – An ROZ present outside the limits of a producing oil field where the rock units produce high percentages of water on Drill Stem Test or attempted completion, but contain sufficient oil to be produced economically by CO2 EOR.

ROZ – Residual Oil Zones. Those intervals beneath the base of the main pay in producing fields as defined by 100% water free production during the early production history of the field.

APPENDICIES

Appendix 1. List of Engineering, Geology and Land Management modules

File Name	File Type	Module Star	Audience
Vacuum Project - Chevron - Sagnak	PPT	Carlsbad Star	Engineers
Foster Oil Field Waters	PPT	Foster South Cowden Star	Engineers
Foster South Cowden Engineering	PPT	Foster South Cowden Star	Engineers
Chevron Goldsmith CO2 Pilot - Jasek SPE	Doc	Goldsmith Star	Engineers
Managing a CO2 Project Goldsmith Landreth Pilot - Thurmond	PPT	Goldsmith Star	Engineers
NGL Recovery Options in CO2Floods - Prim	PPT	Goldsmith Star	Engineers
North Ward Estes Overview - Hagist	PPT	Kermit, Wickett Star	Engineers
Yates field Merchant	PPT	McCamey	Engineers
Kinder Morgan CO2 Projects North Cross and South Wasson	PPT	McCamey, Seminole Star	Engineers
CO2 Surface Facilities	PPT	Midland Star	Engineers
CO2 Wellbore Management Issues	PPT	Midland Star	Engineers
EOR Industry Permian Basin Overview	PPT	Midland Star	Engineers
Kinder Morgan CO2 Scoping CO2 projects San Andres 2008	Excel	Midland Star	Engineers
CO2 Pipeline Maps	PPT	Penwell Star	Engineers
SACROC Carbon Balance	PPT	San Angelo Star	Engineers

SACROC Conformance	PPT	San Angelo Star	Engineers
SACROC Rejuvinating Miscible Flood	PPT	San Angelo Star	Engineers
Seminole CO2 Plant Carmody	PPT	Seminole Star	Engineers
Seminole SSAU ROZ Status Biagiotti	PPT	Seminole Star	Engineers
Atrifical Lift with CO2 and Chemical Treatment	PPT	Wickett, Goldsmith Star	Engineers
Field Trip Well Logs	PPT	Carlsbad Star	Engineers and Geologists
Mosley Canyon Well Logs	PPT	Carlsbad Star	Engineers and Geologists
Foster Field Case History of Water	PPT	Foster South Cowden Star	Engineers and Geologists
Foster Waters	Excel	Foster South Cowden Star	Engineers and Geologists
Stiff Plot Generator	Excel	Foster South Cowden Star	Engineers and Geologists
Stiff Plot Generator with Data	Excel	Foster South Cowden Star	Engineers and Geologists
Conoco #1 73 Elsinore DLL Log	TIF	Ft Stockton Elsinore	Engineers and Geologists
203RW a CO2 Bank Caught in the Act	PPT	Goldsmith Star	Engineers and Geologists
GLSAU Formation Tops	EXCEL	Goldsmith Star	Engineers and Geologists
GLSAU Geology and Volumetrics- Adrian	PPT	Goldsmith Star	Engineers and Geologists
Legado #126R Core Report	EXCEL	Goldsmith Star	Engineers and Geologists
Legado #190 Core Report	EXCEL	Goldsmith Star	Engineers and Geologists
Legado #204R Core Report	EXCEL	Goldsmith Star	Engineers and Geologists
Legado #222W Core Report	EXCEL	Goldsmith Star	Engineers and Geologists
Legado #58 Core Report	EXCEL	Goldsmith Star	Engineers and Geologists
Core analysis McCamey field	PPT	McCamey	Engineers and Geologists
Glossary	DOC	Midland Star	Engineers and Geologists
Geophysical & Geochemical Technique - Monitoring CO2 Floods	PPT	Midland Star	Engineers and Geologists
FutureGen Multiple Potential Water Sources	PPT	Penwell, Pecos Sequestration Star	Engineers and Geologists
FutureGen Penwell CO2 Capture	PPT	Penwell, Pecos Sequestration Star	Engineers and Geologists
FutureGen Proposal	PPT	Penwell, Pecos Sequestration Star	Engineers and Geologists
SACROC Near Surface Environmental Study	PPT	San Angelo Star	Engineers and Geologists
Hugh Value of ROZ at Seminole	PPT	Seminle Star	Engineers and Geologists
West Pearl Queen CO2 Flood - Pawar	PPT	Wickett, Calrsbad Star	Engineers and Geologists
Developing a Modular Curriculum for training University Students	PPT	Midland Star	Engineers, Geoogists, Land
Team Concept of Residual Oil zones	PPT	Midland Star	Engineers, Geoogists, Land
Potential for Long Term Use of Anthropogenic CO2	PPT	Midland Star	Engineers, Geoogists, Land
The History of Oil And Gas in the Permian Basin	PPT	Midland Star	Engineers, Geoogists, Land
Use of TX RRRC, UT Lands and NM Oil Con Div well logs and Data	PPT	Midland Star	Engineers, Geoogists, Land
BEG FutureGen Tinker CCUS Texas intro	PPT	Penwell	Engineers, Geoogists, Land
Energy Bill 2005 FutureGen Coal Gasification	Word	Penwell, Pecos Sequestration Star	Engineers, Geoogists, Land
FutureGen Road Trip 8-21-06	PPT	Penwell, Pecos Sequestration Star	Engineers, Geoogists, Land
Tenaska Trailblazer SOPO	Word DOC	San Angelo Star	Engineers, Geoogists, Land
Trailblazer News Release	Word DOC	San Angelo Star	Engineers, Geoogists, Land
Welcome to Seminole CO2 field Trip	Word DOC	Seminle Star	Engineers, Geoogists, Land
Cycles-Sequence Stratigraphy and Reservoirs - Stoudt	PPT	Carlsbad Star	Geologists
Identifying the Formations we will be discussing	Word DOC	Carlsbad Star	Geologists
Permian Overview - Stoudt	PPT	Carlsbad Star	Geologists

Vacuum Project - CO2 Potential	PPT	Carlsbad Star	Geologists
Vacuum Project -Core and Log Cross Sections	PPT	Carlsbad Star	Geologists
Vacuum Project -Core and Log Cross Sections with Correlations	PPT	Carlsbad Star	Geologists
Vacuum Project -Vacuum-Slaughter Field Comparison - Saller	Adobe PDF	Carlsbad Star	Geologists
Foster South Cowden Cores	PPT	Foster South Cowden Star	Geologists
Foster South Cowden Summary	PPT	Foster South Cowden Star	Geologists
Laguna #11 Foster Logs	TIF	Foster South Cowden Star	Geologists
Laguna #11 Foster Pegues Logs	TIF	Foster South Cowden Star	Geologists
Laguna #12 Witcher Logs	TIF	Foster South Cowden Star	Geologists
Laguna #2 Witcher Logs	TIF	Foster South Cowden Star	Geologists
Laguna All Core Analyses Data	Excel	Foster South Cowden Star	Geologists
Elsinore CO2	PPT	Ft Stockton Elsinore	Geologists
Hunt #57 Elsinore DLL Log	TIF	Ft Stockton Elsinore	Geologists
Hunt #57 Elsinore Sonic Log	TIF	Ft Stockton Elsinore	Geologists
Sandridge 6046 West Ranch Pinon DLL Log	TIF	Ft Stockton Elsinore	Geologists
GLSAU Core Description Corss Section	PPT	Goldsmith Star	Geologists
Goldsmith Geologic Review	PPT	Goldsmith Star	Geologists
San Andres Platform Potential	PPT	Goldsmith Star	Geologists
Gascoyne River - North Ward Estes Analog	PPT	Kermit Star	Geologists
Mother Nature's Waterflood - Artesia Trend	PPT	Kermit Star	Geologists
North Ward Estes - Why CO2 Floods Fail	PPT	Kermit, Wickett Star	Geologists
North Ward Estes Correlation Exercise	PPT	Kermit, Wickett Star	Geologists
North Ward Estes Yates Facies	PPT	Kermit, Wickett Star	Geologists
Mason Ellenburger	PPT	Mason Star	Geologists
Mason Field Trip	PPT	Mason Star	Geologists
Strat framework and Reservoir Delineation McCamey Field	Adobe PDF	McCamey	Geologists
What can core data tell without the core McCamey	PPT	McCamey	Geologists
McCamey core data Interpretation	PPT	McCamey Star	Geologists
McCamey core data Interpretation 2	PPT	McCamey Star	Geologists
McCamey Field	PPT	McCamey Star	Geologists
BEG Hovorka CO2 Capacity fairways	PPT	Midland Star	Geologists
The Long Term Future of the Permian Basin	PPT	Midland Star	Geologists
Ouachita Tectonism	PPT	Orla Star	Geologists
CO2 Sources Natural and Anthropogenic	PPT	Overthrust Star	Geologists
Ouachita Orogeny	PPT	Overthrust Star	Geologists
Cherry Canyon Isopachs	PPT	Pecos, Orla Star	Geologists
South Wells Cherry Canyon Cross Section	PPT	Pecos, Orla Star	Geologists
Santa Rosa Schuyler Wight Ranch	PPT	Penwell Star	Geologists
CO2 Sequestration Site-Defining a Target	PPT	Penwell, Pecos Sequestration Star	Geologists
Insoluble Residues Pecos Sequestration Site Geology	PPT	Penwell, Pecos Sequestration Star	Geologists
Pecos CO2 Sequestration	PPT	Penwell, Pecos Sequestration Star	Geologists
Pecos Sequestration - Sul Ross Presentation	PPT	Penwell, Pecos Sequestration Star	Geologists
Pecos Sequestration Delware Mountain Group	PPT	Penwell, Pecos Sequestration Star	Geologists

Lower Paleozoic Tabosa Basin	PPT	San Angelo Star	Geologists
ROZ Model History Characteristics	PPT	Seminole Star	Geologists
Apache Delaware Mountains	PPT	Van Horn Star	Geologists
Surface to Subsurface in the Permian Basin	PPT	Van Horn Star	Geologists
Van Horn Sandstone Red Rocks Ranch	PPT	Van Horn Star	Geologists
Tenneco #9 and #28 Core Description	PPT	Wickett Star	Geologists
Rocky Arroyo West Pearl Queen	PPT	Wickett, Carlsbad Star	Geologists
South Leonard Queen Complex Geology Part 1	PPT	Wickett, Carlsbad Star	Geologists
South Leonard Queen Complex Geology Part 2	PPT	Wickett, Carlsbad Star	Geologists
Vacuum Project - Land Map	PPT	Carlsbad Star	Land
Booking EOR project reserves	PPT	Midland Star	Land
Land in the Permian Basin	PPT	Midland Star	Land
Sable Field Land Issues on ROZ	PPT	Seminole Star	Land

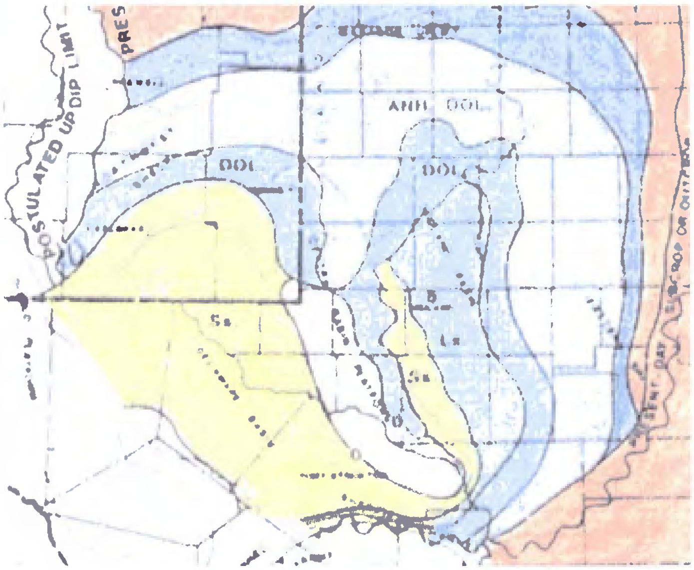
Appendix 2. List of PDF's, of DOE Field Study Technical, and Final Reports, and Other Reports

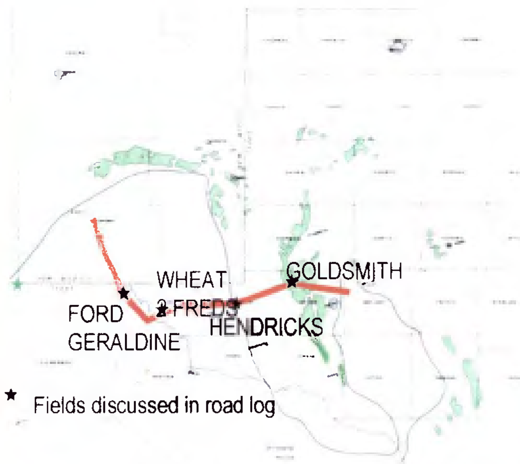
Technical and Final Reports	File Type	Module Star
Laguna Foster South Cowden Technical Report	Adobe PDF	Foster South Cowden Star
Phillips South Cowden Technical Report	Adobe PDF	Foster South Cowden Star
West Pearl Queen DOE Report	Adobe PDF	Wickett Star
West Pearl Queen Environmental Report	Adobe PDF	Wickett Star
West Pearl Queen Sequestration Technical Report	Adobe PDF	Wickett Star
East Ford Geraldine Geology Topical Report	Adobe PDF	Pecos Star
East Ford Geraldine Reservoir Characterization	Adobe PDF	Pecos Star
East Ford Geraldine Topical Using Old Electric Logs	Adobe PDF	Pecos Star
East Ford Geraldine Topical	Adobe PDF	Pecos Star
Ford Geraldine Topical	Adobe PDF	Pecos Star
Ford Geraldine Topical	Adobe PDF	Pecos Star
Ford Geraldine Topical	Adobe PDF	Pecos Star
Ford Geraldine Topical	Adobe PDF	Pecos Star
East Ford Geraldine Geology Topical Report	Adobe PDF	Orla Star
East Ford Geraldine Reservoir Characterization	Adobe PDF	Orla Star
East Ford Geraldine Topical Using Old Electric Logs	Adobe PDF	Orla Star
East Ford Geraldine Topical Tilted Oil/Water Contact	Adobe PDF	Orla Star
Ford Geraldine Topical	Adobe PDF	Orla Star
Ford Geraldine Topical	Adobe PDF	Orla Star
Ford Geraldine Topical	Adobe PDF	Orla Star
Ford Geraldine Topical	Adobe PDF	Orla Star
West Pearl Queen Environmental Report	Adobe PDF	Carlsbad Star
West Pearl Queen Sequestration Technical Report	Adobe PDF	Carlsbad Star
West Pearl Queen DOE Report	Adobe PDF	Carlsbad Star
Summary Field Trip Seminole	Adobe PDF	Seminole Star
USGS Pub 2012	Adobe PDF	Seminole Star

Tenaska Trailblazer Structure Model	Adobe PDF	San Angelo Star
Tenaska Trailblazer Agreement for Geologic Structure Model	Adobe PDF	San Angelo Star
Tenaska Trailblazer Geologic Methodology	Adobe PDF	San Angelo Star

Appendix 3. Road Log Odessa to Orla to Clarsbad, and Figures, see below.

2013 CO2 CCUS Student Module Field Trip
Road Log Day 1
Midland – Kermit – Orla – Carlsbad
By Bob Trentham
Modified from road logs by Bob Lindsay, Bob Ward and Bob Trentham & Peter Scholle.





Interval Mileage	Cumulative Mileage	Description
		Welcome to the 2008 PBS-SEPM Summer Intern and New Hire Geology Field Trip to the Guadalupe Mountains. Today, we will leave CEED and head west on SH 191 through Odessa. We will then be driving west on SH 302 thru Notrees, Kermit and Mentone. Turn north on US 285 to Orla and west on FM 652 to US 62 /180, west/south on US 62/180 to Pine Spring and the Salt Flat Graben. Then backtrack to Carlsbad.

On this trip we will be reviewing the Permian Guadalupian basin and shelf deposits in the Delaware and Guadalupe Mountains. As geologists first studied West Texas, they realized that a large, potentially hydrocarbon-rich, basin of Permian age lay between the Trans-Pecos Mountains, to the west, and exposed Paleozoic outcrops in north-central Texas, to the east. However, the basin was covered by Triassic, Cretaceous, and Tertiary deposits (King, 1977). This thick section of Permian rocks soon became known in West Texas and Southeastern New Mexico as the Permian Basin. If the basin were symmetrical, the deepest portion of the Permian Basin should have been in Winkler County and therefore oil deposits should have migrated up dip and been trapped along the basin margins. There were some who did not follow the conventional wisdom, who realized that the thick salt horizons in the Ochoan thinned across the center of the basin. O. C. "Kip" Harper, in particular, mapping the Triassic red beds thought he found the largest anticline in the world in the center of the basin.

Interval Mileage	Cumulative Mileage	Description

With this different, non-conventional data, companies such as Gulf Oil leased great tracts of West Texas at low prices with long term contracts. What they had discovered was the Central Basin Platform. Once wildcat wells began discovering fields along the Eastern Shelf, such as Westbrook (the first commercial discovery of oil in West Texas) and Big Lake, additional drilling revealed the Central Basin Platform and it became obvious that the simple model of the Permian Basin was actually much more complex. As drilling progressed, the Delaware, Midland and Val Verde basins were recognized to the west, east and south of the Central Basin Platform. The San Simon and Sheffield channels, which connected the basins, were also recognized, as were the surrounding shelves, the Northwest and Eastern Shelves, the Sierra Diablo/Apache Platform and the Marathon Uplift. Deeper drilling discovered additional production down through most of the Paleozoic section, from the Permian to the Ordovician. Since the 1920's well over 3,000 oil and gas fields have been discovered, which are productive from the Central Basin Platform, the Delaware, Val Verde and Midland basins, and the Northwest and Eastern shelves, and the older Tobosa Basin sediments. The deepest wells in the Permian Basin are over 29,000' drilled for gas in the lower Paleozoic in the southeastern Delaware and northwestern Val Verde Basins.

The Paleozoic section of West Texas and SE New Mexico can be divided into the lower Paleozoic Tobosa Basin and the upper Paleozoic Permian Basin. For the brief review to follow on hydrocarbon production, the Tobosa Basin and Permian Basin will simply be referred to as the Permian Basin. In the Permian Basin, hydrocarbon production has been established from most of the Paleozoic section, specifically the Ordovician through the Permian. The basin is estimated to have more than 100 Billion barrels of original oil in place, approximately 30% of that has been produced. Because of the heterogeneous nature of Permian Basin carbonate reservoirs, individual field recoveries range from ~10% to 35%. An additional 5-10% is anticipated to be recoverable with today's technology. It is estimated that an additional 15 Billion barrels of oil may be in place is Residual Oil Zones, of which 2/3 may be recoverable in the future. These ROZ reserves have not been previously factored into the basin OOIP or Proven/Possible or Unrecovered Mobile Oil.

Five percent of all hydrocarbon production in the world, through 1984, was from the Permian Basin. In 1984 alone, three percent of all hydrocarbon production in the world was from the Permian Basin One percent of all proven producible reserves world-wide are from the Permian Basin (**Table 1**). Over 2/3rd of the 68 BBO in U. S. Shallow Shelf Carbonate Original Oil in Place is found within 150 miles of Midland/Odessa (**Fig. 1**). Of that 68 Billion

Interval Mileage	Cumulative Mileage	Description
		barrels of OOIP, only 19.0 BBO (28%) has been produced. An additional 17.5 BBO (26%) are recoverable (**Fig. 2**). Over 1 Billion barrels of oil has been recovered as a result of tertiary (CO2) recovery methods in the basin since 1970, and until recently, over 70% of all CO2 recovery projects have been in the Permian Basin. Most hydrocarbon production, by period in the Paleozoic system, is from the Permian. The Guadalupian, more specifically the San Andres and Grayburg formations, is by volume the largest productive interval, having produced almost 2/3 of the production to date. Hopefully, with these data in mind we can more thoroughly appreciate the remarkable subsurface and surface geology we will be driving over, not to mention a little bit of local history.
0.0	0.0	Start at the UTPB/CEED Building. Go north out of the parking lot on FM 1788; turn left on to SH 191. On the northwest corner of the intersection is a well in the Hallanan (Strawn) Field. Continue on SH 191 toward Odessa. We are traveling across the Midland Basin portion of the Permian Basin. The Midland Basin is less than half as deep (13-15,000') as the Delaware Basin (26-30,000') to the west. Production in this portion of the basin is primarily from lower Paleozoic Fusselman, Devonian and Ellenburger structures and Strawn strato-structural traps. The Spraberry Trend of basinal sand production is restricted to the east but with recent success, the potential for WolfBerry is pushing exploration in this direction. As we approach Odessa, we will cross Billy Hext road. This marks the eastern edge of the Headlee Field. The Headlee Trend extends for over 60 miles from Amacker Tippett Field in Upton County on the south to Ratliff Field in northern Ector county. The Headlee field was discovered in 1953 with production established from the Ellenburger Group at a depth of >13,000'. Within a year, production was also established from the Devonian at a depth of 11,750' to 11,900'. The wells on both sides of the road are presently producing gas from the Devonian. There are two cross sections included (**Fig 3 & 4**) in the road log. The large, fold out section (**Fig. 3**) is a diagrammatic slice east west through the basin approximating the route we will be taking today. The smaller page size (**Fig. 4**) cross section crosses the Central Basin Platform and reflects the variety of structural, strato-structural and stratigraphic traps.

Interval Mileage	Cumulative Mileage	Description
		Crossing Loop 338, we are at the northeast corner of the 1 square mile UTPB campus, where SH 191 becomes 42nd Street. To the south, is a park with soccer and softball fields and fenced-in areas with producing wells in the Headlee Field. There are a number of producing and injection wells and a gas processing station on the UTPB campus. In 1923 the discovery of oil in the Permian Basin changed Odessa from farming and ranching community to a busy center of the oil industry.
0.0	0.0	We are driving upon the Miocene-Pliocene Ogallala Formation. The Ogallala was shed off of uplifts to the west when the Rocky Mountains were uplifted and the Rio Grande rift was formed. Braided stream channels, Aeolian sand and silt, and a cap of caliche make up the Ogallala. It is an excellent source of fresh drinking water and is extensively used by the agriculture industry further north.
0.0	0.0	Intersection of John Ben Sheppard Parkway and 42nd Street. Begin mileage for field trip.
1.0	1.0	Grandview Avenue.
1.0	2.0	Dixie Blvd. Approximate boundary between the Midland Basin to the east and the Central Basin Platform to the west as defined by the San Andres and Grayburg carbonate shelf margin.
1.0	3.0	Andrews Highway. Ector Country Coliseum.
0.3	3.3	Odessa Water Treatment Plant on left.
0.5	3.8	County Road West. East edge of Grayburg, San Andres and Pennsylvanian production in Foster Field. This is one of a number of Grayburg and upper San Andres fields producing from stratigraphic traps along the eastern edge of the Central Basin Platform, starting with the Yates Field in Pecos County and extending as far north as the Means Field in Andrews County. A distance of over 120 miles. The shelf carbonates transition updip into sabkha's with the associated loss of porosity and production.
0.3	4.1	County Road West.
0.8	4.9	Curve left to stop light. Turn right (west) on SH 302.
0.1	5.0	Loop 338 West. Begin SH 302 West. Stay on 302 West.

Interval Mileage	Cumulative Mileage	Description
2.4	7.4	FM 1936.
0.9	8.3	To the south is the west edge of Foster Field. Production ceases where up dip pinchout of porosity occurs. The upper San Andres pinchout is further west than the Grayburg pinchout in Ector County.
1.0	9.3	To the north, the western edge of the production in the Foster Field can be seen.
2.1	11.4	Single producing well on left.
1.5	12.9	Producing wells in Goldsmith East Field, production is from the middle to upper San Andres.
1.2	14.1	Pump Station on right.
1.0	15.3	Junction FM 866.
0.4	15.7	Eastern edge of Goldsmith Field. The Goldsmith Field is one of the larger fields on the Central Basin Platform. Producing from the Permian Grayburg, San Andres, McKnight, Holt, "5600"-upper and middle Clear Fork, and Tubb; Pennsylvanian (Strawn); Devonian; and Ordovician Ellenburger. The main productive intervals are the San Andres, with 590 MM Bbls OOIP in the oil column and additional potential in a large residual oil interval, and 5600-upper and middle Clear Fork, with 640 MM Bbls OOIP. This field is typical of the "structurally controlled" fields along the Spine of the CBP which are the product of Ouachita (Middle Penn to Early Permian) Tectonism. During the San Andres, there were a number of major exposures which resulted in karstification of the San Andres and erosion/non deposition which reduces by almost half of the total thicknesses of the San Andres sediments across the platform. On the east and west margins of the Central Basin Platform, the total San Andres is 1300-1600' thick, whereas at Penwell (on the "spine of the Platform" the San Andres is only 785' thick with middle SADR on the crest of the structure and upper SADR on the flank. A CO2 flood of the Main Pay Zone (MPZ) and Residual Oil Zone (ROZ) was initiated in 2009 in the Goldsmith Landreth San Andres Unit part of the Goldsmith Field north of SH 158. The owner, Legado a smaller independent, purchased ~ 10

Interval Mileage	Cumulative Mileage	Description
		sections of the San Andres portion of the field expressly for the development of the CO2 potential in the MPZ and the ROZ. After deepening wells thru the ROZ and drilling some replacement wells, Legado initiated a 5 spot producer centered pilot in the ROZ to determine the CO2 flood potential. They also put in place a curtain of water injectors around the pilot. After a successful test, they have initiated a phased development of the full field MPZ and ROZ CO2 flood. To separate the CO2 from the produced Natural Gas and Natural Gas Liquids, Legado contracted to have a "turnkey" gas plant built by a company which will separate the CO2, return it to Legado and sell the gas and NGL's into the pipeline.
3.5	19.2	Town of Goldsmith and Refinery to north.
1.4	20.9	Western edge of Goldsmith Field.
0.2	21.1	Junction SH 158 and FM 181. Continue west on SH 302.
1.8	22.9	Production to south. Eastern edge of TXL Field. The TXL Field produces from the San Andres, Upper Clear Fork, Lower Clear Fork, Devonian, Fusselman, and Ellenburger
1.7	24.6	Production in TXL Field to north
0.8	25.4	Junction FM 2019 to south.
0.4	25.8	Anadarko Field Office to south.
0.5	26.3	Town of Notrees
		Just past Notrees is the western edge of the Caprock. Here the Ogallala has been eroded and the road cut is composed of highly fossiliferous lower Cretaceous Edwards Limestone and basal Trinity Sandstone.
3.0	29.3	Ector-Winkler County line. Wheeler Field to the south produces from the Devonian and Ellenburger.
0.5	29.8	Escarpment to north.
3.2	33.0	Historical Marker. Begin stabilized sand dunes. The sands are wind blow from the Pecos River Valley. The sand is carried by prevailing winds and is "dumped" here because it cannot be carried up the escarpment. The sand is almost identical to the producing sand in the Yates and Queen.

Interval Mileage	Cumulative Mileage	Description
2.2	35.2	Waddell Ranch road to north.
3.8	39.0	Circle 2, A & W, Damron and Flying W Fields to the north produce from the Devonian and Ellenburger.
3.3	42.3	U Ranch Road to north.
2.7	45.0	Entering the Kermit Field which produces oil from a stratigraphic trap in the Yates, the Seven Rivers, and the Queen Formations. This is one of many fields along the trend from Ft. Stockton, Texas, to Hobbs, New Mexico, that produces from all three formations. Unlike the eastern side of the CBP where the majority of production is from the lower Guadalupian Grayburg and San Andres shelf carbonates, and the Yates and Queen are not of reservoir quality, on the west side of the platform, the production is primarily from the sands of the Queen and Yates, and the San Andres and Grayburg carbonates, which are present and porous, do not trap oil.
2.1	47.1	Kermit, Texas. The Kermit Deep Field produces oil and gas from a large anticlinal trap in the Devonian and Ellenburger. The Keystone field is 7 miles northeast of the town of Kermit and is one of the giant oil fields in West Texas.
0.5	47.6	Intersection SH 18.
2.0	49.6	Intersection of SH115 & SH302.
		Side trip to Wink Sink We will not go there today.
0.0		*Turn left onto SH 115. Proceed south.*
0.9		*County Road 207.*
0.7		*Arena on left.*
0.6		*County Road 206.*
0.9		*Plains Pipeline Tank Farm on left.*
0.1		*County Road 205, water station on right. Turn left onto CR205.*
0.2		*Pull off road before left hand bend. The Wink Sink #1 is to the southwest inside the fence. Note: We have obtained the owners permission to be here. Do not attempt to gain access to the Sink without permission. Wink Sink #1 began to develop on June 3, 1980. Within 24 hours, it had expanded to a maximum width of 360'. Sagging around the east and south side continued for some time. Continued fracturing along the west and north continues to today. The Wink Sink Lies directly over the crest of the Hendrick Field (Tansill, Yates) and the Capitan Reef Trend. Progressive salt dissolution from the west, a natural brine-density flow cycle associated with fractures over the crest of the reef and brine cycling associated with production have been proposed as the*

Interval Mileage	Cumulative Mileage	Description
		cause of the Sink. The Wink Sink #2, approximately 1 mile to the south began to develop on May 21, 2002. It is presently still growing and is in excess of 700' by 900'. Depth unknown.
3.4	49.6	Intersection of SH 115 and SH 302. Proceeded west on SH 302.
1.9	51.5	FM 874 on right. At this location, we are crossing the trend of the buried Capitan reef. This is the axis of the Hendrick Field trend which extends to the north to the New Mexico State line and south past Wickett. The Hendricks Field, and the Mag Sealy Field to the south in Ward County produce from the Yates and or Tansill where the sands drape across the Seven Rivers age Capitan Reef. The Wink Sink is on the axis of the field and is located to the south at the western edge of the tank farm. In the winter of 2004, a 5 acre infill well, one mile to the north, had a bit drop and subsequent flow of oil from the Salado @ ~1600'. The uplift of the Laramide and the Basin and Range tectonic events has resulted in the dissolution of the Salado Salt over large portions of the Delaware Basin. The dissolution and collapse of the overlying Rustler (Permian) and Santa Rosa (Triassic) Formations has resulted in the development of collapse zones that are filled with as much as 1500-2500' of Cenozoic Alluvium. One zone roughly parallels the position of the Capitan reef along the western margin of the Central Basin Platform. The Wink sinks are situated along the eastern edge of the solution/collapse zone. Mud Log #1 (**ML1**) is an example of the chaotic nature of the Collapse Zone. You will see Mud Logs (ML_) throughout the road logs. These are to provide you with an idea of what the intervals being discussed look like in cuttings (gray bar) on the associated full log.
1.9	53.4	Upper Guadalupian western edge of the Central Basin Platform.
5.2	53.6	Intersection FM1232 to south to Winkler Airport, north to Golf Course. The tank farm to the south is just to the northeast of the original Wink Sink.
8.0	61.6	Winkler-Loving County line. We are at the eastern edge of the deep Delaware Basin. The ultra-deep Fusselman and Ellenburger gas fields are to the south. Five miles to the north is the Evetts Field; it produces gas from a depth of 20,300 feet.
3.3	64.9	Crest of ridge with microwave tower. Center of activity for deep gas play. From this point can be seen a number of wells, both north and south of the road, which are drilling for "Barnett Shale" in the 17000 to 19000' depth as an extension of the Haley

Interval Mileage	Cumulative Mileage	Description
		(Penn) Field.
4.7	69.6	To the south are the Two Freds and Meridian Delaware Sandstone Fields (**Fig. 5**). To the northwest, the Wheat Field. These fields are in one of the five trends producing from stratigraphic traps in a submarine fan complex in the Bell Canyon Formation (**Fig. 6**). We will be seeing these producing deep water turbidites later today in outcrop. These fields, at a depth of ~4200' produce from the uppermost "Ramsey" sand in the Bell Canyon Formation. The difference between a productive Bell Canyon well and a dry hole can be measured in 10's of feet laterally. **ML2** is an example of a potentially productive well with thick Ramsey Sand with shows. **ML3** is an example of a "Ramsey Sand" well that is in an inter-channel position and not potentially productive. In 1920, the Toyah Bell #1 Russell flowed oil but was never completed. The field was opened by the Pecos Valley Petroleum #1 Wheat on Sept 1, 1925, flowing 20 BOPD from the Ramsey Sand at a TD of 4259' By 1958, there were 131 pumping wells and 12 flowing wells in the field. The field, at the time, had produced over 14 MMBO. As an aside, one well in the Wheat Field, the Donnell #3 Victor, was completed in 1951 from the Castile Evaporite at a depth of 2400-2490', pumping 92 BO, 5 BW, it produced a total of 560 BO before being deepened to the Ramsey and eventually plugged and abandoned. There are a number of isolated wells and small fields in the western half of the Delaware Basin that have produced from the Castile. They are probably the result of oil migration from the Delaware Mountain Group, possibly during Laramide or Basin and Range tectonism.
8.5	78.1	Town of Mentone, Texas. Wheat Field produces from sandstone in the Bell Canyon Formation. Moore-Hooper and Vermejo Fields produce gas from Fusselman dolomite at 18,700 feet and from Ellenburger dolomite at 21,100 feet.
3.0	*81.1*	***Pecos River. Reeves County line. The Pecos River is the product of Tertiary headward erosion. Streams originally flowed off of the Rio Grande rift from west to east. Later, headward erosion from the south-southeast captured most of these streams, forming the Pecos slope and river drainage system. The river flowed with a swift current, 10 ft. deep and 100 ft. across. The Pecos could only be crossed in a few places, such as, Horsehead crossing near Pecos, Texas. Another crossing was immediately south of the New Mexico-Texas state line, called Pope's crossing. The last crossing was near Carlsbad, New Mexico.***

Interval Mileage	Cumulative Mileage	Description
1.0	82.1	Town site of Arno, Texas.
1.3	83.4	Intersection of Texas Highway 302 and U. S. Highway 285. Turn right onto Texas Highway 285.
6.2	89.6	Horsehead Draw. Buildings on right.
2.9	92.5	El Capitan and Guadalupe Mountains @ 10:00 in the distance.
1.7	94.2	Orla S.E. Field, Delaware.
1.6	95.8	Entering Orla-Tunstill-East El Mar Bell Canyon trend.
0.9	96.7	4 Mile Draw.
4.4	101.1	Picnic area on left.
3.2	104.3	Town or Orla, Texas. Crossing Chapman-Olds-El Mar Bell Canyon trend. Chapman Deep Field produces gas from the Atoka and Fusselman. Continue north on U. S. Highway 285
9.0	113.3	Geraldine-Ford-Corral Draw Bell Canyon trend. Red Bluff Lake to the right. Southern edge of the Jess Burner Cherry Canyon field, discovered in 1982.
4.4	117.7	New Mexico-Texas state line. We have now entered the Central Standard Time Zone. Set your watch forward one hour.
16.0	133.7	Intersection of U. S. Highway 285 & N. M. Highway 396, at Malaga, N. M. Malaga (Morrow Sandstone) Field. Willow Lake Field, to right, is productive from the Brushy Canyon, Bone Spring, Wolfcamp, Atoka, and Morrow. Continue north on U. S. 285.
4.9	138.6	Loving, N.M. Along the Pecos River ran the Goodnight-Loving Trail. Charles Goodnight and Oliver Loving drove herds of cattle west from Weatherford, Texas to the Pecos River, then north along the Pecos to Fort Summer in the 1860's and 1870's. The trail continued on north to Las Vegas, Raton, Trinidad, Denver, and Cheyenne. In 1867 Charles Goodnight and Oliver Loving were driving a herd of cattle to Fort Sumner, New Mexico. They were a few days behind schedule and decided to have Loving and One-armed Bill Wilson ride ahead of the herd to contact the Army and assure them the cattle would arrive safely. Once they were a

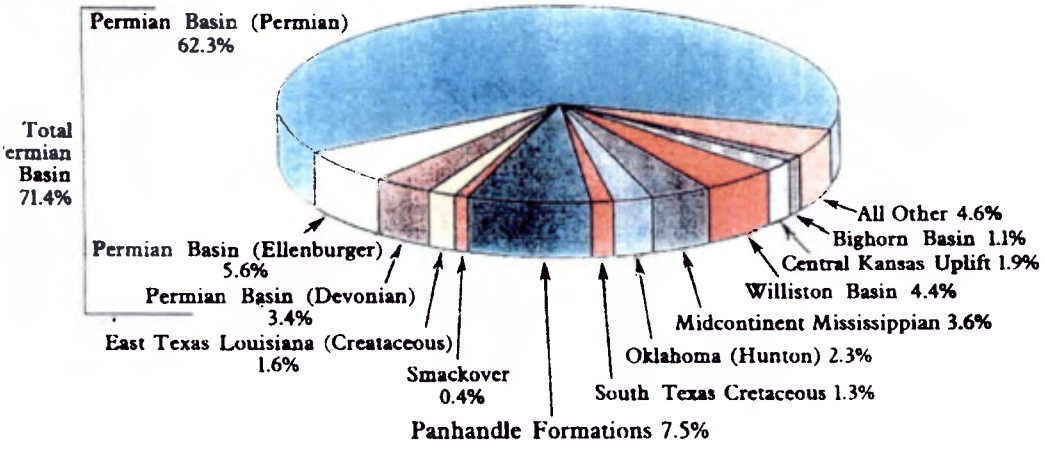
Interval Mileage	Cumulative Mileage	Description
		few days ahead of the herd, Loving and Wilson were jumped by a large band of over hundred Mescalero Apache Indians. They raced four miles on horseback to the Pecos River for cover, ending up behind a sand dune between the foot of the bluff and the river. Loving was shot in the side when trying to make peace with the Indians. In the evening, One-armed Bill stripped down to his underwear and swam down the Pecos in search of Goodnight and the cattle herd. Though wounded, Loving held off the Indians for two days. The Indians finally gave up on capturing or killing him. Loving then crawled five miles upstream and passed out. He was found by three Mexicans and a German boy and transported, for $250.00, to Fort Summer where he died of gangrene on September 25, 1867. His last wish was to be buried back in Texas. Goodnight honored his dying partners request and transported his body 500 miles back to Weatherford, Texas to be buried. The town of Loving, New Mexico and Loving County, Texas were named in honor of Oliver Loving.
2.9	141.5	Railroad crossing and intersection of N. M. Highway 31 and U. S. Highway 285. Note that local farmers level their land and irrigate with a system of irrigation ditches. They utilize water from the Pecos River.
1.8	143.3	On right is Herradura Bend field. It is productive from the basal Brushy Canyon, from a different basin floor turbidite fan than East Herradura Bend field.
0.8	144.1	Town of Otis, New Mexico. Established in 1893, the town is named after T. E. Otis, director of AT&SF Railroad.
0.3	144.4	Intersection U. S. Highway 285 and Derrick Road. Continue straight ahead on U. S. Highway 285.
0.3	144.7	Carlsbad Field. It is productive from the Pennsylvanian Morrow, Strawn, Canyon (mounds), and Permian Wolfcamp and Bell Canyon.
4.1	148.8	Carlsbad, New Mexico city limit. Intersection of U. S. Highway 285 and Calvami Road. Continue straight ahead on U. S. Highway 285. Carlsbad was first settled by Charles B. Eddy, whom Eddy County is named after, in the early 1880's. He laid out the town in the fall of 1888 and planted trees in the winter of 1889-90. The town was originally named Eddy. The mineral content of a spring northwest of town rivaled that of the Carlsbad Spring in Bohemia, so the name of the town was changed from Eddy to Carlsbad. An election on May 23, 1899

Interval Mileage	Cumulative Mileage	Description
		voted on the name change and Governor W. B. Lindsey proclaimed the town Carlsbad on March 25, 1918.
0.5	149.3	T intersection of U. S. Highway 62-180 and U. S. Highway 285. Turn right onto U. S. Highway 62-180, driving northeast.
0.8	151.1	End at Steven Motel on the left. After lunch and check-in, we will have additional presentations and begin the separate meetings for Engineers, Geoscientists, and Land Personnel.

End Day 1.

See Figures beginning next page.

SHALLOW SHELF CARBONATE RESERVOIRS



ORIGINAL OIL IN PLACE = 68 BILLION BBL.

ght Oil Reservoirs in TORIS

Department of Energy(DOE)

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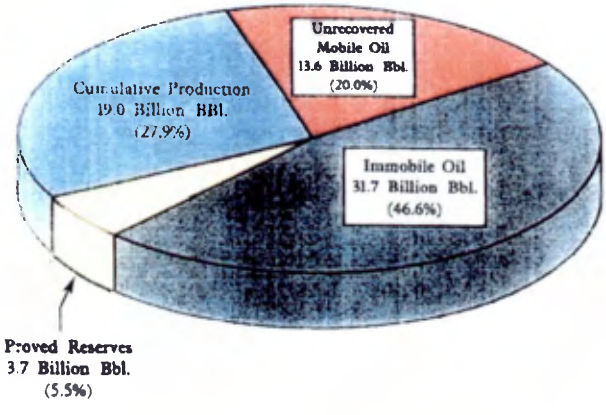
Carlsbad Road Log Day 1, Figure 1.

SHALLOW SHELF CARBONATE RESERVOIRS



ORIGINAL OIL IN PLACE = 68 BILLION BBL.

Light oil reservoirs in TORIS

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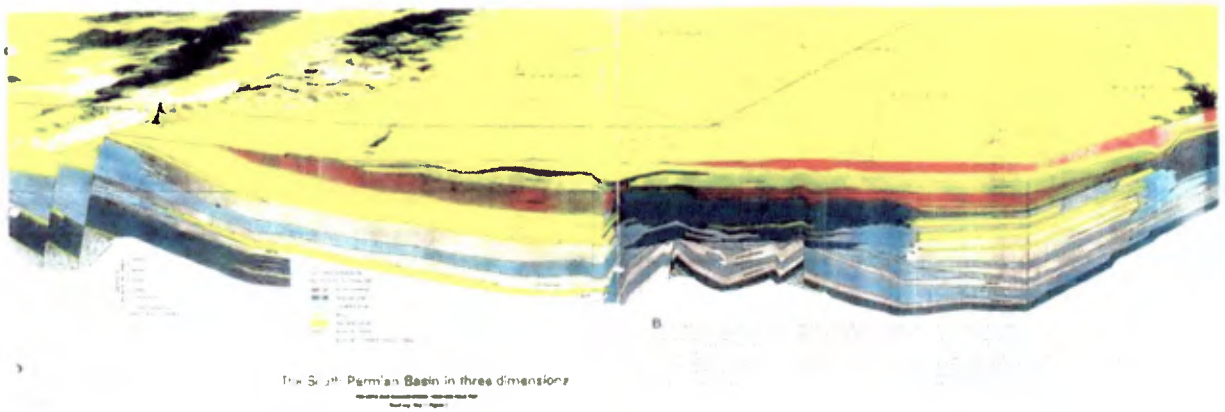
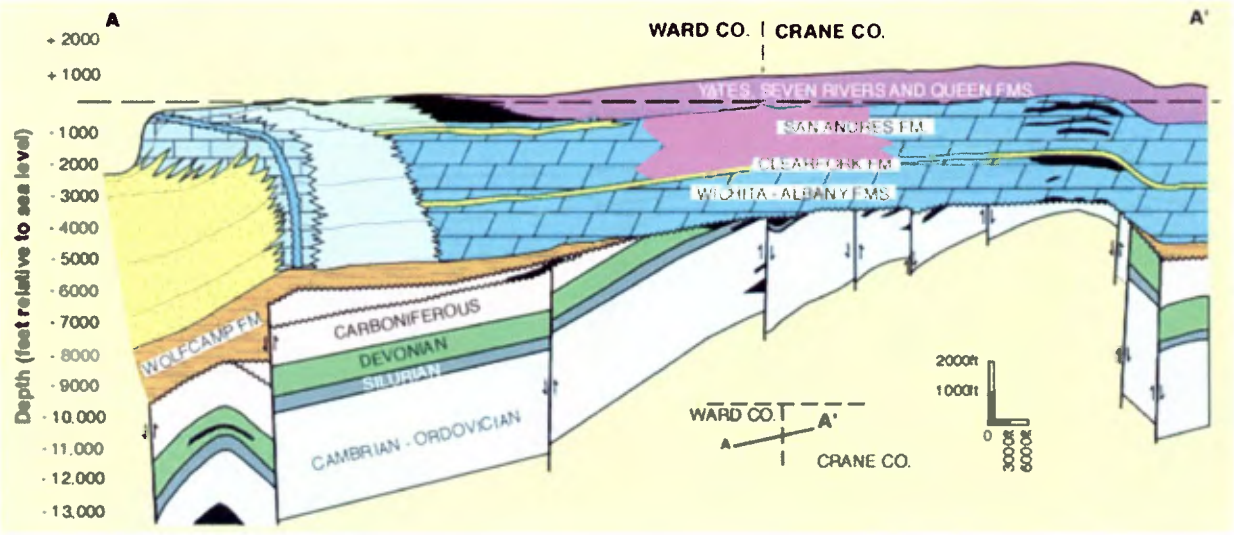
Department of Energy(DOE)

Carlsbad Road Log Day 1, Figure 2.



Carlsbad Road Log Day 1, Figure 3.



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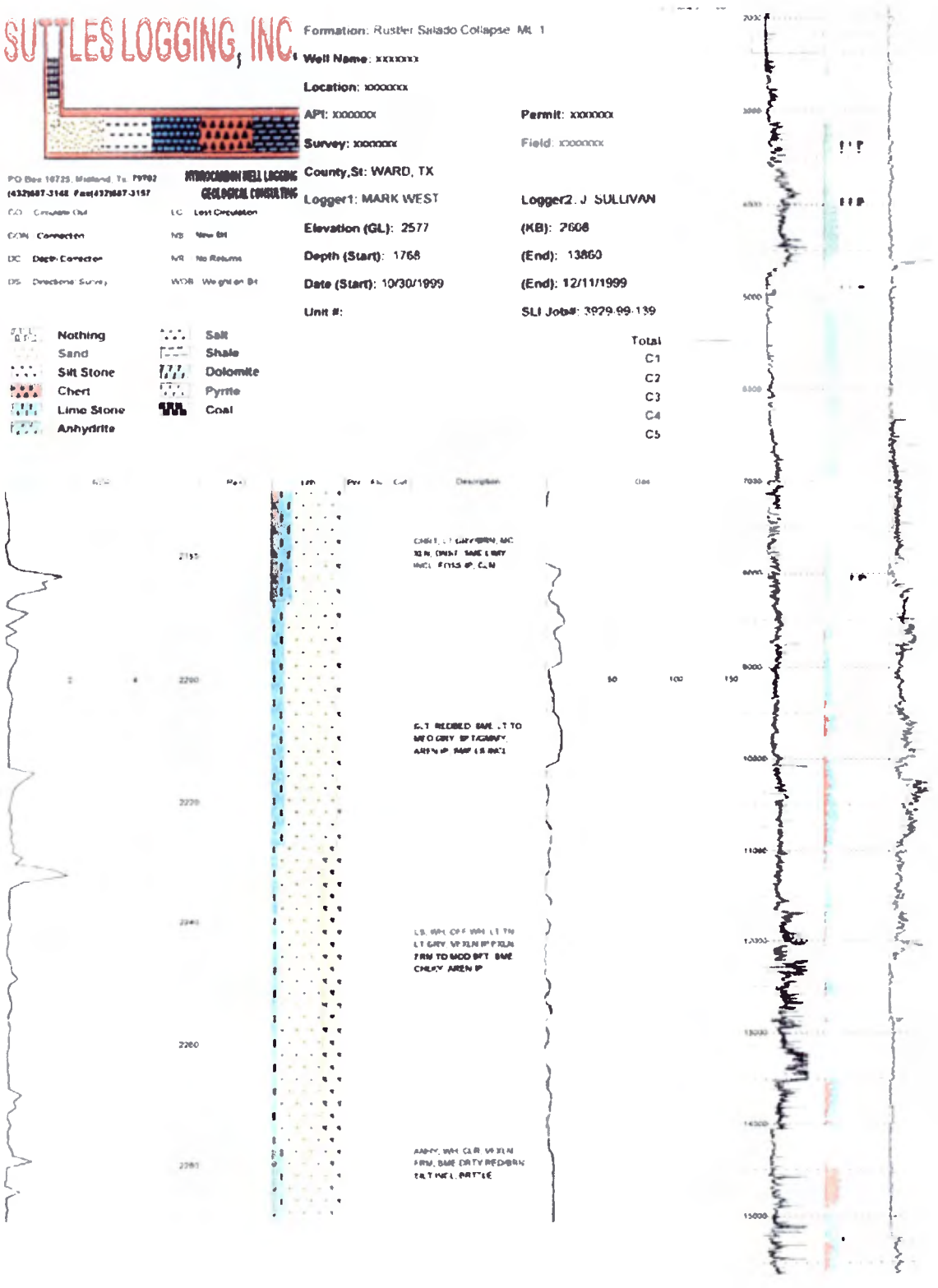
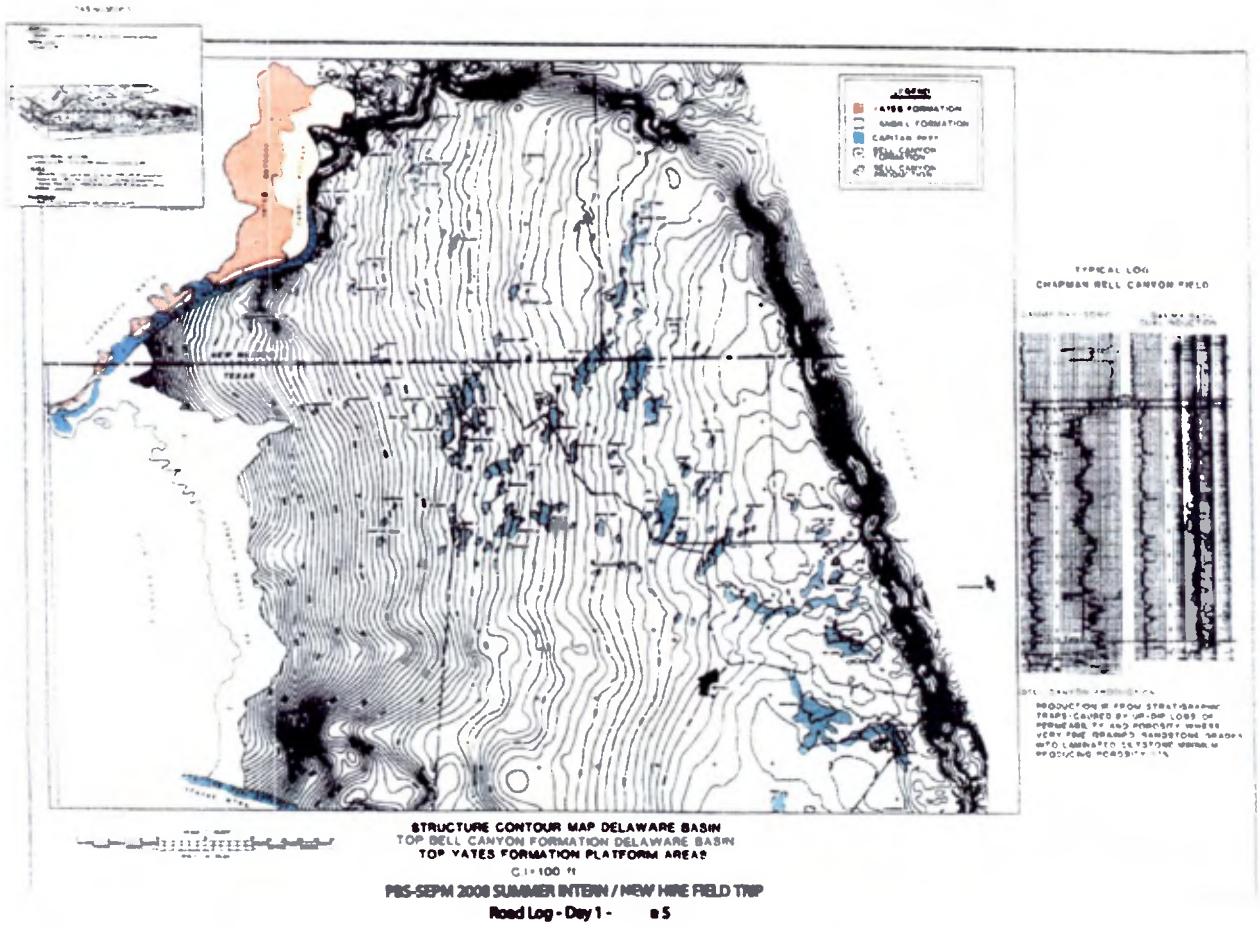


Carlsbad Road Log Day 1, Mud Log 1 Rustler Salado Collapse.



Carlsbad Road Log Day 1, Figure 5. Structure Map of Delaware Basin with Delaware Mountain Group Fields.

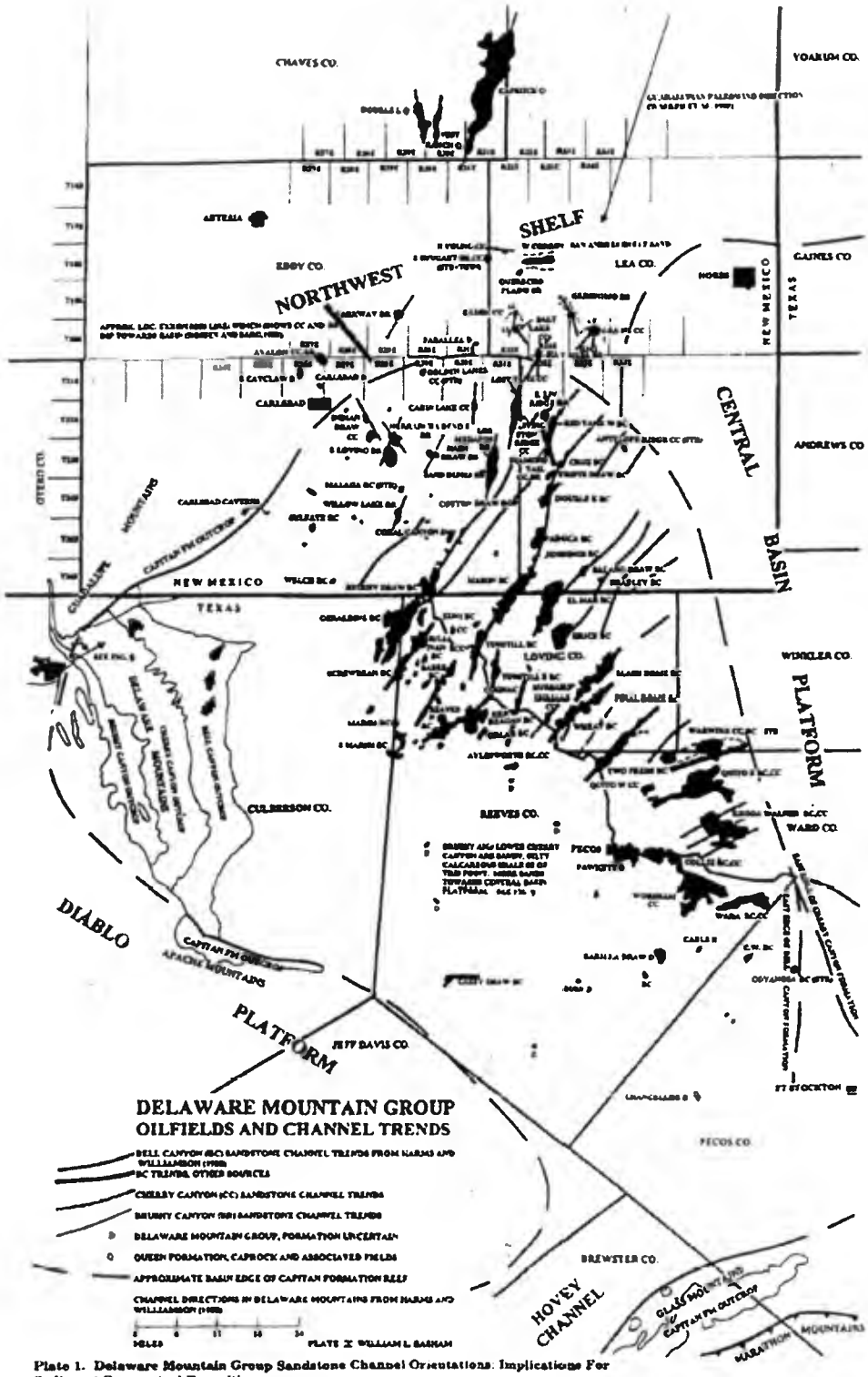


Plate 1. Delaware Mountain Group Sandstone Channel Orientations: Implications For Sediment Source And Deposition.

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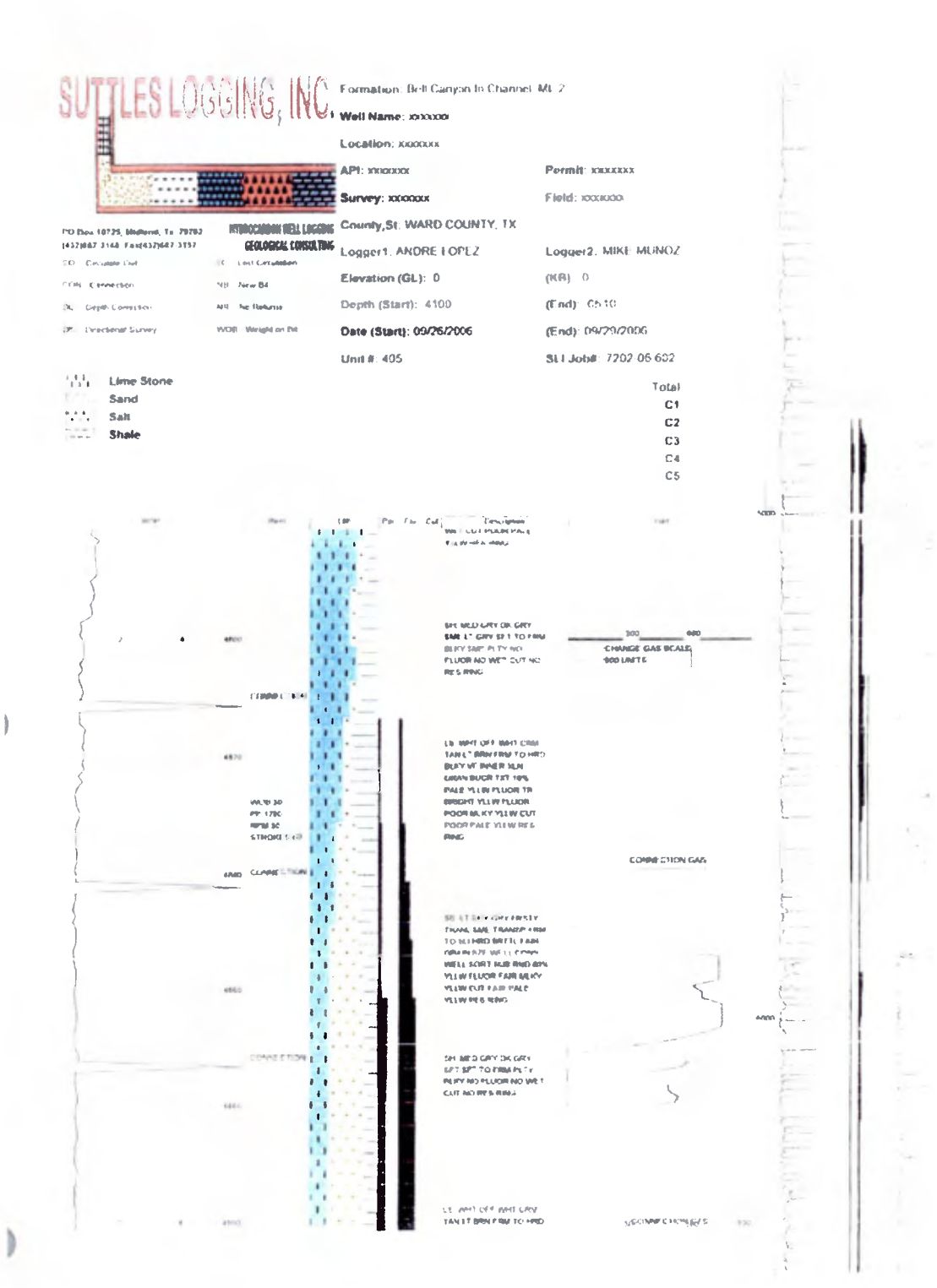
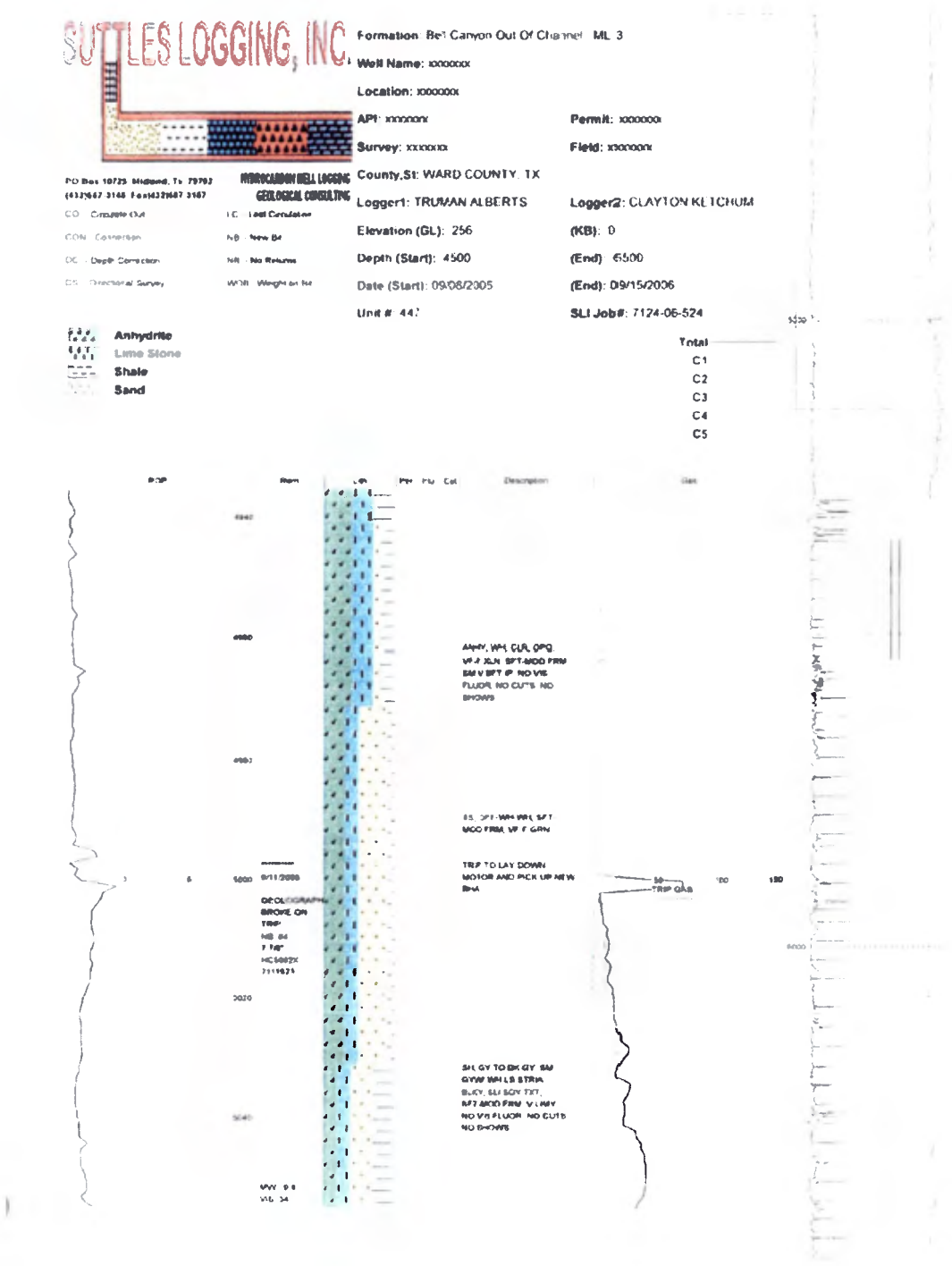
Road Log Day 1 - Figure 6

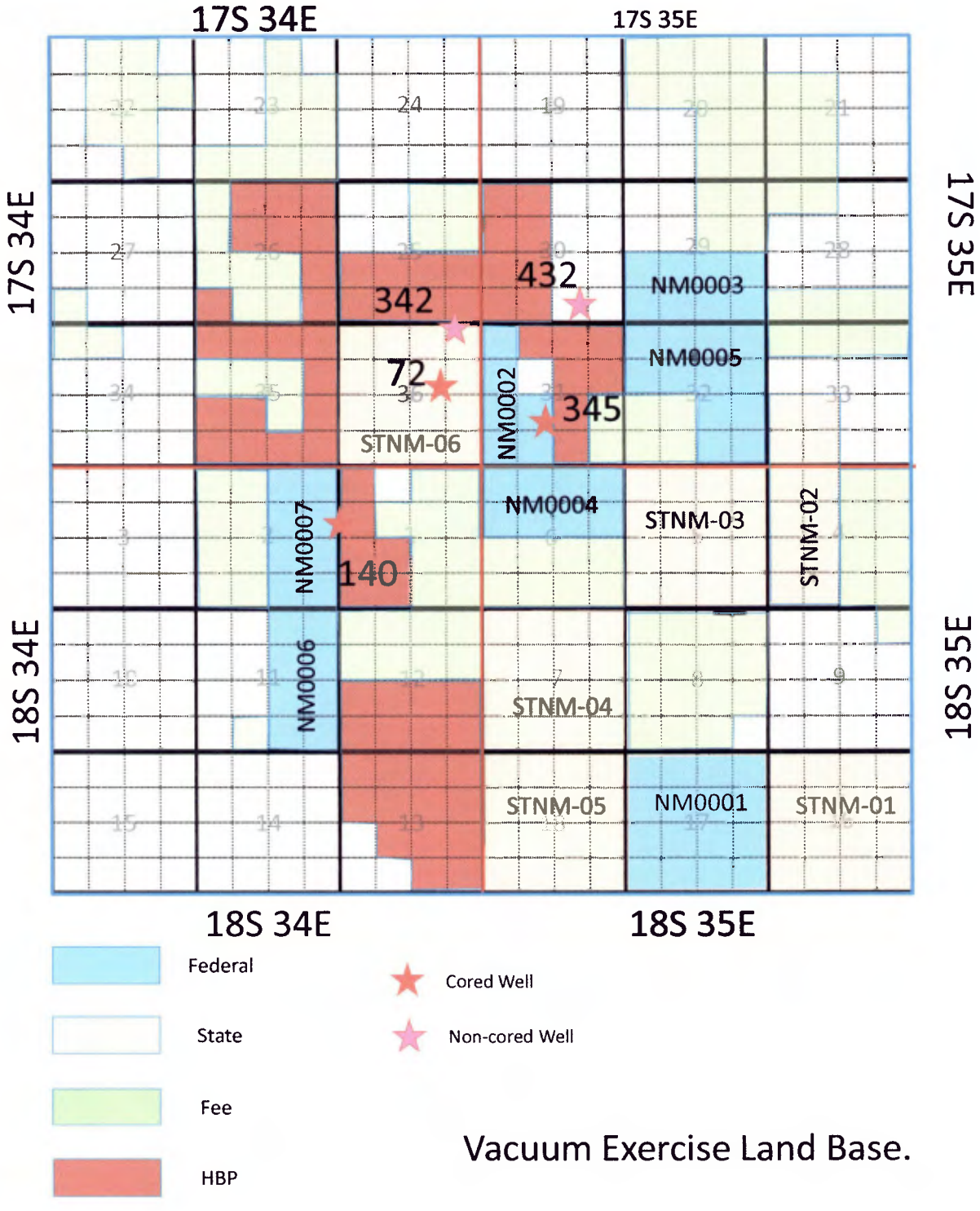
Carlsbad Road Log Day 1, Figure 6. Delaware Mountain Group submarine channel trends and fields.



Carlsbad Road Log Day 1, Mud Log 2. Bell Canyon channel sand.



Carlsbad Road Log Day 1, Mud Log 3. Bell Canyon no channel sand



Vacuum Exercise Land Base.

Appendix 4. Land Map for Vacuum Project

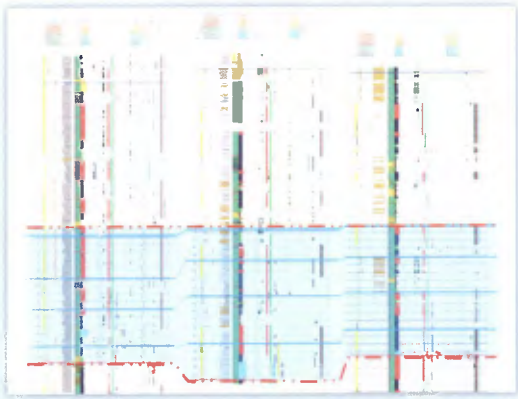
Appendix 5.

Vacuum Team Project

Core Description Exercise - Correlated

The 5 Cycle Sets are correlatable across the field with electric logs. Each one, however, represents significantly different reservoir facies distribution, and would have different reservoir response. When correlating from open marine to tidal flat areas, correlation can become difficult as there are significant changes in the porosity logs.

7



8

Flow Unit 1 is associated with the rapid flooding of the Brushy Canyon Bypass Surface exposure surface. The #140 VGBSAU well is initially high and when flooded, is represented by an interval of carbonate with reworked sand. The #345 CVU well is in a topographically low area on the exposure surface, and the base of the interval is rapidly submerged in 60-80' water, and in an area where an outer shelf reef complex forms. Near the top of the unit there are good reservoir quality ooid shoals. The #140 VGBSAU well is also on a topographically higher area and eventually gets flooded to a depth at which a thin, open marine reef can form above the old exposure surface. This interval never develops good reservoir quality as the porosity is mostly moldic. This Flow Unit, although thick with good oil shows in the #345 CVU and #72 CVU wells, is very heterogeneous, and a poor CO_2 flood target across the area

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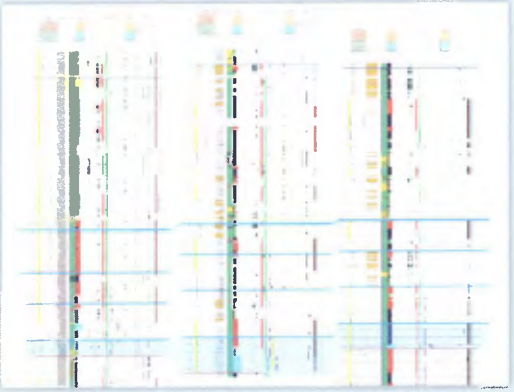
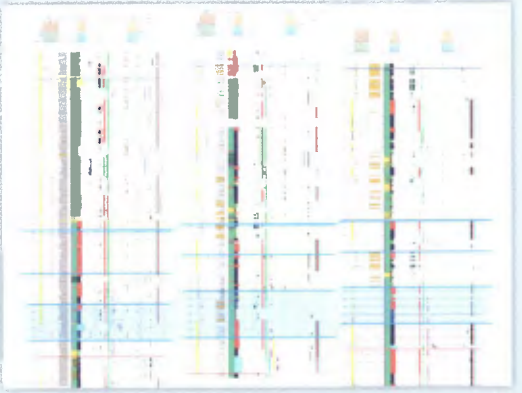


10

Flow Unit 2 is the thickest across the field. The #140 VGBSAU now in the deepest water and has reservoir quality ooid shoals at the top. The #345 CVU well is now the shallowest well with mostly "tite" tidal flats throughout. The #72 CVU well is in a good open marine environment and has a thick section of reservoir quality ooid shoals and good oil stain. The area around the tidal flats in the #345 CVU would be a poor flood target.

11



12

In Flow Unit 3, the #140 VGBSAU is in a good open marine environment and has a thick section of reservoir quality ooid shoals. The #345 CVU also is in a good open marine environment and has a section of reservoir quality ooid shoals. The #72 CVU well is now composed mostly of "tite" tidal flats and would be a poor target.

13

14

In Flow Unit 4, the #140 VGBSAU is again in a good open marine environment and has a thick section of reservoir quality ooid shoals. The #345 CVU has a good open marine environment and has a section of reservoir quality ooid shoals in the lower part capped by a tidal flat sequence. The top of this Flow Unit in the #72 CVU is probably eroded.

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16

Flow Unit 5 has been heavily eroded across parts of the field. The #140 VGBSAU is still in a good open marine environment, but is only one cycle thick, which suggest the Unit was thicker before the exposure and erosion. The #345 CVU is only a partial cycle, and the interval has been completely eroded in the #72 CVU. This interval would be a difficult target. There is also karstification across the field associated with this surface which would potentially disrupt flow uniformity. The karst is seen in the #140VGBSAU well 70-80' below the exposure surface and 10, 20 and 40' below the surface in the #345 CVU well. This behavior is typical of karst development below exposure surfaces where there are significant drops of the water table during lowstands.

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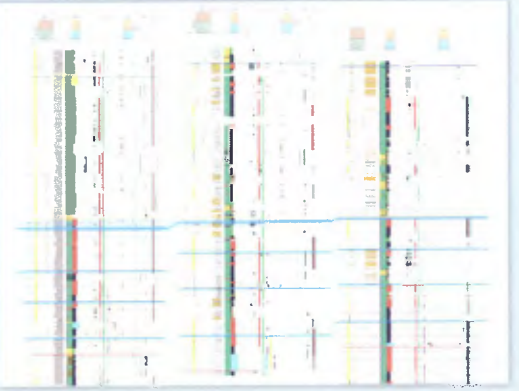

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Although all of the Flow Units have reservoir quality carbonates over a wide area of the field, it would be a mistake to assume that the CO2 would e capable of flooding across the cycle Set/Flow Unit boundaries and therefore, a core based log correlation network is necessary to manage the reservoir. A log based correlation without core could lead to assumptions about the homogeneity of porosity and permeability.

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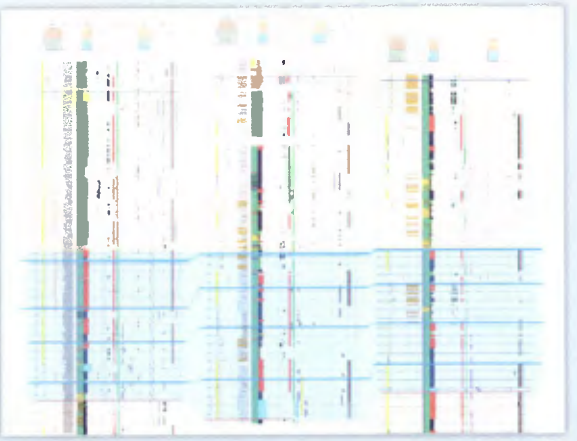

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Appendix 6. List of Core Descriptions, sorted by Star.

Vacuum	Lease	County	Core	Depth	Sec	TWN	RGE
Texaco	#345 CVU	Lea, NM	4338	4750	31	17S	35E
Texaco	#140 VGSAU	Lea, NM	4344	4763	1	18S	34E
Texaco	#72 CVU	Lea, NM	4145	4801	36	17S	34E
Orla	Lease	County	Core	Depth	Sec	Blk	Survey
Continental	#2 Russell "4"	Culberson, TX	3949	4071	4	58 T2	T&P
Continental	#6 Ramsey"26"	Culberson, TX	3893	4035	26	58,T1	T&P
Penrose	#1 Bateman	Culberson, TX	2690	2776	28	45	PSL
Continental	#3-31 TXL	Reeves, TX	3980	4201	31	57 T1	T&P
Goldsmith	Lease	County	Core	Depth	Sec	Blk	Survey
Legado	#26 GLSAU	Ector, TX	44`12	4476	20	44	T 1 N
Legado	#58 GLSAU	Ector, TX	4275	4578	19	44	T 1 N
Legado	#126R GLSAU	Ector, TX	4074	4193	29	44	T 1 N
Legado	#142A GLSAU	Ector, TX	4280	4400	25	44	T 1 N
Legado	#190 GLSAU	Ector, TX	4291	4530	32	44	T 1 N
Legado	#203RW GLSAU	Ector, TX	4145	4446	32	44	T 1 N
Legado	#204R GLSAU	Ector, TX	4141	4450	32	44	T 1 N
Legado	#222W GLSAU	Ector, TX	4309	4429	33	44	T 1 N
Legado	#331 GLSAU	Ector, TX	4105	4195	25	44	T 1 N
Legado	#331 GLSAU	Ector, TX	4362	4482	25	44	T 1 N
McCamey	Lease	County	Core	Depth	Sec	Blk	Survey
Meridian	#9R"A" Baker	Upton, TX	2260	2500	7	R	Denton
Meridian	#19 A.A.Reese	Upton, TX	2433	2829	2	3	MK&T
Gulf	#16 "B" Shirk	Upton, TX	2686	2870	13	3	MK&T
Meridian	#51-R J.F. Lane "A" Acct. 2	Upton, TX	2000	2215	5		GC&SF
Burlington	#N549W McCamey Unit	Upton, TX	2225	2425	5		GC&SF
Burlington	#1087 McCamey Unit	Upton, TX	2040	2336			J Nidever
Meridian	#3R J.F.Lane (3622)	Upton, TX	2270	2450	36	1	MK&TRR
Burlington	#353 McCamey Unit	Upton, TX	2625.0	2802.0	3	3	MK&TRR
Foster	Lease	County	Core	Depth	Sec	Blk	Survey
Laguna	#11 Foster	Ector, TX	4085	4265	36	43 2S	T&P
Laguna	#11 Foster-Pegues	Ector, TX	4100	4216	36	43 2S	T&P
Laguna	#12 Witcher	Ector, TX	4190	4370	36	43 2S	T&P
Sun	#6 Witcher	Ector, TX	3850	4315	36	43 2S	T&P
Mason	Lease	County	Core	Depth			
Min Devel	#C-2-3 Glaze	San Saba, TX	347	1040			
Min Devel	#1-MC Johanson	McCulloch, TX	1125	1822			
Leonard S.	Lease	County	Core	Depth	Sec	Blk	Survey
Tenneco	#9 Leonard Brothers	Lea, NM	3380	3470	14	26S	37E
Tenneco	#28 Leonard Brothers	Lea, NM	3445	3505	14	26S	37E