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ADVANCED CHARACTERIZATION OF FRACTURED RESERVOIRS IN CARBONATE ROCKS: THE MICHIGAN BASIN

Annual Report
October 1, 1998-September 30, 1999

By
James R. Wood
William B. Harrison

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Work Performed Under Contract No. DE-AC26-98BC15100

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Houghton, Michigan

National Petroleum Technology Office
U.S. DEPARTMENT OF ENERGY
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ABSTRACT

In year 1 of this project several important project objectives have been attained, including acquisition and digitization of important data sets, analysis of surface fractures and subsurface diagenetic features over a critical gas and oil field and mapping of basin-scale fracture patterns using literature data. In addition, a strong start was made in writing and testing a project software package, ***Atlas***, that coordinates the digital data in convenient databases and allows the user to graphically display it.

The main objective of this project is to develop a model for fractured carbonate reservoirs based on field data from the Michigan Basin. Accordingly one of the primary tasks was to acquire data from the States 50,000+ gas and oil wells and compile the data in a digital format. The primary data sources in Michigan are paper copies of the original Scout Tickets (17,000+), Driller's Reports and well logs. Over 17,000 Scout Tickets were obtained, scanned and put on CD ROM. Work is in progress on the Driller's Reports, where we have scanned about 50,000 pages out of an estimated 300,000+ pages. All of the scanned images have been attached to ***Atlas.***

Another area where considerable progress has been made is in obtaining copies of the USGS DEM (Digital Elevation Models) for the State of Michigan at the 1/24,000 and 1/250,000 scales. These files have been decompressed and we are in the process of converting them to ArcView Grid files. Preliminary analysis of surface fracture patterns using these data sets has been encouraging. Mosaics of the high-resolution files show excellent ground detail that appears to permit accurate mapping of surface lineations as well as geology and structure. This may be a first application of this type for these data.

So far this work verifies the general picture that the general fracture picture in the Michigan Basin is a dominant NW–SE trend with a conjugate NE – SW trend. DEM data supports the gravity data that this trend is related to a deep basement structural trend coincident with the Michigan Basin Gravity High. In one case studied so far the surface lineations parallel the elongation direction of the field, suggesting that the fracture pattern at depth is manifested at the surface. This has implications for both hydrocarbon exploration, fluid migration and trapping in the Michigan Basin.

EXECUTIVE SUMMARY

The main objective of this project is for a university–industry consortium to develop a comprehensive model for fractured carbonate reservoirs based on the "data cube" concept using the Michigan Basin as a prototype. This project will combine traditional historical data with 2D and 3D seismic data as well as data from modern logging tools in a novel way to produce a new methodology for characterizing fractured reservoirs in carbonate rocks. Advanced visualization software will be used to fuse the data and to image it on a variety of scales, ranging from basin-scale to well-scales.

Results to date include digitizing of well records, detailed mapping of several key fracture-dominated fields (Deep River and N. Adams), writing code for a new software programs ("Atlas"), and acquisition of seismic data. In addition, we have begun negotiations to acquire a 3D seismic survey shot by Marathon Oil Company over Stoney Point Field.

The general fracture picture that is emerging in the Michigan Basin is a dominant NW – SE trend that manifests itself on a field scale and can be mapped in outcrop. The conjugate direction, roughly, a NE – SW trend is also established in some fields. Data (mainly gravity) suggests that this trend is related to a deep basement structural trend coincident with the Michigan Basin Gravity High. This data has been interpreted as evidence for an old rifting episode early in the Proterozoic history of the Basin. The locations and geometries of many gas and oil fields in the central part of the Michigan Basin are consistent with this interpretation: elongated fields oriented NW – SE or SE – NW with many on the margins of the gravity high.

Work is in progress to document this feature on a field scale by mapping the "Top of Porosity" in the Dundee and Trenton Formations. A common practice in Michigan when developing prospects is to map a parameter termed "Top of Porosity", which is essentially the first encounter of the drill bit with diagenetic dolomite. This parameter is recorded in records (scout tickets and driller's reports that have been digitized as part of this project) for several of the carbonate units in the Michigan Basin, including the Dundee and Trenton Formations. In many reservoirs, the main pay zone is altered limestone that occurs off structure. Most of these traps are classified as stratigraphic. The main dolomite zone is typically 4-6 miles long, striking NW with typical widths of no more than ½ mile. The dolomite is clearly secondary and is finely crystalline and vuggy. In core the dolomite is massive with sporadic vugs lined with small dark brown crystals and larger white rhombic crystals. Vugs are approximately 1 ½ inches in diameter and as much as 5 inches long. There is no evidence of a measurable dip to the dolomite zone and it is assumed to be vertical. Many of the wells examined to date were drilled with cable tools and generally flowed oil on the first few feet of penetration, occasionally out of control. Dolomitization is generally attributed to hot (?) brines ascending from below along joints and fractures. Parts of the Dundee Formation may have been subaerially exposed prior to the deposition of the overlying Bell Shale and may have had a extensive karstic topography developed on it.

INTRODUCTION

Carbonate rocks have been selected for this study because in many basins worldwide, fractured carbonate zones form important oil and gas reservoirs. Termed "dolomite chimneys", in the Michigan Basin, they have long been among the most prolific producers of hydrocarbons in the world. However, key aspects of their origin(s), distribution and architecture have been enigmatic. They have been difficult to find and once found, many have proven difficult to produce efficiently. The Michigan Basin is well suited to serve as a model for fractured reservoirs. It is a mature basin that contains almost 50,000 gas and oil wells with extensive data and rock samples. Over 150 million barrels oil has been produced from fractured carbonate reservoirs in Michigan and adjacent states. The Dundee Formation alone has produced over 350 million barrels, approximately 40-50 million from fractured, dolomitized reservoirs. It has been estimated that nearly this amount of hydrocarbons remains to be recovered.

The data collected and the data cube itself will be on the Internet in digital form together with the software packages required to display and manipulate the data. The software will permit visualization and interpretation on both large and small scales. The main deliverable will be a data cube for the Michigan Basin that will include:

- A library of formation tops picks (300,000+)
- digitized well locations (latitude & longitude; 50,000+)
- scanned images of well header records
- digitized and interpreted logs of key wells
- hydrocarbon logs,
- engineering data, and
- key horizons picked from 2D & 3D seismic data, if possible.

The basin model will be developed in ER Mapper. Detailed case histories and tutorials will be provided. Sponsoring organizations include: Marathon Oil Company, Chartwell Properties, L.. L. C., Advanced Hydrocarbon Stratigraphy, Newstar Resources, Dart Energy and Baker Atlas Logging Services.

RESULTS AND DISCUSSION

Task 1. Project Management

Subtask 1.1 Technical Aspects

Project management continues to operate smoothly: links have been established between the main Michigan Tech operations site and the satellite sites in Kalamazoo, Traverse City and Tampa FL. The promised minimum of 2 face-to-face meetings with all personnel has been held, two meetings in Traverse City, one each in Kalamazoo and Tampa. All senior team members (Wood, Harrison, Luo, Chittick) attended at the spring

AAPG meeting in San Antonio where a project meeting was convened. Plans for the Fall 1999 and Winter 2000 meetings and task assignments were discussed and agreed on.

Michigan Tech is part of the National InterNet2 program that is essentially a project to upgrade the current Internet by making it faster and with wider bandwidth. Our DOE project has been suggested as one that might make use of the added capabilities, particularly the live conferencing. We will explore opportunities this next period and report on any progress and opportunities.

Subtask 1.2 Financial Reports and Accounting

Project expenditures are proceeding according to plan. All necessary reports have been filed with DOE Pittsburgh.

Task 2. Basin Analysis

Subtask 2.1 Geology

Subsurface data have been collected for 2 key fractured reservoirs in the Eastern Michigan Basin (Figure 1). These reservoirs are the Deep River Field (Figure 2) and the N. Adams Field in Arenac County, MI. (Figure 3). Descriptions of these fields may be found in the "Oil and Gas Fields of the Michigan Basin Symposium" volumes published by the Michigan Basin Geological Society (1968).The data consist of formation top picks, "top porosity" picks and production data. These data have been loaded into Geographix software and the Atlas software package being developed as part of this project (see below for description of "Atlas").

Lineation Analysis

We have discovered that the set of Digital Elevation Models (DEMs) compiled by the USGS (U. S. Geological Survey) are ideally suited for analysis of surface lineations in the Michigan Basin, as well as elements of geological structure and bedrock geology. A DEM is essentially a grid of surface elevations at various resolutions generally taken from the Mylars of old USGS 7.5 Minute and 1° quadrangles, resampled and compiled. Data is in the public domain and is available for most of the U. S.

All of the 7.5-minute quadrangle DEMs for the State of Michigan available on the web from United States Geological Survey (USGS) has been downloaded (over 900). These files were unzipped and placed in named subdirectories on hard disk and CD ROM. About 1/3 of the Lower Michigan DEMs have been loaded into ArcView, converted to ArcView grid files and displayed as mosaics in ArcView. An example is shown in Figure 4. The DEM data reveal linear surface trends (Figure 4) that may reflect subsurface geology. We are currently compiling all of the 7.5 minute DEMs into ArcView grid files for the entire State of Michigan and will make them available on CD ROM as part of the project deliverables.

Some problems with the DEM data that will need to be addressed:

1. The USGS high resolution DEM data set is incomplete, especially in some key areas within the Michigan Basin.
2. Some data is recorded in meters and some in feet. Data is in integer form and rounded to the nearest unit making the metric data inherently less precise than the data in feet.
3. Processing errors apparent in some of the quadrangles tend to "stripe" the digital image in an east west direction.

These problems may be resolved in several ways:

1. The USGS apparently has more data available for sale than exists on their current free ftp site that can be purchased at nominal cost.
2. Private vendors, such as "The GEMI Store" (www.gemistore.com) will fill in the data gaps with high-resolution data in feet at higher cost.
3. Lower resolution 1:250,000 DEM data, which has already been obtained, can be spliced into the mosaic. This would be a last resort.

Also, we contracted with Geologic Data Systems (Denver CO.) to perform a lineament study over Arenac County, Michigan using 1:100,000 LandSat 5 satellite imagery and 1:80,000 aerial photography. As can be seen from Figure 5, Geologic Data Systems was able to pick many lineaments, essentially using aerial photographs. We will compare Geologic Data Systems methodology for determining lineaments with picking lineaments from DEMs and either combine the two methods or adopt one or the other on the outcome of the comparisons.

Basin wide mapping has begun. All Michigan well locations up to 1997 have been input into Arcview and plotted (Figure 6). Formation top data will be examined and corrected as necessary, gridded, loaded into ArcView and displayed as basin and field scale maps. Other data, such as initial production and cumulative production is more appropriately viewed as bubble plots on basin and field scales, to high-light linear trends.

Subtask 2.2 Geophysics

2.2.1 Seismic

Three 2D seismic lines were obtained from Marathon Oil Company near the Crystal Field in Montcalm county (MOC), loaded into GeoQuest and processed in an attempt to elucidate Dundee structure. The seismic data was shot targeting deeper plays and thus has low fold and offset to adequately resolve shallower plays such as the Dundee. From structure maps, isopach maps and initial production bubble plots, it is apparent that the Dundee of the Crystal field was faulted and probably karstified. The low fold and offset coupled with unknown static conditions creates a condition of low signal to noise ratio, making it difficult to resolve the shallow structure and fractured nature of the Dundee in the Crystal field (T. Bulloch, 1999). Bay Geophysical of Traverse City, Michigan has however, indicated that they have propietary processing techniques, which may be able to

resolve shallow, low fold structure. This project will attempt to acquire data processed by Bay Geophysical, which resolves shallow structure with 2D data.

2.2.2 Borehole

Six image logs (Baker-Western Atlas CBIL logs) have been acquired from our industry partners and work is beginning on analysis and interpretation. At present the main problem is obtaining software that will read these files. Baker Atlas has indicated that they will provide us with a copy of their software package (eXpress & Vision). We also think that GeoQuest will handle these files, but that has not yet been tested. We have the GeoQuest software that will handle Schlumberger logs but at present do not have Schlumberger data. We have Baker Atlas data, but at present do not have the Baker Atlas software. We are at present attempting to remedy these situations. Bill Harrison at Western Michigan University is seeking permission to acquire Schlumberger digital data to enter and process with the GeoQuest software package, and Steve Chittick at Michigan Technological University is working to obtain the Baker Atlas software to process the data we now have and are receiving shortly.

Newstar Resources (Mike Barratt, personal communication) has agreed to donate 20-30 digital wireline logging suites (including image logs) in the Michigan Basin to Michigan Technological University. These logging suites will be used to determine well to field scale fracture trends. Negotiations are also in progress with other companies to obtain their digital image logs and conventional logs. These logs will be loaded into GeoQuest (Schlumberger) and/or eXpress (Baker Atlas) and processed to determine fracture density and orientation, lithology, and oil saturation.

Subtask 2.3 Hydrology

This task as it is scheduled for the 2nd year.

2.3.1 Fluid Pathways

Work has begun on the main problems associated with development of a basin-scale flow model for fluid (hydrocarbon) migration. The top priority is to develop a geologically realistic model for the "geocontainer", that is the shape of the basin boundaries and the rock surfaces and volumes that fill the container. We have decided to use existing public domain gravity data to help define the basement. The lithologic fill will be obtained from the data obtained in subtask 2.1

2.3.2 Flow Model

We now propose an empirical flow model for hydrocarbons in the Michigan Basin based on "show" data acquired from the Scout Tickets, Driller's Reports and Mud Logs (see 2.3.3 below). By "show" data we mean mentions of gas and oil shows recorded on these reports. These data are not normally recorded in digital databases, but we now think that a sufficient number can be obtained that a basin-scale plot would reveal the migration

pathways. This type of a flow model, based on hard data, would be more convincing to operators and most likely of more use. In addition, if successful, it would demonstrate the value of plotting this parameter in other basins.

2.3.3 Gas and Oil Trapping

The show data discussed in 2.3.1above should point toward known gas and oil fields. Thus the trapping mechanisms may be elucidated as well since we would anticipate that the shows would terminate at seals, which are generally either shales, tight limestones or evaporites in the Michigan Basin. We will plot the oil and gas shows along with producing oil plays in a three dimensional display to show migration routes and oil and gas trapping mechanisms.

Task 3. Quantification and Mapping (WBH)

Subtask 3.1 Data Acquisition

Data Cleanup and Digitization

Over 17,000 scout tickets have been digitized as TIF images and added to our database. These are all of our currently available scout tickets. We have begun work digitizing driller's reports as multiple page TIF images. Digital well logs are being acquired from oil and gas company donations and in house digitizing. Well locations for the digital images of scout tickets and driller's reports recently added to our database are shown in Figure 7. Recently, over new 5,400 wells were added to our database, bringing the total number of well locations to approximately 54,000.

3.1.2 Gridding

Progress on the data gridding front has been made in several directions. One, an economical commercial shareware package has been located (QuickGrid, Perspective Edge Software, http://www.interchg.ubc.ca/coulthrd/pes.html . QUIKGRID is a program written for MS WINDOWS which will read in a set of scattered data points (x, y, z) which represents a surface. The program will generate a grid from this data and then display the surface as a contour map, QUIKGRID runs under Windows 95/98 or Windows NT. The generated grid may be output to a file as a series of XYZ triplets, in the DXF 3DFACE format or as an ER Mapper Raster Dataset.

Second, a new gridding algorithm has been under development as part of this project. The goal was to grid tops data in such a way that any field-scale fracture information would be preserved and then to be able to view the gridded data in 3 dimensions. So far an algorithm has been developed and applied to field-scale data for several fields. This

problem is sufficiently solved that we will not focus on it any further, except to note where changes or improvements have been made.

3.1.3 Database Management

All data associated with this project to date has been placed into a MS Access database as promised. In addition, all documents related to the project (reports, software, etc.) have also been placed in a digital database that consists of the MS Windows normal file structure. The database can be accessed using ***Atlas***, the software developed at MTU specifically for this project (see below).

Subtask 3.2 Mapping and Visualization

3.2.1 2D Mapping

Considerable progress has been made it the 2D mapping effort. Base maps have been prepared for the entire State of Michigan and well location data has been included in the database. The data has been loaded into ArcView. The ease of loading and manipulating the data in ArcView, as well as the wide acceptance of ArcView relative to ER Mapper has us considering switching the project visualization software from ER Mapper to ArcView.

Work is nearly complete on a software package, "ATLAS", developed as part of this project. This package allows the user to select wells by "point and click" technology using the ESRI software control Map Objects and Microsoft Visual Basic (VB). The user can point to a well (Figure 8) and immediately access the digital record for that well as well as the scanned (TIF) image of the scout ticket for the well. The package will also extract well tops data for any formation in the database and write it to another ACCESS database file. We intend to use this capability to feed formation top picks into another visualization package. This package will provide 2D ad 3D views of the surface and will allow rapid, easy comparison of multiple fields. The advantages of these packages are low cost and ease of use. Many users just want a "first look" at data and the ability to edit it for errors and additions and deletions before more extensive analysis. We intend to use it on the data collected for this project.

Maps showing hydrocarbon trapping in the Michigan Basin will be determined using data obtained in subtask 2.1 as well. We will map the distribution of all known major fields in the Michigan Basin on several scales (field and basin). We will locate data for gas and oil shows and map these as well as stated in subtasks 2.31 and 2.32. These data are more difficult to come by as they are not usually reported on scout tickets and only sporadically on the driller's reports. We have digital data that pinpoints the wells that have this data available and we will scrutinize the paper copies of those mud logger's logs we can obtain to locate shows in a 3D perpsective.

As stated in subtask 2.1. DEM data is being loaded into ArcView. This data is being combined with cultural data such as rivers and lakes to highlight surface expressions of

subsurface geology. When combined with well location data, visual correlation with surface lineaments, water drainage patterns and well locations should be readily apparent. Other cultural data that has been obtained and can be displayed includes: roads, county and township boundaries, railroads, and miscellaneous transportation features (oil pipelines, transmission lines, airports, etc.).

3.2.2 3D Mapping

A 3D code for displaying the gridded data described in 3.1.2 has been developed. A working version of the code has been written in Visual Basic (VB) and ready to be added to the project software library. The program is based on a commercial software tool sold as an ActiveX object by KL Group named "Olectra Chart". This tool provides all the graphics capability and allows us to bind our databases to a chart and then display the data. The VB code is available for testing.

3.2.3 Reports and Maps

Michigan Atlas – In addition to the DEM data described above, most of the progress for this reporting period has come in the development of the Atlas software. This program is turning out to be a very effective tool for consolidating and displaying the project results. We have begun to release the program to a few selected operators in the Michigan Basin for evaluation and feedback. Atlas can be used effectively to determine if certain data exists for a specific well or a group of wells. Well locations are color-coded indicating which wells have the user-requested data (Figure 9). A detailed summary (30+ pages) of this software is provided in Appendix A.

Subtask 3.3 Fracture Analysis (WBH)

Literature data has been compiled on outcrop fractures in the Michigan Basin. Samples for petrographic examination have been collected and are being prepared for petrographic examination. These data will be digitized and plotted. Maps and reports will be available in the 1st annual report.

Task 4 Geochemical Studies

Subtask 4.1 Diagenesis

Work is in progress to retrieve "top of porosity" picks from as many wells as possible. This will be aided by examining the scanned driller's reports, using the program Atlas 3.0. "Top of porosity" was usually noted in fields with producing wells and generally indicates diagenetic dolomite. The difference between the formation top picked before "top of porosity" and "top of porosity" is unaltered limestone cap rock.

Subtask 4.2 Fluid Geochemistry

A database on subsurface fluid chemistry is being compiled for the Michigan Basin as part of a student project. Results will be presented in the annual report. Fluid analyses will be correlated with latitude & longitude and them plotted according to the formation of origin to see if any significant trends or correlations are present.

Subtask 4.3 Hydrocarbons

Work on hydrocarbons will begin the 2nd year of the project.

Task 5. Technology Transfer (WBH & JRW)

Subtask 5.1 Public Outreach

5.1.1 Internet (WWW)

A new Internet site for this project has been constructed on the Michigan Tech server. Additional information and reports will be placed on the Western Michigan site.

5.1.2 Newsletter

Results from this project will be reported in the next annual edition of the MOFRC (Michigan Oil Field Research Consortium) scheduled for fall.

Subtask 5.2 Workshops (WBH)

No workshops for this project have been scheduled. Some results were presented (Wood) at the PTTC workshop organized by Harrison and held in Mt. Pleasant in February of this year.

Subtask 5.3 Meetings

5.3.1 DOE Contractor Meetings

No DOE contractor meetings have been called as yet for this project.

5.3.2 National and Regional Meetings

The initial project results were presented at the April AAPG meeting in San Antonio, Texas. Some results were also presented at a PTTC workshop organized by W. Harrison in Mt. Pleasant, MI in March, 1999. We have plans to present results at the Annual AAPG Meeting this April in New Orleans.

CONCLUSIONS

At the end of the first year, the project is on schedule and has met or exceeded all major goals. Specifically, acquisition of fracture data and digitization of that data is either accomplished (Scout Tickets, USGS DEM files) or well underway (Driller's reports and well logs). The main areas of concern are acquisition of a 3D data set. It now appears unlikely that Marathon will donate their 3D data over Stony Point although we will continue to pursue that possibility. It is more likely that we will be able to obtain a 3D data set elsewhere. Also, acquisition of formation scanner logs is proceeding more slowly than we like, but we will make renewed efforts to acquire those data in the second year. The general slowdown in the Michigan Oil Industry has impacted these efforts, but with the rising prices for oil, perhaps operations will return to normal and companies will have more time to work with us and will be more inclined to donate data.

The USGS DEM data sets, particularly the 7.5 minute quadrangles, turned out to be the most promising new development in the project as it now appears that the fractures at reservoir depth have surface manifestations, at least in some cases. We intend to pursue this lead, looking at more fields and over more of the State. We believe that this is one of the first uses of this data for fracture analysis related to gas and oil. With the ready availability of DEM data for the rest of the U.S. this may spark interest in using the approach in other States.

Development of the ***Atlas*** software is another accomplishment that has exceeded expectations. It is now ready for release as version 3.0 and will be distributed this winter all interested parties, including several downstate companies we have worked closely with on this project. We are hopeful that providing the companies with the Atlas software and the Scout Tickets database will encourage them to reciprocate.

Future activities scheduled for the 2nd year included continuation of the data acquisition, analysis of the DEM data in conjunction with the subsurface data and refinement of the ***Atlas*** software. In addition, we will start to look at the problem of hydrocarbon maturation and migration in the Basin using the gas and oil show data. It will be necessary to compile this data in a digital form, first by processing the Scout Tickets and then the Driller's Reports. We will present the progress to date at the Annual AAPG meeting in New Orleans this April and plan to distribute the Atlas software on a CD ROM at that meeting. We have found that this meeting is a useful forum for publicizing our efforts as well as obtaining useful feedback and ideas.

Finally, the rise of the Internet and its widespread acceptance in the gas and oil industry has caused us to reconsider our Technology Transfer activities. We are now planning for a wider presence on the Web for the project and are looking at ways to provide access to the rather large databases via the Web. We also need to be more concerned with publicizing the project and the Web site.

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FIGURE CAPTIONS

Figure 1. Location map for Deep River and N. Adams Fields.

Figure 2. Filled contour map of "Top Porosity" superimposed on line contour map of Top Dundee structure for Deep River Field, Arenac County, MI. A common practice in Michigan is to map a parameter termed "Top of Porosity", essentially the first encounter of the drill bit with diagenetic dolomite. In many Dundee Reservoirs, this is the main pay zone and often consists of altered limestone that occurs off structure. In the Deep River Field the main reservoir is a diagenetic dolomite lying roughly NW – SE in a trend that is clearly off the structural highs mapped on the surface of the Dundee Formation. In this figure, the dolomite trend (filled, gray, contours) is superimposed on the structure contours of the Dundee Formation (lines). The initial production (IP) for each well is shown as a white circle with the diameter of each circle proportional to the IP. The main dolomite zone is approximately 5 ½ miles striking N 60 W. Nowhere is it more than ½ mile in width. The dolomite strikes along a structural monocline that dips N 30 E and forms the NE flank of the Deep River dome. There is no evidence of a measurable dip to the dolomite zone and it is assumed to be vertical.

Figure 3. Filled contour map of "Top Porosity" superimposed on line contour map of Top Dundee structure for N. Adams Field, Arenac County, MI. Another example of a stratigraphic trap developed in fractured secondary dolomites is the Adams /N. Adams Field in Arenac County, MI. This field lies slightly NW of Deep River. Here the main reservoir is a diagenetic dolomite trending NE – SW, in contrast to the NW – SE trend observed at Deep River Field. In this figure, the dolomite trend (filled gray contours) is superimposed on the structure contours of the Dundee Formation (lines) with the initial production (IP) for each well shown as a white circle. The diameter of each circle is proportional to the IP. As with Deep River, several deep "bulls eyes" occur in the field.. Two prominent dolomite lineations are apparent, but only one, the main NE - SW, trend was developed. The main dolomite zone in the Adams Field is approximately 3 miles in length and strikes N 30 W. It is about the same width, ½ miles as Deep River but here the dolomite lies more on top of a structural anticline. The model for the dolomitization is the same as Deep River: hot (?) brines ascending from below along joints and fractures. The Dundee at Adams may have been subaerially exposed prior to the deposition of the Bell Shale and may have had a extensive karstic topography developed on it, as evidenced by the deep sinkholes (?) on the flanks of the field. This field is similar to Deep River: a stratigraphic trap developed in porous, fractured secondary dolomite that cuts across structure. The main productive dolomite trend was developed at bout 90° to the trend at Deep River, which would be expected if the conjugate joint set was developed. These two reservoirs show that elongated zones of secondary dolomite probably produced along a common preexisting fractures/joint system were the main control on reservoir development.

Figure 4. Mosaic of Bellaire, Mancelona, Leetsville and Westwood USGS 7.5' DEM quadrangles (10 meter) with and without lineament interpretations. Center map denotes location of quads. Image on the left hand side of the page is an uninterpreted hillshade relief (sun azimuth 315°, sun height 45°) image. Image on the right hand side of the page has linear features marked. The linear features may be surface expression of subsurface features seismically reactivated over time.

Figure 5. Geologic Data Systems Lineament Interpretation Map of Deep River Township, Arenac County, Michigan with wells from the Deep River Oil & GasField overlaid. NW-SE lineaments parallel the elongated and narrow Deep River field. NE-SW lineaments cut across the field at nearly 90° angles. Evidence seems to suggest that surface lineaments are expressions of subsurface faults or movement along faults in the recent geologic past.

Figure 6. Michigan Oil & Gas Wells drilled prior to 1997. Note the NW-SE linear trend of many of the fields. The linear trend nearly parallels a gravity high running down the center of the state. This suggests that basement control might be largely responsible for oil migration paths and accumulations within the Michigan basement.

Figure 7. Locations of wells that have scanned TIF images of scout tickets and driller's reports recently added to the project database. Accessed from the map based program Atlas, these TIF images have already proven valuable. They have provided a quick means to QC data in a digital database. The alternative method to checking the data is to leaf through volumes of paper records, which is tedious and time consuming.

Figure 8. Screen shot of typical first display for the *Atlas* software program.

Figure 9. Print out from Atlas 3.0 showing well locations, roads, rivers, lakes and towns in Isabella County. Wells are color coded to signify presence or absence of user selected data. The current view shows available well locations. The lighter color or red wells indicate well locations that contain scout ticket information. To access the scout ticket information, one merely has to draw a box around the desired wells; a list of permit numbers of the chosen wells is then displayed. By clicking on the permit number of the desired well(s) the TIF image of the scout ticket will be displayed on the screen. Other types of digital data to choose from are multi-page TIF images of driller's reports and LAS (Log ASCII Standard) well log files.

FIGURES

FIG. 1. MAP SHOWING LOCATIONS OF DEEP RIVER AND N. ADAMS OIL FIELDS.

Deep River Field, Arenac County: Top Porosity

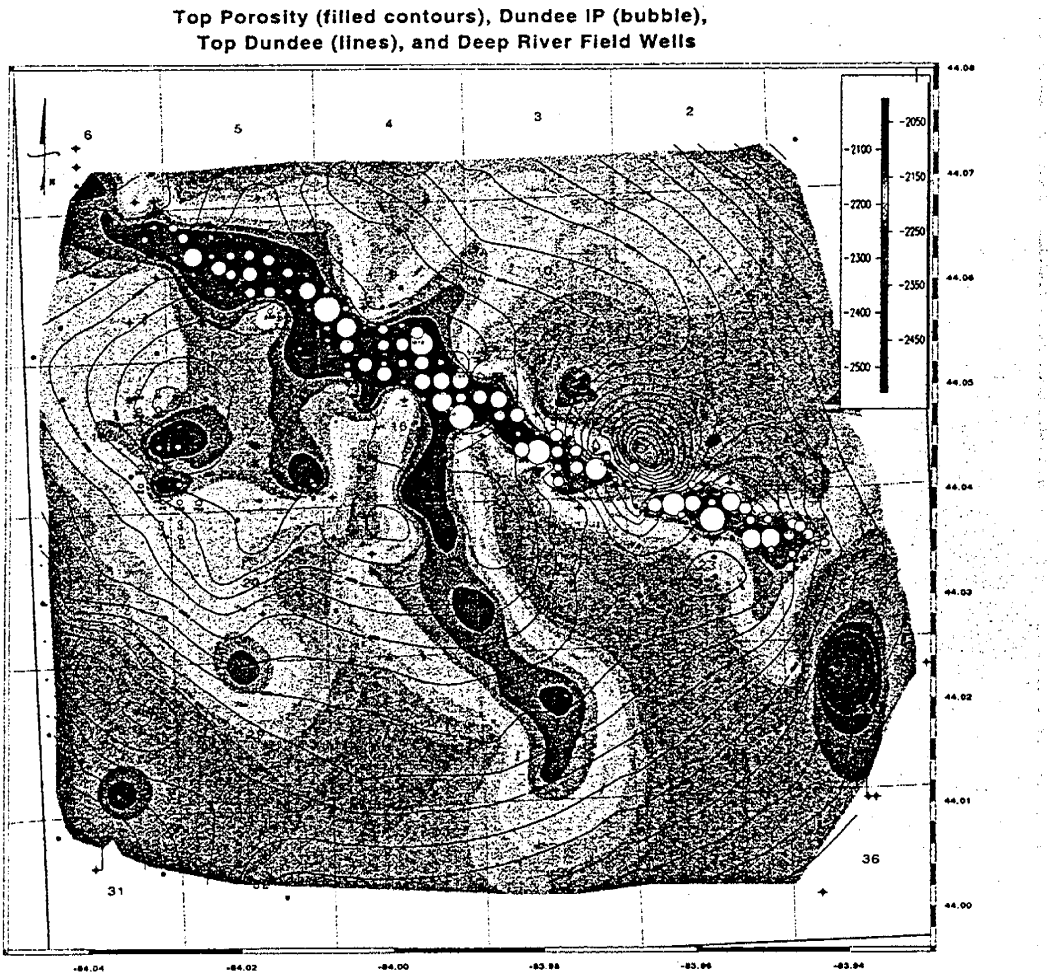


Figure 2. Filled contour map of "Top Porosity" superimposed on line contour map of Top Dundee structure for N. Adams Field, Arenac County, MI.

Adams and North Adams Fields, Arenac County: Top Porosity

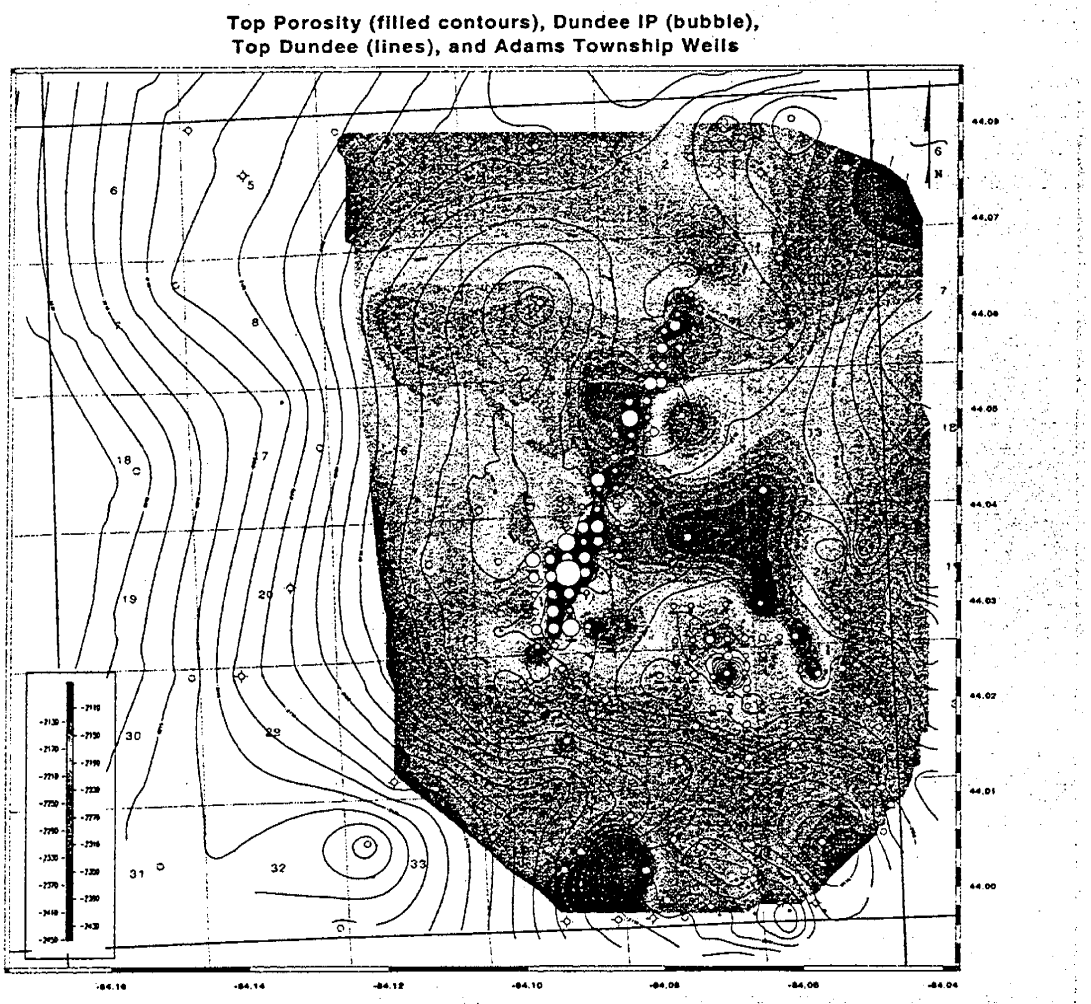


Figure 3. Filled contour map of "Top Porosity" superimposed on line contour map of Top Dundee structure for N. Adams Field, Arenac County, MI.

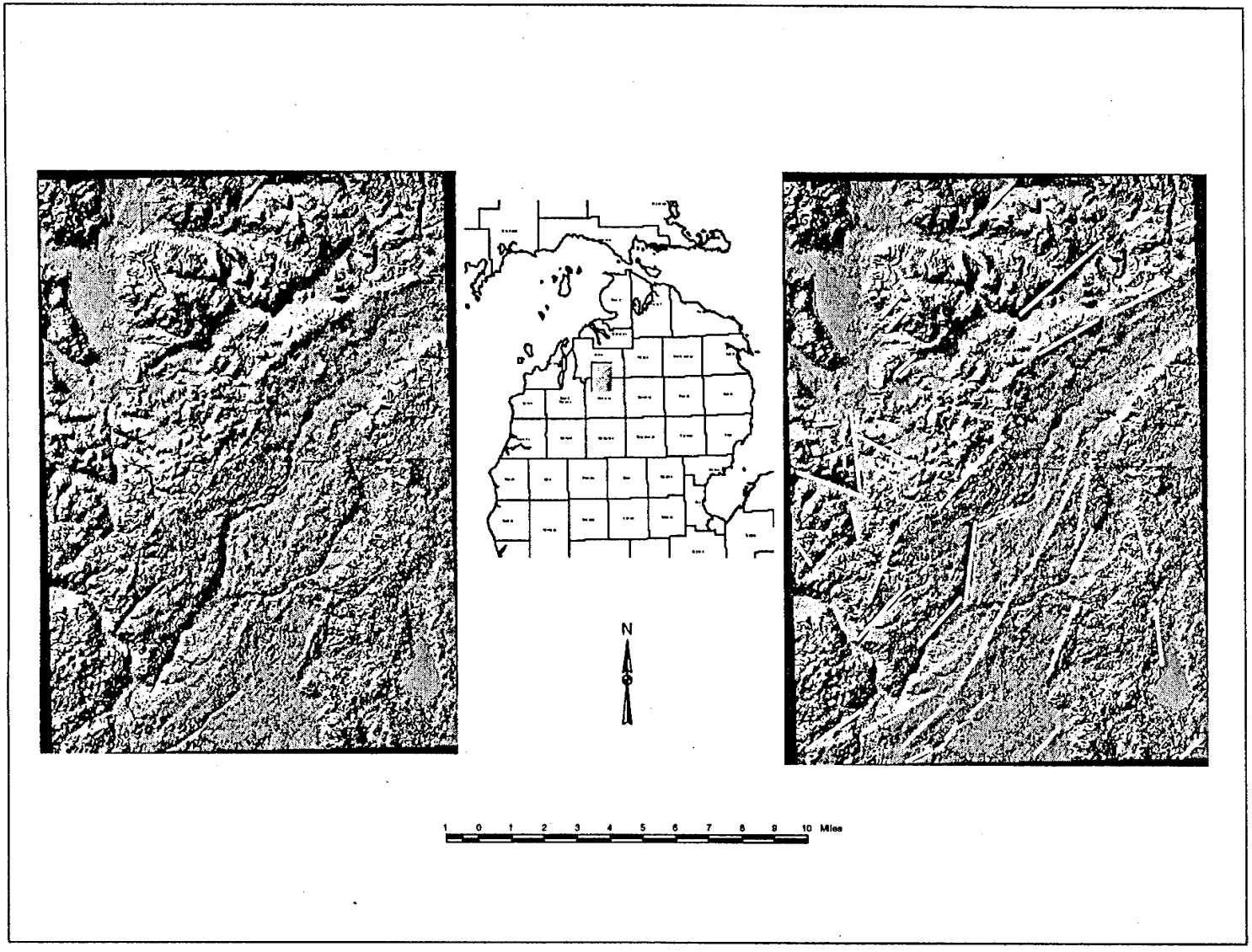


Figure 4. Mosaic of Bellaire, Mancelona, Leetsville and Westwood USGS 7.5' DEM quadrangles (10 meter) with and without lineament interpretations. Center map denotes location of quads.

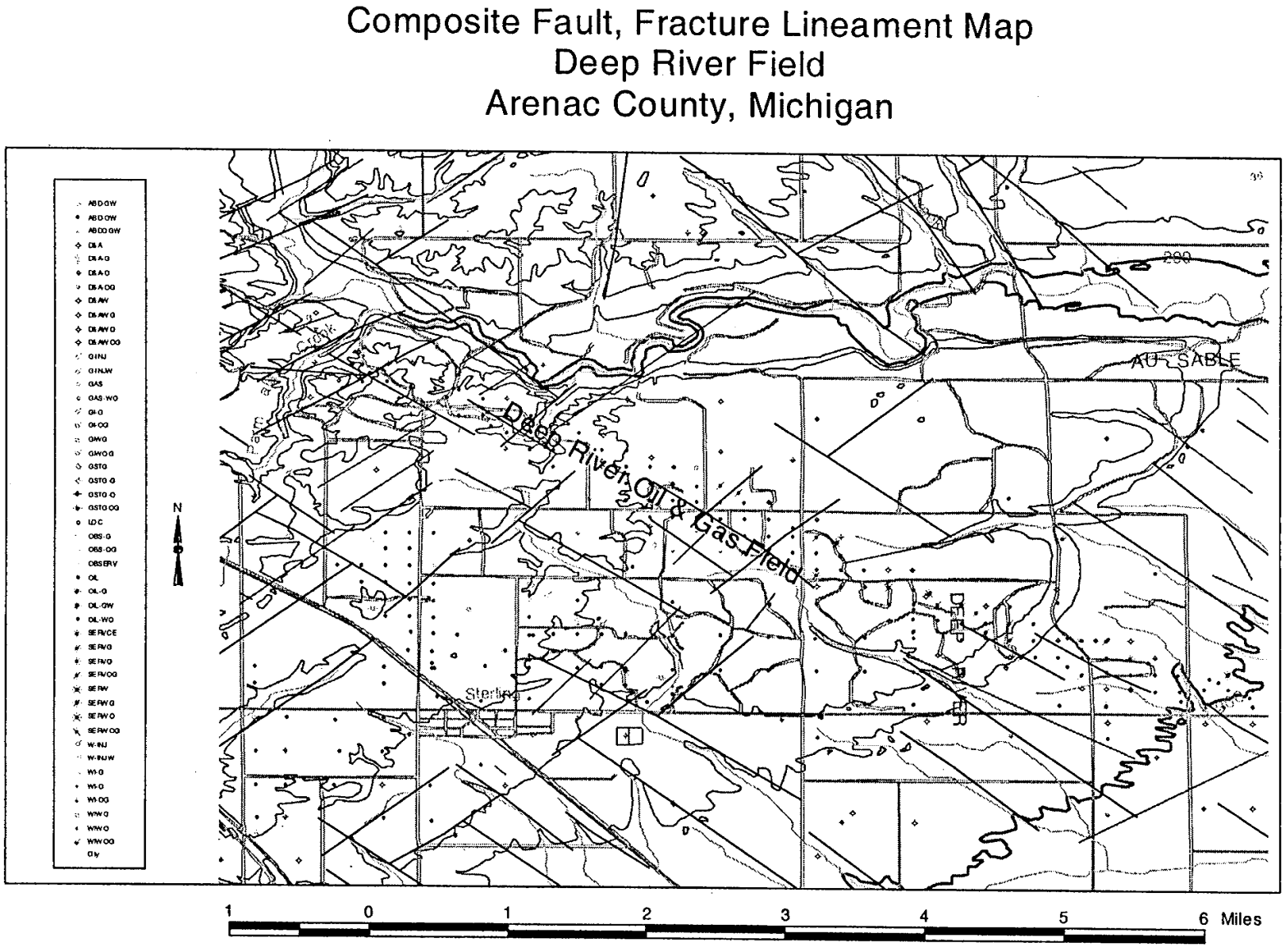


Figure 5. Geologic Data Systems Lineament Interpretation Map of Deep River Township, Arenac County, Michigan with wells from the Deep River Oil & Gas Field Overlaid. Note surface lineaments parallel with the linear profile of the oil & gas field.

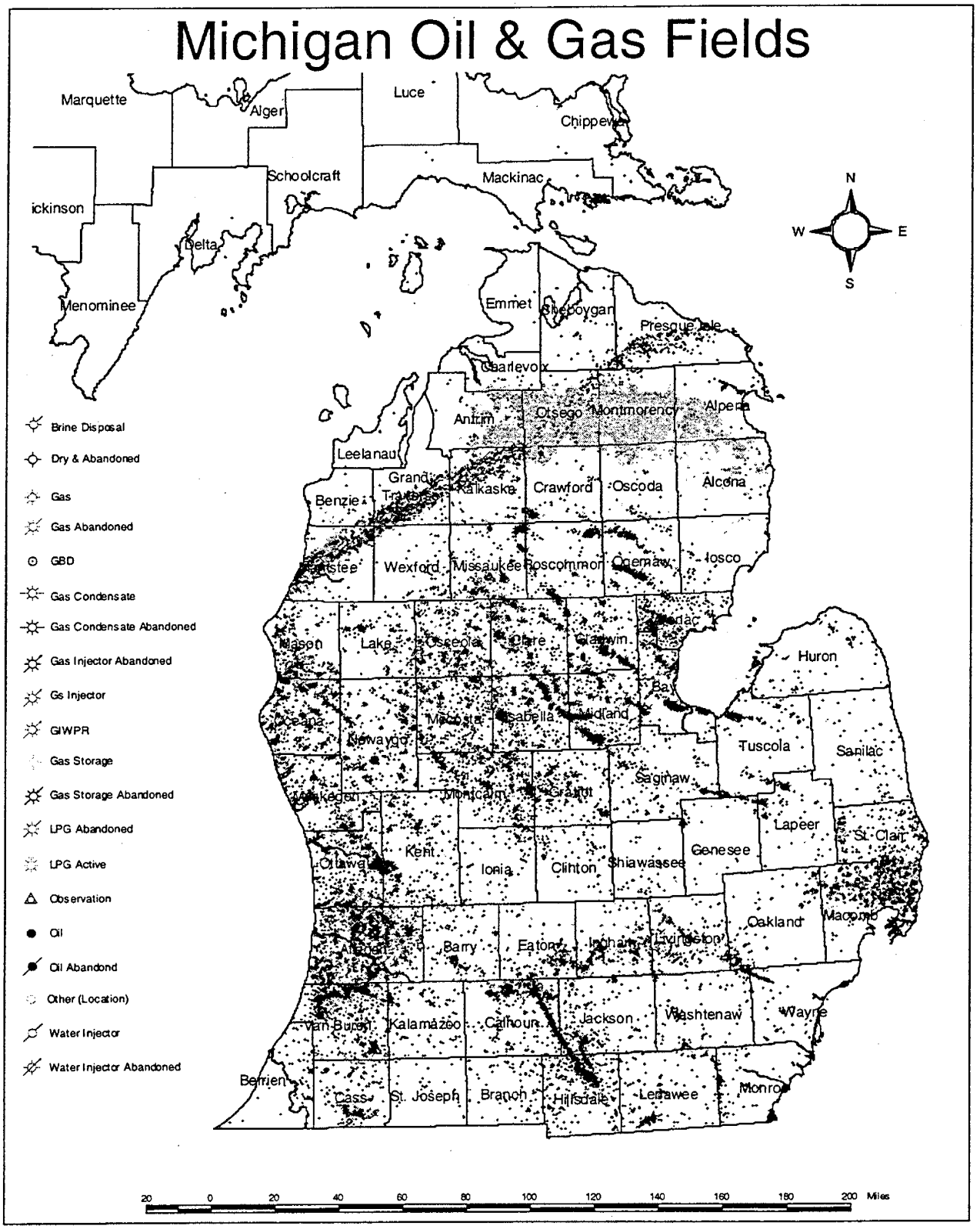


Figure 6. Michigan Oil & Gas Wells Drilled prior to 1997. Note the linear NW_SE trend of the fields.

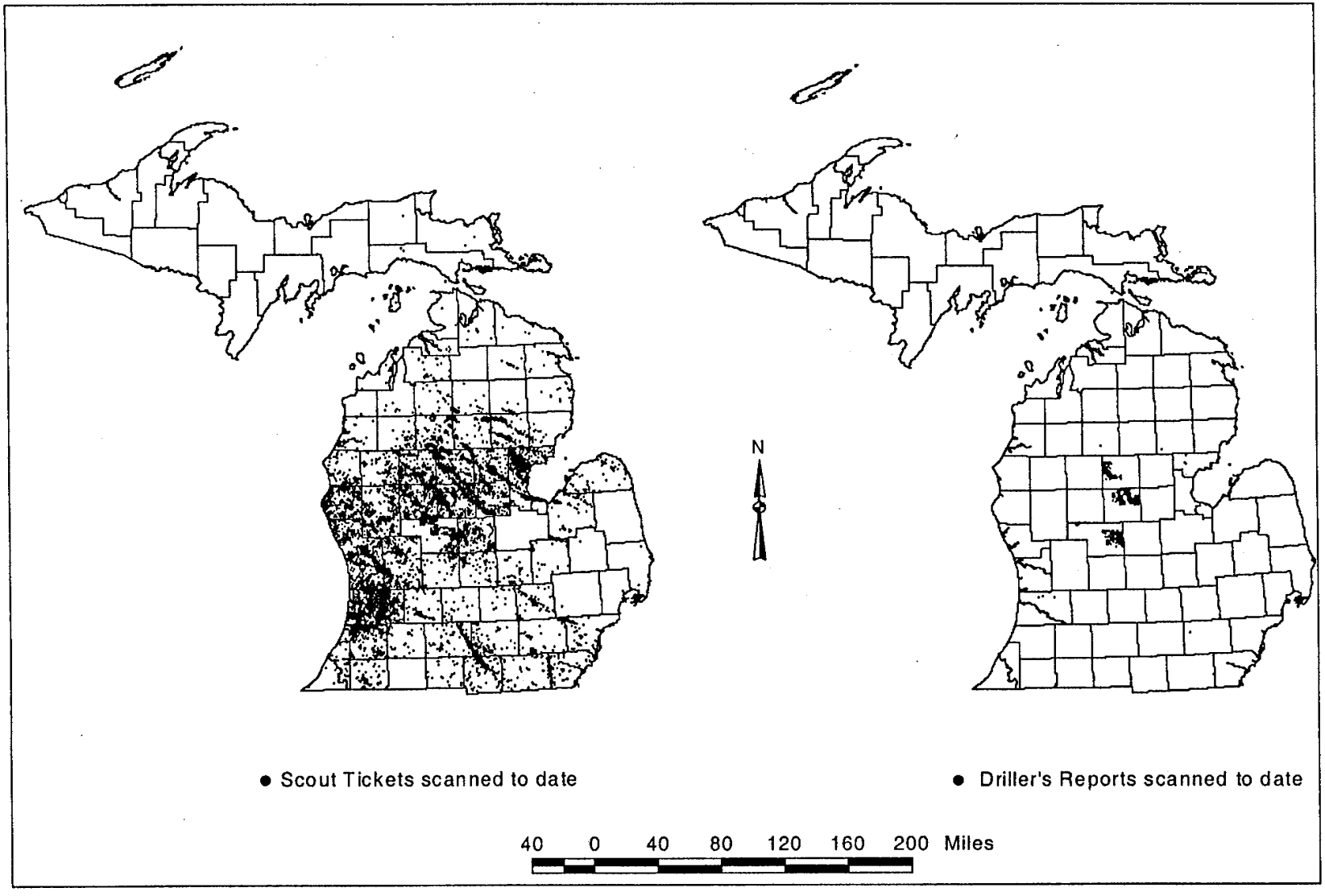


Figure 7. Locations of wells that have scanned TIF images of scout tickets and driller's reports recently added to the project database.

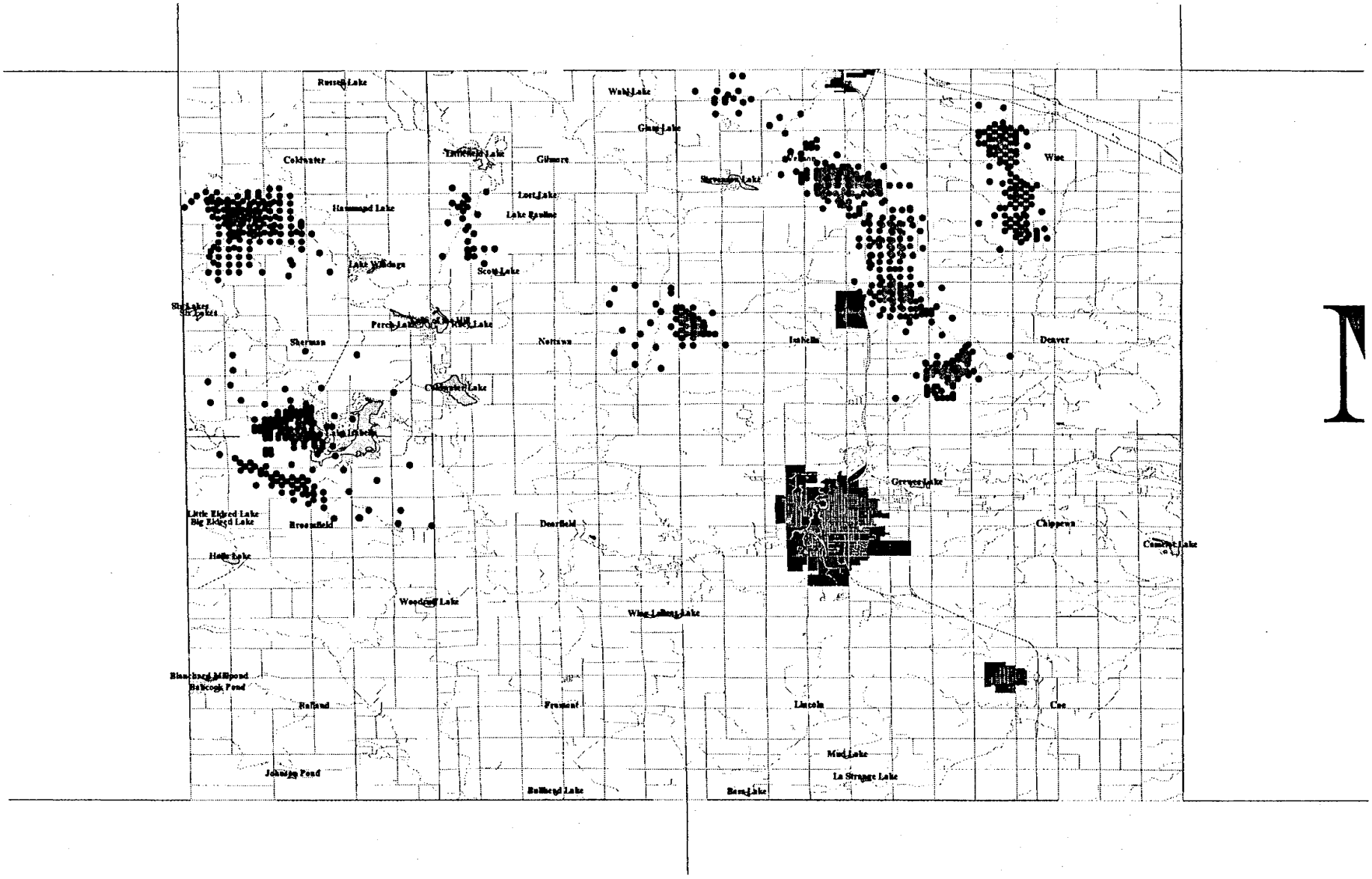


Figure 8. Print out from Atlas 3.0 showing well locations, roads, rivers, lakes and towns in Isabella County. Wells are color coded to signify presence or absence of user selected data.

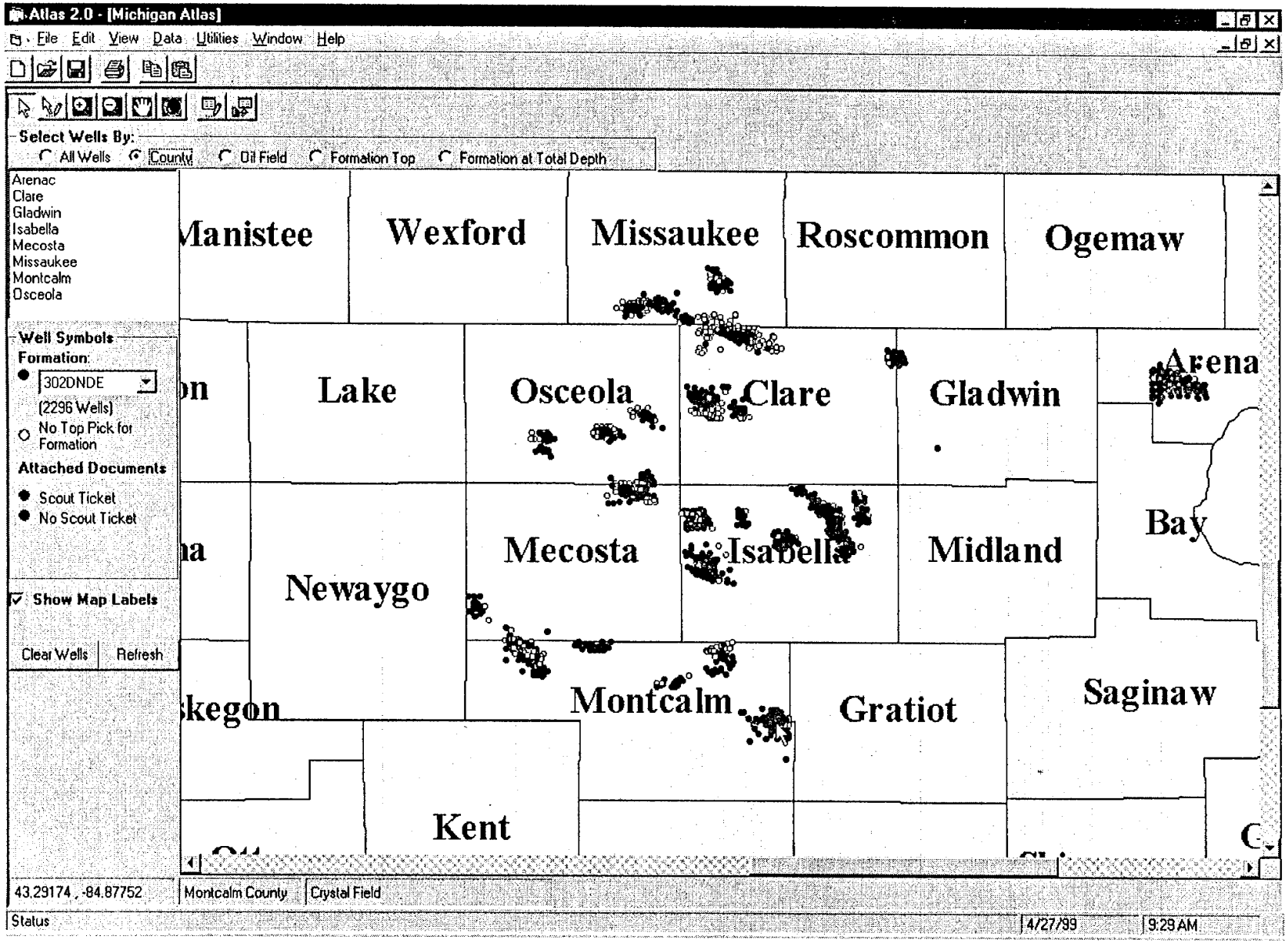


Figure 9. Screen shot of typical first display for the *Atlas* software program.

APPENDIX A

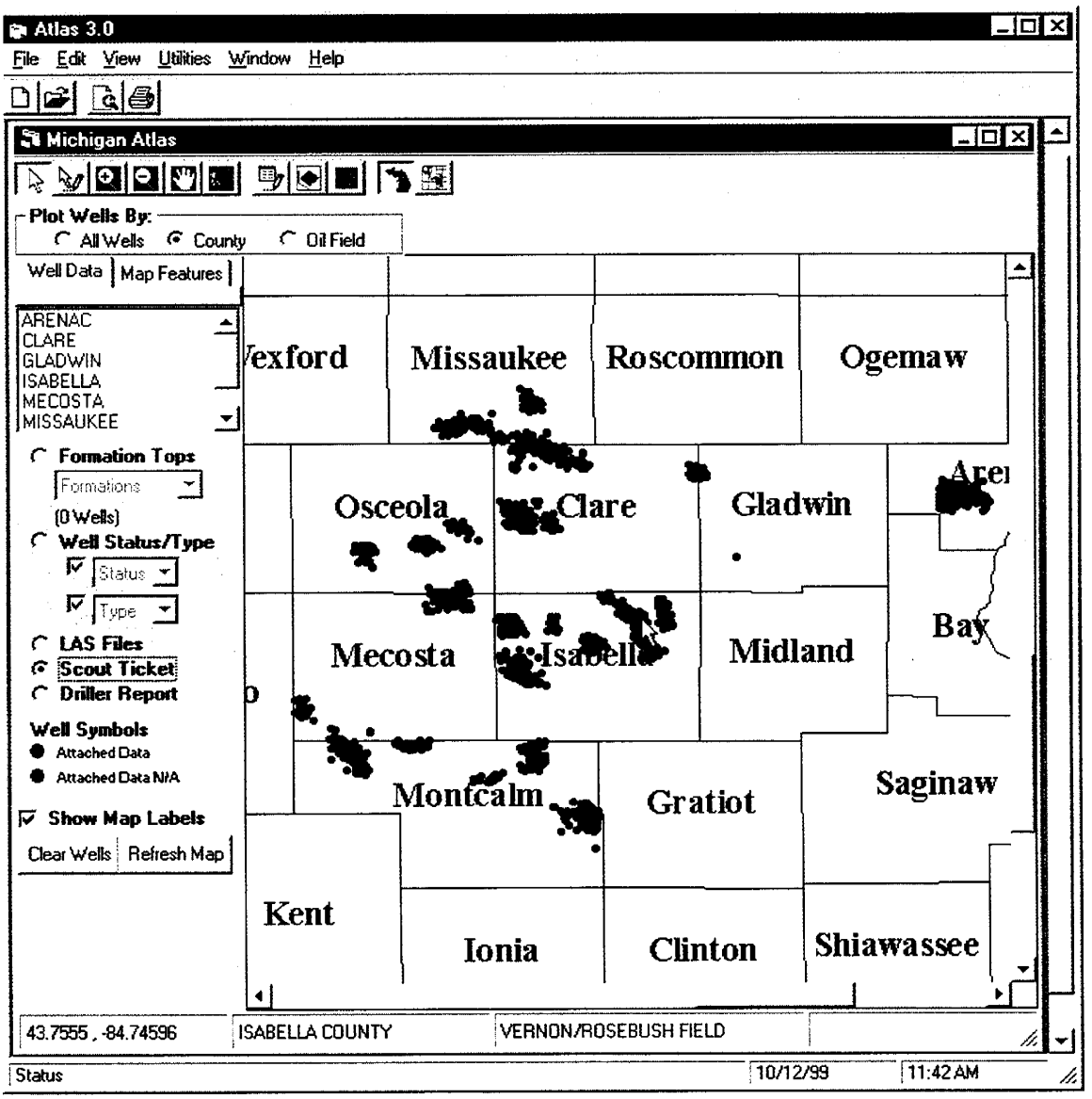
HELP FILES FROM ATLAS 3.0
OCTOBER, 1999

ADVANCED CHARACTERIZATION OF FRACTURED RESERVOIRS IN CARBONATE ROCKS: THE MICHIGAN BASIN

DE-AC26-98BC15100

Atlas

Atlas maps Oil and Gas Wells by County, Oil Field, and by user-drawn areas. Program features include Database Editing, Formation Top and Well Status Displays, Document Image and LAS File Displays, Data Exporting for 3D plotting, Log Viewing, and the display of detailed Map Features by County through the use of the U.S. Census TIGER/Line® data.



Copyright Information

Atlas 3.0

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ImagN' for Windows

(Used for displaying document images.)

Map Objects LT

(Used for displaying maps.)

Defining a Project

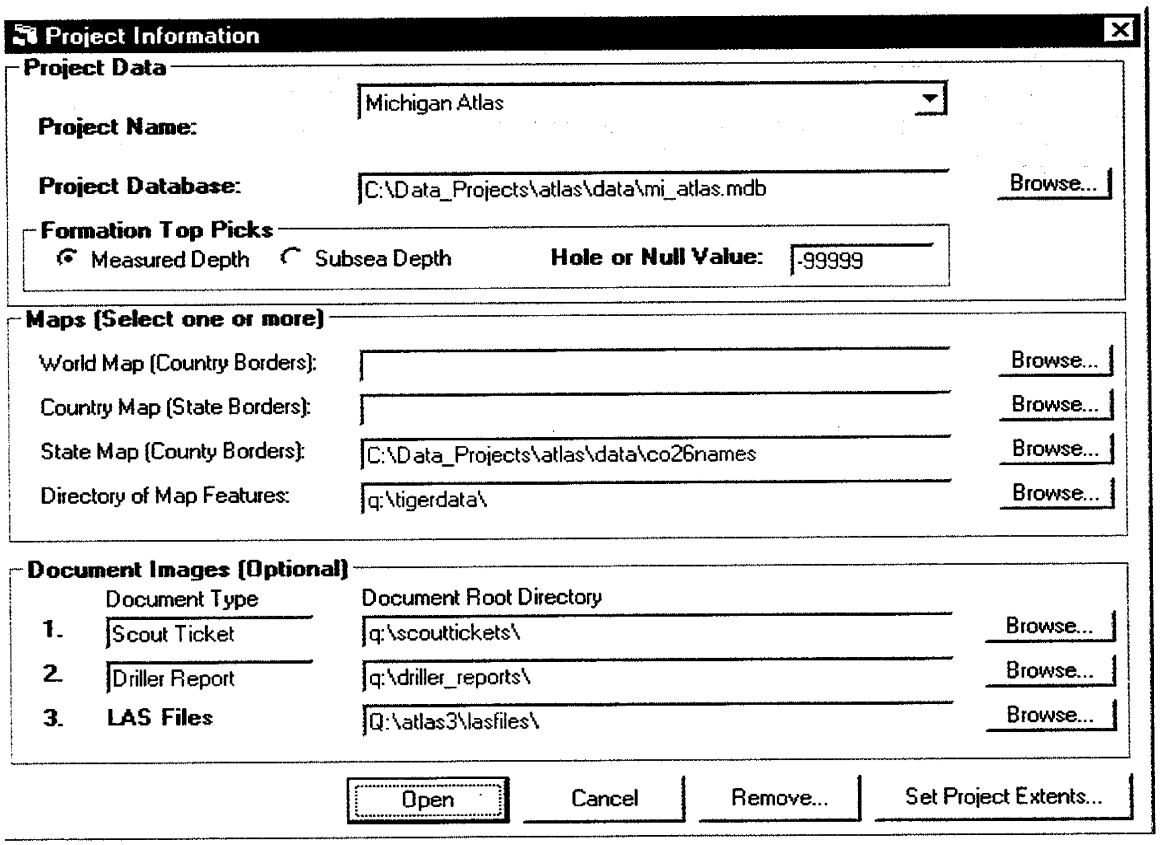
A **Project** is defined to include all of the wells in a given database, along with the Map files of where the wells are located and any supporting document files, such as Scout Tickets or Driller Reports. When a project is loaded, the user must select a subset of the wells in the Project to plot, edit, or export.

The Selected Wells may be:

1. All wells in the project
2. All wells in one or more Counties
3. All wells in one or more Oil Fields
4. All wells located within a user-drawn rectangle

Project Information:

ProjectList.mdb is an MS-Access database, which is loaded into the install directory during Set Up. The table, **Projects**, is updated with the Form, **Project Information**, which is loaded when a user Opens a Project or adds a New Project to **Atlas**.



Project Name

Open an existing Project: Select an existing project by clicking on a Project Name in the List Box.

Set up a New Project: Type the Project Name in the Text Box, and fill in the rest of the project information.

Project Path

Path of the Project Database.

The database included with the Atlas is **MI_Atlas.mdb** and will be installed in the "Data" subdirectory of the Installation Directory.

Formation Depth Option Buttons

The Measured Depth and Subsea Depth Option buttons describe the format of the Formation Depth in the Tops table. Measured Depth is the default.

Hole or Null Value

The value set to be the Formation Depth in the Export table for records, which have no value for the Selected Formation Top. The default value is -99999.

Maps

At least one of the map files (World, Country, or State) must be defined for the Project. In the path given, there must be 3 files associated with the Shape file selected (*.shp, *.dbf, *.shx).

The map files included with Atlas are the shape files needed for the State Map of Michigan. All of the Michigan counties are included in these files.

World Map contains outlines of all the countries in the world.

Country Map contains outlines of all the states in one or more countries.

State Map contains outlines of all counties in one or more states.

Directory of Map Features points to a directory, which holds shape files for individual map features, such as lakes, streams, roads, and township boundaries. These shape files (one per county, per feature) were downloaded from the U.S. Census TIGER/Line® 1995 Data set.

Document Images

Document Images are multiple-page TIFF Image Files, which were created by scanning paper documents associated with the Wells in the Project Database. Atlas allows for two different types of documents, which can be defined by the user.

Document Type is the name given to describe the document.

Document Path is the path of the Root Directory of where the TIFF Images are stored.

Document1 and *Document2* are fields in the Project Database that are set to true if a document of the given type is attached to the well. The **Document1** and **Document2** tables hold the subdirectories and file names of documents 1 and 2 respectively. These tables are connected to the header table through the permit number.

In the Michigan Atlas project, Document 1 refers to the Scout Tickets and Document 2 refers to the Driller Reports. All of the Scout Tickets available for the wells in the database are included with **Atlas** (subdirectory scouttickets), but not all of the Driller Reports are available. The Document Paths can be set to the directories on the CD-ROM and the Atlas program will display them from there.

Example for the Michigan Atlas Database: If the CD-ROM drive is E:\, then the Document1 Type is *Scout Ticket* and the Path is *E:\ScoutTickets*. The Scout Ticket TIF files are stored in Subdirectories under this directory on the CD-ROM. Each Subdirectory is a County Name, and there may be subdirectories under the Counties for the Township names.

Command Buttons

Open

Validate entries on the form and Load the Atlas Form that displays the Maps and Well Locations.

Cancel

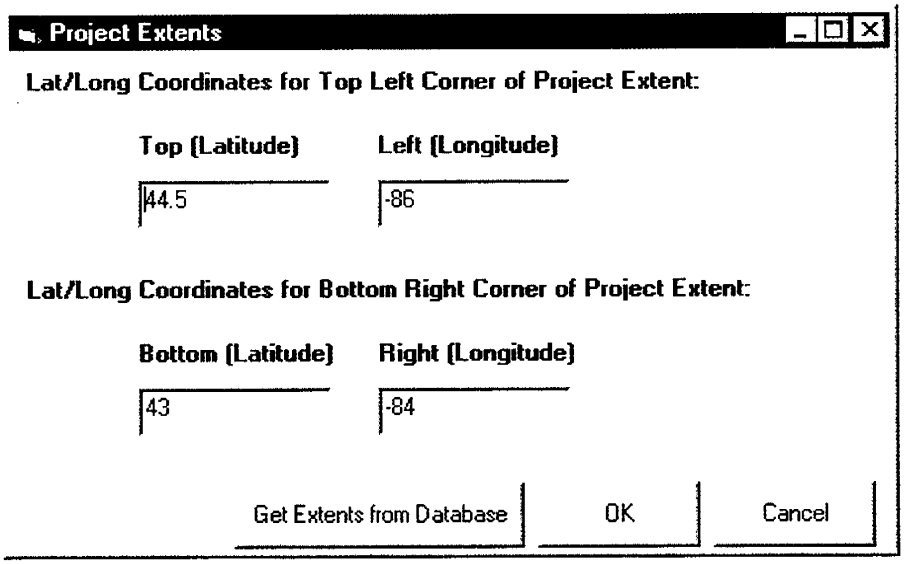
Exit

Remove...

Remove the selected Project Definition from the ProjectList database, but do not delete any data files.

Set Project Extents...

Set the Top-Left and Bottom-Right Latitude/Longitude extents of the project.



If the **Get Extents from Database** button is clicked, the Extent values are filled in by the maximum and minimum Latitudes and Longitudes in the Project Database. Otherwise, the values can be manually entered in. When **OK** is clicked, the values are stored in the **ProjectList.mdb** Database, and are used in the mapping program to zoom in to the extents of the project.

Project Database:

"**MI_Atlas.mdb**" is an MS-Access database, which is automatically installed in the "**data**" subdirectory of the install directory. It contains Well Header and Formation Tops data for 30 Oil Fields in 7 counties in central Michigan. This database can be substituted with similar data in a different MS-Access database as long as the required tables and fields are included. Data can be loaded into the **Atlas** program by:

5. Copying the structures of the tables in MI_Atlas.mdb to new empty tables within a new MS-Access database, and then appending records to the tables, or
6. Opening an existing MS-Access database and renaming the tables and fields to the same names in MI_Atlas.mdb.

Tables:

- **All_Well_Headers**
- **All_Well_Tops**
- **FormationNames**
- **OilFields**
- **Counties**
- **Document1**
- **Document2**
- **LASFiles**
- **DetailMapLayers**
- **UserMaps**

All_Well_Headers

This table holds the general information about each well in the database. Because **Atlas** allows the user to edit fields, all of the fields must be in the database. However, the ones marked with (*Required), must have valid data in order for the functions of **Atlas** to work correctly.

Index: OilField, ASC; Permit, ASC

All_Well_Headers : Table

Field Name	Data Type	Description
Permit	Text	Unique Well Identifer (*Required)
OilField	Text	Oil Field Name (*Required)
Well_Status	Text	W.B. Harrison Status Code
Latitude	Number	Latitude (*Required)
Longitude	Number	Longitude (*Required)
KB	Number	Kelly Bushing (*Required)
IP-Before	Number	Initial Production Before Water Injection
IP-After	Number	Initial Production After Water Injection
IP-Water	Text	Initial Production of Water Out
Top_Porosity	Text	Dundee Top of Porosity
Subsea_TD	Number	Total Depth (Subsea Depth)
Comment	Text	
Document1	Yes/No	Indicates a Document1 (ex. Scout Ticket) is attached to Permit
Document2	Yes/No	Indicates a Document2 (ex. Driller Report) is attached to Permit
LASFile	Yes/No	Indiates a LAS file is attached to Permit in table LASFiles
Operator	Text	Oil Well Drilling Company
LeaseName	Text	Well Name
WellNbr	Text	Well Number
CountyCode	Number	County Code
CountyName	Text	County Name (*Required)

All_Well_Headers : Table

Field Name	Data Type	Description
TWN	Text	Township
RNG	Text	Range
Section	Number	Section
QtrQtrQtr	Text	Civil Location within a 1/4 of a 1/4 of a section
QtrQtr	Text	Civil Location within a 1/4 of a section
Quarter	Text	Civil Location within a section
NSQtrDistance	Number	Feet from North or South quarter of a Section
NSDir	Text	North/South Direction of Footage Call
EWQtrDistance	Number	Feet from East or West quarter of a Section
EWDir	Text	East/West Direction of Footage Call
TD	Number	Total Depth (Measured Depth)
FormTD	Text	Formation at Total Depth
IssueDate	Date/Time	Permit Issue Date
DrillStartDate	Date/Time	Drill Start Date (SPUD)
DrillComplDate	Date/Time	Drill Completion Date
WellType	Text	DNR Well Type Code
WellStatus	Text	DNR Well Status Code
PlotFlag	Text	Used by Atlas program (*Required Field-No data needed)

All_Well_Tops

This table holds multiple records per Permit number, one record for each formation depth. Depth can be either Measured or Subsea Depth, but the user must define which depth is used on the **Project Information** form when setting up the project. **Atlas** assumes the depth is Measured Depth unless the user selects Subsea Depth.

Index: Permit, ASC; Depth, ASC

All_Well_Tops : Table

Field Name	Data Type	Description
Permit	Text	Unique Well Identifier (*Required)
FormationCode	Text	Formation Code (*Required)
FormationName	Text	Formation Description (*Required)
Depth	Number	Depth of Formation (*Required - Measured Depth or Subsea Depth)

FormationNames

List of Formation Codes used in the database and the corresponding descriptions.

Index: DepthSequence, ASC

FormationNames : Table

Field Name	Data Type	Description
DepthSequence	Number	Filled by User to show the Depth sequence of the Formations
FormationCode	Text	Formation Code (*Required)
FormationName	Text	Formation Description (*Required)

OilFields

Stores the name of the Oil Field and the latitude/longitude coordinates for the Top Left and Bottom Right corners of the Oil Field boundaries. When the mouse is moved over an Oil Field, the code for determining the value in the Status Bar uses the Lat/Long ranges in the **OilFields** table to show which Oil Field is being passed over. Also, this table is used to fill the listbox on the Edit Screen for Oil Field. Users can pick an existing Oil Field or Type in a field that is not on the list.

Index: Name, ASC

OilFields : Table

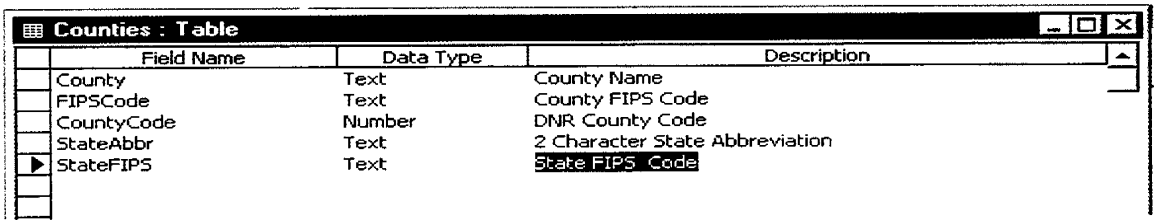
Field Name	Data Type	Description
NAME	Text	Oil Field Name (*Required)
Top	Number	Latitude of Top of Rectangle which bounds the Oil Field (*Required)
Bottom	Number	Latitude of Bottom of Rectangle which bounds the Oil Field (*Required)
Left	Number	Longitude of Left Side of Rectangle which bounds the Oil Field (*Required)
Right	Number	Longitude of Right Side of Rectangle which bounds the Oil Field (*Required)

Counties

Stores the Names and numeric codes of the counties in the scope of the project. This table is used to fill the list box on the Edit Screen for County Name so users will be consistent with

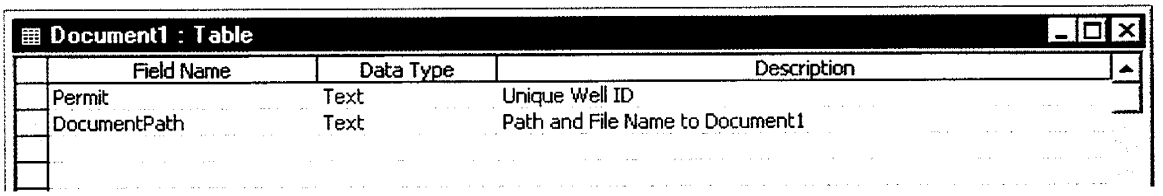
upper/lower case and spelling when entering the County Names. The county code will automatically be updated with the number in the CountyCode field. Because the counties in a state do not change, the list box does not allow new entries to be typed in. To make changes to this table, use Microsoft Access.

Index: County, ASC



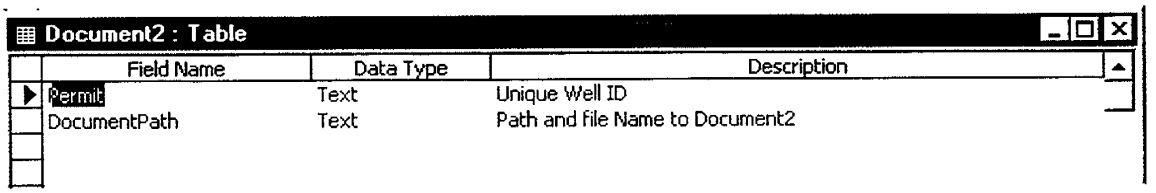
Document1

For each well that has a Document1 (Scout Tickets for Michigan Atlas Example) type of TIFF file associated with it, the Permit and path to the Document file are stored in this table. For each permit in this table, the Document1 field is set to true in the All_Well_Headers table.



Document2

For each well that has a Document2 (Driller Reports for Michigan Atlas Example) TIFF file associated with it, the Permit and path to the Document file are stored in this table. For each permit in this table, the Document2 field is set to true in the All_Well_Headers table.



LASFiles

For each well that has a LAS file associated with it, the Permit and path to the LAS file are stored in this table. For each permit in this table, the LASFile field is set to true in the All_Well_Headers table.

LASFiles : Table

Field Name	Data Type	Description
Permit	Text	Unique Well ID
LASFile	Text	Path and File Name of LAS File

DetailMapLayers

Holds descriptions of each possible Map Feature included in the download from the Census TIGER/Line® 1995 Data. This table is used to construct the shape file name and set the display options for each map layer.

DetailMapLayers : Table

Field Name	Data Type	Description
LayerName	Text	Map Feature Description
Prefix	Text	3-character code to represent layer
Color	Text	Color the feature will appear as on the map
Order	Number	Order in which the layer will be drawn on the map

UserMaps

This table is created and updated by the **Atlas** program when the user selects the counties and Map Feature Layers to display. There is one record per county, per map feature. This table keeps a listing of the current shape files and attributes needed to display them.

UserMaps : Table

Field Name	Data Type	Description
County	Text	County Name
FIPSCode	Text	County FIPS Code
LayerName	Text	Map Feature Name
Prefix	Text	3-character code for Layer
Color	Text	Color of Map Feature
Order	Number	Order of drawing of Map Feature
ShapeFile	Text	Shape file name of feature

Map Files:

The map files are shape files which hold the state and county boundaries, and also provide Latitude/Longitude coordinates for mouse movements over the map. The shape files can be created using software packages like ArcView® and ARC/INFO®.

The shape files included in this application contain the counties within Michigan. They are loaded into the "Data" subdirectory of the Install Directory during Set Up. The set of Shape files for one map should include the Shape (*.shp), the Shape Index (*.shx), and the Shape Database (*.dbf) files.

Maps are referenced in the **Project Information** screen. The user must indicate which maps to use in a project. At least one of the **World**, **Country**, or **State** maps must be defined in order to plot points in a project. (The shape file name is entered without an extension.)

The **Directory of Map Features** refers to a directory containing shape files from the U.S. Census TIGER/Line® data, which are used to display map features like lakes, rivers, and streets. A set of feature shape files for each county in Michigan is included with **Atlas**. To display on the map, use the **Add Map Features** toolbar button to select counties and features.

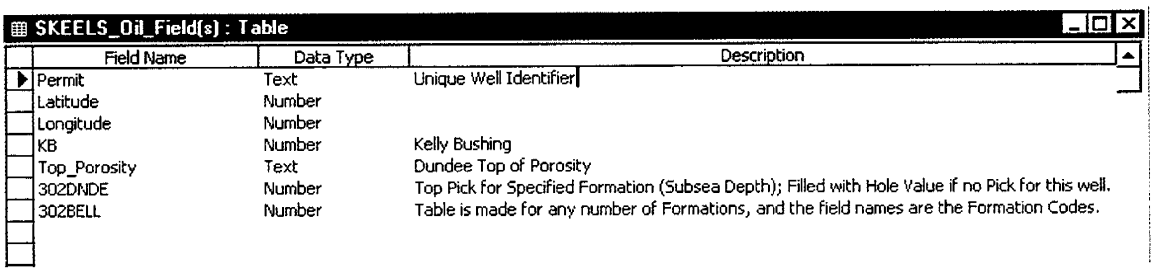
To add Map Features from other states to **Atlas**,

- Add records for any new features to **DetailMapLayers** table in project database.
- Add counties with County and State FIPS codes to **Counties** table.
- Move the new shape files to the directory listed in the **Project Information** Screen.

Export Databases:

After a group of wells has been selected and the points are drawn on the map, the Formation Tops data can be exported into a separate MS-Access database to be used in plotting programs. The user selects one or more formation tops to export. A new or existing Export Database is chosen, and a table is written to hold the exported data.

The table will be created with the description of the Prospect as its name unless the user overwrites the table name. The fields holding the **Subsea Depth** of each Formation Top will be named by the Formation Code.



SKEELS_Oil_Field(s) : Table

Field Name	Data Type	Description
Permit	Text	Unique Well Identifier
Latitude	Number	
Longitude	Number	
KB	Number	Kelly Bushing
Top_Porosity	Text	Dundee Top of Porosity
302DNDE	Number	Top Pick for Specified Formation (Subsea Depth); Filled with Hole Value if no Pick for this well.
302BELL	Number	Table is made for any number of Formations, and the field names are the Formation Codes.

Notes about the Exported Data:

- The exported table will have one record for each well selected.
- If the well does not have a value for the formation tops chosen, the subsea depth value for that formation will be the hole (or null) value which is set in the **Project Information** screen. It is possible for an exported well to have no values for the chosen formations.
- If the Formation Picks are in Measured Depth (also set in the **Project Information** screen), and there is no valid KB (Kelly Bushing), then the record for that well will not be exported. It will be written to a log file in the same directory as the Export Database and will be named after the name given to describe the selected wells with an extension of ".log". The Kelly Bushing can then be entered into the database from the Edit Screen if it is available.
- If the Formation Picks are in Subsea Depth, the KB is still written to the file, but it is not checked for valid data.
- Top_Porosity is the Top of Porosity for the Dundee Formation.

New/Open Project

Atlas keeps a record of multiple projects that can be accessed by the users. The **Projects** table in the **ProjectList** database holds one record per project and tracks the following:

7. Paths and filenames for the database, map files, and document files.
8. Minimum and Maximum Latitude and Longitude coordinates of all the wells in the specified database for use as project extents.
9. Measured/Subsea Depth indicator for Formation Top Picks.
10. Hole (or Null) Value to be used when no Top Pick is found for a specified formation.

Separate projects may be needed for different geographical regions, and it may also be easier to work with a large database if it is divided into smaller databases and treated as several projects.

Menu Option: File, New

Displays a blank **Project Information** Screen. Type in the Project Name and fill in the rest of the project information. If a project name already exists in the **Projects** table, a message is displayed to inform the user a different project name must be chosen.

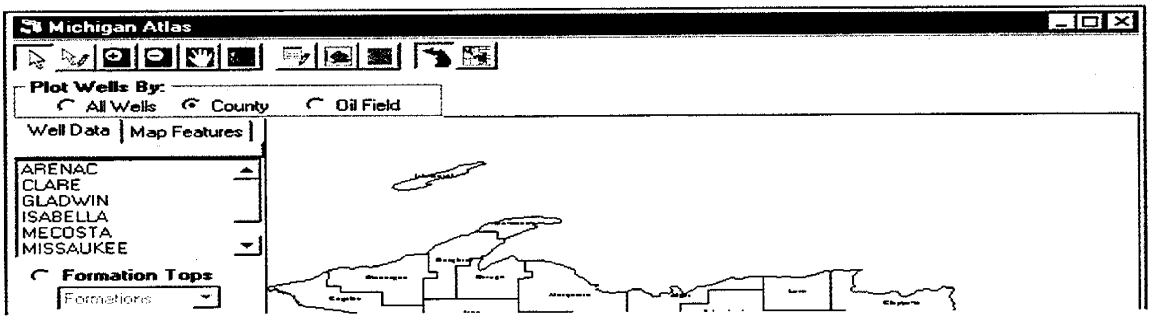
Menu Option: File, Open

Displays the first project in the **Projects** table, but the Project Name is shown as a list box so the user can choose another project. Settings may be updated in the **Project Information** screen, or the project can be opened directly.

Clicking on **Open** from the **Project Information** screen will load the defined map files and make the chosen database available to the Atlas program.

Plotting Wells

Once wells have been plotted on the map, they are available for Editing and Exporting. They can also be re-mapped showing symbols for the presence of attached documents, Formation Top Picks, and Well Status.



"Plot Wells By:"

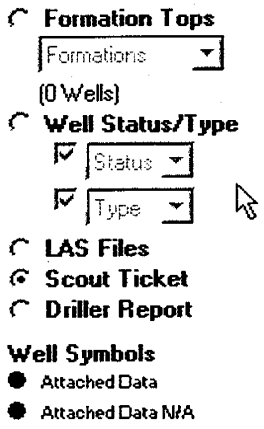
- When the user clicks an option button, the list box is filled according to the option button clicked. The Counties and Oil Fields are queried from the All_Well_Headers table in the database. When one or more items are selected from the list box, all wells that satisfy the selection are plotted.
- When the All Wells option is clicked, the list box is cleared, and all of the wells in the database are plotted.
- The user can select multiple items from the list box by using the shift and control keys. When multiple items are selected, wells are plotted that satisfy at least one of the choices.

Selecting Wells by Clicking on the Map

- Click the Select button and move the mouse over the map until an Oil Field name appears in the 3rd frame of the Status Bar at the bottom of the screen. Click the mouse, and the wells from this Oil Field will be plotted.
- If the cursor is over a county, but not over an Oil Field, the whole county will be plotted when clicked. If there are no wells for the chosen county in the database, the clicked county will be zoomed in and displayed.
- Hold the shift key and click on additional Oil Fields or Counties, and all selected areas will be plotted. All of these wells will be included in the Edit and Export functions.

- Click the Select button and draw a rectangle over an area of interest to the user. The wells located within this latitude/longitude range will be plotted on the map.

Well Symbols



There are 5 types of data attached to each well - Formation Top Picks, Well Status and Type, LAS Files, Scout Tickets*, and Driller Reports*. Initially, all wells are plotted with blue circles. When one of the 5 options is selected, the well symbols change to red if data of that type exists.

When the option button for Formation Top Picks is clicked, a Formation Code must also be selected. All wells with a Top Pick for that formation will be symbolized in red. The number of wells with the selected formation is displayed beneath the list box.

When the Well Status/Type option is chosen, any combination of Status and Type can be selected, and all wells that meet the conditions will be plotted in red.

Once an option has been chosen, additional wells plotted will be coded with the same options.

* In the Michigan Atlas project, the 2 Documents are Scout Tickets and Driller Reports. The documents associated with the wells can be any type of document. The user defines a document description and root directory in the **Project Information** screen when a project is defined or opened. The remaining path information for individual documents are stored in separate tables (Document1 and Document2).

Map Tools

Zoom-In

Select the Zoom-In button and draw a rectangle around the area to enlarge.

Zoom-Out

When the Zoom-Out button is clicked, the map is scaled down by 2 times.

Pan

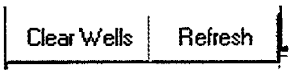
Select the Pan button and drag the mouse from one spot on the map to another to move the map in any direction.

Full Extent

Click the Full Extent button and the whole map will be drawn to a scale that fits on the screen.

Show Map Labels

When this box is unchecked, the labels are removed from the map. This may be necessary when viewing wells that are plotted where the labels are printed on the map.



Clicking on **Clear Wells** will remove all wells plotted on the map. Clicking on **Refresh** will redraw the current selection of wells and reset the list box items.

Status Bar Data

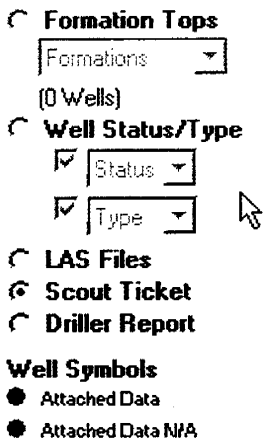
There are 4 frames in the Status Bar at the bottom of the map. The first frame is the Lat/Long coordinates of where the mouse is located. The second frame is the County that the mouse is over. The third frame contains the name of an Oil Field, if the mouse is over an Oil Field. Otherwise, it is empty.

The Fourth frame is used to display the name of a feature when Map Features have been added to the map. If the Map Features tab is clicked and the frame for Water Bodies is clicked, when the mouse passes over a lake, the name of the lake will appear in the 4th frame.

Plotting Formations

When a group of wells is selected and plotted on the map, the Formation List Box is filled with the Formation Codes of Top Picks that exist for the plotted wells. The user chooses to display wells by Formation Code, LAS Files, or Document. The names of the documents are filled by the Document Type, which is entered in the Project Information Screen. The well symbols are plotted in red if data exists for the chosen option type. All other wells are plotted in blue. (ex. Clicking on **LAS Files** changes the well symbols to red for all wells with a LAS file attached. Clicking on **Scout Tickets** changes the well symbols to red for all wells with a Scout Ticket.)

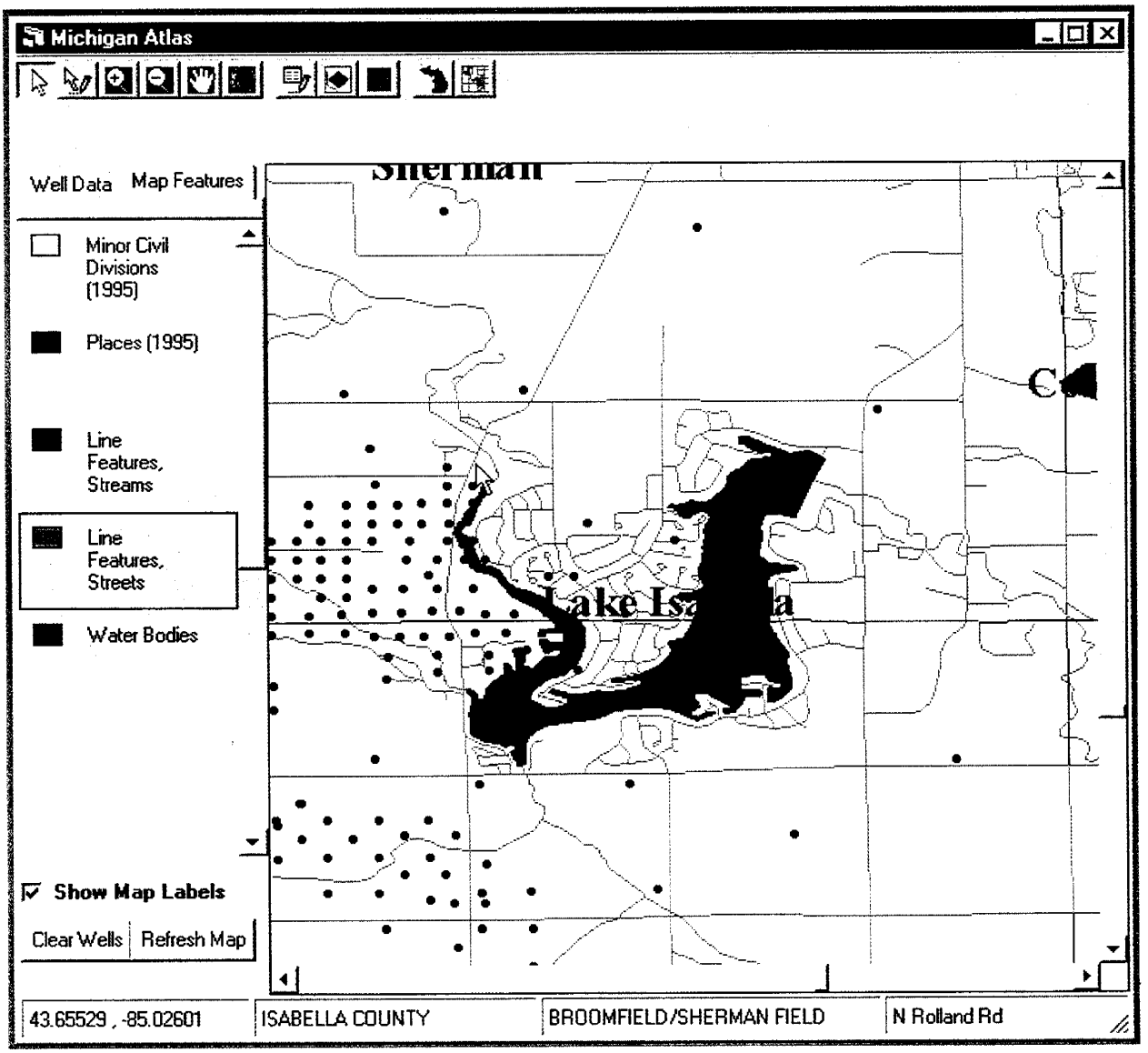
When the user clicks the Formation Top Picks option button, a Formation Code must also be selected. The wells are then re-plotted with red symbols indicating that the well has a pick for the chosen formation. The number of wells with a value for the chosen formation is displayed below the list box.



The next selection of plotted wells will be symbolized with the options of the current group of selected wells. For example, if one field is plotted for the Dundee formation, the next field or county chosen will be plotted for the Dundee formation also. If a county is plotted to show which wells have Scout Tickets, the next selection will be plotted showing Scout Tickets also.

U.S. Census TIGER/Line®; 1995 Data

Users can select Detail Map Layers to the area of the map they are working with. Detailed shape files for each county in Michigan were downloaded and stored in one directory on the **Atlas** CDROM. For each county, there are individual shape files for certain features such as township boundaries, roads, lakes, and streams. Atlas users can select which Counties and which detail maps they want to add to the Map of Michigan.

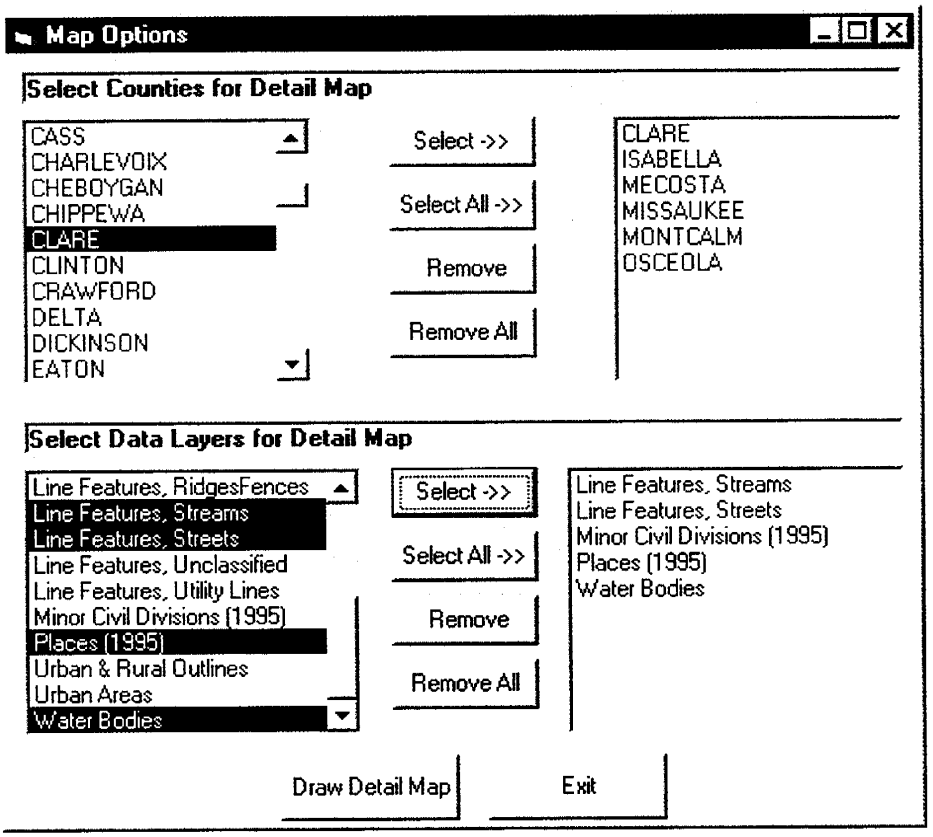


ShapeFile Naming Standards

xxxSSCCC.shp
Each shape file is identified by this format, where xxx is a 3-character code describing the type of detail layer, SS is the FIPS State Code, and CCC is the FIPS County code.

Database

The County FIPS code was added to the **Counties** table. The **DetailMapLayers** table was created to hold a record for each possible Layer Description, Prefix Code, Order, and Color. The **UserMaps** table is generated by **Atlas** to hold the user's current selection of Counties and Detail Layers. The shape file name is generated by the user selections and if it exists, a new layer is added to the map in **Atlas**.



Editing Well Data

Edit Plotted Wells

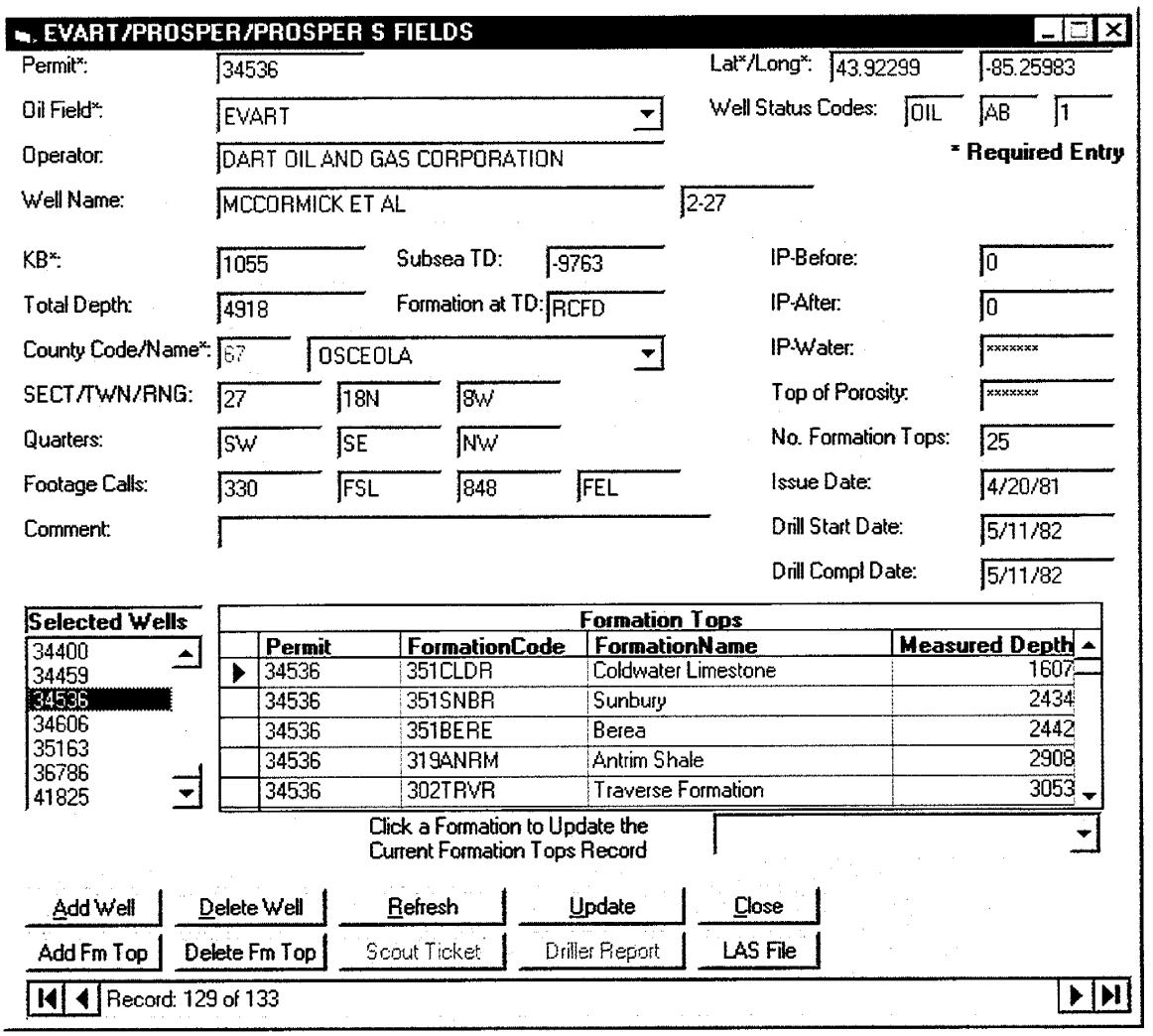
After a group of wells has been selected and plotted, the **Edit Plotted Wells** button is enabled. When clicked, the Edit Screen is activated and the fields of the Header and Tops tables can be edited. Only the plotted wells are available for editing and the Permits are listed in the Selected Wells list box near the bottom left of the Edit Screen.

Select Wells to Edit

This button is used when one or several wells need to be edited or viewed without changing the selection of plotted wells. Clicking on a point or drawing a rectangle around a well or group of wells will activate the Edit Screen just for these wells while keeping the wells previously plotted on the map. A blue rectangle is drawn around the wells being edited.

Edit Screen

The operations performed using this form will update the main database, but will involve only the records selected by the user.



Selected Wells

Click on a Permit number in this list box and the header information and formation tops data for this well will be displayed on the screen.

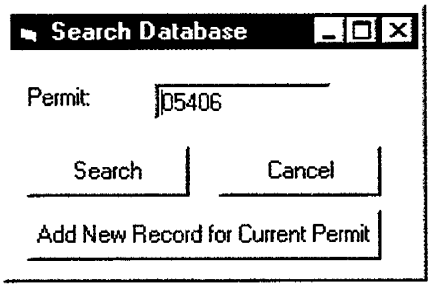
Oil Field

The Oil Field entry is a list box, which is filled from the Oil Field Table. When a new Oil Field is typed into the list, the new field is added to the Oil Field Table with the Top, Bottom, Left, and Right fields set to 0. The Oil Field extents can be updated by the user in MS-Access or by using the Utility, **Get Oil Field Extents**.

County

The County entry is a list box, which is filled from the Counties Table. The County list is set up so users cannot add new counties to the project. It is assumed that the Counties Table will hold all possible Counties for the project. The Counties Table can be filled by the user in MS-Access or by using the Utility, **Fill County Table**, which fills the County Table with the unique county names in the All_Well_Headers Table.

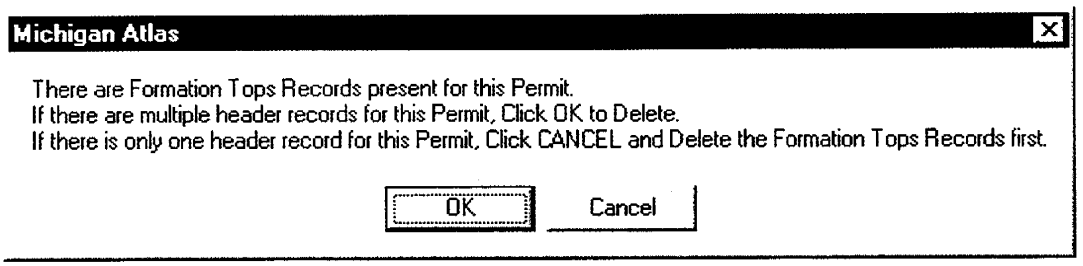
Add Well



- Brings up a Search Window with Permit number of current well.
- The user can search the database for a new Permit number, or add a new record for the current permit.
- **Search** button. If the Permit is found among the group of selected wells, then the data for that well is displayed and the user can edit the fields as needed, or add Formation Tops data. If the Permit is found in the database, but not in the current Selection of Wells, then a message is displayed to tell the user that the Permit entered already exists in the database. If the Permit is not found, then a blank display screen comes up where the user types in data for a new well.
- If **Add New Record for Current Permit** is clicked, an additional record for the current Permit number will be added to the database. All fields will be identical to the current record, and edits can be done from here. (This function may be useful to attach multiple types of image documents that cannot be combined into multi-page TIFF files.)
- **Permit**, **Lat/Long**, **KB**, and **County Name** must have values in order for the program to run properly. **Oil Field** is needed if the database is to be plotted by Oil Field.

Delete Well

Click on the **Permit** number to delete and then click on the **Delete Well** button. If there are formation tops present for this permit, the following message box appears:



Refresh

Refreshes the query, which was run to select the wells displayed on the **Edit Screen**.

Update

Must be clicked in order to save the edits and save the data in a new record. If the **Edit Screen** is closed before the **Update** is done, all entries for the newly added record will be lost, and the permit will not be added to the database.

Close

Closes the **Edit Screen**.

Editing Formation Tops

Add Formation

When this button is clicked, the **Permit** is automatically entered in the next Formation Tops record. Select a Formation from the list box at the bottom right of the screen. When an item is clicked from this list, the **Formation Code** and **Formation Name** are updated. Only the **Depth** needs to be entered manually.

Save changes to the Formation Top Record in the All_Well_Tops Table by clicking on another cell in the grid or clicking the **Update** button.

Delete Formation

Select a Formation Top record from the Formation Tops Grid, and click on **Delete Formation** to delete a formation depth from the database.

Scout Ticket and Driller Report

These 2 buttons correspond to the Documents defined for the project. In our example database, MI_Atlas.mdb, **Document1** references Scout Ticket TIFF files and **Document2** references Driller Report TIFF files. Document1 and Document2 are defined in the **Project Information Screen**. If they are left blank, it is assumed that there are no documents associated with the wells in the database. In this case, the Scout Ticket and Driller Report buttons will be disabled.

If there is a path and file name stored in the Document1 and/or Document2, the Document Name given in the **Project Information Screen** will be displayed on the corresponding button. When the button is clicked, a form is brought up to display the document. The information from the document can be used to fill in data in the database. The buttons are disabled if there is no file in the document fields.

LAS File

The LAS File button is activated if an LAS file is associated with the current well. When clicked, a viewing window displays the text of the LAS file with Next and Previous buttons allowing the user to view multiple LAS files for one well. The LASFiles table stores the permit and path of the LAS File, and the LASFile field in the All_Well_Headers table is set to true if an LAS File exists for a well.

Formation Codes

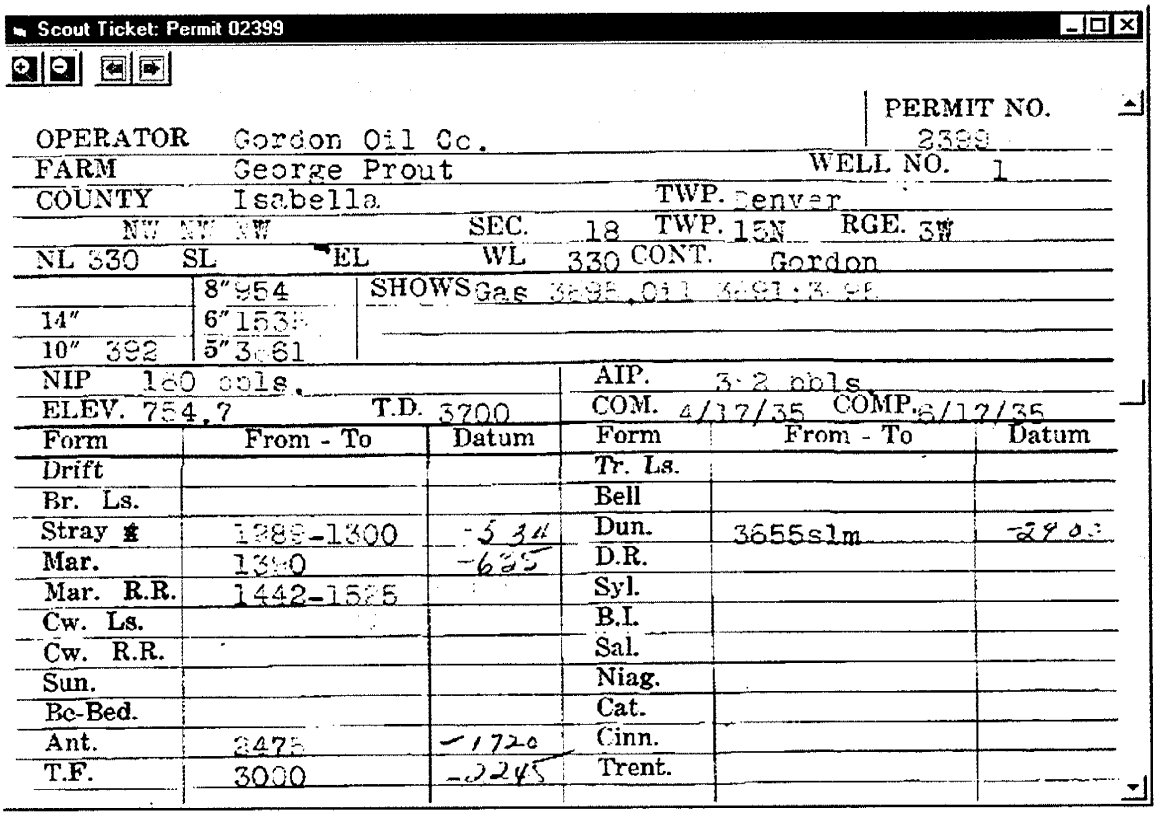
This list box in the lower right corner of the **Edit Screen** displays Formation Codes used in the database (Table, **FormationNames**). When a Formation Code is selected, the **Formation Code** and **Formation Name** of the current Formation Tops Record is changed to the selected item. In order to save the change, click another row in the grid or click the **Update** button.

Update the **FormationNames** Table from MS-Access or use the **Get Formation Codes** Utility to reset the table to hold all of the unique Formation Codes currently in use from the All_Well_Tops Table. To add new codes to the list, type in the new code and description in the Formation Tops grid when adding a new formation top to the table. Run the **Get Formation Codes** Utility to reset the Formation Code List and make the new formation code available for new entries.

Viewing Documents

When the **Document** buttons (**Scout Ticket** and **Driller Report** in the Michigan Atlas project) on the **Edit Screen** are enabled, there is a document image associated with the current well available for viewing. Clicking the button will display the TIFF image of the document. The image has zoom-in and zoom-out buttons, and next and previous buttons for multi-page images.

The image can remain open while entering data into the **Edit Screen**.


Scout Ticket: Permit 02399

PERMIT NO. 2399

OPERATOR Gordon Oil Co.

FARM George Prout WELL NO. 1

COUNTY Isabella TWP. Denver

NW NW NW SEC. 18 TWP. 15N RGE. 3W

NL 330 SL EL WL 330 CONT. Gordon

8"954 SHOWS Gas 3695, Oil 3691-3 98

14" 6"1535

10" 392 5"3561

NIP 160 bbls. AIP. 3-2 bbls

ELEV. 754.7 T.D. 3700 COM. 4/17/35 COMP. 6/12/35

Form	From - To	Datum	Form	From - To	Datum
Drift			Tr. Ls.		
Br. Ls.			Bell		
Stray ⁂	1388-1300	-534	Dun.	3655slm	-2803
Mar.	1390	-625	D.R.		
Mar. R.R.	1442-1525		Syl.		
Cw. Ls.			B.I.		
Cw. R.R.			Sal.		
Sun.			Niag.		
Bc-Bed.			Cat.		
Ant.	2475	-1720	Cinn.		
T.F.	3000	-2245	Trent.		

Background

Atlas displays multiple page TIFF images. When documents are scanned, they can be saved as TIF Group 4 compression and all pages for a document can be combined into one physical file. **Atlas** allows the user to define 2 different document types. For example, the Michigan Atlas project references Scout Ticket and Driller Report documents. TIF images for Well Logs could also have been defined. The document type description is entered in the Project Information Screen along with the root directory of where the documents are located. The description is displayed on the Command buttons on the Edit Screen that display the document for an individual well.

The ScoutTickets table (references for Document1) and DrillerReports table (references for

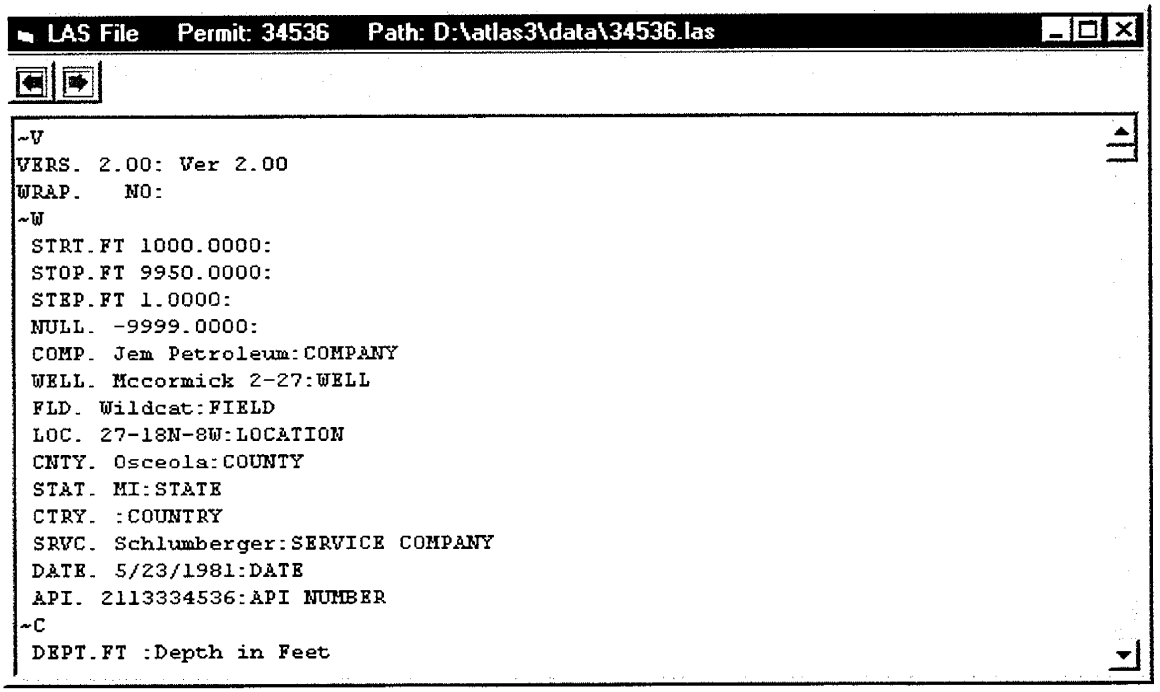
Document2) hold the Permit and path to each document. The fields Document1 and Document2 in the All_Well_Headers table are set to true if a TIF file exists for the well.

Even though Atlas defines only 2 document types, users can connect more documents to a well without adding additional pages to a multi-page TIFF file. For example, suppose the project already references Scout Tickets and Driller Reports and now the user wants to display Well Logs.

11. In the Scout Ticket root directory, make another folder. (ex. d:\scouttickets\WellLogs\)
12. Add Well Log files to this directory. (ex. D:\scouttickets\WellLogs\montcalm\02394.tif)
13. Add a record to the ScoutTickets table (Permit: 02394,DocumentPath: WellLogs\montcalm\02394.tif)
14. Set Document1 to true in the All_Well_Headers table. This can be done in an Access Query.
15. When the Scout Ticket button is clicked, the Next Document and Previous Document buttons will be enabled, and the user will be able to view all of the documents available for the well. The Next and Previous Page buttons will also work if each document has multiple pages.

Viewing LAS Files

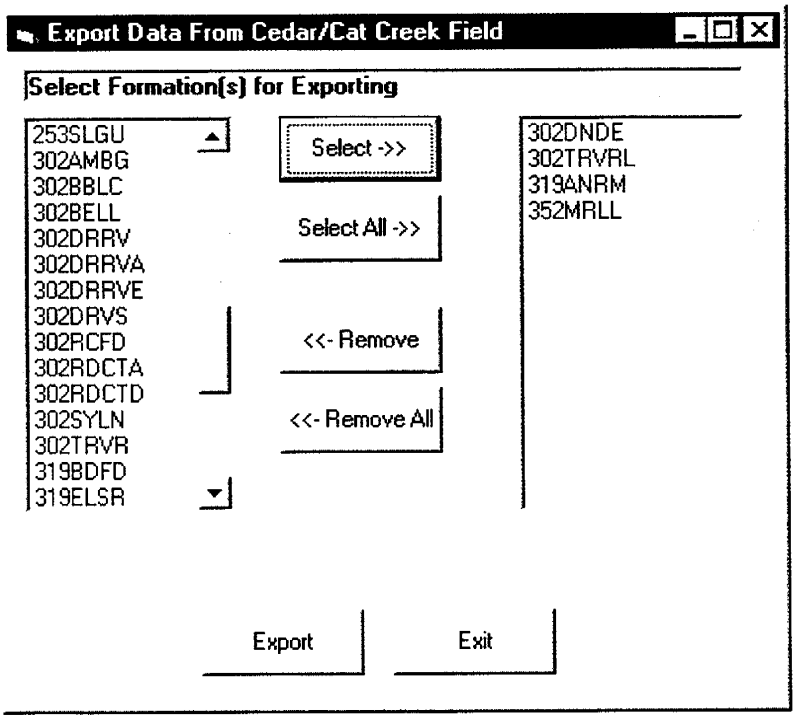
When the **LAS File** button on the **Edit Screen** is enabled, there is a LAS File associated with the current well. Clicking the button will display the text of the LAS file. Next and Previous buttons are enabled if the well has more than one LAS File referenced.



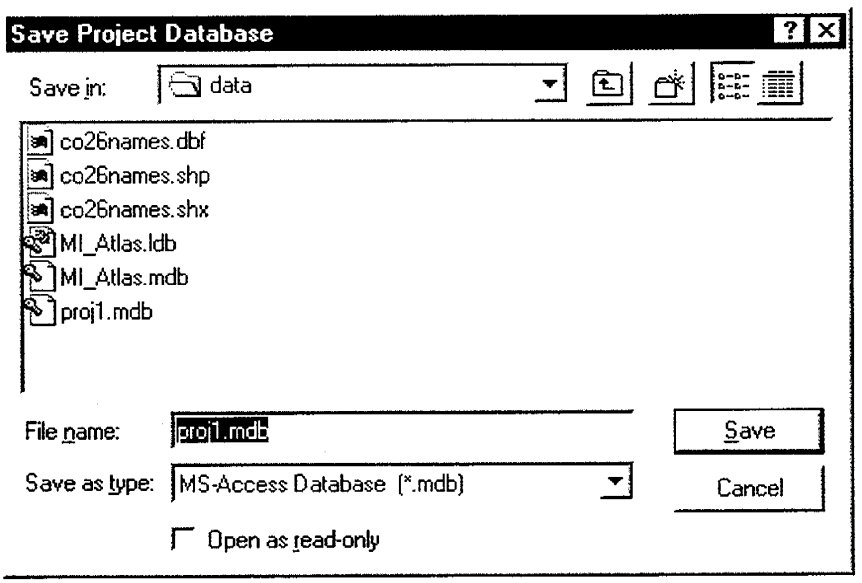
Export Formation Tops

The Export function saves Permit, Lat/Long, KB, Dundee Top of Porosity and formation depths selected by the user for the wells plotted on the map. This MS-Access database file can then be read into other programs for 2D and 3D plotting, isopach maps, etc.

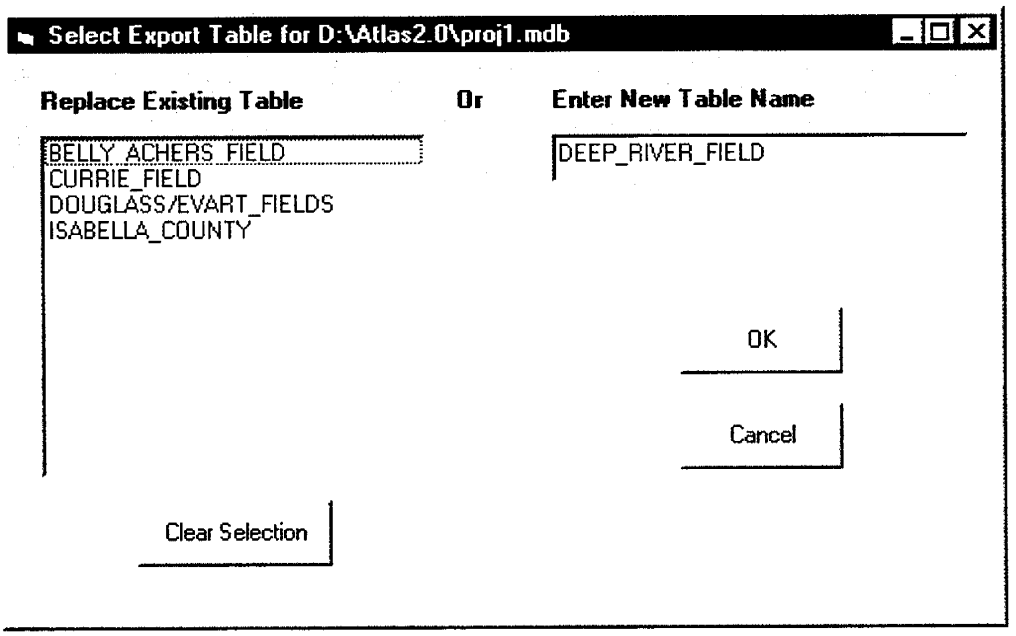
- Plot a selection of wells on the map.
-  Click the **Export** button from the ToolBar.
- Choose the formation(s) to be included in the exported table. The shift and control keys can be used with mouse clicks to select Multiple formations. Use the Select and Remove buttons to move formation codes to and from the selection lists. The formations in the right-hand list will be used in the Exported Table.
- Click **Export**.



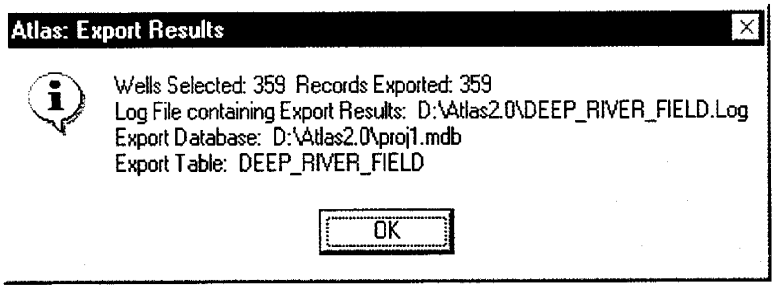
- Create a new project database or select an existing Project database (MS-Access database *.mdb) to store the exported table.
- If an existing database is selected, a message pops up to remind the user that the Exported table will be added to this database.



- Create a new Export Table or replace an existing Export Table within the project database. Existing Tables are listed on the left, and the name to be used for the new Export Table is on the right. When possible, the program provides a name that should describe the Wells Selected. The user can choose either of these, or type in a new table name.



- When **OK** is clicked, the table is created in the database and a Log file is written to the same directory as the Export Database to record the Export Results. If a Well is missing its KB (Kelly Bushing), and the Formation Picks are in Measured Depth, Atlas cannot calculate Subsea Depth. An Export Record is not output for these wells, but the Permit and Well Name are listed in the Log file so users can correct the data.

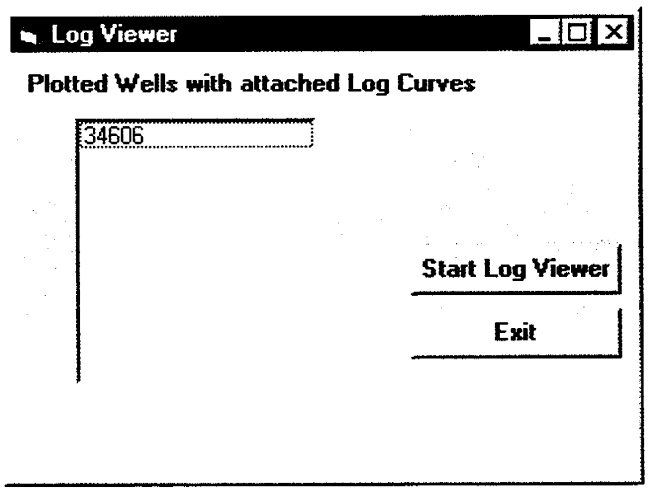


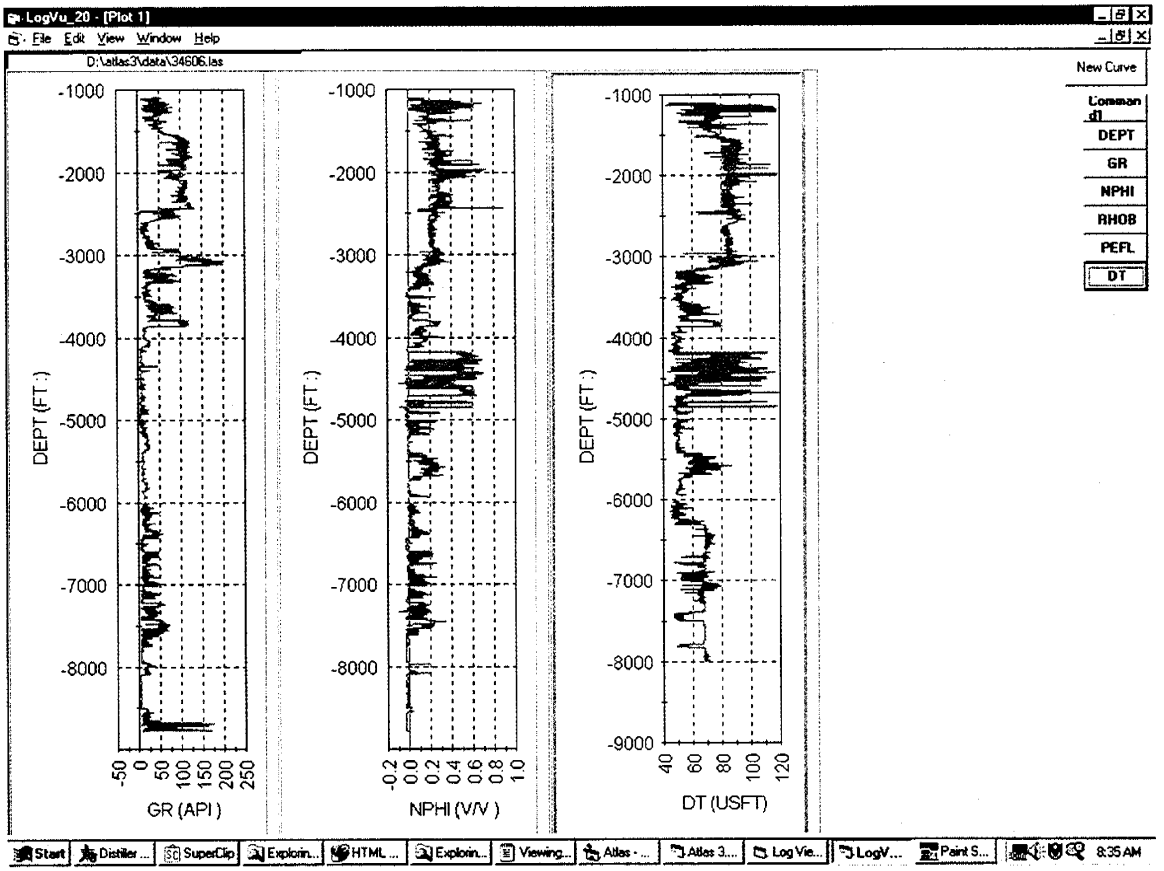
- The program is then returned to the **Export Data From...** screen, where the user can click **Exit** to return to the map, or make new formation selections and export another table.

Well Log Viewer

LogVu is a separate program for viewing log curves defined in an LAS file. **Atlas** activates LogVu and sends the LAS paths to LogVu to open the well logs.

16. Plot a group of wells on the map.
17. Click the **LAS Files** button to show which wells have LAS files. (optional)
18.  Click the **Log Viewer** button.
19. With the cursor changed to a crosshair, click on a well or draw a rectangle around a group of points to select wells for viewing well logs.
20. The selected wells that have LAS files attached will be displayed in the Log Viewer Screen. Select one Permit number and **Start Log Viewer**.




LogVu_20 - [Plot 1]
File Edit View Window Help
D:\atlas3\data\34606.las
New Curve
Comman d1
DEPT
GR
NPHI
RHOB
PEFL
DT
DEPT (FT)
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-50 0 50 100 150 200 250
GR (API)
-0.2 0.0 0.2 0.4 0.6 0.8 1.0
NPHI (V/V)
40 60 80 100 120
DT (USFT)
Start
Distiller ...
SuperClip
Explorin...
HTML ...
Explorin...
Viewing...
Atlas - ...
Atlas 3....
Log Vie...
LogV...
Paint S...
8:35 AM

Get Oil Field Extents

This creates or updates the **OilFields** table in the project database. This table lists all defined Oil Fields in the database and holds lat/long coordinates for the top-left and bottom-right corner of the rectangle surrounding the Oil Field.

If the table does not exist in the user's database, the table is created with the fields NAME, Top, Bottom, Left, and Right. If the table does exist, the user can exit the utility or choose to have the table overwritten with updated data from the database.

A Totals Query appends the minimum and maximum latitudes and longitudes of each Oil Field in the **All_Well_Headers** table to the **OilFields** table. The Top (maximum Latitude) / Left (minimum Longitude) and Bottom (minimum Latitude) / Right (maximum Longitude) coordinates represent the rectangular extents of each Oil Field on the map.

Use of OilFields table:
When the mouse is moved over the map, the **OilFields** table is searched for the mouse location by comparing the mouse location with the extents of each field. When the mouse location is found to be within the range of the extents, the Oil Field name of that record is displayed in the Status Bar at the bottom of the map. The values of the extents in the **OilFields** table may need to be manually adjusted in MS-Access to account for the following:

21. Oil Field boundaries are not always a perfect rectangle and may overlap. Plot the Oil Field by selecting from the list. Then compare the lat/long coordinates shown on the Status Bar when the mouse is moved to the coordinates in the **OilFields** table. Make any necessary adjustments.

22. A well may have an incorrect Latitude/Longitude or be labeled as being in the wrong field. This will make the rectangle extents for the field much larger than what is correct. Fix the well or change the extents in the **OilFields** table to exclude the well in error.

The **OilFields** table is also used to fill the list box for the Oil Field field on the Edit Screen. When an Oil Field is chosen from the list, the **All_Well_Headers** table is updated (completed after the **Update** button is clicked). A new Oil Field can be added to the list by typing in the Oil Field name in the text part of the list box. This will add the new Oil Field to the **OilFields** table, but the Top, Left, Bottom, and Right coordinates will be set to zero. The **Get Oil Field Extents** utility can be run again to set the extents or they can be manually entered using MS-Access.

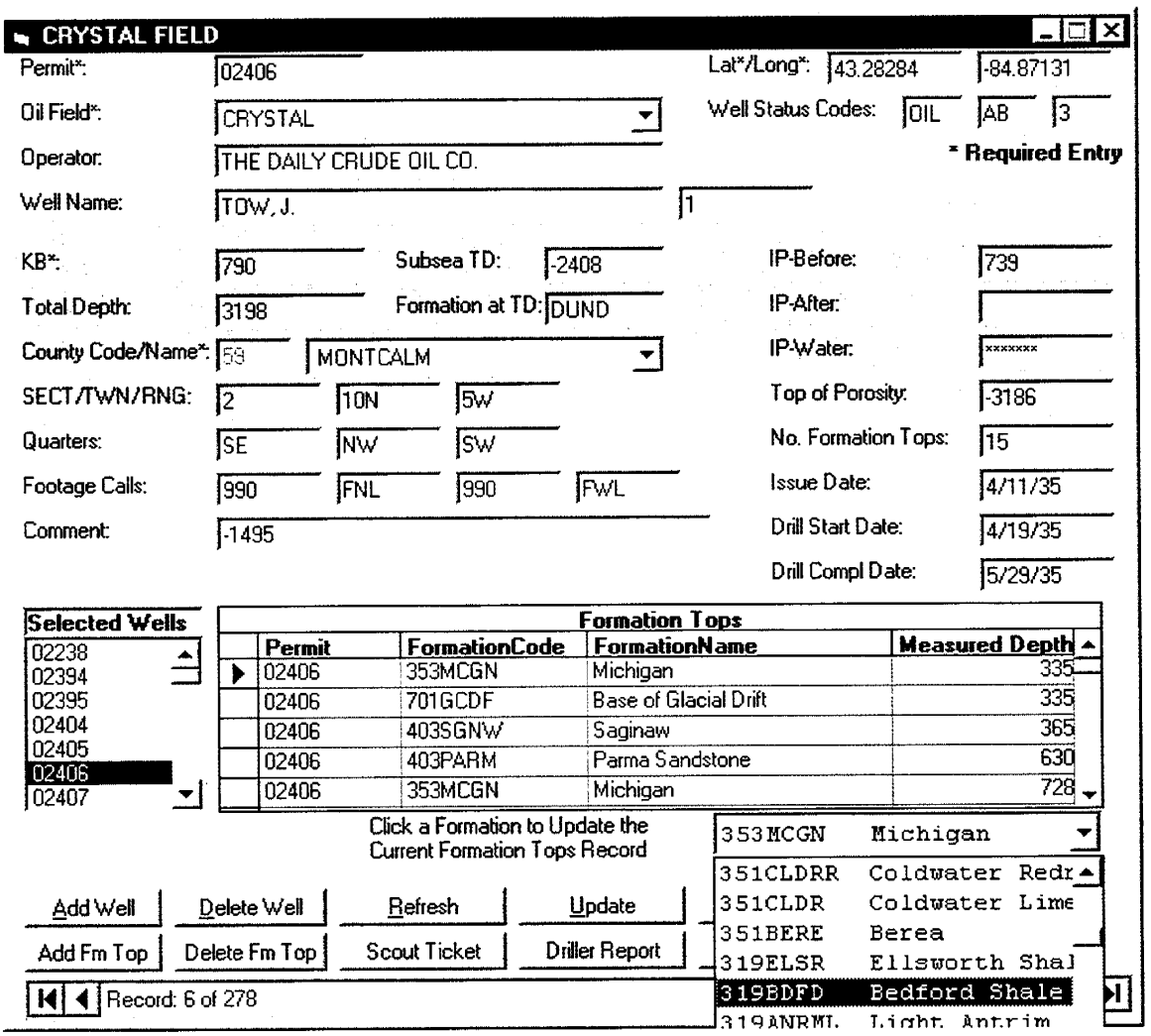
* Remember that any manual changes made to the OilFields Extents will be overwritten by the maximum and minimum longitude and latitude values found in the All_Well_Headers table if the **Get Oil Field Extents** utility is rerun.

Get Formation Names

This utility creates or updates the **FormationNames** table in the project database. Each formation beneath the earth's surface is referenced by a standard formation code for a particular area. This table stores the available codes and formation descriptions available for the current project.

If the table does not exist in the user's database, the table is created with the fields DepthSequence, FormationCode, and FormationName. If the table does exist, the user can exit the utility or choose to have the table overwritten with updated data from the database.

Unique Formation Codes and Formation Names are appended to the **FormationNames** table from the **All_Well_Tops** table. This table is then used to fill the list box on the Edit Screen that is used for filling in Formation Codes in the Formation Tops grid (Updates the All_Well_Tops table). It is important to choose the Formation Codes from the list when adding or updating Formation Picks, so the codes will be consistent within the database.



If a new code needs to be added to the list, it can be manually typed into the Formation Code and Formation Name columns in the Formation Tops grid on the Edit Screen. When the **Get Formation Names** Utility is run again, the **FormationNames** table will be updated with the new Formation Code and the new code will appear in the list box.

Connect LAS Files

This utility reads a directory file list and adds the path for each *.las file to the **LASFiles** table in the project database. The **LASFiles** table holds the permit number and path for a LAS file so the content of the LAS file can be displayed and the Log Curves can be charted using the LogVu progam.

If the table does not exist in the user's database, the table is created with the fields **Permit** and **LASFile** (LAS File path). If the table does exist, the user can exit the utility or choose to have additional LAS files added to the table.

LAS File references are added just like the Document Images (Scout Tickets and Driller Reports). The root directory is stored in the ProjectList.mdb database associated with the Project Information Screen, and the subdirectories and file names are stored in the LASFiles table. It is assumed that the first 5 digits of the LAS File name is the permit number. This permit number and the path of all the LAS Files in the given directory are added to the **LASFiles** table. The **LASFile** Yes/No field is updated to true on the **All_Well_Headers** table for all permits added to the **LASFiles** table which are also in the **All_Well_Headers** table.

Multiple LAS files for each permit can be added. For example, if 12345.las holds 5 log curves, 12345Logs2.las may hold 5 more curves. If the Allow Duplicates check box is checked, two records are added to the LASFiles table:

12345 12345.las
12345 12345Logs2.las