USING RECENT ADVANCES IN 2D SEISMIC TECHNOLOGY AND SURFACE GEOCHEMISTRY TO ECONOMICALLY REDEVELOP A SHALLOW SHELF CARBONATE RESERVOIR: VERNON FIELD, ISABELLA COUNTY, MI.

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ABSTRACT

In this reporting period, we extended the fault study to include more faults and developed new techniques to visualize the faults. We now have used data from the Dundee Formation to document 11 major faults in the Michigan Basin and are in the process of reviewing data from other horizons. These faults appear to control the locations of many of the large anticlinal structures in the Michigan Basin and likely controlled fluid movements as well. The surface geochemistry program is also moving along well with emphasis on measuring samples collected last sampling season. The new laboratory is now functional and has been fully staffed as of December. The annual project review has been set for March 7-9 in Tampa, Florida. Contracts are being prepared for drilling the Bower's prospects in Isabella County, Michigan, this sprig or summer.

- Results – The main results from this period are delineation of nine more major faults in the Central Michigan Basin, extending the total count to eleven.

- How Results will be Used and Why –These additional faults will be used to construct a structural and fluid flow model of the Michigan Basin. Geochemical surveys planned for 2002 will be include traverses across the major branches of the fault system. We will concentrate on developing targets near the faults

- Remarkable Findings/Unexpected Results –The discovery and delineation of the new fault pattern in the Central Michigan Basin continues to be the major new finding in this study.

- Potential Applications –New drilling prospects are being evaluated in relation to their proximity to the major faults. Geochemical surveys are being planned to cross the major faults to test the hypothesis that they are fluid conduits and leak hydrocarbons more readily.

- Did data support project as expected or not? – So far the new fault data supports the project mission of locating bypassed oil in shallow shelf carbonates. The Dundee Formation is an even more attractive target now that basin-scale fault maps are available. The fault locations are being refined as more horizons are processed.

- What remains to be done? – Cross sections need to be constructed using the fault data and lithologic data needs to be acquired and incorporated into the cross-sections.

- Should something else have been done? - If we had known going into this project that re-working the existing formation tops data would yield such a detailed picture of the Central Basin structure, we might have focussed on that earlier in the project.

- What lesson was learned? Several lessons were learned, possibly foremost being that the old drilling records are still a valuable source of data.

- Future plans – We intend to keep pursuing this new direction, refining and filling in the basin model as well as using it to suggest areas that possible targets for surface geochemistry surveys.

DISCLAIMER

LIST OF GRAPHICAL MATERIALS

EXECUTIVE SUMMARY

The major result for this past period was the mapping of new faults in the Central Michigan Basin. These faults were discovered through the use of dense gridding of formation tops data on a basin scale. Contour and surface relief maps were used to delineate the faults. Presently, approximately 12 faults have been mapped. Two major faults identified border deep basin “holes” in the Dundee Formation top surface and appear to control the distribution of some major hydrocarbon deposits in the basin. A number of the larger fields in the Dundee are located in small closures on the upthrown sides of these faults. Work is in progress to further map these faults, including looking at other horizons and constructing cross-sections.

The geochemical sampling program resulted in collection of additional samples at Vernon Field and nearby, bringing the total number of sample collected to over 1500 along 8 traverses. Most of the locations were analyzed using the GMS microbial techniques and will be analyzed for soil iodine and soil gas. As previously reported studies were begun collecting and analyzing hydrocarbon gases (C1 – C8) directly at MTU. We have set up a gas chromatograph and have begun running samples. We are currently running additional analyses for soil gas and sorbed soil gases.

Possible sites for two further demonstration wells are being evaluated, one an extension to the Vernon Field and a second in the Dundee Formation to the Northeast of Vernon. Surface geochemistry is still being run over these sites and the results will be discussed this winter at the annual meeting

Two additional parties, an independent consultant and a small company, have asked us to run geochemical samples for them over several of their prospects. We take this as a positive sign that people are taking a second look at the usefulness of surface geochemistry surveys and we will probably oblige them in the not too distant future. Both prospects are in shallow shelf carbonates. In addition, a student supported on the project has finished collecting data over a pinnacle reef complex in Manistee County, Michigan and has obtained very promising results. It appears that he has succeeded in imaging a reef and plans are moving ahead to drill the prospect.

A 3rd annual meeting for the Class Revisit work group is tentatively scheduled for the week of March 1-7 in Tampa, Fl.

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TECHNICAL REPORT

The main goal of Budget Phase II is to develop and apply a new exploration and development strategy for intercratonic basins using the Michigan Basin as a model. In addition to the Michigan Basin, the Illinois and Williston Basins in North America are cratonic basins that can be expected to have similar features. We also need to identify between 3-5 sites for new demonstration wells

This project enters Budget Phase II with two major accomplishments from Phase I. One is the successful launching of the surface geochemistry program, which collected over 800 samples from the site of the 1st demonstration well in Vernon Field. The second is the recent mapping of the Central Michigan Basin that has resulted in identifying a number of major faults that control the location of many of the reservoirs in the Michigan Basin as well as fluid movements. These faults were located from a combination of structure and surface relief maps obtained by gridding the surface data for major stratigraphic horizons in the Michigan Basin (Figure 1), particularly the Dundee Formation, using top picks from databases previously compiled. Faults were inferred where the contour lines were most dense ("stacked") as well as from the prominent lineations displayed in the surface relief maps.

The first demonstration well for this project was drilled in December 2001 in the Vernon Field. A second demonstration well, the Bowers #1, is tentatively scheduled in Vernon Field for summer of 2002. A permit has been drawn from the State of Michigan and the surface site has been surveyed. Sites for subsequent wells are being studied in Manistee, Osceola and Livingston Counties. Surface geochemical data is being collected from these sites to complement geologic and geophysical studies.

Significant New Results

The most significant new results from this reporting period fall into two categories: geologic and geochemical. The significant geological result was delineation of a number of major faults in the Central Michigan Basin (Figure 2) while the principal geochemical result was the calibration of the Michigan Basin for geochemical signals via microbial data.

While a number of secondary faults undoubtedly remain to be mapped, we feel that the faults mapped are the major faults in the basin. They extend 100 -150 miles in a Northwest – Southeast direction and have a maximum vertical relief of 500 – 600 feet. The general picture is a structural providence of several broad elongate plateaus bounded by steep fault-controlled escarpments that drop abruptly over 500 feet to form deep-basin valley floors. The valley floors are particularly pronounced in two areas where they form two deep basins separated by a single narrow plateau. The steep ridges are consistent with normal faults and known reservoirs lie close to the faults on the upthrown sides. It has long been known that oil fields in the Michigan Basin define persistent linear trends in the Central Basin and undoubtedly many wells were spotted based on extrapolation of these trends.

The new structural picture of the Michigan Basin will be used to prepare a new exploration model for the basin based on a strategy of conducting surface geochemistry surveys over areas that appear to be gaps in the current exploration coverage. The new model provides detailed exploration-scale prospect maps in which existing fields can be used as analogs for unexplored areas.

The results of geochemical work to date have been to give a better picture of threshold values that can be used to infer the presence or absence of hydrocarbons. Trost (1993, A Limited Data set Comparison of Headspace Soil Gas and the "MOST" Biogeochemical

Technique to Evaluate Drill Site Potential, Bulletin of Association Petroleum Geochemical Explorationists, 9(1), Gary Price (ED), p. 63-80) suggests that the values provided by GMS from their microbial data can be generally classified as:

MICROBIAL VALUE	RANKING	N SAMPLES	PERCENT
0-30	POOR	402	36
30-60	MARGINAL	455	42
60-90	GOOD	199	18
>90	EXCELLENT	46	4

The data we have acquired using microbial technology (MOST) are shown in the two right hand columns above. The sample locations are plotted in Figure 3. Of the nearly 1100 geochemical samples collected, about 22% (245) rank as “Good” or better. (Values for all 1100 samples ranged from 1 to 157.) Using these criteria, our first demonstration well, the Smock 1-23, had microbial values that lay in the ranges “Marginal” to “Good”, while the second demonstration well has microbial values that are mainly marginal. The rational for drilling these projects was to “ground truth” the geochemical data, regardless of whether the geochemistry was good or poor. However, we have turned up a prospect (Mable Lake) based solely on geochemical data that ranks “Good” to “Excellent”. The difficulty here is that the geology does not appear to be as good. We are in the process of evaluating this prospect further.

One of the more obvious potential applications of the new structural data is to develop an exploration strategy for the Central Michigan Basin based on a better knowledge of fault locations and patterns, which in turn is what controls the locations of fields and large-scale fluid movements. We can now see that many fields lie close to the major faults, primarily on the upthrown side. There are a number of areas along the faults where the well control is poor and the contours don’t have the same character, that is they are too regular compared to nearby areas that have been more control. These would be likely areas to run geochem profiles.

These new data/findings support the project since they could lead to new ways to look for hydrocarbons in intercratonic basins. In that light, we are considering expanding the demonstration to the Williston Basin, which is also an intercratonic basin and where our industry partner has operations in shallow-shelf carbonates.

Key Lessons

If we had known going into this project that re-working the existing formation tops data would yield such a detailed picture of the Central Basin structure, we might have focussed on that earlier in the project. However, what made the difference was finally looking at the data on the right scale (i.e. looking at detailed structure contour maps over several counties instead of single fields). It also helped to get the contour intervals set just right, too few and the structure does not show up, too many and the structure is obliterated. In this case it was basically persistence in re-working the data trying different approaches that finally paid off. It also helped immensely that software development had progressed to the point that we were able to redo maps many times, changing and adjusting parameters, which resulted in the discovery.

Several lessons were learned, possibly foremost being that the old drilling records are still a valuable source of data. It does pay to keep looking at the data as new conceptual models and new technologies become available. We feel that we are essentially now just at the beginning of revising the structure and exploration model for the Michigan Basin, and by analogy, perhaps for analogous basins as well. Combined with the progress we have made

learning about and using surface geochemistry, we are optimistic that we will emerge with a new paradigm for interior basin exploration.

Future Work

A number of tasks remain to be done. The most immediate include constructing accurate structural cross-sections that include key horizons, relating the structural data to the gravity data and constructing a model that relates the sedimentary structures to the paleo-rift environment. An example is shown in Figure 4.

We intend to keep pursuing this new direction, refining and filling in the basin model as well as using it to suggest areas that should be targets for surface geochemical surveys and eventually drilling prospects. In that vein, we have several opportunities to run geochemical surveys in the basin with companies that were not part of the original proposal, but who are now sufficiently interested as a result of some the Eastern AAPG presentations our group made in Kalamazoo last September. Some of these sites that have been sampled are shown in Figure 3.

We also need to keep looking for and evaluating new sites for demonstration wells. We have a second demonstration well, the Bowers in Vernon Field extension, sited and permitted and plan to drill spring or summer of 2002. We have leads on 3 more possible sites, one in Coldwater Field in Isabella County, one in Osceola County (the Orient prospect) and a third also in Isabella County, the Mable Lake prospect. The Mable Lake prospect is a result of geochemical profiling; the largest anomalies were found here, as well as the largest number of consistently high anomalies. These results will be reported on more fully in future reports as the prospect matures. We are also working good anomalies near Bear Lake in Manistee County that would likely be a pinnacle reef play.

Example: Vernon Field Fault

One of the basin-scale faults we identified happens to run close to the Vernon-Rosebush Fields (Figure 5b). We have tentatively termed this the “Vernon Fault” since Vernon Field lies just above it on the upthrown side. Figures 5a and 5b show the different interpretations of the formation tops data for the Dundee Formation assuming no fault (5a) and a fault present (5b). There are several noteworthy features. One is that the structural contours over both Vernon and Rosebush fields hardly change at all from 5a to 5b; apparently the structures are so tightly constrained that the presence of a large fault less than a mile away has little effect. However the structural picture close to the fault is changed significantly.

A second observation concerns the presence of a large anticlinal structure just south of Vernon-Rosebush that is apparently cut by the main fault. This situation seems unlikely and means that the main Vernon Fault cannot be the only structural element present. Other possibilities include the presence of secondary faults that border the southern anticline or perhaps structures related to salt tectonics, since the Salina Formation is known to be present in the area. The structural picture north of the anticline seems reasonable but the relationship between the fault and the southern anticline needs further work.

REPORT BY TASK

Task 1 Project Management – J. Wood

Task Description - Coordinate all aspects of the project between Michigan Technological University (MTU) at Houghton, Michigan, Western Michigan University in Kalamazoo, MI and Cronus Exploration Company LLC in Traverse City, MI. Produce a working document that will outline the project in detail as well as set a schedule of visits and meetings. Coordinate all necessary meetings and will serve as the central repository for all project deliverables and reports.

Subtask 1.1 Technical Aspects - J. Wood

Policy – Preparation and Enforcement
The principal subtasks performed were the preparation of this document, including the master outline and coordinating a geochemical sampling party. Separate subcontracts were negotiated and submitted to Western Michigan University and Cronus Exploration Company LLC by Michigan Technological University.

TRAVEL, STUDENTS AND EXPENDITURES

To date eight sampling trips have been made to downstate Michigan to Vernon Field and vicinity. Several trips have also been made to potential project sites. Expenses were paid for Wood and Bornhorst to present papers on the project at the Eastern AAPG meeting this past September.

The project presently supports 1 Masters student, Mr. Chris Seaman. Deyi Xie graduated with a Ph.D. this past summer. He was partially supported on this project.

Subtask 1.2 Financial Reports and Accounting - A. Hein

Financial documents
All monthly, quarterly and annual statements and documents have been submitted, including the project Management Plan

C. Asiala has organized a system for keeping copies of all expenditures, bills, invoices and related financial documents that concern this project. The university is keeping track of personnel time and pay for all parties. So far only Michigan Tech is drawing personnel salaries from this project.

Subtask 1.3 Archives - C. Asiala

Archival of Materials and reports
Electronic copies of geochemical data have been received from vendors and archived in project databases. These databases have been backed up. Printed versions will be included in reports, including this one.

The Atlas program has been altered to plot the GeoChem Sample locations in bubble plots according to the type of chemical concentration chosen by the user. The GeoChem data can be plotted simultaneously with the well locations or it can be plotted separately. The

GeoChem data can also be edited from within the Atlas program. The GeoChem data is stored in 2 tables separate from the well data tables. The first table holds the Permit (unique number assigned to the sample) and its latitude/longitude coordinates. The second table holds the Permit, type of concentration, and concentration value. This allows multiple GeoChem concentration values for each sample.

The Subsurface Visualization Lab Web Site (**http://www.geo.mtu.edu/svl**) has been updated with reports and figures that pertain to the project. Ongoing updates will be added throughout the project.

Processing of DEM and SDTS files

In addition to the work in the first Budget Period on Digital Elevation models (DEMs), work has expanded this Budget Period to include gravity data from NOAA on the Central Michigan Basin. This data will be integrated with the rest of the project data and used to help interpret the structural model for the Michigan Basin.

Task 2 Reservoir Characterization – W. Harrison

Task Description - Collect, analyze and integrate geologic and engineering data on the Vernon reservoir, particularly structural and stratigraphic data and engineering properties. Determine the reservoir architecture as well as possible prior to drilling the test well. Acquire and interpret 2D seismic line(s). Design, execute and interpret surface geochemical survey(s). Make economic projections and help site wells for development.

Subtask 2.1 Surface Geochemistry – T. Bornhorst

Work on this task will continue in Budget Period II. To date over 1500 samples have been collected from 1090 locations.

Subtask 2.2 Reservoir Geology – S. Chittick

Subsurface data

We have continued to update and edit subsurface data in our master database files. Presently most of our efforts are going into correcting bad entries and removing duplicate records.

Subtask 2.3 Engineering Parameters- W. Harrison

No activity this period. Work will take up when drilling targets have been selected for the Phase II demonstration wells.

Subtask 2.4 2D Seismic- W. Quinlan

Acquisition of new seismic data has been deleted from the project task list; instead we will acquire and process existing data.

Task 3 Analysis of Producibility Problem(s) – W. Quinlan

Subtask 3.1 Drilling – E. Taylor

No activity this period.

Subtask 3.2 Well Logging – S. Chittick

No activity this period.

Task 4 Technology Transfer – W. Harrison

Task Description - Transfer of the technology is recognized as a crucial element in this project. Special efforts will be made to deliver the results in a useable form to our target audience through:

- Meetings and personal contacts.
- Workshops and training courses on use of the data and software
- Electronic distribution of results and data on Internet
- Establishing computer links between Michigan Tech and selected companies

As a result of presentations made on the project results at the Eastern AAPG meeting in Kalamazoo last September, several individuals have expressed interest in ATLAS and we are in the process of transferring the program to them.

Subtask 4.1 PTTC Workshops – W. Harrison

Workshops

A mini-workshop was held in Kalamazoo at the EAAPG meeting in September. J. Wood presented recent developments in the ATLAS program. There were about 30 attendees.

Case histories

None

Tutorials.

None

Subtask 4.2 Reports – J. Wood

Publications
Publish project results in DOE reports and in scholarly journals.

Presentations

Wood, J. R., 2001 – September EAAPG in Kalamazoo, MI. Presentation of project to date, including last demonstration well and surface geochemistry results.

Wood, J. R., 2001 – September EAAPG in Kalamazoo, MI. Presentation ATLAS software.

Bornhorst, T. J.., 2001 – September EAAPG in Kalamazoo, MI. Presentation of project to date, including surface geochemistry results.

Barnes, D., 2001 – September EAAPG in Kalamazoo, MI. Presentation of structural data and interpretation for Vernon Field.

Wood, J. R., 2000 – June SPE Meeting in Long Beach, CA. Presentation of project to date, including surface geochemistry results

Harrison, W. B., 2000 – June DOE Contractors Meeting in Long Beach, CA. Presentation of project to date, including surface geochemistry results

Present results at local and national meeting of geological societies, such as the AAPG.

Subtask 4.3

WEB Site

Publish project results, updates and news in hardcopy and electronic newsletters published by The Subsurface Visualization Lab at Michigan Tech. Place relevant results on Internet in timely fashion.

FIGURES

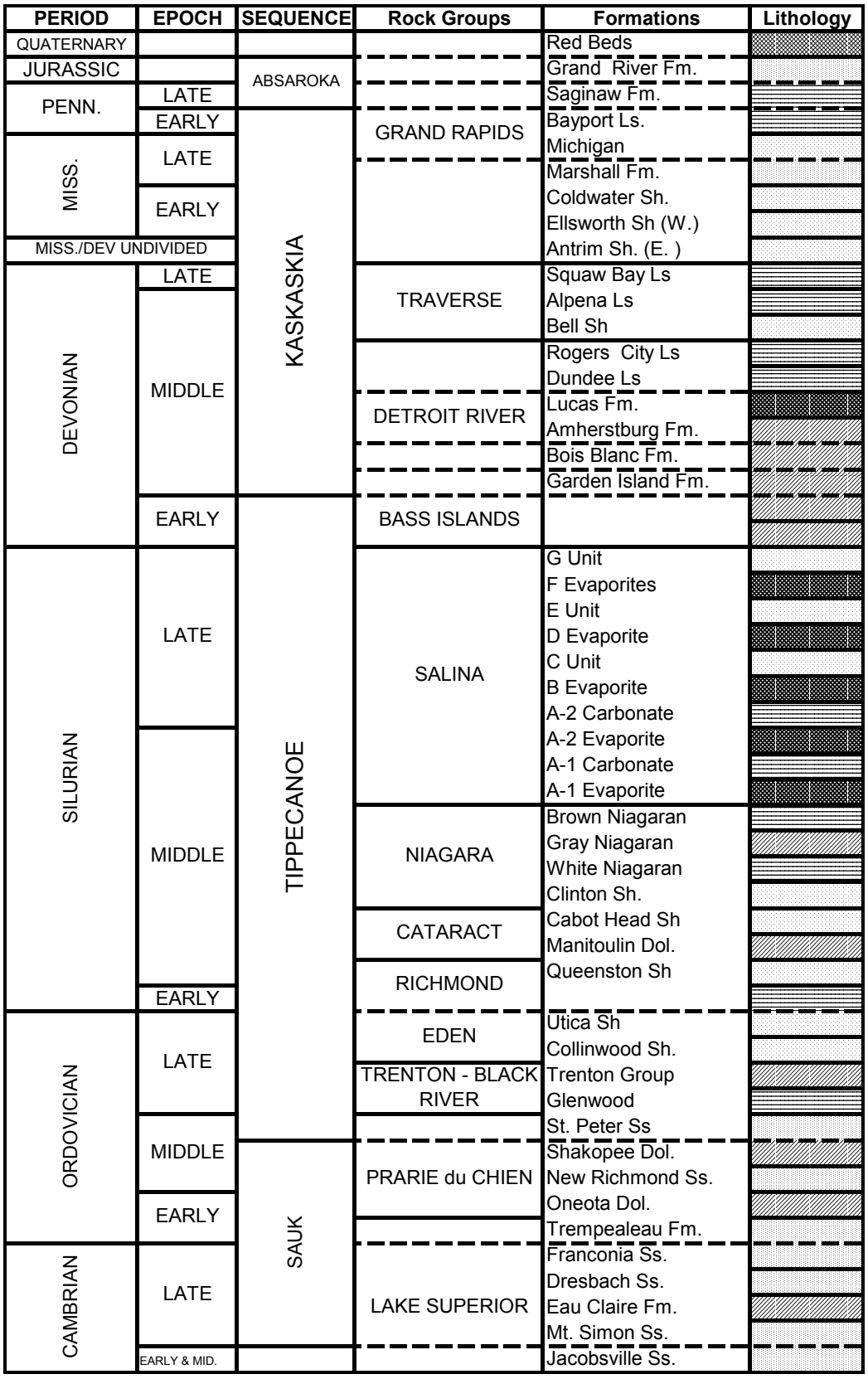

Figure 1. Generalized stratigraphic column for Michigan Basin.

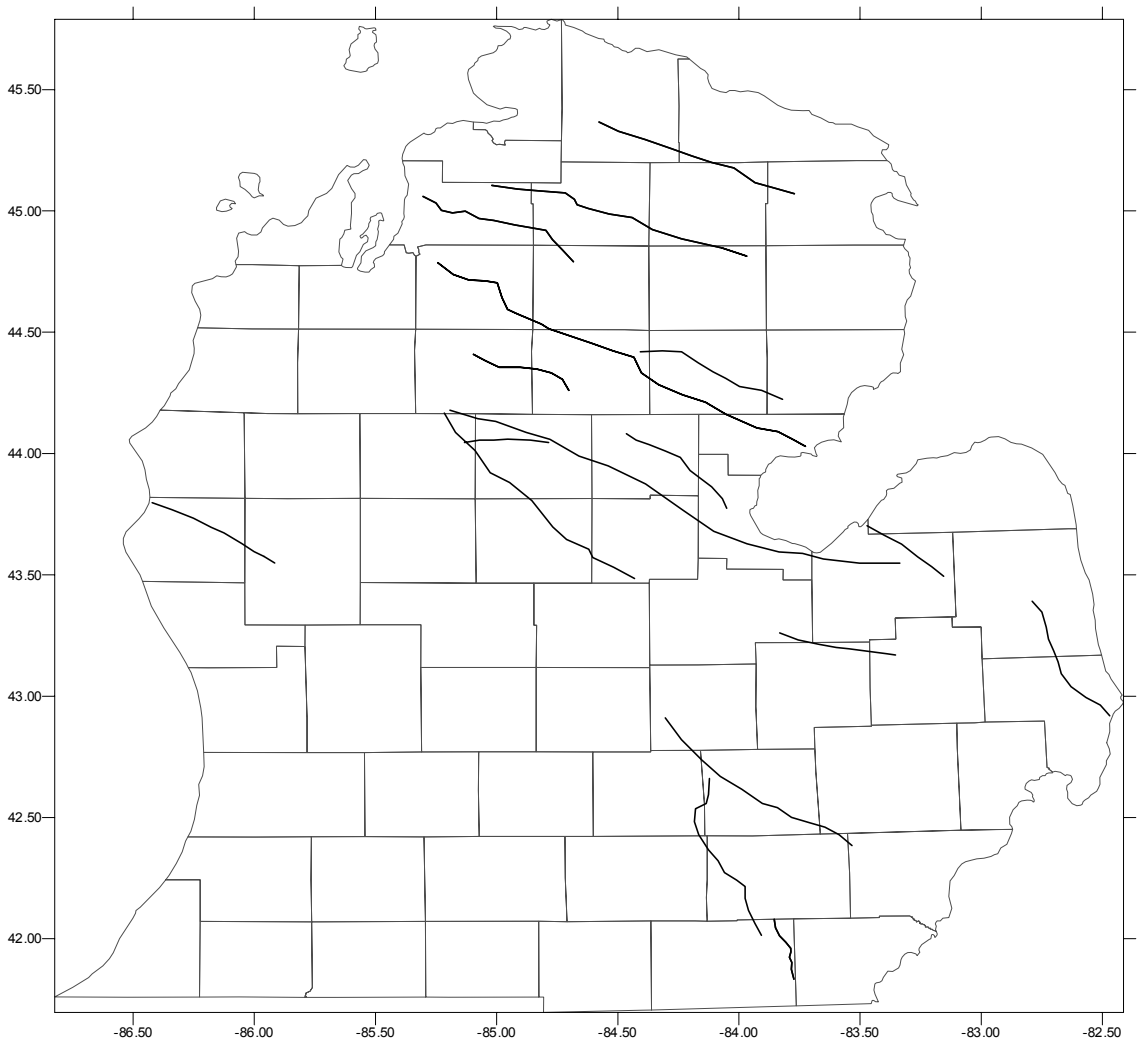

Figure 2. Index map showing major faults in the Central Michigan Basin.

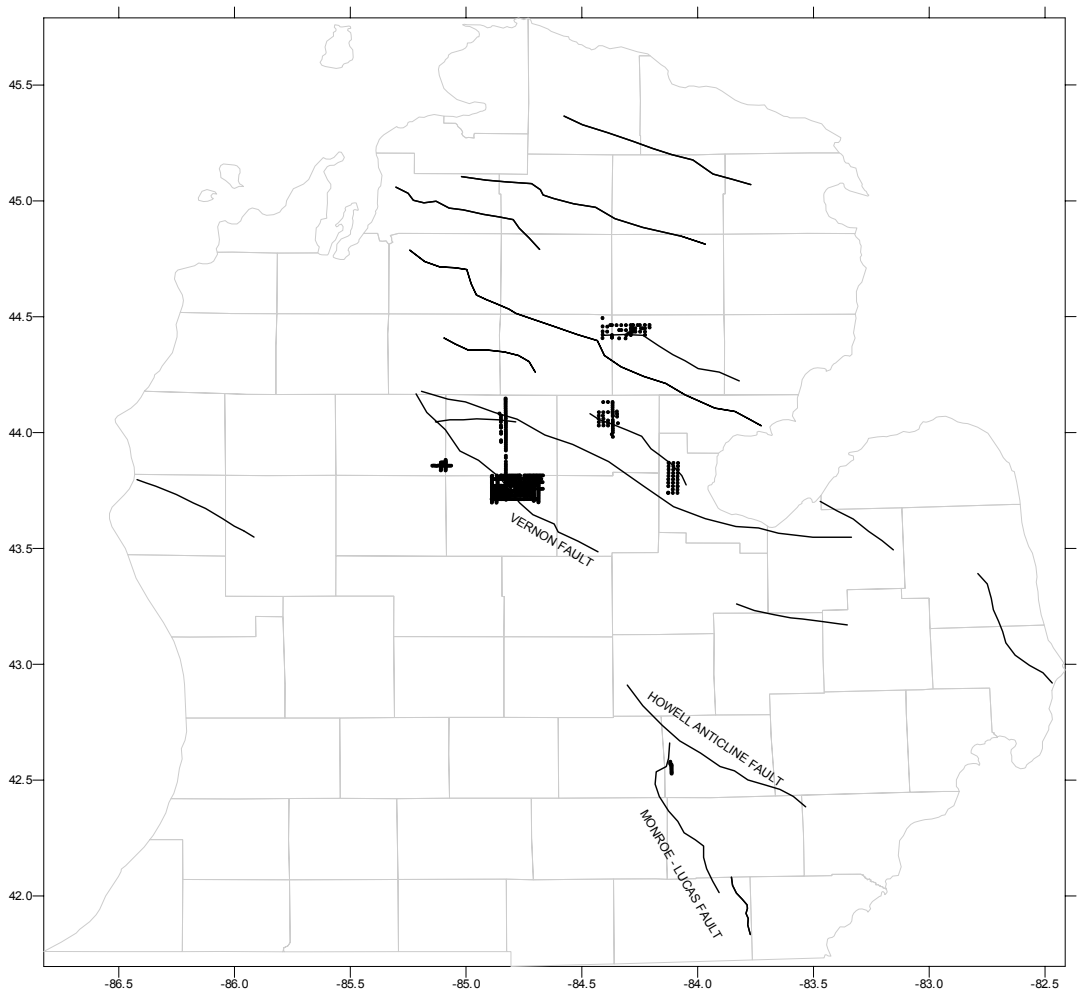

Figure 3. Location Map of Microbial Samples.

East-West Lithologic Cross Section

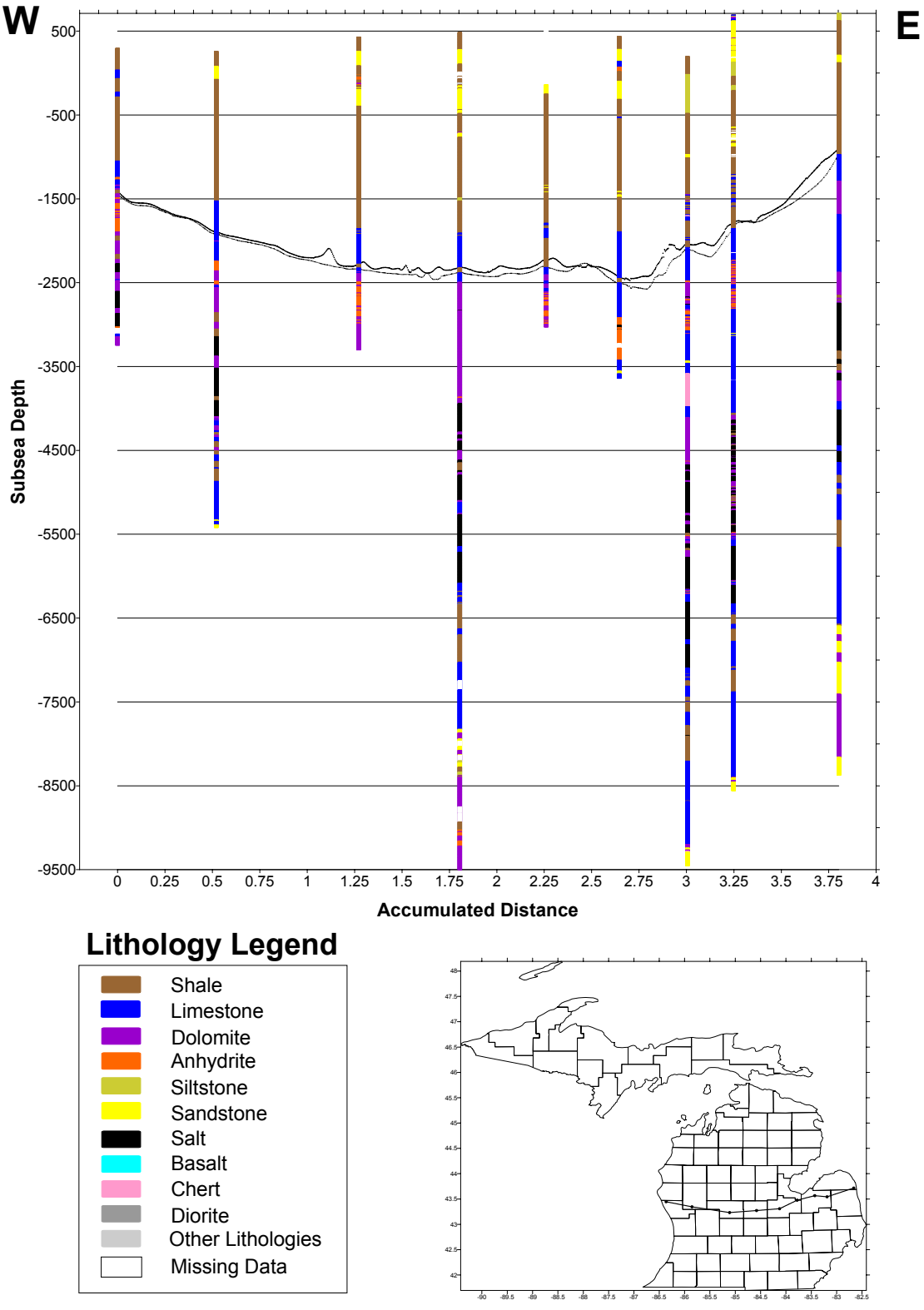

Figure 4. East-West Lithology Cross Section, showing the Bell Shale (top curve) and Dundee (bottom curve) Formations.

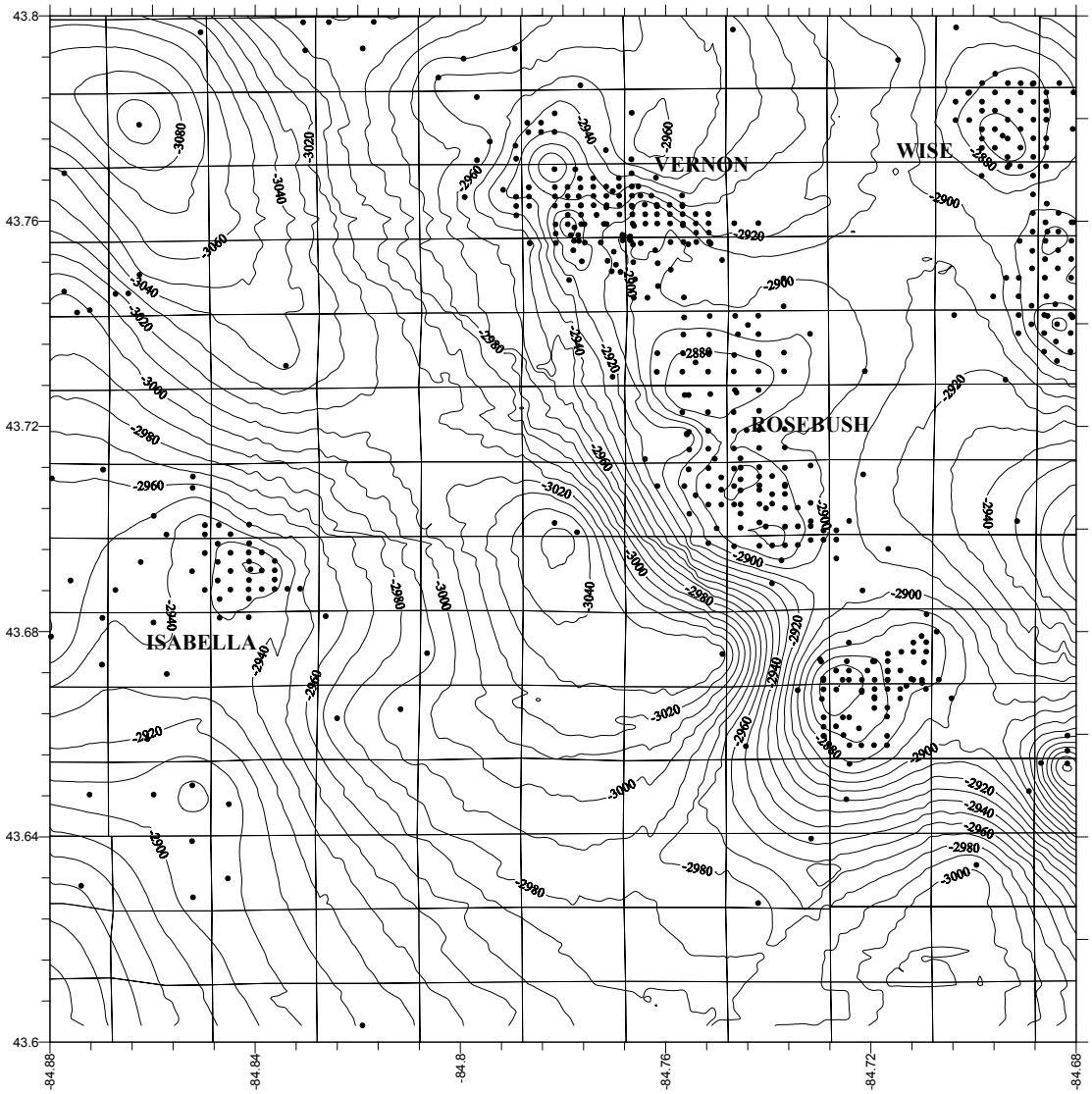

Figure 5a. Contour Map on top of Dundee Formation for Vernon-Rosebush Fields. No faults.

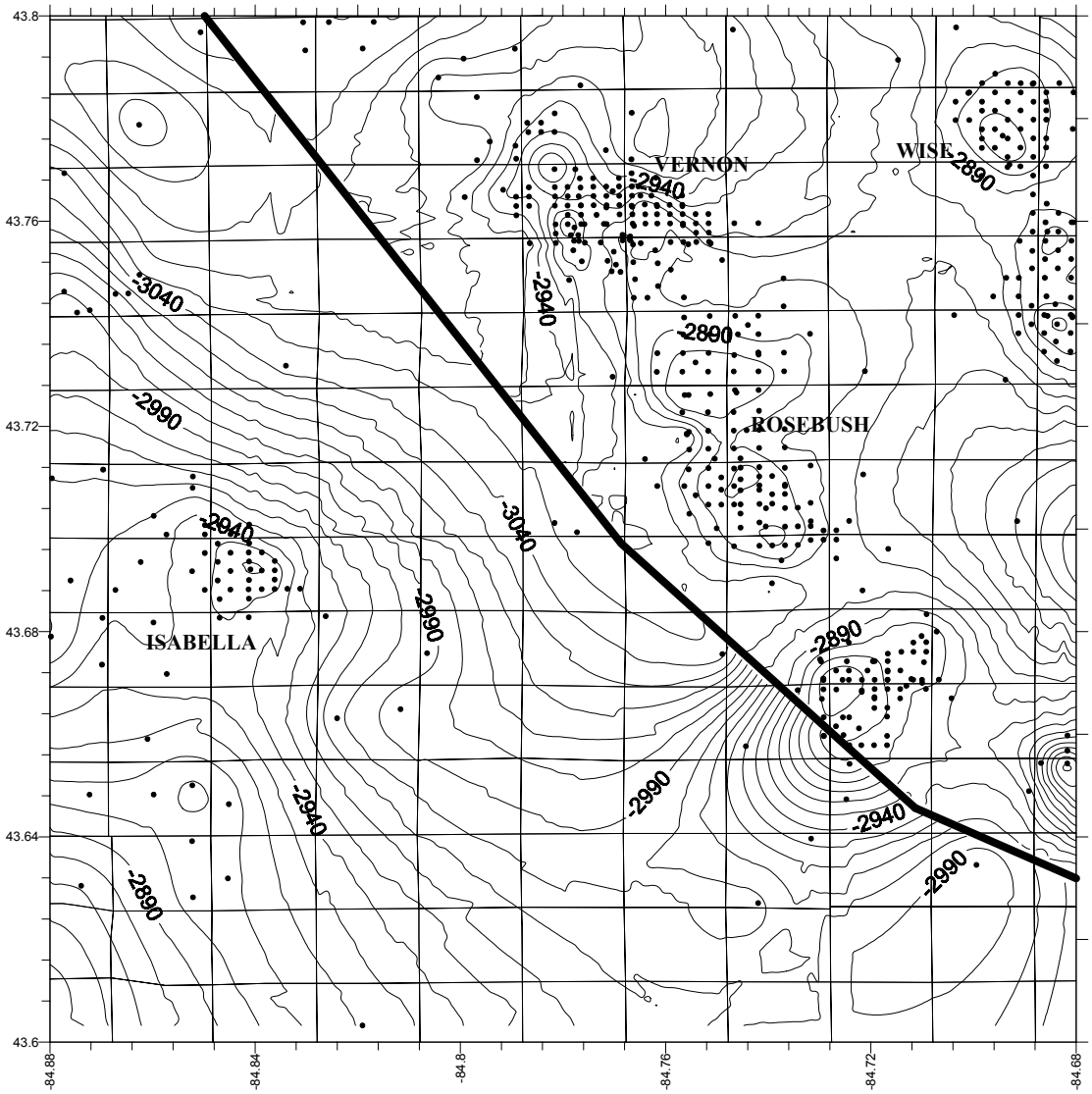

Figure 5b. Contour Map on top of Dundee Formation for Vernon-Rosebush Fields with fault.