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

TYPE OF REPORT: FINAL

REPORTING PERIOD START DATE: MARCH 21, 2000

REPORTING PERIOD END DATE: SEPTEMBER 20, 2005

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DATE REPORT WAS ISSUED: JANUARY, 2006

DOE AWARD NUMBER: DE-FC26-00BC15122

NAME AND ADDRESS OF SUBMITTING ORGANIZATION:

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ABSTRACT

In this project two major field demonstrations were carried out in conformity with the goals of the Class Revisit Program. The first demonstration was at Vernon Field in Isabella County Michigan, and the second was the Springdale demonstration in Manistee County, MI (Figure 1). The Vernon Field project targeted the Devonian Dundee Formation, a prolific producer in Michigan while the Springdale project targeted the “Brown Niagaran” an informal stratigraphic unit in the Lower Silurian (Figure 2). The first well at Vernon Field, the State Vernon & Smock #13-23 (Permit: 53945), was spudded on October 12, 2000 but was not economically successful, even though an extensive geochemical program was carried out. A second well, the Bowers 4-25 HD (Permit: 54950), was drilled to test the geochemical anomaly, but was also plugged and abandoned on December 3, 2002. No further wells were drilled at Vernon Field.

The Springdale demonstration was much more successful, current production exceeds 257,000 BBLS/oil and 1,600,000 MCF gas, and demonstrated what appears to be the pattern for the future in Michigan and by extension to other mature gas and oil provinces. Specifically, Springdale is going to be a million barrel field, counting both oil and gas equivalent, and is probably one of many such fields in the Michigan Basin that will be discovered and exploited in the future. The key technologies employed at Springdale were 2D seismic and horizontal drilling. The horizontal drilling essentially probed the formation for porosity and hydrocarbons, was then used for production, and is scheduled for follow-up flooding duty. This type of play is typical of many of the recent plays in Michigan in that they are conceived, planned and conducted by a relatively small company and consultants. A rough rule of thumb is that probably no more that 6-12 professionals, including landmen and management, were/are involved in these plays and the key is very low overhead, with much of the risk spread over 5-10 investors. The DOE investment (approximately $2 million) has been timely and significant; both Vernon and Springdale relied on DOE funding in the early, critical stages. We estimate a total (gross) yield of $40 – 60 million, based on a total Springdale production of 1 million barrels of oil and oil equivalents, with over $5 million paid back to State in royalties and lease fees.

Vernon Field was instructive too, since it demonstrated the utility of surface geochemistry and provides a type case for exploitation of mature fields. The initial geochemical surveys were consistent with the later, very comprehensive survey (>1200 samples) and consistently indicated that Vernon was not a prime target. In retrospect, we should have conducted a comprehensive survey at the beginning, or at least established a regional baseline in order to better access our results. The lesson learned is two-fold: don’t skimp on the geochemical surveys upfront and walk away if they are not optimistic. Perhaps, that should be very optimistic. The difficulty is that an industry used to making decisions based primarily on seismic data and interpretation is reluctant to invest in another technology, particularly one that is unproven in their eyes. Nevertheless we see a bright future for surface geochemistry in the exploitation of mature basins provided that two things develop: one is better technology, perhaps based on “sniffer” approaches which permit real-time data collection and assessment, and, two, lower costs per sample. These are not unrelated; field-based data collection and interpretation will eliminate lab costs, which can be 50-70% of total survey costs. In this respect, the geochemical industry seems to be working at cross-purposes: lab costs increased on the order of 50-100% over the 5-year time span of this project.

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(a) 55797: State Springdale & Herban 12-16 HD1
(b) 55782: State Springdale & O'Driscoll 16-16 HD1
(c) 56362: Kovach 15-16 HD
(d) 56146: State Springdale & Wilburn 1-21 HD
(e) 56530: State Springdale & Stedronsky 10-15 HD
(f) 56163: State Springdale & Stedronsky 14-15 HD

(g) 56365: State Springdale 13-14 HD
(h) 56543: State Springdale & Trezil 9-15 HD
(i) 56337: State Springdale 7-21 HD
(j) 56830: State Springdale & CSX 2-22 HD
(k) 56887: State Springdale & Mann 9-21 HD
(l) 56361: State Springdale & Messner 6-16 HD
(m) 56897: State Springdale & Gaddy 16-17 HD
(n) 56931: State Springdale & Gentz 7-22 HD

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(a) 55797: State Springdale & Herban 12-16 HD1
(b) 55782: State Springdale & O'Driscoll 16-16 HD1
(c) 56362: Kovach 15-16 HD
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1.0 EXECUTIVE SUMMARY

Lessons Learned

In bullet form the lessons learned for this project are:

- Obtain a geochemical survey before attempting further HC recovery from fields that have passed their peak in primary production. Vernon Field could have been written off if such a survey had been conducted.

- Horizontal wells are much more effective than vertical wells in probing for and producing diagenetic/stratigraphic traps; they should be routinely considered.

- If horizontal drilling is contemplated, economies in geochemical surveys can be achieved if sampling is restricted to following the well bore rather than sampling on a grid. Fewer samples, more closely spaced in the region of interest, are likely to be more effective than a coarser grid pattern and will cost much less.

- Emphasis should be placed on development of a sensitive, portable geochemical probe that will permit comprehensive surveys to be conducted in the field without the need to collect and dispatch samples.

- Numerous small fields on the order of Springdale (e.g. 250,000 -1,000,000 bbls oil/gas) can be expected to be recovered in the Michigan basin in coming decades. These will be discovered by small companies and consultants with intimate knowledge of the basin and low operating overhead. As a consequence oil production in the Michigan basin will have a long "tail" and may stabilize at about 1-10 million barrels/year before the last rig is shut down.

Goals and Results

The principal goal of this project was to try to find a means of extending the economic life of a mature basin. The Michigan Basin has been produced since the 1920's and has been in a state of decline relative to its peak production years (1975-85) for about 20 years. This trend will not be reversed, but there is reason for optimism that the basin production will flatten out at a more or less steady state (a long production tail) that is a combination of long-term production from stripper wells and new discoveries. The main result of this project has been to demonstrate that the future of the Michigan Basin, and by extension, the future of other intracratonic basins once they have reached production maturity, probably lies in small fields on the order of 1 million barrels of oil in unconventional settings. In this case, we found economic quantities of gas and oil by looking in the basal carbonates surrounding the very productive pinnacle reefs.

This study has also demonstrated the importance of the horizontal well as an exploration tool, probing tight rock for pockets of porosity, and the importance of persistence. At Springdale, the tight limestone constituted over 80% of the total well length in several cases, yet the 20% that was porous (dolomitized) yielded economic quantities of hydrocarbons. The lesson would appear to be to keep drilling out the program, even if the initial results are not encouraging.

Applications

The Springdale demonstration is a textbook example of how to conduct an exploration program in thin-bedded carbonates using horizontal wells as both probes and producers. Springdale required that the bit be kept in a 10-20 foot zone of interest and used MWD (Measurement While Drilling) to keep the well above a slightly radioactive zone that marked the bottom of the Brown Niagaran (the zone of interest) and the top of the Gray Niagaran.

Did Data Support Project or Not?

The geochemical data did support the project goals nicely, particularly in the Vernon demonstration. The geochemical work essentially said that the Vernon Field was depleted, with only weak positive anomalies in a well-developed halo anomaly. The geochemical data at Springdale is more difficult to assess since it was still being collected right up to the end of the project. It is clear that good soil gas anomalies were recovered, but work is still in progress to relate them to the field and to the C1- C4 mud log data.

Future Work

We generally conclude that the geochemical work done in this project was useful and that all the methods employed were successful in detecting leaking hydrocarbons. However the full potential of the technology is not being realized in the Michigan Basin, probably due to lack of a “killer” application that unequivocally demonstrates that hydrocarbons can be found in commercial quantities using surface geochemistry. Part of this is due to the dominance of seismic technology and the rather skeptical attitude that many geophysicists have toward geochemistry. However the largest drawback is the cost, make that the increasing cost, of conducting a geochemical survey. At roughly $50/sample (collection and analysis), a 1000 sample grid would cost $50,000 and is a factor of 10 too large for the small companies that are now dominant in mature basins, such as the Michigan Basin.

2.0 INTRODUCTION

In this project two major field demonstrations were carried out in conformity with the goals of the Class Revisit Program. The first demonstration was at Vernon Field in Isabella County, Michigan, and the second was in Manistee County, MI (Figure 1). The Vernon Field project targeted the Devonian Dundee Formation, a prolific producer in Michigan while the Springdale project targeted the “Brown Niagaran” an informal stratigraphic unit in the Lower Silurian (Figure 2). The first well at Vernon Field, the State Vernon & Smock #13-23 (Permit: 53945), was spudded on October 12, 2000 but was not economically successful, even though an extensive geochemical program was carried out. A second well, the Bowers 4-25 HD (Permit: 54950), was drilled to test the geochemical anomaly, but was also plugged and abandoned on December 3, 2002. No further wells were drilled at Vernon Field. Springdale was much more successful, current production exceeds 257,000 BBLS/oil and 1,600,000 MCF gas, and demonstrated what appears to be the pattern for the future in Michigan and by extension to other extensively drilled and developed gas and oil provinces.

In the following discussion, we will first cover the Springdale play, both since it was economically successful and hence of more interest to the gas and oil community and also because it was an unconventional play that demonstrated some new principles and concepts. Vernon Field will then be summarized and the principle lessons expounded, but the details of that project have already been exhaustively discussed in previous reports (Quarterly Technical Report September 2002 – December 2002, DOE OSTI Bridge Identifier – 824802 [Appendix A] and Annual Technical Report April 2003 – March 2004, DOE OSTI Bridge Identifier - 827044).

3.0 SPRINGDALE

Springdale play is located in Springdale Township, sections 14-16 and 21-23 (Figure 3) and targets mainly the “Brown Niagaran” (Figure 4). The play was originally based on a seismic anomaly that roughly encircled the early play boundaries and appeared as a “disrupted” zone in the Brown Niagaran. Subsequent work and field development suggests that the original seismic anomaly was simply coincidental and served to focus attention on the area and helped sell the original wells. It is now established that the play is confined to the so-called Brown Niagaran, a fairly narrow zone, 10-20 feet total thickness, lying just below the A1 Evaporite/Salt. The play was exploited by a series of horizontal wells, 14 wells at present, which served both as exploratory probes looking for favorable reservoir rock and to produce hydrocarbons if reservoirs could be located. The favorable rock is generally dolomitized carbonate sandwiched laterally between impermeable tight limestones (Figures 5 & 6). The origin of the dolomite is at present unknown in spite of strenuous attempts to determine its mode of origin and timing. This is largely due to the poor quality of samples and cuttings returned from the horizontal wells. The weight of the pipe in the horizontal bore as well as the fact that it is rotating means that only rock flour is recovered, from which field acid tests can determine if it is limestone or dolomite, but that is about all. No petrographic analysis is possible.

3.1 Characteristics of the "Brown" Niagaran

The nature of the "Brown Niagaran" deserves some comment as it is the key horizon in this play. It is, as mentioned, an informal term used mainly in the subsurface by the gas and oil industry. It lies above the "Gray Niagaran" (Figure 4) which lies above the "White Niagaran". All three are informal terms and are largely differentiated in the subsurface by GR (gamma ray) log character and in surface sample by color, (Brown for Brown Niagaran, etc.). All three units make up the upper Niagaran which with the basal Clinton Shale constitutes the Niagaran Formation, a formal stratigraphic unit. The top of the Brown (Brown, Gray and White will be used from here on to refer to the Brown Niagaran, etc.) is easily picked as the first carbonate below the A1 Salt/Evaporite, where the A1 Salt exists, and with difficulty from the GR where the A1 Salt does not exist. The base of the Brown and top of the Gray is picked as the first GR excursion, which is usually a doublet (Figure 7), and is reported to be a thin bentonite bed. Thus the Brown is fairly easily picked when the A1 is present and when the GR excursion is pronounced, which fortunately includes the Springdale area. One further observation: the bentonite layer, top of the Gray, is used to steer the drill and the driller will occasionally "tag" the top of the Gray to insure the bit is in the Brown. This technique appears to work well in the Springdale area (see Figure 8).

With these considerations in mind, the original Springdale play was developed by a series of 14 horizontal wells that covered most of the acreage with a reasonable density of well bore, with one horizontal well doing the work of 2-3 vertical wells (Figure 3). The downdip limit to the exploration was the oil-water (O/W) contact, roughly coincident with the -4315 contour on the Brown (Figure 9).

3.2 Geology

The geology of the Springdale Brown Niagaran Play can be sketched in simple terms, starting with the A1 Evaporite/Salt which appears to be the seal, or partial seal, for the play (a lateral facies change from porous, reservoir dolomite to impermeable limestone is thought to be a lateral seal, but this is not certain). The A1 Salt is present over most of the Michigan Basin (Figure 10), where it reaches a maximum thickness over 440 feet in the basin center and thins to a feather-edge on the margins (?) (although it is often absent apparently due to dissolution on the edges). In the Springdale area the A1 Salt is everywhere present with an average thickness of 41 feet. The A1 Salt is mainly halite in the basin center but contains progressively more anhydrite as the basin margins are approached. Figure 11 shows the structural attitude of the A1 Salt in the Springdale area while Figure 12 shows the thickness isopach of the A1 Salt in the same area.

With the A1 Salt boundaries established, the top of the Brown is also established and the base of the Brown (top of the Gray) can be established by examination of GR logs. Where the GR doublet (Figure 7) is well developed the top of the Gray can be picked with confidence. Approximately 32 wells in the Springdale area penetrate the Gray top and the MTU database records tops information for most of these. Unfortunately spot checks on a couple of wells revealed gross errors and inconsistencies in the Niagaran top picks in general and so a program of detailed tops verification had to be initiated. This required obtaining paper copies of the logs and digitizing to LAS files and replotting in STRATER © (Golden Software). In addition to the GR curve, the bulk density (RHOB) curves were also digitized along with all other available curves with the exception the resistivity curves. The RHOB curve in particular is useful in identifying the rather complex and confusing stratigraphy of the Silurian Evaporites. NPHI (Neutron Porosity) is also useful, but a practiced eye can do pretty well with just the GR curve. With both GR and RHOB the Silurian section in the Michigan Basin can be pretty well deciphered, as shown in Figure 13, for example.

An isopach map for the Brown in the vicinity of Springdale is presented in Figure 14. This map is based on selected top picks from 32 Niagaran wells that penetrate to the Gray in the Springdale area. Note that some top picks come from the horizontal wells when the bit “tagged” the top of the Gray for steering purposes. This map shows that the Brown can be traced in all directions from Springdale, particularly to the West and Northwest where virtually virgin conditions remain as far as exploration is concerned. It would seem that further Springdale-type exploration in these areas could well be productive, with perhaps 5-10 more Springdales possible in that area alone. In that sense, this demonstration project has succeeded beyond simply producing an economic quantity of hydrocarbons: it shows the way to future development of a much larger area.

3.3 Production

Production from this play has been both gas and oil, with 257,932 BBLS of oil and 1,609,532 MCF of gas as of 10/1/2005 (MI DEQ, 2005). Projected total production is difficult to estimate since more development wells may be drilled in the future, but a minimum of 350,000 bbls of oil from primary recovery and an additional 350,000 bbls on waterflood would appear attainable. These are estimated from data provided to the State of Michigan by Jordan Exploration and pertain only to the presently developed area. Future work could target similar plays in the vicinity of Springdale and elsewhere as the Brown target should be present nearly everywhere in the Michigan Basin (see “Conclusions” below).

Individual wells in Springdale have rather unique production characteristics: they seem to peak almost immediately (Figure 15) and quickly decline or they come on stream at a certain value and they fluctuate slightly around that value for the life of the well. Figure 16 shows monthly and cumulative oil production at Springdale. This behavior doubtless reflects the reservoir characteristics, which is currently thought to be a porous dolomite bounded by tight limestone and possibly above by salt/anhydrite.

Gas production profiles are in Figure 17. Figure 18 shows the monthly and cumulative gas production at Springdale. Their distribution suggests that a regional gas cap exists at Springdale (Figure 19). The O/W contact and the G/O (Gas/Oil) contacts depicted in Figure 9 suggest that the field is similar to a conventional stratified reservoir with an oil leg separating an updip gas column and a downdip water column. This configuration suggests that Springdale can be put on secondary recovery by waterflood by injecting into the water leg using existing wells, including the horizontal wells. It is estimated that this should approximately double primary production.

3.4 Future Work

This demonstration project has ended with the development of the Springdale Field to the point that it is a verified economic success but with much left to be done. Some basic features of the geology still need to be worked out; for example the nature and timing of the dolomitization and the type of structure involved, if any. The timing and source of the Springdale hydrocarbons needs to be determined. It seems likely that they result from the same filling processes that charged the pinnacle reefs, so that the relation of Springdale to the Reef Trends needs to be evaluated.

Also, production from Springdale will proceed to secondary recovery from waterflood as soon as primary production shows signs of dropping off. In fact, the later horizontal wells were placed with this in mind. The efficacy of this project design needs to be evaluated from a total production point-of-view as well as the economics of designing a field development around a series of horizontal wells from inception.

Perhaps the most pertinent future work is the extension of the Springdale play concept to new areas and frontiers. It is very likely that the area adjacent to Springdale will be explored in the near future. It further seems that the concept could be extended to include analogous plays in the Northern Michigan Reef Trend as well as the Southern Reef Trend. Finally, it is logical to extend the concept to other reef trends, such a those in Texas and Alberta, among others.

4.0 GEOCHEMISTRY

4.1 Springdale

A series of geochemical surveys were conducted over the Springdale Field from November, 2003 to November, 2005 (Figure 20a). These surveys have been discussed previously (Quarterly Technical Report September 2002 – December 2002, DOE OSTI Bridge Identifier – 824802 [Appendix A] and Annual Technical Report April 2003 – March 2004, DOE OSTI Bridge Identifier - 827044) and the reader is referred to these for the details of the early results. Here we will focus on the last year of data and analysis and will summarize the entire Springdale program.

The first Springdale surveys were the microbial (GeoMicrobial Technologies ©) but the last two years concentrated on soil gas surveys conducted by Direct Geochemical and GMT. Although the microbial technology was used almost exclusively at Vernon Field (>1100 samples), the switch was made at Springdale to comply with the original proposal to DOE that we investigate a variety of geochemical techniques and vendors.

A novel aspect of the Springdale program was that the sampling was not done on a grid, as was done at Vernon Field, but rather were taken over the surface trace of the planned horizontal well. In this way we hoped to collect sufficient data to characterize the well prior to drilling and at the same time economize on both sampling and analytical costs. As it turned out we estimate that we spend about $20 collecting each sample, including personnel time, travel and materials and were charged an average of $40 per sample for analysis. The total cost for one line (i.e. a series of samples spaced at nominally 100 – 200 meters along the path of the horizontal well) was about $2000 per line (e.g 50 samples per line @ $40/sample).

Results of the Springdale surveys are summarized in Figures 20a-f. Here we plot the correlation coefficients along the well trace (Figures20b-c) or the oil/gas probability (Figures (20e-f) along the well trace. The correlation coefficients are a measure of how well the gases from the sample correlate with the C1-C4 gases measured by the well logger while the probability plots estimate how well the samples predict the occurrence of gas or oil along a given well trace, using data from one well to calibrate or "train" the sample data.

For the soil gas work done in conjunction with Direct Geochemical (Golden, CO), the soil samples were collected just below the "B" soil horizon, shipped in brown sample envelopes, then dried and sieved in the lab for a silt/clay fraction. . An aliquot of each sample was heated in an air-tight glass vial at constant temperature for constant time, usually 70 F (21 C) for 24 hours. At the end of that time, the head space gases were drawn off in a syringe and injected into a gas chromatograph, where the C1 – C8 hydrocarbons were analyzed. Headspace from the vials was analyzed on a HP5890 Series II gas chromatograph for C1-C8 hydrocarbons including methane, ethane, ethylene, propane, propene, i-butane, n-butane, butene, i-pentane, n-pentane, pentene, i-hexane, n-hexane, hexane, i-heptane, n-heptane, heptene, i-octane, and n-octane.

The hydrocarbon concentrations in ppb/v were evaluated in multivariate space to try to reduce the large number of variables to a smaller number (i.e. factor analysis) and to try to discriminate microseepage between areas with oil, gas and dry areas (i.e. discriminant analysis).

The factor analysis resulted in two main hydrocarbon associations (i.e. hydrocarbons in each association are correlated with one another). The light hydrocarbon factor (C1-C4, Figure 20b) is anomalous mainly over the western part of the survey area, which correlates with the gas leg identified by Jordan Oil. The heavy hydrocarbon factor (C6-C7, Figure 20c) is anomalous over the eastern part of the survey area, which is thought to represent the oil leg.

The training set of samples (i.e. oil vs. gas. vs. dry) was chosen based on the mudlog total hydrocarbon concentrations. This assumes that the best production is associated with the highest mudlog concentrations (which might not be the case). It would be beneficial to find out from Jordan Exploration where the best production is coming from in the horizontal wells. The training set samples are indicated in the attached spreadsheet under the "Model" column.

The microseepage associated with oil-prone areas is different than that associated with dry areas (see attached discriminant plot, Figure 20d), which also indicates variables that are important to the discrimination. Using this training set, we are able to predict the oil production associated with the Stedronsky 14-15 well (Figure 20e, assuming that production is coming from the area of anomalous total hydrocarbon concentrations on the mudlog). An area to the west of the Springdale oil production also predicts as oil, but this can only be proven with the drill bit.

Several of the "BL" samples also predict as oil, and the mudlog total hydrocarbon concentrations are also anomalous.

There are fewer "gas-prone" samples in the discriminant analysis, and we therefore have less confidence in this model, i.e. on the plot (Figure 20d) the green gas samples do not separate well from the oil and dry samples. We would therefore, would not have a lot of confidence on the gas probabilities (Figure 20f). Further work is pending on this data and interpretations and will be presented at the annual AAPG meeting in April, 2005 (Seneshen, 2005).

4.2 Vernon Field

Results and data on the Vernon Field project have been reported previously (Quarterly Technical Report September 2002 – December 2002, DOE OSTI Bridge Identifier – 824802 [Appendix A] and Annual Technical Report April 2003 – March 2004, DOE OSTI Bridge Identifier - 827044) and will not be repeated here except to say that the Vernon project demonstrated the value of surface geochemistry (it predicted marginal results and recommended abandonment) and also showed what the geochemical signature of a depleted Dundee Field should look like (Figure 21). The difficulty in convincing industry to rely more on surface geochemistry is that Vernon is regarded as only one verified case study and the cost of such surveys has been increasing to the point that they would constitute a significant additional cost: e.g Vernon Field geochemical work exceeded $40,000 in total costs, including sampling and analysis, for approximately 1100 data points. It is our opinion that companies will spend perhaps 10-15% of that amount for a definitive geochemical survey, but not more. And that will require significantly more education on geochemical techniques and reliability and more case studies.

5.0 CONCLUSIONS

The main conclusions resulting from this study are:

1. The Springdale play represents a new concept in Michigan Basin hydrocarbon exploration, which can be summarized as using horizontal wells to probe for dolomitized zones in the Brown Niagaran, particularly near existing pinnacle reef production. Fields on the order of 500,000 to 1 million barrels of oil or gas equivalent can be expected. Springdale is a good example of the type of innovative thinking and execution that occurs in small exploration companies in the pursuit of hydrocarbons in mature basins. No major company will pursue such leads given the relatively low returns, but these types of plays are very economical for small, low overhead companies, and represent really the last best opportunity to recover hydrocarbons from well picked over basins such as the Michigan Basin.

2. Vernon Field is a good example of a depleted field that is basically “spent” in the sense that no further HCs can likely be produced and the lesson here is that a geochemical survey could have revealed that prior to drilling.

3. Surface geochemistry can be used more often than not as an effective tool to detect the presence or absence of subsurface HCs in both the Dundee and the Niagaran. We are confident that all of the geochemical techniques employed in this study did in fact detect leaking HCs from potential reservoirs but more studies need to be done to convince industry that the technology is useful in reducing risk and is cost-effective. What is really needed is a tool that can be taken into the field to detect leaking hydrocarbons in real time, eliminating the need for laboratory analysis of samples and allowing corrections and resampling to be done in "real time". We predict that a major breakthrough in application of geochemical to the subsurface will occur when such a tool is developed and available at reasonable cost.

In general, this study and the demonstration projects, especially Springdale, suggest that mature hydrocarbon provinces like the Michigan Basin are in a state that they can be expected to yield discoveries similar to Springdale and on the same order of magnitude. In particular, going back and probing formations that were bypassed or neglected during the primary phase of exploration might pay large dividends.

For example, perhaps attention should be focused on rocks like the Brown Niagaran that have so far produced little but which are known to have gas and oil shows and which share a geologic history within a very prolific trend. In this vein it would seem worthwhile to look at wells that penetrate the A1 Carbonate, the formation just above the A1 Salt (Figures 2 and 4) and the Brown, looking for gas and oil shows. It is likely that the same pattern of productive rock that exists at Springdale will also be present in the A1 Carbonate as well as similar carbonates above (the A2 Carbonate, the B Unit, etc.). Now that Springdale has shown the value of probing such potential reservoirs with horizontal wells, it makes sense to similarly probe structures above the Brown.

One possible line of attack is to carefully map the A1 Carbonate around the edges of the A1 Salt and the A2 Salts, looking for small structures and hydrocarbon shows from previous wells. It is possible (likely?) that the A1 and A2 Carbonates have shared the same diagenetic history as the Brown, including the dolomitization episode, and that they were present at the time the pinnacle reefs and the Brown were charged with hydrocarbons. The presence of salt or anhydrite above these carbonates essentially completes the trap so that the critical question boils down to whether or not economic quantities of hydrocarbons were able to penetrate the salt below these units. If so, then both the A1 and A2 carbonates are essentially Brown look-alikes with the advantage that they are considerably thicker, even around the basin margins.

6.0 LESSONS LEARNED

In bullet form the lessons learned for this project are:

- Obtain a geochemical survey before attempting further HC recovery from fields that have passed their peak in primary production. Vernon Field could have been written off if such a survey had been conducted

- Horizontal wells are much more effective than vertical wells in probing for and producing diagenetic/stratigraphic traps; they should be routinely considered

- If horizontal drilling is contemplated, economies in geochemical surveys can be achieved if sampling is restricted to following the well bore rather than sampling on a grid. Fewer samples, more closely spaced, in the region of interest are likely to be more effective than a coarser grid pattern and will cost much less.

- Emphasis should be placed on development of a sensitive, portable geochemical probe that will permit comprehensive surveys to be conducted in the field without the need to collect and dispatch samples.

- Numerous small fields on the order of Springdale (e.g. 250,000 -1,000,000 bbls oil/gas) can be expected to be recovered in the Michigan basin in coming decades. These will be discovered by small companies and consultants with intimate knowledge of the basin and low operating overhead. As a consequence oil production in the Michigan basin will have a long “tail” and may stabilize at about 1-10 million barrels/year before the last rig is shut down.

7.0 TECHNOLOGY TRANSFER

7.1 Presentations

Petroleum Technology Transfer Council, Mt. Pleasant, MI (March 19, 2004) "Imaging of Niagaran Fields Using Well Log Tomography and 3D Visualization", A. Wylie.

Michigan Oil and Gas Association, Gaylord, MI, (April 22, 2004) "Exploitation and Exploration Opportunities in Michigan - New Views of a Mature Basin or Practical Technology combined with Old Fashioned Prospecting", A. Wylie.

Society of Petroleum Engineers, Traverse City, MI (May 16-18, 2004) "Application of Well Log Tomography to the Dundee and Rogers City Limestones, Michigan Basin, USA", J. Wood.

Michigan Basin Geological Society, Traverse City, MI (May 19, 2004), "Alternate Views of Well Logs Using Well Log Tomography", A. Wylie.

Petroleum Technology Transfer Council, Grand Rapids, MI (September 23, 2004), "Views of Existing and Prospective Producing Formations in Michigan", A. Wylie. Included four-day field trip with 10 students, participation by students in PTTC workshop, visits to various outcrops, exercises in core description at the Western Michigan University Michigan Core Repository.

AAPG Eastern Meeting, Columbus, OH (October 3-6, 2004), "Map views of the producing formations in Michigan, the Michigan Basin, U. S.", A. Wylie and J. Wood.

AAPG Eastern Meeting, Columbus, OH (October 3-6, 2004), "Depositional patterns in the Trenton and Black River Formations revealed by well log tomography and K-bentonite time planes, Michigan Basin and beyond", A. Wylie.

AAPG Eastern Meeting, Columbus, OH (October 3-6, 2004), "Application of well log tomography to the Dundee and Rogers City Limestones, Michigan Basin, U. S.", J. Wood.

7.2 Meetings with Jordan Exploration Company, LLC

March 4-11, 2005, Annual Project Meeting and Field Trip to view carbonate depositional environments in the Bahamas in conjunction with Western Michigan University; included student participants and presentations.

May 15-16, 2005, Traverse City, Meeting to discuss Class Revisit project.

June 16-18, 2005, Traverse City, Meeting to discuss Class Revisit project.

August 4-5, 2005, Traverse City, Meeting to discuss Class Revisit project.

September 7-10, 2005, Traverse City, Meeting to discuss Class Revisit project.

December 12-15, 2005, Traverse City, Meeting to discuss Class Revisit project.

March 7-14, 2004, Annual Project Meeting and Field Trip to view carbonate depositional environments in the Florida Keys in conjunction with Western Michigan University; included student participants and presentations.

April 21-23, 2004, Traverse City, Meeting to discuss Class Revisit project.

May 16-18, 2004, Traverse City, Meeting to discuss Class Revisit project.

June 3-8, 2004, Traverse City, Meeting to discuss Class Revisit project.

June 29, 2004, Trusty Steed Prospect geochemical sampling, Grand Traverse County, MI.

July 8, 2004, Traverse City, Meeting to discuss Class Revisit project.

September 9-12, 2004, Traverse City, Meeting to discuss Class Revisit project.

November 9-17, 2004, Traverse City, Meeting to discuss Class Revisit project and Springdale area geochemical sampling, Manistee County, MI.

7.3 Meetings with Direct Geochemical

August 24-26, 2005, Denver, CO. Meeting to discuss geochemical analysis of Springdale Play.

November 9-14, 2005, Denver, CO. Meeting to discuss geochemical analysis of Springdale Play.

7.4 Publications

Wood, J. R., Wylie, A. S., Jr., and Quinlan, W., 2004, Surface Geochemical results complement conventional development approaches: World Oil, v. 225, no. 12, p. 54-57.

Wylie, A. S., Jr. and Wood, J. R., 2005, 3D-Imaging of Core and Log Curve Amplitudes in a Niagaran Reef, Belle River Mills Field, St. Clair County, Michigan, U.S.: AAPG Bulletin, v. 89, no. 4, p. 409-433.

8.0 REFERENCES

Bowers, T. L., 1987, Upper Niagara - lower salina (mid-silurian) sedimentology, and conodont-based biostratigraphy and thermal maturity of the southeast Michigan basin: M.S. thesis, Wayne State University, 120 p.

Direct Geochemical, 2005, Direct Geochemical web page: <http://www.directgeochemical.com/> Accessed 12/15/2005.

DOE Scientific and Technical Information, Information Bridge, 2005, http://www.osti.gov/bridge/, Accessed January 5, 2006.

- Quarterly Technical Report September 2002 – December 2002, DOE OSTI Bridge Identifier - 824802
- Annual Technical Report April 2003 – March 2004, DOE OSTI Bridge Identifier - 827044

Seneshen, D., 2005, Direct Geochemical, personal communication.

Michigan Department of Environmental Quality, 2005, Download Oil and Gas Production History: <http://www.michigan.gov/deq/0,1607,7-135-3311_4111_4231-97834--,00.html> Accessed December 15, 2005.

Quinlan, W., 2004-05, Jordan Exploration Company, LLC, personal communication.

9.0 FIGURES

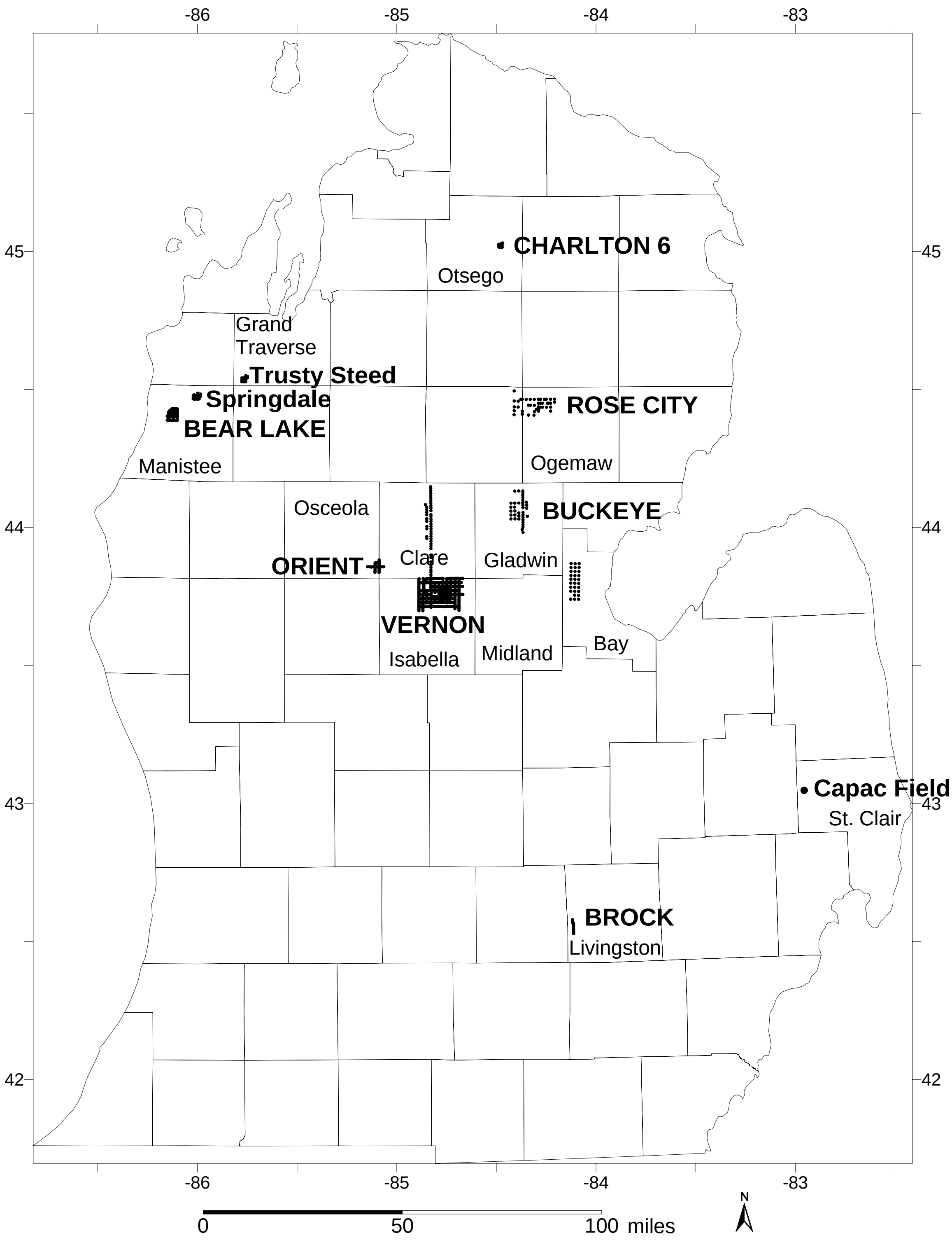


Figure 1. Location map of Lower Michigan, showing geochemical sample locations taken throughout the course of the project.

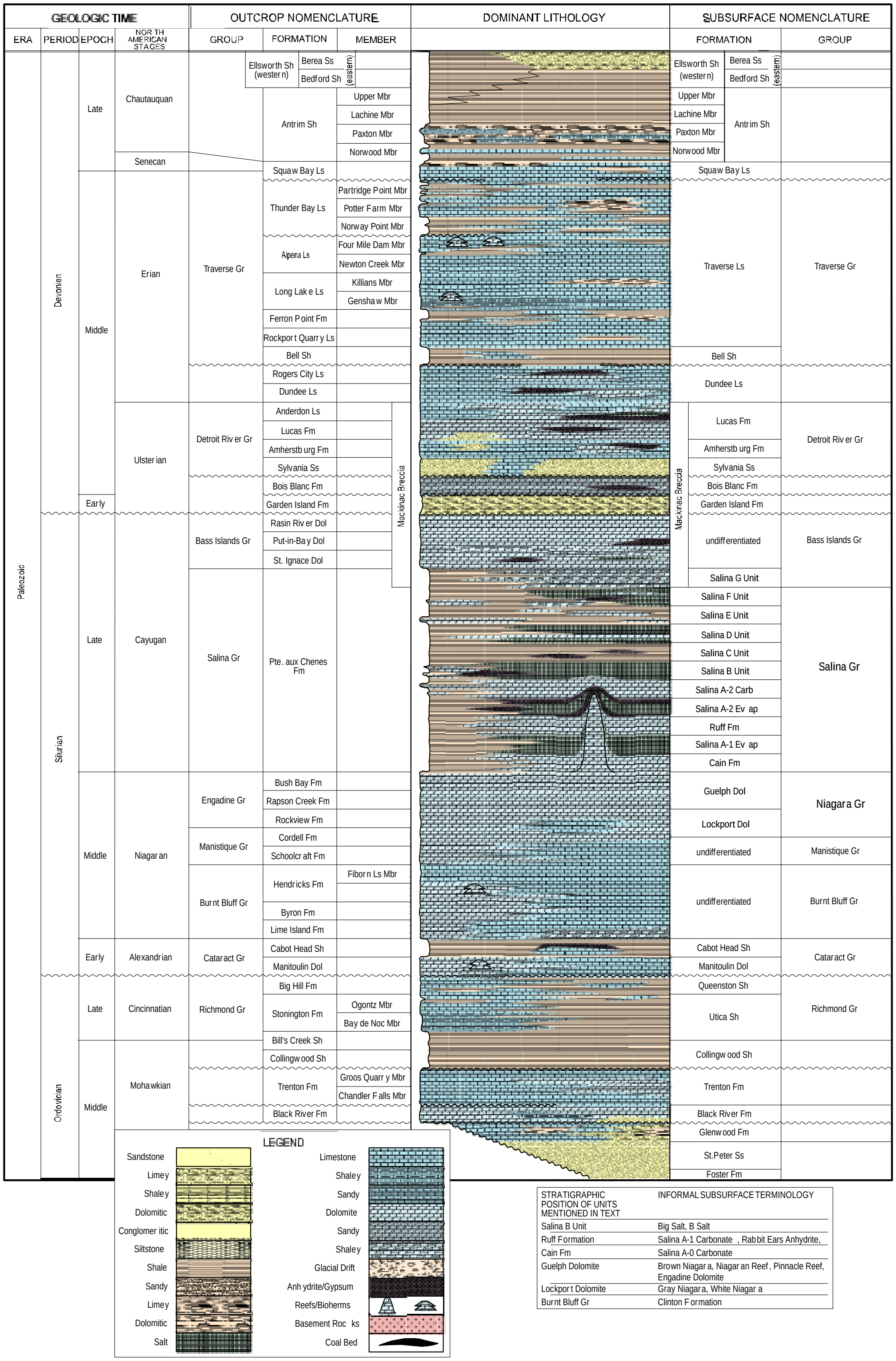


Figure 2. Stratigraphic column for the State of Michigan. The Vernon Field demonstration project targeted the Dundee Formation and the Springdale Fields targeted the Brown Niagaran.

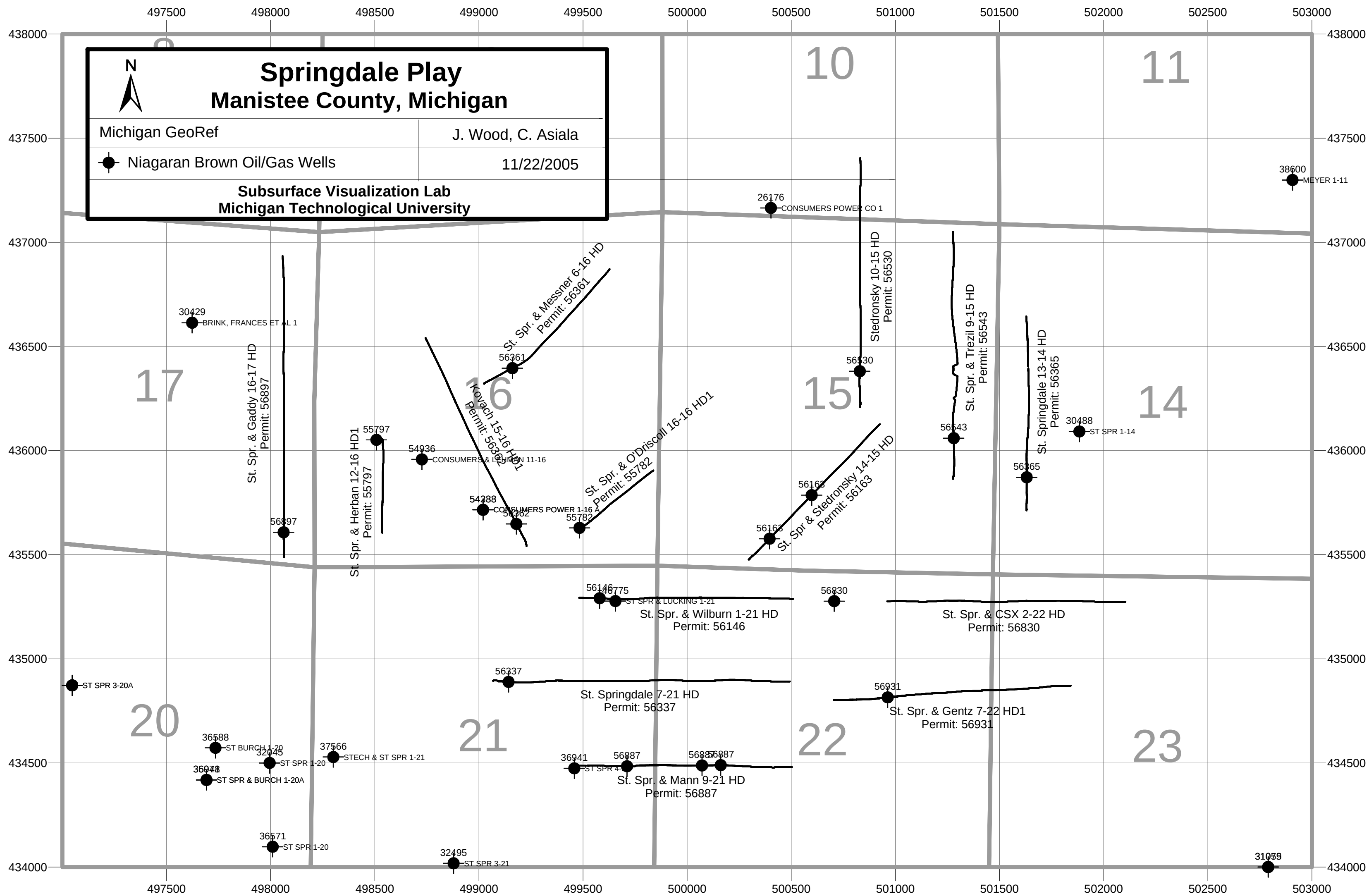


Figure 3. Map showing locations of Springdale horizontal wells. See Figure 1 for location of Springdale Field.

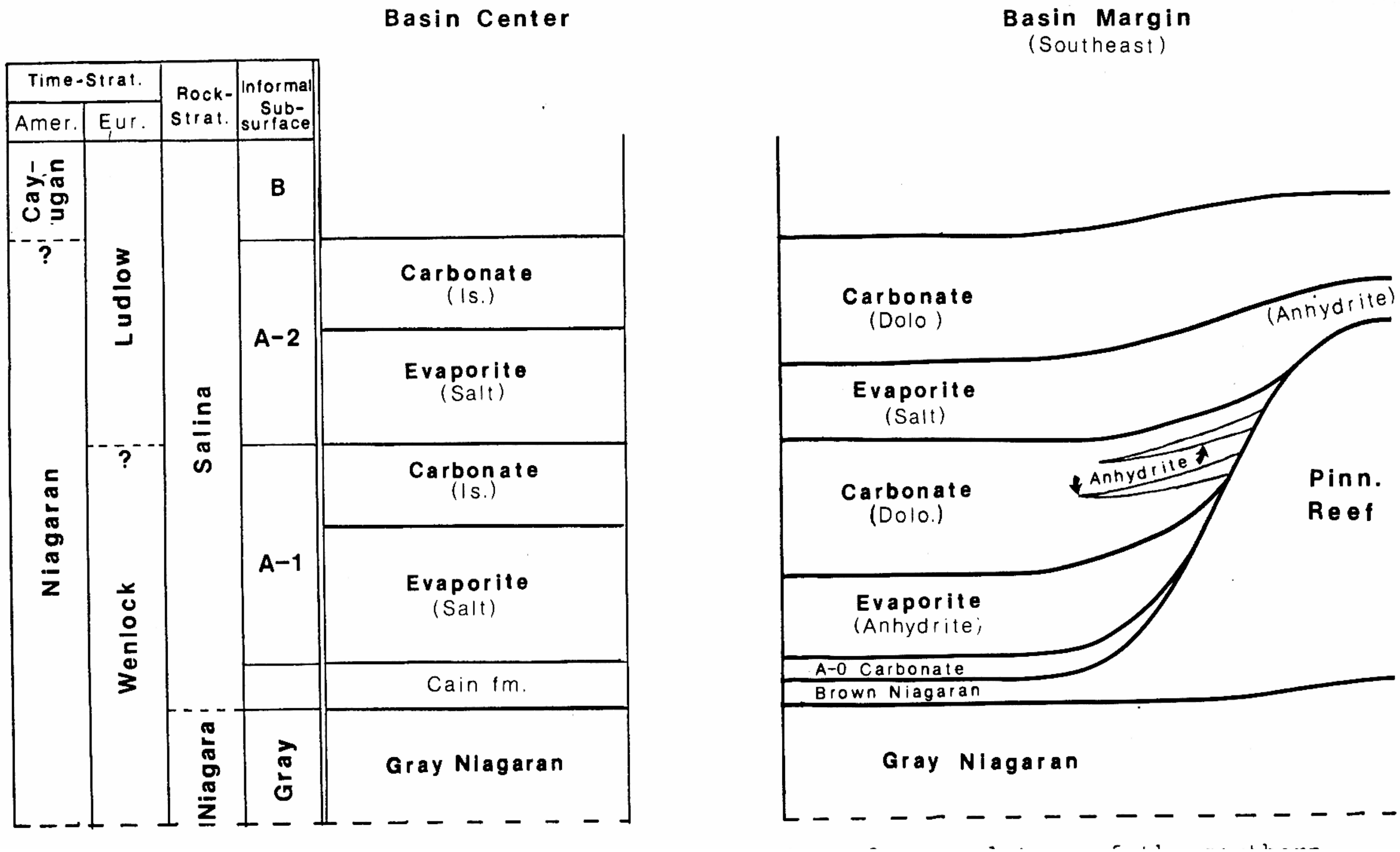


Figure 4. Simplified stratigraphic column for Springdale area based on work of Bowers, 1987 for the Southern Reef Trend. In general the same relations hold for the Northern Reef Trend (NRT) particularly the relations between the Brown and Gray Niagaran and the adjacent pinnacle reefs. The A0 Carbonate is not recognized in the NRT.

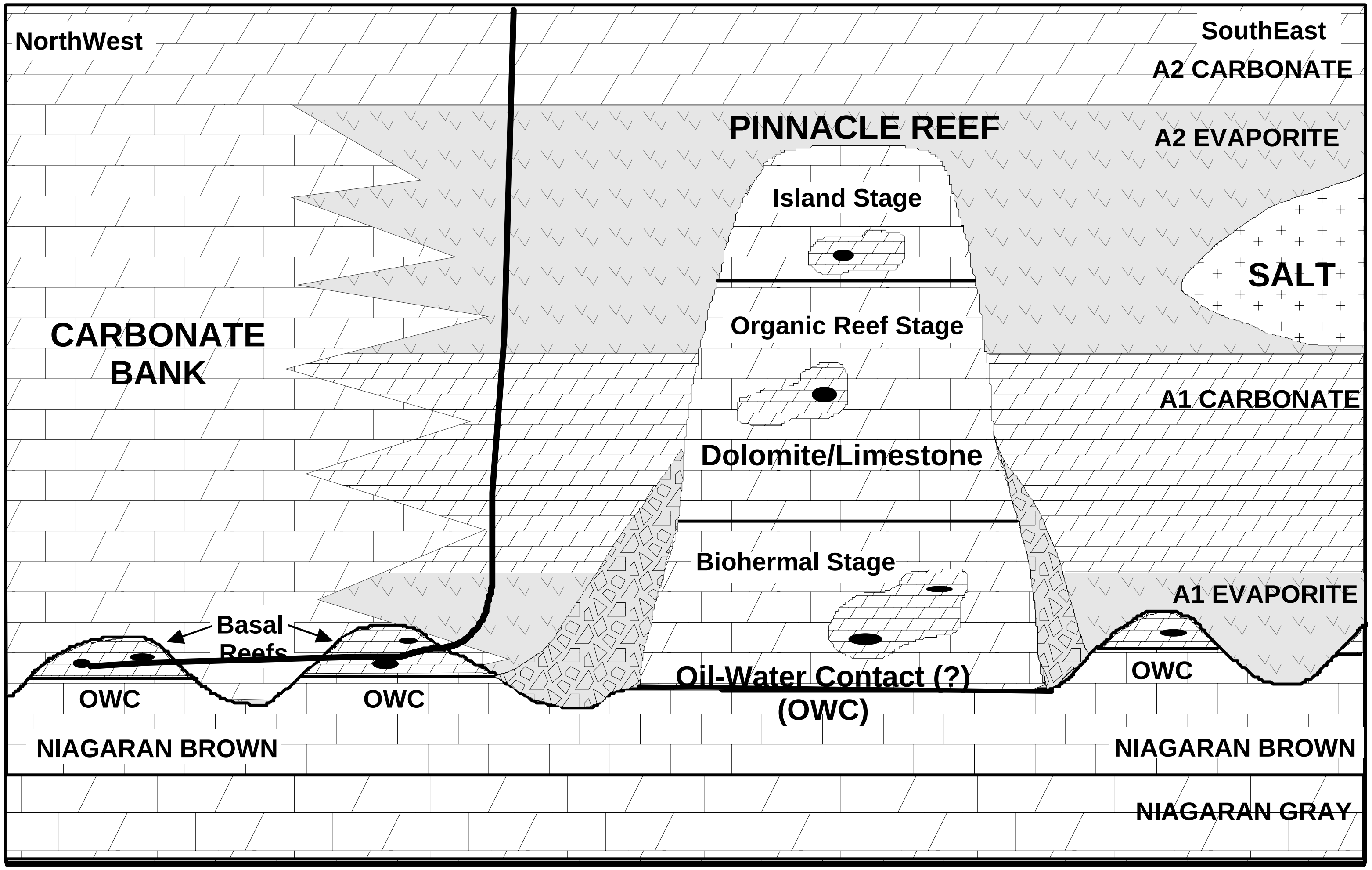


Figure 5. Schematic diagram showing the principal geologic components inferred for the Springdale play. Favorable reservoir rock is almost always dolomitized carbonate sandwiched laterally between impermeable tight limestones and sealed above by salt (anhydrite). Patch reefs may or may not be involved. The A1 Carbonate and the A2 Salts can be traced North and West into the "Carbonate Bank" in wireline logs, but the A2 thins and is not present everywhere. Similarly the Brown Niagaran can be traced North and West, but it also thins (< 10 feet?) and is difficult to pick on wireline logs.

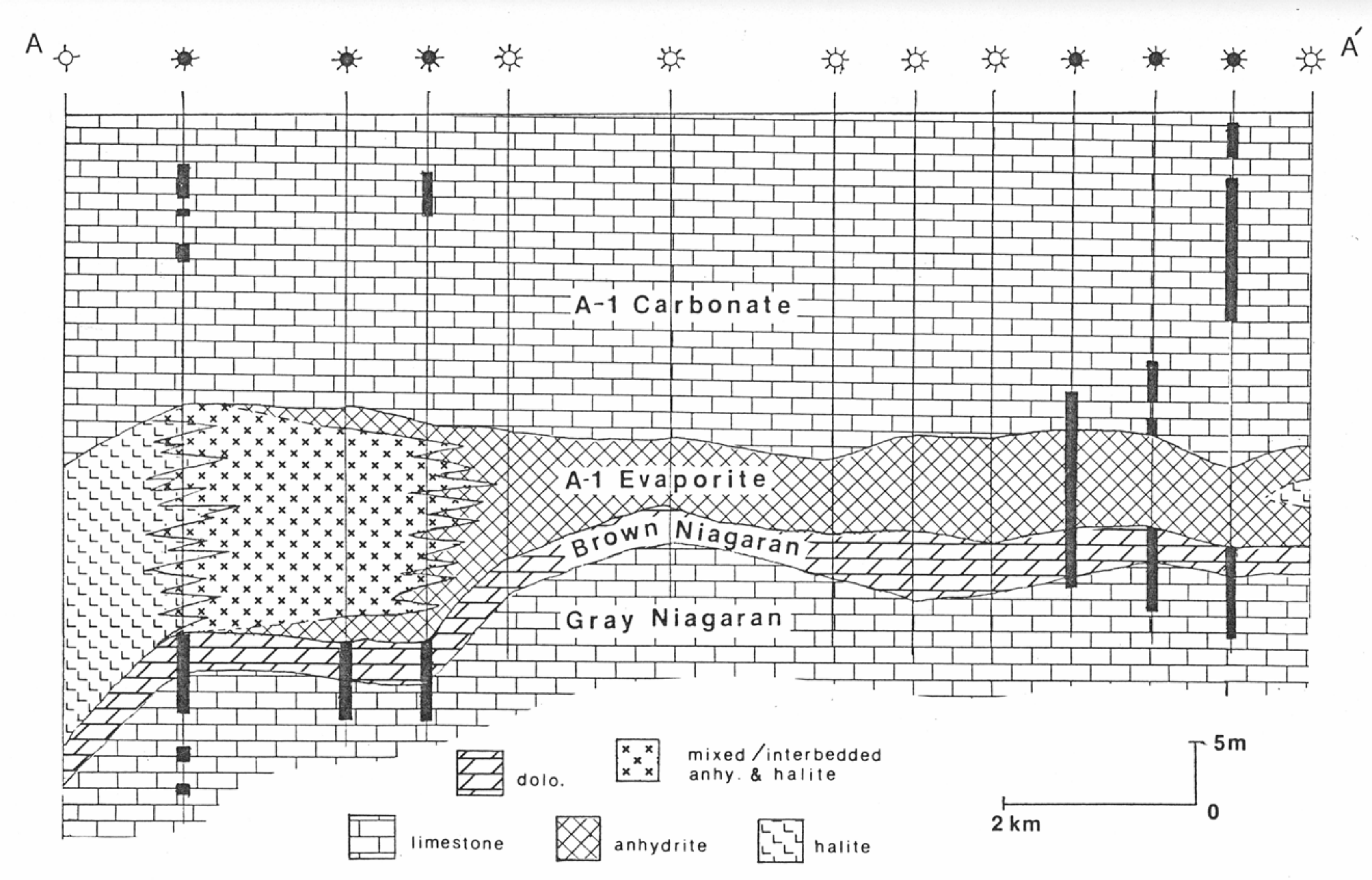


Figure 6. Cross section across pinnacle reef showing stratigraphic relations in Salina and Niagaran Formations based on well logs (Bowers, 1987). Compare with previous figure.

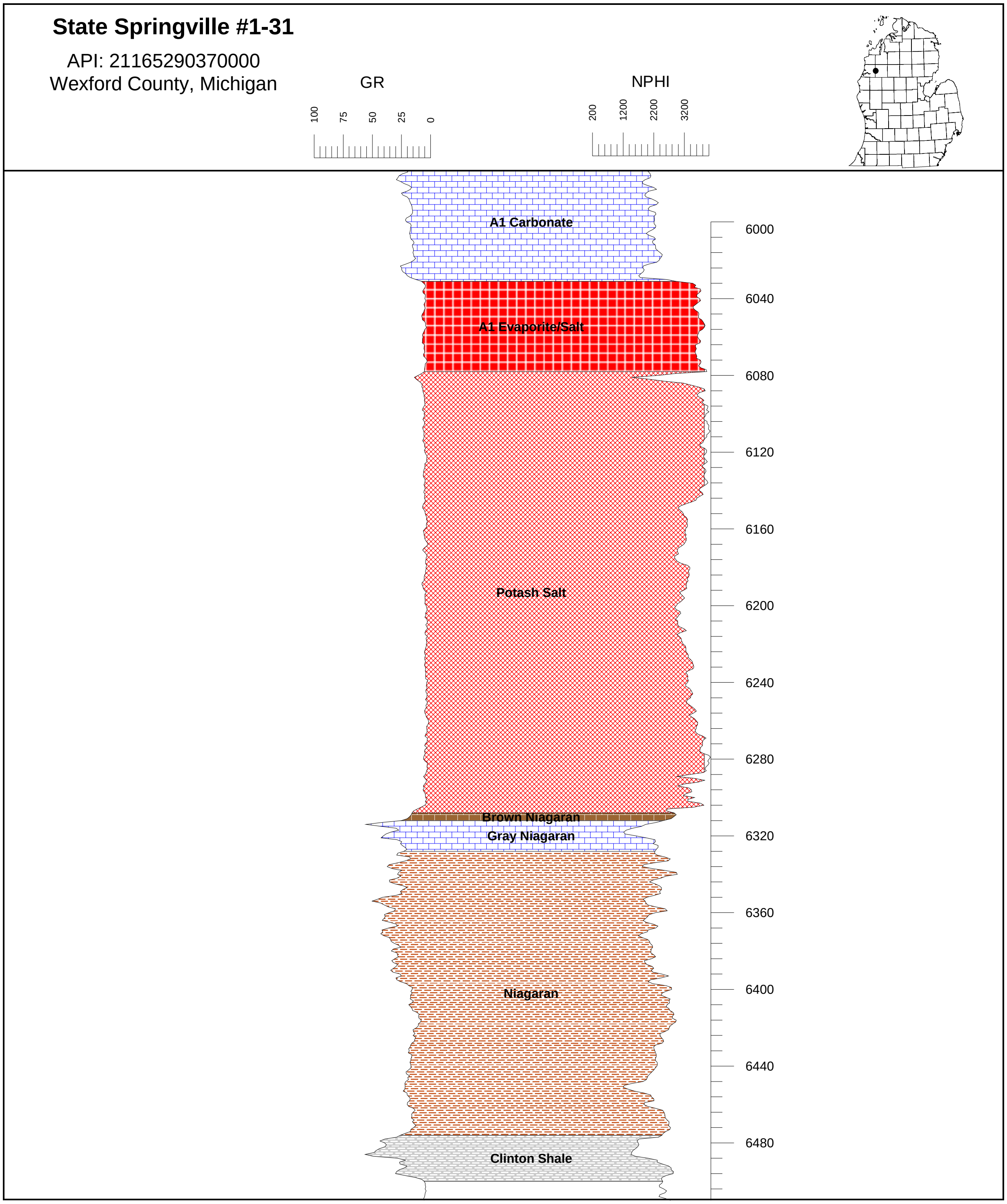
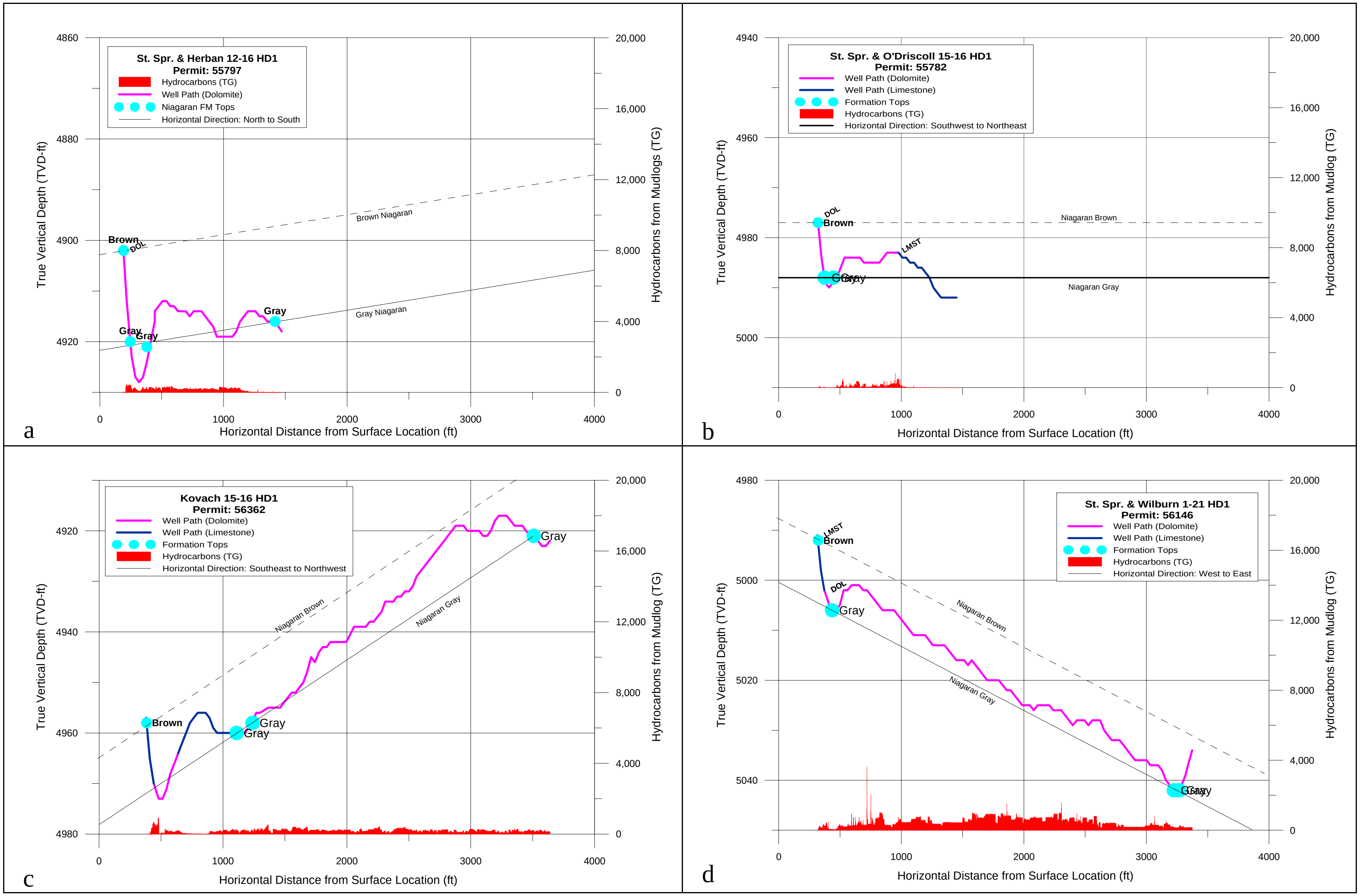
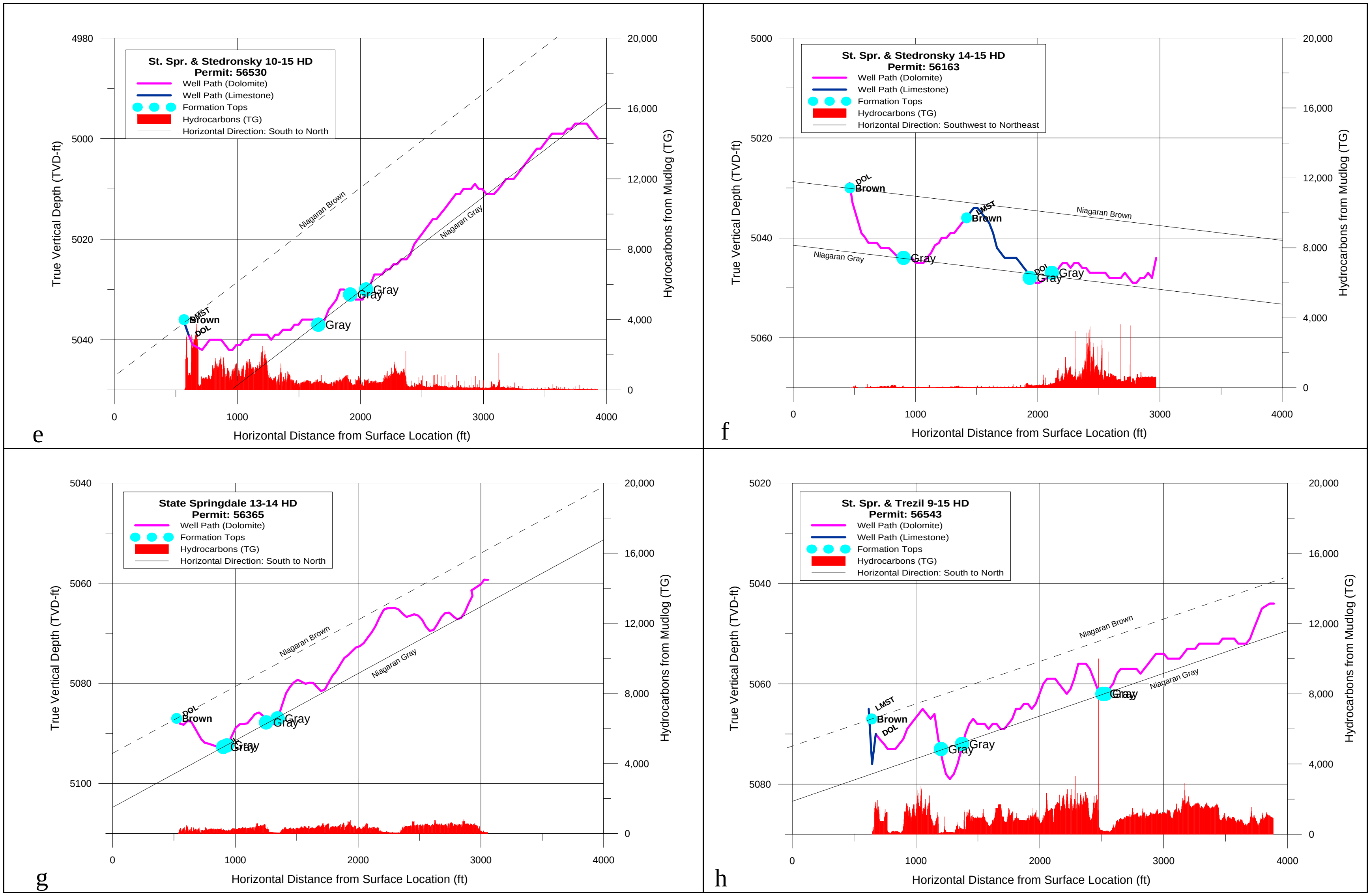


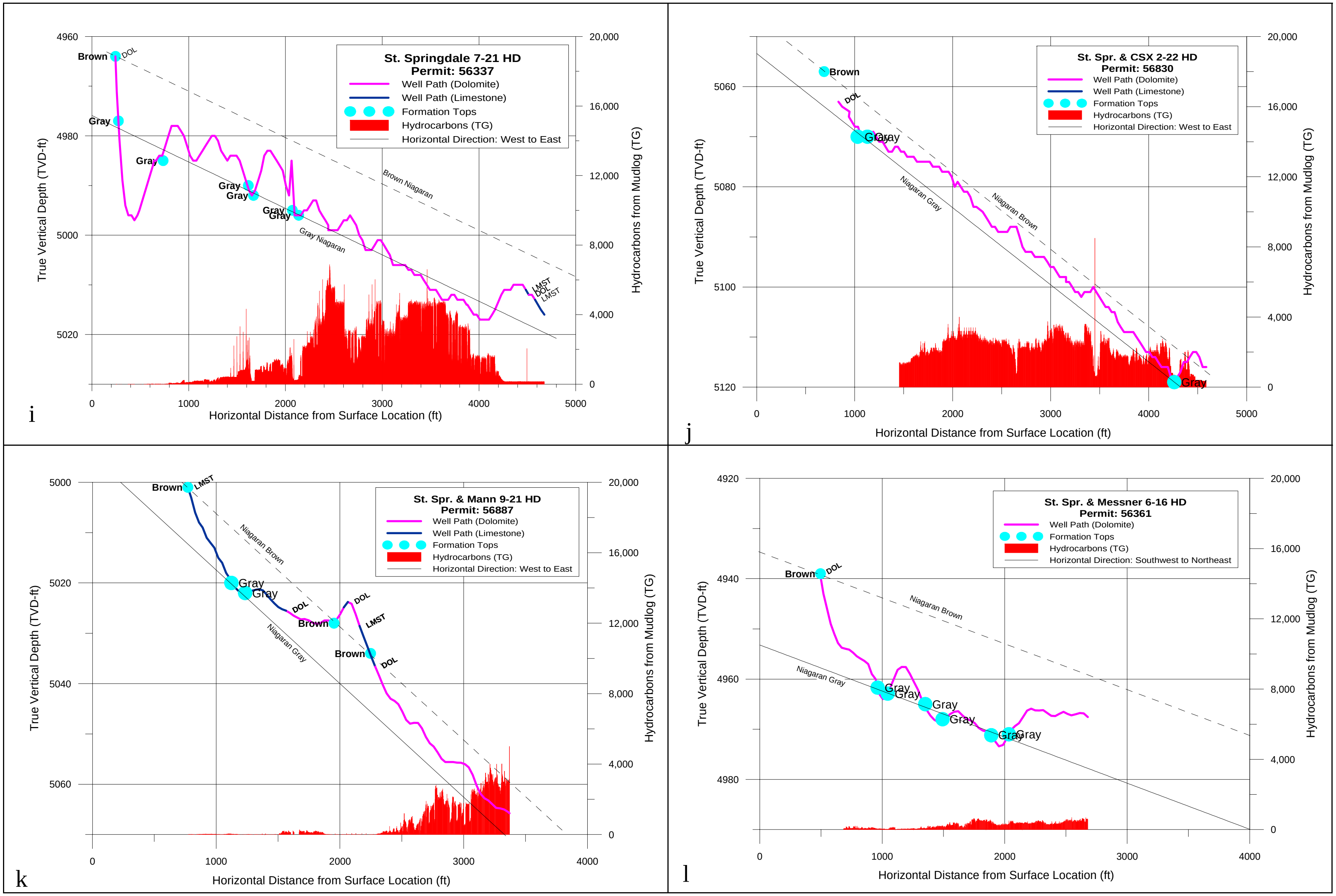
Figure 7. Golden Software Strater diagram showing "doublet" in gamma-ray used to pick top of Gray Niagaran. The Brown Niagaran, which is the target, is between this pick and the bottom of the overlying A1 Salt. This is generally a reliable top pick but is muted in places. The doublet is used to steer the horizontal well and drillers will deliberately drill into the Gray to locate the GR doublet and confirm their stratigraphic position.

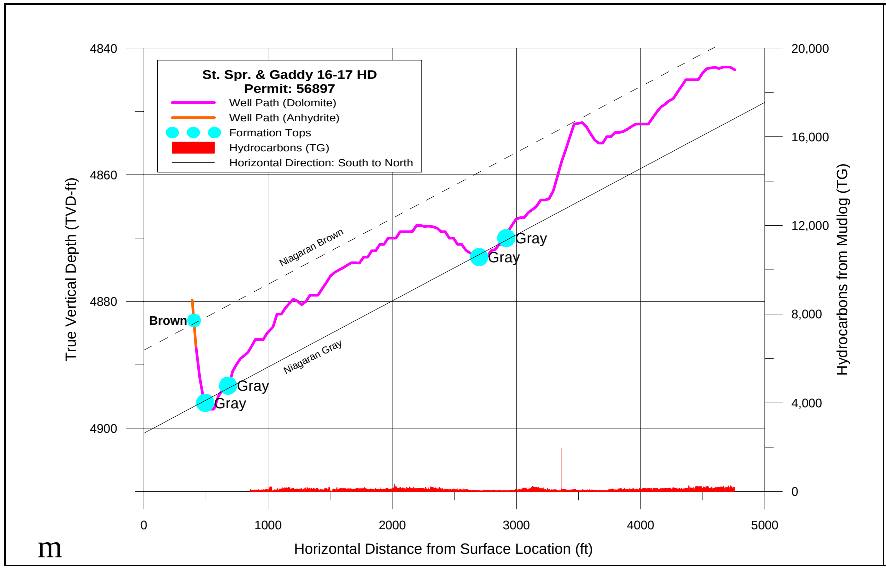
Figures 8a-n. Plots of horizontal well trajectories for Springdale Field taken from data recorded on mud logs. The C1-C4 hydrocarbons recorded on the mudlogs along the paths of the well bores are indicated in the red bar graphs. The blue dots show penetrations of the Brown and Gray Formations. Well bores were plotted by horizontal distance from the surface location and by True Vertical Depth (TVD). Refer to Figure 3 for well locations. The following wells, listed by Permit number and Lease name, were drilled as part of the demonstration:

(a) 55797: State Springdale & Herban 12-16 HD1
(b) 55782: State Springdale & O'Driscoll 16-16 HD1
(c) 56362: Kovach 15-16 HD
(d) 56146: State Springdale & Wilburn 1-21 HD
(e) 56530: State Springdale & Stedronsky 10-15 HD
(f) 56163: State Springdale & Stedronsky 14-15 HD
(g) 56365: State Springdale 13-14 HD
(h) 56543: State Springdale & Trezil 9-15 HD
(i) 56337: State Springdale 7-21 HD
(j) 56830: State Springdale & CSX 2-22 HD
(k) 56887: State Springdale & Mann 9-21 HD
(l) 56361: State Springdale & Messner 6-16 HD
(m) 56897: State Springdale & Gaddy 16-17 HD
(n) 56931: State Springdale & Gentz 7-22 HD

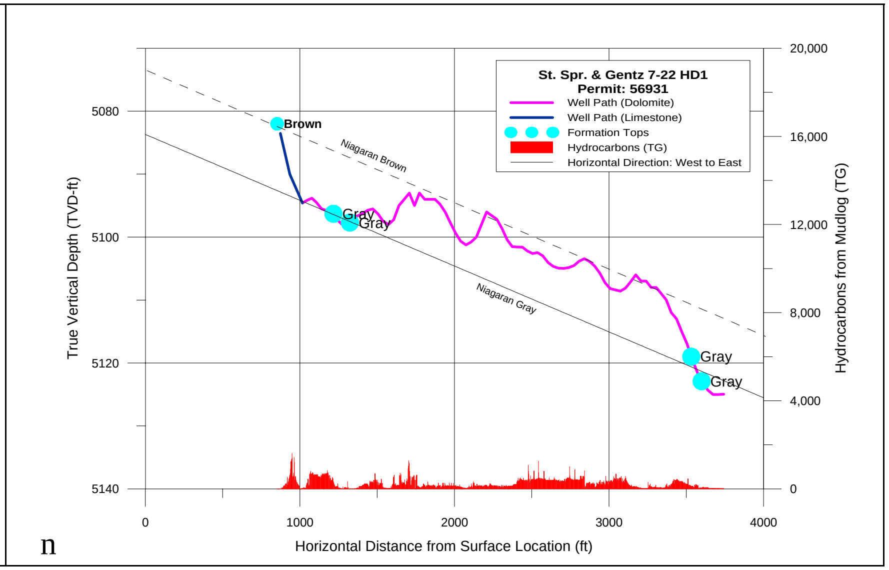

St. Spr. & Herban 12-16 HD1
Permit: 55797
Hydrocarbons (TG)
Well Path (Dolomite)
Niagaran FM Tops
Horizontal Direction: North to South
Brown Niagaran
Gray Niagaran
Brown
DOL
Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlogs (TG)
Horizontal Distance from Surface Location (ft)
a
St. Spr. & O'Driscoll 15-16 HD1
Permit: 55782
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: Southwest to Northeast
Niagaran Brown
Niagaran Gray
DOL
LMST
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
b
Kovach 15-16 HD1
Permit: 56362
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: Southeast to Northwest
Niagaran Brown
Niagaran Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
c
St. Spr. & Wilburn 1-21 HD1
Permit: 56146
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: West to East
Niagaran Brown
Niagaran Gray
LMST
DOL
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
d


St. Spr. & Stedronsky 10-15 HD
Permit: 56530
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: South to North
Niagaran Brown
Niagaran Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
e
St. Spr. & Stedronsky 14-15 HD
Permit: 56163
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: Southwest to Northeast
Niagaran Brown
Niagaran Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
f
State Springdale 13-14 HD
Permit: 56365
Well Path (Dolomite)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: South to North
Niagaran Brown
Niagaran Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
g
St. Spr. & Trezil 9-15 HD
Permit: 56543
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: South to North
Niagaran Brown
Niagaran Gray
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
h


St. Springdale 7-21 HD
Permit: 56337
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: West to East
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Brown Niagaran
Gray Niagaran
i
St. Spr. & CSX 2-22 HD
Permit: 56830
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: West to East
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Niagaran Brown
Niagaran Gray
j
St. Spr. & Mann 9-21 HD
Permit: 56887
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: West to East
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Niagaran Brown
Niagaran Gray
k
St. Spr. & Messner 6-16 HD
Permit: 56361
Well Path (Dolomite)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: Southwest to Northeast
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Niagaran Brown
Niagaran Gray
l



St. Spr. & Gaddy 16-17 HD
Permit: 56897
Well Path (Dolomite)
Well Path (Anhydrite)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: South to North
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Niagaran Brown
Niagaran Gray
Brown
Gray
Gray
Gray
Gray
m



St. Spr. & Gentz 7-22 HD1
Permit: 56931
Well Path (Dolomite)
Well Path (Limestone)
Formation Tops
Hydrocarbons (TG)
Horizontal Direction: West to East
True Vertical Depth (TVD-ft)
Hydrocarbons from Mudlog (TG)
Horizontal Distance from Surface Location (ft)
Niagaran Brown
Niagaran Gray
Brown
Gray
Gray
Gray
Gray
n

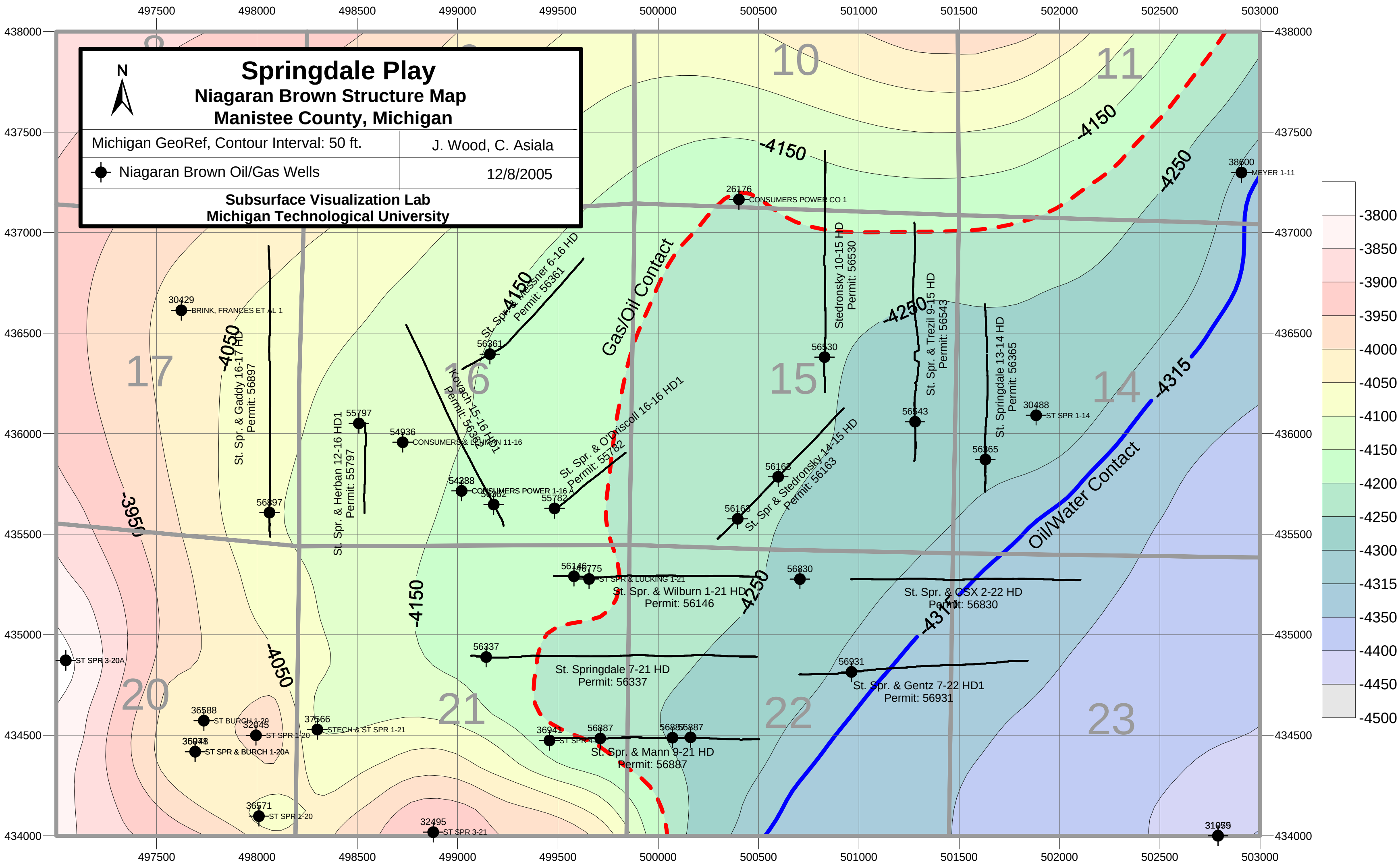


Figure 9. Structure contour map on top of the Brown Niagaran showing the oil/water contact at approximately -4315 feet subsea (blue contour line), and the gas/oil contact at -4200 feet subsea (red dashed contour line). The oil/water contact defines the downdip limits of Springdale Field. A proposed waterflood will begin at the OWC and flood the Brown updip.

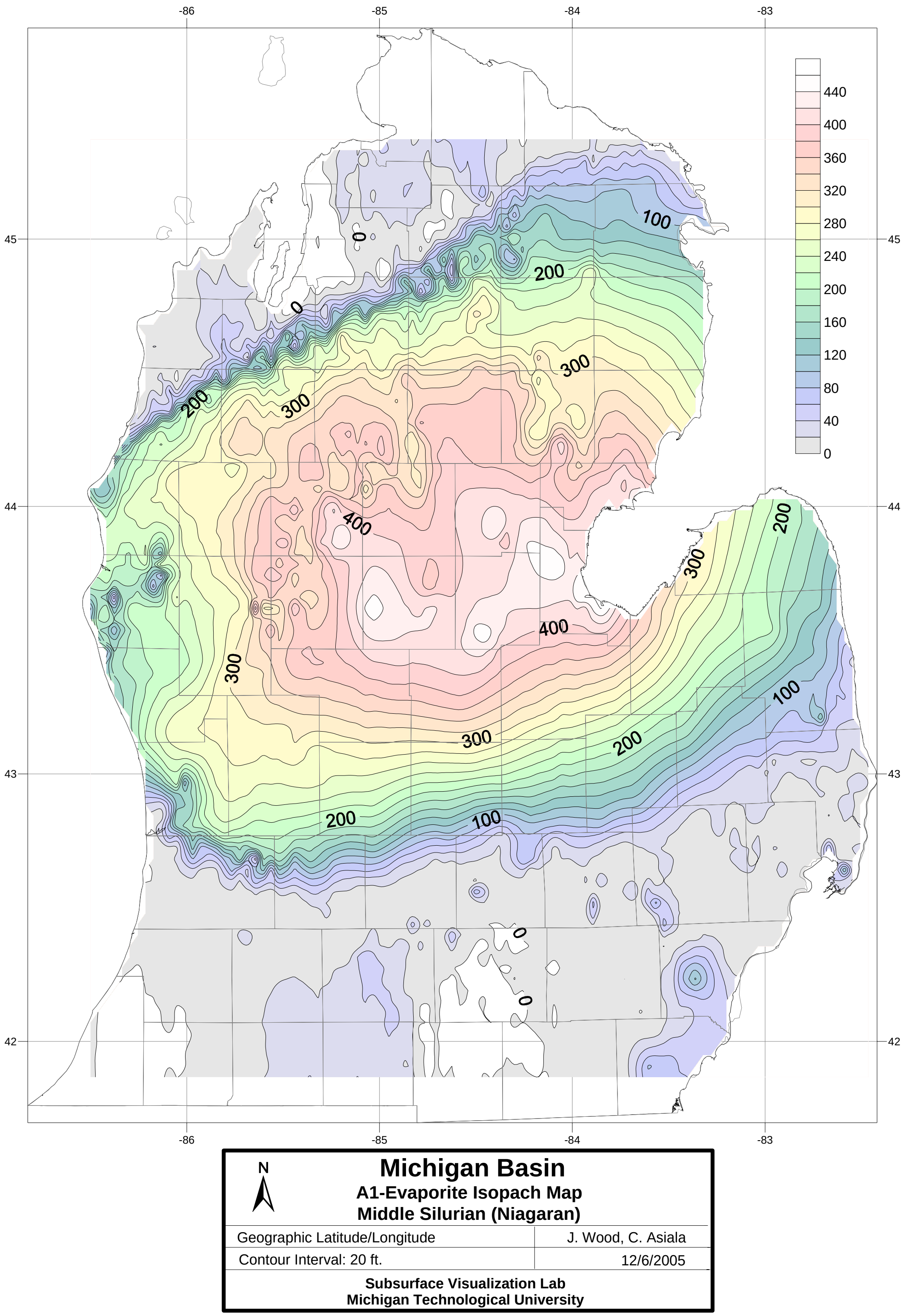


Figure 10. Isopach map on top of the A1-Evaporite over entire Michigan Basin showing the thinning at the basin margins. Springdale Field lies on the extreme thinning edge of the A1-Evaporite.

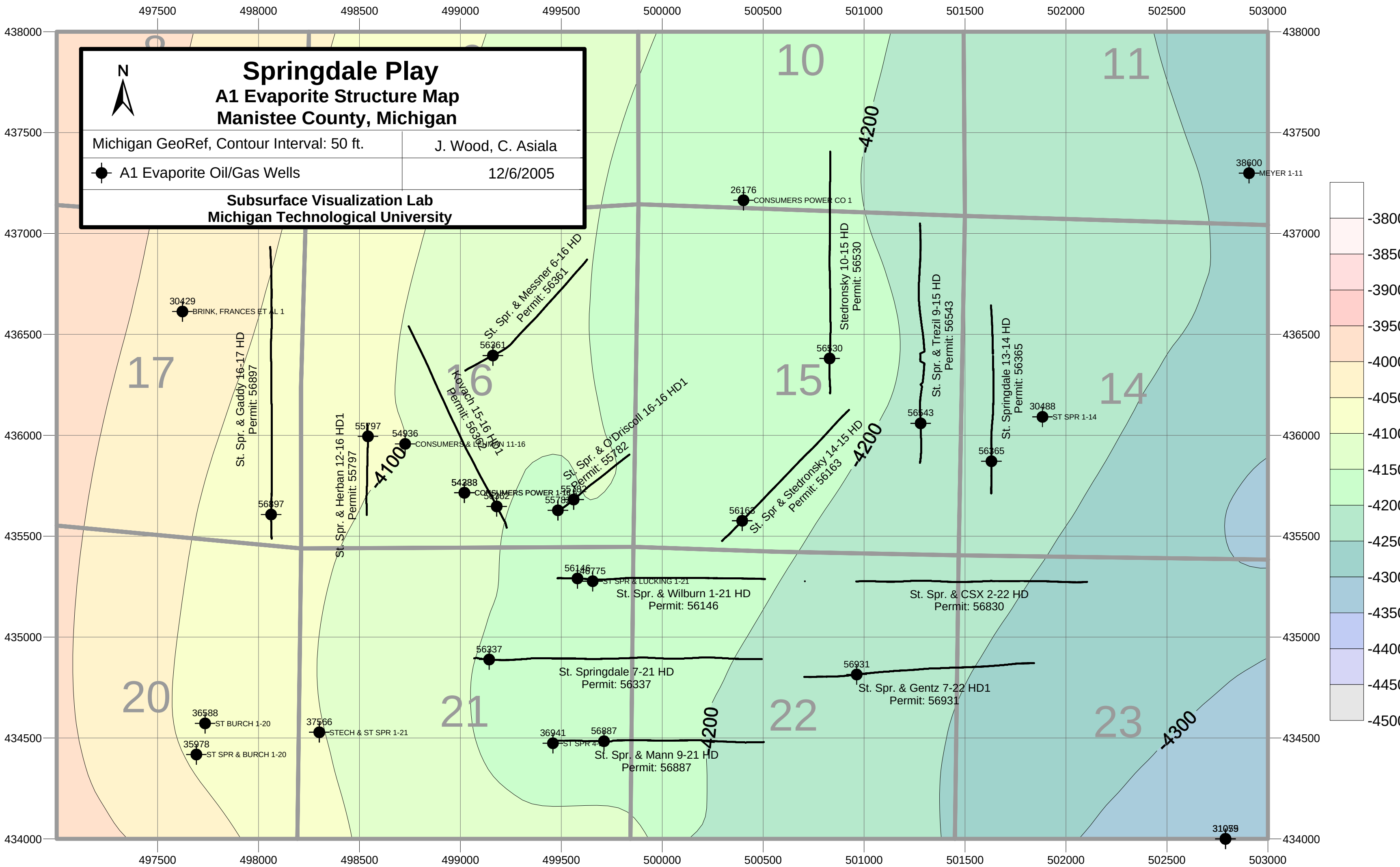


Figure 11. Detailed map showing the structural attitude of the A1 Salt in the Springdale area.

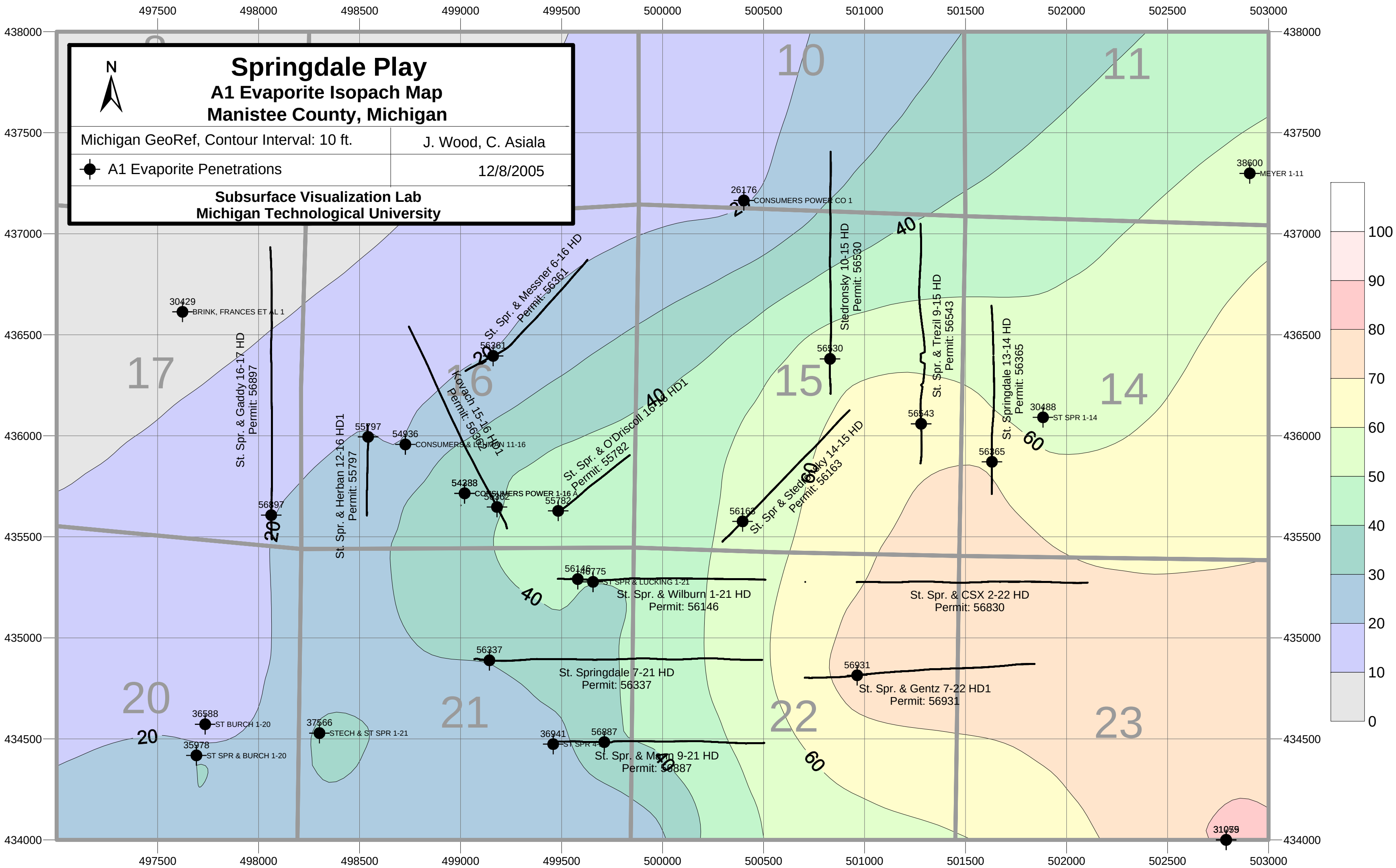


Figure 12. Detailed isopach map of the A1 Salt in the Springdale area showing the thinning over the field. The updip salt seal disappears approximately 3-4 miles north and west of Springdale and may limit the play if the salt is part of the trapping mechanism.

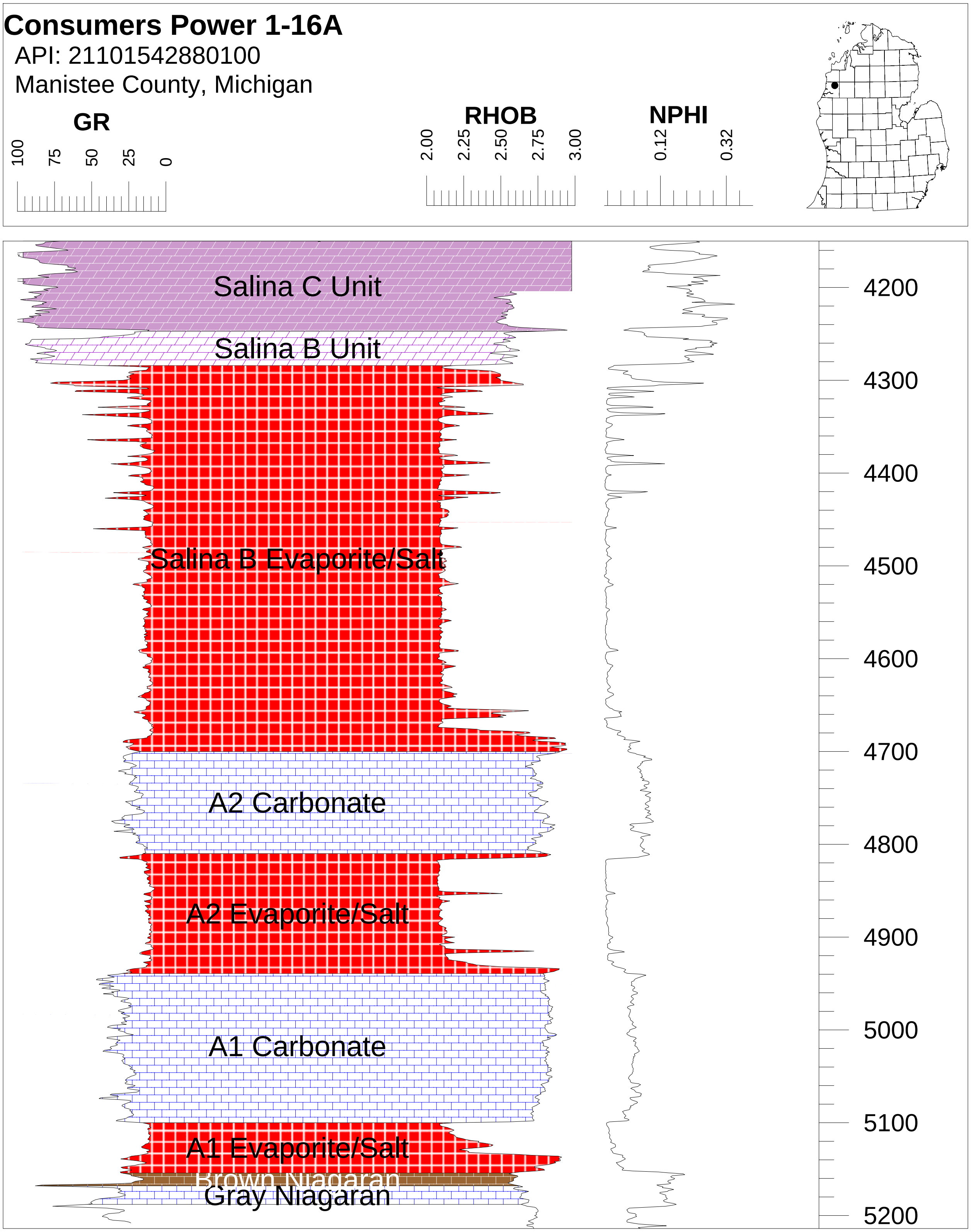


Figure 13. Well logs (GR, RHOB, NPHI) used to identify formation boundaries in the Silurian and Niagaran of the Michigan Basin. Note that NPHI closely tracks RHOB in many instances. The combination of GR with RHOB or NPHI permits fairly precise estimation of formation boundaries.

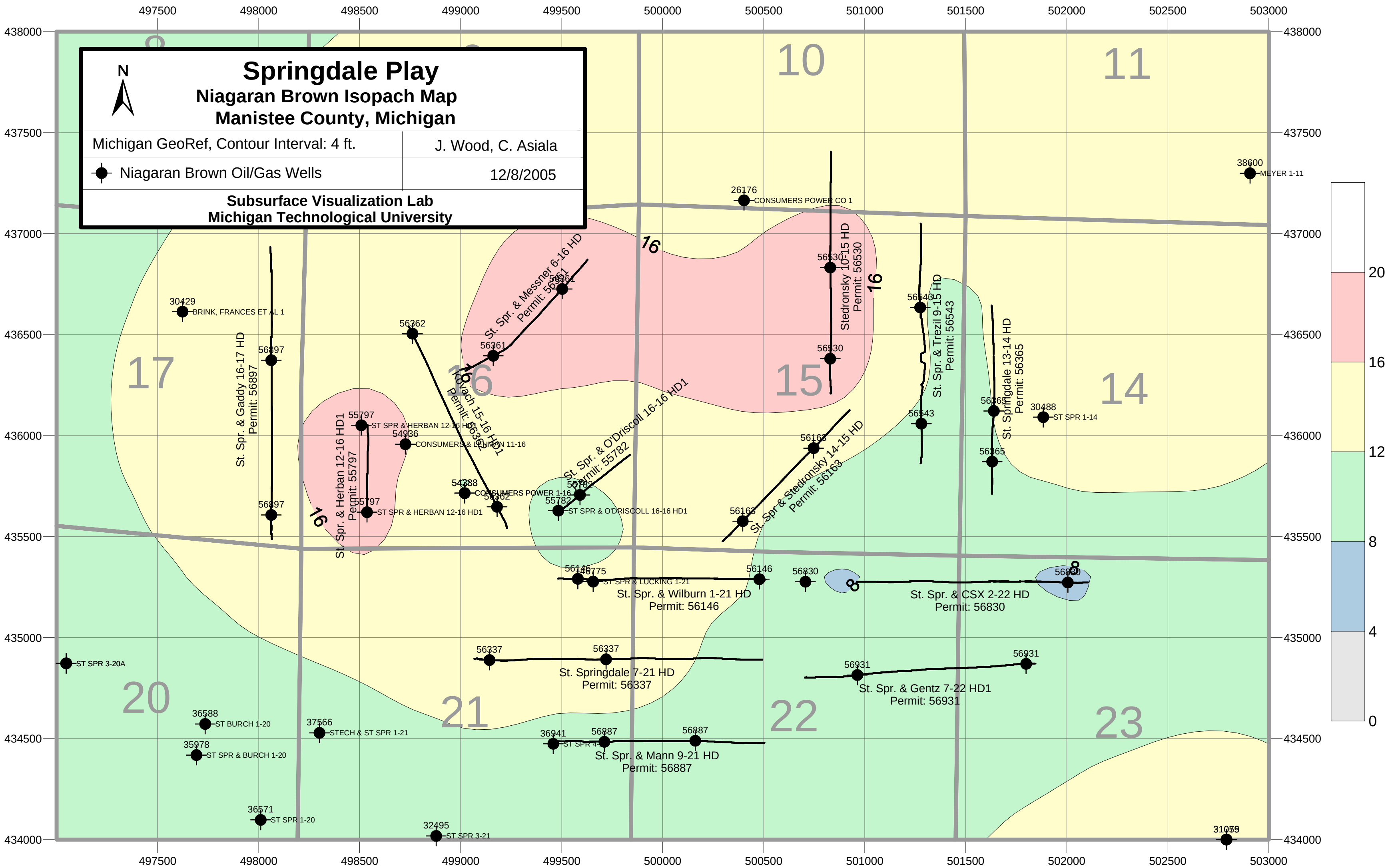


Figure 14. An isopach map for the Brown in the vicinity of Springdale. Contours based on formation top picks from previous well logs as well as the horizontal wells drilled during this demonstration. See figures 8a-n. Typically top picks were estimated at the surface location and the bottom hole location from these plots and used in the contouring.

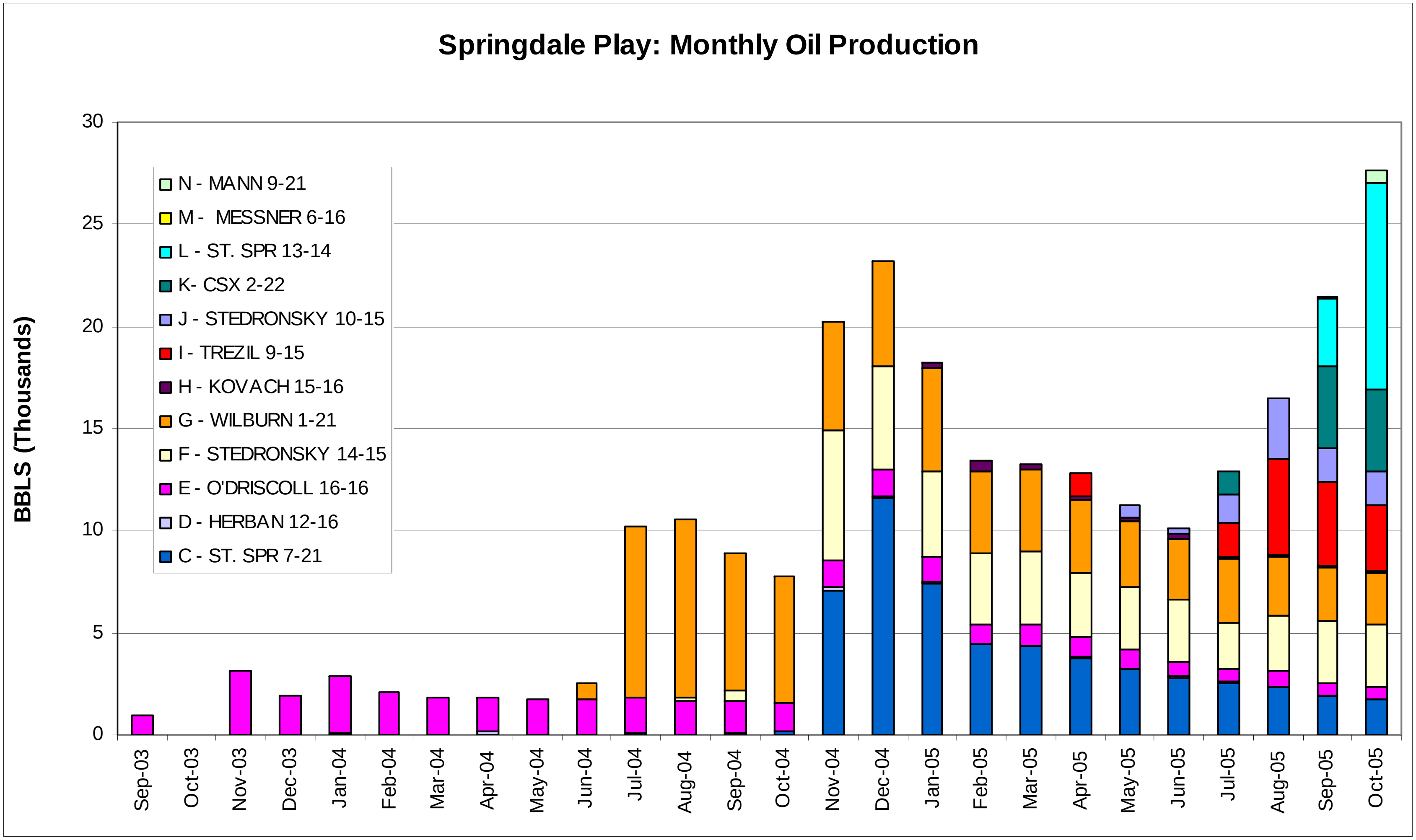


Figure 15. Bar graph showing oil production from beginning of Springdale Play through October, 2005. Note that some wells appear to have peaked and are already in decline while others show steady or rising production.

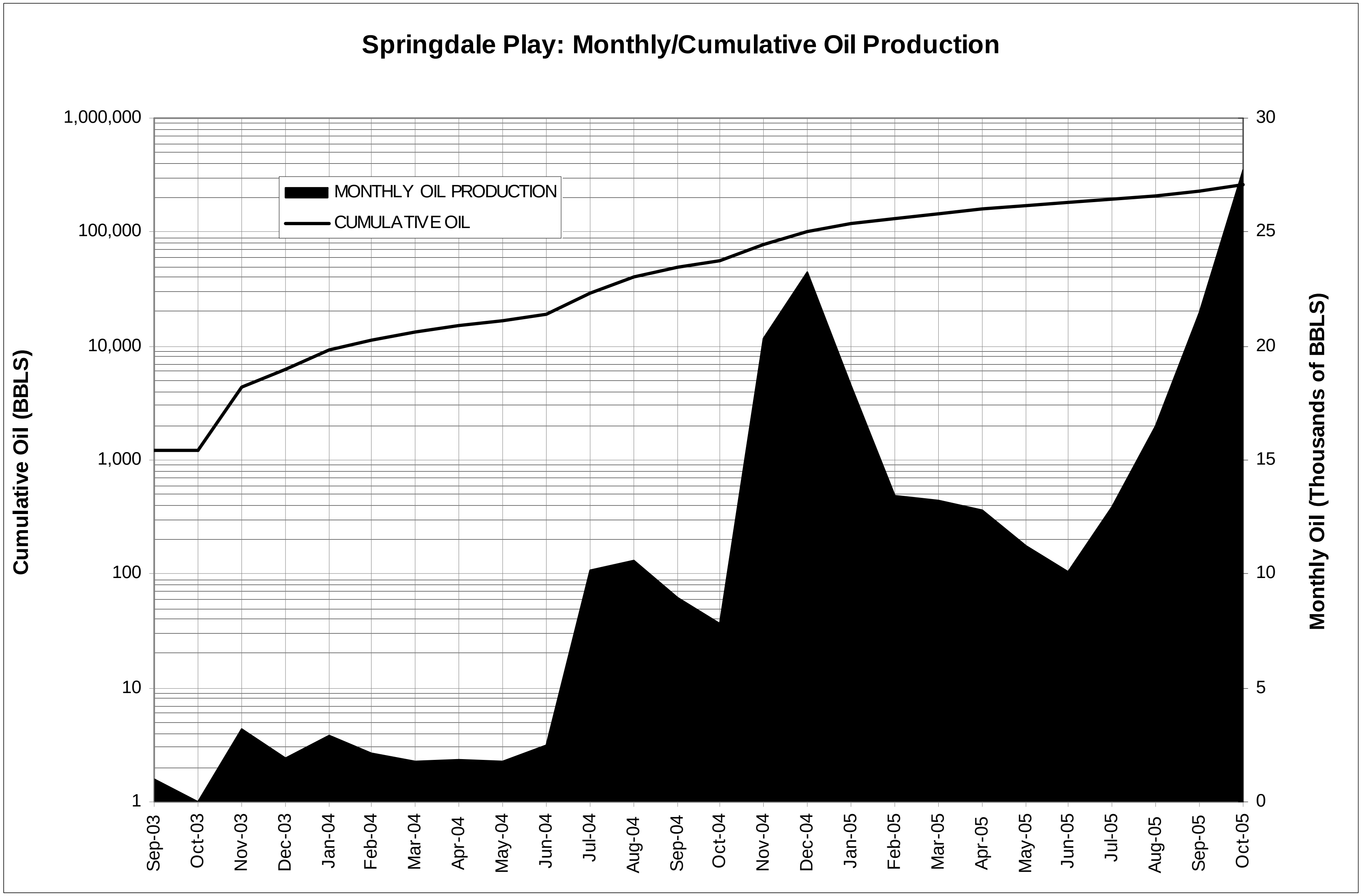


Figure 16. Graph showing monthly and cumulative oil production at Springdale. Monthly production varies widely due to increasing number of wells coming on production. Note that the cumulative production is still rising.

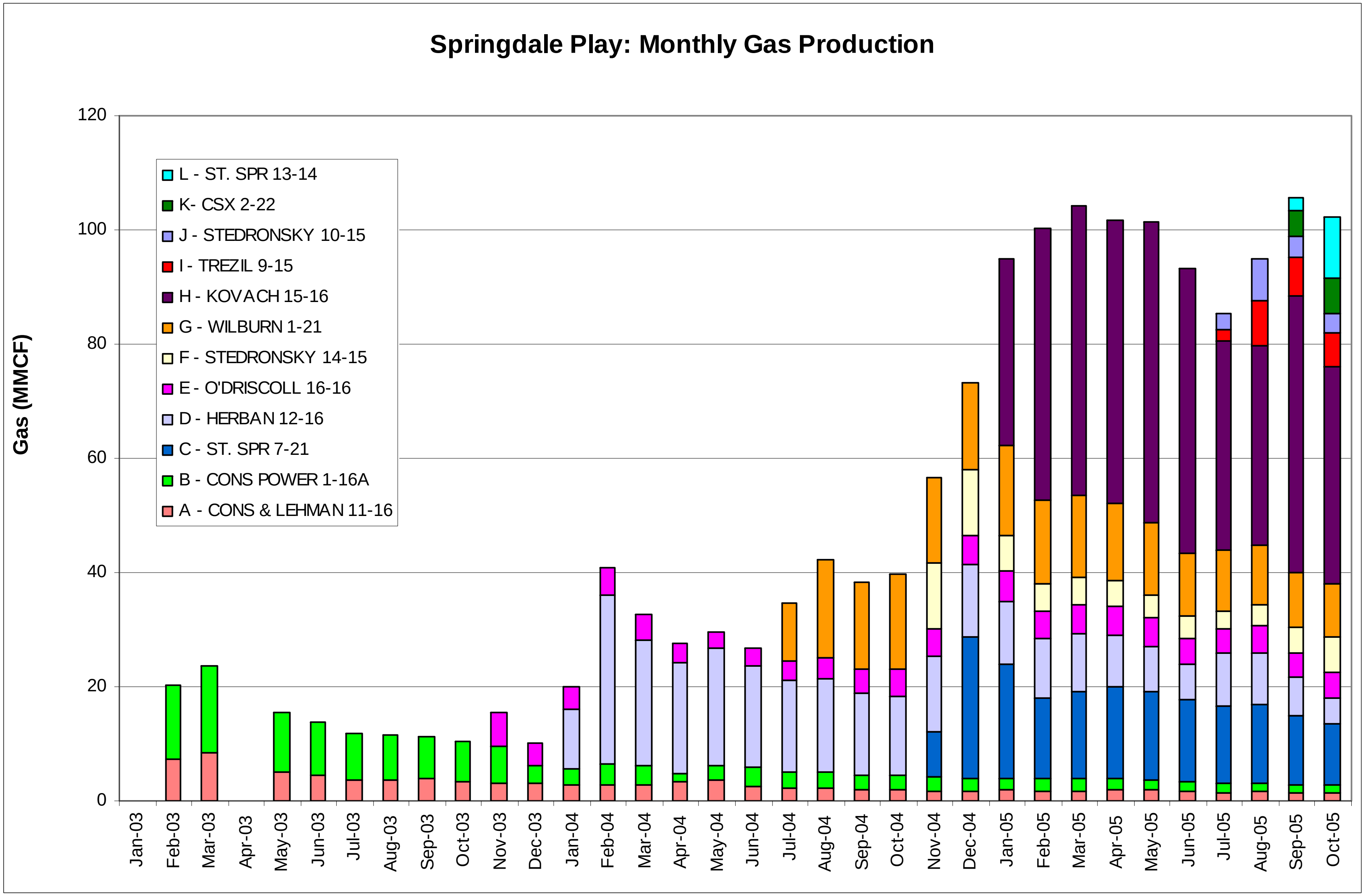


Figure 17. Bar graph of gas production by well at Springdale. Some wells are mainly gas producers (compare with previous figure). Springdale appears to show a rough zonation from water to oil to gas.

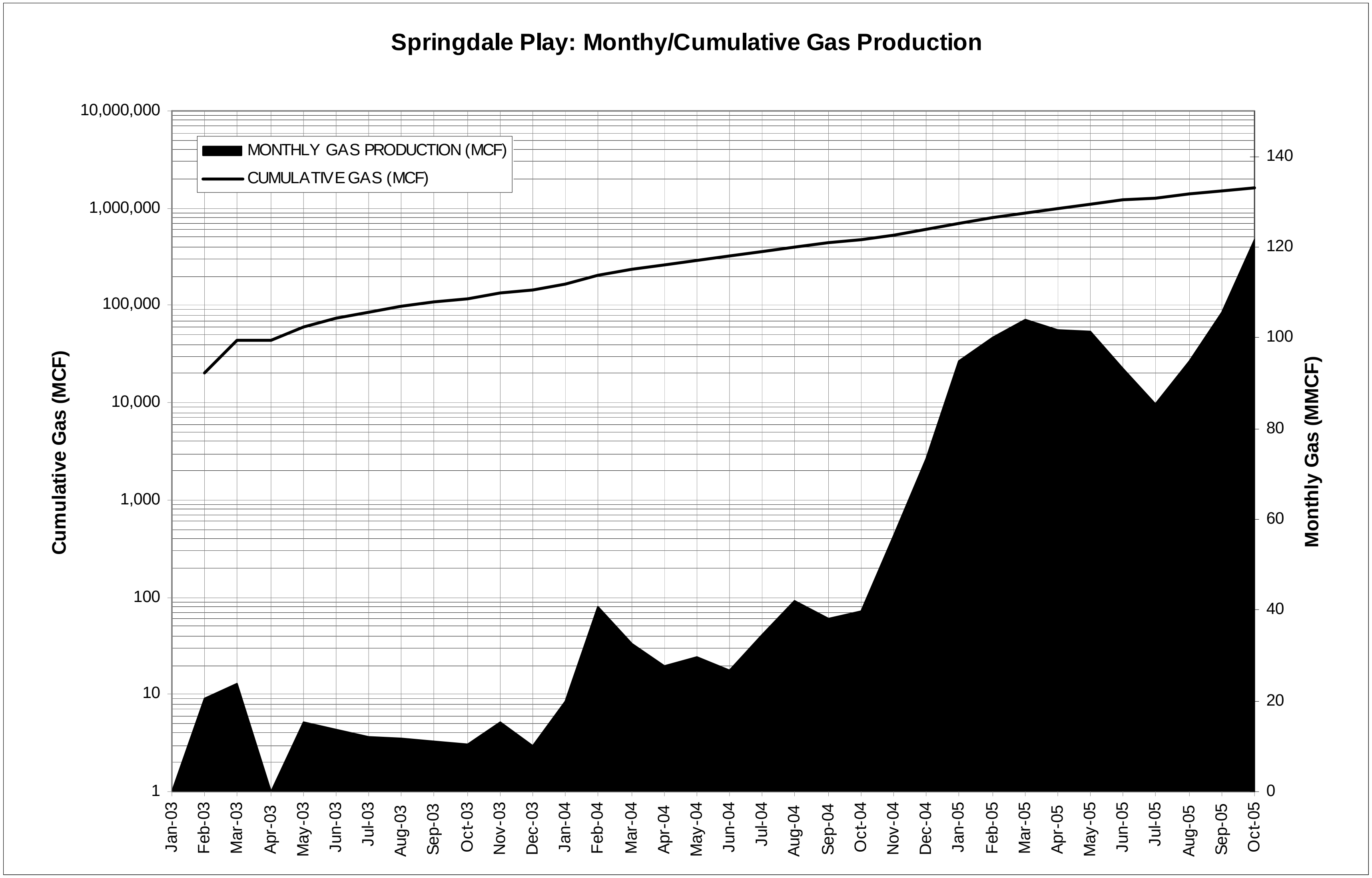
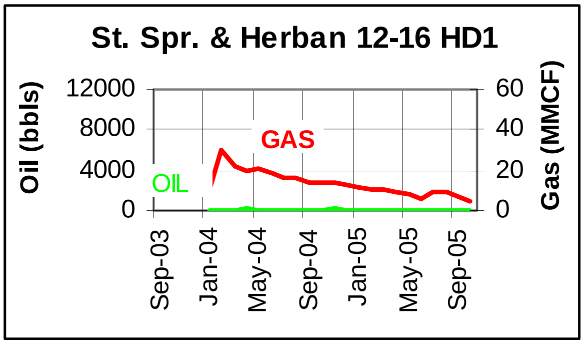


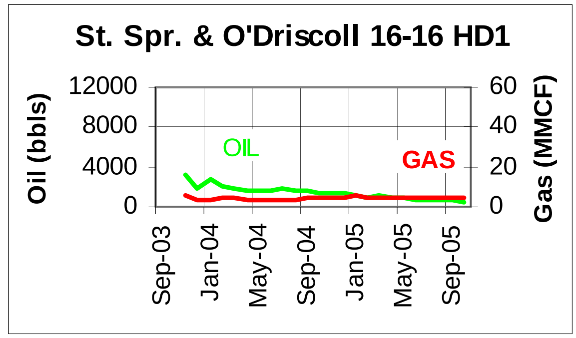
Figure 18. Graph showing monthly and cumulative gas production at Springdale. Monthly production varies widely due to increasing number of wells coming on production. Note that the cumulative production is still rising.

Figure 19a-l. Graphs showing oil and gas production for each of the Springdale Play horizontal wells. Most of these graphs are for only the first several months for most wells.

(a) 55797: State Springdale & Herban 12-16 HD1
(b) 55782: State Springdale & O'Driscoll 16-16 HD1
(c) 56362: Kovach 15-16 HD
(d) 56146: State Springdale & Wilburn 1-21 HD
(e) 56530: State Springdale & Stedronsky 10-15 HD
(f) 56163: State Springdale & Stedronsky 14-15 HD
(g) 56365: State Springdale 13-14 HD
(h) 56543: State Springdale & Trezil 9-15 HD
(i) 56337: State Springdale 7-21 HD
(j) 56830: State Springdale & CSX 2-22 HD
(k) 56887: State Springdale & Mann 9-21 HD
(l) 56361: State Springdale & Messner 6-16 HD


St. Spr. & Herban 12-16 HD1
Oil (bbls)
Gas (MMCF)
12000
8000
4000
0
60
40
20
0
GAS
OIL
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05

a


St. Spr. & O'Driscoll 16-16 HD1
Oil (bbls)
Gas (MMCF)
12000
8000
4000
0
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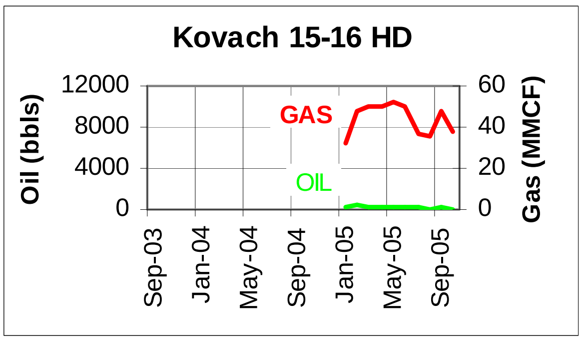
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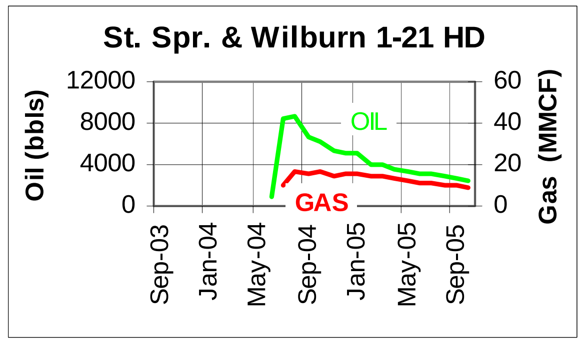
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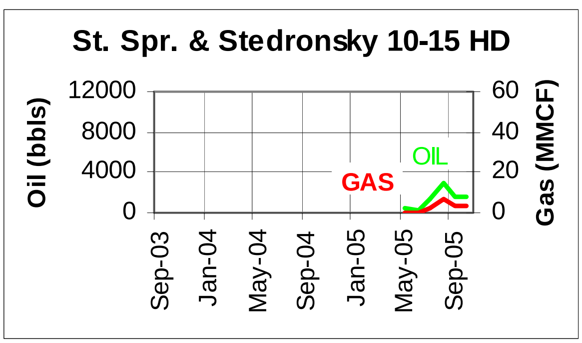
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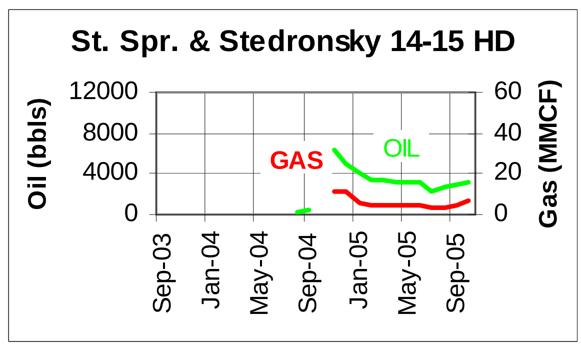
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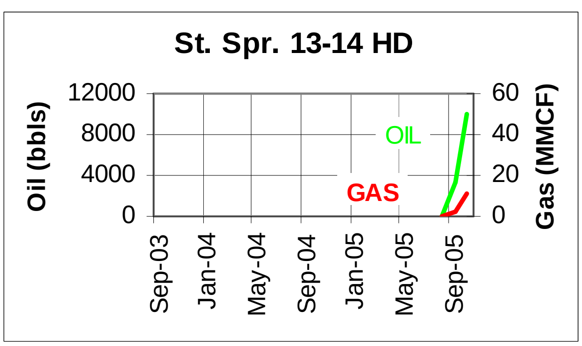
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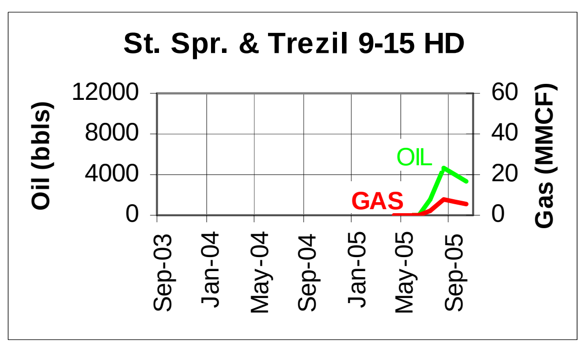
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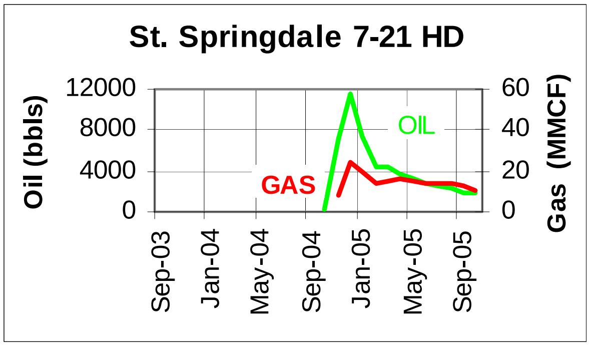
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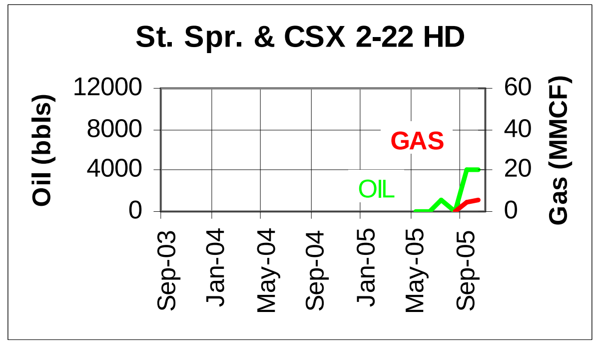
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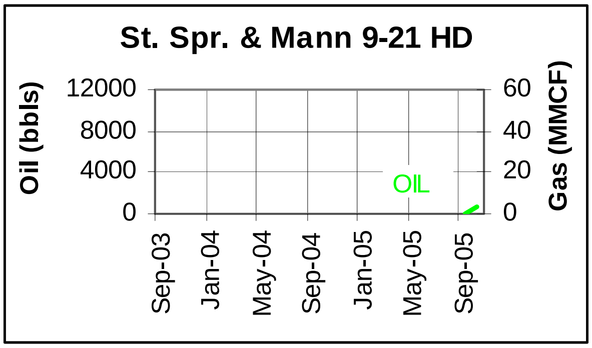
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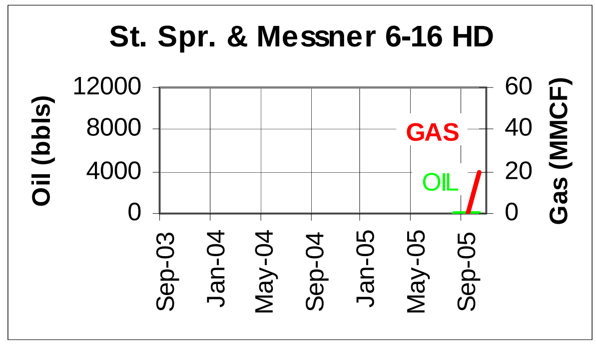
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Figure 20. Soil gas data for the surface geochemical survey at Springdale. The surveys were conducted at different times during the period 2004-2005. Samples (300-400 g) from below the "B" horizon were collected and sent to the Direct Geochemical Labs for analysis of the absorbed gas. See text for details.

(a) Springdale – Geo-Microbial Technologies; Initial microbial samples over Springdale were tested in a grid pattern. Microbial samples were also analyzed over the Mann 9-21 well to compare geochemical results with C1-C8 Hydrocarbon counts.
(b) Springdale – Direct Geochemical; C1-C4 factor scores.
(c) Springdale – Direct Geochemical; C5-C6 factor scores.
(d) Springdale – Direct Geochemical; Discriminant Function plot of C1-C8 Hydrocarbons in Springdale soils.
(e) Springdale – Direct Geochemical; Oil probability
(f) Springdale – Direct Geochemical; Gas probability

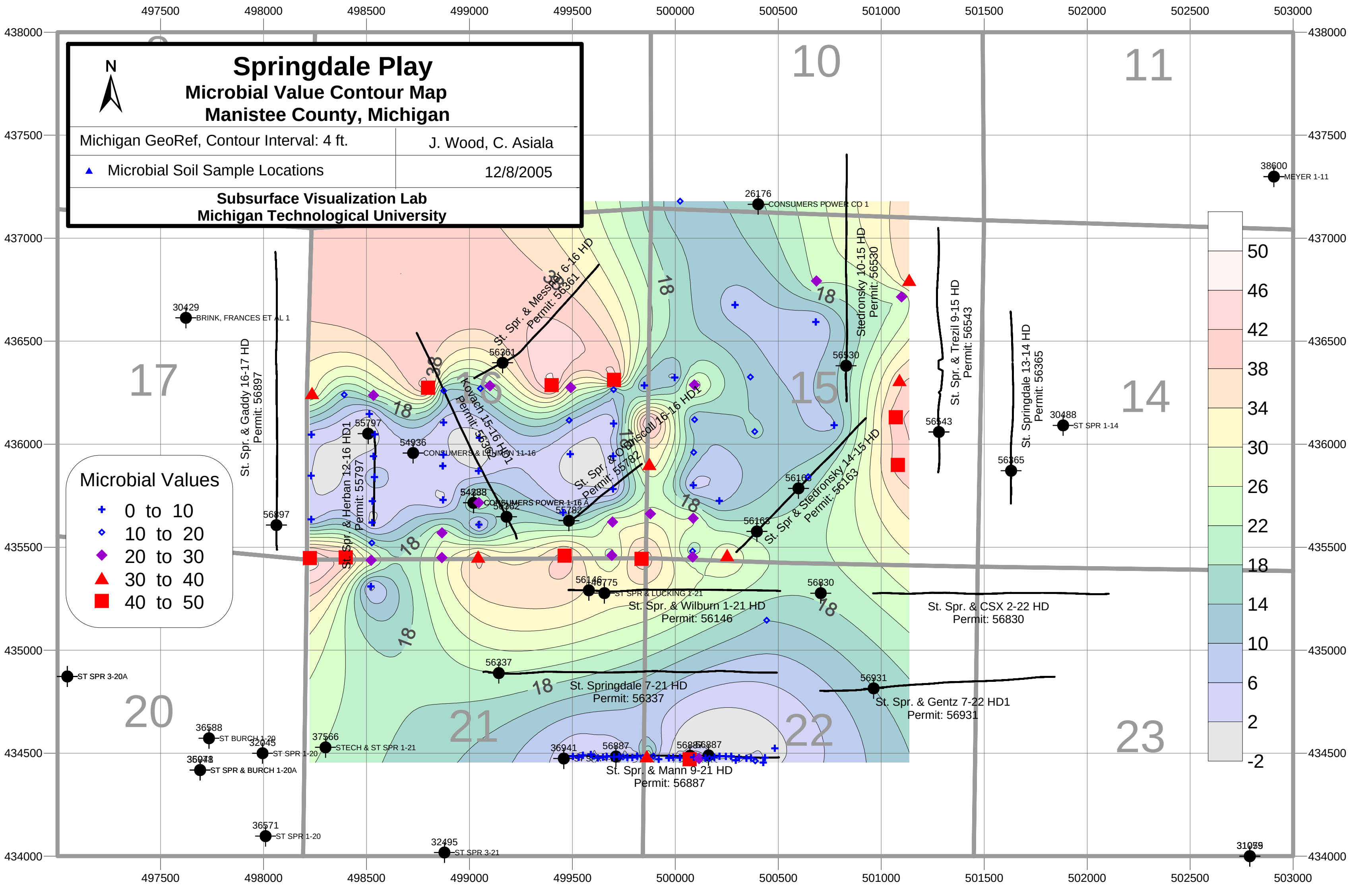

Figure 20a. Springdale – Geo-Microbial Technologies; Initial microbial samples over Springdale were tested in a grid pattern. Microbial samples were also analyzed over the Mann 9-21 well to compare geochemical results with C1-C8 Hydrocarbon counts.

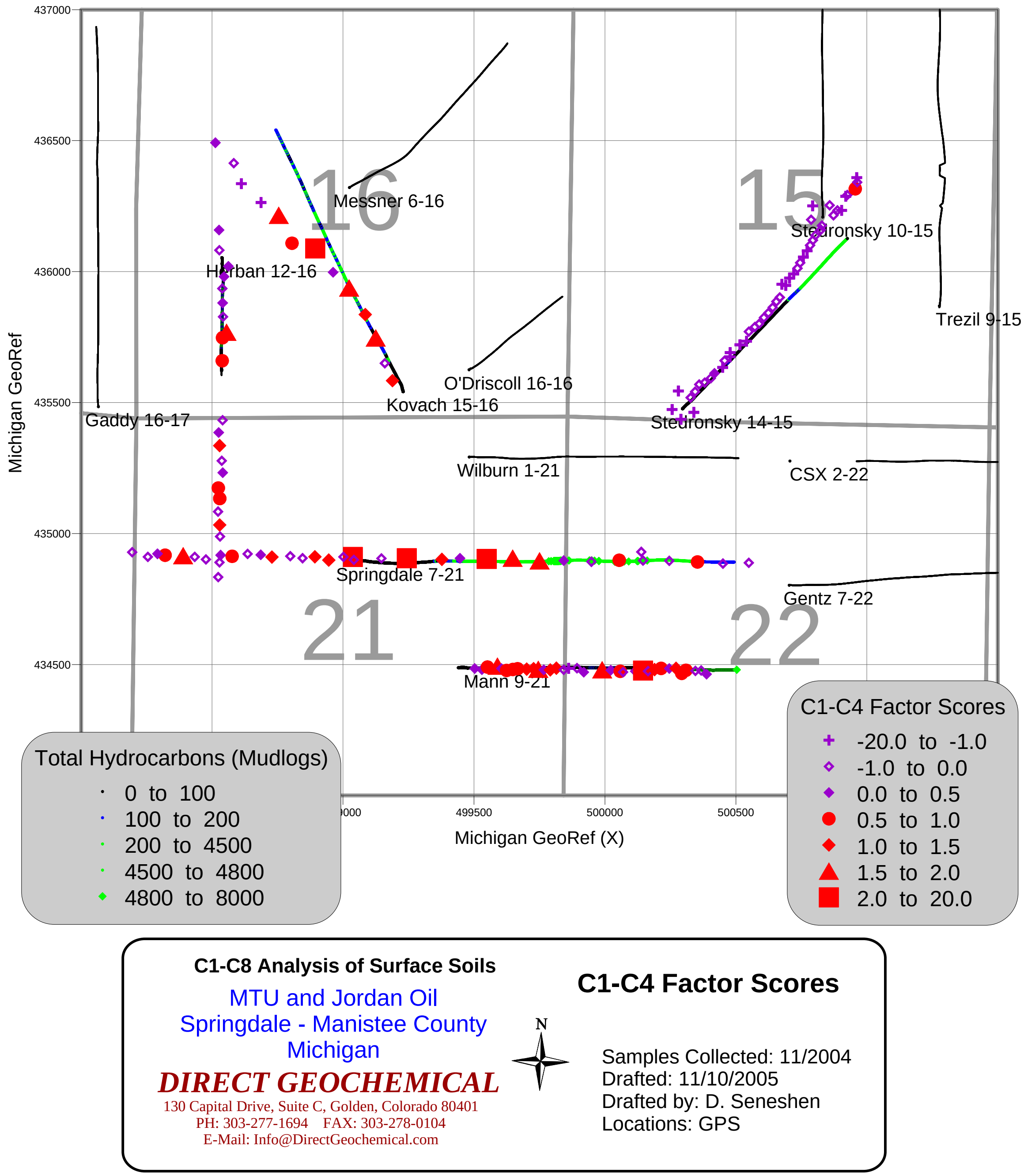

Figure 20b. Springdale – Direct Geochemical; C1-C4 factor scores.

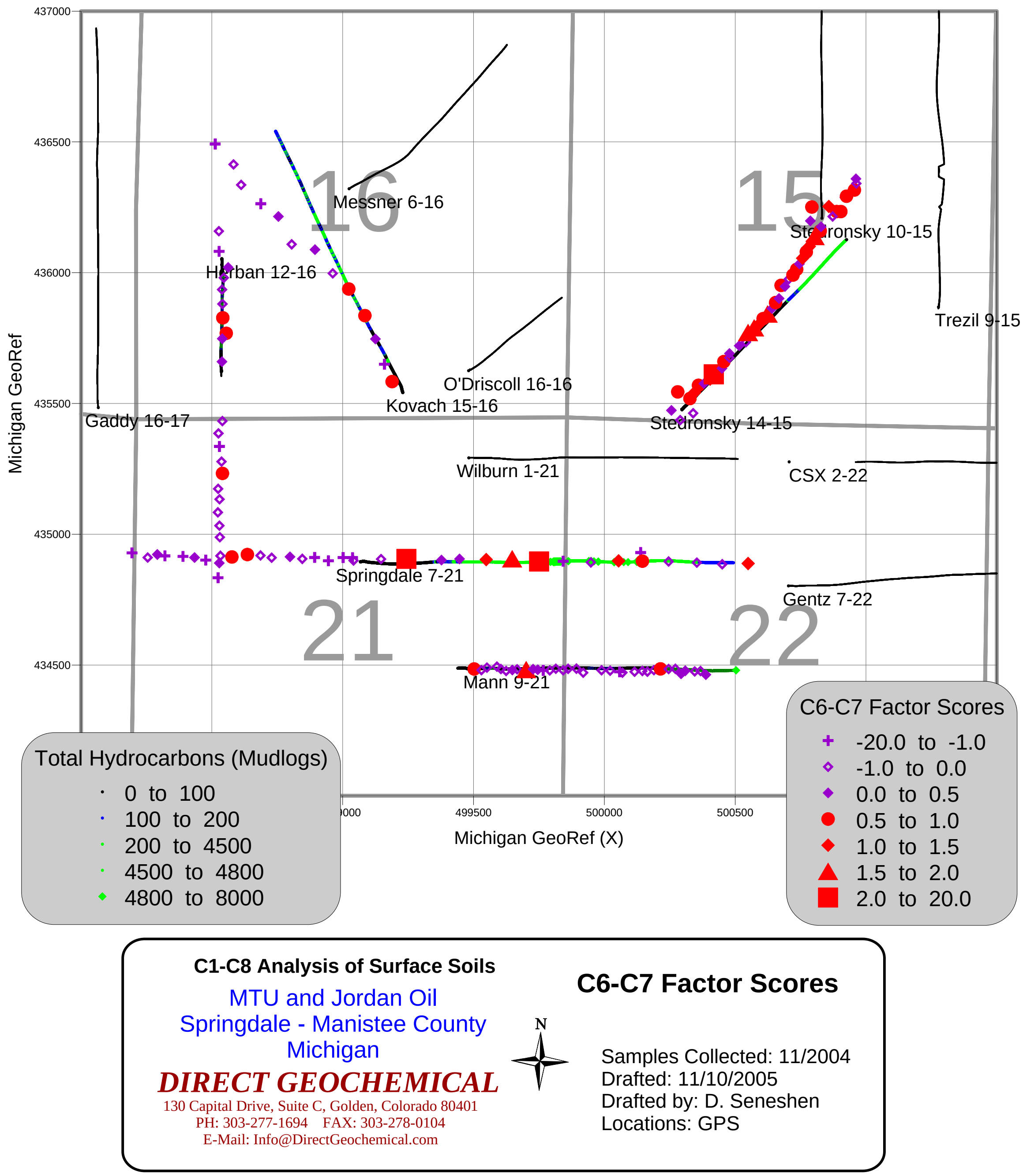

Figure 20c. Springdale – Direct Geochemical; C5-C6 factor scores.

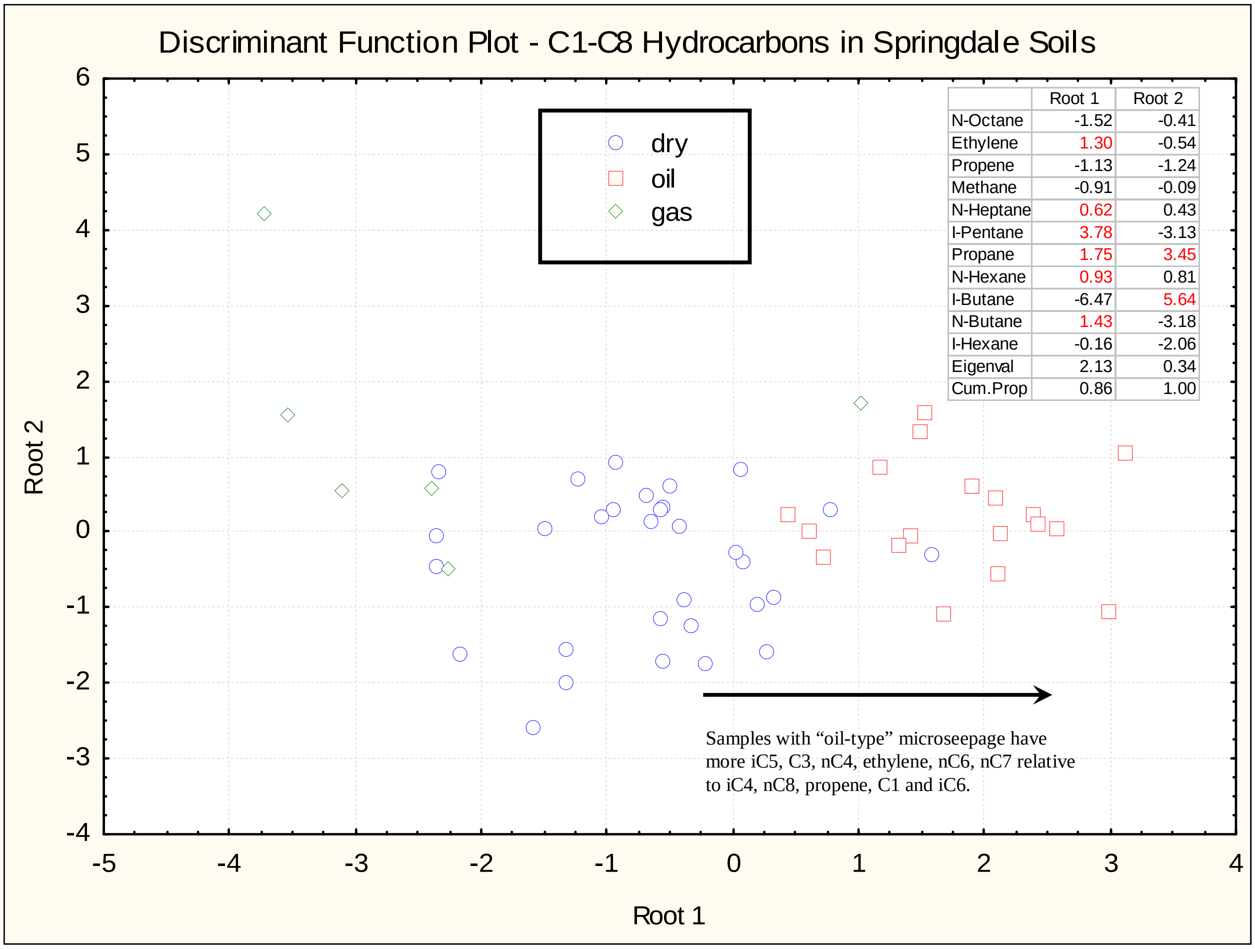

Figure 20d. Springdale – Direct Geochemical; Discriminant Function Plot of C1-C8 hydrocarbons in Springdale soils.

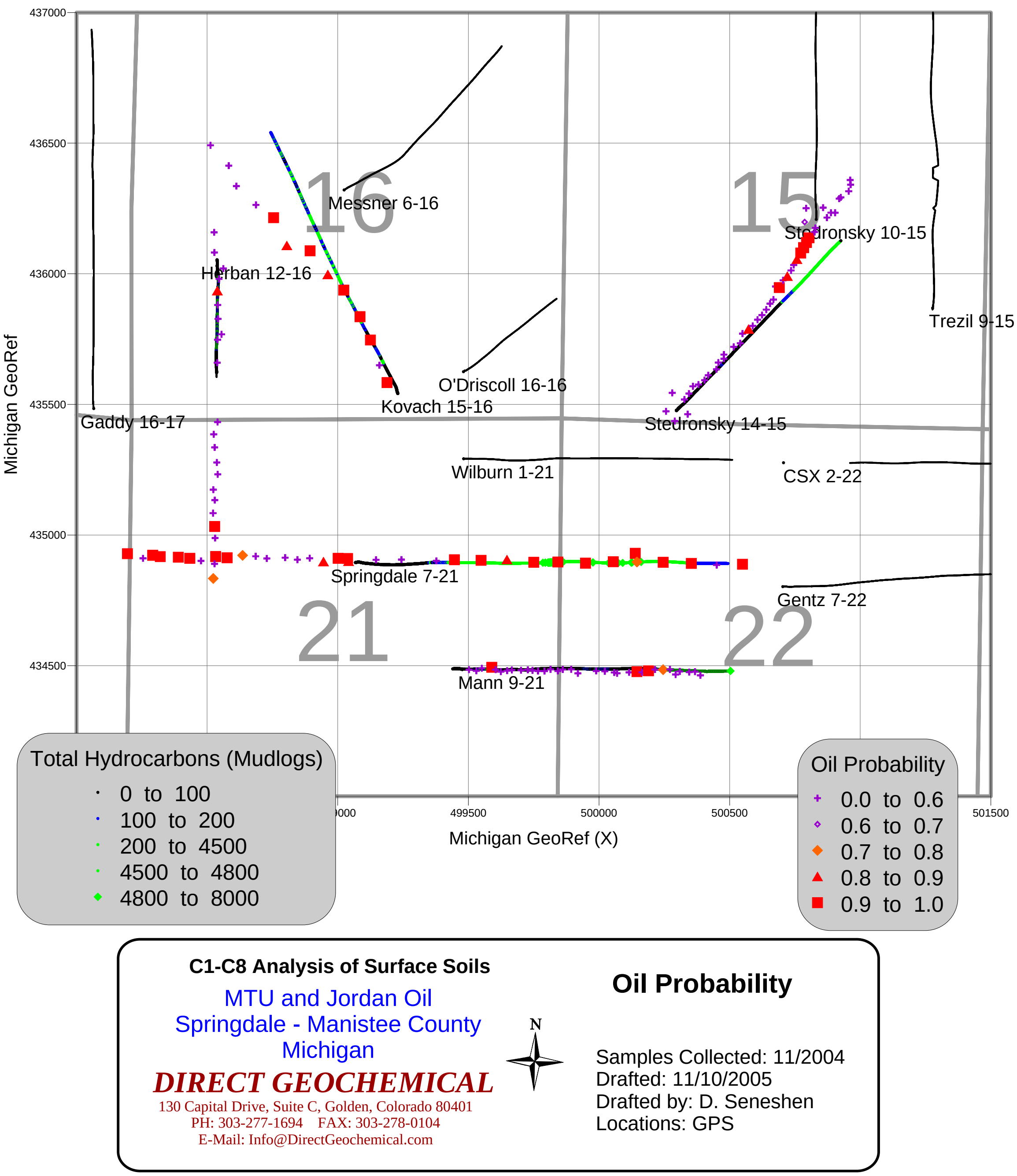

Figure 20e. Springdale – Direct Geochemical; Oil probability.

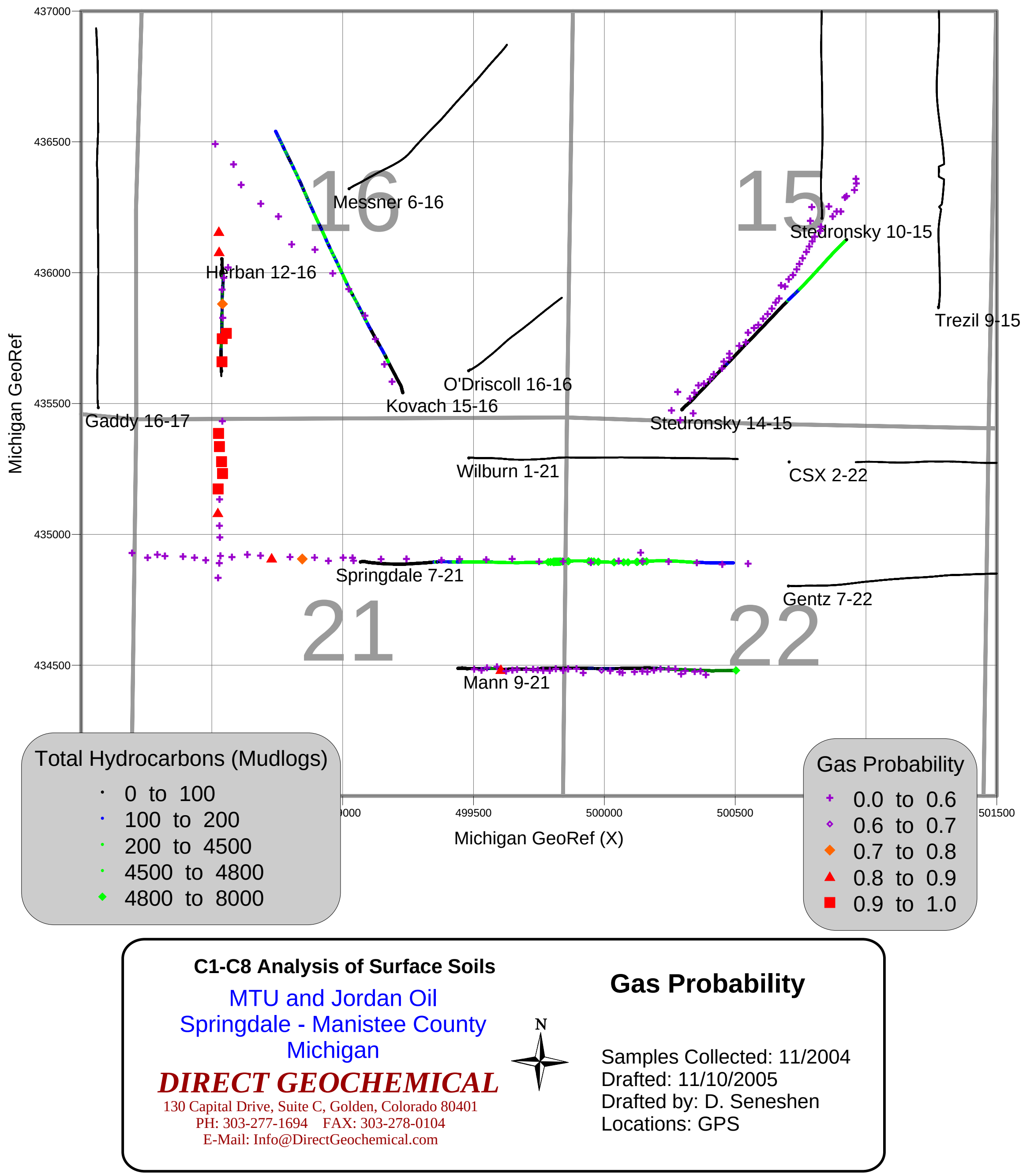

Figure 20f. Springdale – Direct Geochemical; Gas probability.

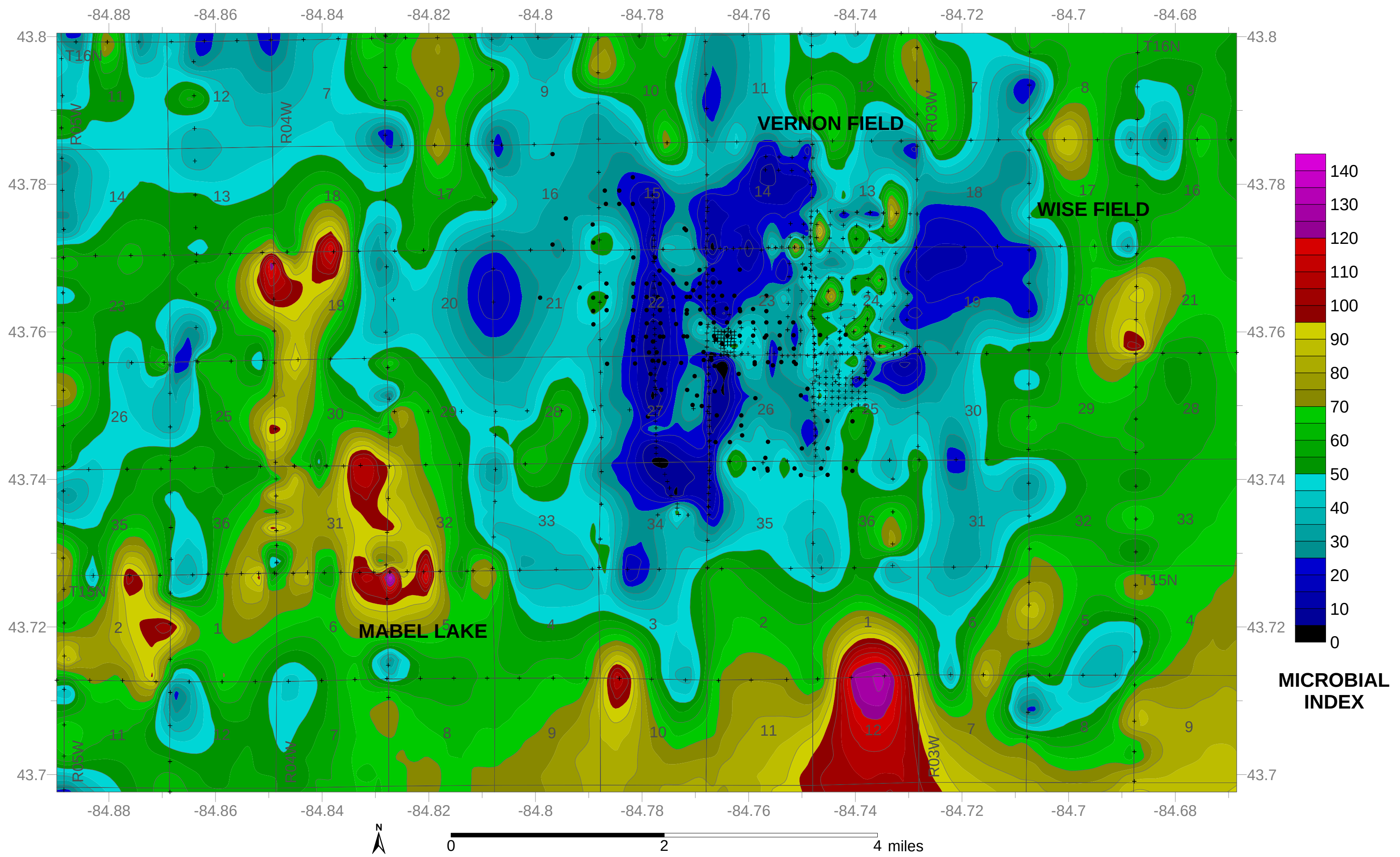

Figure 21. Microbial sample location map and contour map for the Vernon Field and surrounding area in Isabella County, Michigan. Black crosses are the microbial sample locations and black circles are well locations. Blue color filled contours indicate low microbial anomalies. The entire Vernon Field is a large negative anomaly.

10.0 APPENDIX A. Vernon Case History and Well Summary

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

ABSTRACT

Presented in this quarterly report is the Case History and Well Summary for the Vernon Field demonstration project in Isabella County, Michigan. This new case history and well summary format organizes and presents the technical and historical details of the Vernon Field demonstration, as well as the field demonstration results and the applicability of these results to other demonstration projects. This format could be duplicated for other demonstration projects and will be used on all subsequent field demonstrations as they near completion.

Planning for the annual project meeting in Tampa, Florida has begun. This meeting will be held March 7-9, 2003 at the same site as the last three meetings.

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LIST OF GRAPHICAL MATERIALS

Figure 15. State Vernon & Smock 13-23 #HD1 and #HD1A well path, curve, and horizontal laterals. Log curves are gamma ray on left or bottom and neutron curve on right or top in log track. Mudlog images shown along path. Inset map shows location of well and laterals in Section 23, in the southwest quarter and structure on the top of the Dundee.

Figure 16. Dundee cap rock isopach map showing pre-drill geology for the Vernon Field and the location of the State Smock well. North is to the left. Prepared by Eric Taylor.

Figure 17. State Vernon and Smock post drill well bore schematic. See Figure 16 for location of cross section (interpretation by Eric Taylor).

Figure 18. State Vernon and Smock post drill well bore schematic showing interpreted path of laterals (interpretation by Eric Taylor).

Figure 19. Structure map on top of Dundee porosity showing location of Bowers 4-25 well. The State Vernon and Smock well bore and lateral paths are also shown. (interpretation by Eric Taylor).

Figure 20. Bowers 4-25 well log. Gamma ray shown on left and neutron curve on right.

1.0 EXECUTIVE SUMMARY

Goals and Results

The goals of this project were to: (1) test the use of multi-lateral wells to recover bypassed hydrocarbons and (2) to access the potential of using surface geochemistry to reduce drilling risk. Two new demonstration wells, the State-Smock and the Bowers 4-25, were drilled to test the Dundee Formation at Vernon Field for bypassed oil. Neither well was commercial, although both produced hydrocarbon shows.

An extensive geochemical survey in the vicinity of Vernon Field, covering much of Isabella County, has produced a base map for interpretation of anomalies in Michigan. Several potential new anomalies were discovered that could be further investigated.

New Findings

Our knowledge of the state of the upper Dundee Formation greatly increased as a result of the drilling of the State Smock. We now feel that the top of the Dundee near the Vernon Field represents an exposed karst surface spotted with deep sinkholes filled with shale, perhaps similar to modern day topography around Tampa, Florida.

Lessons Learned

The State Smock well has provided us with several lessons, the most important being that in drilling old fields like Vernon, it is best to begin with a drilling program that includes a vertical test well to verify the presence of a pay zone, then follow with a horizontal well with multi-laterals. In the case of the first demonstration well, the State Smock, no vertical well was drilled and the first lateral drilled encountered a shale plug that was avoided with the second lateral. A vertical well would probably have established the absence of a pay zone and avoided the cost of a lateral.. In the second demonstration well, the Bowers 4-25, a vertical well was drilled and when it failed to show a pay zone the well was abandoned. In both cases, the surface geochemistry indicated marginal plays.

It has also been learned that natural fractures may play a key role in the production of these carbonate reservoirs. Isolating productive regions from water conductive fractures may be an important issue in recovering significant bypassed reserves. In addition, formation damage due to pulverized cuttings and drill pipe abrasion appears to be a prevalent issue within porous zones, even after relatively short periods of lateral drilling exposure.

An additional lesson is that geochemical surveys, particularly microbial, are worthwhile in these fields. Microbial surveys are relatively inexpensive and in this case appeared to provide reliable guides to the presence or absence of hydrocarbons.

Finally, the value of spreading the funding over many demonstration wells (5-6 ?) rather than just 1-2 seems justified since that permits better testing of the geochemical predictions.

Applications

The results of the Vernon demonstration wells can be applied to other shallow shelf carbonate reservoirs worldwide. In particular the application of appropriate surface geochemistry surveys seems warranted based on the work done here, as well as the advice to precede drilling the horizontal wells with vertical test wells to establish the presence of a pay zone.

The shallow-shelf carbonates in the Permian Basin, the mid-continent, and Rocky Mountains (e.g. Williston basin) are logical targets for application of these techniques.

Did Data Support Project or Not?

The surface geochemistry data did support the project quite well: it predicted that both of the demonstration wells would likely be marginal. In other words, the geochem did not show the strong anomalies that would justify drilling on the basis of that data alone.

The demonstration wells again showed the value of the vertical probe well in these situations.

Future Work

More geochemical work will be done in conjunction with further field demonstrations as part of this project. Several more techniques will be used, including SPME (Site Specific MicroExtraction) and analysis of carbon fibers.

New demonstration wells are planned for North. Dakota to test the Duperow Formation, as well as several in Michigan to test the pinnacle reef plays. Preliminary results using the microbial techniques show good anomaly patterns for the reefs.

Should Something Else Have Been Done?

The first test well, the State-Smock, should have had a vertical test well and perhaps more faith should have been placed in the geochemical results. However, if the State Smock and the Bowers 4-25 wells had not been drilled, the predictions of the geochemistry would not have been verified.

2.0 EXPERIMENTAL

DOE Field Demonstration Case History and Well Summary: VERNON FIELD, Isabella County, Michigan

As part of the Class Revisit Program, a university-industry-DOE consortium drilled a multi-lateral well and a vertical well in Vernon Field, Isabella County, Michigan Prior to drilling, a surface geochemical survey was run over the area using several different geochemical techniques and a good anomaly was detected using microbial indicators. The surveys were conducted in several stages in May and August of 2000 and later in November as the well was being drilled. The May survey was a north-south line profile across Vernon Field parallel to Mission Road and was designed to test several geochemical methods. These included: surface iodine, enzyme leach on samples from the "B" soil horizon, head space gases from sample depths of about 36 inches, and microbial. The results indicated that the microbial survey produced the best results and this geochemical method was adopted for all subsequent surveys. The May survey detected a positive microbial anomaly over the site of the proposed State Vernon & Smock #13-23 well, which was confirmed by both subsequent surveys.

3.0 RESULTS AND DISCUSSION

DOE Field Demonstration Case History and Well Summary: VERNON FIELD, Isabella County, Michigan

3.1 VERNON FIELD HISTORY

Vernon Field is located in T16N-R4W in Vernon Township, Isabella County MI (Figure 1 and 2). The field was developed in the 1930's. Most wells were drilled by 1935. The field was redeveloped once in the 1950s and several new wells were drilled in the 1980s. The field development predated all other Dundee discoveries in the state except for Port Huron, Muskegon, and Mt. Pleasant. The main producing zone is the upper Dundee ("Rogers City"), which is a shallow-shelf carbonate (Figure 3), locally altered to porous, vugular dolomite by hydrothermal fluids. The field was generally developed on 10-acre spacing (Figure 4) with several secondary disposal wells. Most wells had high initial production rates of up to 5000 barrels of oil per day, however, the production rates dropped off rapidly and many wells were abandoned by the late 1940s (Figure 5 and 6). The field produced 5 million barrels of oil from the original 78 wells with an average recovery of 5,700 barrels (bbls)/acre. The field is situated on a plunging anticline, but the oil pool is primarily the result of an updip permeability barrier-type stratigraphic trap, sealed to the south by impervious limestone. The top seal is the Bell Shale. Reservoir pressure is maintained by a strong bottom-water drive and the original oil-water contact is projected at a subsea depth of -2950 feet. The maximum gross pay thickness is 55 feet.

3.2 RESERVOIR PROPERTIES

Dundee reservoirs are generally composed of two lithologic types - limestone and dolomite. The limestone depositional facies reflect original depositional lithologies including grainstone shoal carbonate sand, fenestral peritidal packstones and wackestones, and stromatoporoid/coral boundstone patch reefs. The dolomite facies are related to the overprinting of burial diagenetic fabrics onto the limestones including hydrothermal dolomites resulting in fractured and vuggy fabrics and sucrosic to laminated dolomite with nodular to bedded anhydrite fabrics. Dolomite reservoirs have pervasive replacement of the original limestone fabric. However, in some cases the original depositional fabric is preserved and provides a template for additional diagenesis. Solution enhanced pores, vugs, and fractures are common and often contain saddle or hydrothermal dolomite cements (HDT). In some Dundee Fields the drillers report bit drops of two to three feet (Fitzgerald and Thomas, 1932) suggesting open fractures may be common. In the Vernon Field, fluorite has also been found in the solution cavities in the reservoir rock as well developed crystals (Fitzgerald and Thomas, 1932) suggesting that Mississippi-valley-type (MVT) hydrothermal processes may have played a role in the creation of the reservoirs. Stylolites are abundant in the Dundee as the result of chemical compaction during burial diagenesis.

Fractures enhance the permeability, especially the vertical permeability, in many Dundee reservoirs. The original limestone porosity fabric has also been altered and modified by the movement of fluids along these fractures. Fractures have enhanced permeability and porosity and thus oil productivity but they have also allowed the coning of water during production of these reservoirs.

In the Vernon Field, the reservoir occurs in the upper portion of the Dundee Formation in the Rogers City Member. The reservoir is comprised predominately of vuggy dolomite lenses or beds interbedded with tight dolomite. Net porous interval to total interval ratio (net to gross ratio) is estimated at 60 percent. Fractures help connect vuggy and matrix pores.

Openhole electric logs and porosity logs are not common in most Dundee fields developed before 1970. However, drillers logs and sample reports are available for many of the wells and can be useful for interpretation. Initial potential data from the wells can be used to characterize the general reservoir architecture and pore network.

3.3 PRODUCTION ENGINEERING -how wells completed and produced

Engineering parameters are generally not directly available for the old wells in this field. It may be possible to estimate some parameters from production history data and the few wireline logs in the field. Production history data has been compiled courtesy of Eric Taylor, Consulting Geologist from Traverse City, Michigan (Figure 5). Very high initial rates were recorded from the field, but production dropped rapidly.

An observation by Bill Harrison (personal communication) indicates that the water production history in Dundee dolomite reservoirs is different than the water production from limestone reservoirs. In addition, historical reservoir management practices by the operators have had dramatic effects on the recovery of oil, gas, and water. Limestone fields are mainly solution gas or pressure depletion drive reservoirs and are good candidates for enhanced recovery. Dolomite reservoirs are primarily water drive and may have high primary recovery and limited enhanced recovery potential.

3.4 GEOCHEMICAL

A surface geochemistry program was initiated at Vernon Field in order to discover if geochemical anomalies were associated with the field. The surveys were designed to examine four different geochemical techniques based on a literature review and discussions with vendors. The four geochemical techniques to be evaluated were: surface iodine, microbial, enzyme leach, and soil-gas. These are established techniques with a supportive literature and a number of service companies willing to conduct the surveys and/or do the analyses. In this study, project personnel collected all samples and interpreted the data. Commercial service companies conducted the analyses.

Although we started with no bias toward or against any one technique, we moved to an initial position favoring the microbial data because it gave a positive (apical) anomaly that is easy to interpret. Another technique that might be as good or even better, direct measurement of soil gas hydrocarbons, was not pursued as vigorously due to the cost of analysis ($50 - 200/sample) and the difficulty of sample collection (samples are taken from 3-4 foot depths). However, this technique might have warned us that the demonstration well was located over a poor site. We are not yet committed to any one technique and will continue to examine other geochemical techniques in subsequent demonstration well areas.

3.4.1 Sampling Program

A geochemical sampling program for the Vernon Field, Isabella Co., Michigan was initiated during the spring of 2000. An area of Vernon Field approximately 2-3 square miles in area was sampled over a period of six months from May 2000 to November 2000. Four separate sampling trips were taken and over 360 sample sites visited. Multiple samples were collected at several sites.

On May 12, 2000, the first or reconnaissance phase of geochemical sampling over the field was completed. The Mission Road profile (Orientation Profile) was completed and a total of 50 locations spaced 300 feet apart were sampled (Figure 3). The Mission Road profile is a N-S profile adjacent to Mission Road across the field. Four types of samples were collected: surface microbial, enzyme leach, iodine, and soil gas. In addition, 3 samples were collected over the proposed horizontal drill hole, the State Smock.

The initial line survey was extended to include 148 more samples arrayed across five 5 1-2 mile lines (Figure 7). Samples were collected for 3 types of analysis, microbial, iodine, and enzyme leach (sorbed soil gas was dropped.) To date, eight sampling trips have been made to Vernon Field and vicinity and over 800 samples have been collected for geochemical analyses.

3.4.2 Sample collection

Soil samples were collected for microbial analysis, surface iodine, enzyme leach selective extraction, and soil head gas at selected localities. Duplicate samples were analyzed to evaluate precision error. Sample site locations were recorded in the field with a hand held GPS and plotted on base maps derived from the Michigan DNR spatial data library.

On the first sampling trip, samples were collected along a line profile (1D survey) at 200 meter (600 feet) spacing (Figure 4). It was necessary to establish a grid spacing that would adequately sample the anomaly without over sampling. One requirement we attempted to meet was to sample one square mile per day. As mentioned, the MRP was sampled at nominally 200 meters (600 feet). Although this spacing appeared adequate, it was decided tighter spacing was needed over the fields and a spacing of 100 meters was adopted for the grid in both directions. This spacing works out to 8 samples per mile or 64 samples per square mile. This spacing was found to produce good contour maps of the microbial anomalies but may not be sufficiently dense to resolve all features. Assuming 20 minutes to walk 1 mile, then 8 samples per mile leaves 5 minutes per station if we want to cover 1 mile in an hour. Microbial samples can be collected in this time, including reading and recording the site location. We found that one man could easily make four 1-mile traverses per day e.g. cover ½ square mile. The optimal sampling team was found to be a team of two men sampling 1 square mile per day, each collecting 32 samples.

3.4.3 Microbial

The microbial oil survey technique is based on the principal that hydrocarbon gases in the soil directly influence the microbial population over an oil reservoir. These gases escape from the hydrocarbon reservoir and migrate upwards in very small quantities (microseeps). Specific organisms are associated with hydrocarbon gases and there is an expected positive correlation with amount of microbes and occurrence of hydrocarbons at depth. The microbial technique is based on the premise that microbes living in the soil are unique depending on their food (energy) source. Microbes that thrive on light hydrocarbon gases (C1 - C4) in particular are known to feed exclusively on these gases, even to the extent that one microbe may consume only one type of gas composition (e.g., C3). The technique is based on culturing these microbes in a laboratory for a period of time on a special substrate and then counting the microbe population. Samples are collected 8 inches below ground surface and cultured within 48 hours of collection. The main assumption is that the microbes will be present if the gases are present and that the microbes will be absent otherwise. Since C2 - C4 hydrocarbons are widely thought to originate only from gas and oil accumulations, the presence of microbes specialized to feed on these gases is taken as evidence of a migration of hydrocarbons from the reservoir to the surface. An anomaly should remain only as long as hydrocarbons of sufficient quantity exist in the subsurface to provide microseepage of gases to the surface. Thus, this technique can be used to detect by-passed oil in depleted reservoirs.

Geo-Microbial Technologies Inc. in Ochelata, OK did the analyses (www.gmtgeochem.com).

The raw results for microbial are given in Table 1. Microbial data are log-normally distributed based on visual inspection and the KS statistical test. The median value is 12. The 90% quintile is a value of 30 and values above 30 are considered anomalous. A total of 6 out of 50 analyses are greater than 30 with 3 of these samples taken directly above the proposed horizontal well. Microbial data show an apical anomaly over the center of the Vernon field. Microbial is variable and generally below 25 off of the center of the field. These results suggest by-passed oil potential is good in the area of the proposed horizontal well.

The microbial Mission Road profile results are shown in Figures 8 and 9. Samples were collected at 200 meter (600 feet) spacing. It is apparent that the high values occur over the known extents of Vernon Field, and the samples collected over the proposed drill site initially appeared to show anomalies. Results for the 2D microbial survey over the Vernon Field study area are shown in Figure 10 and 11. The sampling locations are indicated and the bubbles in Figure 10 represent values of microbial density as cultured in the laboratory from the field samples. In general, the data show lows to the west over the part of Vernon Field that is still under production, increasing to the East with a still unresolved high outside the filed to the Northeast. This high nominally lies along Isabella Road and has been termed the Isabella High. The origins of this high are unknown, but may be due to gas in the shallow Pennsylvanian Stray Formation. Geologic data suggests that it is unlikely to be due to a Dundee source but this has not been definitively ruled out. There is a microbial high over the demonstration well, but statistical analysis suggests that this should be regarded as a marginal anomaly. Data collected over the site of the second well, the Bowers #4-25 in the East Vernon Prospect (Figures 9 and 10) show a similar anomaly.

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:

TABLE 1.

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 10. Of the nearly 1100 geochemical samples collected (about 300 from outside the Vernon Field), roughly 22% (245) rank as "Good" or better. (microbial values for all 1100 samples ranged from 1 to 157.) Using these criteria, our first demonstration well, the State Vernon & Smock #13-23, had microbial values that lay in the ranges "Marginal" to "Good", while the second demonstration well, the Bowers 4-25, 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.

3.4.4 Sorbed Soil gas

The sorbed soil gas method (Horvitz, 1985) involves acid extraction of light hydrocarbon gases that are sorbed onto clays or incorporated into carbonate cements in near-surface soils. The gases accumulate through microseepage from the hydrocarbon reservoir. Geo-Microbial Technologies, Inc. (GMT) determined the sorbed soil gases by flame ionization detector gas chromatography of the scrubbed and liberated gases. Soil samples were collected from approximately one-meter depth, placed into a metal collection can along with biocide (supplied by GMT). The concentration of light hydrocarbons can be used as an indicator of increased hydrocarbon microseepage. The ratios of the hydrocarbons, combined with published empirical soil gas ratios (Jones and Drozd, 1983) can be used to establish whether a prospect is in an oil, gas, or mixed prone region.

GMT website http://216.29.207.22/gmtgeochemcom/#

3.4.5 Surface Iodine

Iodine in surface soil samples has been demonstrated in the literature as an effective pathfinder for oil and gas in the subsurface (Gallagher, 1995). High concentrations of iodine are documented elsewhere around the perimeter of subsurface oil and gas accumulations, "classic" halo anomaly, and directly above the accumulation, apical anomaly. The halo effect is interpreted as the surface expression of a reduction pipe above the oil and gas accumulation. Soil was collected from the top one inch of the A-horizon for surface iodine analysis. Data and interpretations for this survey are shown in Figure 12 and discussed in the geochemical conclusions.

Graystone Exploration Labs Inc., Golden, Colorado conducted the analyses. (http://www.geo-tech.org/survey/ssiweb/ssiweb.html)

3.4.6 Trace Element and Rare Earths - Enzyme Leach Selective Extraction

The enzyme leach selective extraction method is based on selective extraction of elements trapped on amorphous MnO_2 (Clark). Amorphous MnO_2 is a very effective trap for migrating cations, anions, and polar molecules. Oxidation anomalies are predicted over reduced bodies in the subsurface for a suite of elements including Cl, Br, I, As, Sb, Mo, W, Re, Se, Te, V, U, and Th (oxidation suite). Rare-earth elements often follow the same pattern as the oxidation suite. Base metals can be anomalous, but with lower contrast with the background. According to Clark, the most common form of oxidation anomalies is as a halo with a central low over the reduced body in the subsurface. These anomalies may be symmetric, asymmetric, or partial around the buried reduced bodies. Clark provides an electrochemical interpretation for halo oxidation anomalies. Apical anomalies are most often interpreted as related to faults. Since enzyme leach anomalies take 100's of years to develop, they will exist long after oil has been extracted from a reservoir.

Soil was collected from just below the top of the B-horizon for enzyme leach selective extraction analysis. Analyses were done by Actlabs-Skyline, Tuscon, AZ (www.actlabs.com). The plotted results are shown in Figures 13 and 14.

3.4.7 Site Specific Micro Extraction (SPME) fiber

A new sampling technique not used at Vernon but planned for other demonstration sites.

3.4.8 Geochemical Conclusions

There is hydrocarbon microseepage from the Dundee reservoir of the Vernon Field that is detectable by surface soil geochemical techniques. Microbial data show a pronounced apical anomaly over the field and were elevated above the horizontal well. (The sorbed or headspace gas data strongly suggested that the location was poor.) The microbial data suggest good potential for by-passed oil especially over undrilled areas of the field. The microbial results have reasonable repeatability.

The surface iodine and oxidation suite enzyme leach results show a halo anomaly coinciding with the main part of the Vernon field with low values above the subsurface accumulation of oil in the Dundee and higher values at the edges of the field. Iodine values generally show opposite trends from the microbial data. Iodine surface samples are slightly different from Iodine values from the op of the 'B' soil horizon.

Enzyme leach trace elements show a halo pattern. Cu, Ni, Mn, and Th show good halos and Sr, Rb, Zr, Ce, and Sm show fair halos. Some trace elements are not useful for defining anomalies representing the field area.

The Smock demonstration well showed that hydrocarbons were present in the Dundee horizon, but the distribution was spotty. Geochemical and well results indicate that the geochemical data has to be properly calibrated for local conditions and that good sampling protocol and a tight sampling grid are essential.

3.5 SEISMIC

Preliminary cost analysis carried out in the pre-planning stages for the Vernon Field demonstration showed 3D seismic to be to expensive for this type of project (the cost is comparable to the entire drilling operation).

A goal of using advanced 2D seismic technology in this project was postponed to Phase II to allow more time to design the survey and integrate it with the surface geochemistry. Drilling schedules, dictated by expiring leases, did not permit us to implement both a seismic and surface geochemistry program is Phase I or Phase II. However in the Vernon Field, having subsurface control through 100+ wells pretty well defined the subsurface anyway. In addition, the thin reservoir interval and seismically 'fast' carbonates may not be resolvable given required shooting parameters including surface glacial til and surface infrastructure.

3.6 WELL DETAILS - STATE VERNON & SMOCK 13-23 #HD1 AND #HD1A

3.6.1 Overview

The State Vernon & Smock #13-23 was spudded October 5, 2000 in the Vernon Field and drilled to a total depth of 4630 feet, bottoming in the (Middle Devonian) Dundee Formation. Unfortunately, despite the good reservoir rock and numerous oil shows, the interval could not be produced and was abandoned January 12, 2001. The reason for the failure to produce is tentatively assigned to the hypothesis that the interval was previously drained by earlier wells.

The rational for selecting the Vernon area was the presence of attic oil. The Jordon prospect is situated on the most prolific lease in the Vernon Field. The object of the well was to test the ability of horizontal drilling technology to locate and produce reserves indicated by a surface geochemical survey. It was anticipated that the flexibility offered by the horizontal technology would permit probing the subsurface for pockets of by-passed oil via lateral offshoots. This was thought to be necessary due to the known production difficulties arising from the highly irregular contact between the top of the Dundee Formation and the bottom of the overlying Bell Shale. It is widely believed in Michigan that this contact represents an ancient erosion surface developed on karst. Given that the pay zones are usually only 10-15 feet thick, it is necessary to probe close to the contact without entering the bottom water and avoiding the overlying shale. The difficulty is measurably increased by the tendency to encounter shale "plugs" at the contact, which may be mud-filled sinkholes several 100 feet deep and 50-100 feet in diameter.

3.6.2 Prospect Background

Developed in 1933, the Stough farm was a lay down 80 acres tract with 5 oil wells on it. Cumulative production for the lease is 1,000,000 barrels oil or 200,000 barrels per well. This amounts to a recovery per acre of 12,500 barrels. These outstanding recovery numbers are to be expected as the lease is favorably positioned near the updip margin of the reservoir dolomite facies. The average gross pay thickness for the 5 wells was 40 feet with several of the individual producers having as much as 55 feet of pay. The recoveries also indicate the reservoir quality is superior in this area. The State Vernon and Smock #13-23 HD1 also stood to benefit from oil reserves left behind by the original wells. Relatively recent infill drilling in Vernon indicates the reservoir holds bypassed oil as water coning and/or faulty drilling procedures damaged the old producers.

A successful re-entry/sidetrack of an old hole sparked interest in Vernon, which resulted in 16 holes being drilled in and around the field during a four-year period from 1981 to 1985. Central Michigan Exploration re-entered and sidetracked the Bigelow-Stephens #1 (P.N. 1301) in March of 1981. The well is located in the NW¼ NW¼ SE¼ of section 22. Completed in 1933, the original hole was drilled 57 feet below the top of the Dundee and into the water. The well was plugged 45 days after reaching total depth. Upon topping the Dundee with the sidetrack, the new hole took off flowing at a rate of 200 BOPD natural. The well maintained a flow rate of 100 BOPD with no water for the first year of operation. Since the end of 1982, mechanical problems have hindered production. Estimated cumulative total for the Bigelow-Stephens #1 is 50,000 barrels of oil. Of the new 16 wells drilled during the early 1980's, 7 were located in the interior of the field. However, all 7 were disadvantaged by being located 165 feet or less from an old plugged producer. Ideally, the new holes would have been spotted at undeveloped sites on the 49 acre units. Despite this drawback, 6 of the 7 wells proved to be semi-commercial for local operators. Initial production averages were 25 BOPD with 100 BWPD. Per well cumulative totals are approximately 30,000 barrels of oil. Although the oil recoveries achieved by the infill wells are rather modest, the numbers are considered important because they demonstrate the Vernon reservoir contains oil reserves bypassed by the original development.

One of the Vernon infill wells was the Stough #1A-23 (NW¼ SW¼ SE¼, 23) drilled by Summit Petroleum in 1982. The up hole portion of this well bore will be utilized in the drilling operations for the proposed horizontal well. The Stough #1A-23 is located 130 feet south of an old, plugged producer. Originally planned as a deeper Richfield test, the well encountered severe lost circulation zones in the middle Dundee and as a result drilling had to be halted at the base of the horizon. Open hole wireline logs and a mud log are available from this test. The neutron porosity log indicates the upper Dundee lithology is dolomite with estimated porosity ranging between 5% and 12%. The resistivity logs exhibit 32 feet of gross pay section and can be used to calculate a maximum water saturation of 30%. The logs also display a oil-water contact at a depth of -2937 subsea. The drill cuttings from the top of the Dundee are described as porous dolomite with 100% fluorescence and streaming cut. A good gas show was measured across the upper 25 feet of the Dundee by the gas detector.

The Stough #1A-23 was completed for 18 BOPD and 100 BWPD. Cumulative oil production is approximately 30,000 barrels. Based on the optimistic log and sample data from the well, these production numbers are disappointing. However, the completion of the well may have been undermined by a poor cement job. The cavernous porosity in the middle Dundee made a quality cement job difficult. The bond log from the well indicates the top of cement is at 3670', only 40' above the Dundee pay zone. In conclusion, although the Stough #A1-23 proved to be a marginal producer, the encouraging log and sample data suggests the reservoir contains significant bypassed oil in the prospect area.

A lateral hole was thought to be an excellent method to evaluate this prospect. One advantage a horizontal well bore offers is that it allows the well to be produced at a higher rate without significantly reducing the bottom hole flowing pressure. This minimizes the chance of water coning thereby delaying water production. Where a conventional well can be produced at 50 BOPD, a horizontal well can be produced at 100 BOPD. This reduces payout time and increases return on investment. The horizontal well path was orientated south and east from the Stough #1A-23 surface hole. The objective of the horizontal well was to follow the upper reservoir dolomite updip until it pinched out. The lateral hole was projected to start out at a TVD of -2905 subsea. Anticipated length of the lateral section was 1000 feet.

3.6.3 Location

The State Vernon and Smock #13-23 HD1 drilling unit was drilled in Phase I of this project. It is described as the SW¼ SE¼ of section 23 and the NW ¼ of the NE¼ of section 26, Vernon Township, Isabella Co.

Jordon secured approval from the Michigan Department of Environmental Quality (MDEQ) on the 80 acre Smock drilling unit in April 2000. The unit has an old Dundee well existing upon it (used as a brine source well for Isabella County), therefore, a spacing exception had to be petitioned to allow the 2 wells (the existing John Stough 1 and the Smock 13-23 HD) to produce. Jordon was able to get the unit ratified without the need for a time exhaustive formal hearing, and received approval from the MDEQ on April 24, 2000. The drilling permit application was then applied for pertaining to this unit. The permit was issued on June 14, 2000 for the State Vernon & Smock 13-23 HD1 (permit number: PN 53945).

Jordon conducted a Baseline Environmental Assessment (BEA) upon the proposed Smock 13-23 HD drilling unit, including the drill site and future production facility site. The purpose of the BEA was to delineate any existing environmental contamination upon the unit prior to conducting any operations. The BEA was then submitted to the MDEQ for adequacy determination, which upon ratification, releases Jordon (Cronus) and its partners from liability associated with the existing contamination. The MDEQ affirmed the BEA on April 3, 2000.

3.6.4 Drilling and Casing history

The demonstration well was sited to pass on an East-West line between a gap in the 10-acre pattern (Figure 15 and 16) based on subsurface geology and historical production from previous wells. The first lateral drilled as expected until the bit exited the curve and failed to penetrate either limestone or dolomite. Drilling continued for 751 feet until it was determined that the shale was too extensive and the bit was pulled back, repositioned to penetrate 9 feet deeper and to the northeast of the first lateral. The second lateral penetrated carbonates as expected, including approximately 110 feet of good dolomitic reservoir.

3.6.5 Horizontal laterals

The first lateral reached the top of the Dundee Formation at -2902 feet on October 26. Seven-inch casing was set at 4229 MD and the lateral continued another 980 feet to 4982 MD. The trajectory of this lateral is shown in Figure 15 and 16. The lateral encountered shale immediately upon entering the target zone and was deviated upward then down in an effort to escape the shale. However, the well was thought to have hit the porous dolomite hydrocarbon zone (PDHZ) in the last 50 feet (Figure 15, 17, and 18) between depths of -2915 to -2920. The only hydrocarbon show was a gas show of 320 units measured at 4192 MD just at the Dundee-Bell Shale contact. This lateral was abandoned on November 3, 2000 .

Based on information obtained from the first lateral, a second lateral was drilled on November 4th. This well was kicked off from the casing point at 4229 feet MD and targeted for the top of the PDHZ encountered in the first lateral. Accordingly the well was deviated down (Figures 15 and 18) and to the northeast. At 8 feet below the first lateral, the well encountered the PDHZ at about 4400 feet MD and attempted to follow the contact another 230 feet to 4630 feet MD (Figures 17 and 18) where it again encountered shale. At this point drilling was stopped on November 6th and attempts were made to produce the interval based on good hydrocarbon shows from 4405 to 4630 feet MD.

3.6.6 Open hole testing, coring, mudlogging, and logging

No drill stem testing or coring was performed in this well.

A mudlog was recorded in both laterals and included data on sample lithology, hydrocarbon shows, and gas in the mud.

A gamma ray tool was included in the drill string while drilling the horizontal laterals (LWD - logging while drilling) to aid in determining the well bore location relative to the Bell Shale or any shale plugs.

Michigan Wireline Services recorded a gamma ray neutron open hole log in the well from surface to a depth of 3157 ft, the start of the curve, on October 17, 2000. An open hole pump down gamma ray-neutron-casing collar log was recorded in the curve and second lateral by Baker Hughes on November 14, 2000.

3.6.7 Completion

Work was undertaken to isolate and produce the reservoir section of the second lateral. During initial testing, it became evident that natural fracturing within the reservoir was contributing water production while bypassing recoverable oil reserves. In addition, it was learned that extensive formation damage while drilling probably resulted in plugging of the pay section within the lateral. Plans to run 4.5" casing through the second lateral were contemplated to effectively isolate the pay sections and effectively treat and produce them but was never completed due to economics and the low likelihood of successfully isolating the interval.

3.6.8 Comparison of Actual Results vs. Predicted

It is possible to construct a detailed geologic model that fits the observations from the pre-existing wells and the demonstration well. We presently think that a karst model best fits the data, but this is open to other interpretations. The best way to visualize the karst model is through cross-sections taken at approximately right angles. Figures 17 and 18 are two such cross-sections. Figure 17 is a North-South cross-section taken along the line of section indicated in Figure 16. Figure 18 is an East-West cross-section taken approximately along the well trajectory, that is approximately along the trace of the lateral offshoots of the demonstration well shown in Figure 15. Note that the vertical scale is approximately the same in both cross-sections but the horizontal scale is smaller in Figure 18 than in Figure 17 by a factor of roughly 2X.

Together these figures suggest that the overall geologic model for the Upper Dundee at Vernon Field is one of karstic topography with mud filling sinkholes or small canyons in the secondary dolomite facies but not the original limestone facies. It may seem curious that the sinkholes are confined to the dolomite facies, but a logical scenario is that the fluids that dolomitized the limestone simply followed the preexisting joints and fractures that developed the karst surface. It is possible that this is a faulted topography with some with minor (10-20 feet?) offsets. In any event, this model fits the observations and is consistent with what we know about the Dundee Formation in general.

3.7 WELL DETAILS - BOWERS 4-25 #1

3.7.1 Overview

As a follow-up to the State Smock well, the Bowers 4-25 vertical well (originally proposed as the White #1-24 horizontal well and then the Bowers 1-25 HD) 80 acre unit, SW ¼ SW ¼ of section 24 and the NW ¼ NW ¼ of section 25 of Vernon Twp) was proposed to evaluate a 200 acre undeveloped prospect area adjoining the Vernon field to the east (Figure 19). The Vernon Dundee production is associated with dolomitization of the upper Dundee (Rogers City) interval. The dolomite body is defined by the existing well control to date that encompasses some 2000 acres (Figure 16). The extent of the dolomitization is considered to be fracture controlled. Immediately surrounding the dolomite trend are wells in which the dolomite is overlain by dense limestone cap rock. The thickness of the cap rock in this border area ranges upwards to 75 feet. Wells within this thickness range generally exist within ½ mile of the dolomitized area. Further out from the dolomitized area, the cap rock thickness is 100 feet or more as regionally the 350 foot Dundee section consists predominantly of limestone in the prospect area.

3.7.2 Prospect Background

The Bowers 4-25 attempted to extend the Vernon field eastward. The existing well control suggests the fairway of dolomitization continued in this direction. The 200 acre prospect is rather well defined by existing Dundee penetrations with anomalously thin or no limestone cap rock These wells include the 3 Dundee oil wells on the Verette lease (SE¼ SE¼, 23). Drilled in 1933, the 40-acre tract cumulated 132,558 barrels before abandonment in 1938. The Verette #1 (NW¼ SE¼ SE¼, 23) was one of the strongest wells in the field, completing for 5000 BOPD natural. The reservoir dolomite development is apparently significant in the area of this well bore. The Verette production is the eastern most in the field to date. It is important to note the Verette #2 (NE¼ SE¼ SE¼, 23) did not encounter any limestone cap rock. This establishes upper Dundee dolomitization within 330 feet of the Bowers 4-25 HD unit boundary. Along with the Verette wells, four dry holes located on the east side of the Vernon field define the East Vernon prospect. All four wells have anomalously thin limestone cap rock sections. (refer to Figures 16 and 18). The cap rock sections penetrated in these wells are similar to the proximal wells, which immediately border the Vernon dolomite trend in its entirety. As shown on the prospect maps, the trend of upper Dundee dolomitization is interpreted to extend through the Verette lease and into parts of sections 24 and 25. Another important geological aspect of the East Vernon prospect is the fact that it is favorably positioned at the updip margin of the dolomitization. In addition, the prospect area borders the southern lateral seal and the predicted subsea elevation of the top of the Dundee reservoir at the Bowers location is even with the best wells in the field.

Expected maximum gross hydrocarbon column thickness was 45 feet. The Bowers 4-25 HD prospect was an ideal application for horizontal drilling as the technology offered an excellent method to explore for upper Dundee porosity across a large area. The intended TVD for the initial leg of the horizontal hole will be -2920 subsea. Anticipated length of the lateral is 1800 feet. Recoverable reserves for the East Vernon prospect are estimated at 1,500,000 barrels of oil utilizing a 50% recovery factor. The reserves estimate benefits from the fact the prospect is positioned at the updip limit of the Vernon reservoir. Because the prospect is located up structure, drainage from the old wells is expected to be minimal with the oil-water contact remaining at or near -2950 subsea. For the Bowers 4-25 #1 HD test, recoverable oil reserves were estimated to be 350,000 barrels.

3.7.3 Location

The Bowers 4-25 drilling unit was drilled in Phase II of this project. It is described as the 80-acre unit, SW ¼ SW ¼ of section 24 and the NW ¼ NW ¼ of section 25 of Vernon Township, Isabella County. The permit for this well, 54950, was issued on February 7, 2002.

3.7.4 Drilling and Casing history

The well was spudded on November 27, 2002. Total depth of 3769 ft was reached on December 4, 2002 without significant shows of hydrocarbons. The well was plugged and abandoned on December 5, 2002.

3.7.5 Horizontal laterals

The Bowers 4-25 was originally planned as a north to south horizontal test but was drilled as a vertical test due to the results and costs of the State-Smock well. Directional surveys near total depth indicated a deviation of the vertical well of approximately one degree.

3.7.6 Open hole testing, coring, mudlogging, and logging

No drill stem testing or coring was performed in this well.

A mudlog was recorded in the well from 2900 ft to total depth. The top Dundee was encountered at 3710 ft measured depth (-2910 ft subsea). Top porosity and/or top dolomite was encountered at 3764 ft measured depth. The well began flowing water with a sour crude odor at 3766 ft. A gas increase was noted beginning around 3750 ft measured depth but no oil fluorescence or oil cuts were seen in the cuttings.

An open hole gamma ray-neutron log was recorded in the well by Baker Hughes on December 3, 2002 (Figure 20).

3.7.7 Completion

No completion was attempted due to the poor hydrocarbon shows.

3.7.8 Comparison of Actual Results vs. Predicted

The Bowers 4-25 well was originally planned as a multi-lateral well to probe for bypassed hydrocarbons, but after the State Smock came up dry, the drilling strategy was changed back to include a vertical probe well. When the Bowers well failed to establish a viable production interval in the Dundee, and the dolomite came in 14 feet below the oil-water contact, the well was abandoned. The surface geochemistry program came off as planned and suggested a marginal well. In this case, the actual results produced a better result than the original proposal in that the cost of an expensive lateral well was avoided.

4.0 CONCLUSION

DOE Field Demonstration Case History and Well Summary: VERNON FIELD, Isabella County, Michigan

The State Smock well has provided us with several lessons, the most important being that in drilling old fields like Vernon it is best to begin with a drilling program that includes a vertical test well to verify the presence of a pay zone, then follow with a horizontal well with multi-laterals. In the case of the first demonstration well, the State Smock, no vertical well was drilled and the first lateral drilled encountered a shale plug that was avoided with the second lateral. A vertical well or a single-lateral horizontal well would probably have established the absence of a pay zone and avoided the cost of a lateral. In the second demonstration well, the Bowers 4-25, a vertical well was drilled and when it failed to show a pay zone the well was abandoned. In both cases, the surface geochemistry indicated marginal plays.

It has also been learned that natural fractures may play a key role in the production of these carbonate reservoirs. Isolating productive regions from water conductive fractures may be an important issue in recovering significant bypassed reserves. In addition, formation damage due to pulverized cuttings and drill pipe abrasion appears to be a prevalent issue within porous zones, even after relatively short periods of lateral drilling exposure. An additional lesson is that geochemical surveys, particularly microbial, are worthwhile in these fields. Microbial surveys are relatively inexpensive and in this case appeared to provide reliable guides to the presence or absence of hydrocarbons. Finally, our knowledge of the state of the upper Dundee Formation greatly increased as a result of the drilling of the State Smock. We now feel that the top of the Dundee near the Vernon Field represents an exposed karst surface spotted with deep sinkholes filled with shale, perhaps similar to modern day topography around Tampa, Florida.

5.0 REFERENCES

Fitzgerald, P. E. and W. A. Thomas, 1932, The occurrence of fluorite in the Monroe Formation of the Mount Pleasant oil pool: Papers of the Michigan Academy of Science, Arts and Letters, v. 16, p. 415-420.

Horvitz, L., 1985, Geochemical exploration for petroleum: Science, v. 229, p. 821-827.

Jones, V. T., and R. J. Drozd, 1983, Predictions of oil or gas potential by near-surface geochemistry: AAPG Bull., v. 67, p. 932-952

Newcombe, R. B., 1932, Oil and gas fields of Michigan: Michigan Geologic Survey Publication 38, Geological Series 32, p. 165-167.

6.0 FIGURES

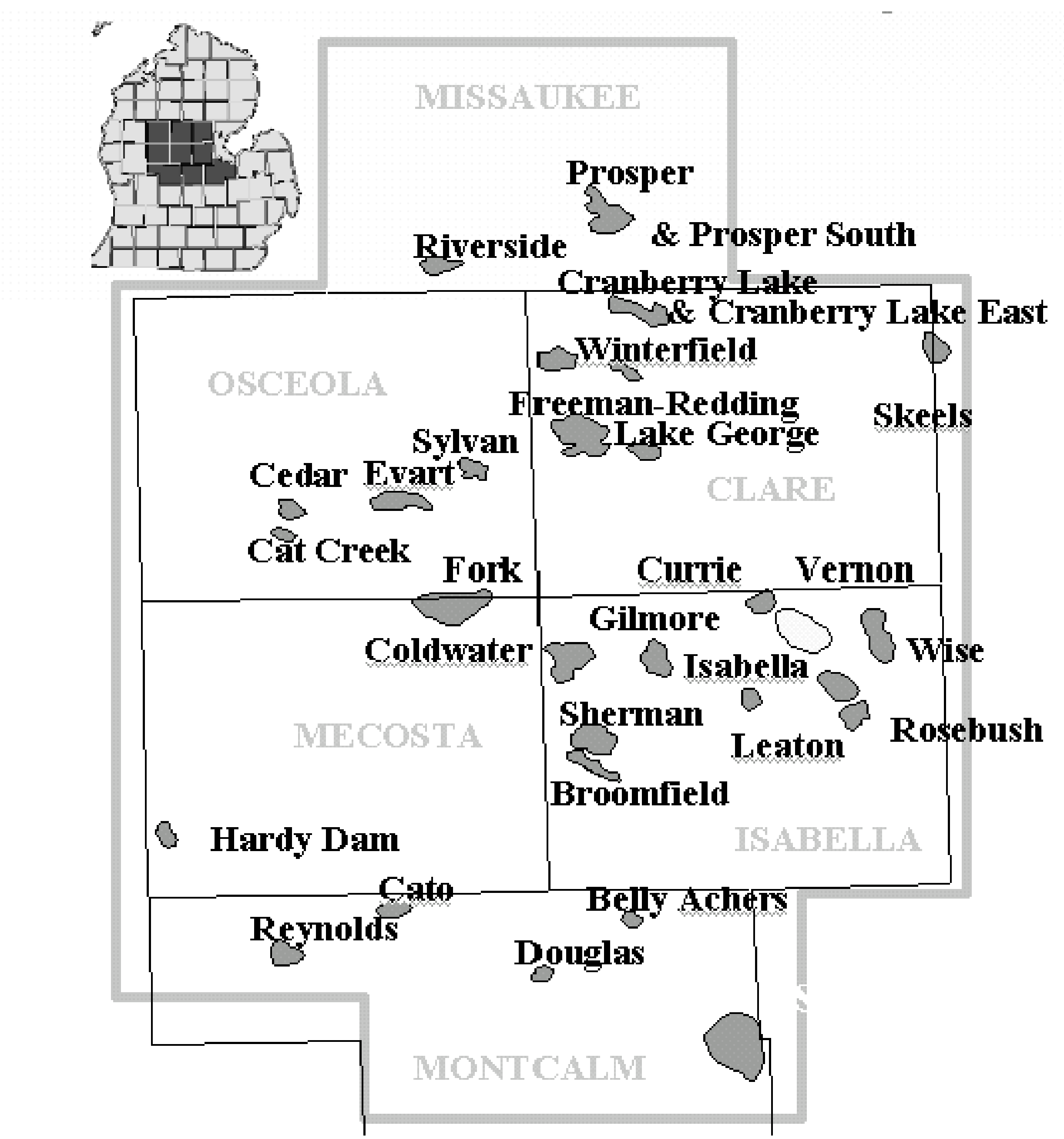

Figure 1. Six county index map for central Michigan showing the location of Vernon Field and other Dundee Fields. Vernon Field is located in north central Isabella County. Noth is toward the top of the page. Inset map shows location in lower peninsula of Michigan.

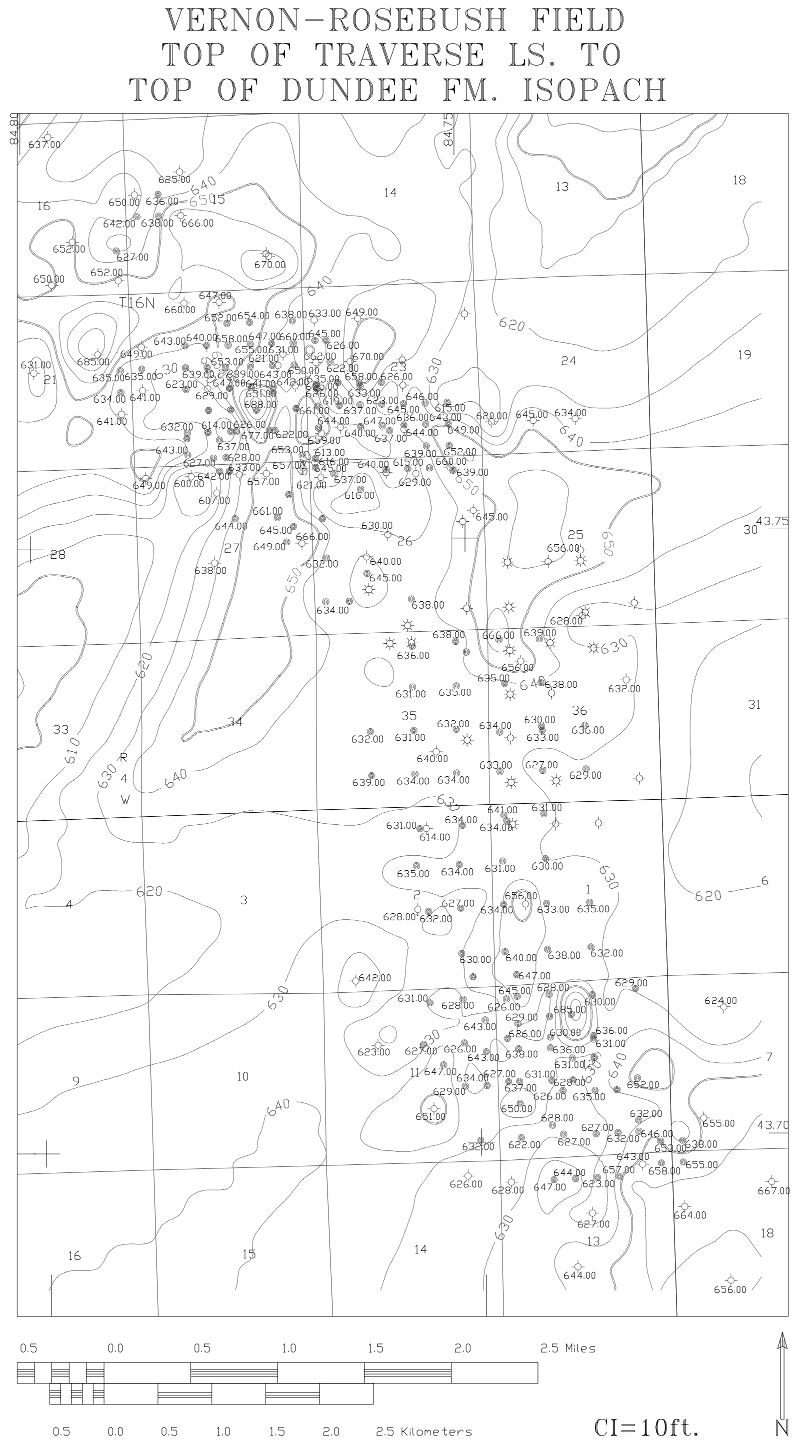

Figure 2. Index map showing Vernon-Rosebush Field area and isopach map from top of Traverse to top of Dundee Formation (interval overlying the productive interval); contour interval 10 ft. Green well symbols are oil wells producing from the Dundee/Rogers City or Dundee/Richfield and red well symbols are gas wells producing from the shallower Stray sand. Rectangle indicates Vernon Field.

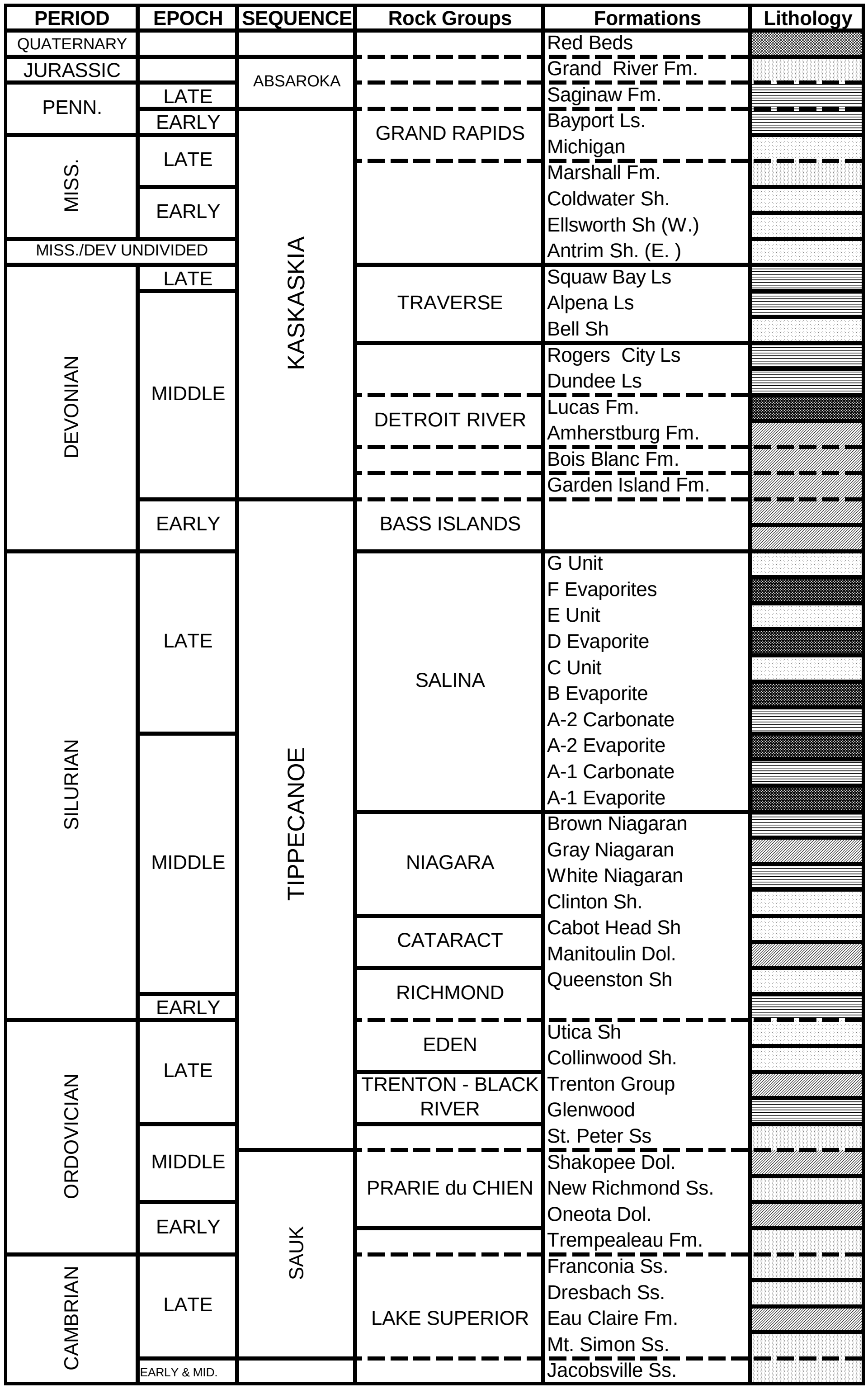

Figure 3. Generalized stratigraphic column for Michigan Basin.

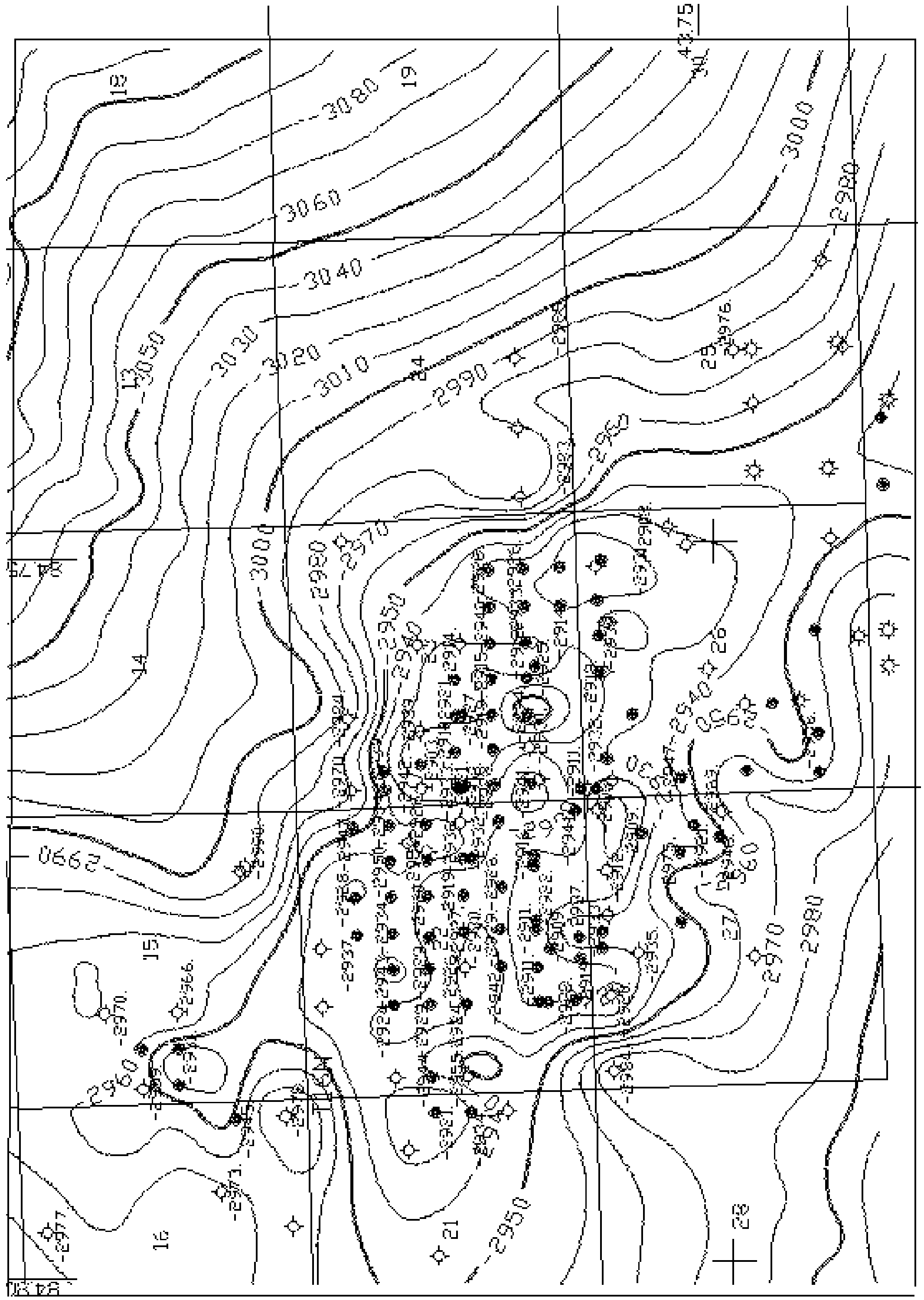

Figure 4. Structure map over Vernon Field showing approximately 30 ft of structural closure; contour interval 10 ft. Black dashed line shows location of Mission Road geochemical profile. Green well symbols are producing wells or abandoned producers. Rectangles are one square mile sections. North is to the left.

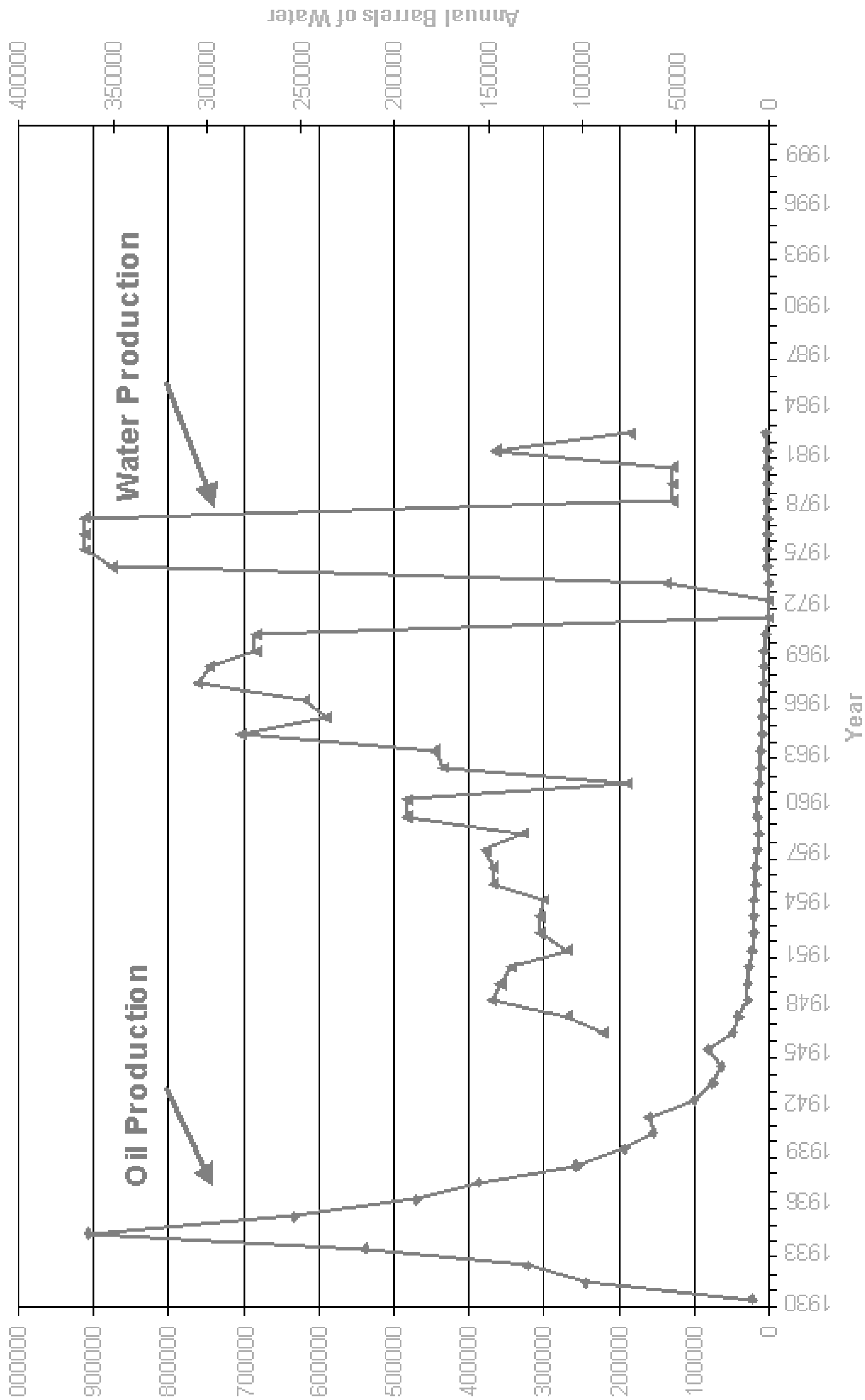

Figure 5. Annual oil and water production for the Vernon Field 1930 through 1983.

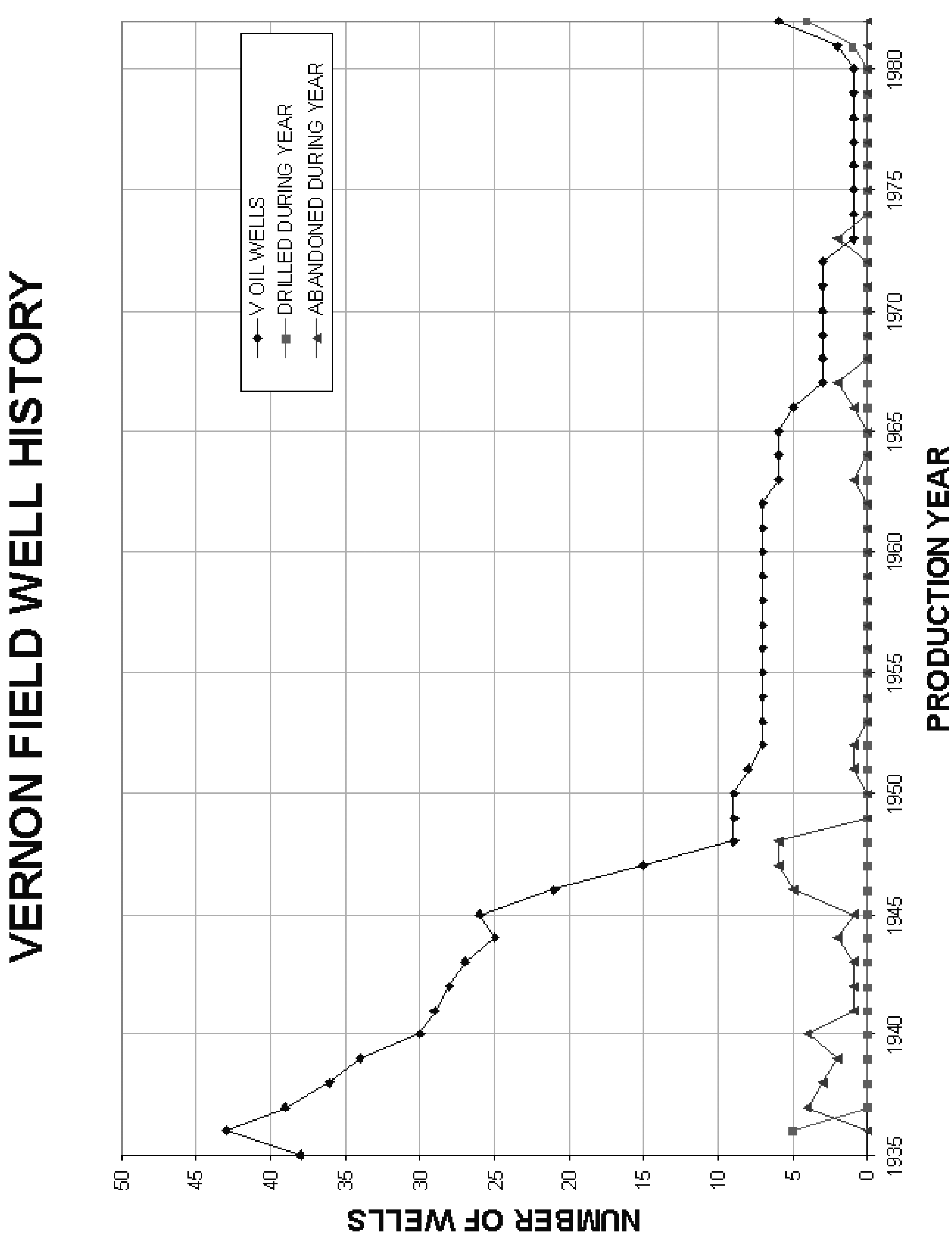

Figure 6. Annual drilling history for the Vernon Field 1930 through 1983.

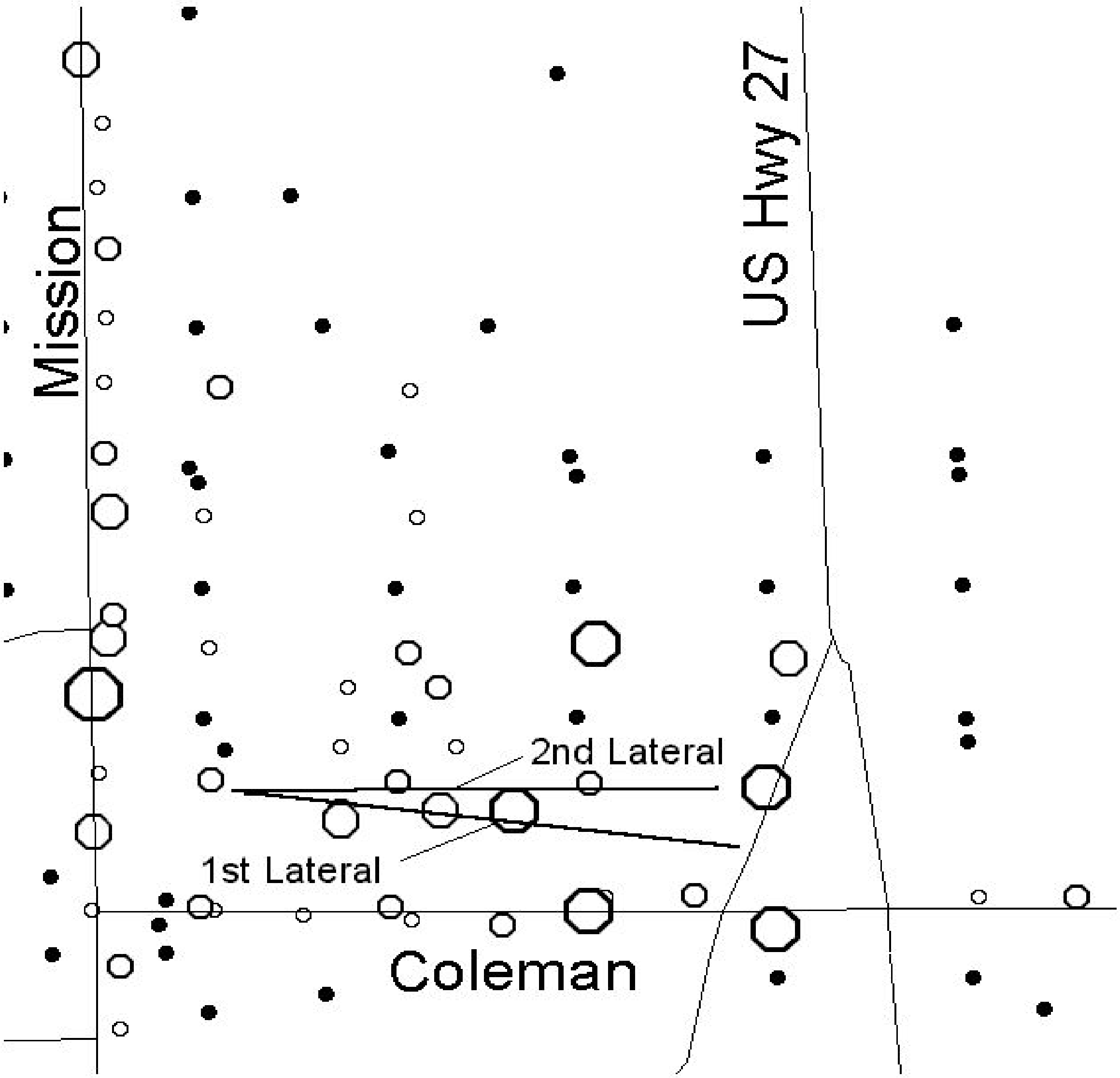

Figure 7. Approximate location of two laterals from State Vernon and Smock well. Solid black circles are oil wells and open circles are microbial sample points. The size of the open circles is proportional to the geochemical signal.

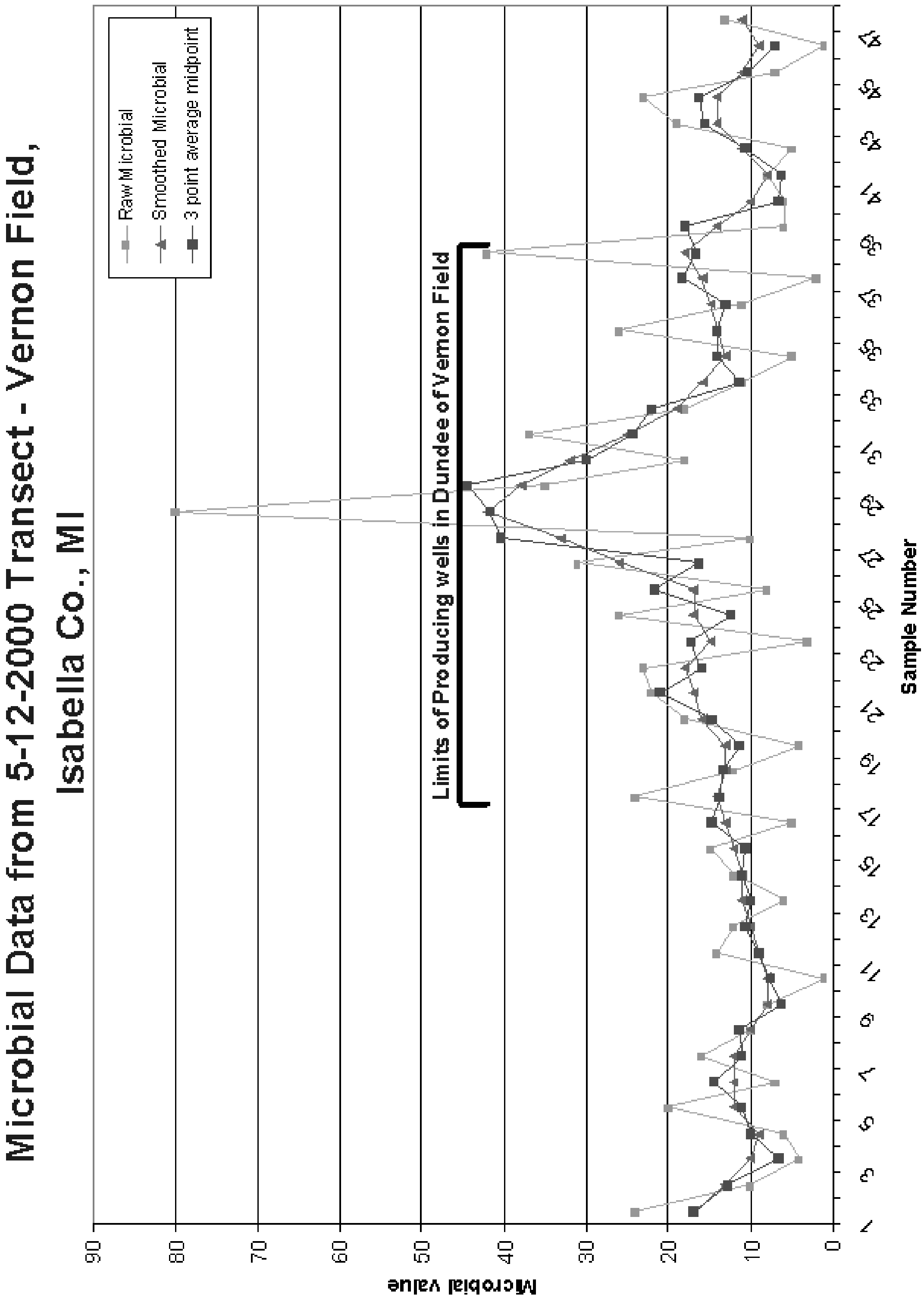

Figure 8. Mission Road Microbial data profile showing ray, smoothed and three-point averages of microbial data. North is toward the top of the page.

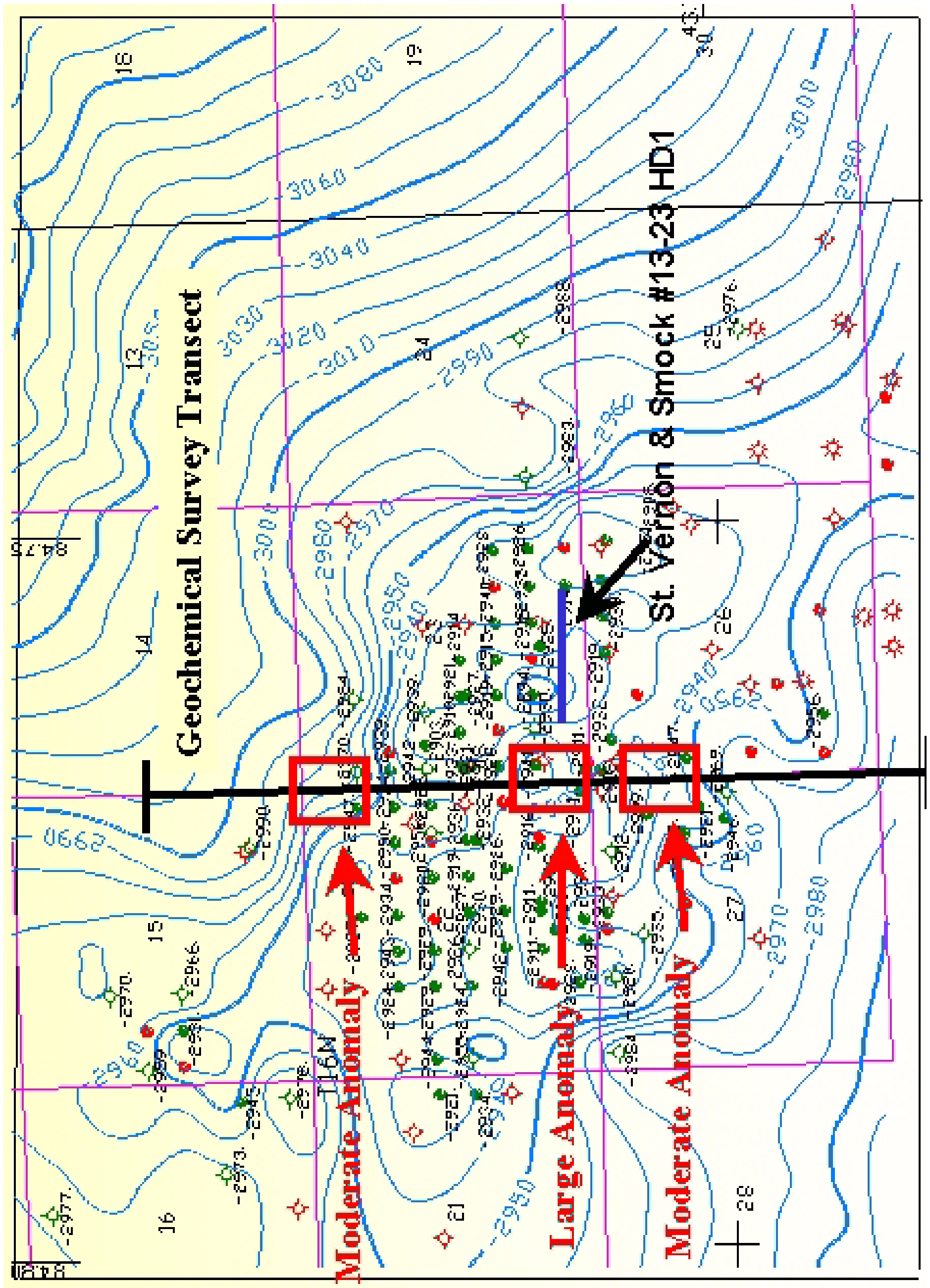

Figure 9. Structure contour map showing location of geochemical anomalies along the Mission Road profile. The location of the State Vernon and Smock well is also shown. Contour interval is 10 ft and north is to the left.

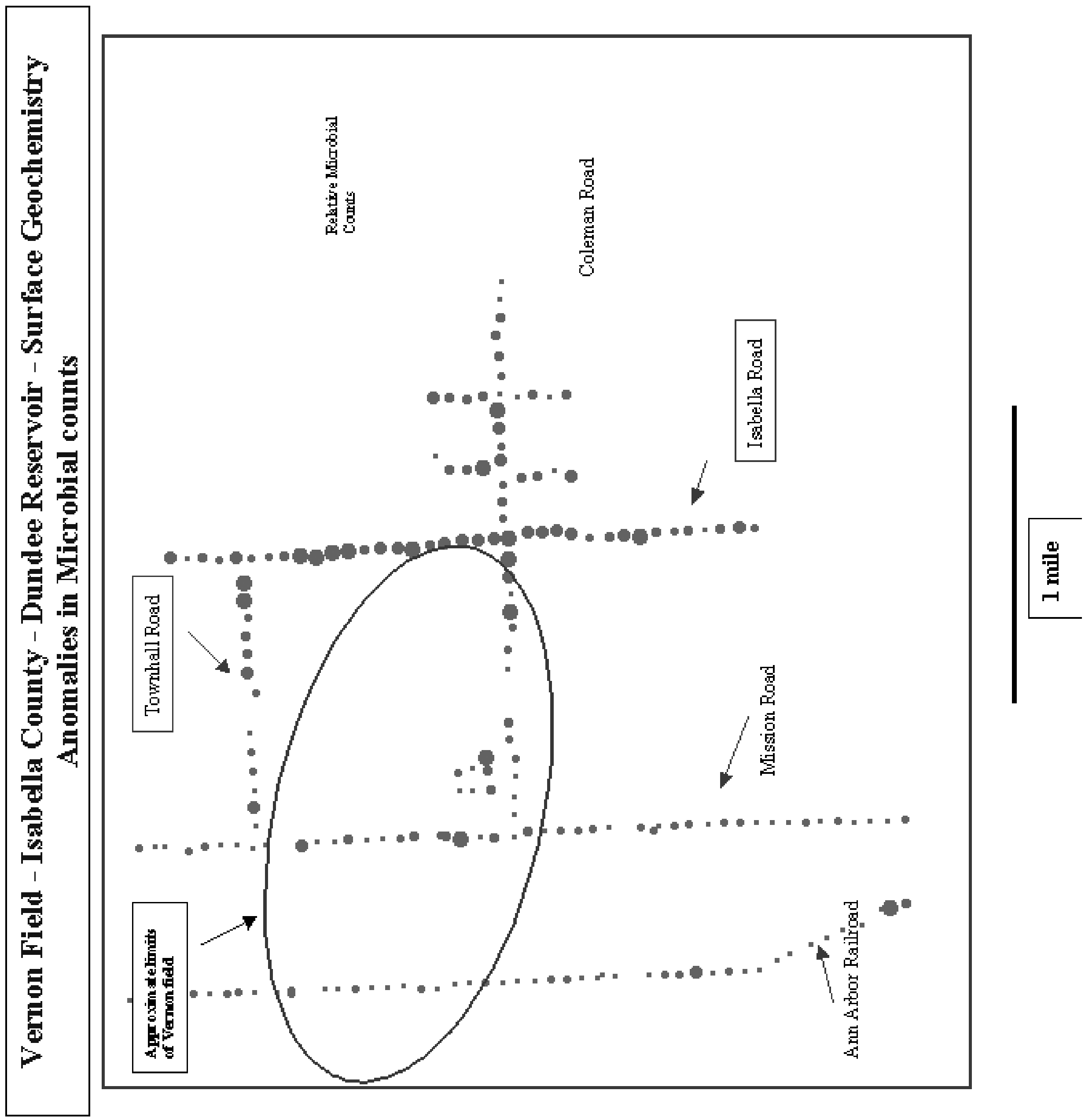

Figure 10. Vernon Field area map showing microbial geochemical profiles. Bubbles are proportional to size of anomalies. North is to the right.

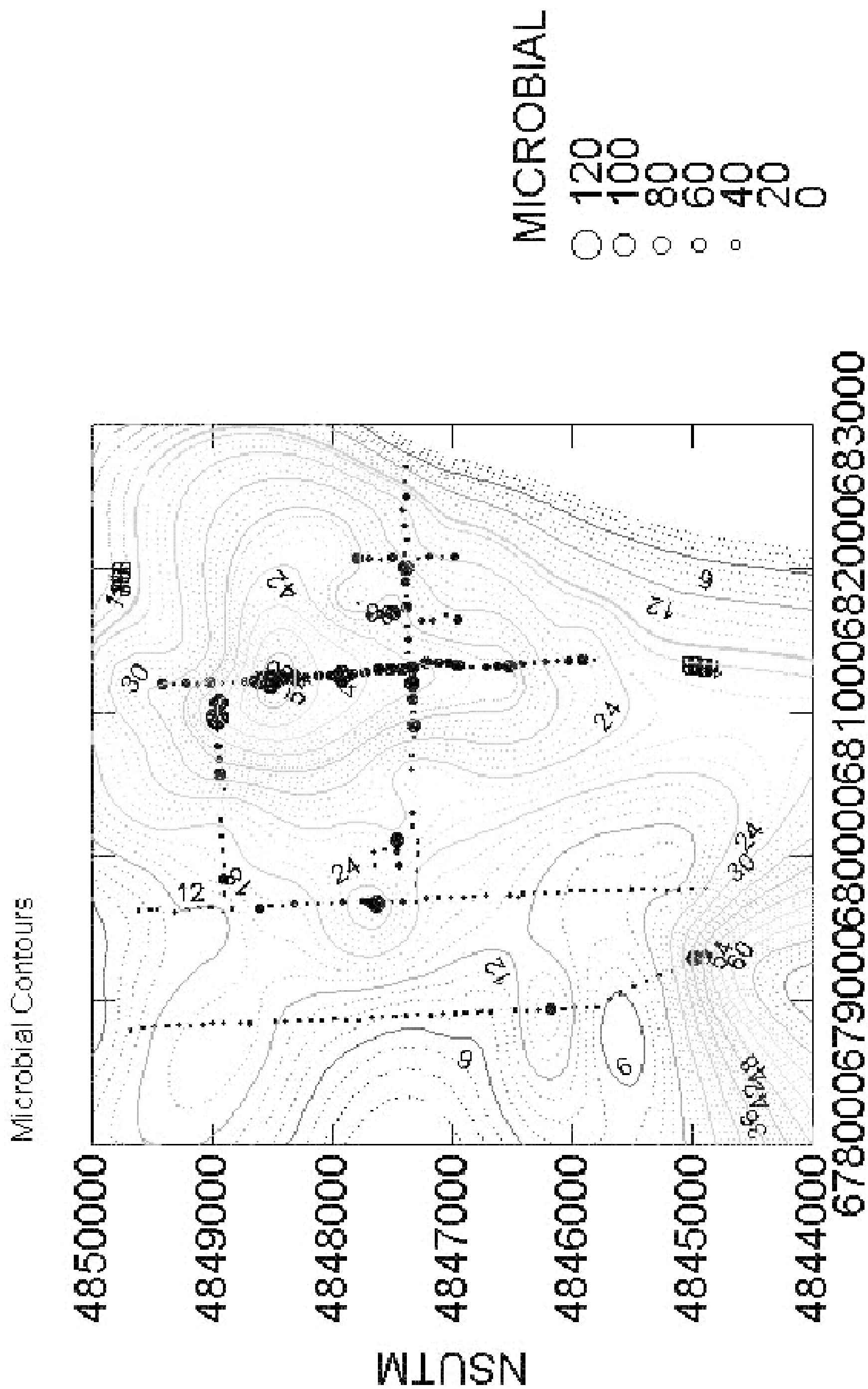

Figure 11. Vernon Field area map showing contoured microbial geochemical profiles. Bubbles are proportional to size of anomalies. Contour interval is two units. North is to the right.

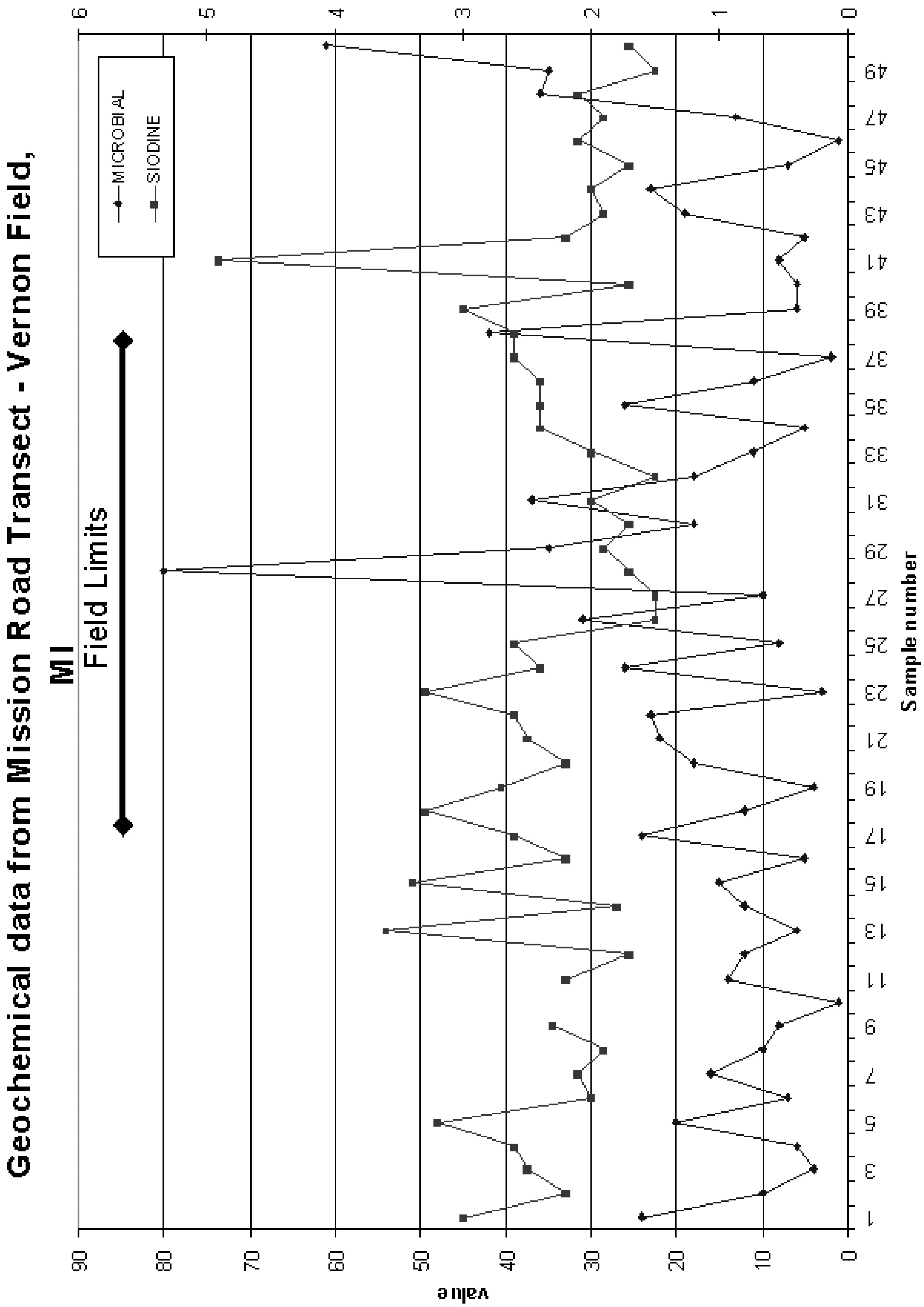

Figure 12. Iodine and microbial data for Mission Road profile.

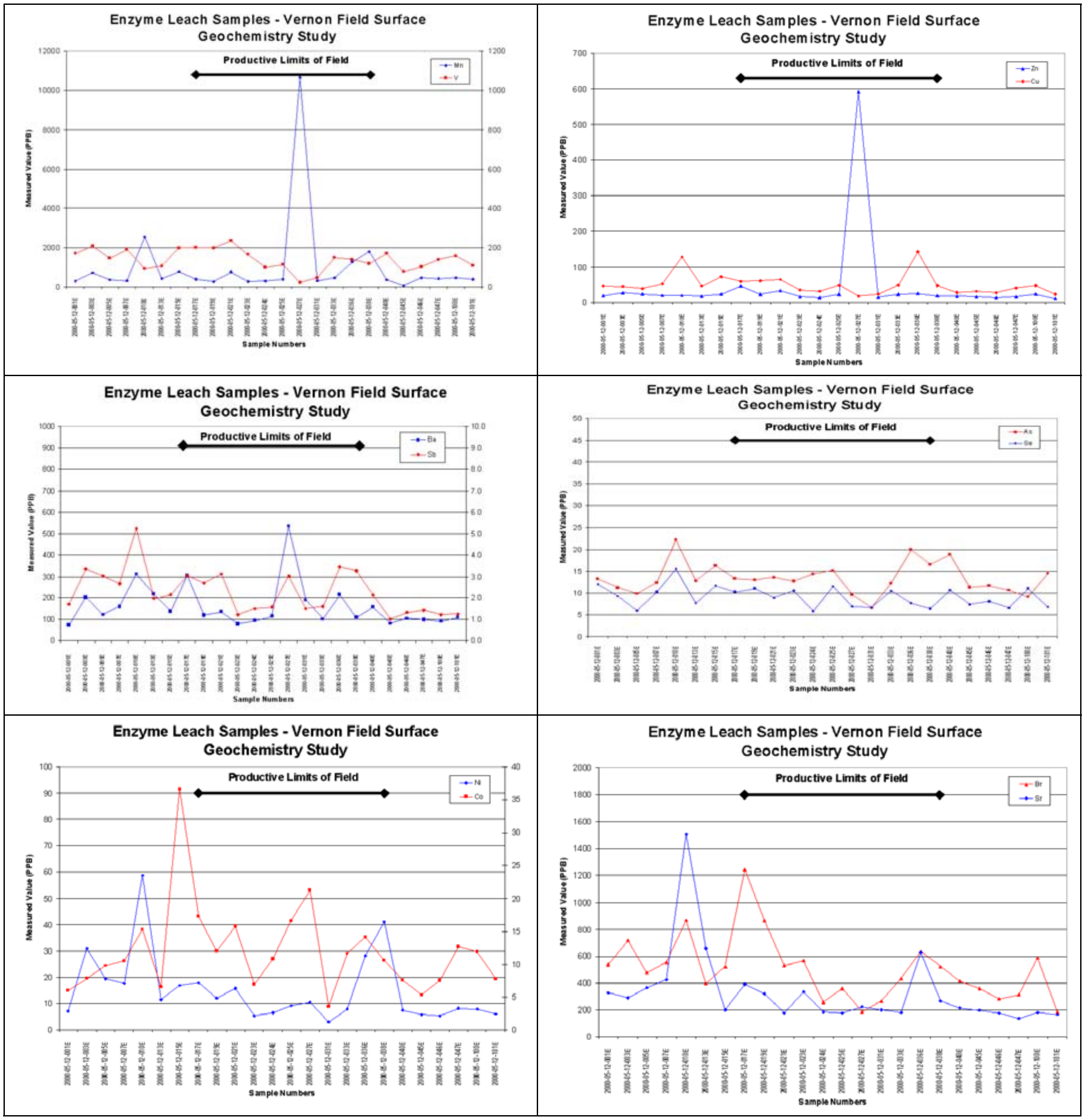

Figure 13. Enzyme leach trace element Mission Road profiles for Mn and V, Zn and Cu, Ba and Sb, As and Se, Ni and Co, and Br and Sr.

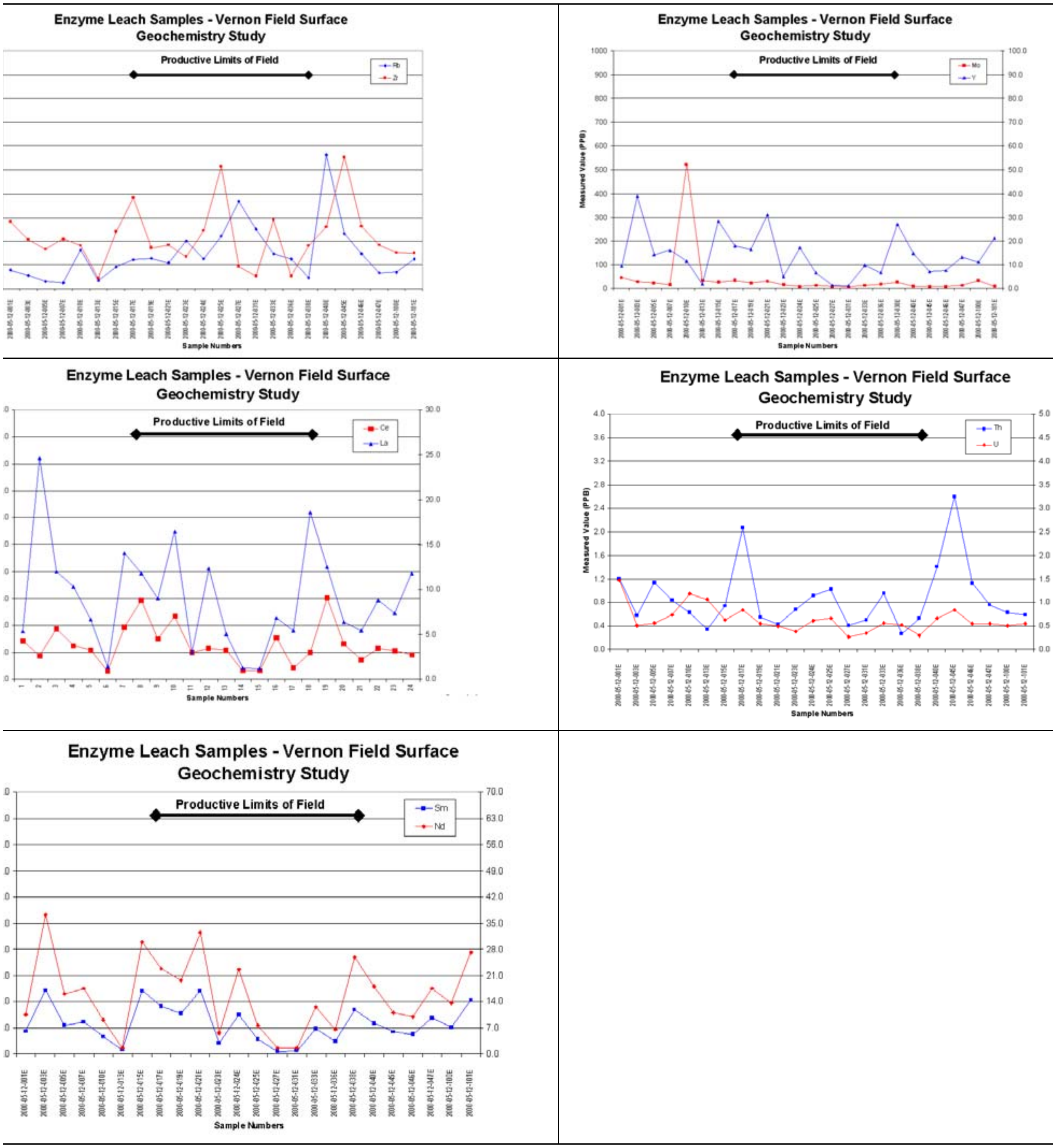

Figure 14. Enzyme leach trace element Mission Road profiles for Rb and Zr, Mo and Y, Ce and La, Th and U, and Sm and Nd.

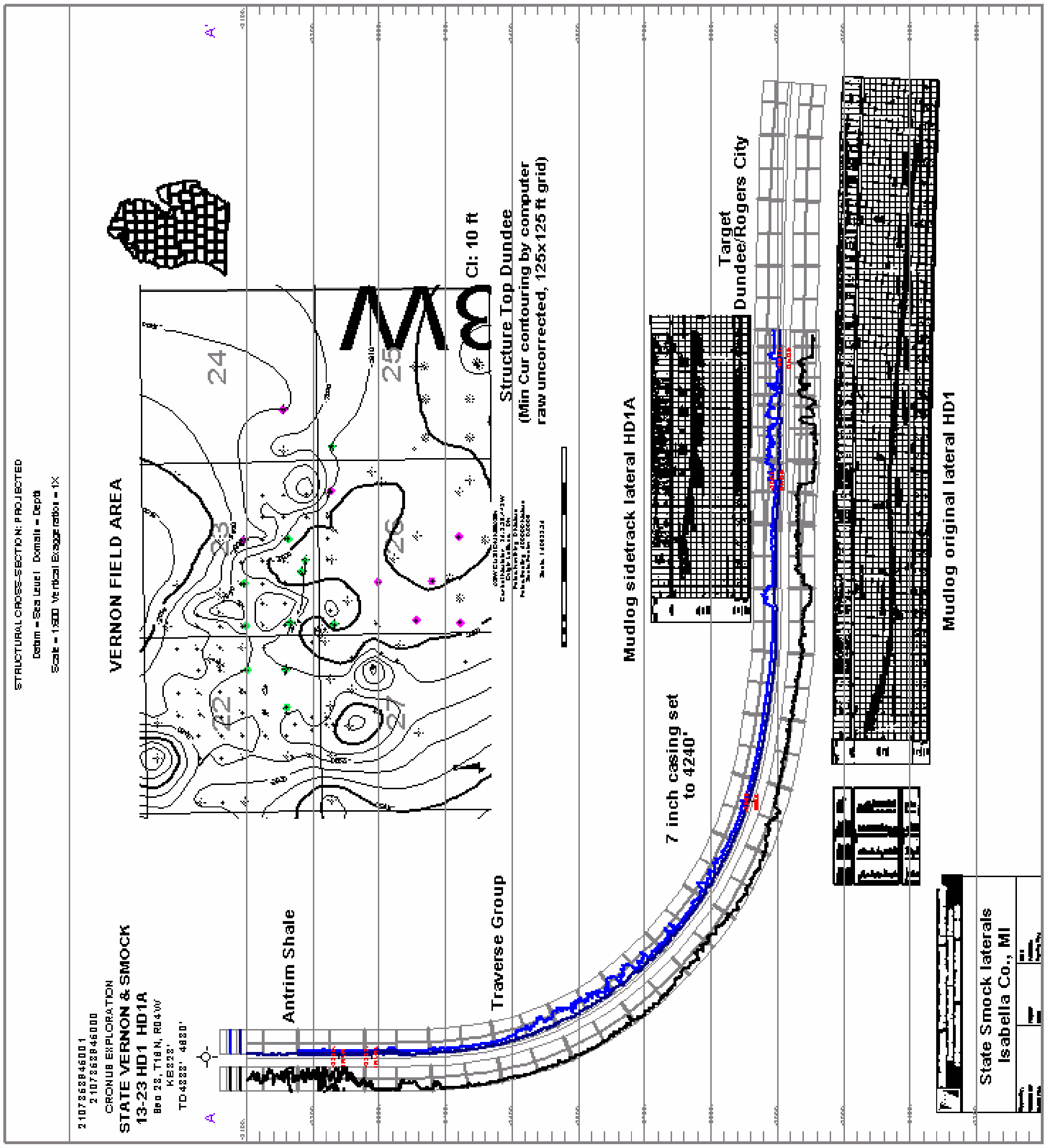

Figure 15. State Vernon & Smock 13-23 #HD1 and #HD1A well path, curve, and horizontal laterals. Log curves are gamma ray on left or bottom and neutron curve on right or top in log track. Mudlog images shown along path. Inset map shows location of well and laterals in Section 23, in the southwest quarter and structure on the top of the Dundee.

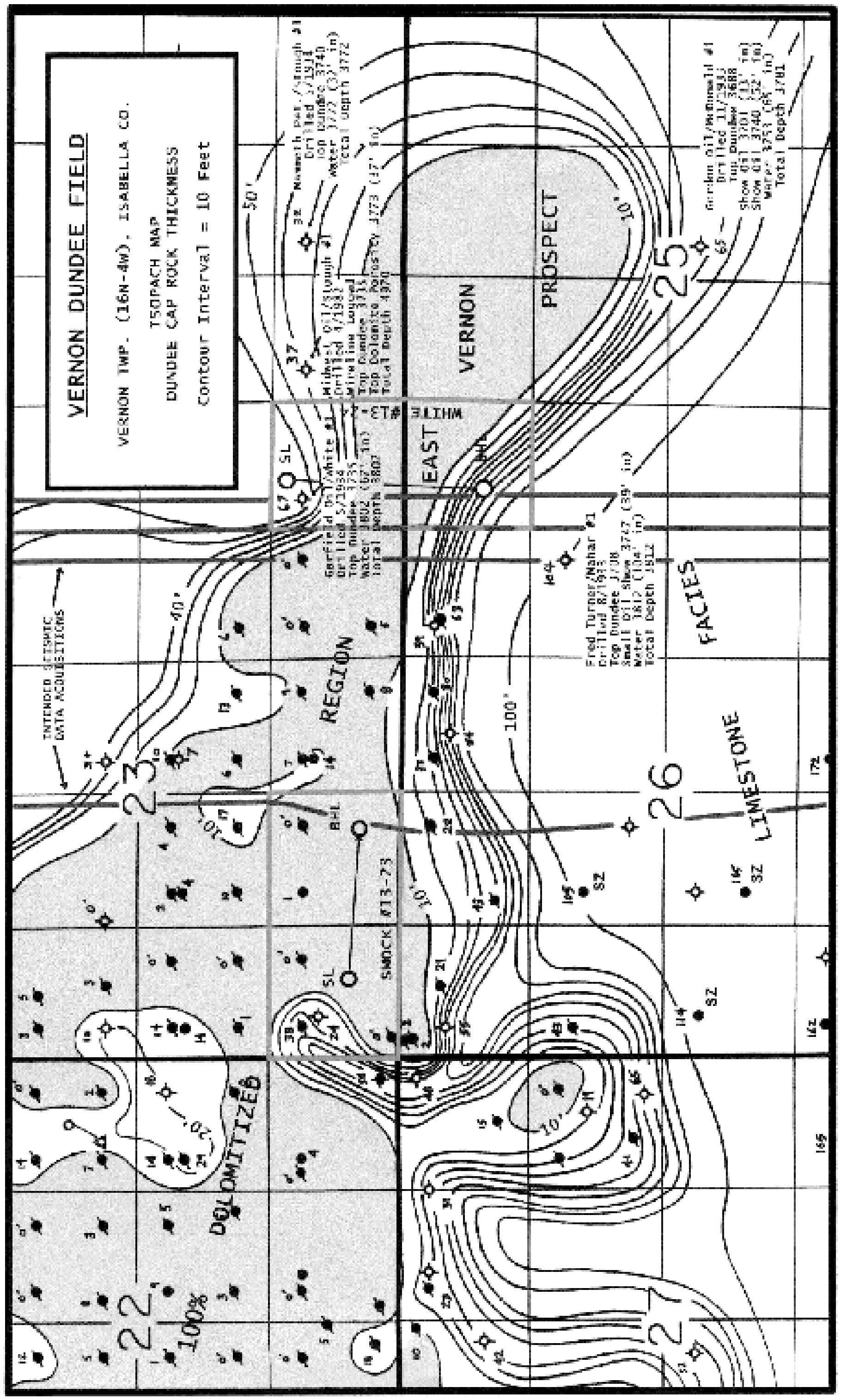

Figure 16. Dundee cap rock isopach map showing pre-drill geology for the Vernon Field and the location of the State Smock well. North is to the left. Prepared by Eric Taylor.

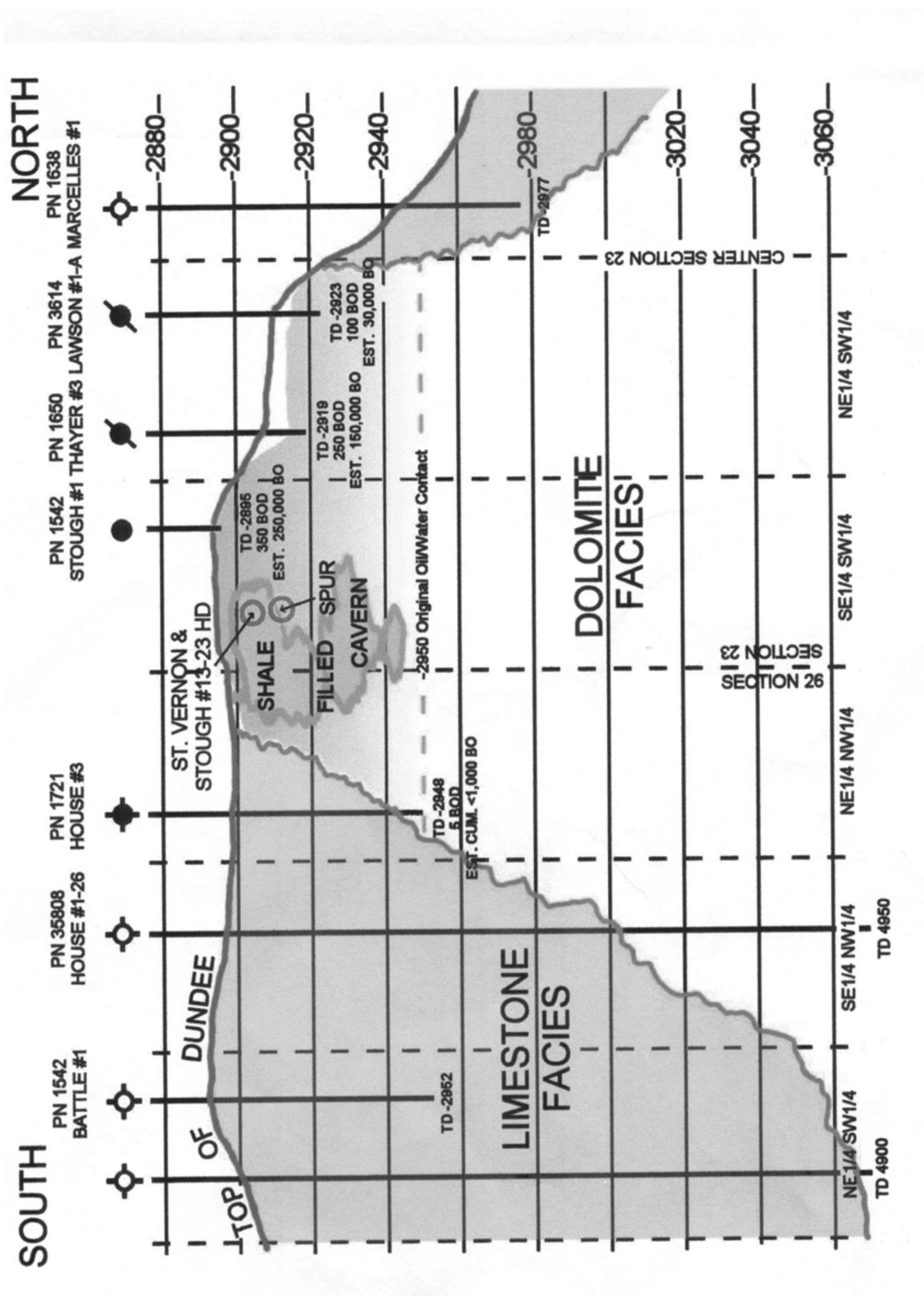

Figure 17. State Vernon and Smock post drill well bore schematic. See Figure 16 for location of cross section (interpretation by Eric Taylor).

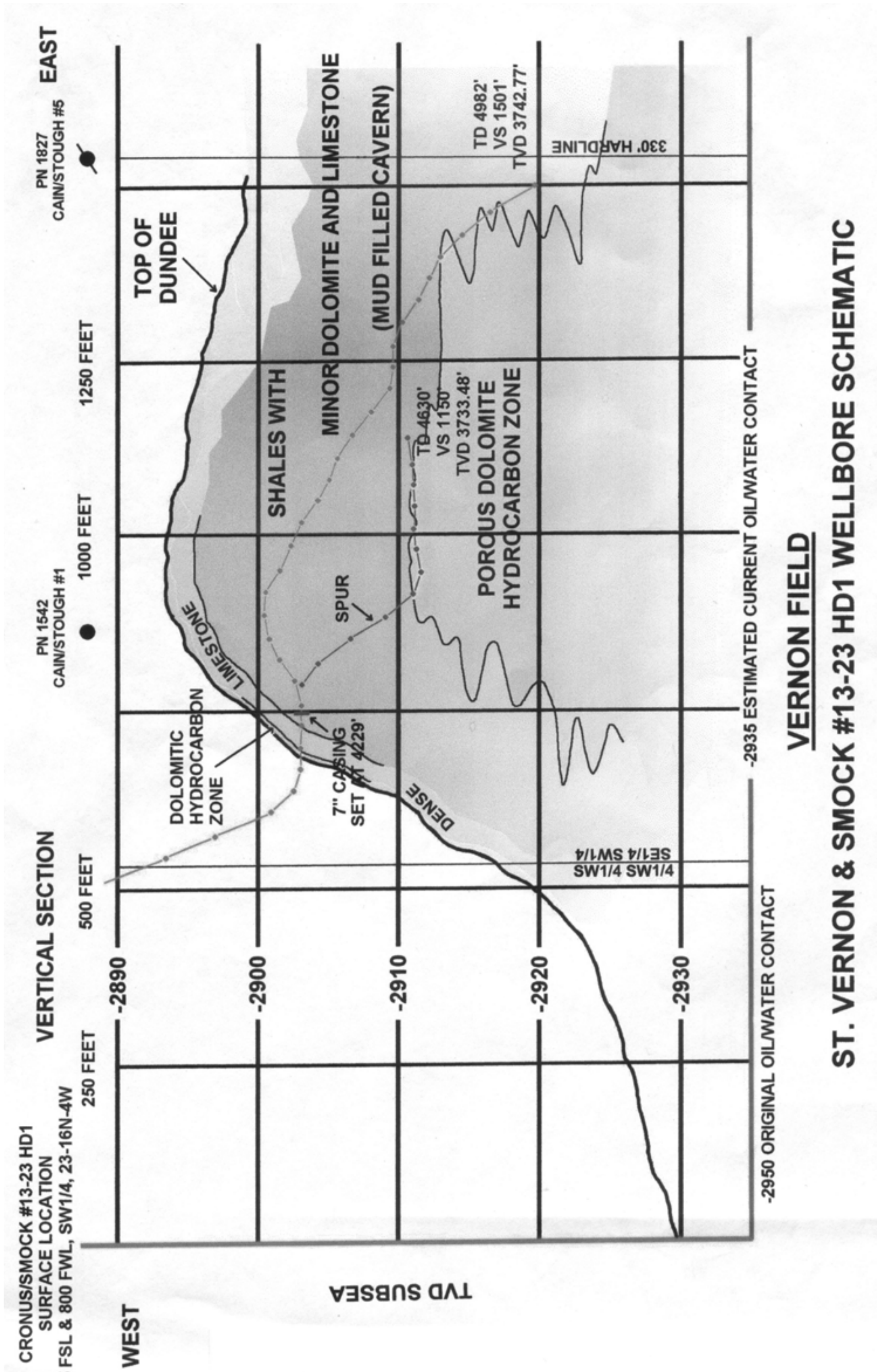

Figure 18. State Vernon and Smock post drill well bore schematic showing interpreted path of laterals (interpretation by Eric Taylor).

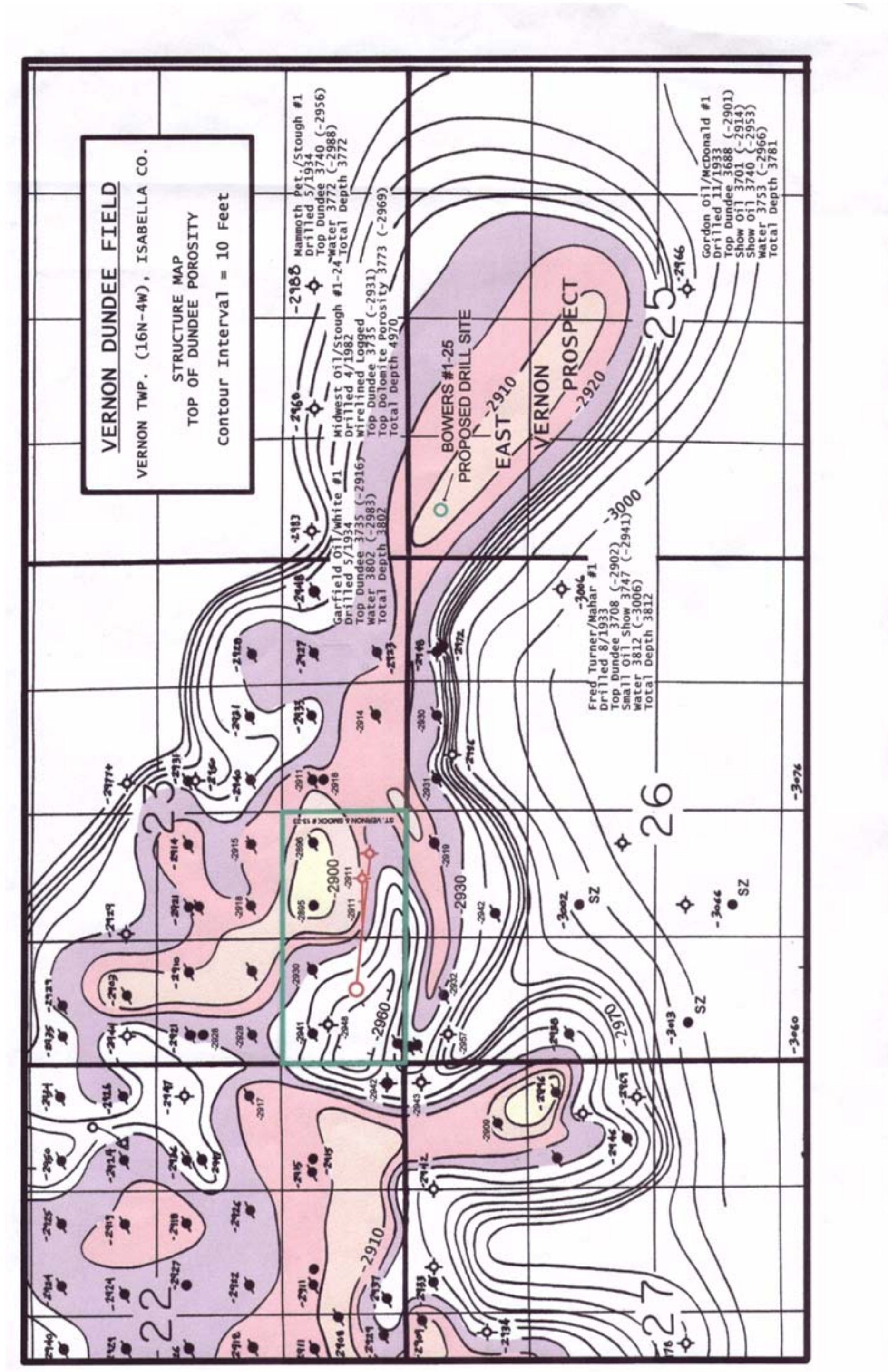

Figure 19. Structure map on top of Dundee porosity showing location of Bowers 4-25 well. The State Vernon and Smock well bore and lateral paths are also shown. (interpretation by Eric Taylor).

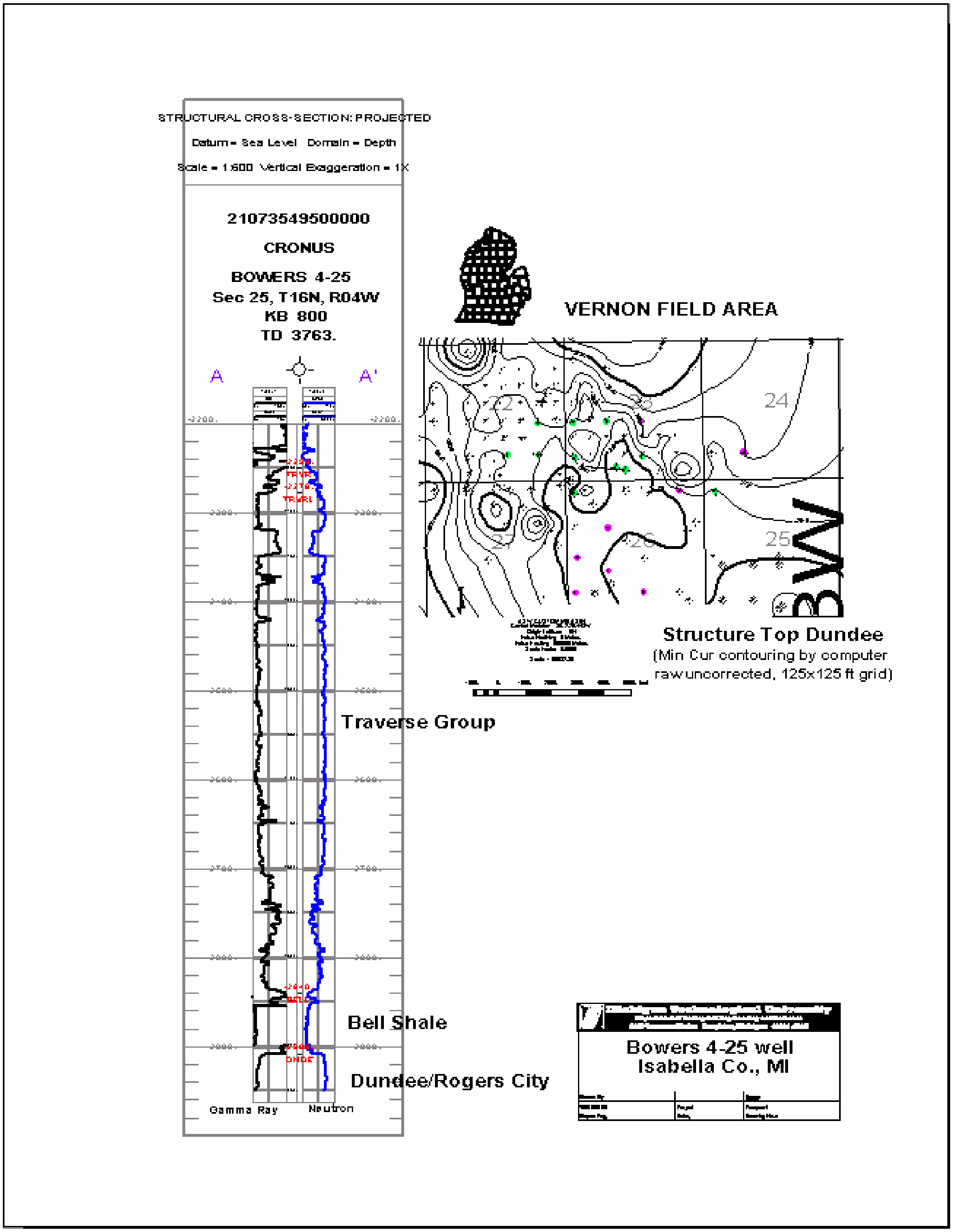

Figure 20. Bowers 4-25 well log. Gamma ray shown on left and neutron curve on right.

7.0 APPENDIX 1 - AAPG papers presented on Vernon Demonstration

7.1 AAPG Eastern Meeting, Kalamazoo, MI 2001

Results of Surface Geochemistry Survey over the Vernon Field, Isabella County, MI

BORNHORST, T.J., WOOD, JAMES R., and CHITTICK, S.D., Michigan Tech. Univ., Houghton, MI; HARRISON, W.B., BARNES, D., Western Michigan Univ., Kalamazoo, MI

Four surface geochemical techniques have been tested at the Vernon Field in support of a demonstration project partially sponsored by the U.S. Department of Energy to detect and recover bypassed oil. The techniques included surface iodine, enzyme leach, microbial and soil gas. The most extensive sampling (350+ samples) was for the microbial oil survey technique in which microorganisms are cultured from soil taken 20 cm beneath the surface. Results from a smaller number of iodine samples (collected from soil within an inch of the surface), headspace soil gases (collected from 1 meter beneath the surface) and selectively extracted trace elements (from the top of the B-horizon) and soil gas hydrocarbons (extracted from soil of the top of the B-horizon) will be presented as well.

The detection of subsurface accumulation of oil and/or gas by surface geochemical techniques is based on microseepage of reservoired hydrocarbons to, the surface and has been used elsewhere in combination with other data to reduce drilling risk. Except for the enzyme leach techniques, the surface geochemical signal recorded is transient (i.e. not cumulative) and will respond to changes in the reservoir. Only transient techniques are useful to detect by-passed oil. The microbial anomaly was apical while the others are best interpreted as edge anomalies or halos around the target.

The initial collection of geochemical samples was completed during the summer of 2000 and sampling will be continued during the summer of 2001. The challenge with all of the surface geochemical techniques is definition of anomalies and their interpretation. The cause of the surface geochemical anomalycan be from a variety of depths beneath the surface. The initial results demonstrate that hydrocarbon microseepage from the Dundee reservoir is detectable by surface soil geochemical techniques.

7.2 AAPG Eastern Meeting, Kalamazoo, MI 2001

Results of Recent Drilling at Vernon Field, Isabella County, MI. and A Geologic Model for the Top of the Dundee Fm.

WOOD, J. R, BORNHORST, T. J. AND CHITTTICK, S. D. Michigan Tech. Univ., Houghton, MI, HARRISON, W. B., BARNES, D. Western Michigan Univ., Kalamazoo; MI, QUINLAN, W. Cronus Energy LLD, and TAYLOR, E., Consultant, Traverse City, MI

A horizontal well with dual laterals was drilled at Vernon Field in the fall of 2000. This well was designed to probe the field for bypassed oil and was sited based on data from previous wells. The initial lateral penetrated the Dundee Formation at -2905 feet subsea and continued approximately due East for 1501 feet, mostly in hard shale (plug?) with no hydrocarbon shows. The second lateral was offset to the Northeast and about 9 feet higher in the section. This lateral encountered good shows and good reservoir rock but efforts to bring it on production failed. The well was plugged and abandoned January 5, 2001.

The main reason for the failure of the well to produce was excessive water production probably due to two main causes: (1) water introduced into the lateral via fractures, and (2) a higher water table than anticipated due to efficient previous production. If fractures were the reason, then serious doubt is cast on the use of laterals to produce bypassed oil from fields of this type. Although the use of a multi-lateral well did allow us to probe the formation for good reservoir rock, the same strategy may have doomed the effort to put the well on production by increasing the chances of cutting water-bearing faults or fractures. On the other hand, a vertical well sited over the shale plug encountered in the first lateral would have likely failed too.

A geologic model was constructed for Vernon Field that takes into account the lithologies encountered in this well. The basic model is that the first well drilled into a large shale plug which is interpreted as either a mud-filled sinkhole originally formed on the surface of karsted Dundee limestone or a shale-filled low on a similarly exposed karstic surface. It appears that the dolomitization was a hydrothermal event following karstification, either subaerially or submarine.