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A Systems Approach to Identifying Exploration and Development Opportunities in the Illinois Basin: Digital Portfolio of Plays in Underexplored Lower Paleozoic Rocks

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A Systems Approach to Identifying Exploration and Development Opportunities in the Illinois Basin: Digital Portfolio of Plays in Underexplored Lower Paleozoic Rocks

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ABSTRACT

This study examined petroleum occurrence in Ordovician, Silurian and Devonian reservoirs in the Illinois Basin. Results from this project show that there is excellent potential for additional discovery of petroleum reservoirs in these formations. Numerous exploration targets and exploration strategies were identified that can be used to increase production from these underexplored strata. Some of the challenges to exploration of deeper strata include the lack of subsurface data, lack of understanding of regional facies changes, lack of understanding the role of diagenetic alteration in developing reservoir porosity and permeability, the shifting of structural closures with depth, overlooking potential producing horizons, and under utilization of 3D seismic techniques. This study has shown many areas are prospective for additional discoveries in lower Paleozoic strata in the Illinois Basin.

This project implemented a systematic basin analysis approach that is expected to encourage exploration for petroleum in lower Paleozoic rocks of the Illinois Basin. The study has compiled and presented a broad base of information and knowledge needed by independent oil companies to pursue the development of exploration prospects in overlooked, deeper play horizons in the Illinois Basin. Available geologic data relevant for the exploration and development of petroleum reservoirs in the Illinois Basin was analyzed and assimilated into a coherent, easily accessible digital play portfolio.

The primary focus of this project was on case studies of existing reservoirs in Devonian, Silurian, and Ordovician strata and the application of knowledge gained to future exploration and development in these underexplored strata of the Illinois Basin. In addition, a review of published reports and exploration in the New Albany Shale Group, a Devonian black shale source rock, in Illinois was completed due to the recent increased interest in Devonian black shales across the United States. The New Albany Shale is regarded as the source rock for petroleum in Silurian and younger strata in the Illinois Basin and has potential as a petroleum reservoir.

Field studies of reservoirs in Devonian strata such as the Geneva Dolomite, Dutch Creek Sandstone and Grassy knob Chert suggest that there is much additional potential for expanding these plays beyond their current limits. These studies also suggest the potential for the discovery of additional plays using stratigraphic concepts to develop a subcrop play on the subkaskaskia unconformity boundary that separates lower Devonian strata from middle Devonian strata in portions of the basin. The lateral transition from Geneva Dolomite to Dutch Creek Sandstone also offers an avenue for developing exploration strategies in middle Devonian strata. Study of lower Devonian strata in the Sesser Oil Field and the region surrounding the field shows opportunities for development of a subcrop play where lower Devonian strata unconformably overlie Silurian strata. Field studies of Silurian reservoirs along the Sangamon Arch show that opportunities exist for overlooked pays in areas where wells do not penetrate deep enough to test all reservoir intervals in Niagaran rocks. Mapping of Silurian reservoirs in the Mt. Auburn trend along the Sangamon Arch shows that porous reservoir rock grades laterally to non-reservoir facies and several reservoir intervals may be encountered in the Silurian with numerous exploration wells testing only the uppermost reservoir intervals. Mapping of the Ordovician Trenton and shallower strata at Centralia Field show that the crest of the anticline shifted through geologic time. This study illustrates that the axes of anticlines may shift with depth and shallow structure maps may not accurately predict structurally favorable reservoir locations at depth.

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Executive Summary

Devonian, Silurian and Ordovician reservoirs account for approximately 8% of the petroleum produced in Illinois. These reservoirs are illustrative of the potential for Lower Paleozoic production and the opportunity for new exploration targets in the Illinois Basin. Devonian reservoirs, both siliciclastic and several types of carbonate, have been established but lightly explored. Silurian reservoirs, commonly associated with various reef settings, exhibit compartmental characteristics that extend both development and new play production. Non-reef Silurian production has also been established. Ordovician reservoirs are limited to the Trenton carbonate, closed structure fields leaving the prolific Albion-Scipio type hydrothermal play as a potential target. The Lower Paleozoic units have not been extensively explored, in part because of the greater drilling depths and the common practice of testing deeper horizons in fields where shallower production has been established. This strategy has brought sporadic results because structural closure may shift with depth and numerous traps in Lower Paleozoic units are stratigraphic in nature.

This project has been undertaken in conjunction with the Indiana Geological Survey, the Kentucky Geological Survey and the Illinois State Geological Survey. The project has focused on study of existing petroleum reservoirs and the potential for new discoveries in lower Paleozoic units. Major tasks for this project include creating a digital catalogue of existing reservoirs and developing models of the stratigraphic and structural framework of Lower Paleozoic units using available subsurface data. Many of these products are available in digital format on the websites of the Illinois, Indiana and Kentucky Geological Surveys. Results from these studies suggest that applying new exploration strategies to the Illinois Basin can result in significant new discoveries in Lower Paleozoic units.

Several major lower Paleozoic field discoveries were made during the course of this project and these strata have received more exploration interest from small independent petroleum companies. A Petroleum Technology Transfer Counsel (PTTC) sponsored workshop highlighting findings from field studies undertaken for this project was presented by Illinois Geological Survey Staff on March 5, 2008 at the annual Illinois Oil and Gas Association Meeting in Evansville, Indiana. There was standing room only with over 100 attendees at the workshop, most representing small producers active or interested in becoming active in exploration in the Illinois Basin. The workshop was well received and generated additional exploration interest lower Paleozoic units.

Findings include additional exploration and development potential in many lower Paleozoic strata. There is reservoir potential in the New Albany Shale Group in addition to the established scientific consensus that the New Albany Shale is the source rock for nearly all of the petroleum found in Illinois Basin reservoirs Silurian in age or younger. There are secondary sources in Ordovician age strata that appear to be confined to Ordovician age reservoirs. Field case studies show that several different exploration strategies can be implemented to increase discoveries. Additionally, improved development strategies may be used to increase petroleum recovery in existing fields. Middle Devonian Geneva Dolomite and Dutch Creek Sandstone reservoirs can be highly prolific and are commonly associated with structurally high features or are draped over underlying Silurian reefs. These formations are frequently highly porous. A stratigraphic entrapment component is an exploration strategy that does not appear to be in use. Exploration for subcrop or unconformity traps in lower Devonian strata also has potential

in some portions of the basin. Case studies of Silurian reservoirs in the Mt. Auburn trend along the Sangamon Arch show that there is a likelihood of overlooked reservoirs particularly in wells that only penetrate the uppermost portion of Niagaran strata which is usually the case. Development of reservoir quality porosity and permeability is facies related and occurs in dolomitized intervals of fossiliferous grainstone. The distribution of these reservoirs is complex and several intervals were identified and mapped in the Mt. Auburn trend. Study of lower Paleozoic reservoirs in the Centralia field shows that the crest of the anticline in the field shifts with depth. This illustrates that the practice of drilling deeper on shallow structures may not be an effective exploration strategy for lower Paleozoic reservoirs. Study of Trenton outcrops in northern Illinois shows that there are several types of porosity development in these rocks and faulting and karstification along fault trends has played a major role in porosity development and permeability pathways. These findings may have application and development of Trenton reservoirs in deeper portions of the basin.

A synopsis of major findings follows:

- The Lower Paleozoic strata in the Illinois Basin have a strong potential to contain significant economically viable reserves.
- The New Albany Shale is an excellent source rock with total organic carbon values upwards of 10%, and is in the oil generation window throughout the Basin.
- The New Albany Shale is under-explored for natural gas that is co-generated with the oil. Several tests have been conducted with varied results.
- The Middle Devonian strata have significant potential, especially when new exploration techniques, such as 3-D seismic, are applied.
- Lower Devonian cherts are largely un-explored outside of a very limited region. Additional fields could contain significant untapped reservoirs.
- Some Devonian reservoirs are related to erosion of and deposition on actively growing positive areas and structures (e.g. Sesser and Assumption Consolidated oil fields).
- Much Silurian production is connected with reef structures, either directly as in the pinnacle reef plays and the patch reefs of the Mt. Auburn Trend, or as associated strata as in the Springfield East play.
- There is still potential for additional pinnacle reef discoveries.
- 3-D seismic is an under-utilized tool in the Illinois Basin.
- Existing Trenton production is mostly limited to areas with high degrees of closure, beneath shallower production on large structures.
- Porosity development in the Trenton production is tied to diagenetic alteration.
- The primary reason the Trenton is underexplored because it is the lowest of the proven oil strata in the Illinois Basin.
- Fractures resulting from deeper basement faults can create significant off-structure potential.
- Axial shifts and erosional events can mask Trenton highs, exploration needs to evaluate structural variation at depth.
- There is potential for a sag or down drop fault block pay in the Trenton, similar to Albion-Scipio in the Michigan Basin and recent discoveries in the Northern Appalachian Basin

Methodology

The Illinois State Geological Survey, Indiana Geological Survey and the Kentucky Geological Survey have interpreted thousands of well records to construct basinwide cross sections, contoured structure maps and isopach maps. Deep well data has been analyzed. Detailed cross sections, structure maps and thousands of well records were analyzed and interpreted to develop a catalogue of existing Lower Paleozoic fields. Data from previous studies as well as new data were analyzed to develop products for exploration and development of reservoirs in lower Paleozoic strata in the Illinois Basin. Samples were selected and analyzed from existing oil collections and new oil samples have been collected and analyzed for gas chromatography analyses. Available cores from Lower Paleozoic strata were examined, described and sampled for thin sections. New field studies were completed. Regional cross sections were constructed and interpreted. Regional contoured structure maps and select regional seismic lines were analyzed to examine the structural evolution of the Illinois Basin.

New field studies have been completed for Middle Devonian, Lower Devonian, Middle Silurian, Lower Silurian and Ordovician Trenton reservoirs. Hundreds of well files have been interpreted and pertinent data entered into the ISGS well data file. Detailed maps have been constructed that provide new understanding of play trends in Lower Paleozoic units in the Illinois Basin.

Construction of 10 digital regional cross sections across the Illinois Basin was completed. Contoured structure maps on the Beech Creek “Barlow” Limestone and Ste. Genevieve Limestones at 100 and 20 foot contour intervals were completed and are available on the ILoil website. Formation depths were interpreted from geophysical logs and assembled into a database for construction of contoured structure maps for the top and base of the New Albany Shale, base of Silurian and top of the Trenton/Galena Formations. Over 100,000 formation depths have been mapped, edited and added to the digital data for construction of contoured structure maps.

Data for waterflood units in Lower Paleozoic units has been added to the ILoil website and is available online including graphs of annual petroleum and water production. Over 140,000 geophysical logs have been scanned in areas best suited for exploration in Lower Paleozoic units. These logs are accessible for viewing and downloading from the ILoil website.

Publications and contract reports pertinent to exploration and development of Lower Paleozoic reservoirs have been added to the ISGS website. Examples of the types of information included in these publications are statewide structure maps on the Ordovician Trenton and Devonian New Albany Shale as well as Field Studies of the Devonian Hoing Sandstone reservoir in the Colmar-Plymouth Field, and Silurian Kankakee dolomite reservoir at the Buckhorn Field in Adams, Brown and Schuyler Counties, Illinois.

Project Results and Discussion

Overview Discussion of Devonian, Silurian, and Ordovician Reservoirs

An overview discussion will take place in descending order starting with Middle Devonian reservoir, then Lower Devonian, followed by Niagaran age Silurian reservoirs, then Lower Silurian reservoirs followed by Ordovician Trenton/Galena reservoirs. Correlation charts developed by the Illinois Basin Consortium and shown in figures 1 and 2 were used in this study to construct cross sections and to develop structure and isopach maps. Units that produce from existing Devonian, Silurian and Ordovician age lower Paleozoic units are identified by green dots in the correlation charts (figures 1 and 2). A generalized stratigraphic column of strata in the Illinois Basin highlighting the major unconformities and erosional surfaces is shown in fig. 3. There is a wide distribution of Lower Paleozoic reservoirs (fig. 4). These reservoirs account for approximately 8 percent of production in the Illinois Basin.

New Albany Shale review

There has been increased interest in the New Albany Shale in recent years as production from other Devonian age black shales has been realized in numerous US basins.The Upper Devonian New Albany Shale is a thick, organically-rich source rock that is present virtually everywhere that oil and gas are produced in the Illinois Basin. It is thickest in southern Illinois and western Kentucky, where it is more than 400 feet thick.

- The source rock is predominantly Type II Oil Prone material and is the major source of oil in Silurian through Pennsylvanian reservoirs in the Illinois Basin.
- Numerous studies of the New Albany Shale in Illinois (by Cluff et. al. 1981, Cluff and Barrows) describe an organic rich source rock that is generally in the oil window with some areas of intense generation that likely produced gas in the deep basin and in the Fluorspar District in southeastern Illinois.
- There has been recent gas exploration in the New Albany in Illinois, sparse reports of gas discoveries to date have been on anticlinal structure domes, along the LaSalle Anticline trend, at Russellville and Westfield, and on the Clay City Anticline.
- Although the original gas wells drilled are vertical wellbores, it is thought that production can be improved using horizontal drilling programs, such as one recently undertaken at Russellville.
- In Indiana, exploration of the New Albany in predominantly reef-drape structures along the Terre Haute Reef Bank has resulted in several gas discoveries.
- The gas is likely from a mix of thermogenic and biogenic processes. Whether this reef drape play is a model for a gas play in the New Albany in Illinois has yet to be determined.
- A recent horizontal wildcat effort by Bravo is located in southern Saline County, south of the Cottage Grove Fault, and flanking the Hicks Dome feature. The gas play in this area would be a thermogenic play if it proves to be commercially viable. Bravo Natural Gas, LLC (Bravo) Tulsa, Oklahoma, drilled two exploratory New Albany Shale wells in 2006 on a 150,000 acre block controlled by the company in Saline County, Illinois. Bravo chose this geologic area due to its proximity to the thermally mature Hicks Dome area, in the thick untested New Albany Shale penetrations on the acreage block, and

depths/pressures sufficient to yield significant gas in place.
The Gray #1-34, Section 34-T9S-R6E, was originally drilled vertically to a depth of 4580' to gather extensive electric log data. After plugging back, a 3500' horizontal leg was drilled in the New Albany Shale and tested in the Gray #1-34H well. Gas shows, sample evaluations, gas analysis, and electric log data confirm that the Gray #1-34H well penetrated highly fractured thermogenic New Albany Shale. Subsequently, the Herrmann #1-7, Section 7-T10S-R7E, was drilled three miles to the southeast of the Gray #1-34 at an updip location. Gas shows were also encountered throughout the New Albany Shale in the 4324' Herrmann #1-7 well. Both wells penetrated over 300' of very organic, black carbonaceous New Albany Shale.

Reservoirs in Devonian Strata

The sub-Kaskaskia unconformity separates oil productive Middle Devonian dolomite and dolomite cemented sandstones from Lower Devonian through Silurian strata. In the central and deepest portion of the basin the sub-Kaskaskia unconformity separates Middle Devonian carbonates from Lower Devonian carbonates and siliciclastic cherts. In the western portion of the Illinois Basin, the sub-Kaskaskia unconformity represents a much longer period of erosion than in the central portion of the basin. In some areas lower Devonian through upper Ordovician strata have been eroded and Middle Devonian units may directly overlie Ordovician strata. Interpretation of stratigraphic relationships and analysis of facies changes and diagenetic alteration of sub-Kaskaskia rocks shows good potential for additional discoveries in subcrop plays in Middle Devonian through Lower Silurian rocks.

Details of the stratigraphic relationship of Middle Devonian and Lower Devonian reservoir units are shown in figure 5. Middle Devonian oil productive units include the Hoing Sandstone member of the Cedar Valley Formation, the Lingle Formation, and the Dutch Creek Sandstone and Geneva Dolomite members of the Grand Tower Formation. Middle Devonian strata are separated from Lower Devonian rocks by the sub-Kaskaskia unconformity. Lower Devonian producing horizons include the Clear Creek Chert, Backbone Limestone, and Grassy Knob Chert.

The youngest lower Paleozoic reservoirs in the Illinois Basin are found in the Middle Devonian Hoing Sandstone member of the Cedar Valley Formation in westernmost Illinois in the Colmar- Plymouth field. The field was discovered in 1914 and produces from a shallow depth of 450 feet below the surface. It has produced 5 million barrels of oil from 500 wells in an area of 2,500 acres. There is approximately 50 feet of structural closure in the field. The reservoir rock is composed of well sorted, well rounded, medium-grained sandstone cemented with dolomite. Porosity of the reservoir interval averages 19% in core samples and the average permeability exceeds 1 darcy in core samples.

The lowermost members of the Middle Devonian Grand Tower Formation contain some of the most prolific lower Paleozoic reservoirs in the Illinois Basin. The Dutch Creek sandstone grades laterally into the Geneva Dolomite, both are the lowermost members of the Grandtower Formation and unconformably overlie Lower Devonian units. The stratigraphic and facies relationships of these units are shown in the regional cross section in figure 6. The distribution of these two facies as mapped by ISGS geologists in 1965 is shown in figure 7. The 1965 map shows a distinct tongue of Dutch Creek Sandstone with limited areal distribution. Recent work shows a much broader

distribution for the Dutch Creek Sandstone, increasing the potential area of this play.

Middle Devonian Dutch Creek Sandstone Reservoirs

The Dutch Creek Sandstone is found just above the pre-Middle Devonian unconformity. The sand source is thought to be reworked St Peter Sandstone and other older Ordovician sands that were exposed on the ancient Ozark highlands and swept into the Illinois Basin (Collinson, 1969.) Meents (1965) mapped a regional tongue of Dutch Creek sand primarily located in Wayne County, but North (1969) suggested the Dutch Creek was more widely distributed in the basin.

The Dutch Creek Sandstone is dolomite cemented, fine to medium grained with well sorted and well rounded quartz grains. The histogram of core measured porosity shown in figure 8 illustrates distribution of samples in the 7 – 12% porosity range as well as a distribution of values in the 14 – 20% range. Permeability shown in figure 9 ranges from 10 – 50 millidarcies in samples of marginal reservoir quality and from 70 md to greater than 1 darcy in samples from good to excellent reservoir quality.

Existing Dutch Creek production is primarily located in Wayne County. Production is associated with localized highs contoured on overlying younger Middle Mississippian marker horizons such as the Beech Creek "Barlow" Limestone. These localized highs are not evident on regional Barlow contoured structure maps (figure 10). The regional Barlow map shows that the Dutch Creek pays are found on the northern margin of the deep structural drop-off into the Fairfield Basin.

A closer look at the Dutch Creek pays, imaged on the ISGS vintage 20 foot Barlow contour maps, tells a different story (fig. 11). At Mayberry field, 16 Dutch Creek producers have a strong association with a sharply defined anticlinal nose that trends East-West, dying out into the deep Fairfield Basin to the east.

At Aden field, located on a sharply defined, narrow, elongate anticline that trends directly south off the broad toe of the massive Clay City anticlinal structure, there are 3 Dutch Creek producers and one pay described in the Grand Tower "fracture zone." The pays are associated with more than 20 feet of closure on the crest of the structure. One of these Dutch Creek producers, the Texaco Silverman #16, flowed on choke for 5 years and had a cumulative production of about a half a million barrels. It is one of the deepest producers in the basin at below 5400 feet.

At Mill Shoals field, the Dutch Creek pay is also associated with another sharply defined, narrow, elongate anticline that trends directly south off the toe of the Clay City Anticline. The Dutch Creek pays are on the highest part of the structure with at least ten feet of closure.

The structures defining these fields may be associated with deep basement linear features and it seems possible that episodic movement along zones of weakness may have resulted in fractured reservoirs. Other Dutch Creek pays are associated with sharply defined anticlinal structures, such as at Goldengate Consolidated field, which also flanks the northern margin of the deep Fairfield Basin. There, 18 Dutch Creek producers are found on the crest of the structure with over 20 feet of closure.

Middle Devonian Geneva Dolomite Reservoirs

Fields in the Geneva Dolomite in Illinois have been documented in the recent ISGS publication, Illinois Petroleum Series158 titled: The Origin of Prolific Reservoirs on the Geneva Dolomite (Middle Devonian), West-Central Illinois Basin. The Geneva Dolomite is a widespread, brown sucrosic porous dolomite with localized areas of highly developed porosity and permeability. The distribution of the Geneva Dolomite is shown in figure 12. The most productive Geneva Dolomite reservoirs are associated with pronounced structural closure caused by differential compaction over older Silurian age pinnacle reefs. Hydrocarbon becomes entrapped in the younger, porous strata that is draped over the reefs. The Devonian New Albany Shale is the ultimate seal for Geneva Dolomite reservoirs studied to date, including Sandoval, Raccoon Lake, Tonti, Miletus and the oil field at Stephan A. Forbes State Park. Geneva Dolomite reservoirs are also associated with pronounced structural closures at Patoka, Centralia, Salem, and St. James fields.

Maps constructed using modern log suites in the Miletus Field illustrate some of the subtleties of the underlying pinnacle reefs that are not evident in maps constructed for earlier publications that show nearly circular bulls-eye type structural closure at older fields such as Sandoval and Raccoon Lake. A recently constructed structure map, contoured on the top of the Geneva, shows that pinnacle reefs are not flat topped, they undulate or form as clusters (fig. 13). The underlying Silurian Pinnacle reef at Miletus Field is composed of 3 or more separate pinnacles. Each individual pinnacle is separated from the other pinnacles by paleotopographical lows or saddles that tend to be non-productive from the overlying Geneva Dolomite. An isopach map of the Middle Devonian carbonates overlying the Geneva Dolomite at Miletus Field (fig. 14) shows that pronounced thinning of these carbonates coincides with the crest of the structure shown in figure 13 and further thins over the structural relief of the pinnacle clusters. This thinning may be partially caused by differential compaction over the rigid reef core through time relative to greater compaction of the reef flank sediments and subsequent compensating deposition of the Devonian sediments. Thinning of the Middle Devonian carbonate section overlying productive Geneva Dolomite is common to all fields studied in Marion County, Illinois. The ultimate seal in these fields appears to be the Devonian New Albany Shale. The trap in these fields show an inverse relationship between the amount of structural closure and the amount of thinning of the carbonate interval separating the Geneva reservoir rock and the New Albany Shale seal (fig. 15). Petroleum is trapped when closure on the impermeable New Albany Shale encompasses the Geneva Dolomite. As a result, greater structural closure requires less carbonate thinning over the Geneva and more subtle structures exhibit greater thinning of carbonates.

A histogram of porosity values measured from core samples in figure 16 illustrates very high porosities with an interval ranging between 12 – 16% and an additional interval ranging from 17 – 26%. Permeability measured from core samples in figure 17 also show a range of values from 30 md to 500 md representing good to excellent reservoir qualities.

An example of core from a Geneva Dolomite reservoir is shown in figure 18. This example is from the Plains Illinois #25 Smail well in St. James Field. It shows a relatively abrupt contact between the overlying light gray limestone of the Grand Tower Formation and the oil stained highly porous and permeable brown sucrosic dolomite of the Geneva Dolomite. An example of a thin section of a highly porous and permeable reservoir

sample is shown in figure 19. The thin section shows a large amount of intergranular porosity stained in blue surrounding well developed fine-grained zoned dolomite rhombs. The porous reservoir intervals are evident on the neutron density curves of the geophysical logs as shown in figure 20.

Lower Devonian Reservoirs in South Fairfield Basin Area

The Lower Devonian pays in Illinois are in the Clear Creek, Backbone, and Grassy Knob Formations (fig. 21). It is uncertain if the Bailey, the oldest Lower Devonian formation, produces in Illinois. Lower Devonian rocks are characterized in large part as cherty, sometimes dolomitic limestones with the exception of the Backbone which is described as a clean, white limestone. Production is primarily associated with the pre-Middle Devonian unconformity surface where it is coincident with positions on positive structural features with demonstrated structural closure. All Lower Devonian production is found at or near the crests of domes/anticline noses. Like the Dutch Creek play, it is probable that fracturing and diagenesis at the unconformity exposure surface play important roles in reservoir formation. At the unconformity surface, diagenetic alteration, solution, fracturing and an irregular surface topography are likely. The Lower Devonian subcrop map generally defines trends for the unconformity play. In the center of the Basin, the Clear Creek is present at the unconformity surface.

The Clear Creek is the productive horizon along the margins of the south end of the deep Fairfield Basin, at Sesser, Benton North, and Whittington fields (fig. 21). Most wells only penetrate the top few feet of the Clear Creek, leaving the strata beneath the Clear Creek sparsely tested in the deep basin, and making it difficult to evaluate whether the underlying Backbone, Grassy Knob, or Bailey are potential reservoir zones. The south Fairfield Basin Lower Devonian pays are all located on well defined anticlinal structures. The role of fracturing is unknown but seems likely to be important to reservoir quality and permeability. The fault systems are shown on the regional structure maps; the presence of the Lower Devonian pays near faulted zones or deep structural lineations is probably not a coincidence.

Lower Devonian Grassy Knob Chert

The only Grassy Knob production is at Walpole Field in Hamilton County, Section 27, T6S, R6E. It is documented in at least one well, the Henry Energy Satterfield #1. It is the deepest producing zone in Illinois with the Grassy Knob at 5822 feet. The deeper pay was discovered in the Grassy Knob at Walpole Field in 1984. The well was also completed in the Clear Creek at a depth of 5324-34 feet. The well site geologist report indicates that there are numerous porous zones within the Grassy Knob that may be possible pay zones, but log calculations may overestimate the water saturation. The Satterfield #1 has a total cumulative production of over 45,000 barrels from the two Lower Devonian zones. A nearby well, the McPeak #1, was reportedly completed in the Clear Creek pay at 5314-5320 feet, and from a cherty, sandy, dolomitic zone interpreted as the Dutch Creek Sand from 5293-5297 feet, although this zone is suspected to be Clear Creek dolomite, not sand. The McPeak #1 has a cumulative production of over 51,000 barrels. If the Dutch Creek produces at Walpole, which is uncertain because it may be part of the Clear Creek rather than the Dutch Creek, this would make Walpole the southern-most production from the Dutch Creek in Illinois. Structure at Walpole is part of the Dale Anticline, a major anticlinal structure that defines the southern margin of the

deepest part of the Fairfield Basin.

The Barlow regional structure map shows Walpole field as an anticline extending south, off of the larger Dale Field structure. At least 20 feet of Barlow closure is mapped on the crest of Walpole. The field has 3 wells completed in the Grassy Knob and the Clear Creek from a cherty dolomite. It also produces from about 150 wells that are completed in Mississippian sandstones and limestones. It has produced nearly 2 million barrels of oil since its discovery in 1941.

Lower Devonian Clear Creek Chert

In the south Fairfield Basin area, the Clear Creek pay is established at Sesser, Benton North, Taylor Hill, and Whittington fields. Whittington produces from the upper Clear Creek, a cherty, dolomitic limestone. Whittington has produced over 5 million barrels of oil from 156 wells. There are 31 Devonian producers and about 125 wells producing from Mississippian sandstones and limestones in the field.

Lower Devonian Pays on the Sparta Shelf

Lower Devonian carbonates form important reservoirs on the Sparta Shelf, an area west of the Fairfield Basin and considered part of the west flank of the basin. It is separated from the Fairfield Basin by the DuQuoin Monocline. There appear to be several types of pays within the Lower Devonian on the Sparta Shelf, but all the reservoirs have one thing in common; production is generally in the top part of the strata, near and beneath the pre-Middle Devonian unconformity. The Lower Devonian formations are progressively truncated to the west along the unconformity. This results in a series of subcrop belts of older Devonian beds in a westward direction. It is difficult to correlate the Lower Devonian units and map the subcrop using old electric logs. Our work in the next year will examine this subcrop play and study the cores and cuttings. Additional work will examine the role of tectonics on the Sparta Shelf.

The lowermost Lower Devonian Bailey sediments are thought to be transitional from Silurian to Devonian age. Pinnacle reefs developed in the Silurian Moccasin Springs are thought to have continued to grow into the time of Bailey deposition. Along the western margin of Clinton and Washington Counties and continuing west, Silurian reefs were truncated and altered by subaerial exposure, probably during the development of the pre-Middle Devonian sub-Kaskaskia unconformity. Oil production west of the Grassy Knob truncation appears to be limited to the erosionally thinned Bailey and the Silurian reef and reef flank carbonates. In eastern Washington and Clinton counties, it appears that a thicker sequence of Lower Devonian sediments is preserved and some fields, such as Nashville North, produce from Lower Devonian reef drape dolomite. Further to the east, Lower Devonian production at Cordes, Beaucoup, and Irvington fields appears to be from dolomite along larger anticlinal structures. In these fields, there is also established Trenton production. Additionally, these anticlinal features commonly produce abundant oil from Mississippian siliciclastics.

Silurian Reef Production

Stratigraphic relationships of Silurian reservoir units are shown in figure 22. Silurian Reef production is well documented in numerous papers, many of which are now available on the ISGS website. Silurian pinnacle reef reservoirs are most commonly

found on the Sparta Shelf in western Illinois. New data compiled for this includes an analysis of porosity and permeability data measured from core samples of Silurian reef rock. A histogram of porosity measured from core samples shows a distinct bimodal distribution of values. There is a distribution of samples with poor reservoir quality, averaging between 2 and 4% porosity and a second group of samples with excellent reservoir quality averaging between 18 and 20% porosity (fig. 23). Cumulative production differences from separate Silurian reef wells reflect this bimodal distribution of poor and excellent reservoir quality. Some Silurian reef wells are excellent producers while other nearby wells are marginal producers or non-commercial.

Silurian Production Associated with the Sangamon Arch

The Sangamon Arch is a masked paleo-structural feature that today has no distinct structural expression. Present day structure shows a regional, basinward dip to the south-southeast, modified by gentle anticlines. Silurian rocks of the Niagaran series are unconformably overlain by Upper Devonian, New Albany Shale sediments on the crest of the broad positive paleo-structure. Niagaran muddy carbonate and carbonate bank deposits were exposed to prolonged erosion, probably during the Lower Devonian and Middle Devonian. No Lower Devonian rocks are present on the crest of the paleo-arch. Middle Devonian sediments lap onto the flanks but apparently never were deposited on the Arch. Diagenetically-altered Silurian carbonate mud and bank deposits form reservoirs along the flanks of the Sangamon Arch (fig. 24). Occasionally larger framework fossils are observed but the Silurian rocks differ from the “pinnacle reef” buildups observed to the south in the Sparta Shelf area. One large trend of carbonate reservoirs is known as the Mt. Auburn Trend within the Sangamon Arch region. Continuous core from Mt. Auburn has flat to slightly inclined laminated dolomitic limestone with pinpoint porosity and tiny vugs. Springfield East Field forms a small reservoir in Sangamon County, T15N, R3E. Core from a Springfield East producer (Ramsey Edna-Noll) shows the mottled, altered limestone and dolomite reservoir. Clay filled clasts and burrows can be seen, and thin, hairline sub-vertical fractures have been observed. Porous reservoirs commonly appear as dolomite with pinpoint to small vugular pores. Contrasting the producing well with a nearby dry hole, the producer appears to be more pervasively dolomitized. The dolomite in the dry hole tends to have been selectively altered to dolomite along laminae or thin beds or in smaller patches. The Silurian producers in the Sangamon Arch area (blue crosses in figure 24) have an overall linear NE to SW trend, and the coincidence of porous carbonates on the crests of present-day anticlinal features is thought to lead to the best reservoirs. The overall trend may be disrupted by a subset series of nearly perpendicular lineations trending NW to SE.

Silurian production is from Niagaran rocks, similar in age to those found in Silurian pinnacle reefs. Reservoir porosity in this play develops in biohermal build-ups that appear to be shallow water reef-bank or patch reef in nature. A histogram of porosity measured from core samples shows an interval in the 13% - 20% range with good to excellent reservoir quality (fig. 25). The histogram of permeability shows a wide range of values from 50 millifdarcies to over 1 darcy, representing good to excellent reservoir quality (fig. 26.).

On the southern flank of the Sangamon Arch, Middle Devonian rocks lap onto the Arch but never breached the arch. Chert pebble conglomerates have been observed in

dry holes flanking the Sangamon Arch. Middle Devonian Lingle Limestone may be productive at their pinchouts. Unconformity sandstones of the Upper Devonian form important, although discontinuous traps such as the large structural nose at Kincaid field. Farther southeast, on the crest of larger anticlines with pronounced structural closure, Middle Devonian Lingle or Grand Tower carbonate reservoirs are observed.

Lower Silurian Reservoir at Buckhorn Field

The Buckhorn Field in Adams and Brown counties in Illinois is one of the most productive Lower Silurian fields in the Illinois Basin. The field was discovered in 1961 with a substantial field extension discovery in 1981. This field has produced over 2 million barrels of oil from a depth of 650 feet below the surface. The producing horizon is from a sucrosic dolomite located at the base of the Silurian carbonate section in the Kankakee Formation and directly overlies the sup-Kaskaskia unconformable surface on the Ordovician Maquoketa Shale. The log in figure 27 shows a typical stratigraphic sequence for the area. The Devonian New Albany Shale is the ultimate seal for the field. There is a thin Middle Devonian section of Cedar Valley Limestone that is in unconformable contact with the Lower Silurian Kankakee Formation. The upper portion of the Kankakee Formation is composed of dense light gray carbonate mudstone. The lower portion of the Kankakee Formation contains the reservoir interval which is composed of porous dolomite. The neutron porosity curve on the right side of the log shows approximately 20 percent porosity.

Structure played a minor role in petroleum accumulation at the Buckhorn Consolidated Field. The distribution of producing wells in this field correspond closely with areas where thickening is present in the interval from the highly radioactive “hot spot” marker bed in the New Albany Shale to the top of the Ordovician Maquoketa Shale. This thickening reflects a drainage system of subtle paleovalleys (fig. 28) which eroded into the surface of the Maquoketa Shale prior to accumulation of Kankakee carbonates. These channels are delineated by the 110-ft contour of the “hot spot” to Maquoketa interval. This area is shaded in fig. 28 and the outline of the basal porous zone in the Silurian Kankakee is also shown.

The stratigraphic cross section A-A’ (fig. 29) is across the paleochannel (datum is the radioactive “hot spot”). Development of the paleochannel involved erosion of a regional drainage system into the underlying Maquoketa Shale. Silurian age Kankakee carbonates accumulated in the paleochannel in response to the initial Silurian marine transgression. These carbonates accumulated in an equatorial, intertidal to shallow subtidal environment. Later diagenetic events, likely related to concentrated flow of subsurface brines along the floors of the paleovalleys, led to preferential dolomitization and dissolution of fossils to form moldic and vuggy porosity in the basal Silurian carbonates.

Ordovician-Trenton

Production from Ordovician age sediments in the Illinois Basin is limited to the Trenton Group equivalent, the Galena Group (fig. 30). Approximately 13.5 million barrels of produced oil is attributed to Trenton fields in Illinois. Bounding the basin to the east, although not considered Illinois Basin production, is the Lima-Indiana hydrocarbon province. An estimated 100 million barrels of Trenton oil has been produced from this region along the Findlay-Cincinnati Arch in east-central Indiana. Another 150 million

barrels of oil has been recovered from the Trenton section of the Albion-Scipio and adjacent fields along the Kankakee arch that separates the Illinois and Michigan basins.

Ordovician oil pools in the Illinois Basin are generally small, with recoveries ranging up to 5 million barrels. The pools are associated with well-defined, closed structures and were commonly discovered by drilling deeper into structures with established shallower production. Thirty five separate pools, mostly discovered between 1940 and 1960, have been established in Illinois (fig. 31). The reservoirs are small, ranging in size from 10 to 2, 000 acres and are at depths ranging from 700 to over 4000 feet. The oil typically has a high paraffin content and a gravity of 40^{o} or greater unless it has been degraded in shallower pools.

Stratigraphy of the Trenton plays an important role in the establishment of petroleum reservoirs in the Basin. Kolata et al (2001) has postulated that the Sebree Trough, an arm of the open ocean to the south of the Illinois Basin, brought nutrients in up-welling currents that feed an assemblage of fauna that remain as widespread grainstone beds seen in the Trenton section across the basin (fig. 32). Crews (1985) correlated these permeable grainstone beds from the central Basin, DuQuoin Monocline area west across the Sparta Shelf into the Missouri outcrops (fig. 33). These beds are important conduits for the migration of dolomitizing fluid and ultimately, oil migration into the present reservoir settings.

Dolomitization is a common and essential characteristic to the Trenton reservoirs that bound the Illinois Basin and is also a component of the Trenton reservoirs in Illinois. Crews thin section analysis of grainstone beds on the west flank of the Illinois Basin showed at least 10% dolomitization. Along the crest of the La Salle Anticline on the east flank of the Basin, the reservoir beds in Westfield oil field are reported by the operator to be very dolomitic and bounded sharply by unaltered, impermeable limestone. These reservoir beds are commonly less than 5 feet thick (fig. 34).

Porosity and permeability of the Illinois Basin reservoirs is consistently low. Porosity rarely exceeds 10% (fig. 35) and permeabilities exceeding 100 millidarcies are likely fracture related (fig. 36). This is in contrast to the Albion-Scipio and Appalachian Basin fault related play where porosity and permeability can be exceptionally high as a result of extensive dolomitization and solutioning along extensional fault zones.

The model describing the reservoir enhancing component of the fault related play in Michigan and regions to the east is likely similar to the mechanism that produced reservoir potential rock in the Illinois Basin. Hydrothermal fluids moved up through fractures and faults in the Trenton carbonates and were sealed within the Trenton by the overlying, impermeable Maquoketa Shale. The fluids were therefore forced to migrate through relatively porous and permeable grainstone beds, selectively dolomitizing and solution enhancing these beds. Production from the Trenton in the Basin is restricted mostly to the upper 100 feet of the carbonates which indicates that fluid migration through the grainstones may have been concentrated closer to the sealing beds of the Maquoketa Shale.

Evidence for hydrothermal influence can be observed in several areas within and immediately flanking the Illinois Basin (fig. 37). These areas include the Fluospar District in southeastern Illinois where fluorite has been mined and the Mississippi Valley mineralization areas in the northwestern region of Illinois and the southeastern part of Missouri where lead and zinc have been mined. Flurospar has also been observed in a core of the Devonian Geneva Dolomite from Patoka Field, a central Basin location. There is no Trenton production and few exploration wells in the Basin based on the Albion

Scipio and Appalachian Basin fault related plays. The fact that widespread evidence of hydrothermal influence exits within the Illinois Basin indicates that these fault related, sag type plays are a potential source of production in the Basin.

Southwestern Indiana has a well developed dolomite trend with numerous hydrocarbon shows. Based on the only core available within the trend, the dolomite is finely crystalline, calcareous (10-40% calcite), and quite permeable. The dolomite forms lenses at different levels within the Trenton that are laterally discontinuous.

The potential for discovery of more Trenton, closed structure reservoirs also exists. Fields with both vertical and tilted axial planes are documented. Tamaroa Field is an example of a field where the structural closure of the Mississippian reservoir is offset by approximately 0.5 mile to the closure on the underlying Ordovician Trenton reservoir. There is potential for locating Trenton reservoirs in established fields even where Trenton dry holes have been located along the structural high of shallower horizons if these fields display a tilted axial plane.

Secondary Porosity Development in the Trenton (Galena) Dolomite of Northern Illinois

The objectives of this study were description of the geology of north central Illinois, identification of secondary porosity features in the Trenton at its outcrop area in north central Illinois, characterization of the fracture and karst conduit network, development of a karstification model, development of a triple porosity fluid flow model, and identification of potential hydrocarbon source beds & traps.

Porosity types recognized include single Porosity: Containing one porosity type such as intergranular matrix porosity (i.e. sandstone.), double porosity: Containing two porosity types, such as matrix and fracture porosity, and triple porosity: Containing three porosity types, such as matrix, fracture and karst conduit porosity (i.e. fractured and karst dolomite).

Secondary porosity types identified in the Trenton Dolomite are: Matrix; increased porosity due to reduction in volume resulting from dolomitization, Fracture; northwest and northeast vertical fractures and horizontal bedding plane fractures, and Conduit; vertical and horizontal karst pipes forming at the junction of the vertical fractures and the junction of the vertical and horizontal fractures.

Karstification history of the Trenton occurred in the following sequence: Galena deposition (mid-Ord), uplift and meteoric karstification (mid-Ord), Maquoketa through Devonian deposition (mid-Ord thru Dev), hydrothermal karstification (late Paleozoic), uplift, erosion, and further meteoric karstification (late Paleozoic thru present).

Findings from this study are as follows: Secondary porosity in the Trenton occurs as conduits, fractures, and matrix vugs; Fractures and conduits are arranged in an orthogonal pattern with conduits forming at the fracture junctions. The karstification processes occurred in the following order: 1. Meteoric karstification in post-Trenton, 2. Hydrothermal karstification in late Paleozoic, 3. Post-Paleozoic meteoric karstification.

Additional findings are primary fluid flow occurs through conduits, followed by flow from fractures, with fluid storage occurring in the matrix. Triple porosity and

permeability are present; Source beds for the Trenton are the overlying Maquoketa shale and the underlying Guttenberg (Decorah) shale; Hydrocarbon can be trapped in faulted karst domes.

Source Rocks

Gas chromatography analyses of oil from 4 Trenton reservoirs, 4 Silurian reservoirs and 3 Devonian reservoirs have been completed for the source rock-oil correlations studies. Preliminary interpretation of gas chromatographs show strong similarities among Trenton samples and similarities among Silurian age oil but Silurian age oils are very different from Trenton age oils. Trenton age oils are largely devoid of n-C_{17} and higher components while the heavy end of the Silurian age oils taper off gradually. Selected gas chromatographs are shown in figures 38, 39, and 40.

Present Day Structure Maps

Existing reservoirs in lower Paleozoic units in the Illinois Basin produce from pronounced closed structures. Recent research on the structural evolution of major features in the Illinois Basin suggests that the Illinois Basin was influenced by nearby late Paleozoic events related to the nearby Appalachian – Ouachita Orogenies (Kolata and Nelson 1991) as well as Ancestral Rockies events associated with compressive block style deformation (Marshak et al. 2003). These findings suggest the potential for fracture and fault related reservoir discoveries within lower Paleozoic units. Examples of digital structure cross sections constructed for this project are shown in figures 41 and 42.

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Figures

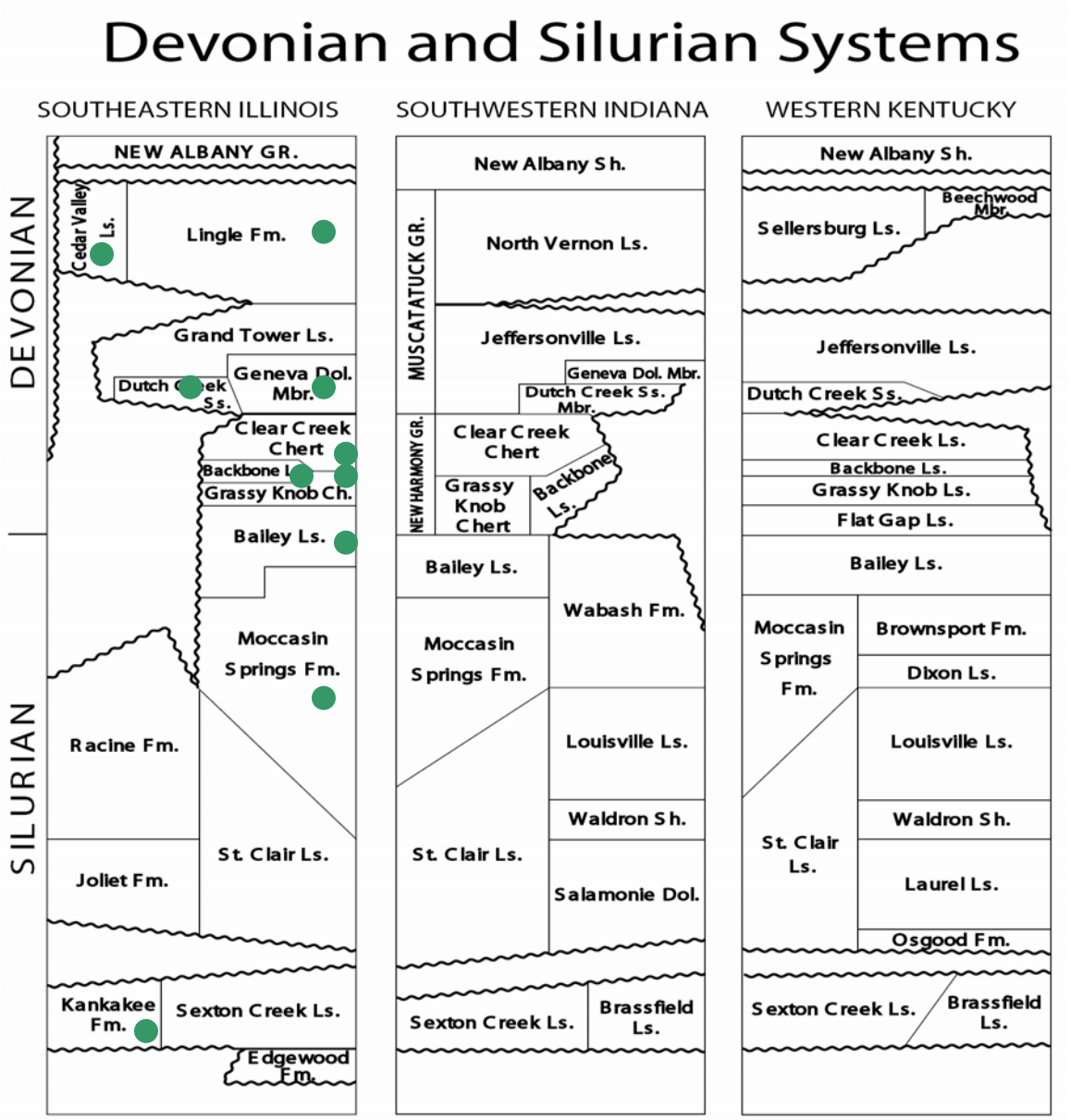


Figure 1. Correlation Chart used for Devonian and Silurian strata in the Illinois Basin. Green dots indicate oil producing horizons. From Shaver et. al., 1986

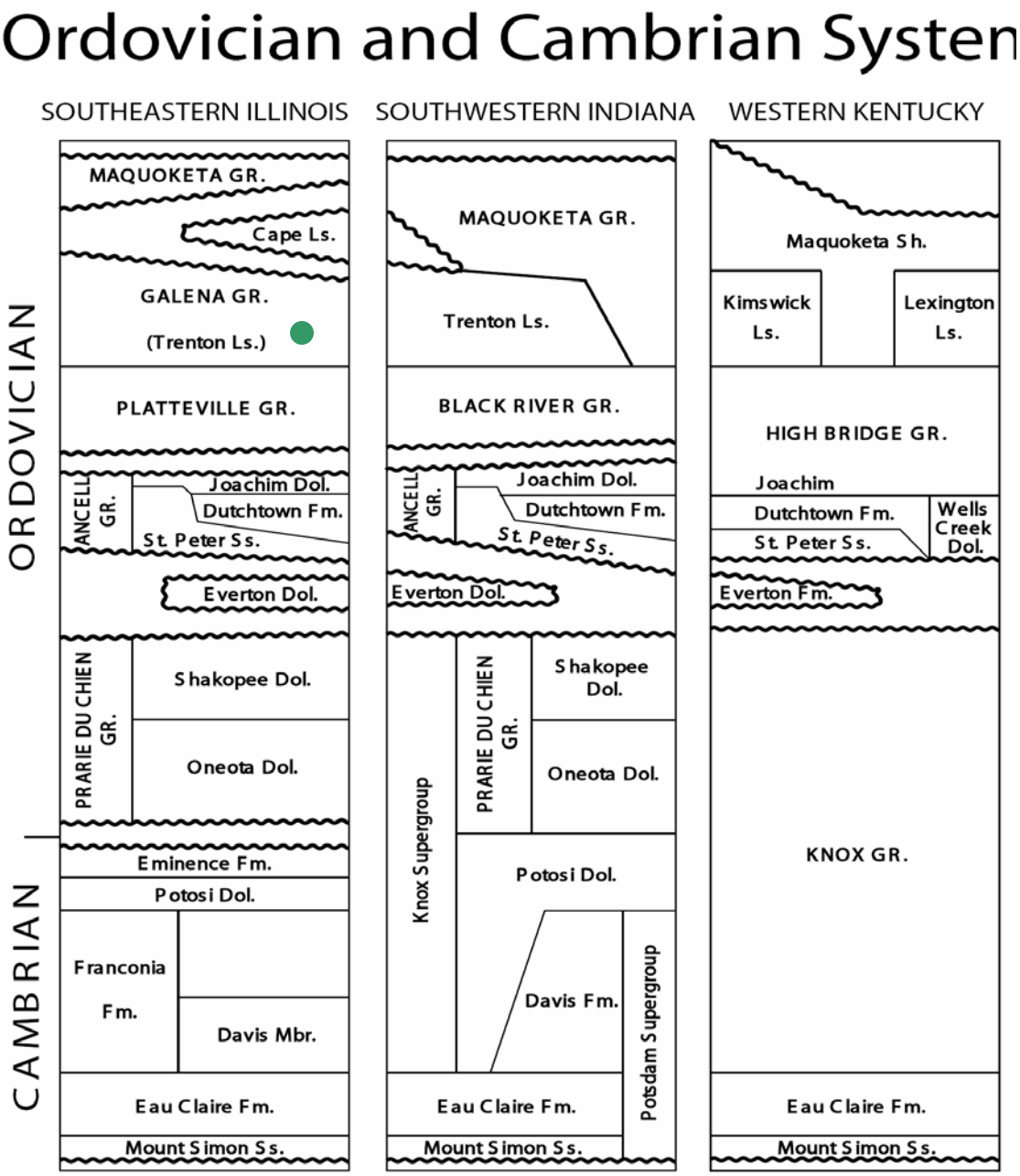


Figure 2. Correlation chart used for Ordovician and Cambrian strata in the Illinois Basin. Green dot indicate oil producing horizon. From Shaver et. al., 1988

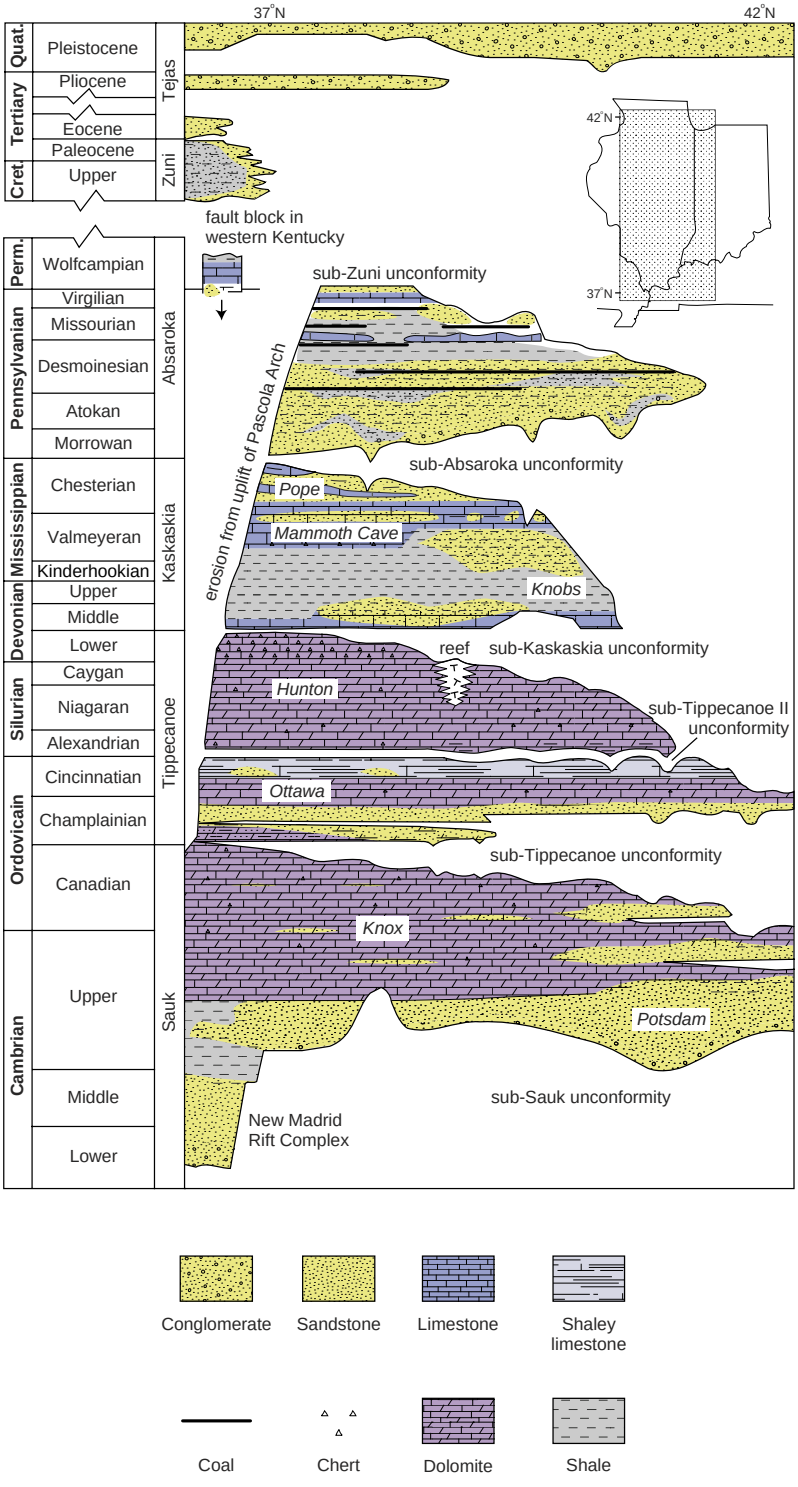


Figure 3. Stratigraphic column of entire rock sequence in the Illinois Basin. From Kolata and Noger, 1991

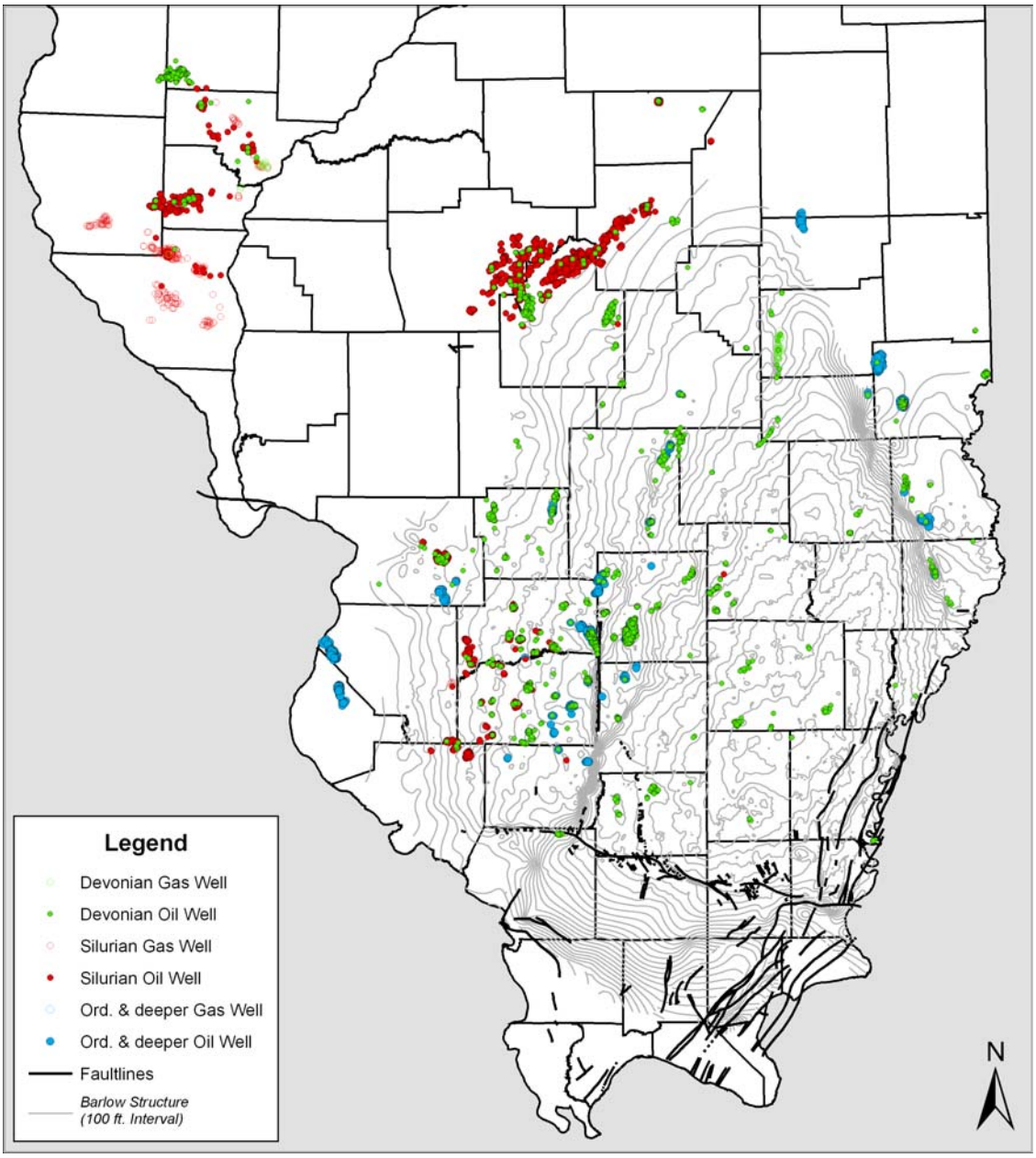


Figure 4. Map showing location of wells with production from Lower Paleozoic horizons in Devonian, Silurian and Ordovician strata.

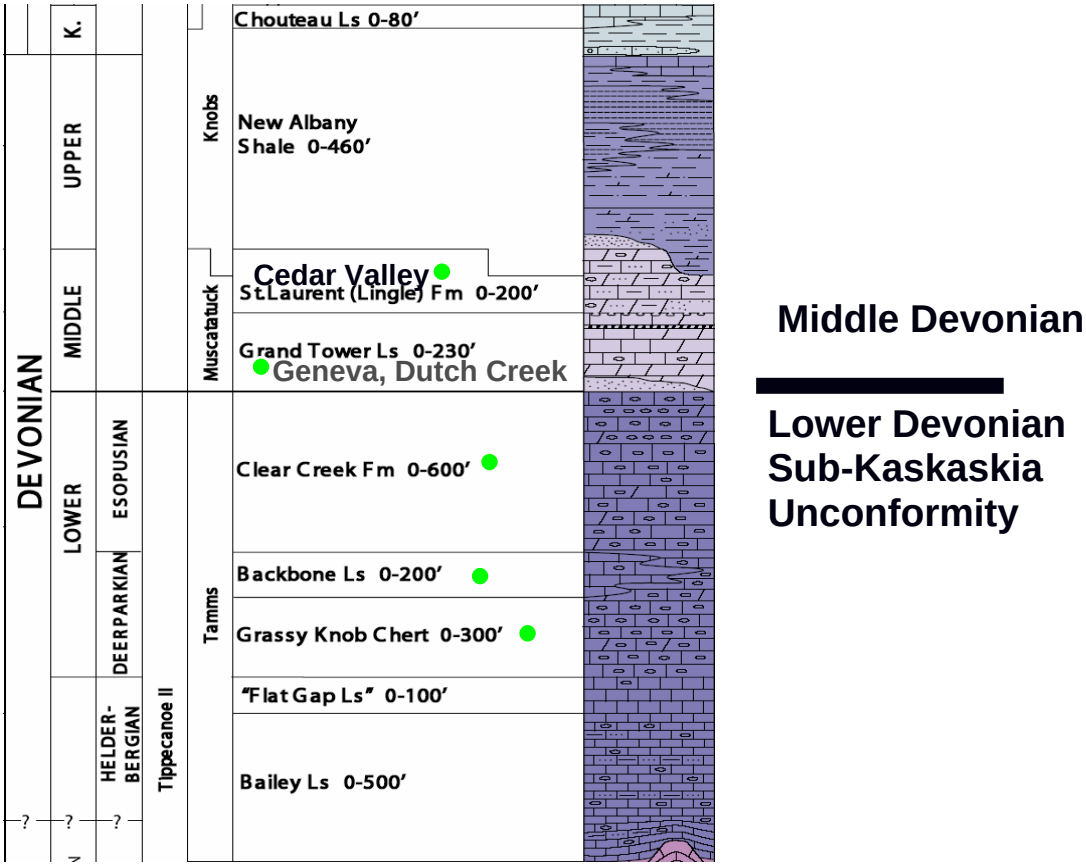


Figure 5. Stratigraphic column of Middle and Lower Devonian units in the Illinois Basin. Units that are oil productive are indicated with a green dot. Modified from Kolata 2005.

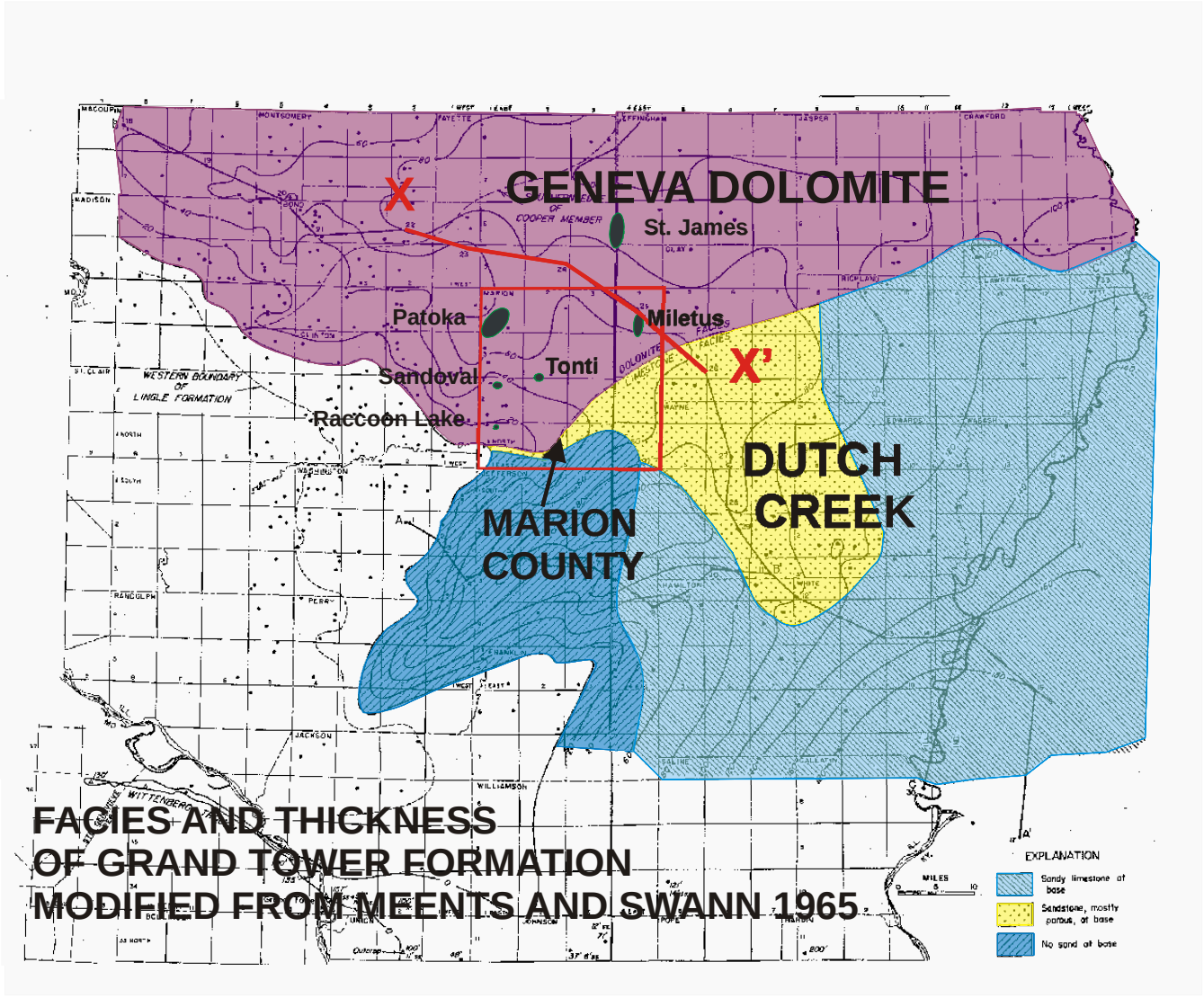


Figure 7. Map showing distribution of Middle Devonian Dutch Creek Sandstone and Geneva Dolomite facies (Modified from Meents and Swann. 1965)

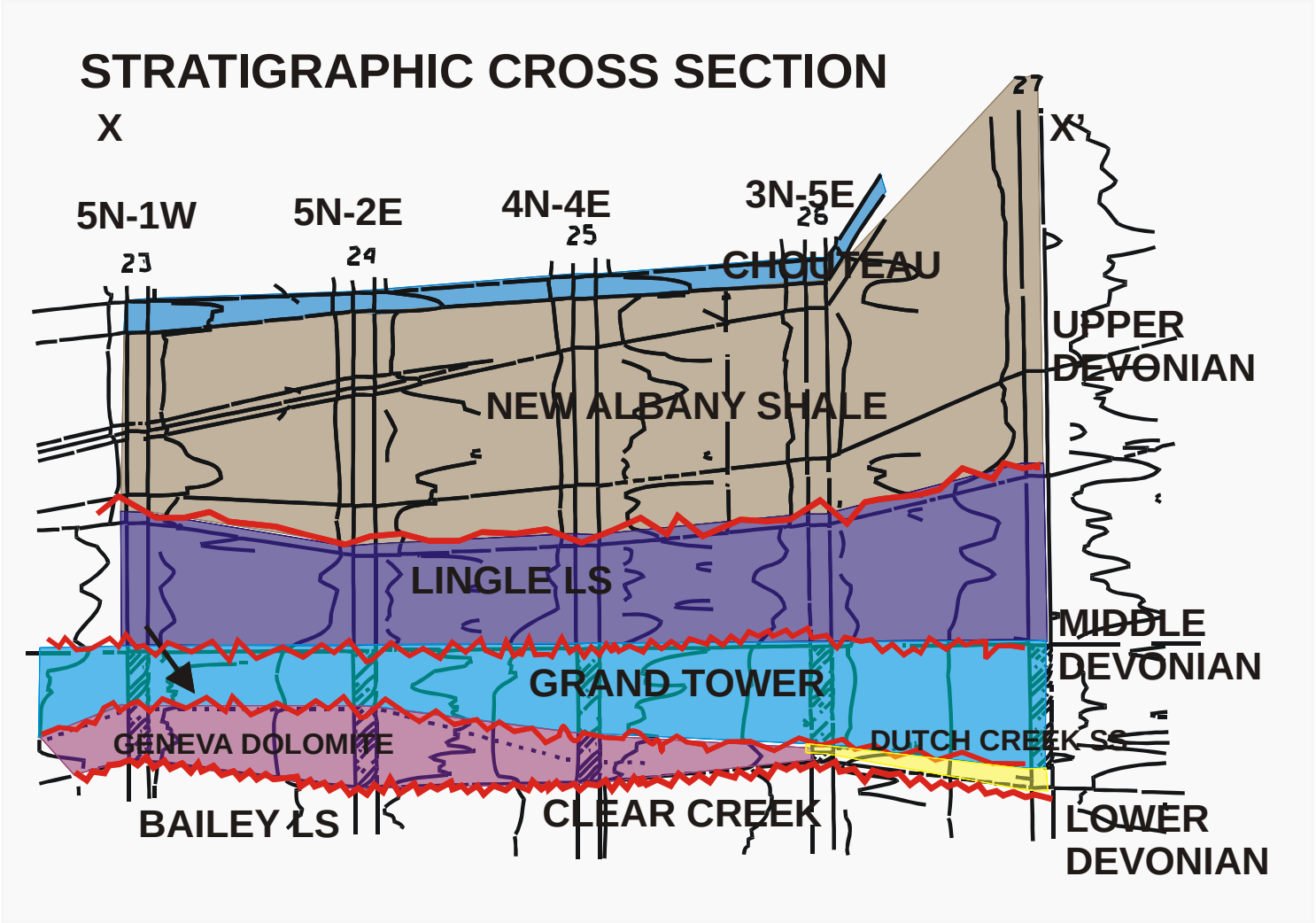


Figure 6. Cross Section illustrating facies relationships of the Geneva Dolomite and Dutch Creek Sandstone members of the Grandtower Formation. Modified from Meents and Swann, 1965.

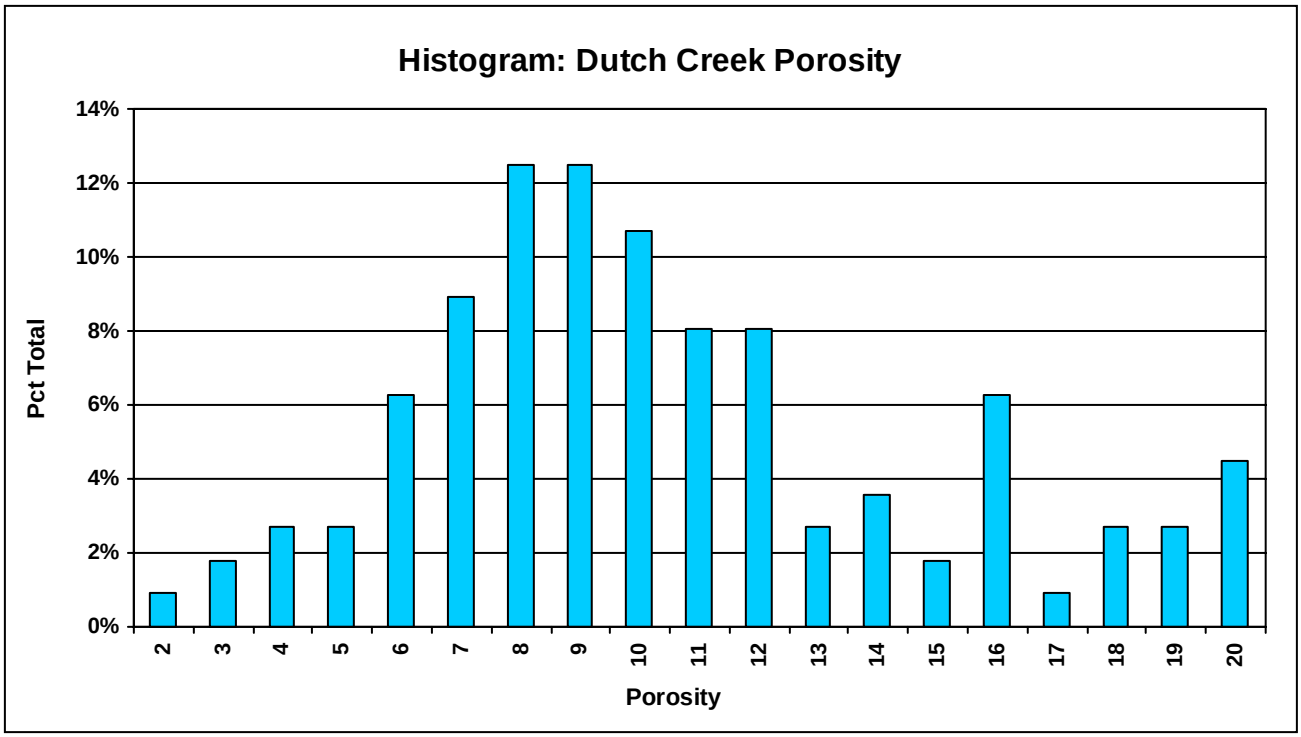


Figure 8. Histogram of porosity measured from core samples of Dutch Creek Sandstone.

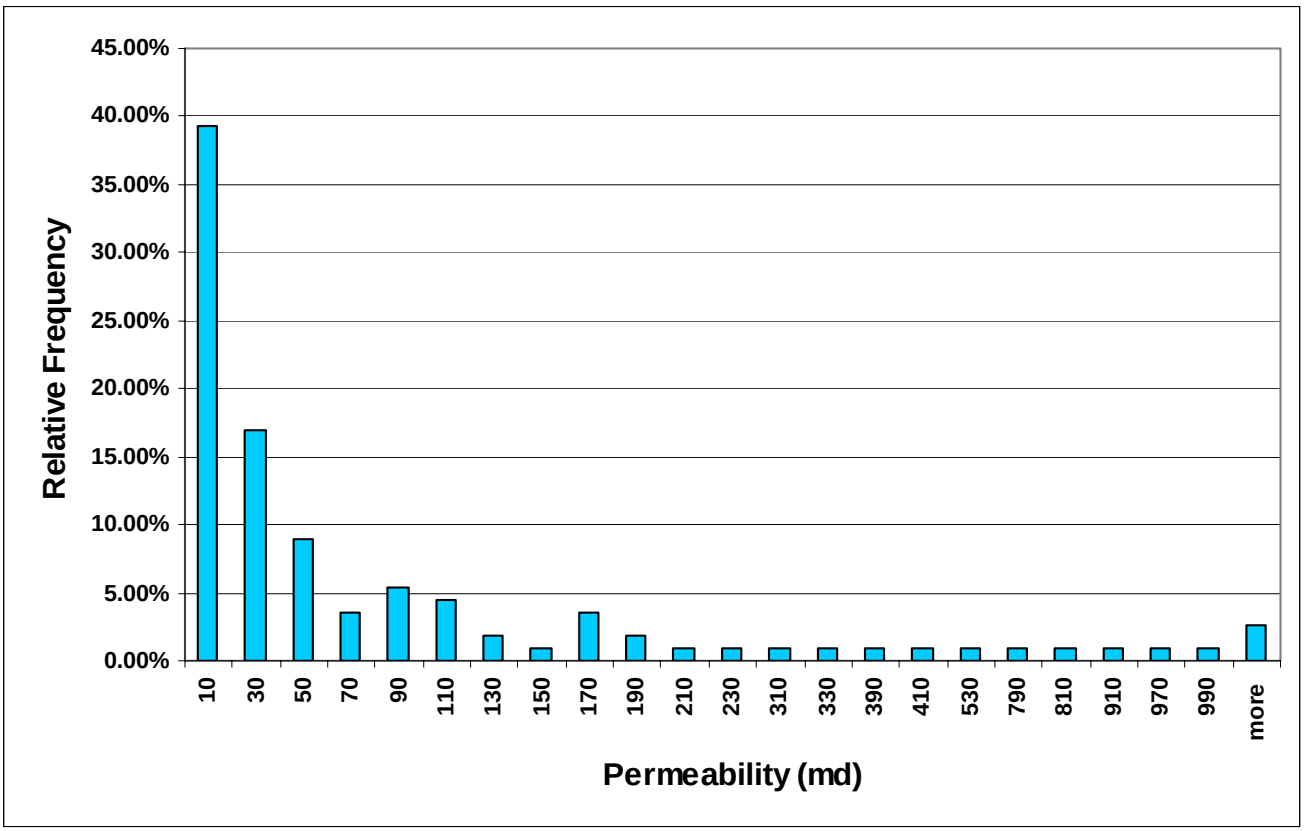


Figure 9. Histogram of permeability measured from core samples of Dutch Creek Sandstone.

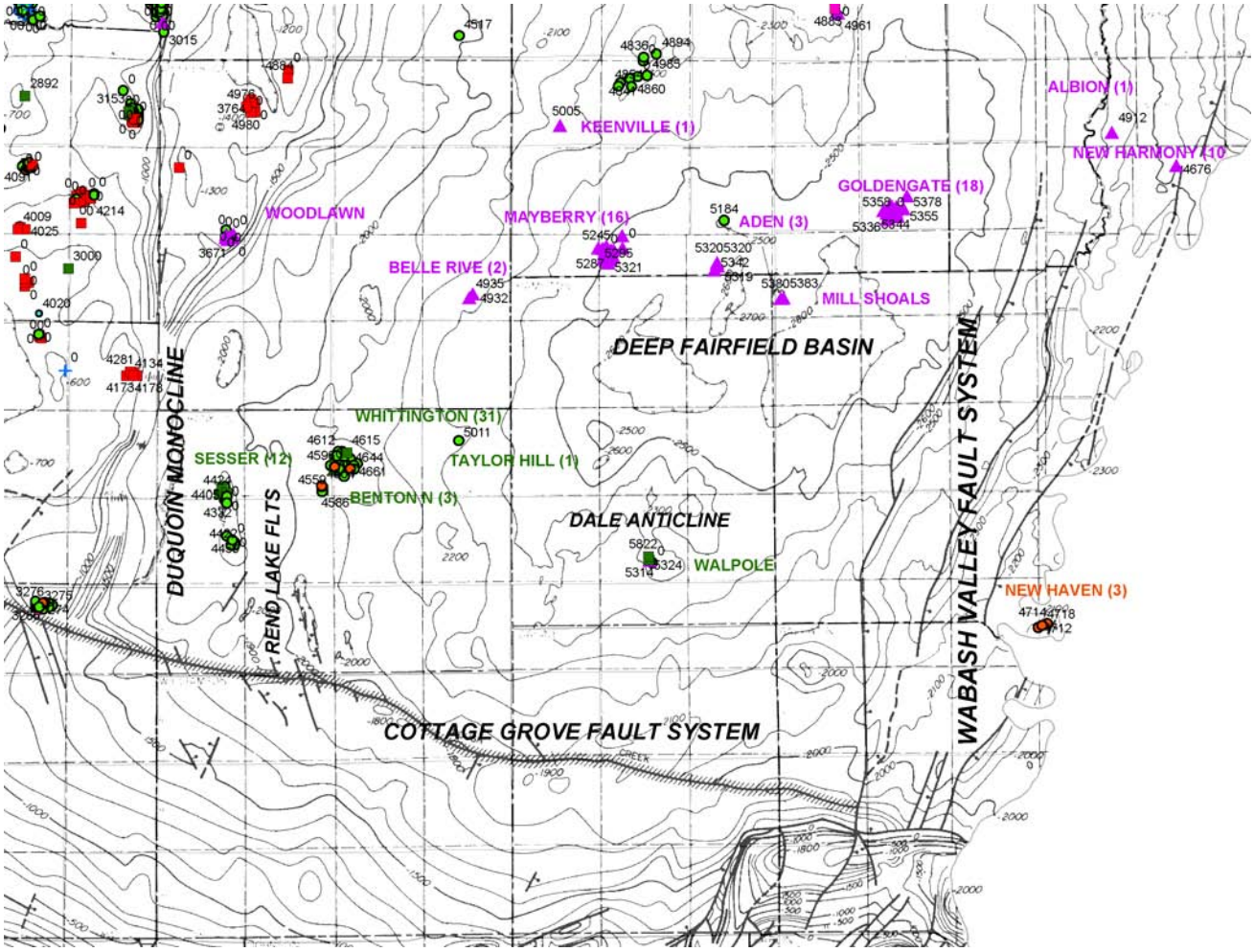


Figure 10. Middle and Lower Devonian producing wells located on regional structure map contoured on the Middle Mississippian Barlow Limestone.

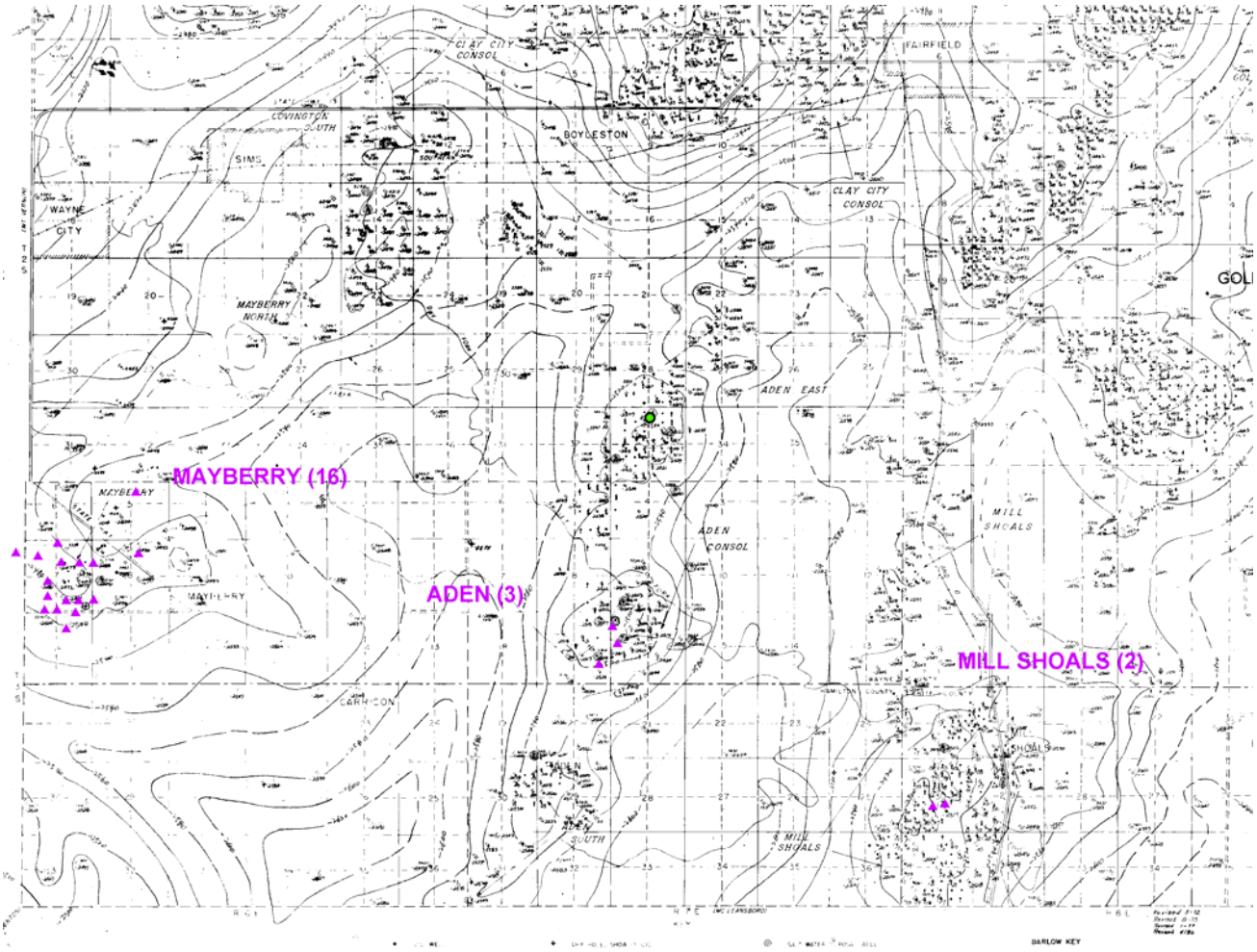


Figure 11. Dutch Creek producing wells shown on Barlow Limestone structure map contoured on a 20 foot interval.

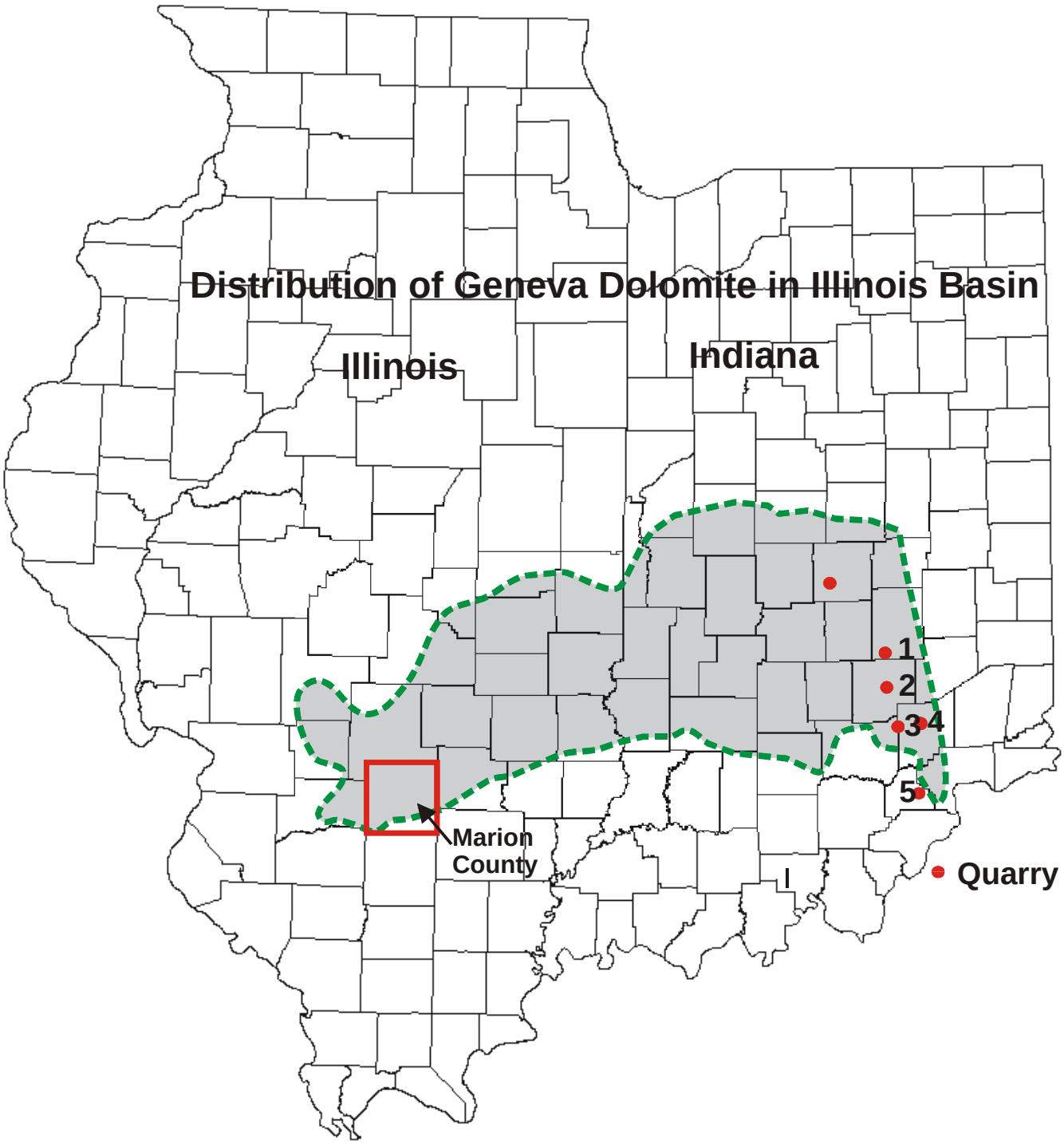


Figure 12. Distribution of the Middle Devonian Geneva Dolomite in the Illinois Basin. Modified from Seyler et. al., 2003

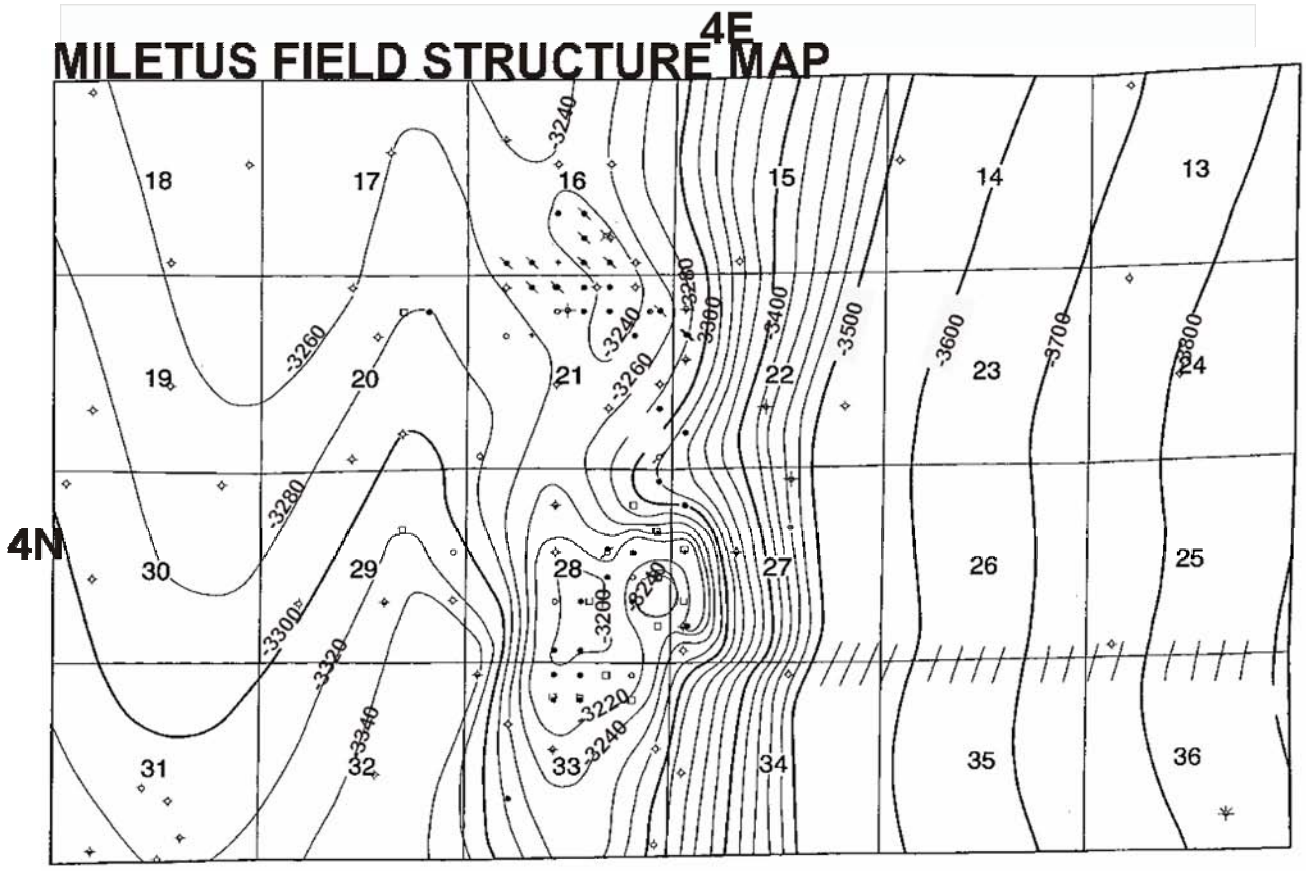


Figure 13. Detailed structure map contoured on the top of the Geneva Dolomite in Miletus Field. From Seyler et. al., 2003.

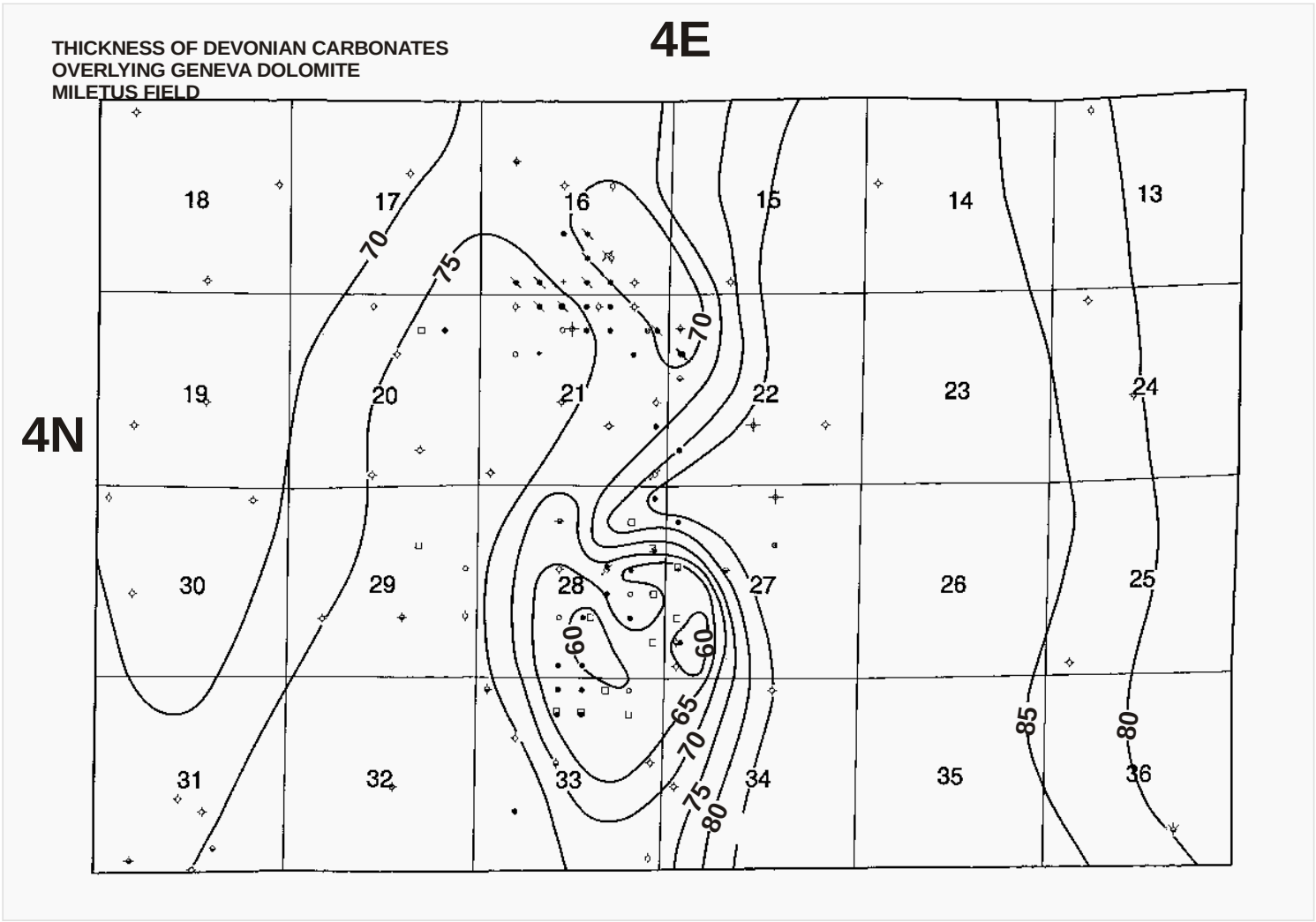


Figure 14. Isopach map of the thickness of Middle Devonian carbonates overlying the Geneva Dolomite at Miletus Field. Thinning of the carbonate unit is illustrated. From Seyler et. al., 2003.

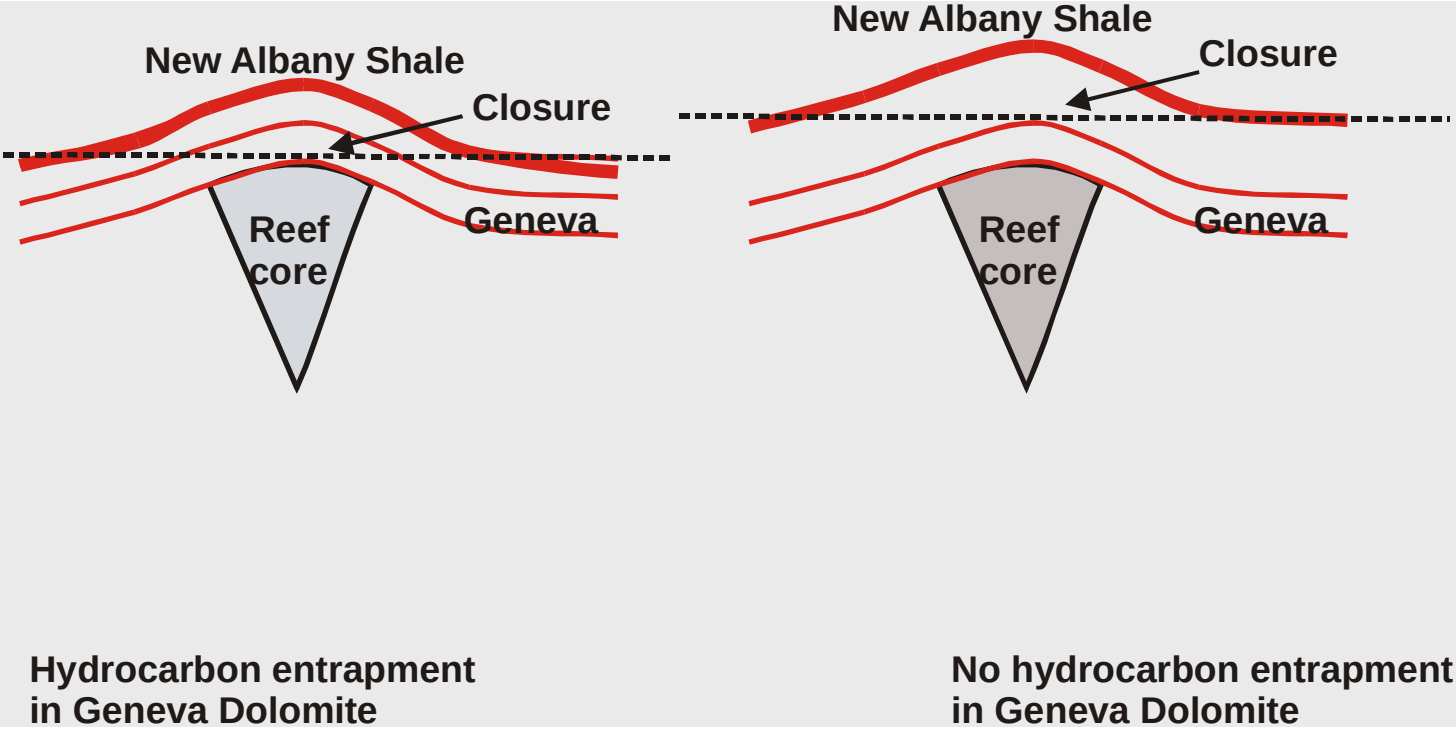


Figure 15. Cross Sections of vertical seals, thickness of Middle Devonian carbonates, and their relationship to hydrocarbon entrapment. From Seyler et. al., 2003.

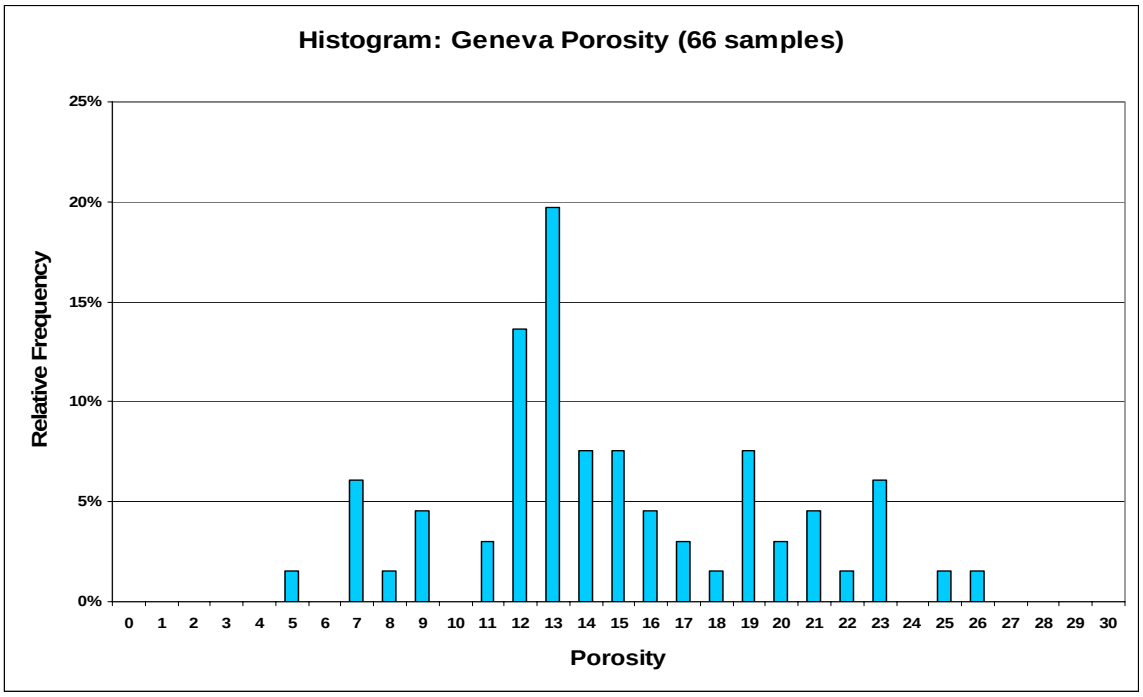


Figure 16. Histogram of porosity values measured from core samples of the Middle Devonian Geneva Dolomite.

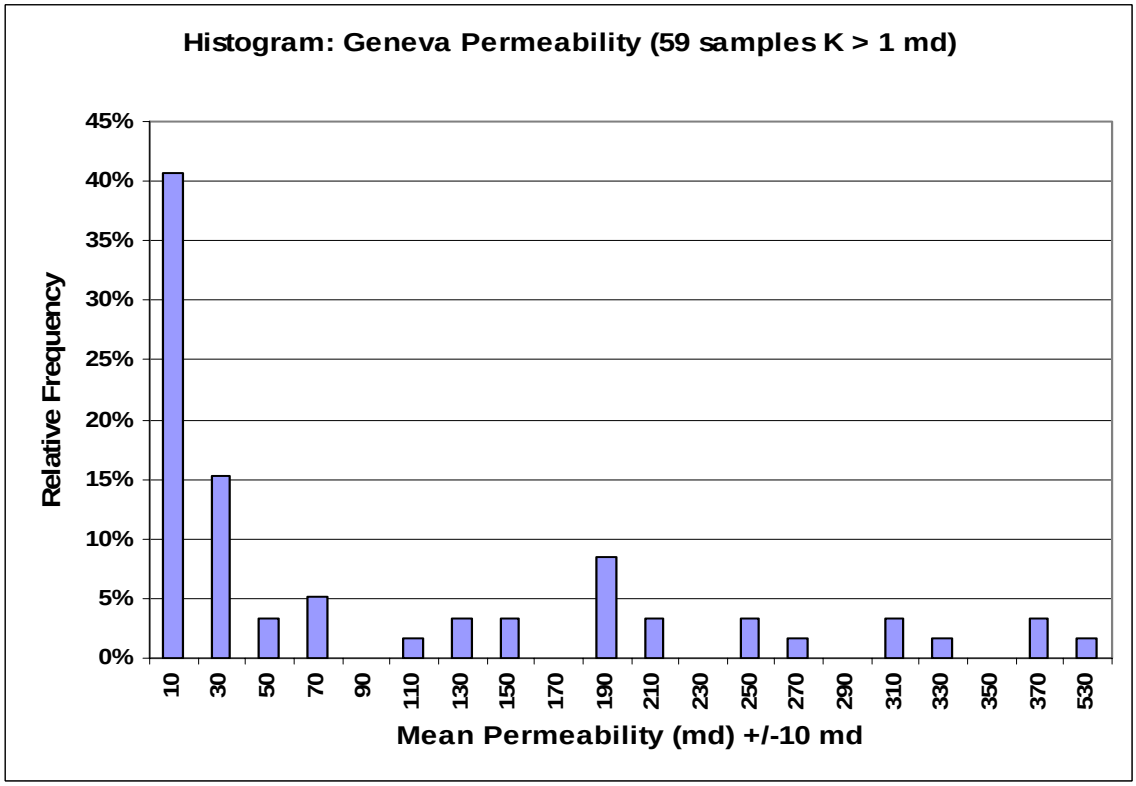


Figure 17. Histogram of permeability values measured from core samples of the Middle Devonian Geneva Dolomite.

Figure 18. Core of the Middle Devonian Grandtower Formation. The lower portion of the core is Geneva Dolomite.

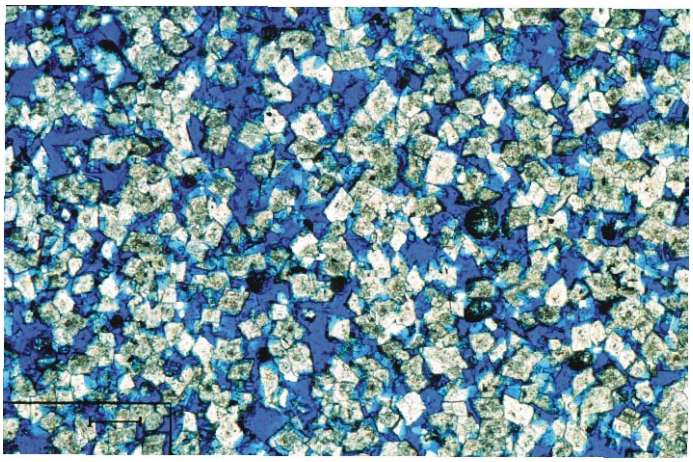


Figure 19. Close-up of Geneva Dolomite reservoir rock composed of brown sucrosic dolomite with moldic and vuggy porosity. Thin section of reservoir rock with porosity stained blue. Large amounts of intergranular and moldic porosity are evident in in this fine-grained dolomite. Zoned rohmbs can also be observed in thin section. Scale bar is .25mm.

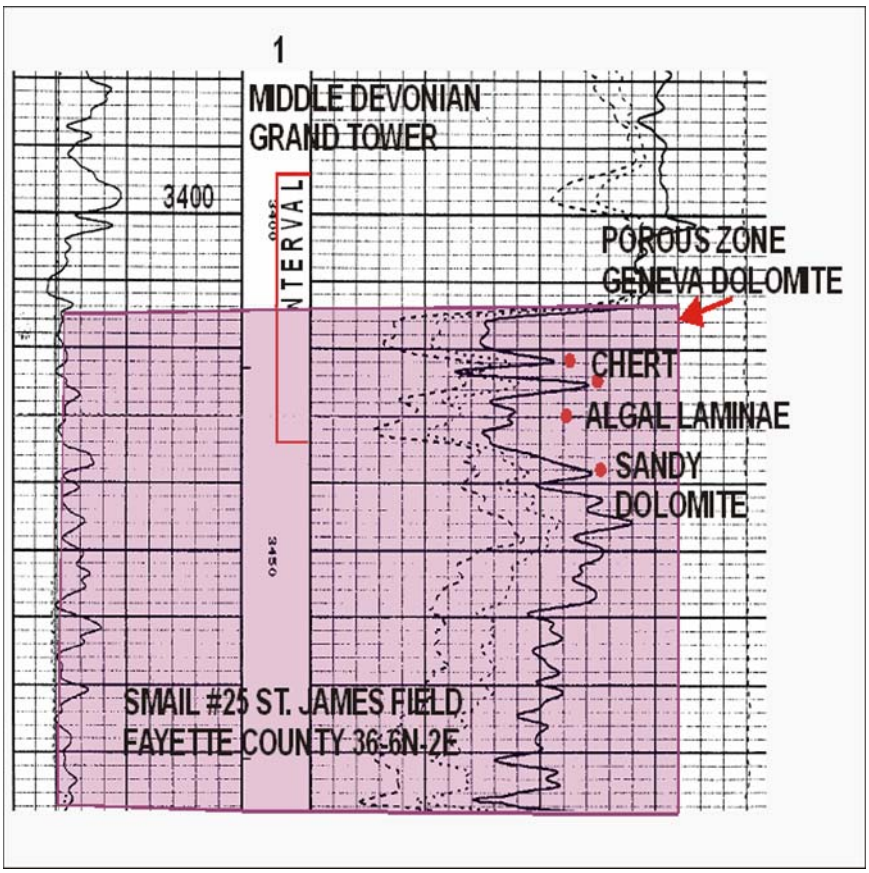


Figure 20. Geophysical logs of the Geneva Dolomite reservoir interval from the #25 Smail well. Log calculated porosity is 20 percent.

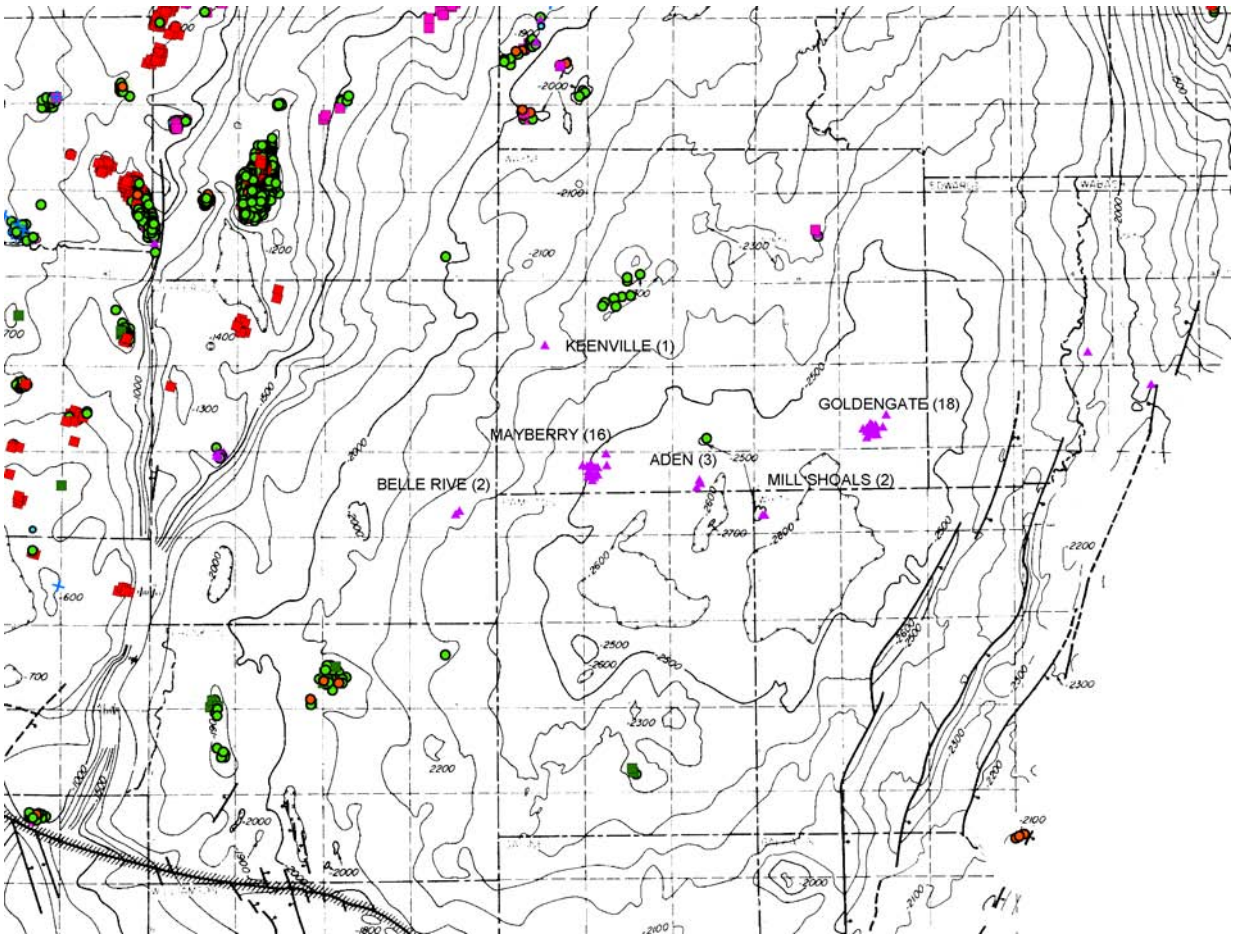


Figure 21. Distribution of Lower Devonian producing wells in Illinois.
color scheme for the pays is:
Trenton: red box
Silurian: blue cross
Hunton/Dev-Sil: aqua cross
Lower Devonian: dark green box
Devonian generic, undifferentiated: bright green dot
Lingle/Middle Devonian undifferentiated: orange dot
Geneva or Grand Tower: pink dot
Dutch Creek or Hoing: purple triangle
Upper Devonian undifferentiated or unconformity sands at base of New Albany: yellow dot
New Albany pay: black triangle.

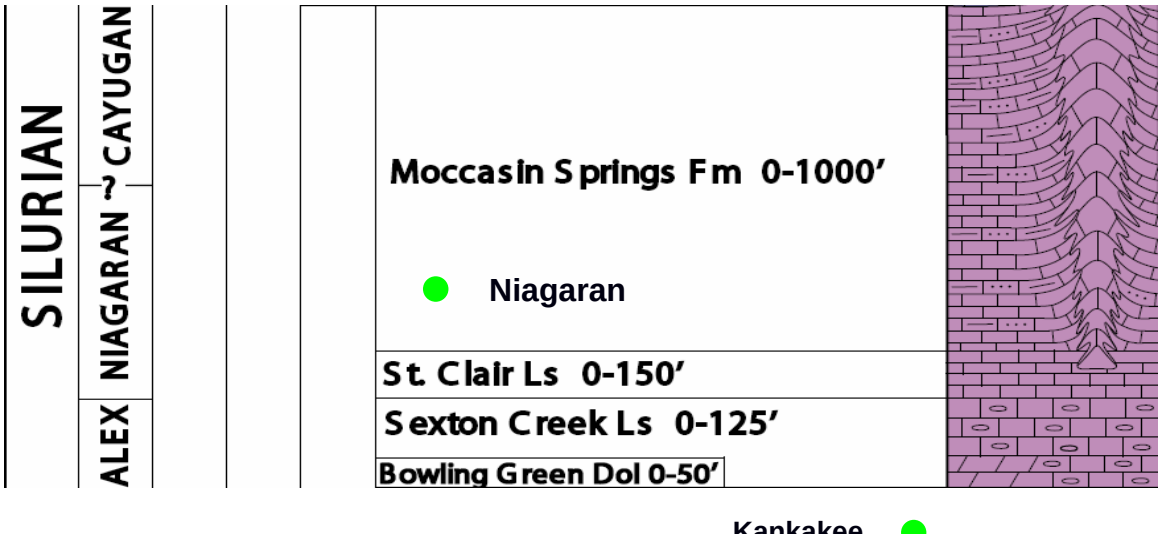


Figure 22. Stratigraphic Column of Silurian strata in the Illinois Basin. Units with production are indicated by green dots. From Kolata, 2005.

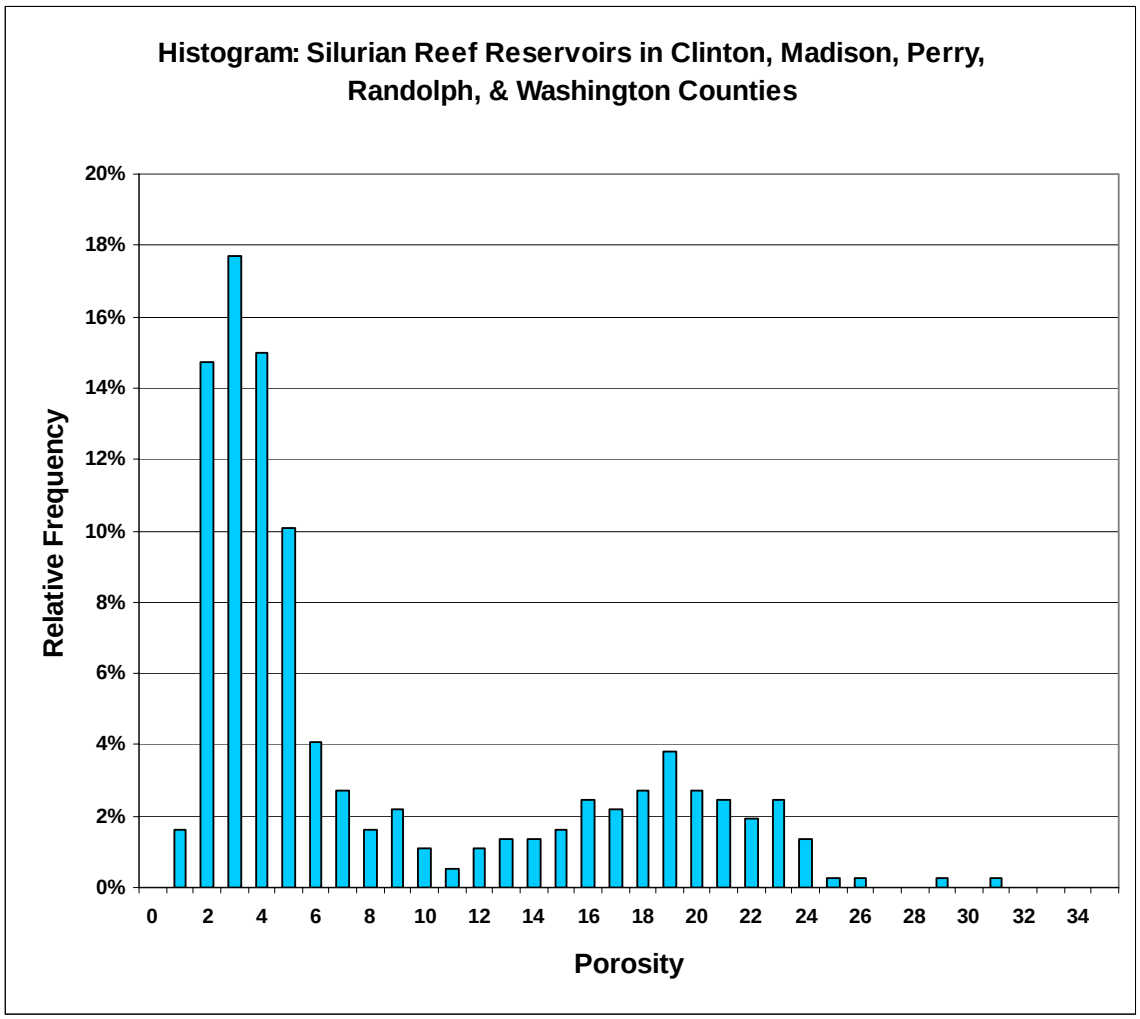


Figure 23. Histogram of porosity values measured from core samples from Silurian Reef Reservoirs in Madison, Clinton, Perry, Randolph and Washington Counties.

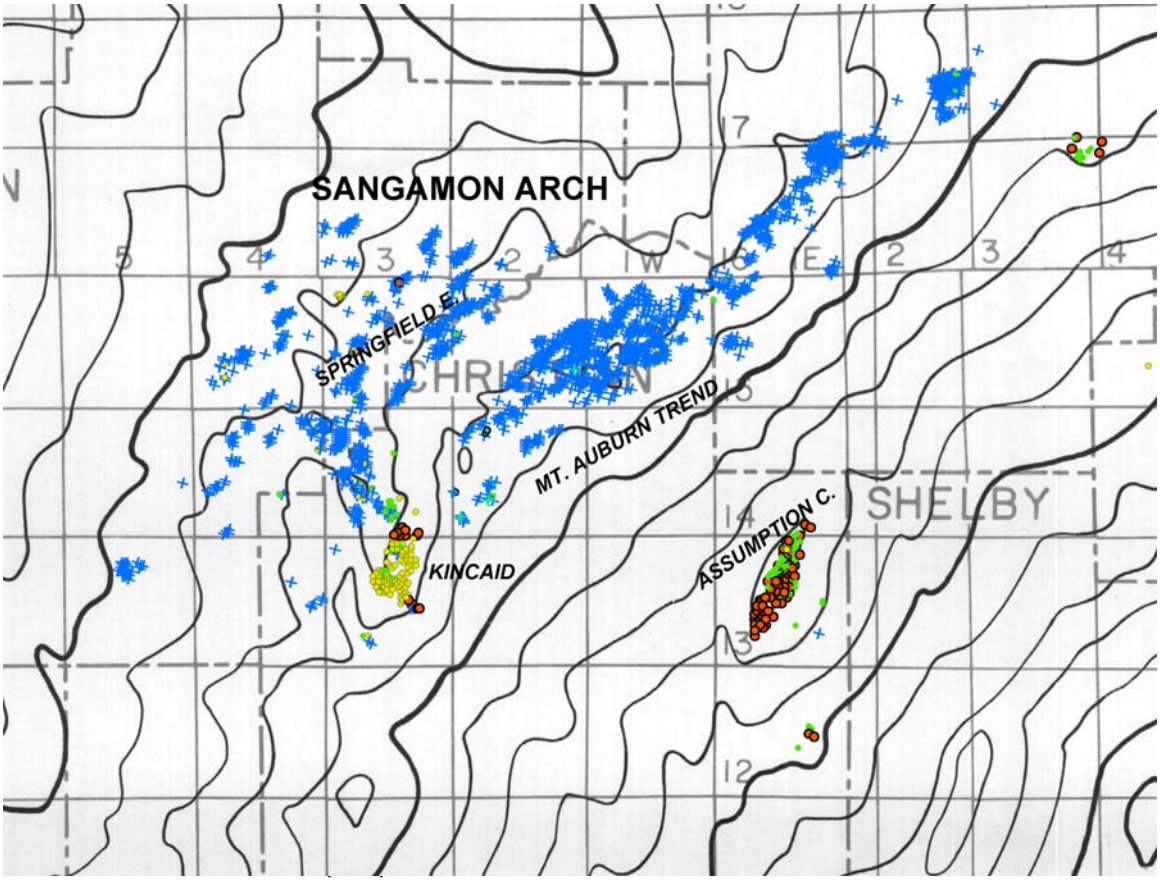


Figure 24. Production along the Sangamon Arch in Illinois. Silurian: blue cross; Hunton/Dev-Sil: aqua cross; Lower Devonian: dark green box,Devonian generic, undifferentiated: bright green dot, Lingle/Middle Devonian undifferentiated: orange dot
Upper Devonian undifferentiated or unconformity sands at base of New Albany: yellow dot

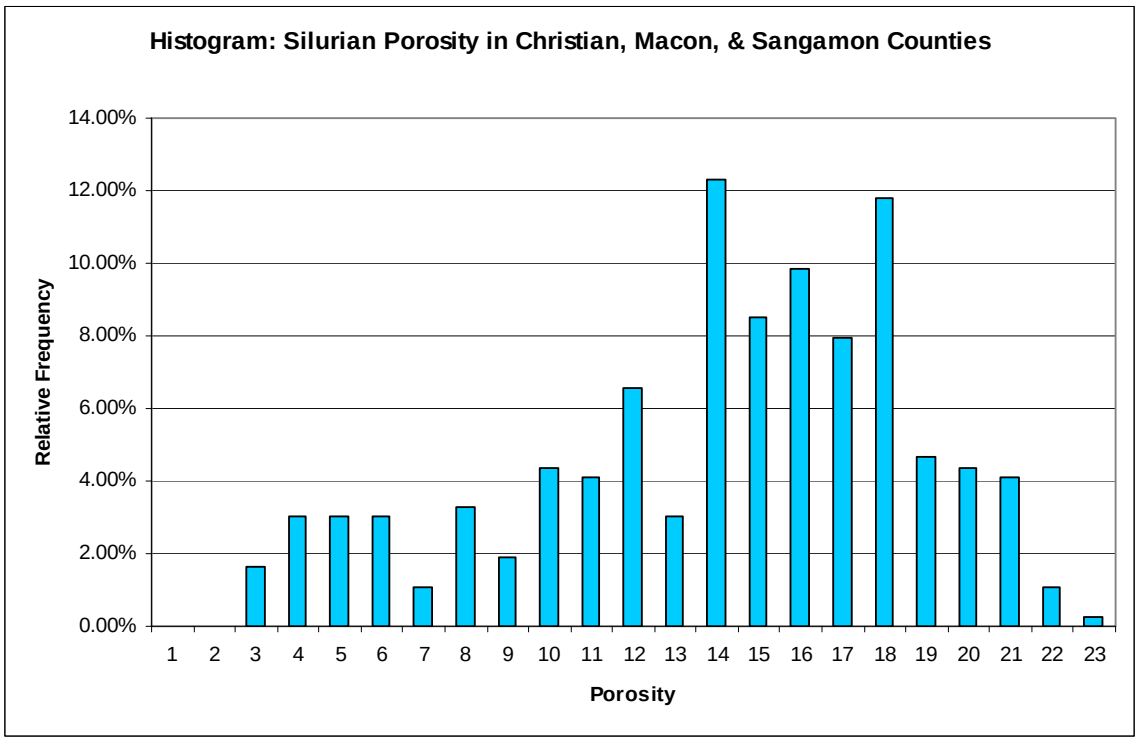


Figure 25. Histogram of porosity measured from core samples of Silurian rock from the Sangamon Arch.

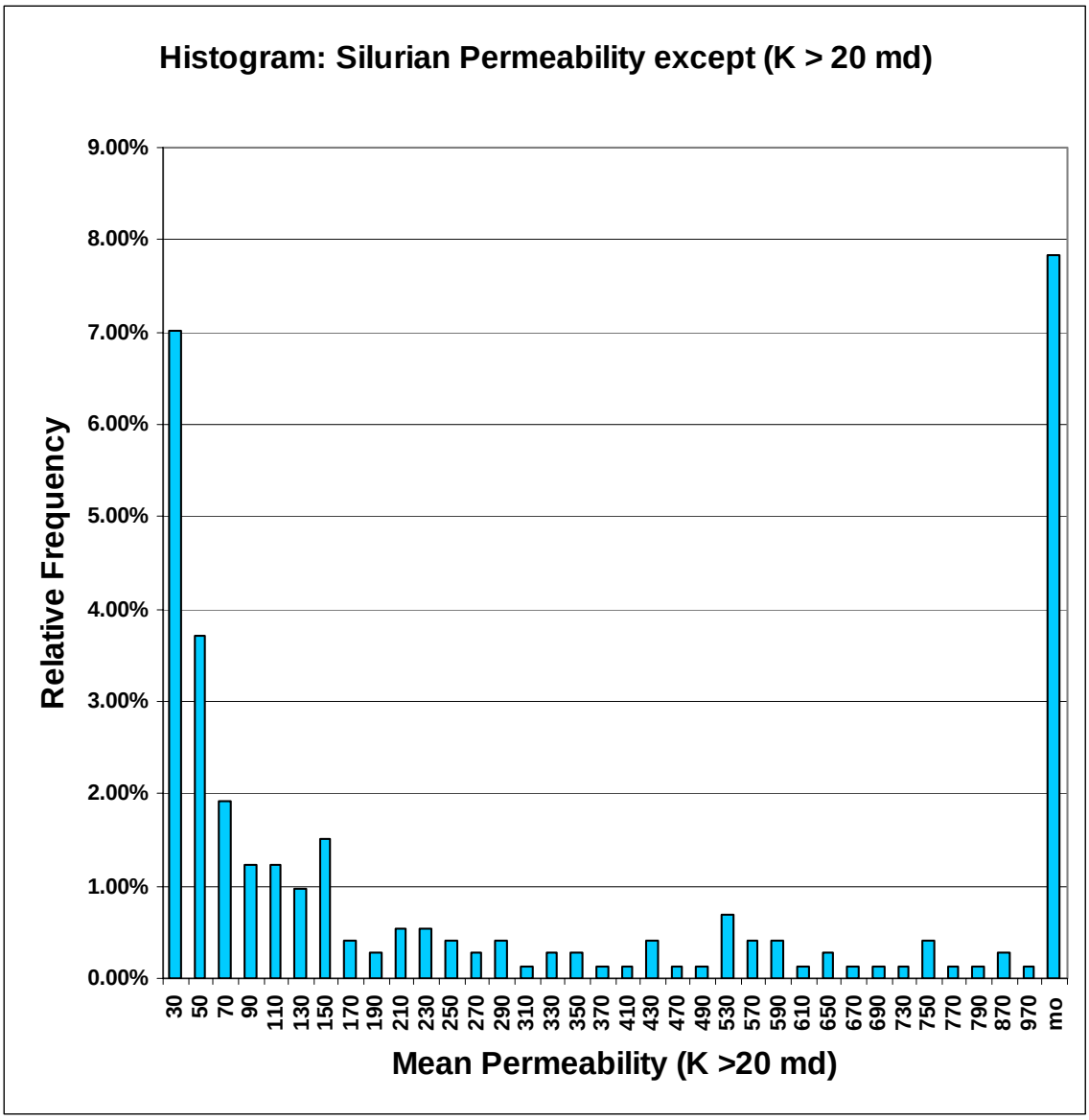


Figure 26. Histogram of permeability measured from core samples of Silurian rock from the Sangamon Arch.

BUCKHORN CONSOLIDATED FIELD

KANKAKEE LIMESTONE POOL

T1,2S - R3,4W
Brown County, Illinois
Joan Crockett, Beverly Seyler, Stephen T. Whitaker

POOL DATA:

Discovery year, Buckhorn portion:	1961
Discovery year, Buckhorn East portion:	1980
Field consolidation:	1985
Number of productive wells:	205 (est.)
Cumulative production (7-87):	1,500,000 BO (est.)

R & R Enterprises
No. 5 Hecox
Sec. 35, 1S-4W
SW NW SE

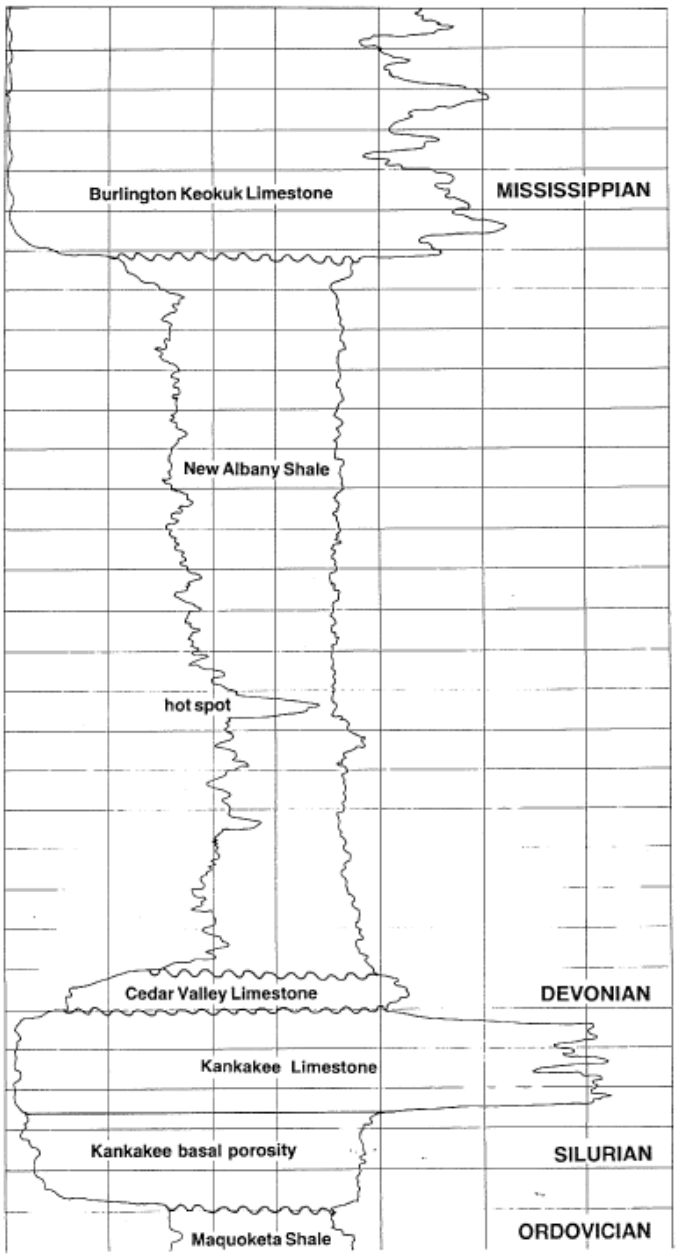


Figure 27. Typical log for Silurian reservoir at Buckhorn Consolidated Field. From Crockett et. al, 1988

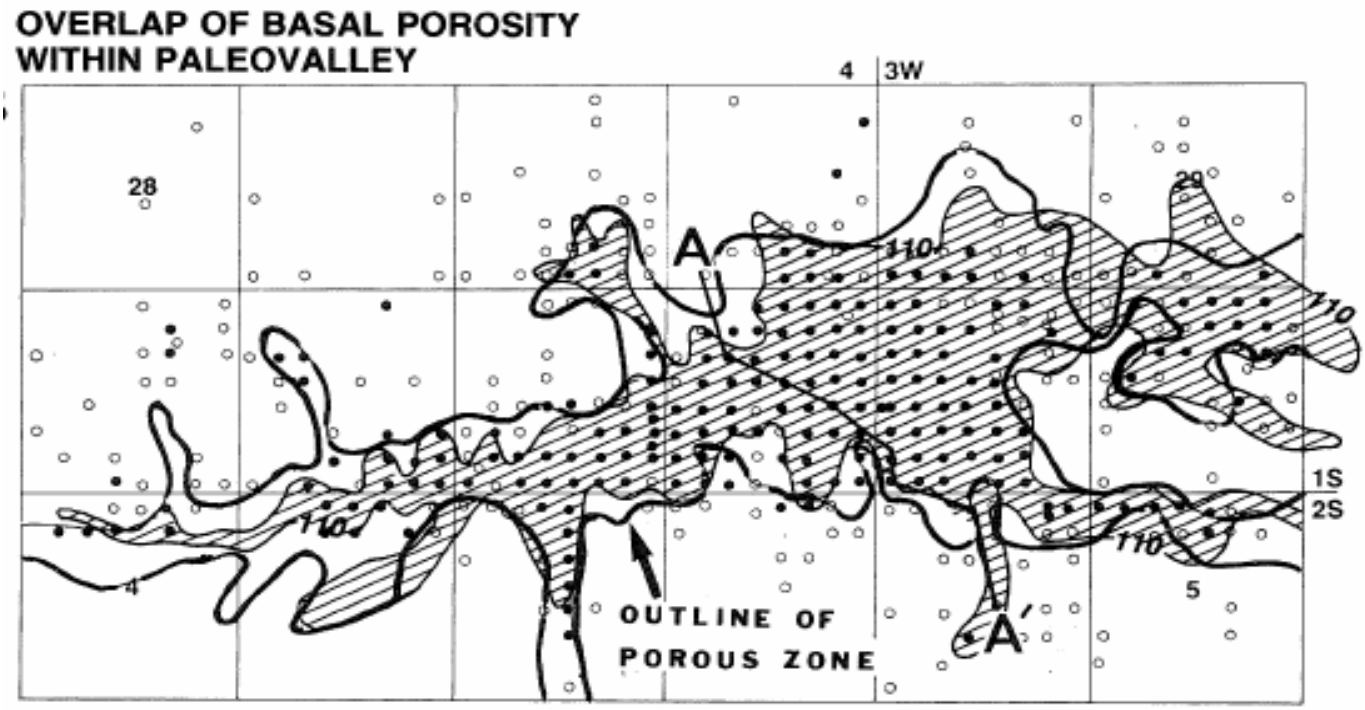


Figure 28. Map outlining drainage in the Maquoketa Shale coinciding with wells producing from basal Silurian dolomite directly overlying valleys eroded into the Ordovician Maquoketa Shale. From Crockett et. al.,1988.

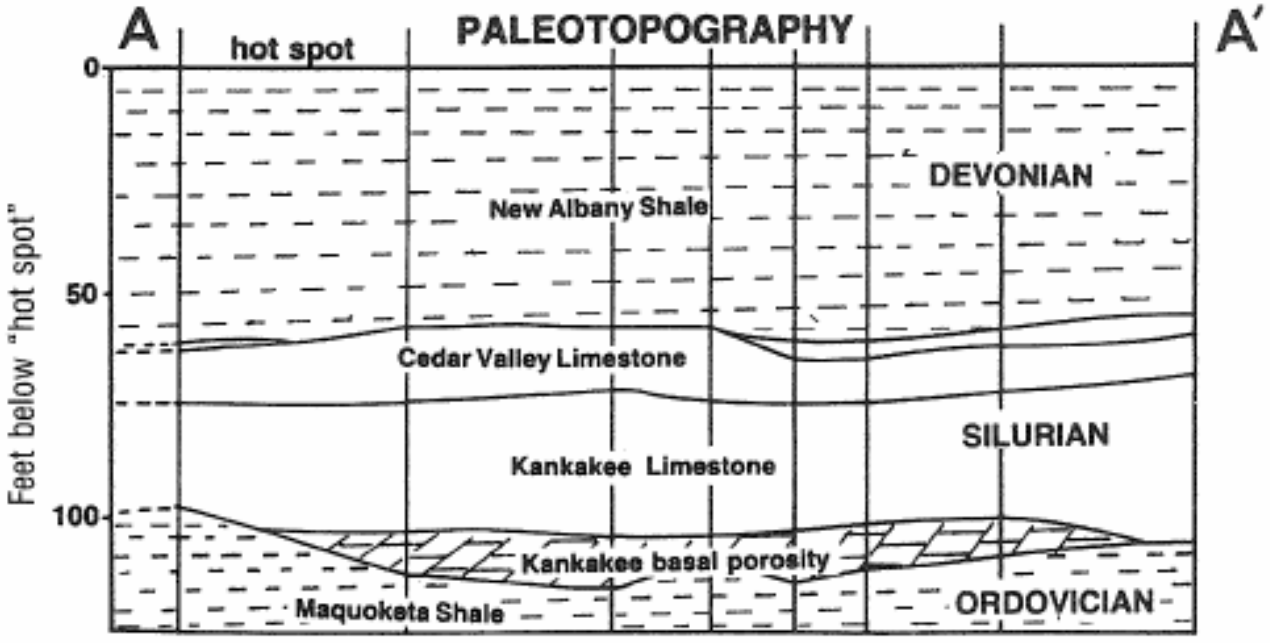


Figure 29. Schematic cross section shown on map in figure 28. Illustrates coincidence of dolomitization of lowermost Silurian rock in valleys eroded into the Ordovician Shale. From Crockett et. al., 1988

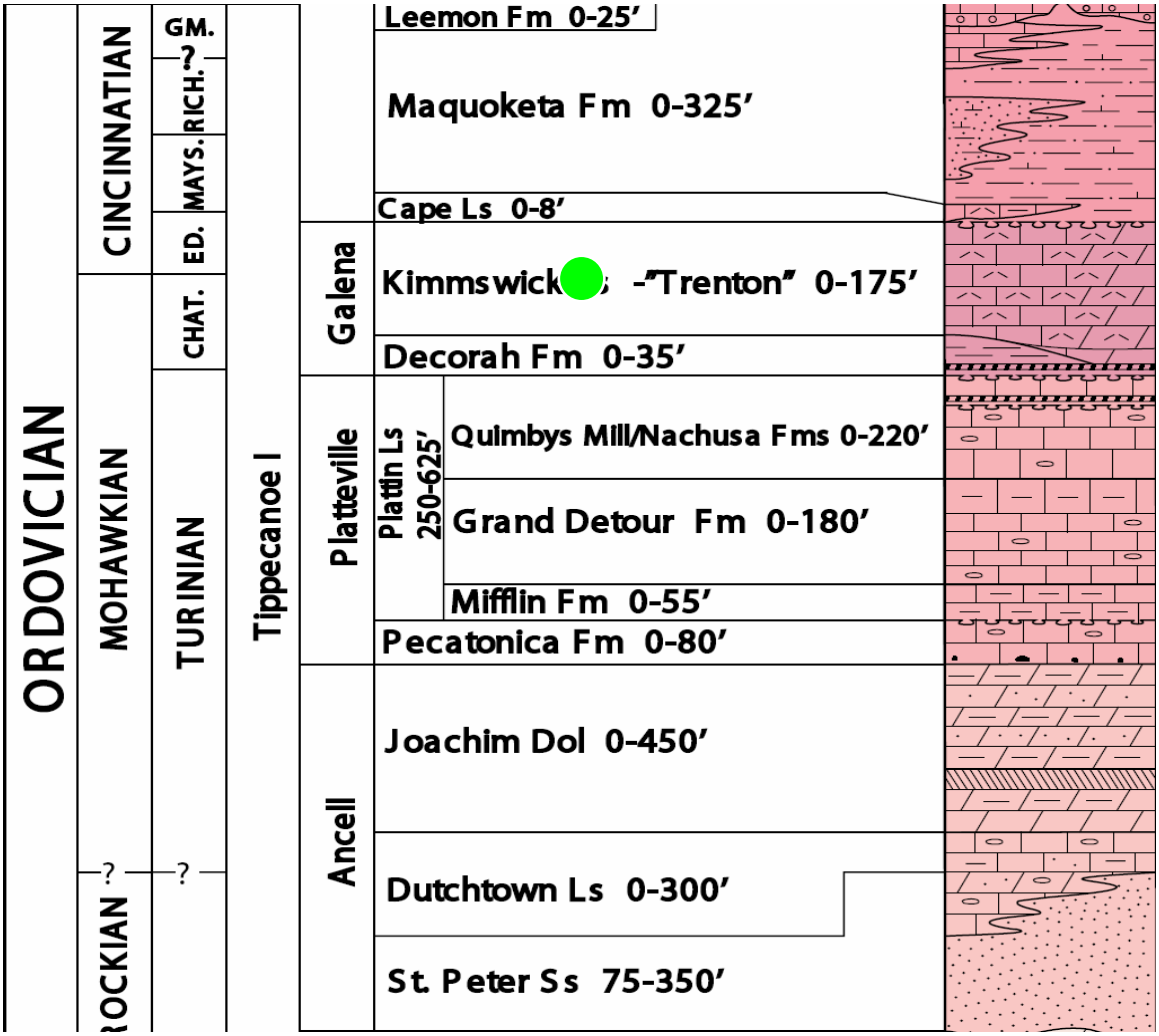


Figure 30. Stratigraphic column of Ordovician strata in the Illinois Basin. Producing unit indicated by green dot. From Kolata, 2005.

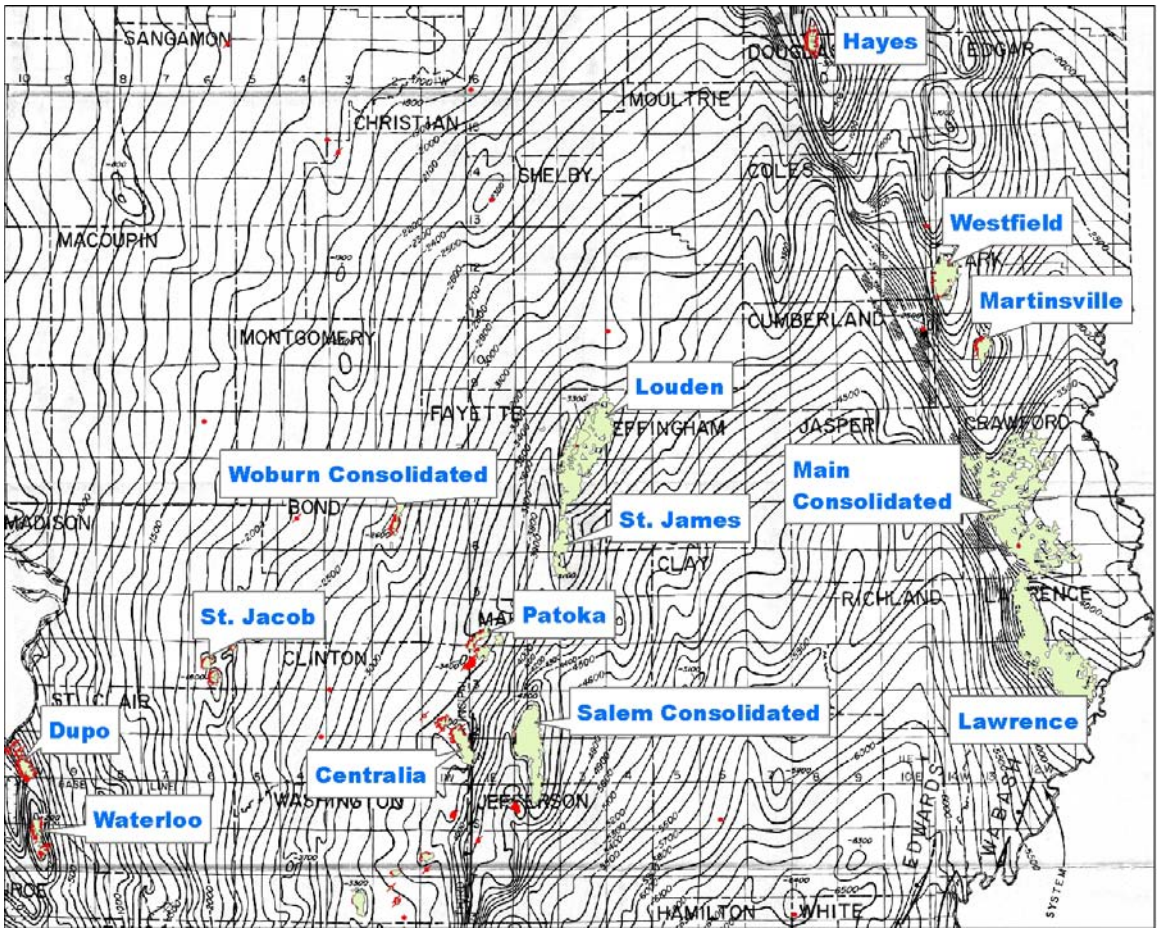


Figure 31. Distribution of wells producing from the Ordovician Trenton Formation in Illinois.

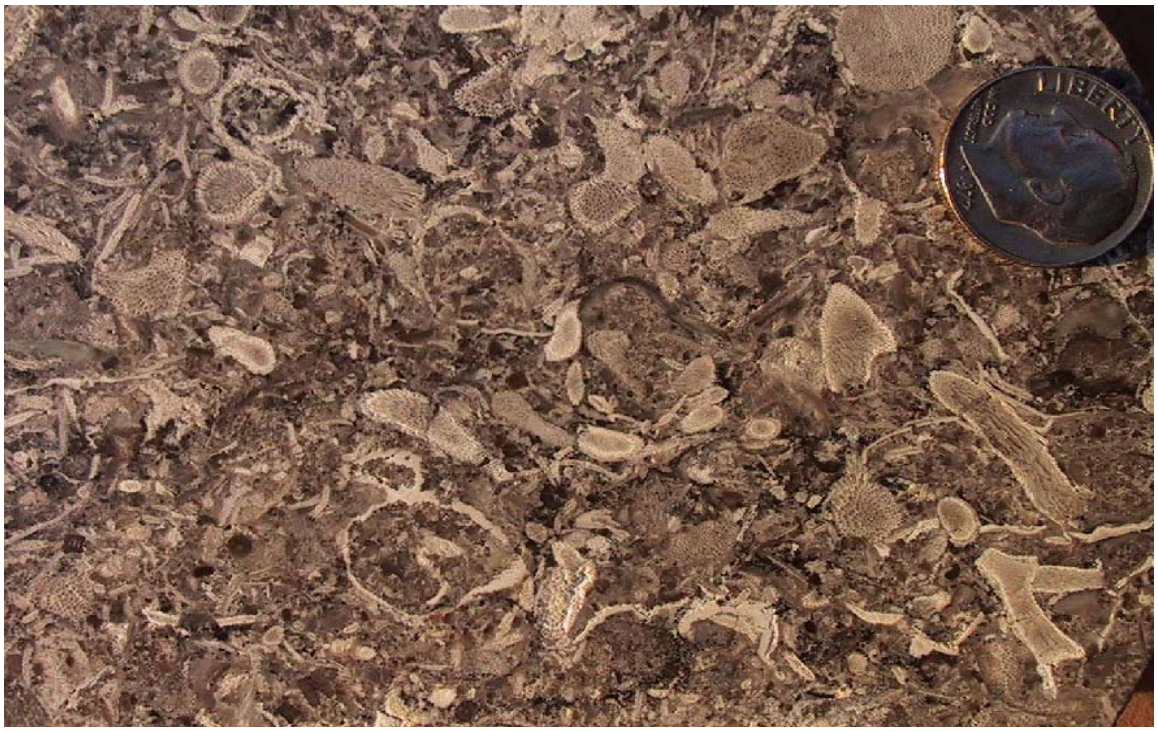


Figure 32. Fossiliferous grainstone in Ordovician Trenton Formation.

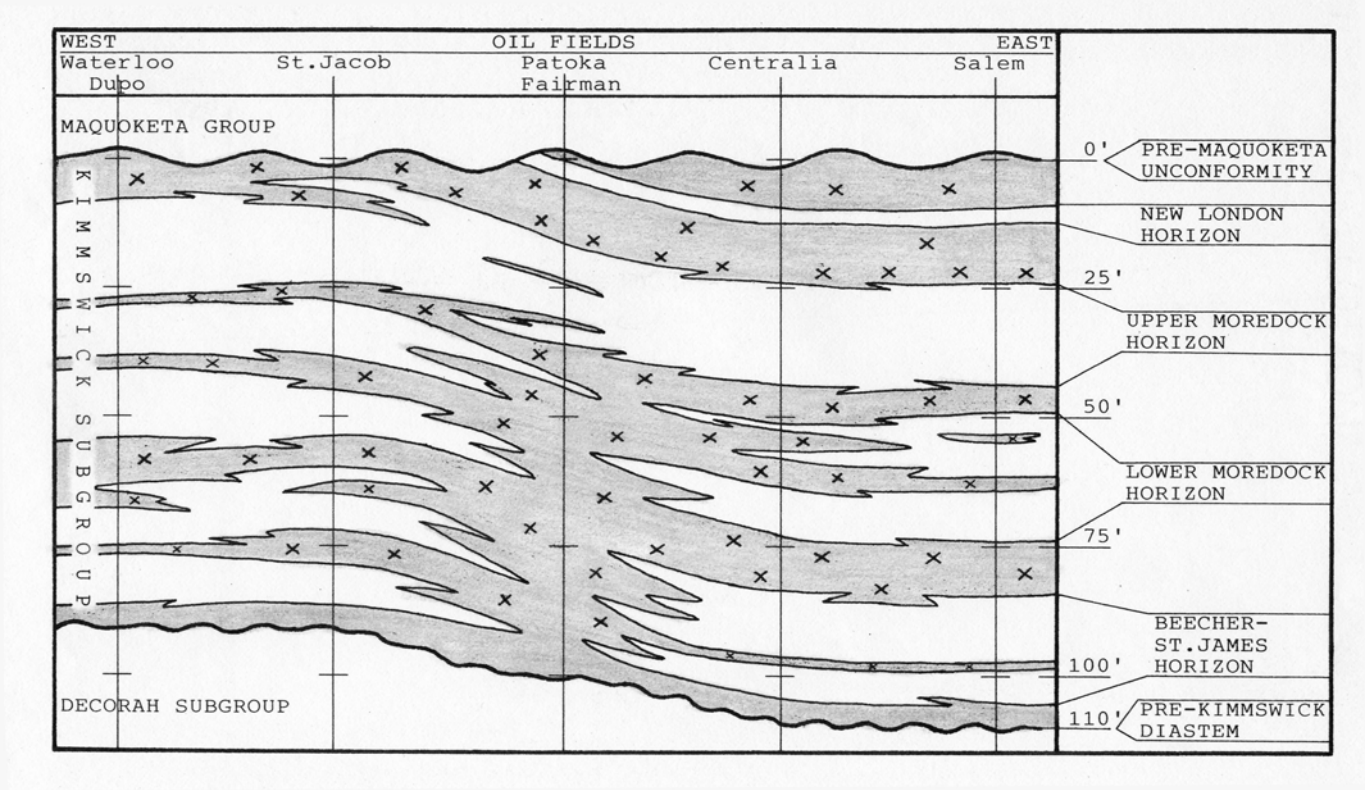
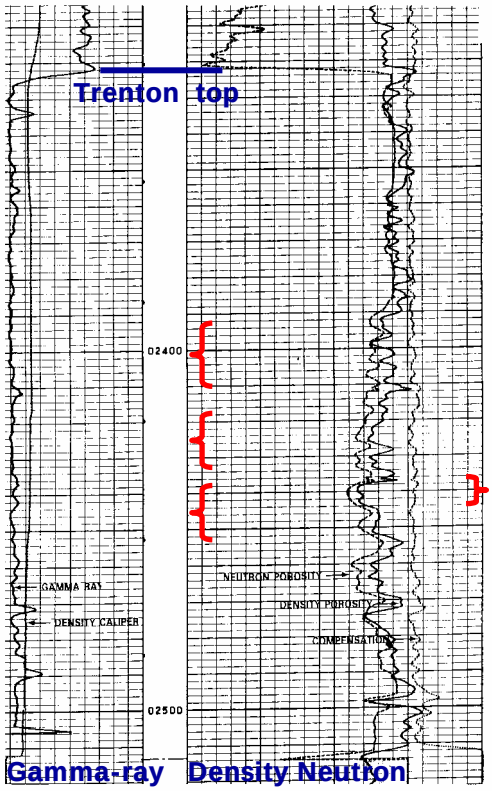


Figure 33. Correlation of porous grainstones in the Trenton Formation from western to central Illinois. From Crews 1985.

Westfield Field
Clark County

Drake #6-T
IP 35 BOPD
26 BWPD



Knierim
Horizontal
7% Porosity
Dolomitic

Figure 34. Geophysical log from Trenton reservoir at Westfield.

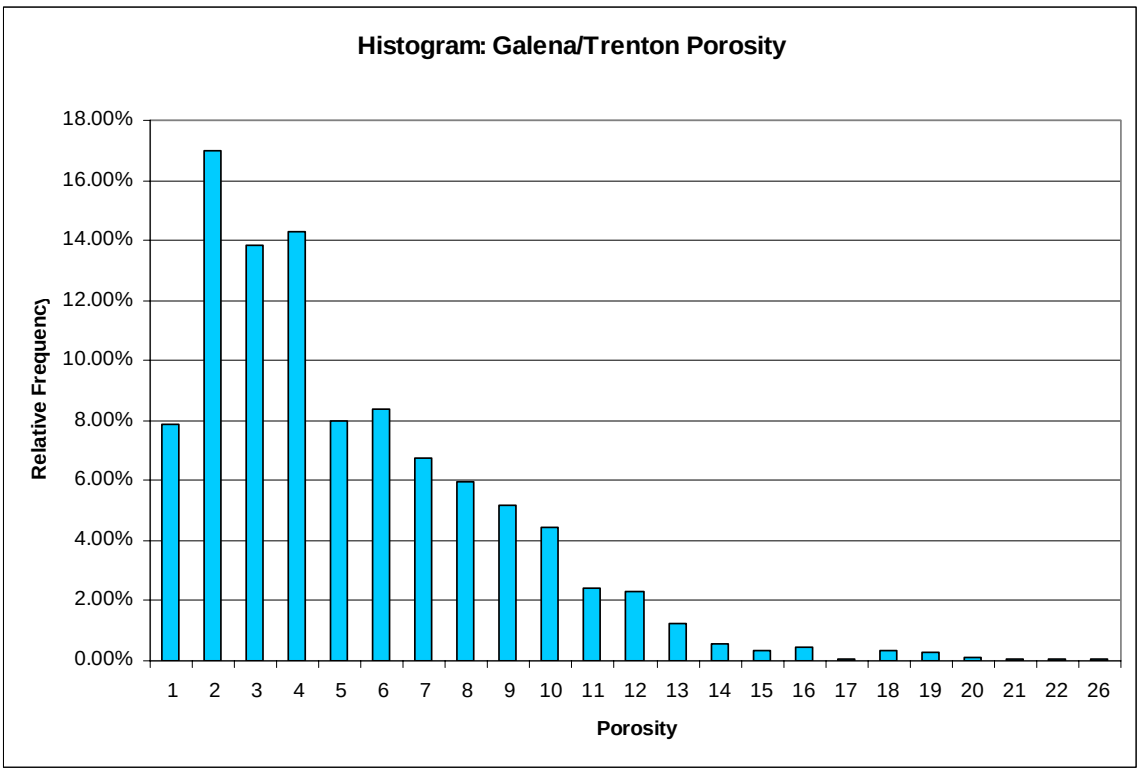


Figure 35. Histogram of porosity measure from Trenton core samples.

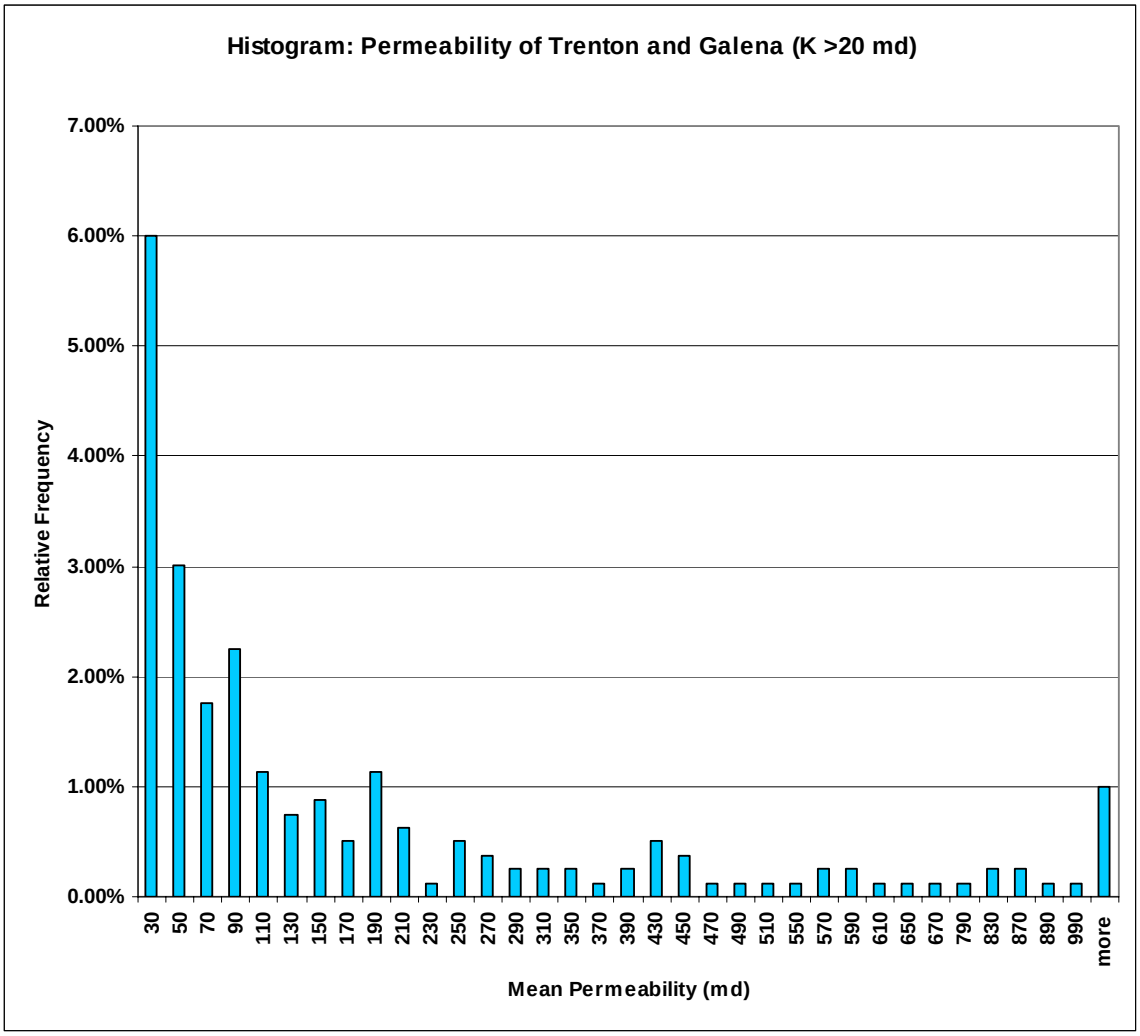


Figure 36. Histogram of permeability measured from Trenton core samples.

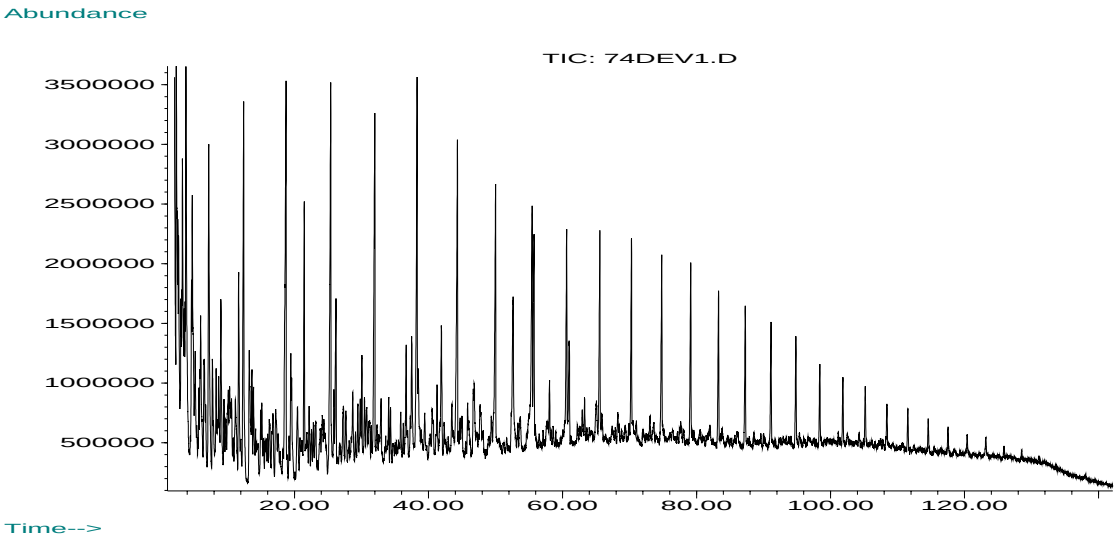


Figure 37. Gas Chromatograph of Devonian oil sample from Weaver Field in Clark County in eastern Illinois.

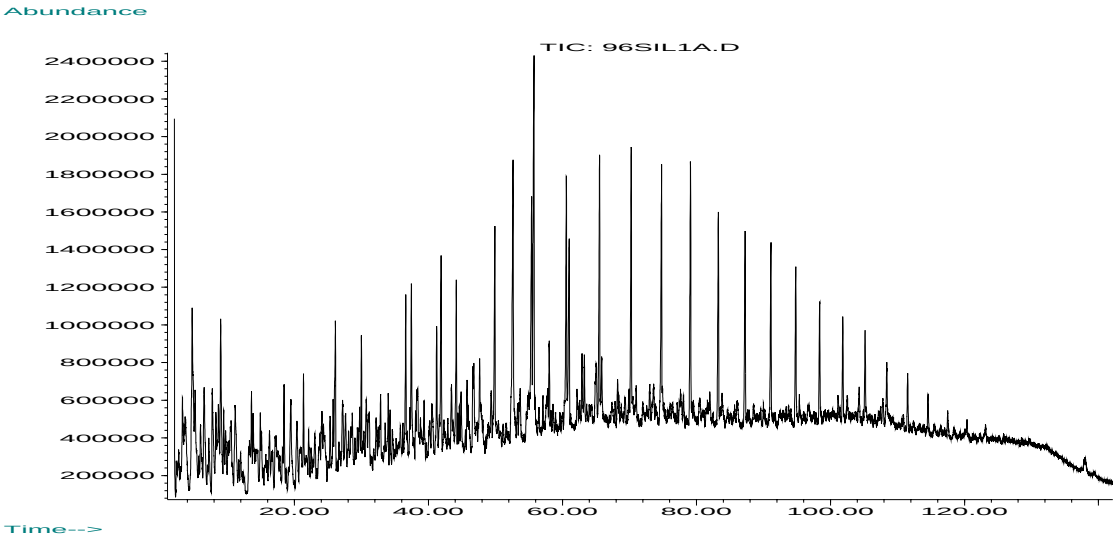


Figure 38. Gas Chromatograph of Silurian oil sample from Wapella Field in Dewitt County Illinois.

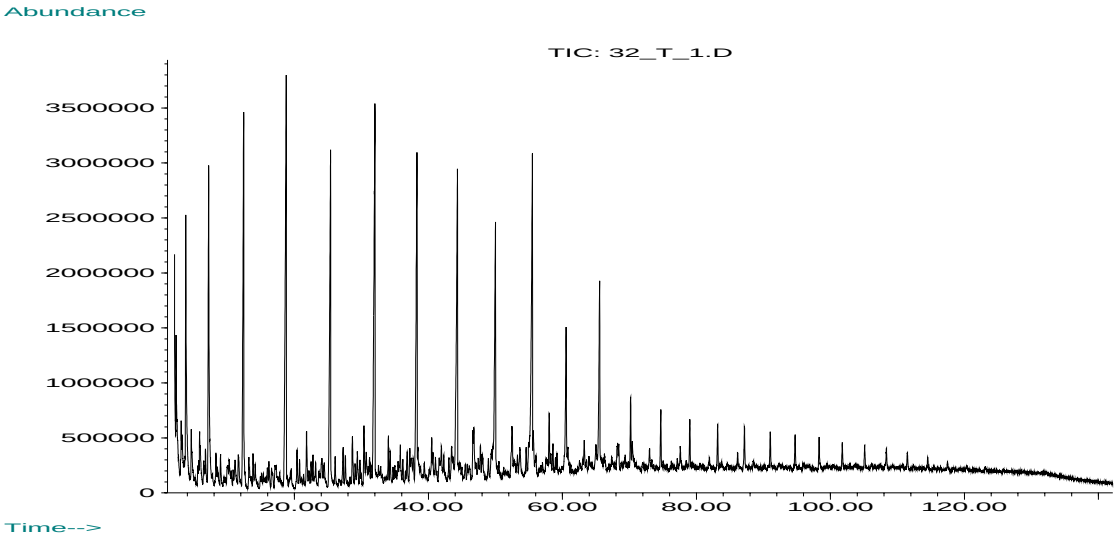


Figure 39. Gas Chromatograph of Ordovician Trenton oil from Posen Field in Washington County Illinois.

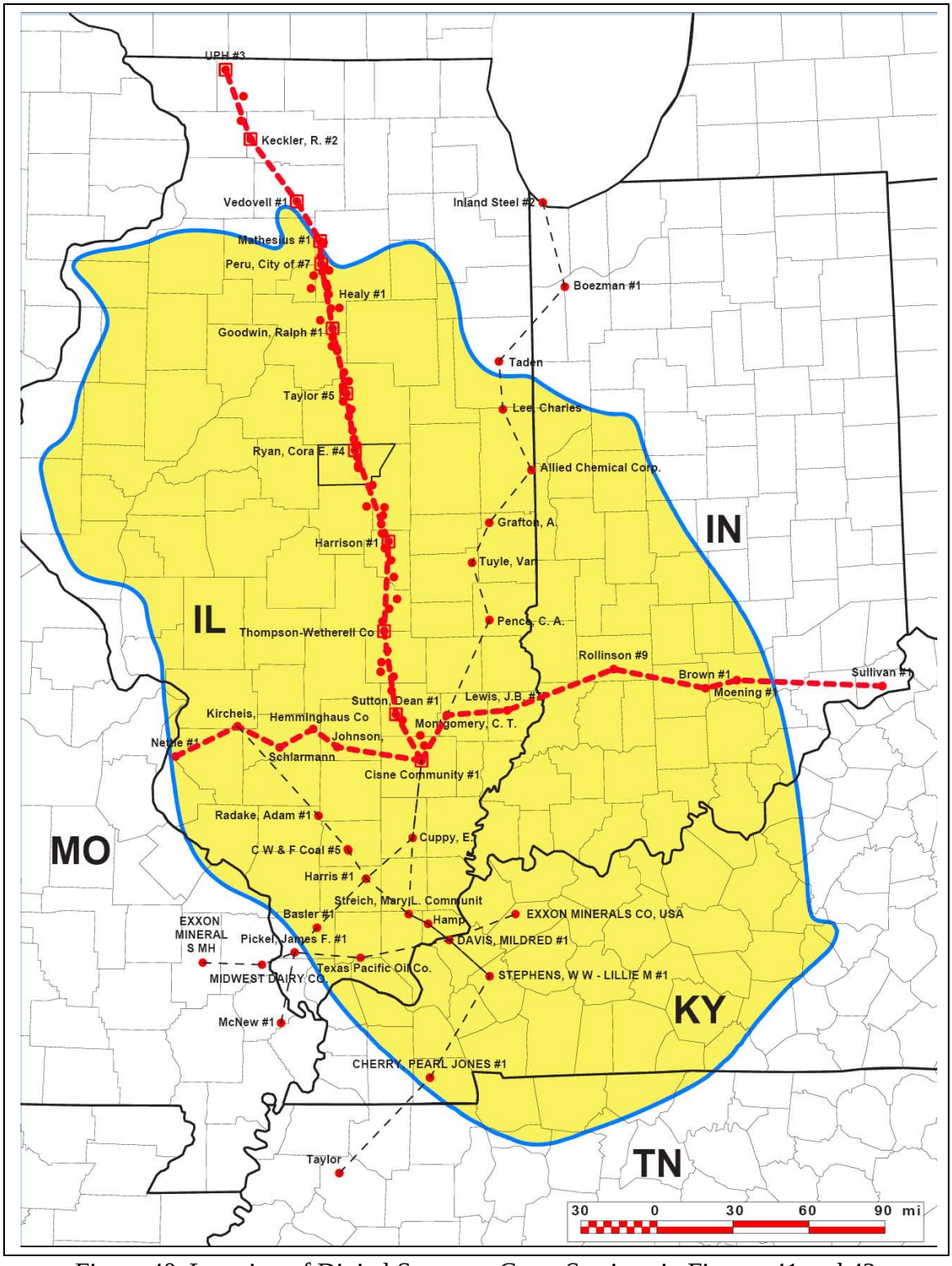


Figure 40. Location of Digital Structure Cross Sections in Figures 41 and 42

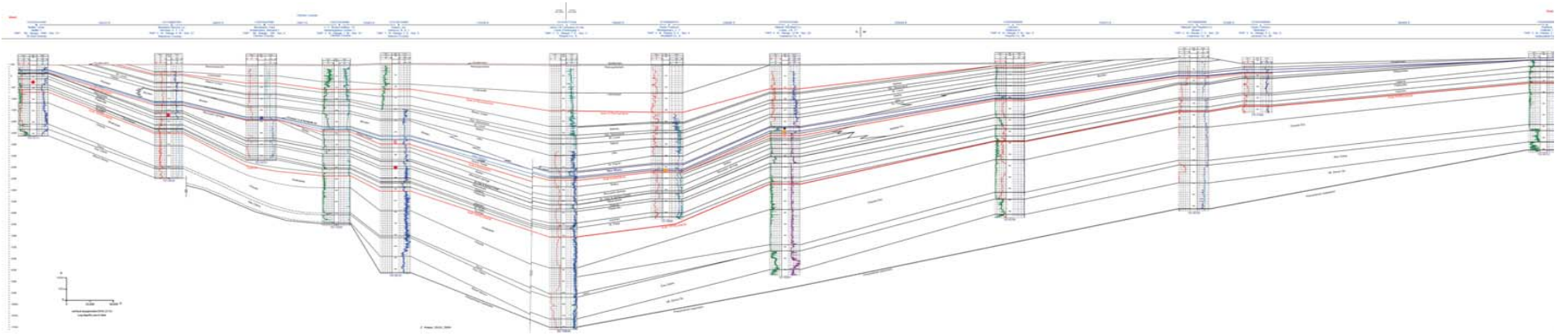


Figure 41. Digital structure cross section the 11:30 cross section runs mainly N-S.

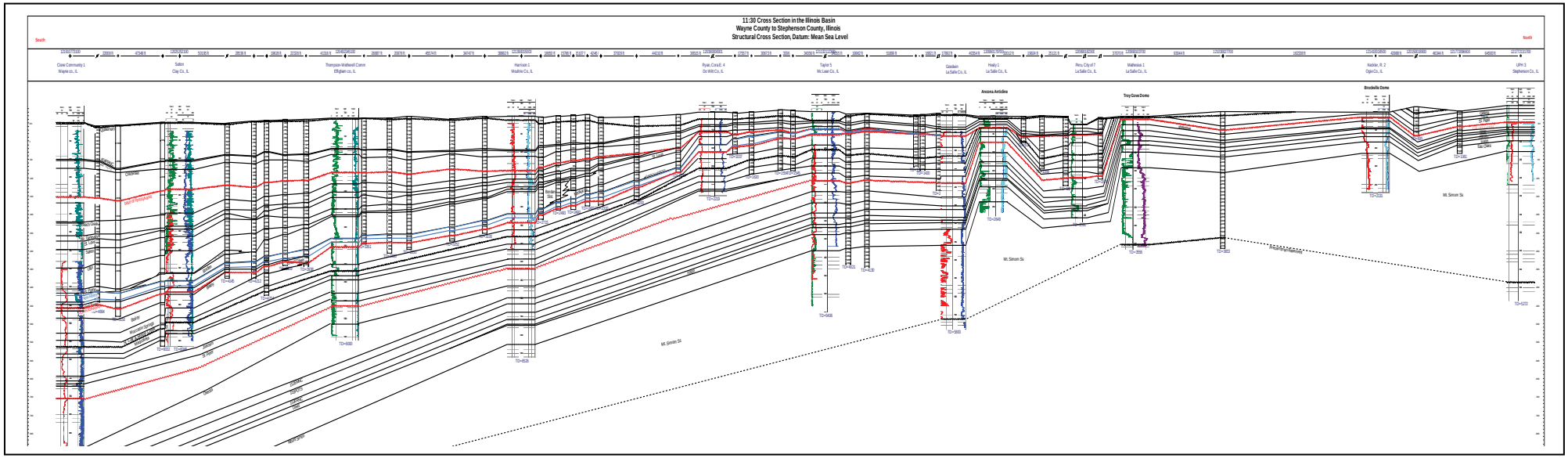


Figure 42. Digital structure west-east cross section of the entire basin from western Illinois to eastern Indiana. Pay zones are color coded

FIELD STUDIES

The Lower Devonian Clear Creek Chert Pool in the Sesser Oil Field, Franklin County, Illinois: Joan E. Crockett

Introduction

Sesser Oil Field is located in southern Illinois, in northwest Franklin County, Townships 5 and 6 South, Range 1 East about 8 miles north of the Cottage Grove Fault and immediately east of the DuQuoin Monocline (Figure 1). It was discovered in 1942 and has produced 4.9 million barrels (bbls) of oil as of January, 2007 from Devonian and Mississippian strata. It currently produces about 25,000 bbls annually. The Rend Lake Fault forms the down-dropped margin of the Sesser Anticline to the east of the field, while the low or sag to the west of Sesser Anticline is associated with the DuQuoin Monocline. West of the DuQuoin Monocline, strata are uplifted about 1200 feet on the Sparta Shelf, a relatively higher, broad shelf proximal to the Ozark Uplift in Missouri.

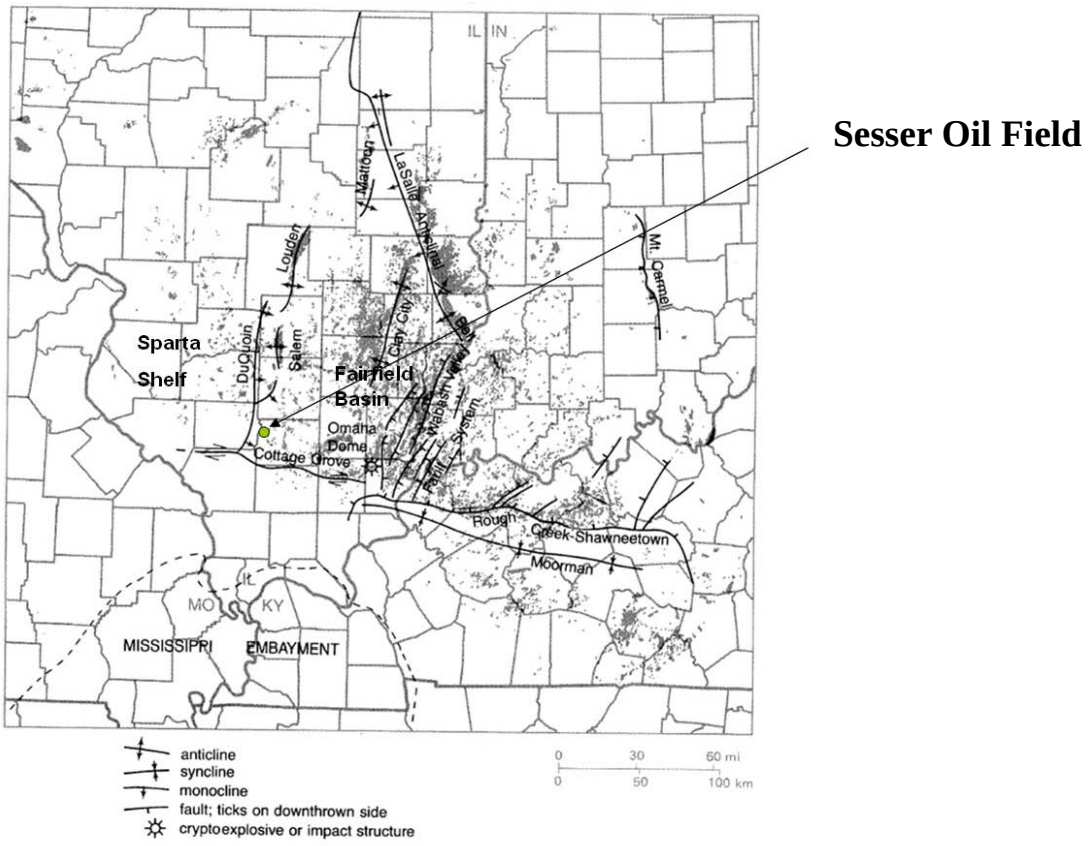


Figure 1. Location map showing Sesser Oil Field location and generalized structural features and distribution of oil fields in the Illinois Basin (modified from Seyler and Cluff, 1991).

The discovery well of Sesser Oil Field is the Old Ben Coal #1, in Section 25, T5S, R1E NW NE NW, drilled by Sun Oil Company and completed as an Aux Vases Sandstone (Mississippian) producer at a depth of 2690' to 2707' in April, 1942. Initial production (IP) of the well was reported at 50 barrels of oil per day (BOPD); no water production was reported. The well was plugged in 1946.

The next pay discovery in Sesser field was the Lower Devonian Clear Creek Chert In 1949 . The discovery was made by Paul Moseback's Bays #1 well in section 35-5S-1E (Figure 2.) The well was completed from 4402 to 4434 feet. The initial production reported on the Bays #1 was 35 BOPD. Clear Creek Chert production continued to be developed in the 1950s, 1970s and 1980s.

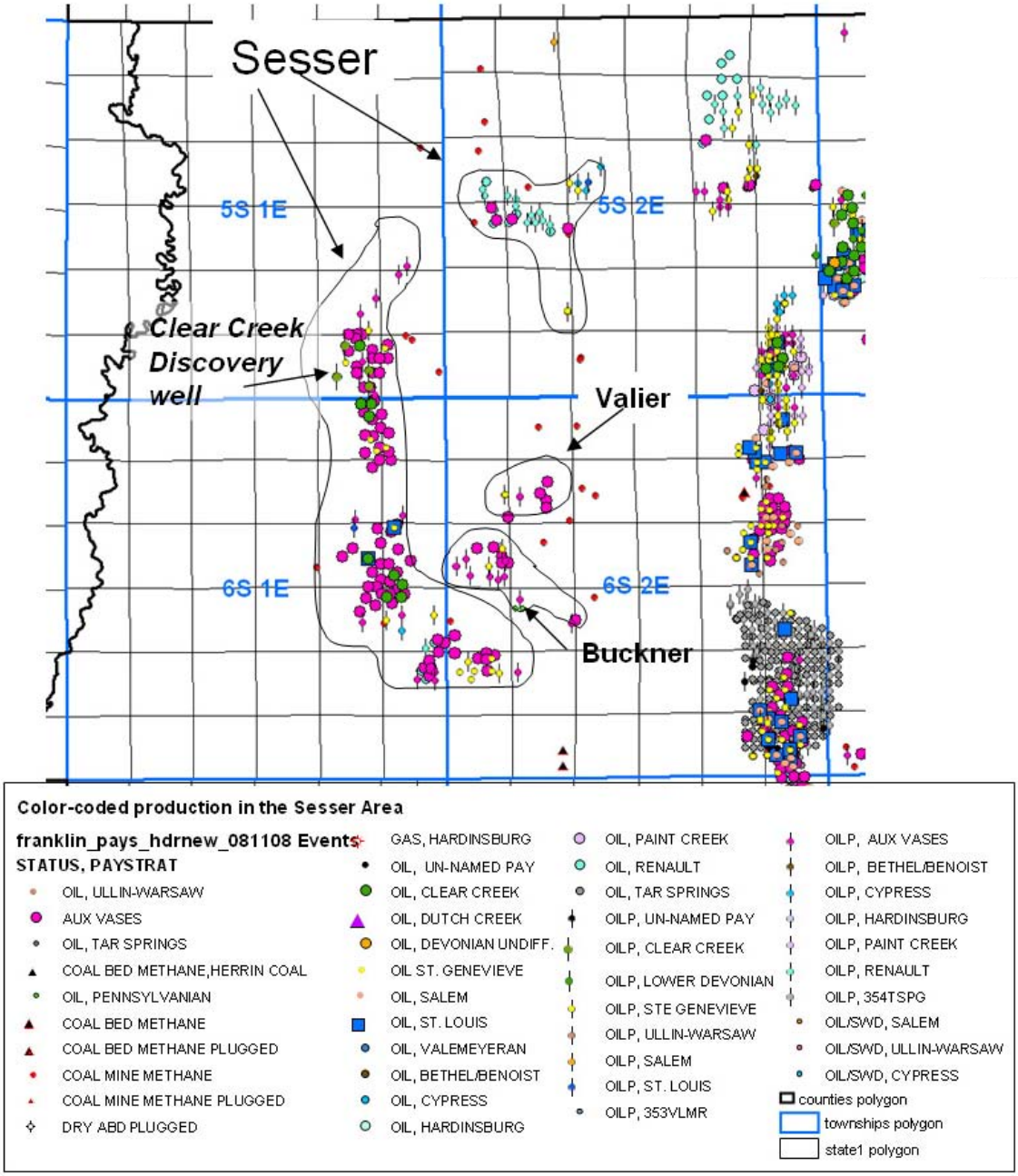


Figure 2. Color-coded pay map and Clear Creek Chert pay discovery well, Sesser area. Production form the Clear Creek Chert is found in 3 separate pods associated with separate structural highs along the anticline's hinge trend. Mississippian production also follows the north-south elongate anticlinal trend.

Additional pay zones were later established in Mississippian carbonates and sands in the 1950s. Three waterflood units which produce from and inject into the Aux Vases Sandstone (Mississippian) have been established in the field.

Stratigraphy

Surficial deposits in the area consist of approximately 25 feet of Quaternary glacial deposits (Piskin and Bergstrom, 1975) that unconformably overlie Pennsylvanian sediments. Bristol and Howard (1971) mapped Pennsylvanian sediments of Desmoinesian age beneath the Quaternary at Sesser. A chart depicting the general stratigraphic relationships in southern Illinois strata is shown in Figure 3.

Approximately 1600 feet of Pennsylvanian rocks rest unconformably on Mississippian rocks of the Chesterian Series (Kinkaid Limestone or Degonia Sandstone Formations (Bristol and Howard, 1971)). Pennsylvanian coal was once actively mined in underground mines at Sesser. Many wells are drilled through mine pillars to Mississippian oil-productive strata at Sesser field.

Nearly 2800 feet of Mississippian rocks are present in the Sesser area. A large portion of the oil that is produced from Sesser Oil Field is from Mississippian reservoirs, the Aux Vases Sandstone being the predominant target in the field with 90 producing wells (Figure 2). There is a minor amount of Cypress Sandstone production (4 wells). Production from the Renault Limestone is from 26 wells. Ste. Genevieve Limestone carbonates and sandy carbonates, the O'Hara Limestone Member, Spar Mountain Sandstone Member, and the McClosky Limestone Member, produce in 26 wells. The St. Louis Limestone produces from 4 wells. To date, no production in the lower Mississippian formations has been established at Sesser. Many wells only drill to the Aux Vases or Ste. Genevieve formations leaving deeper strata sparsely tested.

Underlying the Mississippian rocks, Upper Devonian New Albany Shale Group sediments are the source rock and a seal for the oil produced at Sesser. The New Albany Shale Group is approximately 40 feet thick over Sesser, and formations from the top to base include (in descending order) the Hannibal-Saverton Shale, Grassy Creek Shale, and the Sweetland Creek Shale (Cluff and Lineback, 1981).

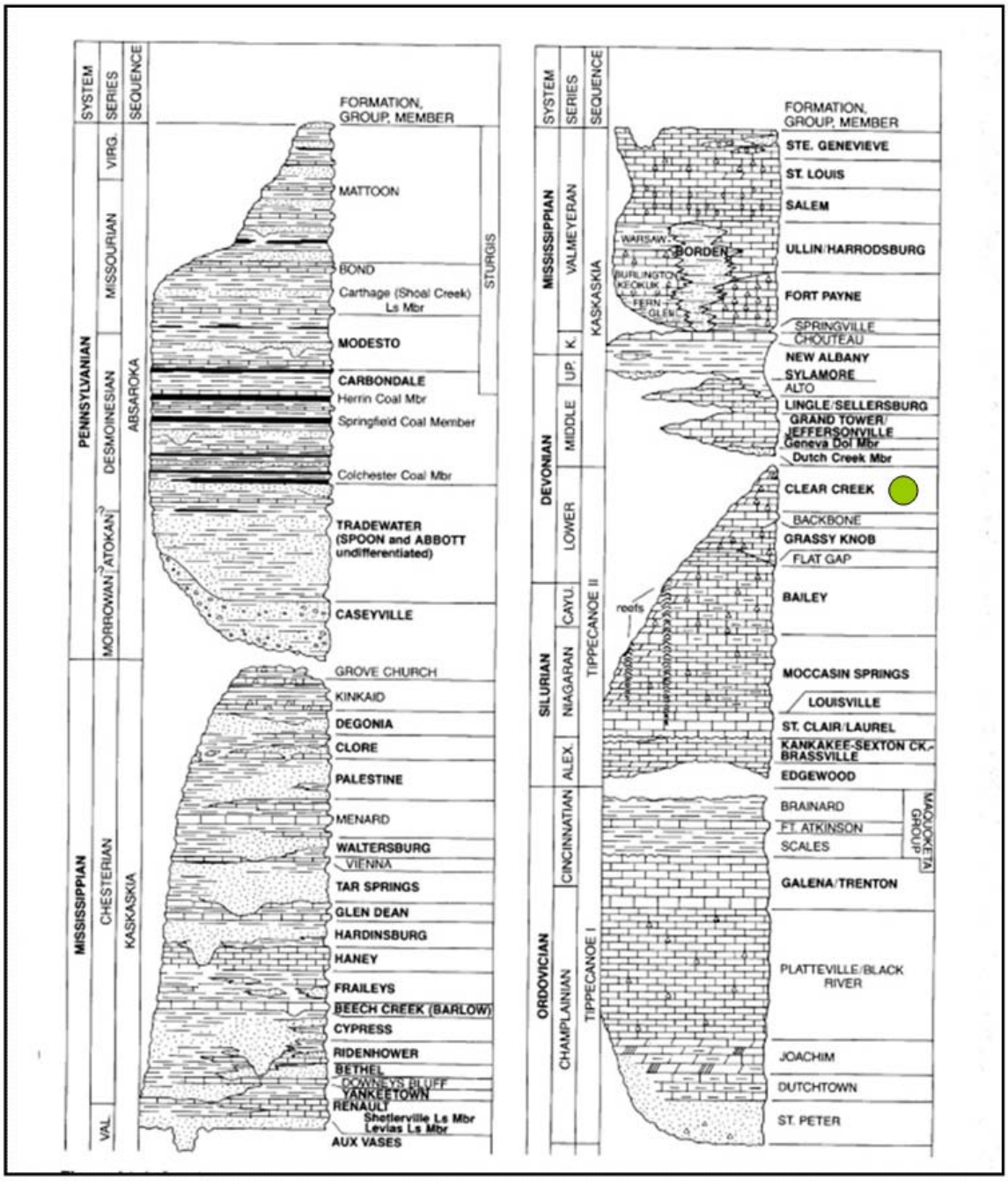


Figure 3. Stratigraphic section of Ordovician through recent rocks in Southern Illinois. Green dot shows stratigraphic position of Clear Creek Chert. Note the Sub-Kaskaskia unconformity that separates rocks of the Kaskaskia Sequence from the Tippecanoe II Sequence. From Howard (1991).

Below the New Albany Group, in disconformable contact, is the Middle Devonian Lingle Limestone. The Lingle Limestone is a brown to gray, silty, argillaceous limestone to dolomitic limestone that may be cherty or fossiliferous. Mapping in this study finds the Lingle Limestone is 40 to 50 feet thick at Sesser

In Franklin County the Middle Devonian Grand Tower Limestone is absent west of Range 2 East which includes the Sesser field area. Reasons for the absence of Grand Tower strata in the west portion of Franklin County and to the west on the Sparta Shelf are not clear. It may be due to non-deposition or erosion (Meents and Swann, 1965, North, 1969). Devera and Hassenmuller (1991) suggested that the Sesser area was part of the Middle Devonian Sparta Shelf uplift, and deposition did not occur on the paleo-high structure. Kolata and Nelson (1991) describe the timing of the tectonic uplift of the Sparta Shelf (hinged along the DuQuoin Monocline) as occurring in Silurian and Devonian times. Because of the absence of the the Grand Tower Limestone at Sesser the Lingle Limestone is in unconformable contact with the Lower Devonian Clear Creek Chert.

The Clear Creek Chert is the youngest Lower Devonian strata in the area and was originally described (Worthen, 1866) at a location along Clear Creek in Union County, southwestern Illinois. The Clear Creek is dominantly a dolomitic, somewhat fossiliferous limestone containing beds or lenses of gray to grayish white siliceous spiculitic chert. The uppermost Clear Creek at Sesser includes stray sand grains that may represent Dutch Creek sands; no bedded sand is observed at Sesser. Limestone-dolomitic limestone facies may be separated from bedded or nodular chert by stylolitc partings. Alterationof the original siliceous limestone has occurred, possibly by dissolution of limestone, replacement of limestone by chert, and fracturing.

The Clear Creek Chert is about 144 feet thick in Sesser. The formation thickens basinward (to the east and south) to at least 400 feet thick in the deep Lower Devonian embayment in the Webber well in Saline County in 6-T8S-R6E, approximately 25 miles southeast. East of Sesser, the Clear Creek section is more completely preserved and a thicker section remains. West of Sesser, across the hinge of the DuQuoin Monocline, and on to the Sparta Shelf, the Clear Creek has been entirely removed by erosion.

The electric log from the Hair #1 well, drilled in 1952 by C. Edwin Hair, in section 35, T5S-R1E, is shown, with formation boundaries and productive zone marked (Figure 4). The Devonian Lingle Limestone commonly has a low spontaneous potential and high resistivity.

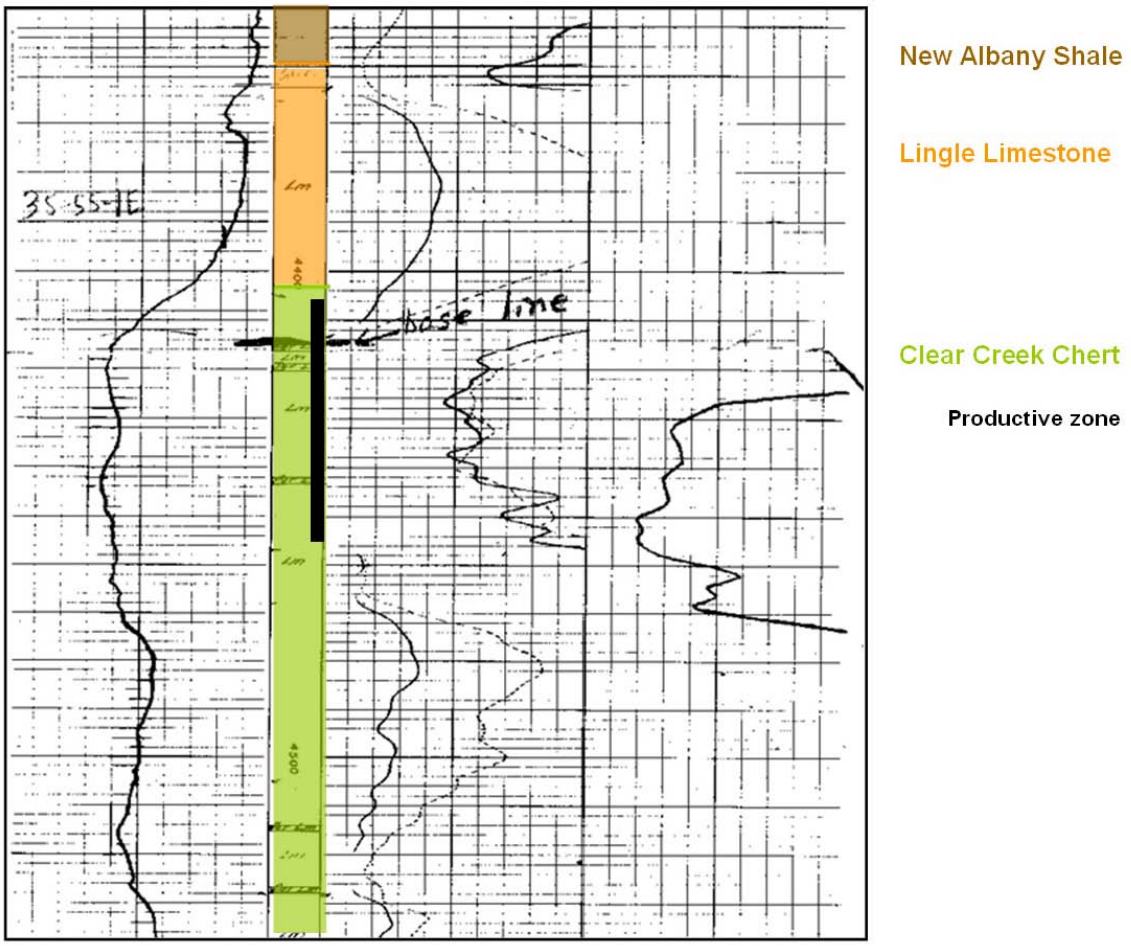


Figure 4. Electric log from C. Edwin Hair's Hair #1 well 35-5S-1E Franklin County showing Clear Creek Chert characteristics in Sesser Field. Words "base line" and associated arrow and line are not part of this study.

The Clear Creek contact is marked by a rapid increase in the Spontaneous Potential (SP) log, and where the SP achieves its greatest positive deflection, a marked reduction in the Resistivity log is seen. This log signature commonly marks the top of the cherty, dolomitic limestone zone that, if located on a structurally-high position, is a favorable oil-productive zone. The porous low resistivity zone in the Hair well is about 30 feet thick, with increasing resistivity at the base of the zone. Below this zone, the SP diminishes and resistivity increases, finally going off-scale.

Beneath the Clear Creek Chert, in conformable contact (Collinson et al., 1967) is the Backbone Limestone. The Backbone Limestone is described as a facies that rims the deeper part of the Illinois Basin, but thins or becomes absent due to facies changes in the deepest part of the basin (Willman et al.1975). The Backbone is a light gray to white, massive crystalline, pure limestone with a few scattered chert nodules. The limestone contains abundant fossils. At Sesser, regional correlations suggest the Backbone is about 66 feet thick. Collinson et al. (1967) reports that the Backbone represents fossil debris swept into the basin from the basin margins.

Beneath the Backbone is the Grassy Knob Chert. The Grassy Knob Chert is a light gray to buff, cherty limestone with at least two thick chert zones that may be traced regionally across the basin in the subsurface. Fossils are rare in the Grassy Knob Chert, according to Collinson (1967). Willman et al. (1975) describe the Grassy Knob contact with the Bailey (below) as gradational. Regional correlations in this study suggest the Grassy Knob is 430 feet thick.

Underlying the Grassy Knob is the Bailey Limestone. The Bailey is "a gray to grayish-green, silty, cherty thin-bedded, very hard limestone," with black to dark gray chert occurring in nodules and thin beds (Willman et al., 1975). The Bailey is thought to be transitional from Silurian in age at its base, grading to Lower Devonian in age at the top. The Bailey Limestone at Sesser is 430 feet thick.

The overall thickness of the Lower Devonian at Sesser is about 665 feet thick. In contrast, the Lower Devonian at the Webber well in Saline County 25 miles to the southeast is 1105 feet thick. Stratigraphic correlations show that the thinning observed at Sesser is due to erosion at the sub-Kaskaskia unconformity, which resulted in the removal of the upper part of the Clear Creek Chert.

The Silurian succession at Sesser Oil Field is composed of red, green, and gray limestone. Silurian rocks are 311 feet thick at Sesser and are separated from the Ordovician Maquoketa Shale below by an erosional unconformity.

At Sesser Oil Field, the Maquoketa Shale is markedly thinner than in the area surrounding it. The Maquoketa is 130 feet thick at Sesser, whereas the formation is about 175 to 200 feet thick in surrounding areas to the north, west and east. The Maquoketa is predominantly gray to gray-green shale.

Below the Maquoketa is the Galena Group (Trenton Limestone). Rocks of the Ordovician Galena Group are the oldest pay zone known to produce oil and gas in Illinois. The Galena is a gray to buff colored, fossiliferous limestone that may contain fractured dolomite. In the Sesser area, the Galena is 116 feet thick and tested slight shows of oil and gas in the lower Galena.

Below the Galena is the Decorah Shale, a thin shale that overlies the Platteville Group. The Elcoex/Triple T #1, the deepest well drilled in the field, reached a total depth of 6060 feet in the Platteville Group which consists of gray, fine-grained, lithographic gray limestone.

Regional Structural Setting

Sesser Anticline lies near the southern limit of oil production in Illinois. The map of regional structural features in Illinois (figure 1) shows that the Sesser structure lies adjacent to four major regional structural features, the Cottage Grove Fault to the south, the DuQuoin Monocline to the west, the Rend Lake Fault System immediately east of Sesser, and the Fairfield Basin to the northeast. Sesser Oil Field is located on the elongate north-south trending Sesser Anticline with approximately 50 feet of closure mapped on the Beech Creek (Barlow) Limestone (figure 5).

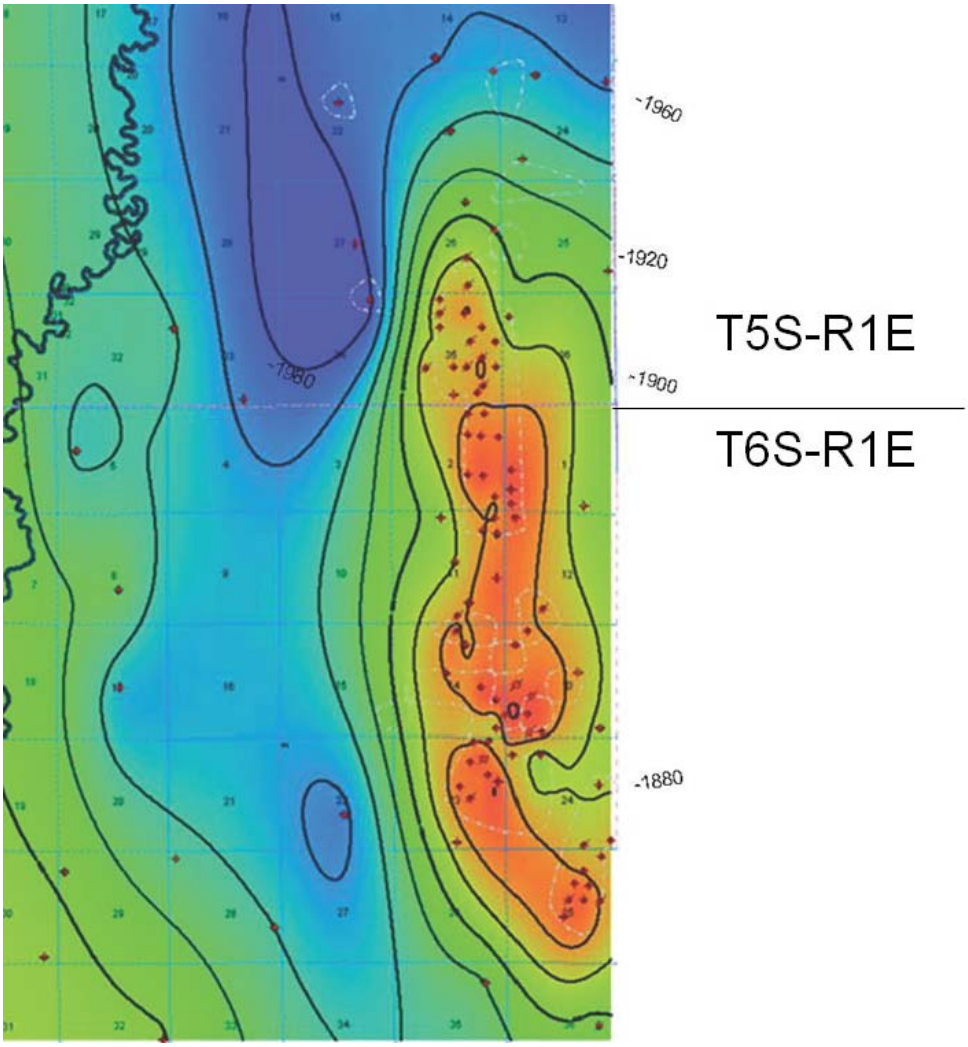


Figure 5 . Structure contour map on the base of the Beech Creek Limestone in the Sesser Oil Field area. Color ramp from blue (lowest) to orange (highest) Contour interval 20 feet.

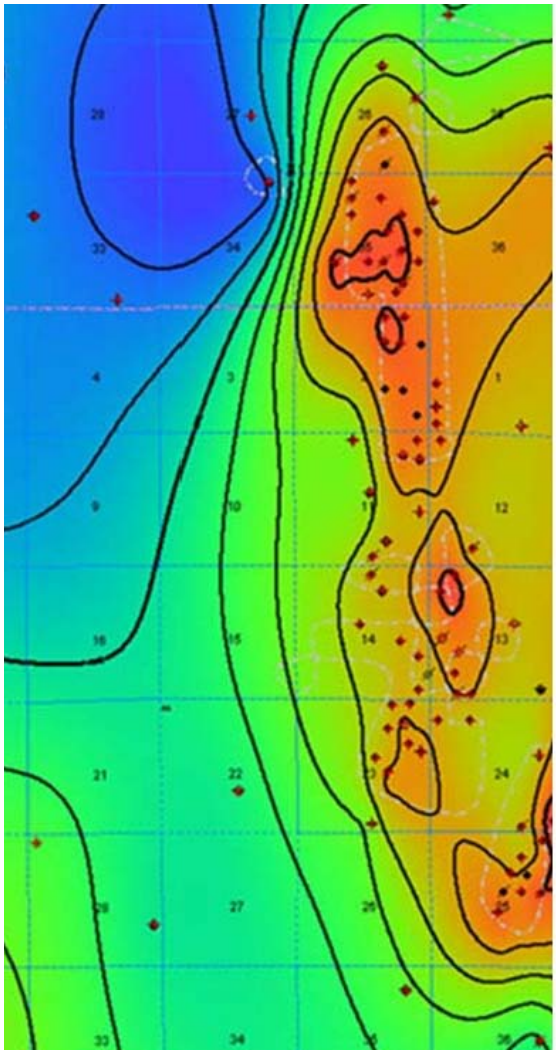
Nelson (1995) reports that the Sesser Anticline probably developed in latest Mississippian to early Pennsylvanian time, but this study suggests that the region also may have been an active structural high during the erosional event marked by the Sub-Kaskaskia (post-Clear Creek) unconformity. Evidence suggesting that the Sesser and Benton Anticlines may have been structurally high in early Middle Devonian time is based on the absence of Middle Devonian Grand Tower strata in western Franklin County and erosional truncation and thinning of the underlying Clear Creek Chert at Sesser Oil Field.

Sesser Oil Field Maps

The base Barlow Limestone subsurface structure map (Figure 5) shows the north-south trending Sesser Anticline. . The anticline has two small structural dome-like closures; one in the SE quarter of section 2-T6S-R1E, and another along the section line dividing sections 14 and 13, T6S-R1E. Mississippian and Lower Devonian production is closely associated with the highest structural closure. The west margin of the field is steeply-

dipping. The eastern flank of the anticline dips more gently. Mississippian oil production is found under the eastern flank, but no Clear Creek production has been established there. Few wells test the Clear Creek on the eastern side of the field.

The Ste. Genevieve Limestone, another prominent regional mapping horizon, occurs about 300 feet below the Beech Creek (Barlow) Limestone. A structure map on top of the Ste. Genevieive Limestone (figure 6) shows an elongate anticline that generally parallels the structure mapped on the Barlow, but has additional structural closures.. One closure is in the south half of 35-T5S-R1E, as well as in 2-T6S-R1E, and in 13 and 14 -T6S-R1E, and in the southern portion of Sesser Oil Field, in section 23-T6S-R1E.



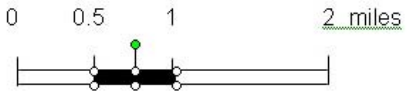


Figure 6 . Structure contour map on top of the Ste Genevieve Limestone, Sesser Oil Field area. Color ramp from blue (lowest) to orange (highest) Contour interval 20 feet.

The paucity of wells drilled to the Devonian off the Sesser structure makes it difficult to interpret the structure over Sesser and on its flanks. In order to interpret the structure on the base of the New Albany, interval thickness projections from the Barlow to the base of the New Albany were made using the nearest neighbor wells that penetrated the Devonian. The structure on the base of the New Albany mapped using this technique is shown on Figure 7. On this map, structure on the base of the New Albany over the DuQuoin Monocline, the Rend Lake Fault zone, and the Sesser Anticline is interpreted to generally parallel those structures mapped on the base of the Barlow and the Ste. Genevieve.

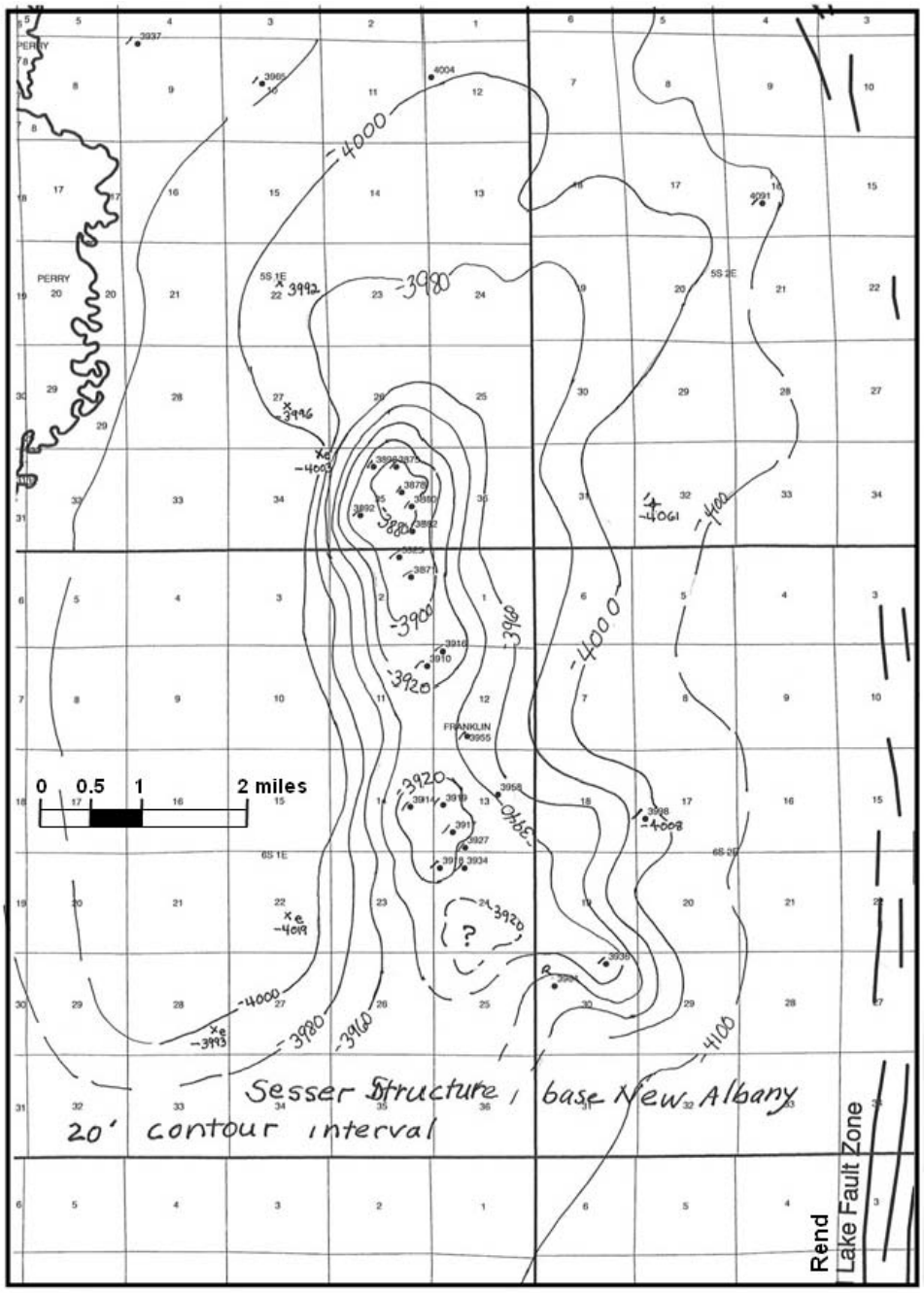


Figure 7 , Base of the Albany Shale, Sesser Oil Field are using nearest neighbor projected interval thickness technique. Contour interval 20 feet

An elongate dome is present on the north part of the anticline, with up to 40 feet of closure in Sections 35 T5S-R1E and continuing south into 2-T6S-R1E. South of section 2, a subtle saddle is present in section 12-T6S-R1E. A small closed dome is present south of the saddle in sections 13 and 14, T-6S-R1E. Another undrilled closure may be present south of there, in sections 23 and 24-T6S-R1E, based on comparison of closure in the Barlow and Ste. Genevieve Formations.

The west margin of Sesser drops at least 60 feet from the crest mapped on the base of the New Albany over about a half mile (1.3°) on the west flank, while on the east margin of the anticline, structure drops about 60 feet over the distance of a mile or more (0.65°).
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Clear Creek Chert Oil Production at Sesser

Initial production figures from Clear Creek Chert wells in Sesser Oil Field north pool range from 20 to as high as 100 BOPD. Wells in the south pool had higher initial production rates, ranging from 52 to 241 barrels of oil per day. In both Sesser pools, the wells with high IP's (over 100 BOPD) were wells that were co-mingled with shallower Mississippian production making any accurate assessment of the initial production rates and cumulative totals from the Clear Creek impossible.

Three Clear Creek Chert wells (out of thirteen total Clear Creek Chert producers) report production from only the Clear Creek Chert. An average cumulative production for these Clear Creek wells is about 32,100 bbl. All other wells are reported in co-mingled leases or co-mingled dual-productive wells with Aux Vases production.

Farrar Oil Company's Burlington Northern Greenwood #1, in section 2 T6S-R1E was completed in the Clear Creek Chert in1977. The Burlington Northern Greenwood #1 remains an active oil well and a cumulative production of 33,554 barrels of oil, as of July, 2008 (PI Dwights Plus Pipeline Production Report). The well produced 987 barrels in 2007 and has been producing approximately 1000 bbls/year for the last 5 years.

The Bartoletti #3, in 35-T5S-R1E was completed in 1985, also by Farrar Oil. A Cumulative production of 32,155 barrels of oil is attributed solely to the Clear Creek as primary production for the Bartoletti #3. The Bartoletti #3 was apparently shut in from 1993 to 2000, and then resumed production from 2001 until being plugged in 2006.

The National Associated Petroleum/Lindsay-Bartuelle #1-H in the south pool, in section 13-T6S-R1E reported production from only the Clear Creek. The well was drilled in 1956 by National Associated Petroleum. All the National Associated Petroleum wells in the Clear Creek Chert are classified as temporarily abandoned with permits recording the intent to restore operations in the Clear Creek Chert. There has been no record of activity nor has any production has been reported from these Clear Creek Chert wells since 1963.The Lindsay Bartuelle #1-H produced 22,396 barrels of oil from the Clear Creek. The remaining Clear Creek producers on the National Associated Petroleum/Becker leases in the southern pool were all co-mingled with Mississippian production.

Log Evaluation of Reservoir Quality in the Clear Creek

A few wells in the Farrar/Continental Resources lease holdings had Density and Neutron logs run. The highest Density or Neutron porosity obtained from the Clear Creek from the logs was 13% porosity. The porosity from the logs is in thin beds, nearly at the resolution of the log scale . A log analyst from the Illinois Basin (C.D. "Mac" McGregor, personal communication, 2008) evaluated several wells and the most promising calculation showed that in the Reeves-Bartoletti #A1 well in 35-T5S-R1E, there is 12% porosity at 4436'. Using a true resistivity of 15 ohms and a water resistivity value of 0.4 ohms, he calculated 43% water saturation. The well had initial production of 36 barrels of oil, 36 barrels of water, after perforations, treatment with 3,000 gallons of 15%, acid and a Fracture treatment with 20,000 gallons gel frac fluid and 42,000 # sand. The co-mingled lease's cumulative production was 49,163 barrels, with probable co-mingled production from Aux Vases included in the total. The well is plugged.

Lithology and Petrography at Clear Creek Chert at Sesser

One core with chips was studied at Sesser, the Hair #1 in the north part of the field (in 35-T5S-R1E.) The Hair #1 well had a cored interval in the Clear Creek from 4400' to 4555', 4555' being the well's total depth.

Core chips from the well are half-fist-size or smaller. They are generally fine-grained, dense, gray limestone with asymmetrical white to grayish-white chert nodules, lenses or layers and dark, clay-rich stylolitic partings. The chert may be porous or it may be dense with no apparent porosity or permeability. Hairline fractures are visible in some hand samples. Many fractures and dolomite layers appear to be associated with horizontal bedding planes.

In thin section, the uppermost Clear Creek at Sesser Oil Field is a fossiliferous dolomitic, cherty limestone (figure 8 and 9). Blue epoxy reveals zones with abundant porosity. Some sand grains are scattered irregularly in the matrix. Irregularly distributed crystalline dolomite and microcrystalline to crystalline chert and drusy quartz overgrowths are common in the upper 70 feet of the Clear Creek (figure 9).

Stylolites, with black organic material are common, and are in close association with layers of crystalline dolomite (figures 10 and11). This suggests that stylolites were sites of pressure-solution leaching, and compaction of the original carbonate and concentration of diagenetic dolomite. Fracturing may be related to solution-collapse or tectonic deformation. In places, both healed fractures and porous hairline fractures are observed.

Fossils in the Clear Creek in thin section appear to be disarticulated, abraded marine fossils. Some porosity appears to have developed where fossils have been leached or removed by solution, with partial replacement by dolomite and later by silica.

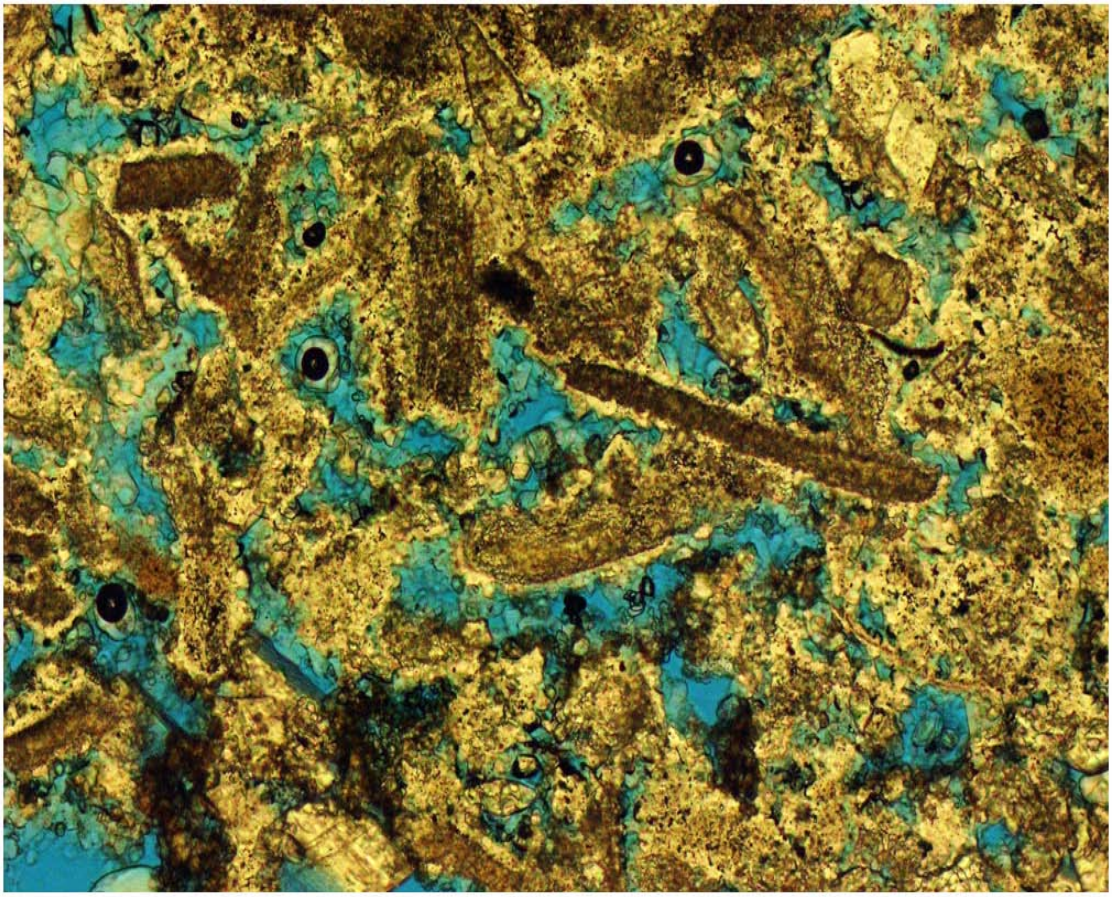


Figure 8. Thin section of Clear Creek Chert porous reservoir zone. Porosity in blue. C. Edwin Hair's Hair # 1 well, 35-5S-1E Franklin County. Depth 4413'. Magnification 50x. Polars not crossed.

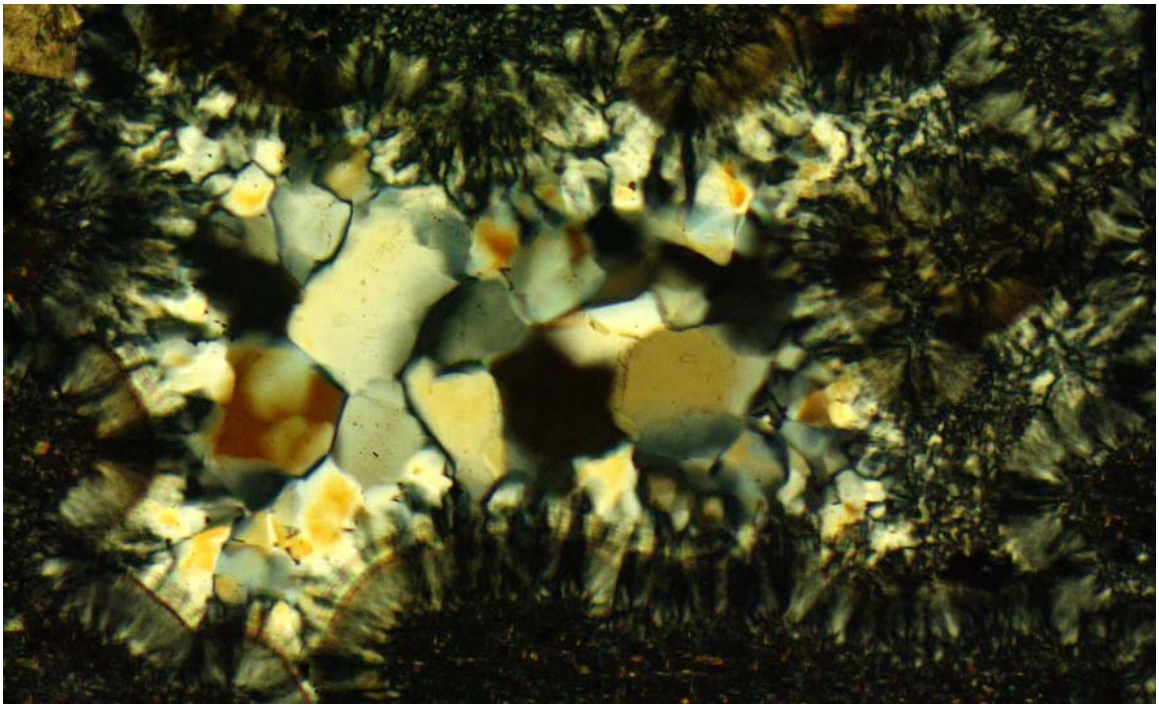
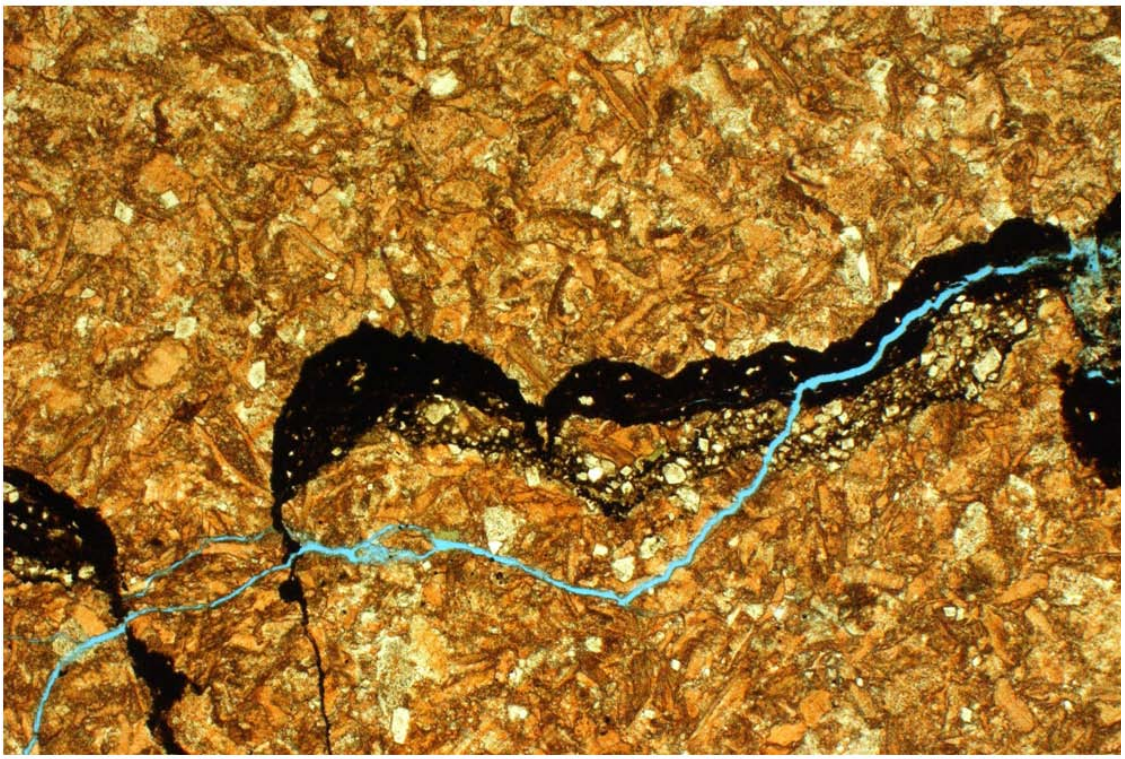


Figure 9. Thin section of Clear Creek Chert showing vuf filled with fibrous chert on edges and mosaic chert in center. C. Edwin Hair's Hair # 1 well, 35-5S-1E Franklin County. Depth 4405'. Magnification 50x. Polars crossed.



.Figure 10. Thin section of Clear Creek Chert showing styolite, microfracture and sand grains concentrated on styolite.. C. Edwin Hair's Hair # 1 well, 35-5S-1E Franklin County. Depth 4503'. Magnification 25x. Polars not crossed.

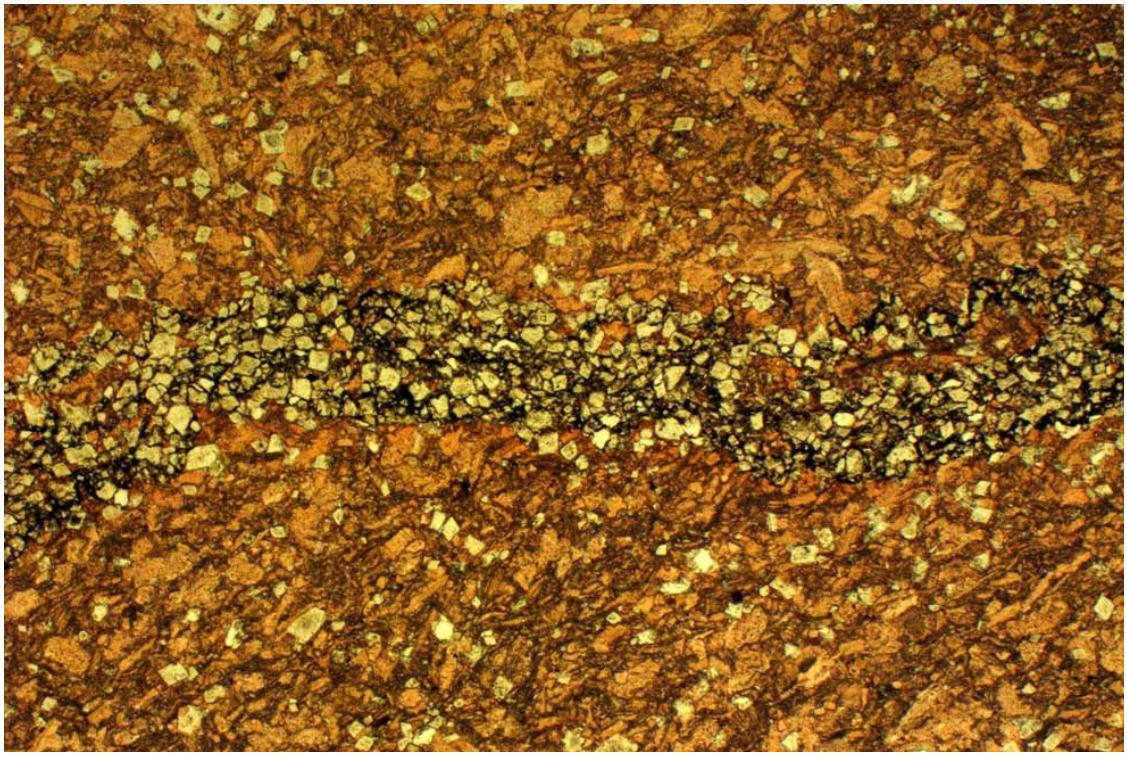


Figure 11. Thin section of Clear Creek Chert showing styolite with dolomite and sand grains concentrated on styolite. C. Edwin Hair's Hair # 1 well, 35-5S-1E Franklin County. Depth 4473'. Magnification 25x. Polars not crossed.

Discussion of lithology and petrography

Erosional processes and diagenesis in the Clear Creek have resulted in porosity development by leaching carbonate and silica fossil fragments. Stylolitic partings apparently were sites of pressure-compaction, leaching and recrystallization of dolomite. Later episodes of dolomite and silica cementation occurred in patches and along stylolites and fractures.

Similar to Saller et al. (2001) model for the Dollarhide Field in Texas, the Clear Creek model for Sesser includes

- Deposition on a marine carbonate shelf, with sponges, echinoderms, bryozoans and possible ostracods; subsequent reworking of fossils to disaggregate and abrade the fossils, and possibly debris flow down-slope
- Uplift along DuQuoin Monocline removed upper Clear Creek section by erosion at Sesser
- Early marine meteoric diagenesis in the exposed Clear Creek along the sub-Kaskaskia unconformity may have enabled meteoric dolomitization as well as leaching of carbonate
- Dissolution of silica in many sponge spicules, resulting in porosity development in upper Clear Creek
- Alternatively, or in addition, dolomite and silica cement may be associated with hydrothermal groundwater movement along faults
- re-precipitation of silica as microcrystalline chalcedony and quartz in patches, nodules, or lenses
- Later, fracturing; some fractures are healed, some are open

Clear Creek play potential

Where a relatively thick section of Grand Tower sediments is preserved (east of Sesser, Benton, and Whittington, in southeastern Illinois), there is only one established Lower Devonian field, at Walpole (Hamilton County, section 27-T6S-R6E). The anticlines at Sesser and Benton and the structural nose at Whittington, in the absence of Grand Tower deposits, may have enabled accumulation of hydrocarbons from New Albany source rocks in the low areas adjacent to the Sesser, Benton, and Whittington anticlines, into Clear Creek reservoirs. This study suggests that less than 50 feet of intervening Middle Devonian strata, and diagenesis at the sub-Kaskaskia unconformity are favorable factors for development of Clear Creek reservoirs in this area.

No waterflood operations or enhanced oil recovery operations are known to have been conducted on Clear Creek wells in Illinois. Some Lower Devonian cherty carbonate reservoirs in Texas have been documented to be excellent candidates for waterflooding as well as carbon dioxide injection (Saller et al., 2001.)

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Springfield East Oil Field: Bryan Huff

Springfield East Oil Field in Sangamon County (Figure 1) was studied as representative of Silurian oil fields in Sangamon and Christian counties. These oil fields include discontinuous, small, though some quite productive reservoirs. Most of these fields are discovered by drilling on trend of previously discovered fields with ensuing development consisting of several offset wells defining the limits of the reservoir.

Springfield East was discovered by the Aladdin Oil Company #1 Scott in Section 21, Township 15 North, Range 4 West that was drilled to a total depth of 1605 feet. The well was completed in February 1960 for an initial production of 582 barrels of oil per day (BOPD). It was completed open hole in the Silurian dolomite from 1592-1606 feet. Hibbard production was discovered in November by the Morgan & Wilkening # 1 Herndon in Section 29, Township 15N, Range 4W. The well was completed for an initial production of 50 BOPD as a dual completion in the Devonian and Silurian. The deepest well in the area is in section 29 and is 2824 feet deep. It tested strata into the Knox Dolomite with no additional pay zone discoveries.

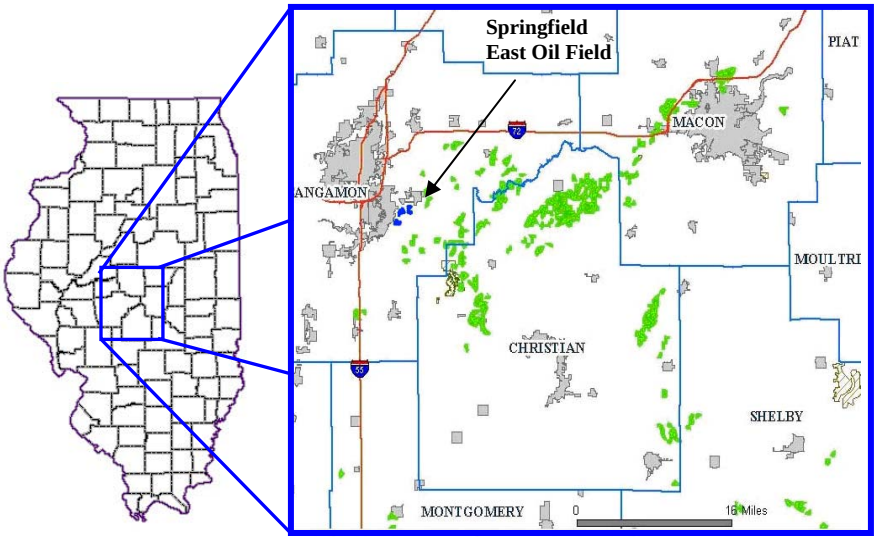


FIGURE 1. Location Map of Springfield East Oil Field (in blue) in west-central Illinois. Expanded view shows county names, municipalities in gray, other oil fields in green. Note the northeast-southwest trend of oil fields in the area.

STRATIGRAPHY

Surficial sediments in the area consist of approximately 50 feet of Quaternary glacial deposits. These overlay Pennsylvanian sediments of Missourian age. The Pennsylvanian rocks unconformably overlie Mississippian strata. Directly below Springfield East field all Chesterian sediments have been eroded and the first Mississippian strata encountered is the Valmeyeran Ste. Genevieve Limestone (Figure 2). To the east as one enters Christian County Chester sediments younging towards the east are encountered. The lowest Mississippian strata in the area is the Chouteau Limestone which overlies the

Devonian New Albany Shale Group (Figure 3). The lower Devonian limestones were not deposited over this area and this hiatus is represented by a thin, discontinuous sandstone/sandy dolomite/dolomite lag deposit (Hibbard Sandstone) that marks the disconformity between the Devonian and Silurian rocks. Mapping shows this sandstone/sandy dolomite is sporadic and, in areas, is concentrated in channels cut into the underlying Silurian dolomite and that there is a very high correlation between these channel deposits and producing oil well occurrence.

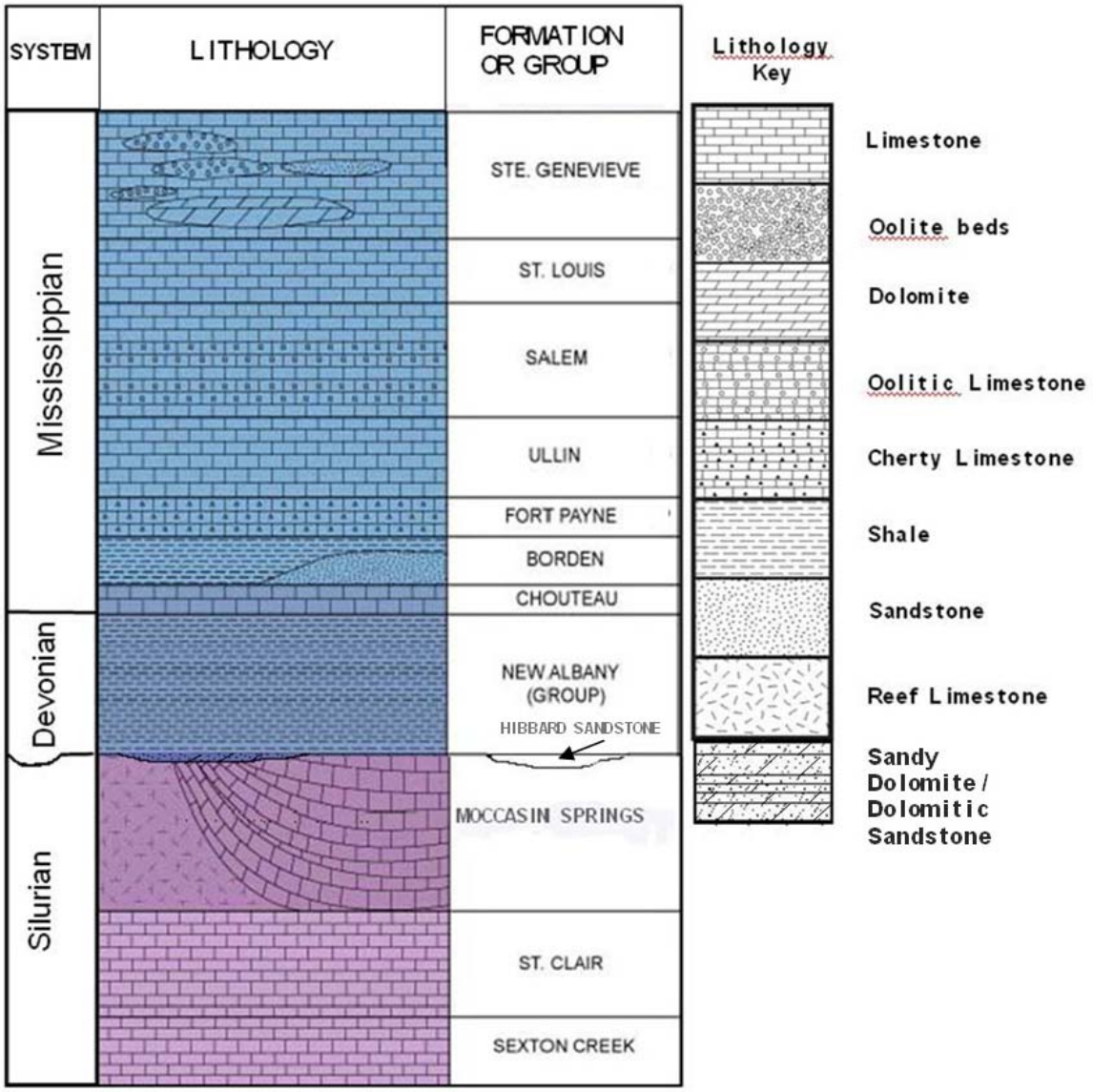


FIGURE 2. Schematic stratigraphic section of Mississippian through Silurian strata in the Springfield East field area.

Eastern American Energy Corporation
Thomas Scott # 1
330' NL 485' EL SW/c
Section 21 Township 15 North Range 4 West
Sangamon County, Illinois

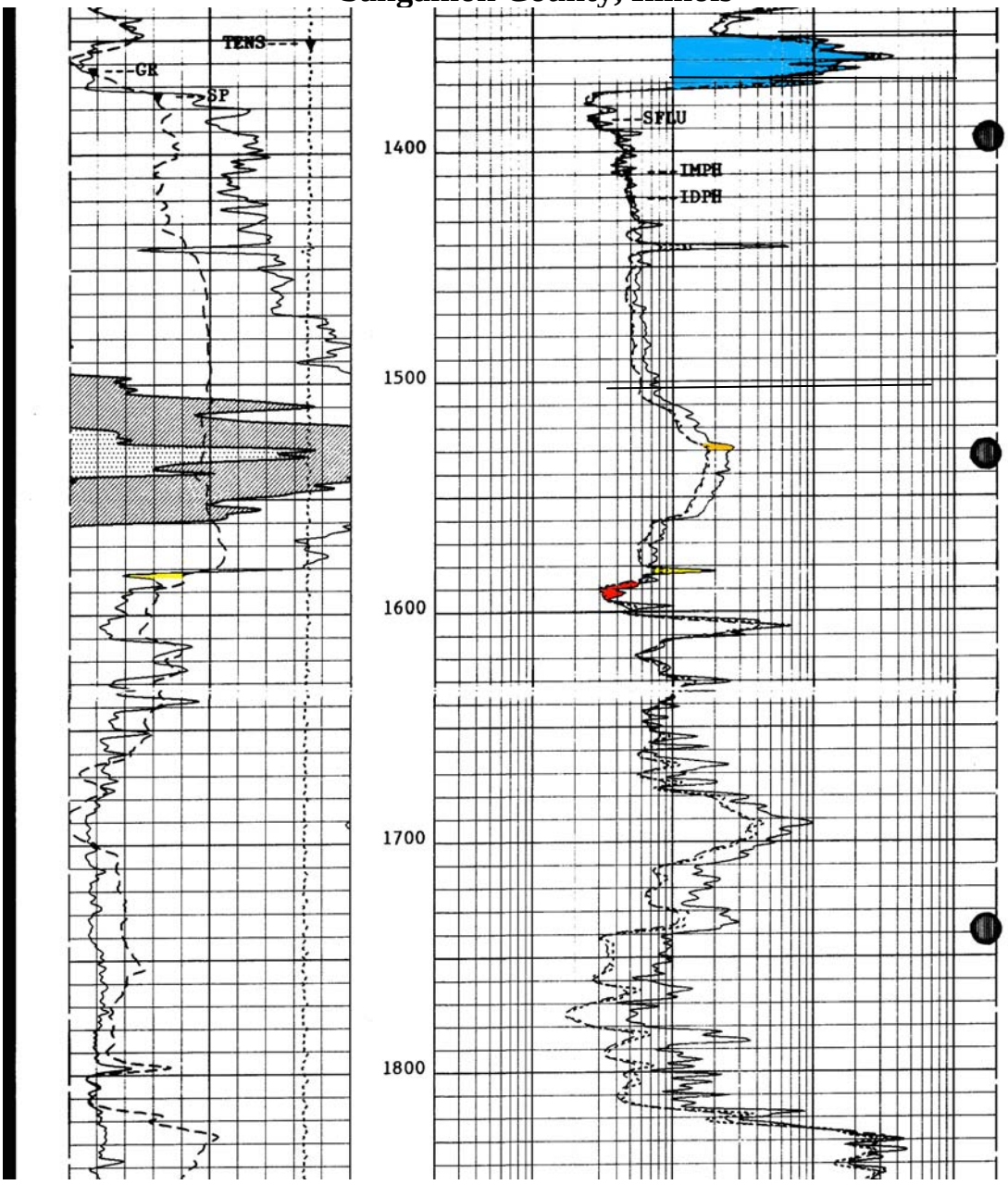
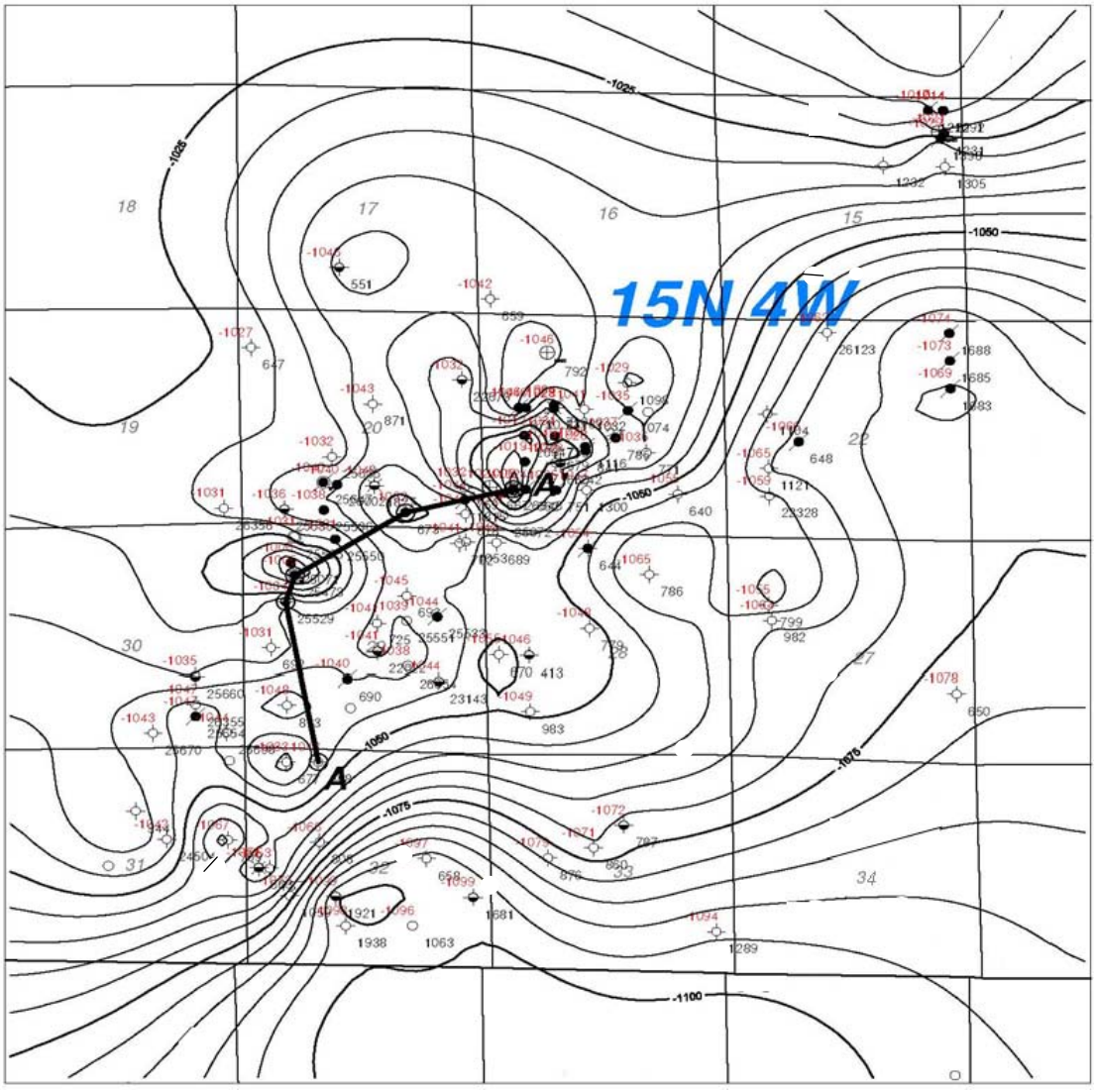


FIGURE 3. Induction, gamma ray and spontaneous potential logs from Springfield East Field showing the Mississippian Chouteau Limestone in blue (1350-1375), Devonian New Albany Shale (1375-1580), New Albany hard and hot zone (1528), Devonian Hibbard Sandstone in yellow (1580-1588), Silurian top (1588) Pay zone development is shown in red at 1588-1595.

STRUCTURE

Regional mapping on the top of the Silurian by Whiting (1956, p. 3 and 5) shows a southwest northeast striking monocline dipping to the southeast. Mapping on top of the Silurian at Springfield East shows that the major feature in the field is a structural nose 4 miles wide dipping southeastward at less than 0.2 degrees (figure 4). Major oil production is out of a mile wide structural high on the nose with approximately 28 feet of closure in section 21. Lesser production comes from 2 small (>1/4 mile) structural highs on the nose trending in a line southwest of the major high. These highs have closures ranging from 10 to 25 feet.



- Dry and Abandoned
- Dry and Abandoned Show of oil
- Dry and Abandoned Show of oil and gas
- Oil well
- Dry and Abandoned Converted to oil well
- Oil well, plugged
- Salt Water Disposal
- Oil well converted to Salt Water Disposal
- Dry and Abandoned Converted to oil well, plugged
- Well with no top available
- -1072 Silurian top elevation data point
- 1063 API Well ID Number

Figure 4. Structure on top of the Silurian at Springfield East Oil Field. Line of cross section A-A' (Figure 9) shown. Contour interval 5 feet.

RESERVOIR CHARACTERISTICS

The primary reservoir in this field is the uppermost Silurian dolomite. The dolomite is finely crystalline, gray to blue and shows extensive fracturing, solution collapse, vugs and fossil molds (figures 5, 6 and 7). Pay zone thickness is estimated at 10-15 feet thick based on log responses. The porosity and permeability were possibly developed during early to middle Devonian exposure and erosion (Whiting, 1956, p.9). Reservoir quality porosity and permeability are discontinuous across the field. The isopach map of the Devonian sandstone shows a strong correlation between the occurrence of Devonian dolomitic sandstone in channels eroded into the Silurian Dolomite and the occurrence of oil wells (figures 8 and 9) supporting a theory that reservoir development is more pronounced in channels were water would have been concentrated and accelerated dissolution of the original rock.

The Hibbard sandstone is listed as a producing formation for 2 wells. Its contribution to production is unknown but probably minimal. It is a gray-green-brown fine grained sandstone with a dolomite matrix. The only rock available for description came from a well that did not produce out of the Hibbard; no reservoir quality rock was available for description.

Figure 5. Slabbed core of Silurian reservoir from Springfield East Field showing vugs, solution features and fractures. Depth 1569-1575. Scale in inches. Eastern American Energy Ramsey /Noll et al. #1 29-15N-4W, Sangamon County.

Figure 6. Exterior view of core showing vugular nature of reservoir rock from Springfield East field. Scale is in inches. Silurian dolomite depth 1571'. Eastern American Energy Ramsey /Noll et al. #1 29-15N-4W, Sangamon County.

Figure 7. view of core showing vugs and solution-collapse in reservoir rock from Springfield East field.
Scale is in inches. Silurian dolomite depth 1572'.
Eastern American Energy Ramsey /Noll et al. #1
29-15N-4W Sangamon County.

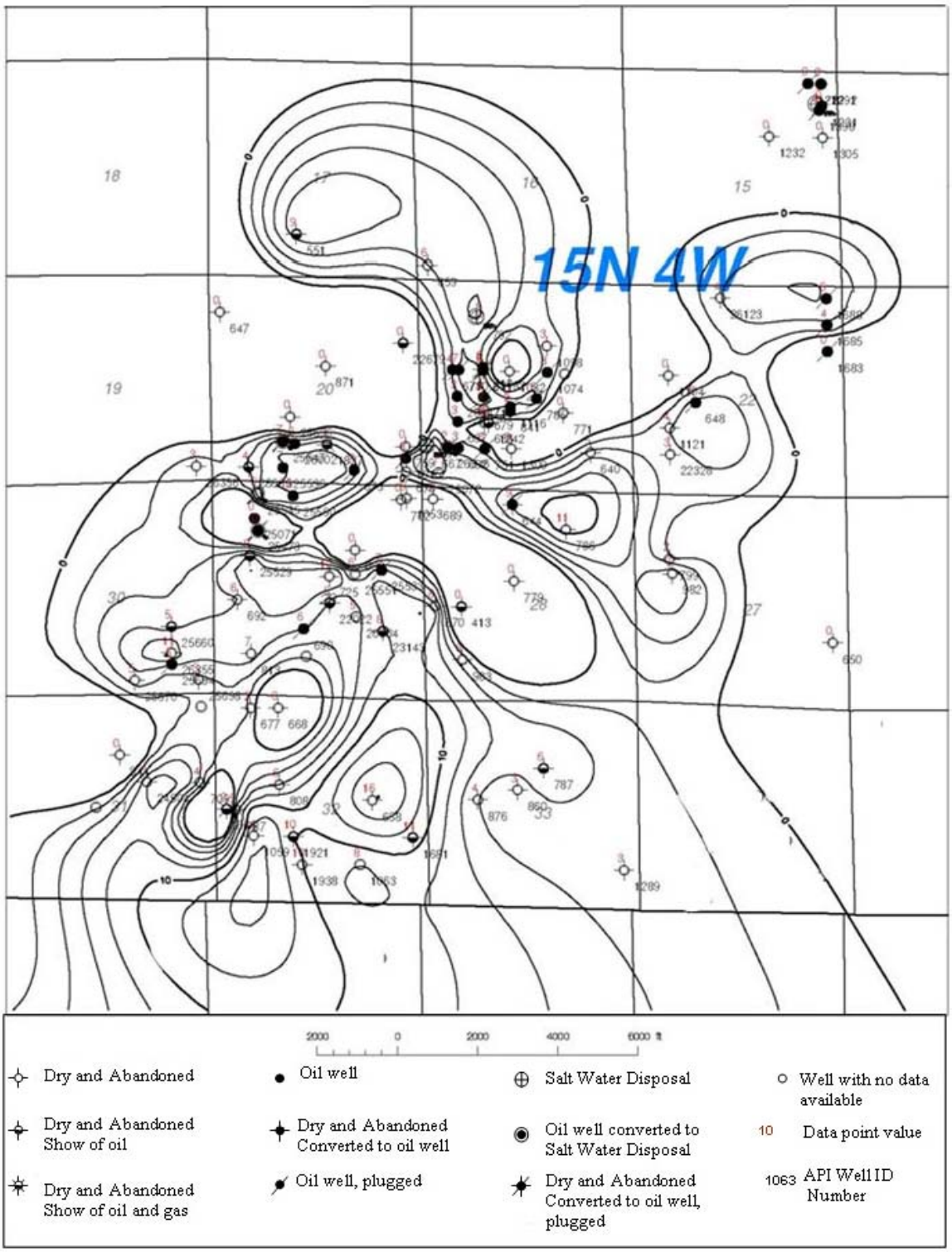


Figure 8. Isopach of Lower Devonian sandstone showing correlation between sandstone occurrence in channels and occurrence of oil wells. Isopach interval 2 feet.

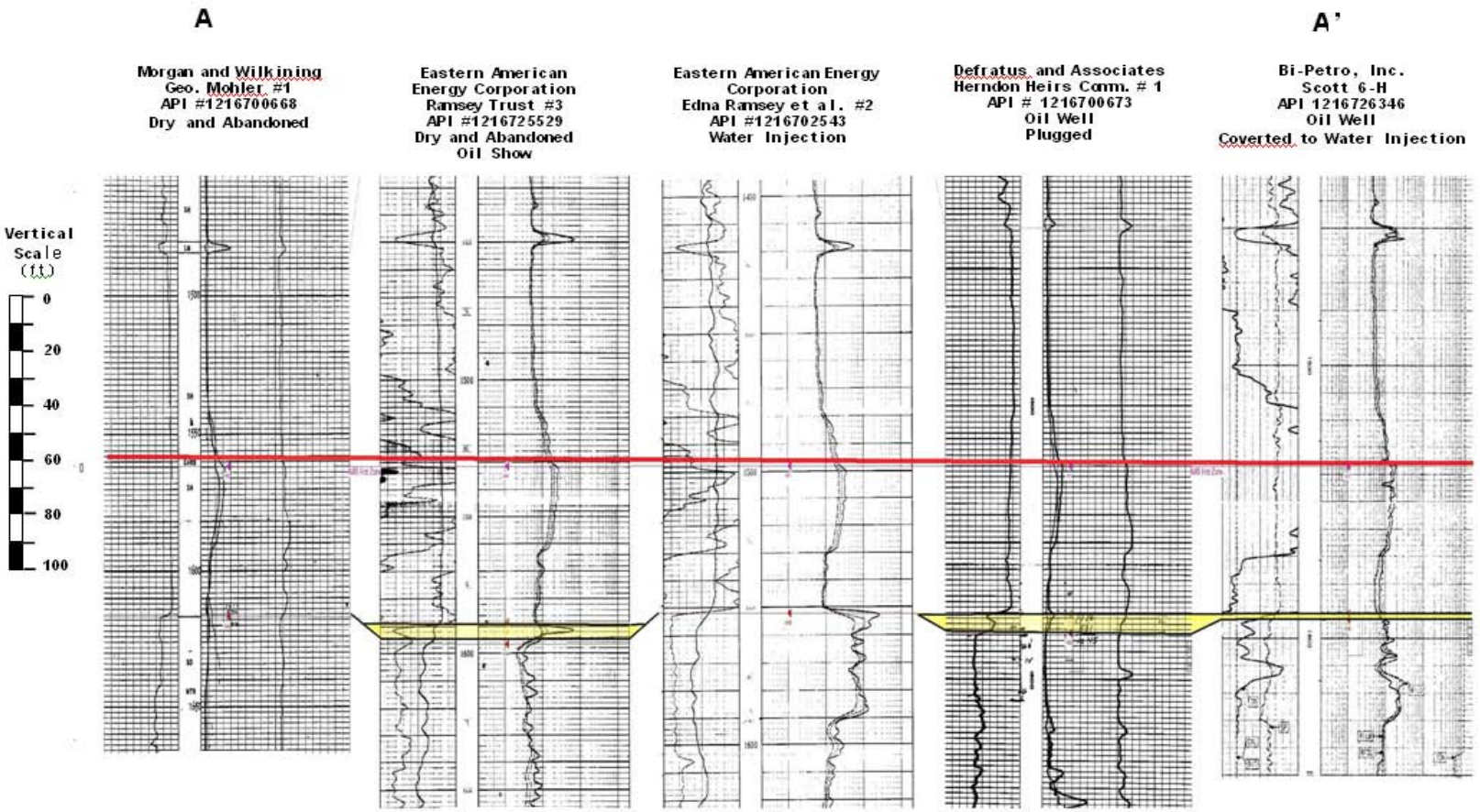


FIGURE 9. Cross section from A to A' (for line of section see figure 4) showing a cross section hung on a New Albany Shale hard and high gamma ray zone (red line)that shows stratigraphic relationships during New Albany time. Note how Devonian Dolomitic sandstone (yellow) fills channels in the Silurian rocks. Well spacing is not relative.

PETROGRAPHY

Under the microscope the reservoir rock is a relatively pure oil stained brown dolomite (figures 10, 11 and 12). The dolomite is fine to coarse grained; the fine grained dolomite is the result of dolomitization of the micrite matrix. Coarse grained dolomite has replaced fossils and may occur in areas where moldic porosity caused by dissolution of fossil fragments creating voids for the crystals to grow. Ghosts of replaced crinoids, brachiopods and bryozoans are abundant. Porosity is primarily moldic after fossils and, in some areas, can be greater then 30%. Other notable features are occasional silt sized grains of quartz and a few stylolitized fractures.

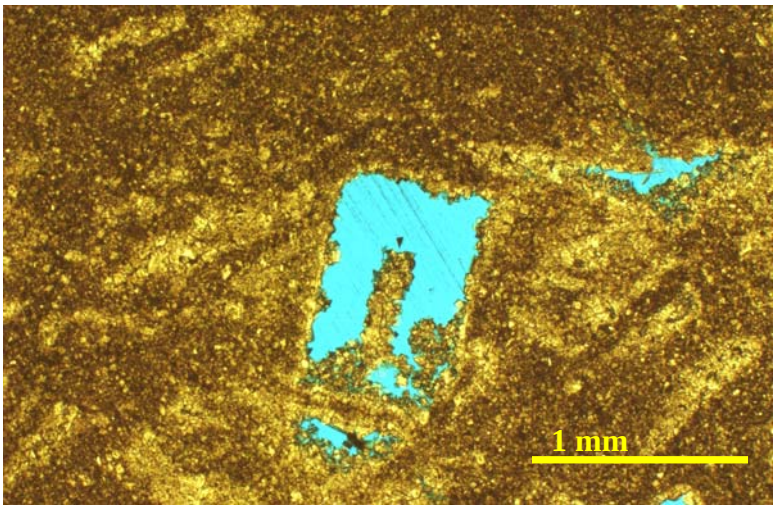


FIGURE 10. Photomicrograph of reservoir rock showing petroleum stained dolomite; fine grained dolomite has replaced matrix. Coarse grained dolomite in fossil ghosts and moldic porosity after a crinoid fragment. Porosity shown in blue. Polarizers not crossed. Depth 1587.6'. Eastern American Energy Ramsey /Noll et al. #1 29-15N-4W Sangamon County. Magnification is 25x.

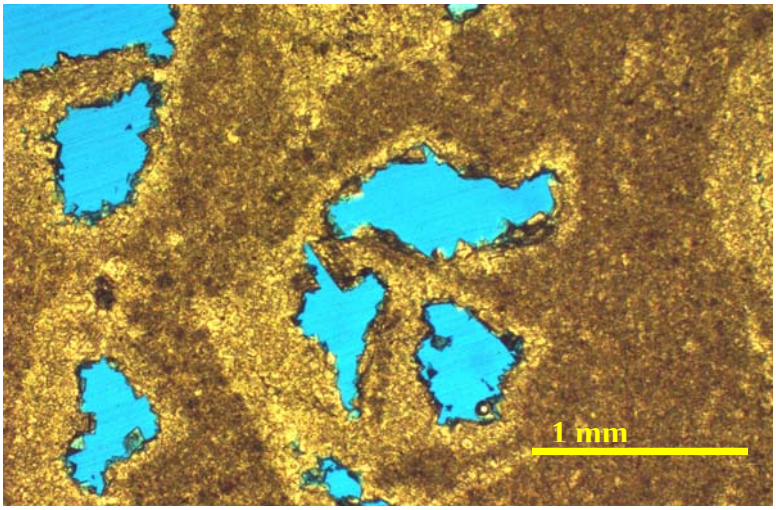


FIGURE 11. Photomicrograph of reservoir rock showing well developed moldic porosity in fossil fragments. Porosity shown in blue. Polarizers not crossed. Depth 1570.5'. Eastern American Energy Ramsey /Noll et al. #1 29-15N-4W Sangamon County. Magnification is 25x.

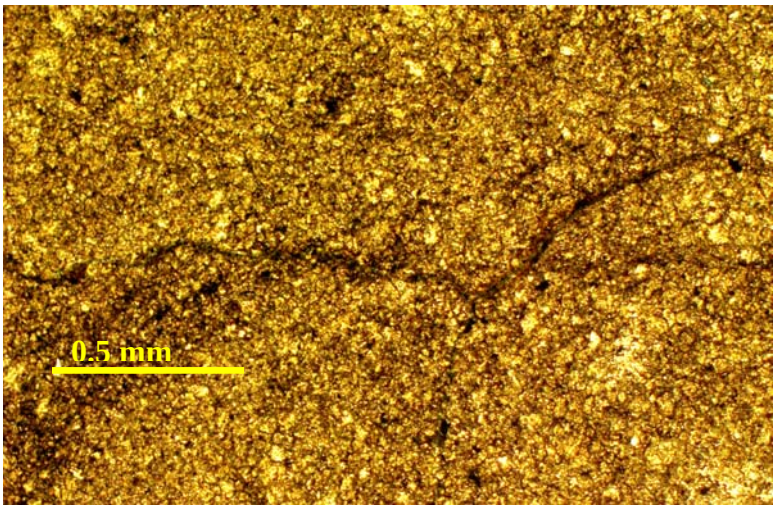


FIGURE 12. Photomicrograph of core showing styolitized fracture. Polarizers not crossed.Eastern American Energy Ramsey /Noll et al. #1 Depth 1570.5'. 29-15N-4W Sangamon County. Magnification is 50x.

COMPLETION TECHNIQUES

Holes in the field were drilled to total depth using rotary tools. Casing was usually set at or slightly below the top of the Silurian. No liner was set and almost all tests were open hole completions. In deeper Silurian zones wells had casing set through the pay zone and were perforated

An average acid treatment of 2500 gallons was given to most wells. Treatments ranged from 500 to 11000 gallons of acid. Wells were then given a water-sand fracture treatment averaging 7000 gallons of water and 8600 pounds of sand.

PRODUCTION

Thirty-one oil wells have been completed in the field since its discovery in 1960. All were productive in Silurian rocks, 2 listing additional production from the Hibbard Sandstone. Initial production from the wells range from 7 to 528 barrels of oil per day (figure 13).

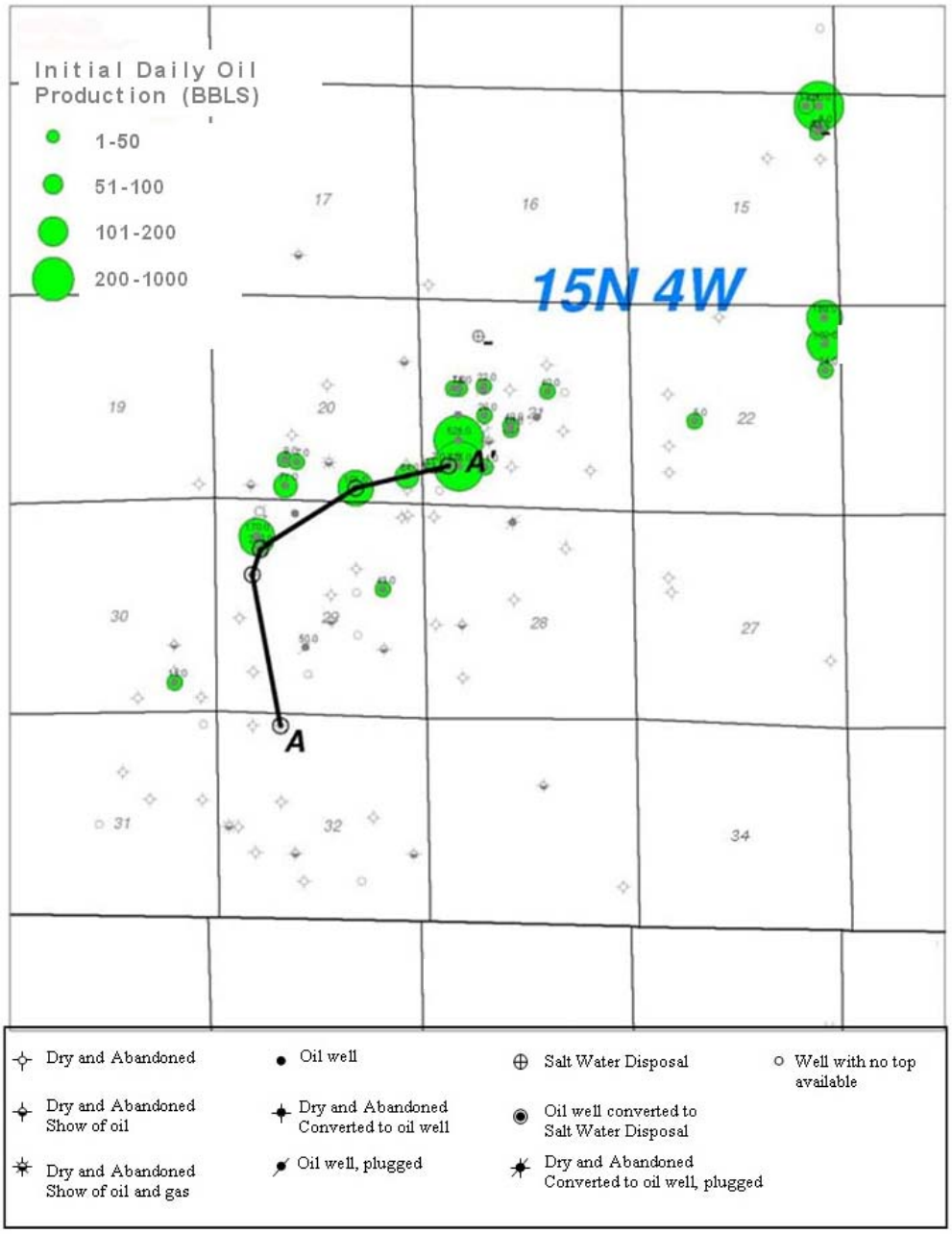


Figure 13. Bubble diagram showing initial production rates for wells in the Springfield East oilfield. Line of section A to A' of figure 9 shown.

Through 2006 the field has produced 679,500 barrels of oil. The discovery well, the #1 Scott, accounts for over 45% of this volume having produced a total of 308,578 barrels of oil when it's last production was recorded in November of 2001. The decline curve (Figure 14) indicates that no new production is found in the field and no waterflood is attempted at current production rate there is an estimated 27,600 barrels of recoverable oil remaining before production for the field falls below 50 barrels/year.

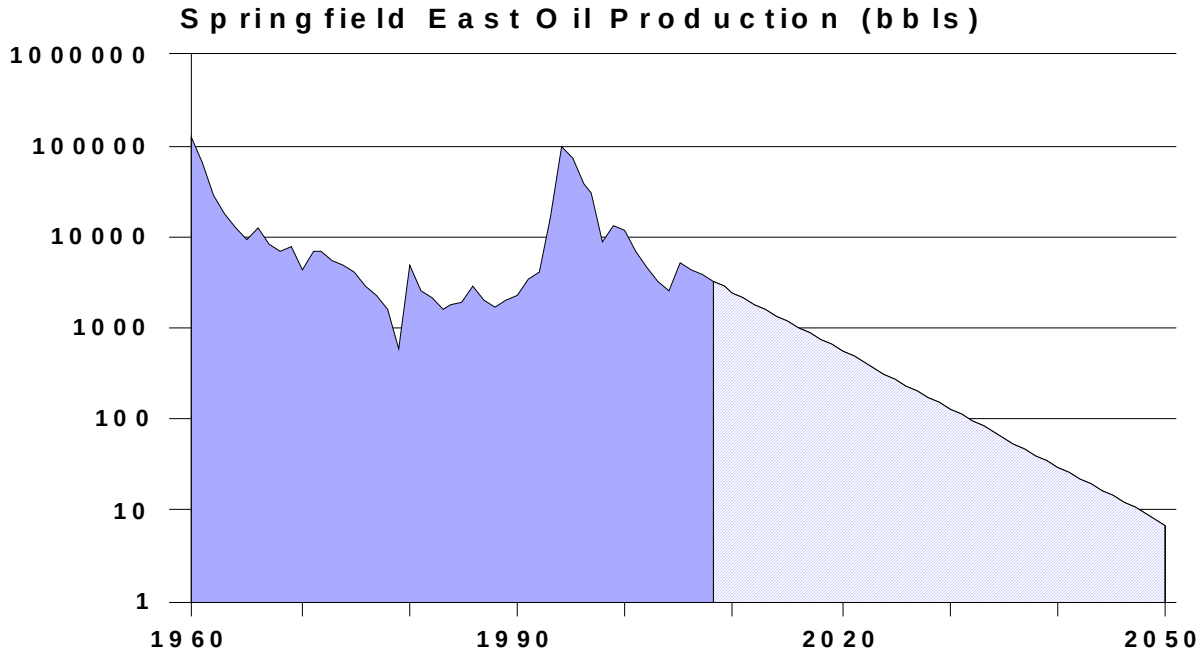


FIGURE 14. Springfield East oil production. Values after 2006 are estimated based on historical decline for reserve calculations (hatchered area).

This field, as most reservoirs in the Mount Auburn trend, has not been waterflooded. The discontinuous non-communicative reservoirs of limited area and limited reserves make the field a questionable candidate for waterflooding. Three floods have been attempted in other fields in the Mount Auburn trend in larger reservoirs. While a sharp waterflood peak does not occur, a boost in production is evident and results are good with a long term increase after fill up. Similar results could be expected from Springfield East Oil Field.

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Silurian Carbonate Reservoirs of the Mount Auburn Trend Along the Sangamon Arch, West-Central Illinois Yaghoob Lasemi

Abstract

The Silurian succession of the Sangamon Arch, a broad southwest-trending structure in west-central Illinois, is composed of hydrocarbon-bearing carbonate rocks. Over 12 million barrels of oil have been produced from these rocks in the Mount Auburn trend, along the southern flank of the arch, chiefly from dolomitized carbonate reservoirs in the upper part of the Niagaran series. To date, there has been no detailed study of the Niagaran reservoirs in the Sangamon Arch area; there is a general lack of understanding of the reservoir facies types, distribution, geometry, porosity development, petroleum entrapment and their controls.

Detailed subsurface studies along the Mount Auburn trend have revealed the presence of permeability pinch outs at several horizons. They include dolomitized wackestone-grainstone facies in the upper part (reservoir units A-C) and patch reefs facies in the lower part of the Niagaran succession (reservoir unit D). The reefs are composed mainly of coral skeletons, but their internal structure is poorly preserved as a result of pervasive dolomitization. These reservoirs are characterized by lenticular bodies of limited lateral extent that grade laterally and vertically into an impermeable limestone facies or a very finely crystalline, argillaceous dolomite facies. They were deposited along a southwest trending platform margin that was roughly parallel to the Sangamon Arch trend and graded basin ward into muddy carbonates below wave base.

Hydrocarbon production along the Sangamon Arch thus far has been chiefly from the non-reef carbonate reservoirs in the uppermost part of the Silurian succession. Most wells drilled thus far have only tested the uppermost part of the Niagaran succession; only a few wells have tested the lower reservoirs that include the newly-recognized patch reefs. The results of this study suggest that there is an excellent possibility for finding more productive Niagaran dolomitized patch reefs and non-reef reservoirs along a vast area of the Sangamon Arch.

1. Introduction

The Middle Silurian (Niagaran) rocks in the Mt. Auburn Trend of the Sangamon Arch in west Central Illinois (Figs. 1 and 2) contain prolific petroleum reservoirs, which have been producing for over 80 years. The first commercial production from the area was in 1925 from the Decatur Field, but the major activity did not begin until 1954 after Sun Oil Company completed Damery No. 1 in December 1953, which flowed over 700 barrels of oil per day after a fracturing treatment of the Silurian reservoir (Whiting, 1956). The Mt. Auburn trend along the southern flank of the arch includes several oil fields (Fig. 2) that have produced over 12 million barrels of oil chiefly from the dolomitized carbonate reservoirs that occur in the upper few feet of the Silurian succession. However, there have been conflicting views on reservoir development, petroleum entrapment and their controls. To date there has been no documented studies regarding the reservoir facies types, porosity, occurrence, and petroleum entrapment of the Upper Silurian rocks of the Sangamon Arch.

The objectives of this report are to determine reservoir facies types, occurrence, geometry, distribution, porosity development and petroleum entrapment of the Silurian carbonate reservoirs of the Mt. Auburn Trend of the Sangamon Arch for exploration,

development and secondary recovery enhancement. This study should generate interest for exploration in the unexplored areas of the Sangamon Arch. It could also result in developing models for depositional environment and reservoir development of the Silurian rocks in other productive areas of the basin.

Reservoir characterization of the Silurian deposits in the Mt. Auburn Trend was established using available subsurface data, including well samples (cuttings/cores) and geophysical logs to determine facies types, facies geometry, entrapment and their control. The area of Blackland North Field and the Southern margin of the Harristown Field was chosen for a more detailed subsurface mapping. The wells in this area were mainly drilled in the early 1980's and as a result more complete subsurface data are available. These maps and stratigraphic cross-sections of different areas of the Mt. Auburn Trend were constructed using GeoGraphix and Adobe Illustrator software. The reservoir facies are classified on the basis of the Dunham (1962) and the Embry and Klovan (1971) textural schemes.

2. Geologic setting and stratigraphy

The Sangamon Arch is a broad southwest trending structure in west Central Illinois, which was formed as a result of upward warping during Silurian and Devonian times (whiting and Stevenson, 1965). It is located in the shelf area just northwest of the Illinois Basin where the Lower to Middle Devonian deposits are absent (Fig. 1). The isopach map of the New Albany Shale Group along the Mt. Auburn Trend (Fig. 3) shows the pre-New Albany structure of the arch. The general thinning of the shale towards the center of the arch suggests that the axis of the arch was still active during Late Devonian time. The exposure of the arch during the Early and Middle Devonian times resulted in partial erosion of the Silurian deposits and formation of an uneven topography. The uneven topography is nicely displayed by the structure contour map of the base of the New Albany Shale Group (top of the Silurian succession), showing several noses and minor closures (Fig. 4) and by a series of cross-sections that are prepared on a Silurian datum (see reservoir characterization below). The structure contour map (Fig. 4) also indicates the direction of the regional dip in the study area, which is on the whole towards the southeast.

The Mt. Auburn Trend is located along the southern flank of the Sangamon Arch in west central Illinois. It encompasses several oil fields and covers parts of Macon and Christian Counties in west central Illinois (Figs. 1 and 2). The Silurian deposits in the Mt. Auburn Trend (Fig. 5) are overlain by the Upper Devonian New Albany Shale Group with a pronounced erosional unconformity (sub-Kaskaskia unconformity) and are underlain by the Upper Ordovician Maquoketa Shale Group with a distinct unconformity (sub-Tippecanoe II unconformity) (Fig. 6).

In the Mt. Auburn Trend, the Middle Silurian (Niagaran) Moccasin Springs Formation is the only petroleum producer. The formation comprises several dolomitized producing horizons that grade laterally and vertically to impermeable fossiliferous limestone (argillaceous and cherty in some parts) or to a very finely crystalline argillaceous and calcareous dolomite (Fig. 5). The Silurian succession is a part of the Silurian-Middle Devonian Hunton Megagroup (Swann and Willman, 1961), which constitutes the upper part of the Tippecanoe Sequence of Sloss (1963) (Fig. 6).

3. Reservoir characterization

Detailed subsurface studies along the Mt. Auburn trend have revealed the presence of permeability pinch outs (here referred to reservoir units) at several horizons displaying a shallowing-upward cycle. They include dolomitized wackestone to grainstone facies in the upper part and coral patch reefs in the lower part of the Niagaran succession. These coarsely crystalline dolomite reservoirs are interlayered with tight limestone or impermeable very finely crystalline argillaceous dolomite. The laterally extensive impermeable units have formed flow barriers that divide the Niagaran deposits into stratigraphic cycles of porous and impermeable horizons. The reservoirs were deposited along a southwest trending platform margin that was roughly parallel to the Sangamon Arch trend and graded basinward into muddy carbonates below wave base similar to the numerous modern and ancient examples (e. g., Wilson, 1975, Tucker and Wright, 1990; Flugel, 2004).

The reservoir units are defined on the basis of facies and their stratigraphic position and are designated, from top to base, as reservoir units A, B, C and D. The isopch map of units A-C (greater than 8 percent porosity) for the Blackland North and the southern part of the Harristown Field are shown in figures 8, 10 and 12. These maps, together with a series of stratigraphic cross-sections in different parts of the Mt. Auburn Trend, reveal the lateral distribution and vertical compartmentalization of the reservoirs recognized. Examination of the numerous wells in the Mt. Auburn Trend indicates that most of the wells drilled thus far have only tested the uppermost part of the Niagaran succession; only a few wells have tested the lower reservoirs that include the newly-recognized patch reefs.

3.1. Non-reef reservoir facies A-C

The non-reef facies A-C are characterized by porous dolomitized wackestone to grainstone facies with packstone and grainstone being the predominant precursor facies (Figs. 7 B-E and 14 B). They consist of coarsely crystalline dolomite that may contain partially dolomitized echinoderm (mainly crinoids) fragments (Fig. 7 C-E) and molds of bioclasts including crinoids, bivalves, brachiopods and other non-recognizable grains. In some areas or in some samples within a reservoir, only dolomite crystals are recognized (Fig. 14 A), showing a very faint relic that could represent the organic residue of the original bioclasts. It appears that the dolomitizing fluid initially affected the groundmass (cement or matrix) and the more susceptible fossil fragments; crinoids were the last grains to be dolomitized (Fig. 7 C-E). A later reservoir porosity enhancement occurred by partial dissolution of the dolomite crystals along the pore walls by fluids undersaturated with respect to dolomite (Fig. 14 A and F). The reservoirs are surrounded by impermeable limestone (Fig. 7 A) or shaley and calcareous, very finely crystalline dolomite (see cross-sections AA’ to FF’ below), suggesting sea level fluctuation and seawater chemistry as primary control for dolomitization of the compartmentalized Silurian reservoirs. This interpretation is further supported by the resistance of dolomite layers to chemical compaction and resulting cementation as opposed to limestone (e. g., Brown, 1997; Lucia, 2004; Ehrenberg, 2006).

3.1.1. Reservoir unit A

Unit A is a lenticular reservoir of limited lateral extent (Fig. 8) that is recognized in the uppermost part of the Silurian deposits. It is up to 14 feet thick separated from the unit B by about 10 feet of impermeable fossiliferous limestone (Figs. 9 and 11 and 16-20). This limestone contains chert nodules and is a laterally persistent horizon in the Mt.

Auburn Trend, except in areas that is removed by pre-Devonian erosion. Unit A is capped by another impermeable limestone of variable thickness (Figs. 9 and 11 and 16-20), but where it is removed by erosion, the New Albany Shale becomes the capping facies for petroleum entrapment (see Philips No. 1 in Fig. 19 and Drysdale No. 1 in Fig. 20). Reservoir A is a permeability pinch out primarily controlled by depositional setting of the Silurian deposits. In some areas of the Mt. Auburn Trend, however, the absence of reservoir A may be the result of post Silurian erosion, which is well illustrated in cross-sections DD' and EE' (Figs. 19-20). Deep erosion in Dipper No.1 (Fig. 19) and in Drysdale No. 1 (Fig. 20) has removed the interval that could otherwise embrace reservoir A.

3.1.2. Reservoir Unit B

Reservoir B is another lenticular horizon along the trend of the Sangamon Arch and is best developed in the Blackland North Field (Fig. 10). It is up to 5 feet thick and occurs just below the impermeable and persistent limestone marker (Figs. 11 and 18). A tight limestone of up to 6 feet separates unit B from the underlying unit C. In the southeast of the Blackland North Field and in other fields of the Mt. Auburn Trend, Unit B and the tight underlying limestone may thin out or pinch out to form a single C reservoir (see Fig. 13, and Dipper No. 1 in figure 19). The pinch out of reservoir A could be the result of pre-Devonian erosion (see Hill Estate No. 1 in figure 18).

3.1.3. Reservoir Unit C

Reservoir C could attain a thickness of over 20 feet in parts of the Mt. Auburn Trend and is more extensive than the other reservoirs (Fig. 12). It is overlain by up to 6 feet of impermeable limestone in Blackland North Field (Figs. 11 and 18). This tight limestone thins out laterally beyond the resolution of the geophysical logs (see Hill Estate No. 1 in figure 18). Due to lateral thinning of this tight limestone, reservoirs B and C may coalesce forming a composite reservoir underlying the widespread impermeable cherty limestone marker (Figs. 9, 13, 16-17 and 19). Reservoir unit C is also lenticular and pinches out laterally to impermeable limestone (see Elder No. 1 in figure 20), shale/argillaceous limestone (e. g., Nolan No. 3 in figure1) or impermeable, very finely crystalline argillaceous dolomite.

4. Reef reservoir facies D

To date, there have been no documented reports of any reef reservoirs in the Sangamon Arch area. The inspection of well sample and cores (Dipper No. 1 in Blackland Field North, Macon County and Elder No. 1 in Mt. Auburn Consolidated Field, Christian County) and well log stratigraphic correlation with other areas of the Sangamon Arch (for example, Parks Comm. No. 2-L in the Mechanicsburg Field, Sangamon County and Garver No.1 in the Harristown Field, Macon County) led to recognition and documentation of a reef facies in the study area of the Sangamon Arch (Figs. 14 C-D and 22).

The reef facies is characterized by porous dolomitized coral reef/reef rudstone facies and is the lowermost productive horizon recognized in the Sangamon Arch area (Fig. 14 C-F, 16-17, 19-20 and 22). It consists of coarsely crystalline dolomite containing remains and molds of reef building organisms (mainly corals). The reef building skeletons are recognizable in cores and hand samples (Fig. 14 C-D), but the detail of their structure is lost due to pervasive dolomitization so that in thin sections only a very faint

relic of the organic material of the original skeleton is visible (Fig. 14 E-F). Both intercrystalline and moldic porosities are present and the total porosity could reach over 20%.

The reefs occur as patch reefs of a very limited lateral extent and with a thickness of up to 30 feet, which grade laterally and vertically into impermeable, bioturbated and bioclastic mudstone to wackestone or to a very finely crystalline, argillaceous dolomite inter-reef facies. The reefs and associated facies display a shallowing-upward cycle and may occur in 1 to 3 horizons (Figs. 9, 18, 20 and 22). The patch reefs developed on the monocline platform of the Sangamon Arch with a very gentle slope (ramp platform of Ahr, 1973, 1998), similar to the southern part of the Persian Gulf (Purser, 1973), where the wave energy was not strong enough for the reef builders to construct barrier reefs or large pinnacle reefs described in other parts of the Illinois Basin (e. g., Bristol, 1973). Similar to the non-reef reservoirs (see above), dolomitization of the reef facies occurred very early during diagenesis and seawater chemistry and/or sea level fluctuation appear to have primarily controlled dolomitization.

The majority of wells in the study area have not tested the lower part of the Niagaran deposits that include the newly-recognized patch reefs, so the potential of these prolific lower horizons has been mostly overlooked. Examination of a few highly productive wells indicates that the highest initial production (up to 3000 barrels per day) is normally associated with this type of reservoir. Therefore, there is an excellent possibility for finding more productive Niagaran patch reefs along a vast area of the Sangamon Arch.

5. Conclusions

1. Four dolomitized permeability pinch outs are recognized in the Silurian deposits of the Mt. Auburn Trend including non-reef reservoir units A-C in the upper part and patch reef reservoir unit D in the lower part of the Niagaran series.

2. The reservoirs are surrounded by impermeable limestone (Fig. 7 A) or shaley and calcareous very finely crystalline dolomite suggesting seawater fluctuation and seawater chemistry as primary control for dolomitization of the compartmentalized Silurian reservoirs.

3. The laterally extensive impermeable units have formed flow barriers that divide the Niagaran deposits into stratigraphic cycles of porous and impermeable horizons. The reservoirs were deposited along a southwest trending platform margin that was roughly parallel to the Sangamon Arch trend and graded basin ward into muddy carbonates below wave base.

4. Examination of the numerous wells in the Mt. Auburn Trend indicates that most of the wells drilled thus far have only tested the uppermost part of the Niagaran succession; only a few wells have tested the lower reservoirs that include the newly-recognized patch reefs, so the potential of these prolific lower horizons has been mostly overlooked.

Figures Mt Auburn Trend Sangamon Arch

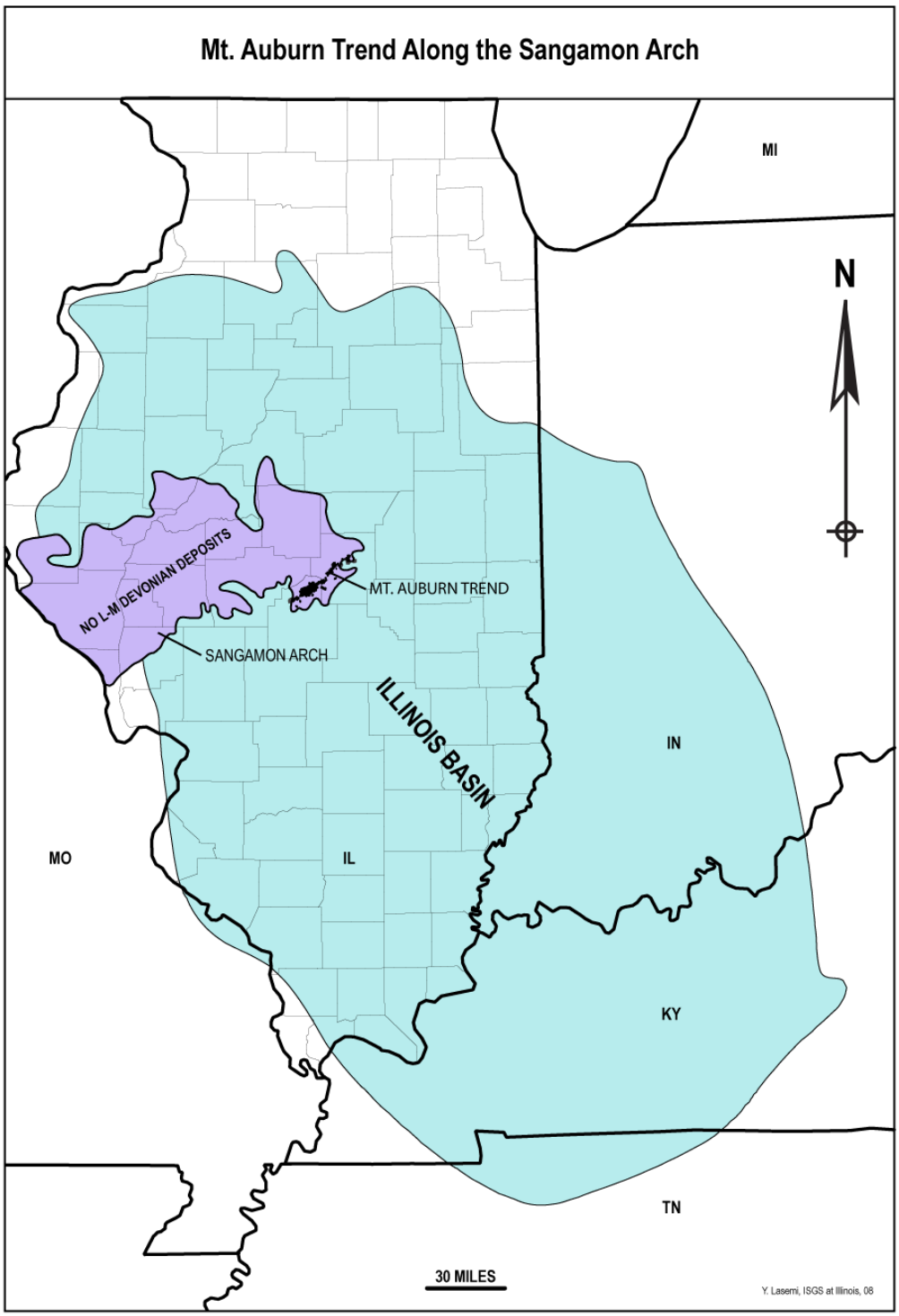

Figure 1. Outline of the Sangamon Arch in west central Illinois, which is defined by the zero isopach contour of the Lower- Middle Devonian deposits in the northwest of the Illinois Basin (Whiting and Stevenson, 1965). The Mt. Auburn Trend (the subject of this study) is located along the south eastern flank of the arch and includes several oil fields (see figure 2).

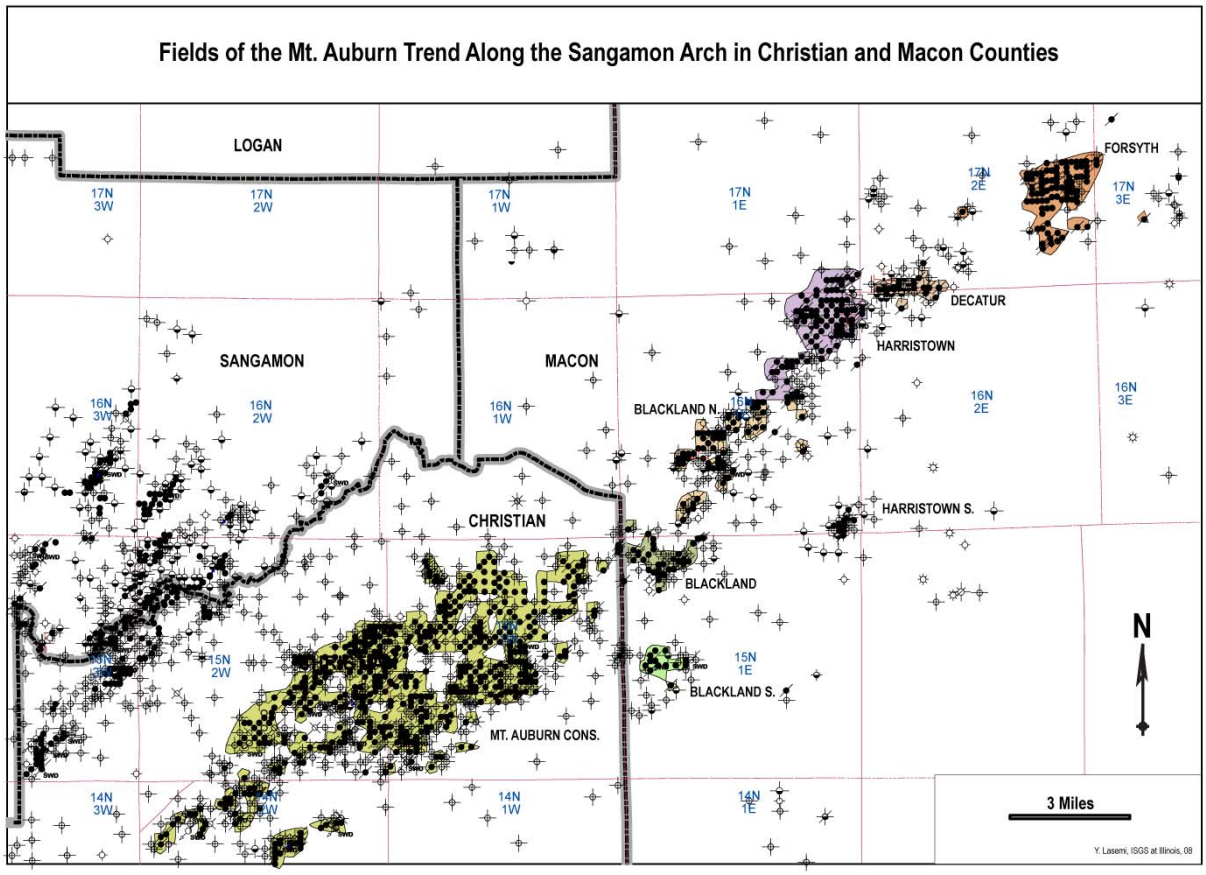

Figure 2. The eastern part of the Sangamon Arch showing the Mt. Auburn Trend at its southeastern flank. The trend is delineated by a number of oil fields that have produced from the Silurian reservoirs.

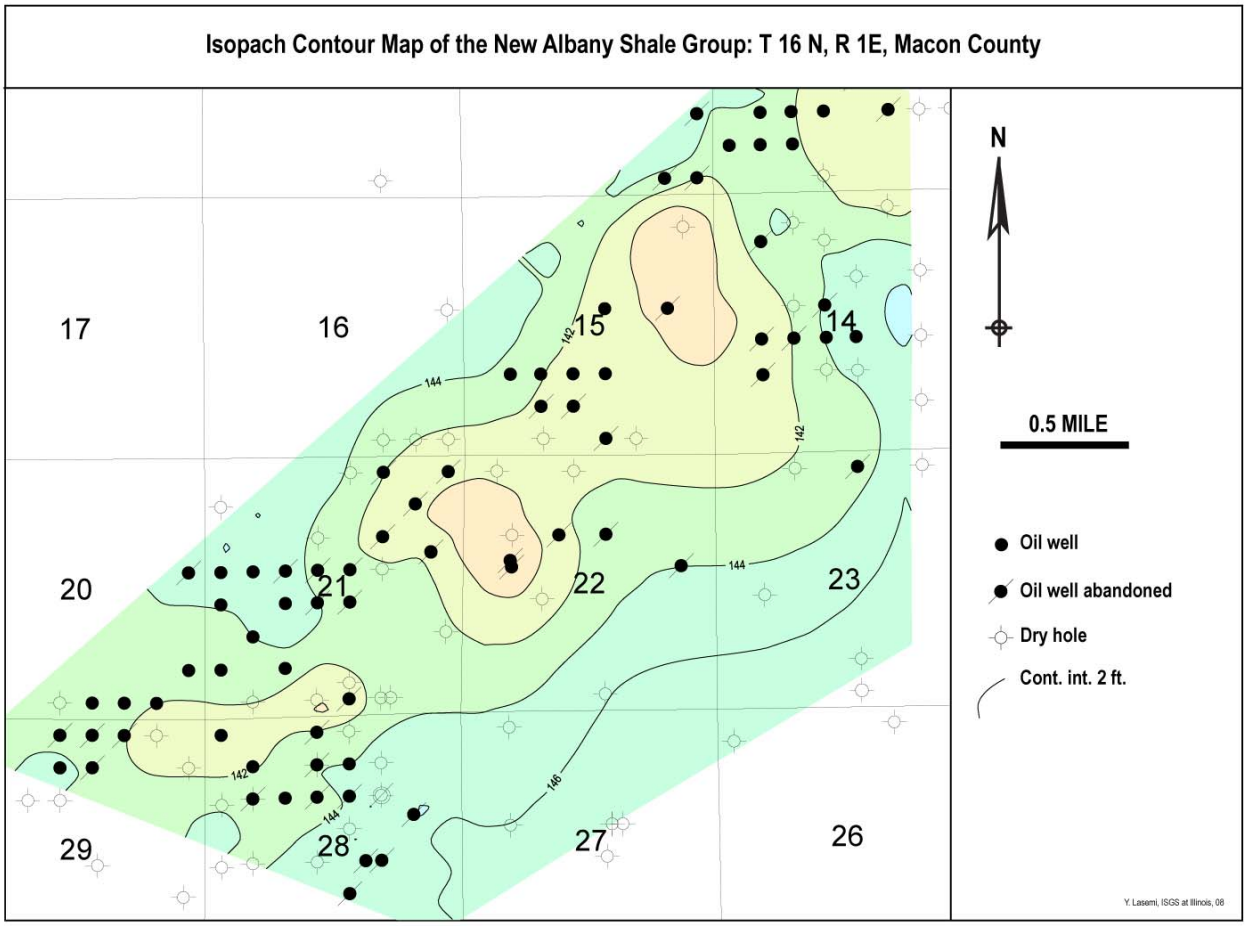

Figure 3. Thickness map of the New Albany Shale Group (from the top of Silurian deposits to the base of Chouteau Limestone); the New Albany thins towards the center of the arch suggesting that the arch was still active at the onset of the Upper Devonian deposition.

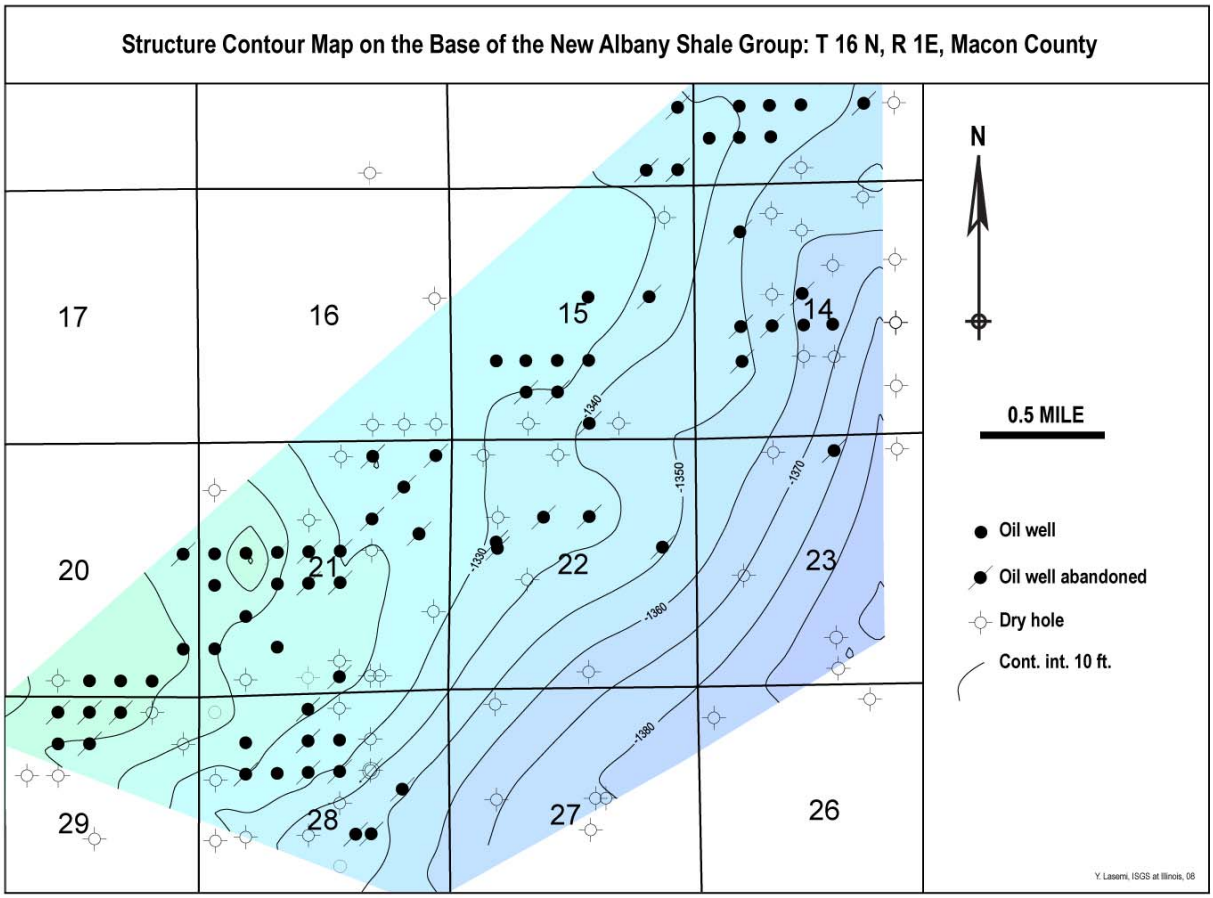

Figure 4. Structure contour map of the base of the New Albany Shale Group showing the direction of the regional dip that is towards the southeast. Note minor closures and noses that are due to uneven Pre-New Albany topography.

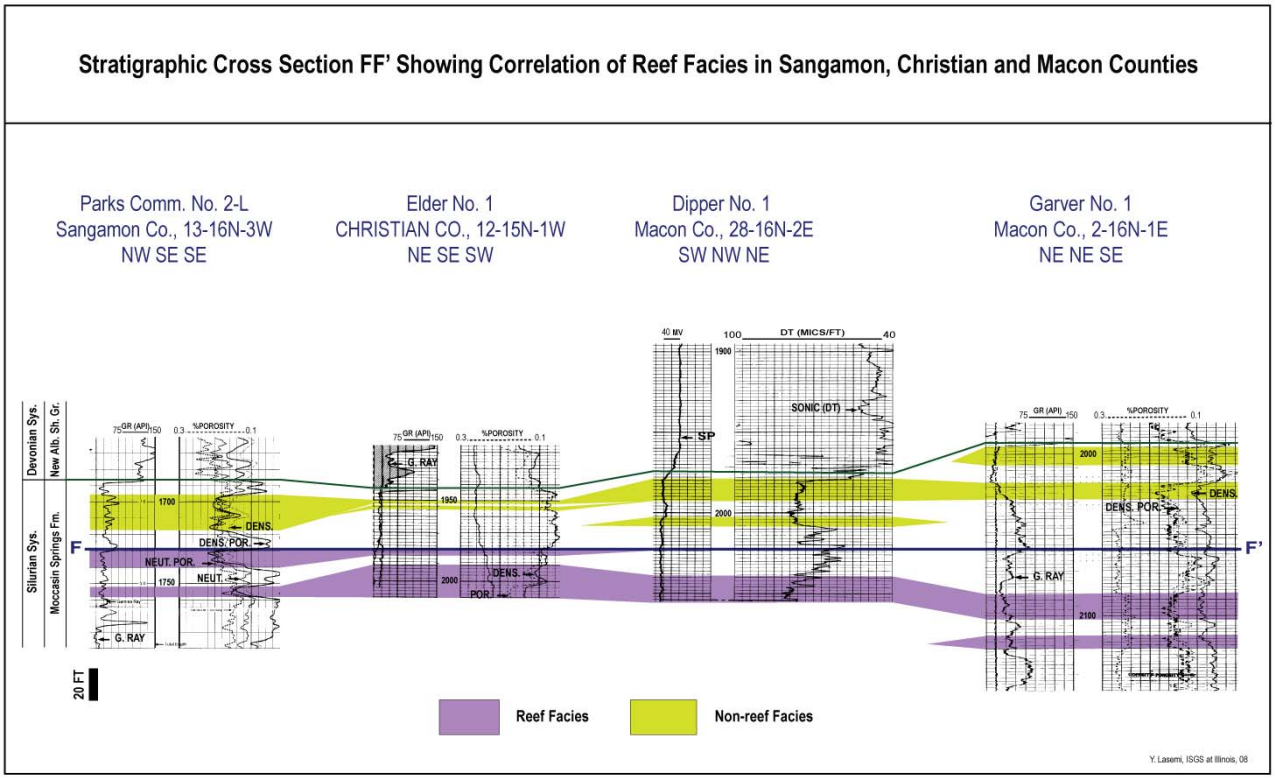

Figure 22. Cross-section FF' showing the correlation of reef and non-reef reservoirs in Macon, Christian and Sangamon Counties; note that the reef facies may occur in more than one interval in the lower part of the Niagaran Series (for the line of cross-section see Fig. 15).

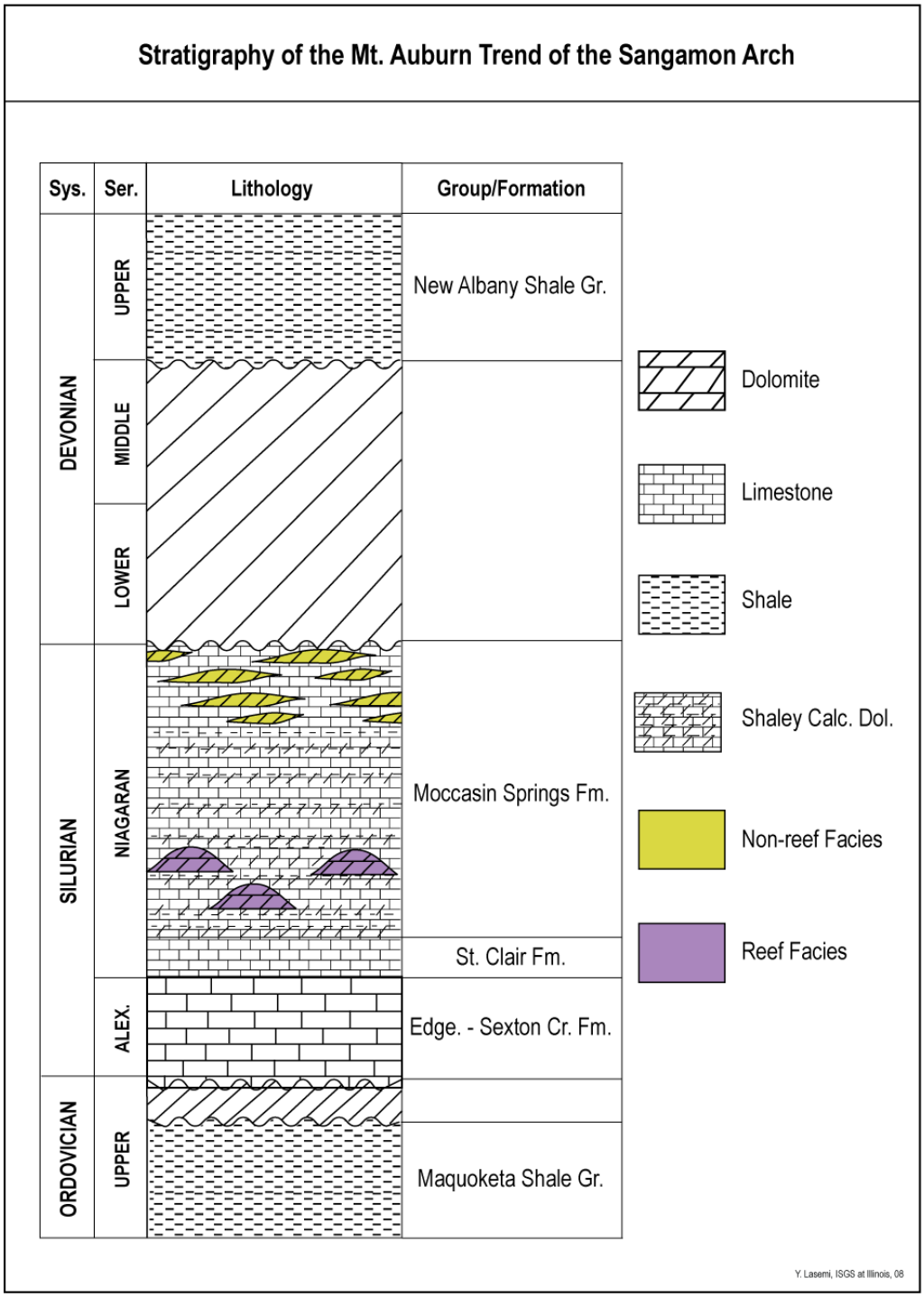

Figure 5. General stratigraphic column of the Upper Ordovician to Upper Devonian strata in the Sangamon Arch area showing the absence of Lower- Middle Devonian deposits.

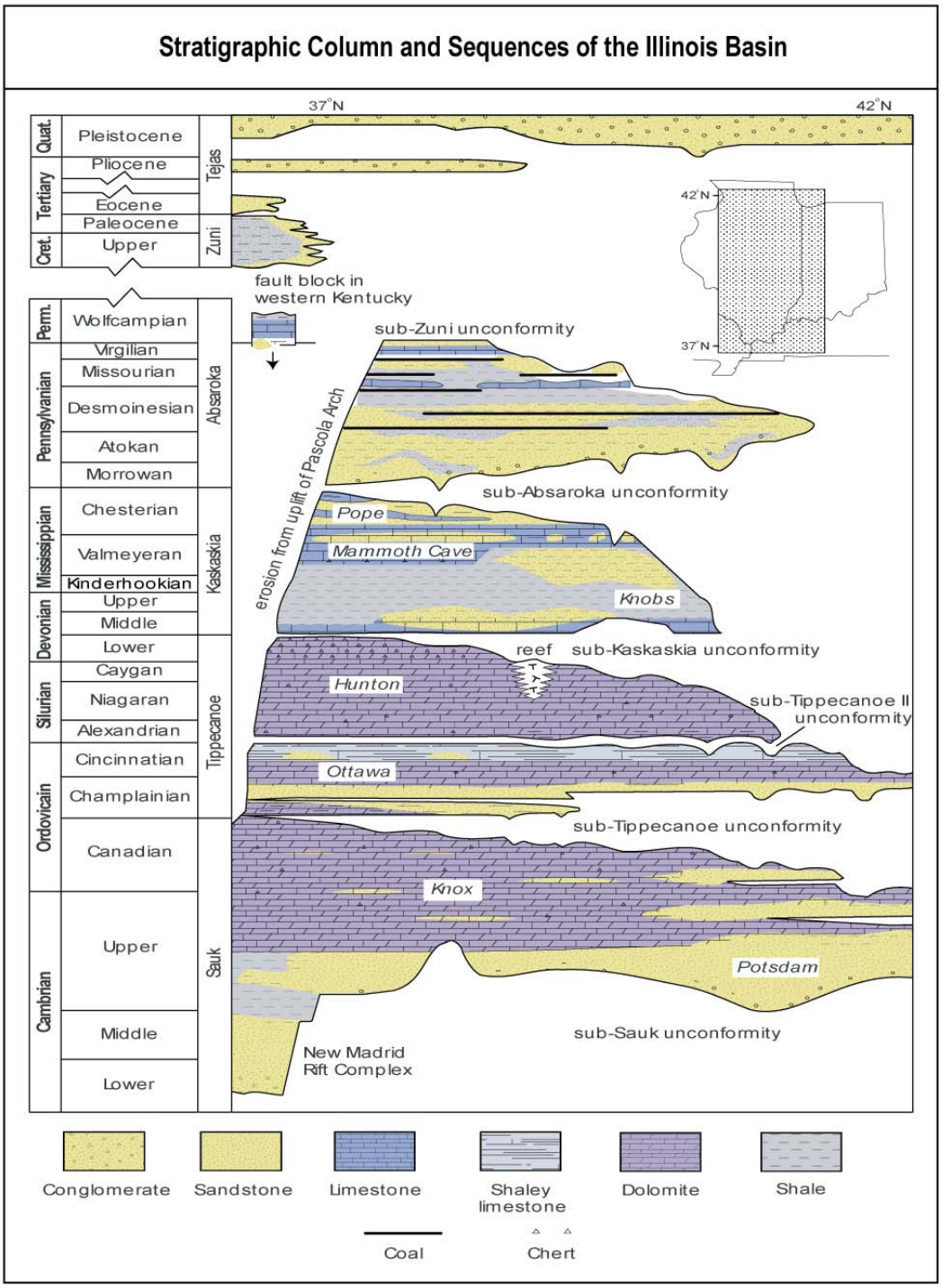

Figure 6: Stratigraphic column and sequences of the Illinois Basin (based on Swann and Wilman, 1961). In the Sangamon Arch area, the Upper Devonian deposits rest on the Silurian strata with the pronounce sub-Kaskaskia unconformity.

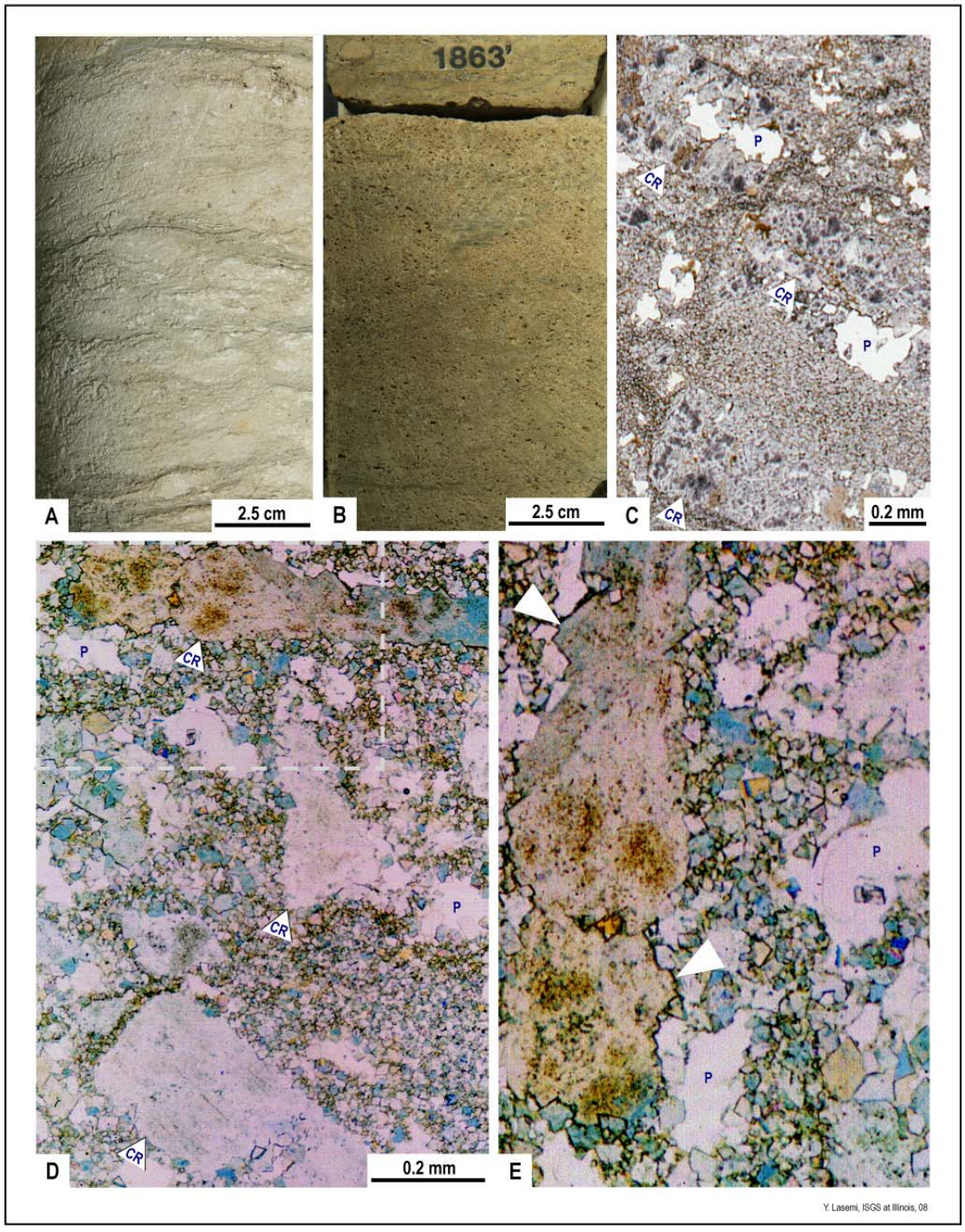

Figure 7. (A) Core of a limestone (bioturbated lime mudstone to wackestone facies) that is normally interlayered with reservoir facies. (B) Core slab of a porous dolomitized grainstone facies. (C) Scanned thin section photograph of B in plane light showing the remains of partially dolomitized crinoids (CR) and the pore spaces (P) formed as a result of dolomitization. (D) Photomicrograph of C under polarized light showing dolomite crystals and remains of crinoids (CR). (E) Enlarged portion of D (upper left rectangle outlined by white dashed lines) showing irregular dolomitization front (Arrow) and formation of dolomite rhombs and void spaces at the expense of crinoids.

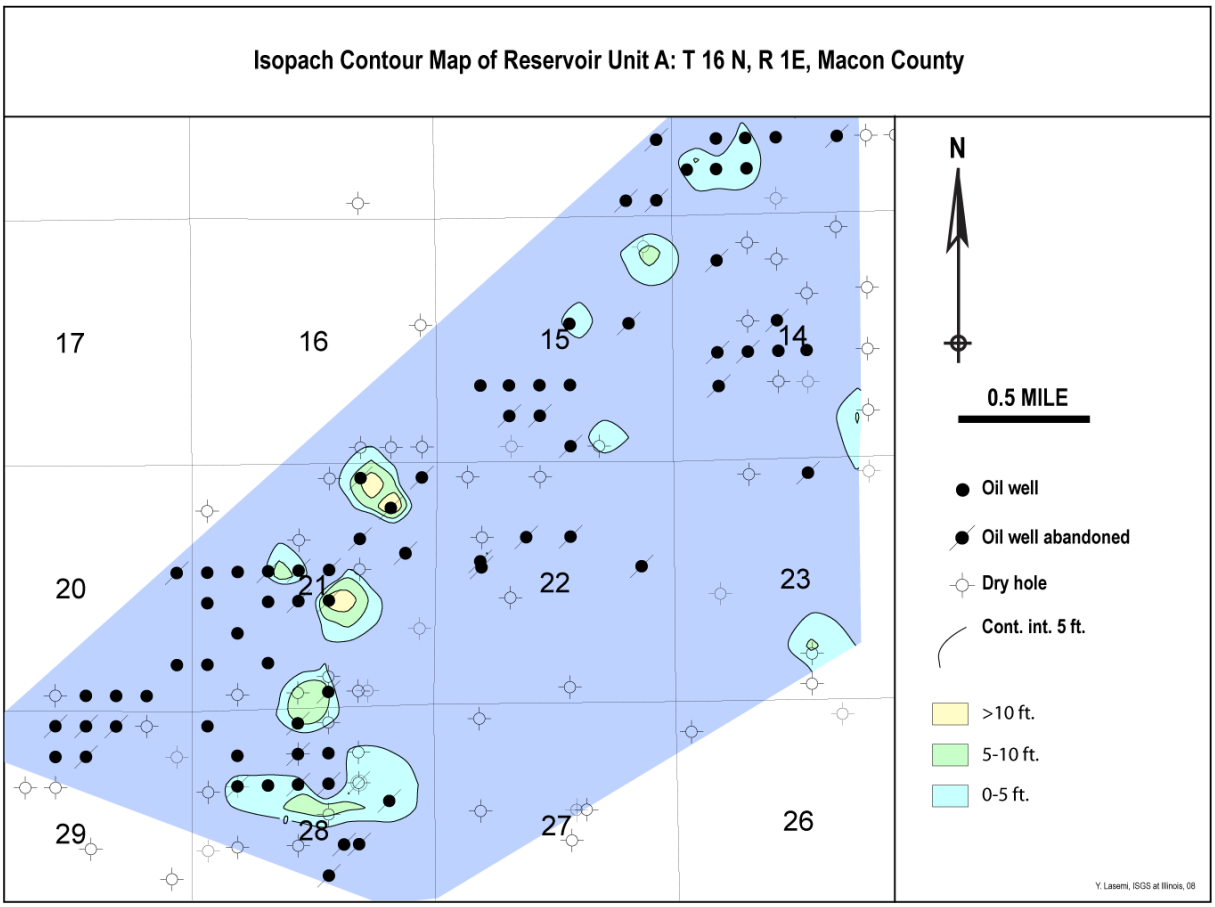

Figure 8. Thickness map of reservoir unit A (greater than 8% porosity) showing lenticular bodies that laterally pinch out to impermeable limestone facies.

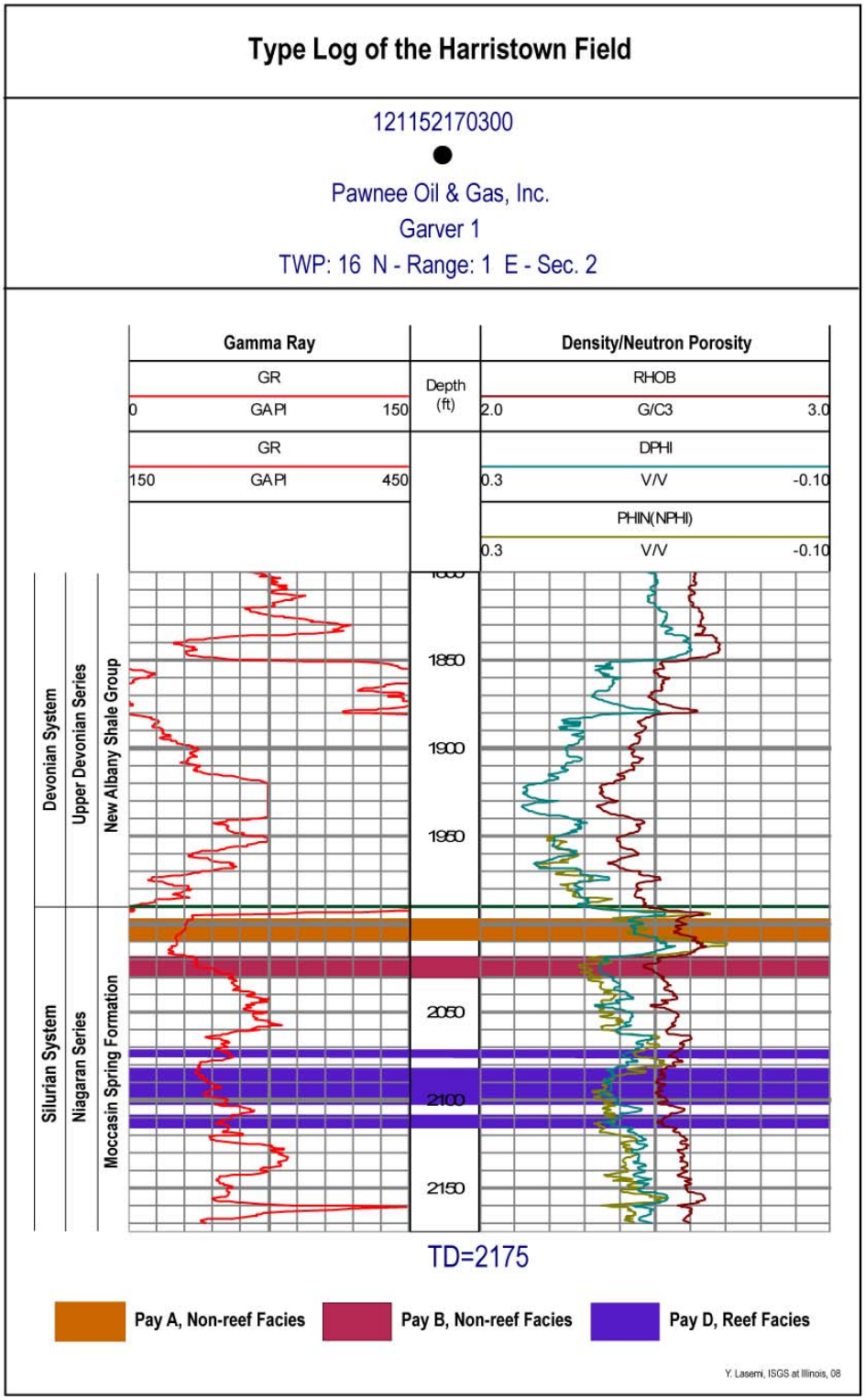

Figure 9. Type log (Gamma Ray, Density, and Density/Neutron porosity curves) of the Harristown Field in Macon County showing the development of non-reef reservoir units (Pays) A and B and a lower reef reservoir D.

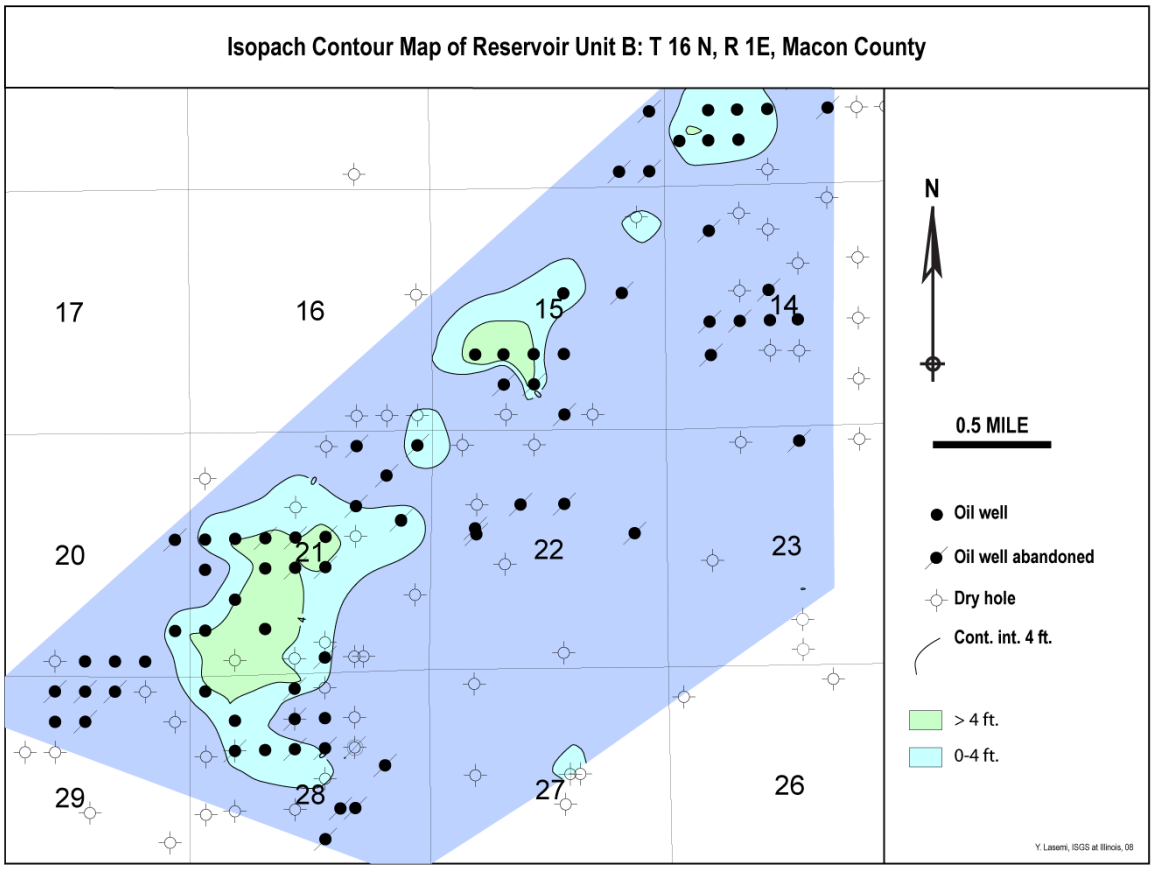

Figure 10. Thickness map of the reservoir unit B; similar to reservoir A, this reservoir is characterized by dolomitized lenticular permeability pinch outs along the Mt. Auburn Trend.

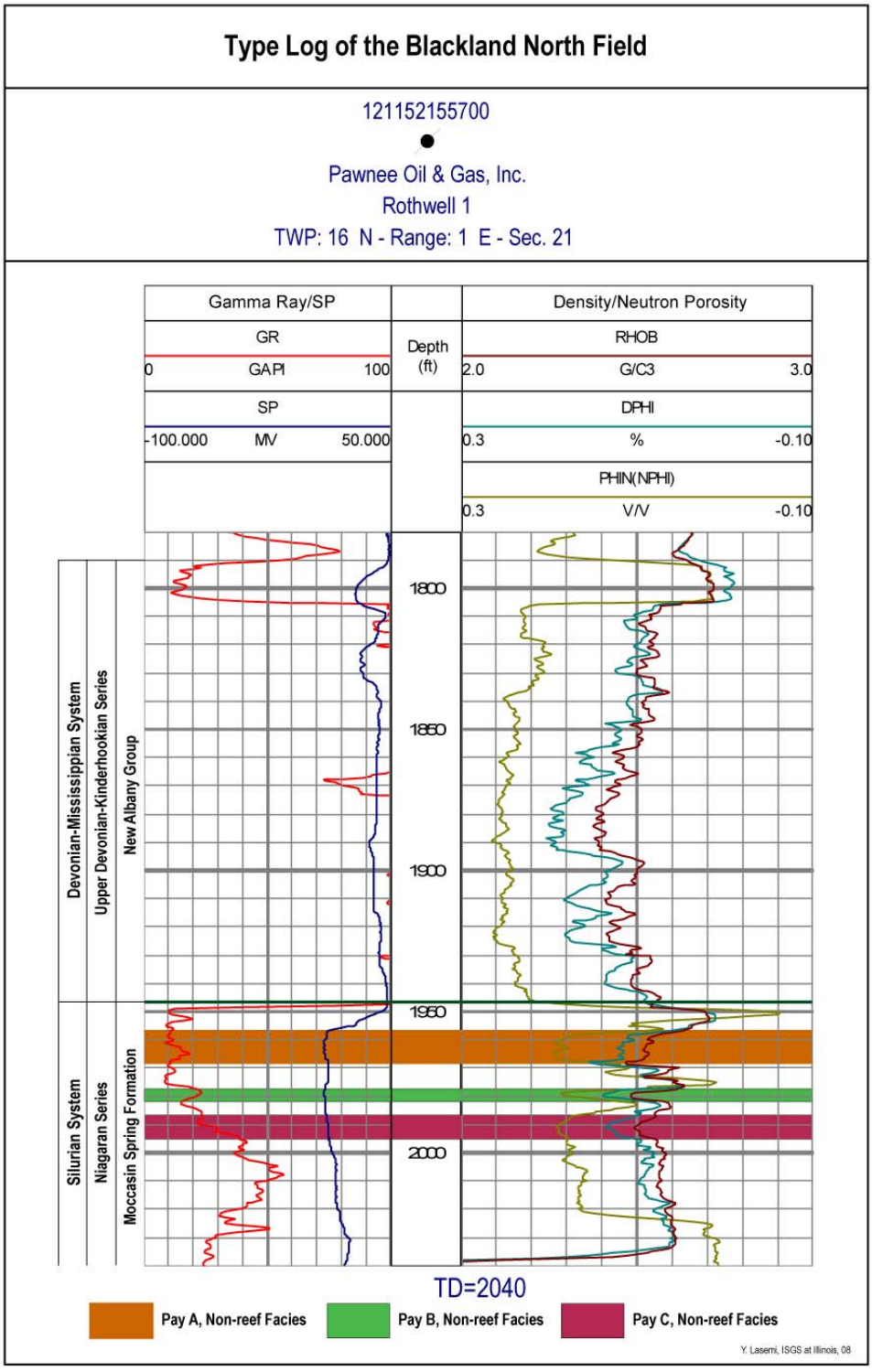

Figure 11. Type log (Gamma Ray, SP, Density, and Density/Neutron porosity curves) of the Blackland North Field in Macon County showing the development of non-reef reservoir units A, B and C.

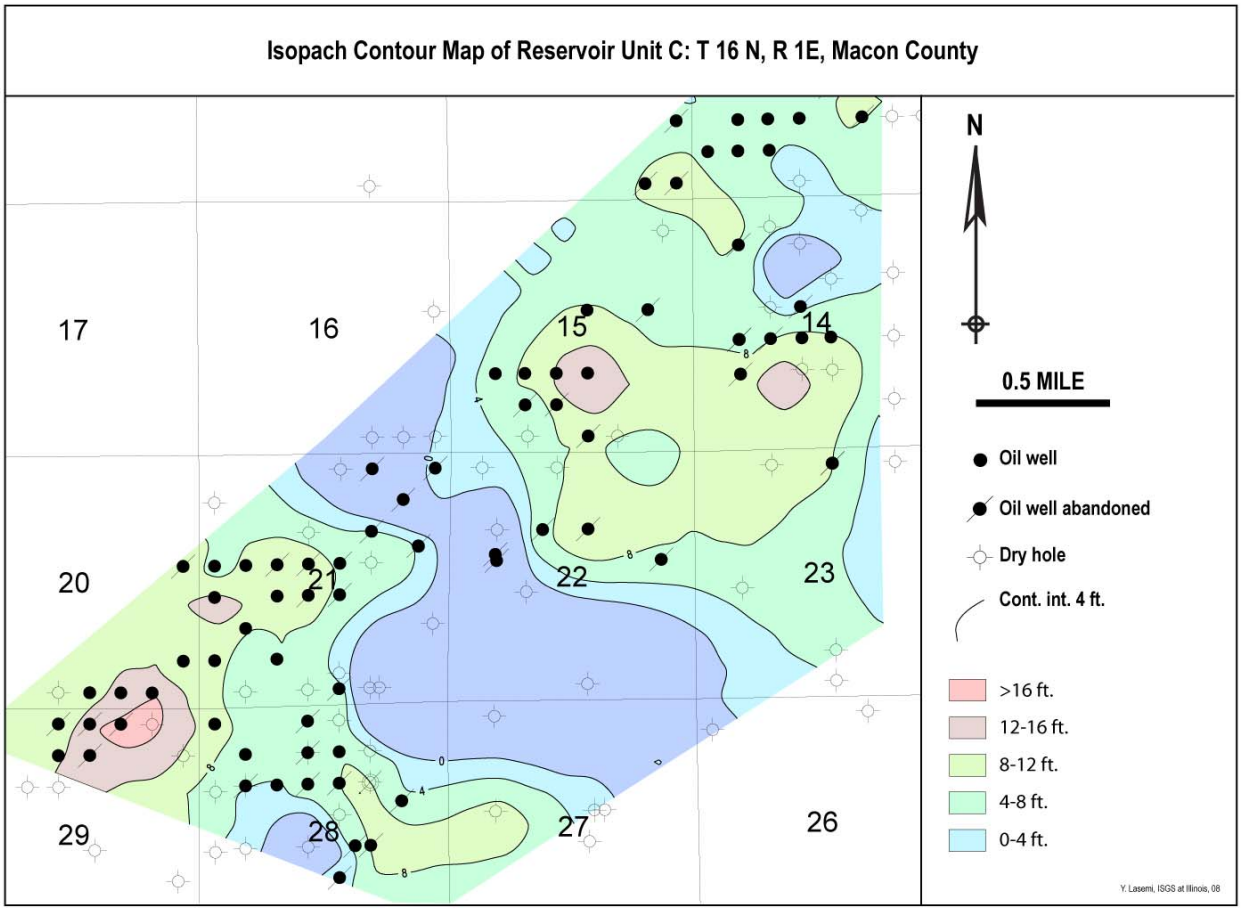

Figure12. Thickness map of the non-reef reservoir unit C; this lenticular reservoir is more persistent than the other reservoir units.

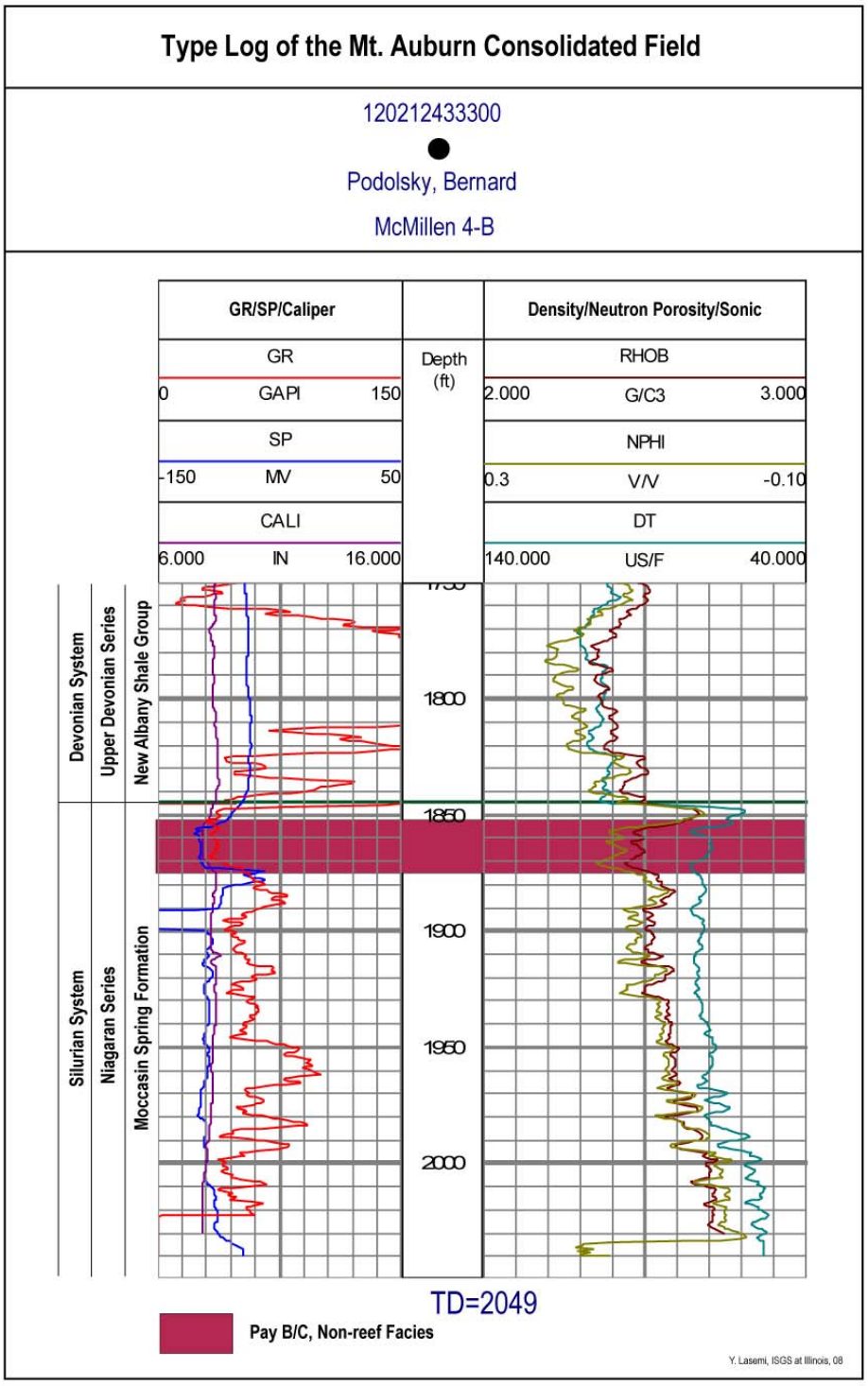

Figure 13. Type log (Gamma Ray, SP, Caliper, Density, Neutron porosity and Sonic curves) of the Mt. Auburn Consolidated Field in Christian County. Similar to other areas of the Mt. Auburn trend, reservoir unit B is absent or it is combined with C to make a single reservoir.

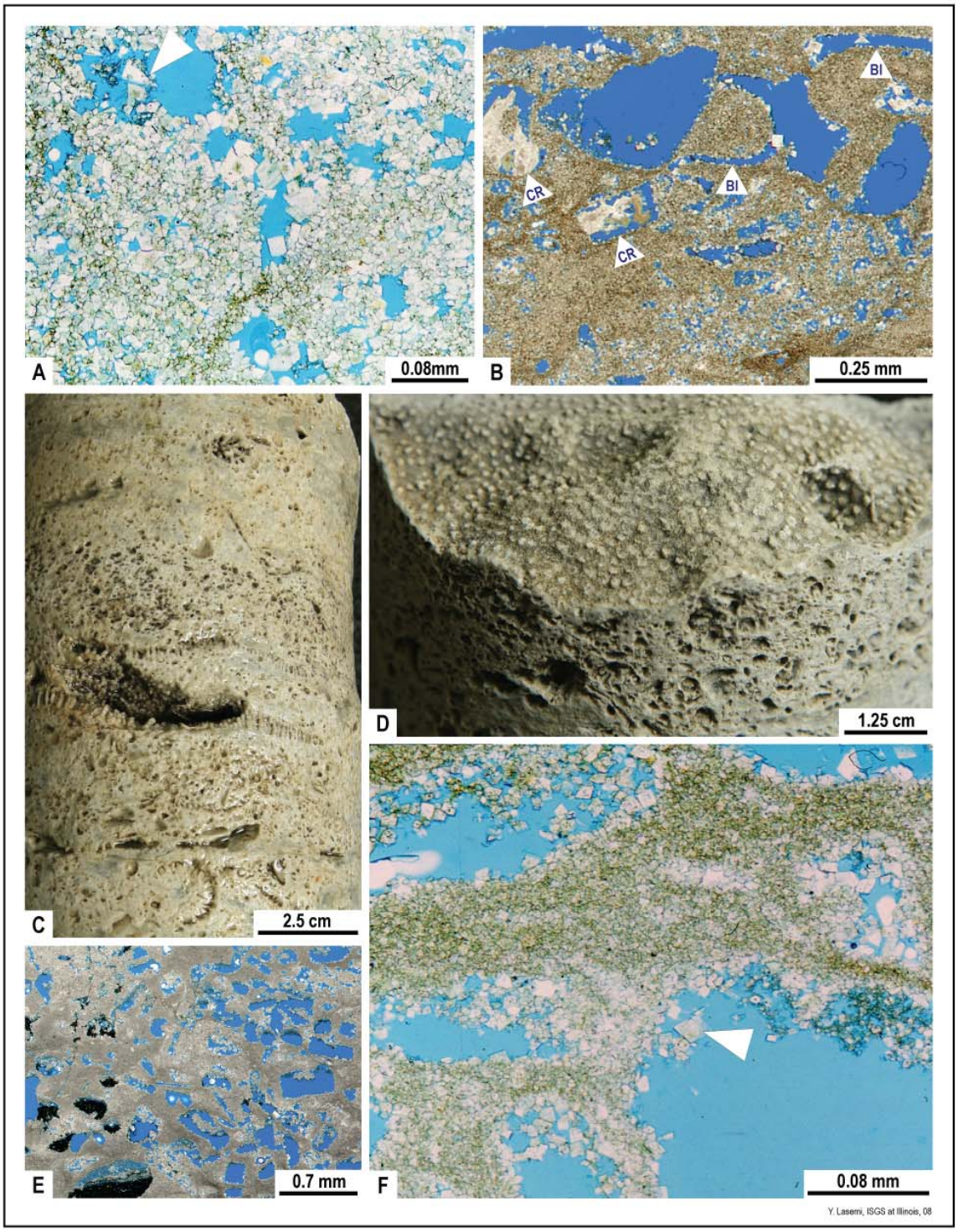

Figure 14. (A) Blue dye impregnated photomicrograph of a porous dolomitized non-reef reservoir in which the original texture has been destroyed by pervasive dolomitization. Note the dissolution of the dolomite rhombs and enlargement of the pore spaces (white arrow). (B) Scanned thin section photograph of a non-reef wackestone-packstone reservoir showing partially preserved crinoids (CR) and molds of bivalves (BI) and other unrecognizable grains in a finely crystalline dolomite groundmass. (C-D) Core photographs of a dolomitized reef facies composed mainly of coral skeletons. (E) Scanned photograph of a thin section of D showing vugular porosity as a result of dissolution of the skeletons that are hardly recognizable in thin diction. (F) Photomicrograph of an enlarged portion of E. Note the organic residue of the original skeletons and the dissolution of dolomite rhombs (white arrow) to form larger pore spaces.

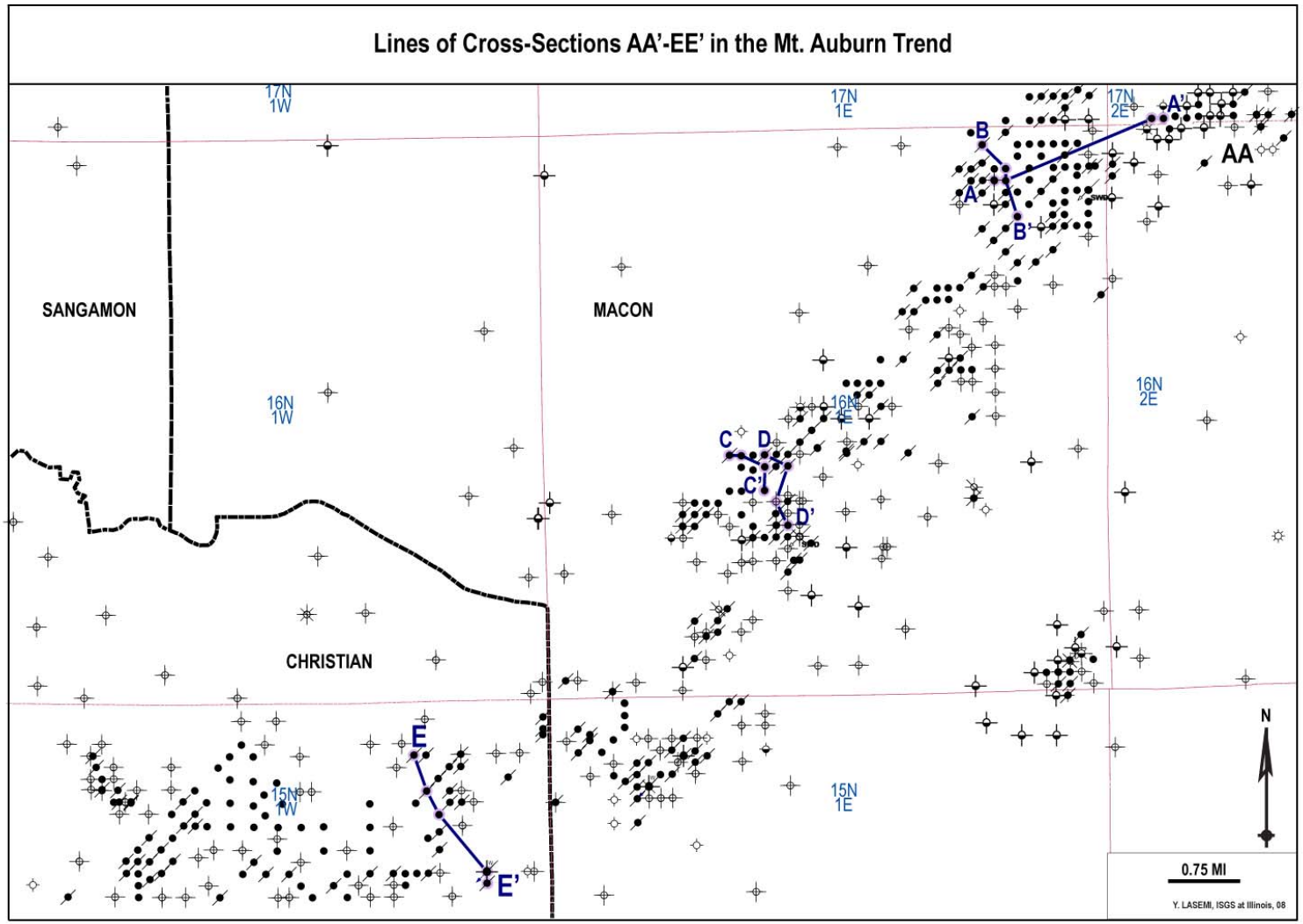

Figure 15. Map of a part of the Mt. Auburn Trend in Christian and Macon Counties showing the lines of cross-sections AA' to EE'.

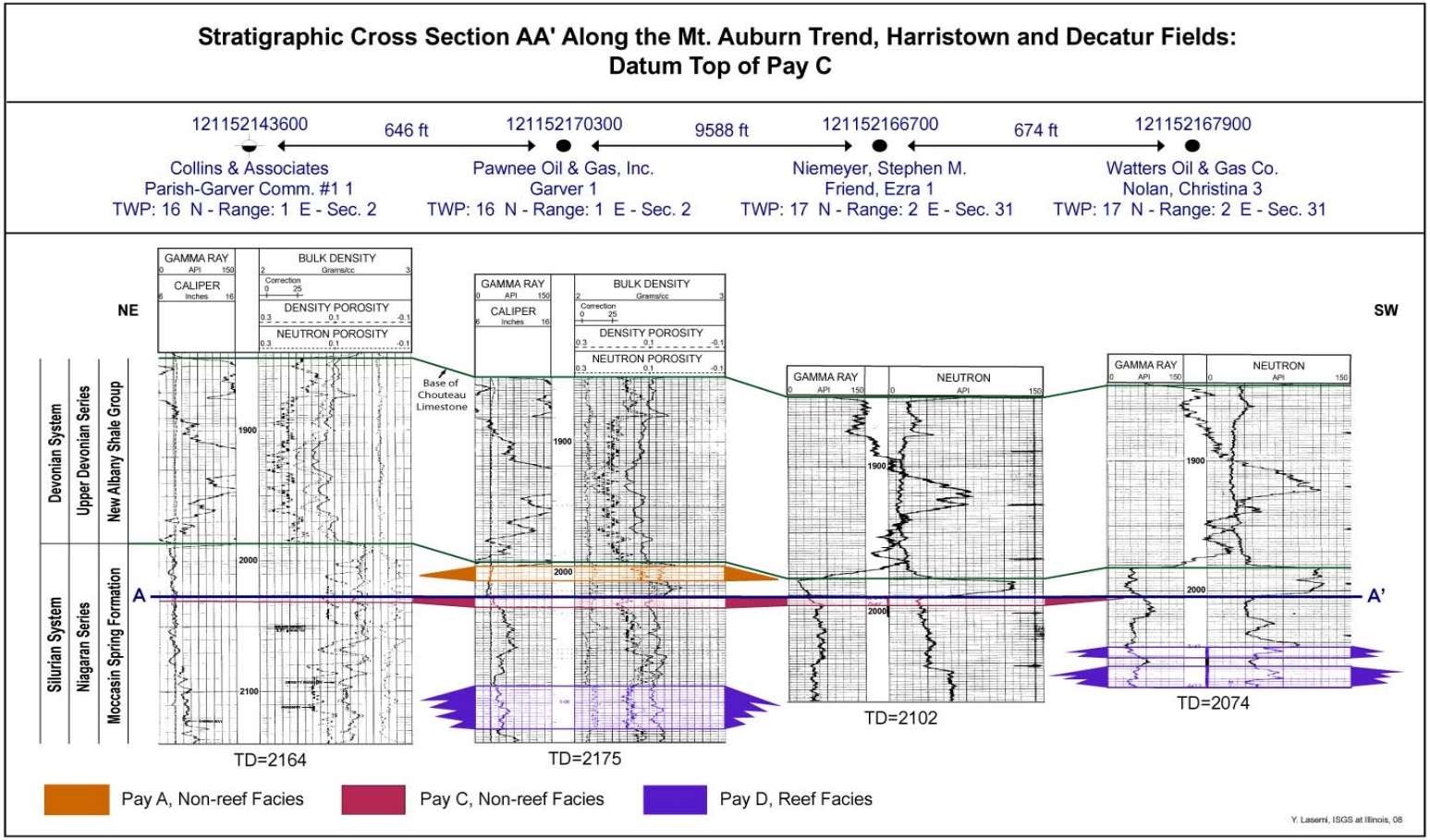

Figure 16. NE-SW cross-section AA' along the Mt. Auburn Trend showing the lenticular nature of the porosity pinch outs within the Silurian impermeable carbonates. Note the uneven topography of the Silurian surface in this cross-section and in figures 18-21 (for the line of cross-section see Fig. 15).

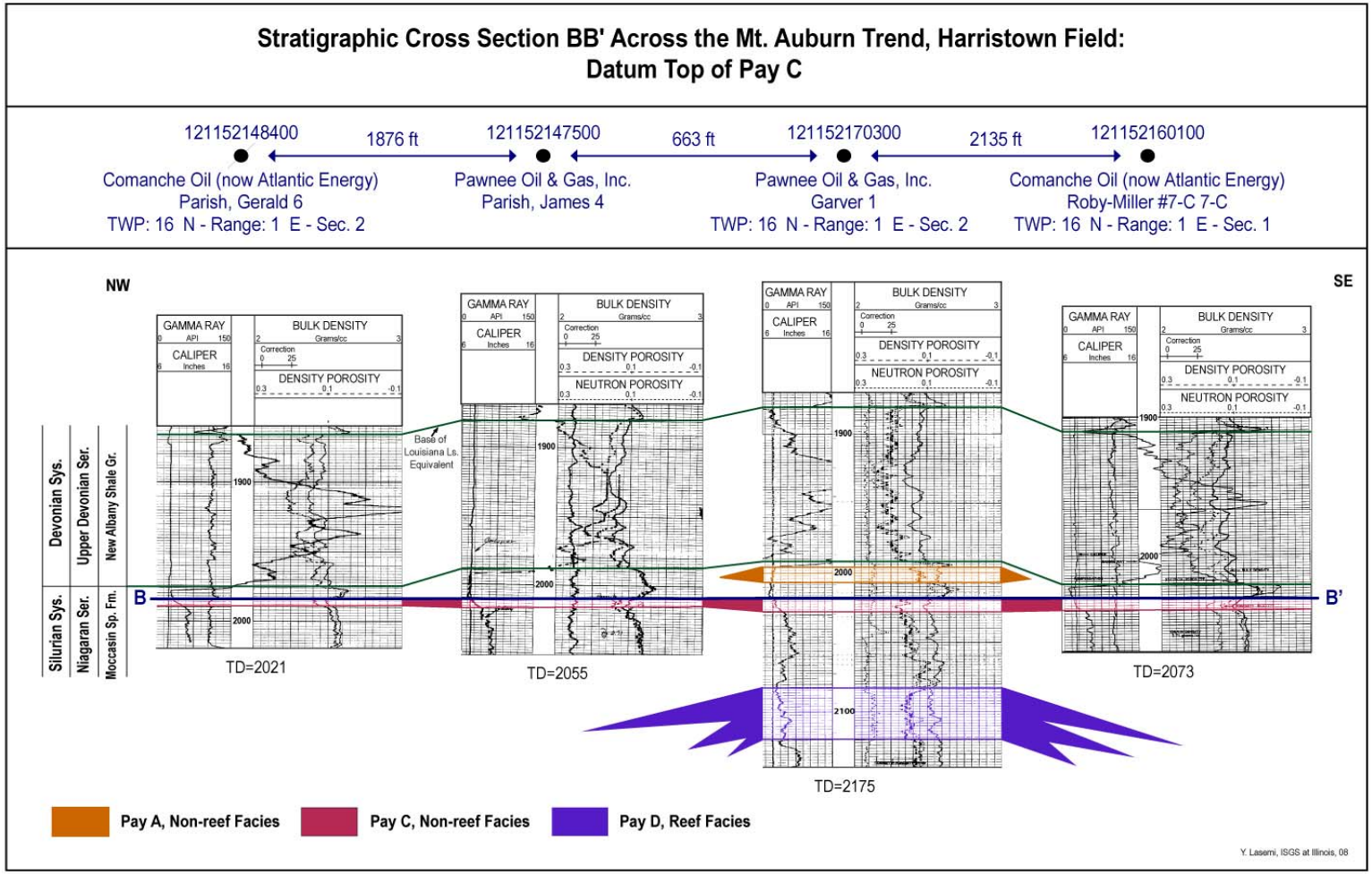

Figure 17. NW-SE cross-section BB' across the Mt. Auburn Trend. Note that reservoir C is more persistent than reservoirs A and D (for the line of cross-section see Fig. 15).

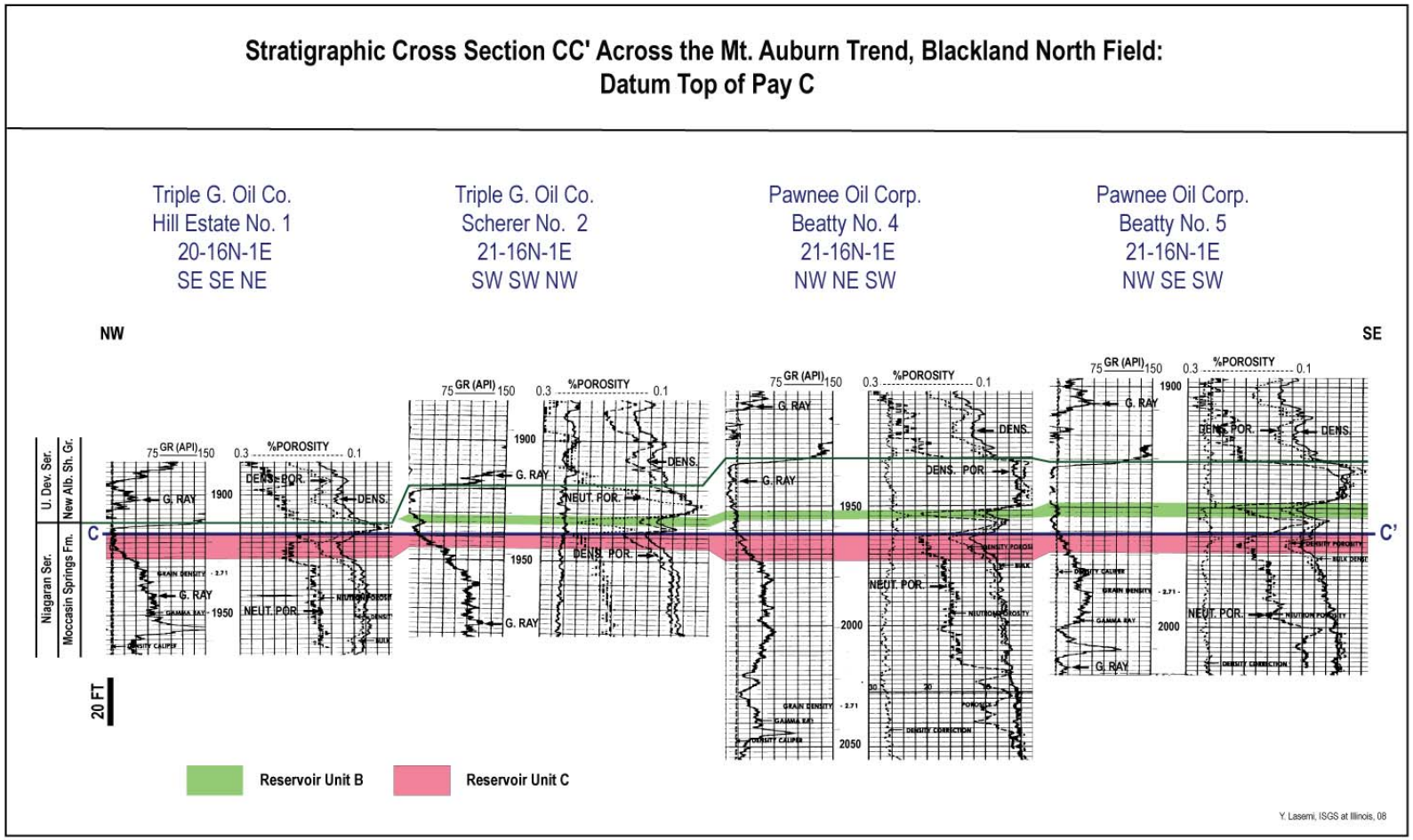

Figure 18. NW-SE cross-section CC' across the Mt. Auburn Trend showing the development of reservoir units B and C. Note that reservoir B pinches out in Hill Estate No. 1 as a result of pre-Devonian erosion (for the line of cross-section see Fig. 15).

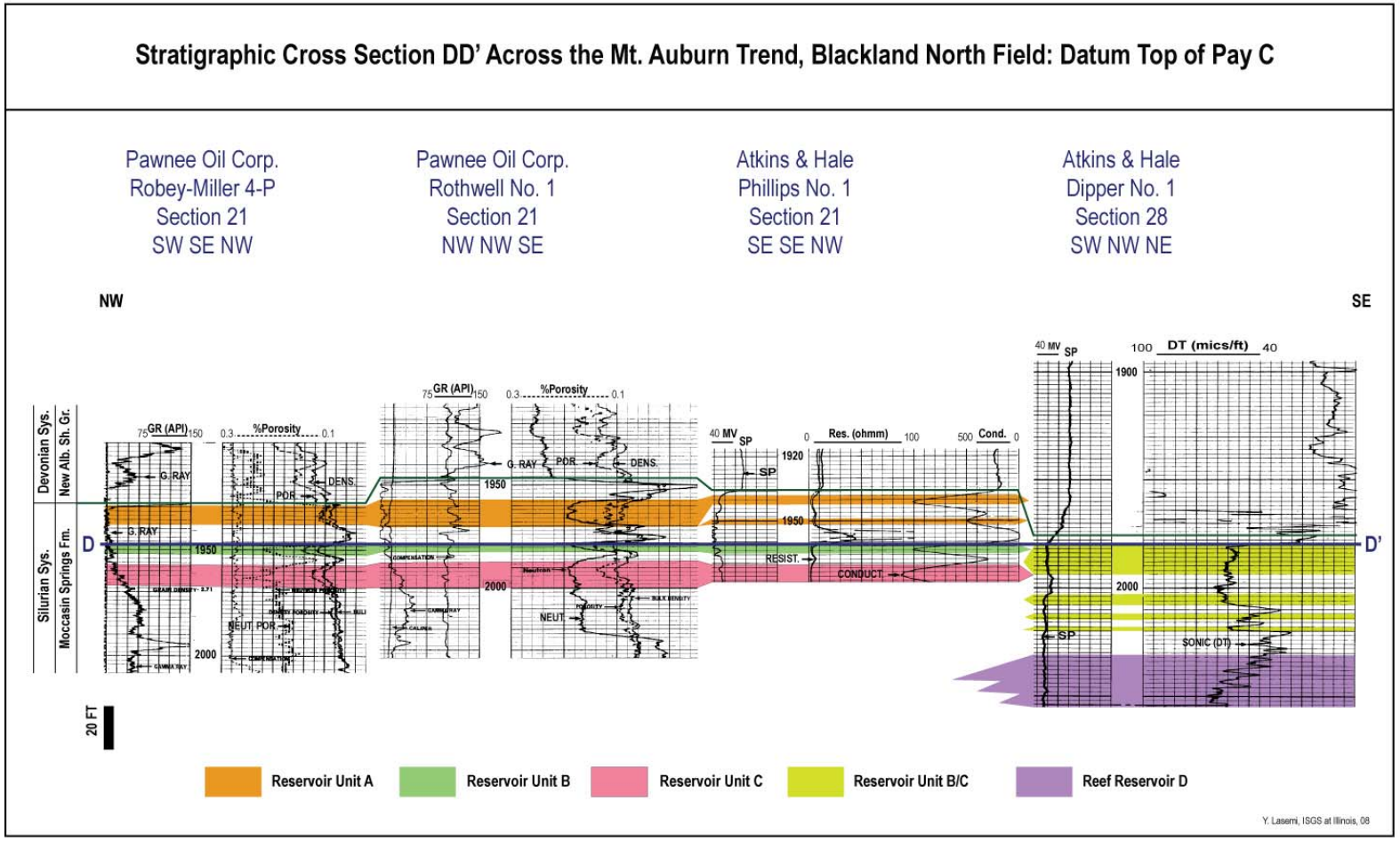

Figure 19. Cross-section DD' across the Mt. Auburn Trend showing the development of reservoir units A-C and reef reservoir D (Dipper No. 1). Note that other wells were not deep enough to test the reef reservoir. Note also that the absence of reservoir A in Dipper No. 1 could be the result of post Silurian erosion. In Dipper No. 1, the absence of the tight limestone between A and B has resulted in the formation of a single reservoir (for the line of cross-section see Fig. 15).

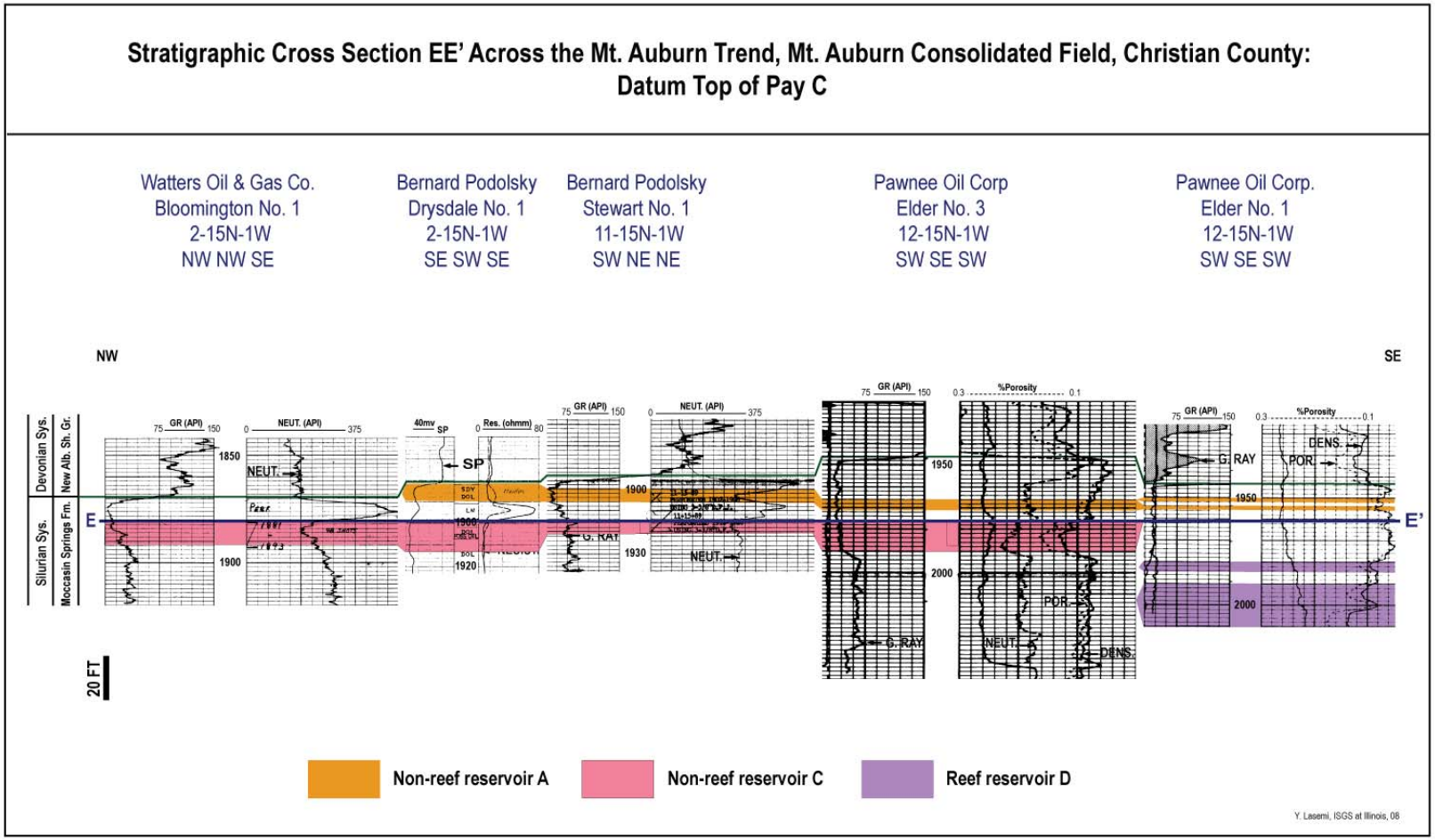

Figure 20. NW-SE cross-section EE' across the Mt. Auburn Trend in Christian county showing the occurrence of non-reef reservoirs A and C and reef reservoir D. Note that reservoir C is more persistent than reservoirs A and D, but it pinches out in Elder No. 1. The upper reservoir is missing in Bloomington East No. 1 towards the northwest, as the result of post Silurian erosion (for the line of cross-section see Fig. 15).

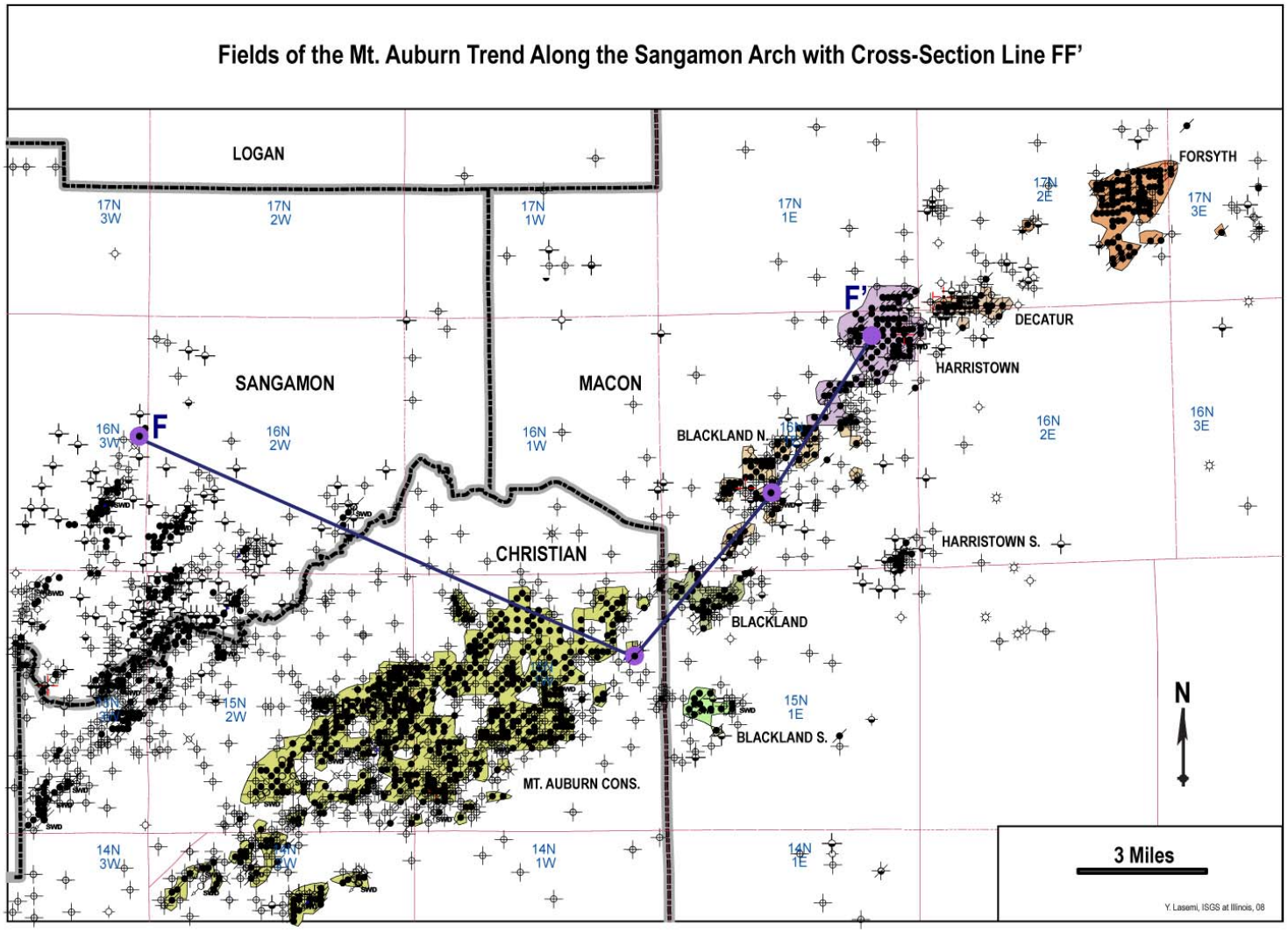

Figure 21. Line of cross-section FF' to correlate the reef reservoir in Sangamon, Macon and Christian Counties.

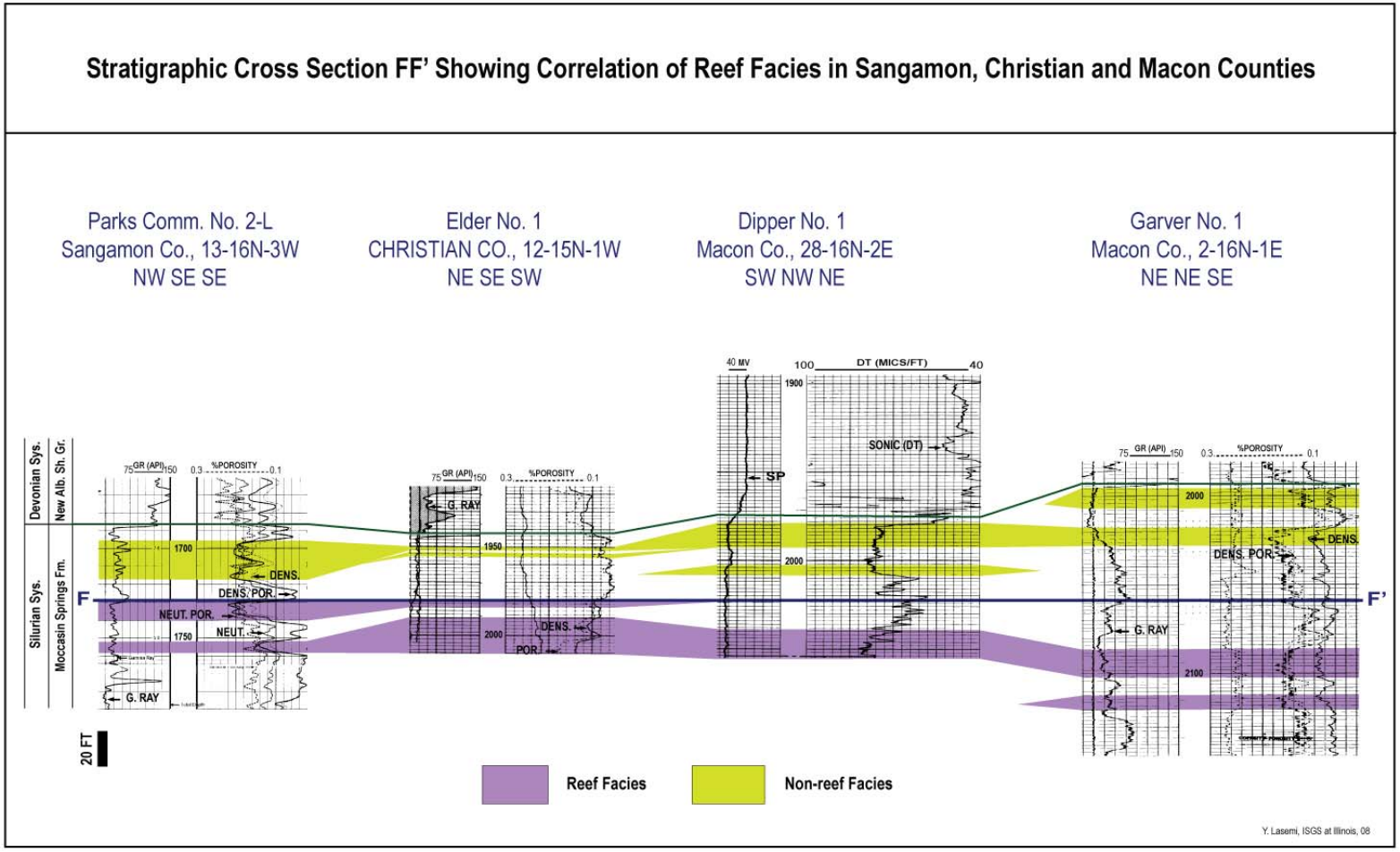

Figure 22. Cross-section FF' showing the correlation of reef and non-reef reservoirs in Macon, Christian and Sangamon Counties; note that the reef facies may occur in more than one interval in the lower part of the Niagaran Series (for the line of cross-section see Fig. 15).

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Centralia Field Study Devonian And Ordovician Reservoirs: **Jon Brenizer**

Geological setting:

Regionally the Centralia field is located directly west of the DuQuoin Monocline, in and around Centralia, IL (see Figure 1). This places the field on the western edge of the deepest part of the basin. The field is located on the Centralia anticline, which has experienced significant growth between the Ordovician and Late Paleozoic time.

History of development:

The Centralia Field was discovered in 1922, with the first producing well drilled into Pennsylvanian sands. The first well was drilled on the highest point on the anticline, in the southern end of the field. Deeper wells were drilled into a variety of Chesterian aged sandstones and the wells were eventually deepened into the Middle Devonian dolomitic sandstones. The first Devonian wells were deepening of shallower wells, and were first drilled on one of the highest areas of the Mississippian structures. The initial well was located off of the Trenton structure, and the initial production, while significant, was less than 10-20% of the initial production values at the northern end of the field. The field was a gas driven system, as indicated by both significant gas present in drill stem tests and personal accounts of gas flaring. Of the 330 completions of producing wells in the Devonian strata in Centralia, 324 of them were completed between December 1939 and August of 1940 (figure 2). These two factors served to shorten the length of production from the Devonian strata, causing the period of primary production to be less than 6 months in most cases, and less than 2 years in all cases. Production dropped an average of 85-90% from the first month to the second month, and a similar amount in the second month (figure 3). By the end of the first year, production is less than 1-5% of the initial production.

Trenton production was discovered in August 1940, but was largely ignored in the drive to drill Devonian wells. The discovery produced 100 barrels per day, but the decline was much more gradual than the Devonian wells and primary production lasted 7 years, and produced almost 100,000 barrels of oil. In the late 1940's many of the Devonian wells were deepened to the Trenton, and production ranged from 0-300 bpd. The northern end of the field was again the highest producing area, with values around 200-300 barrels per day. These wells were less productive overall, with primary production averaging 40-50,000 barrels over the life of the well. Several wells were notable however, in that they lasted up to 14 years in primary production and produced more than 100,000 barrels. The wells responded well to water flooding, and production was increased from several hundred barrels per year to several thousand per year for periods ranging from 2 years to 6 years (figure 4). Several of the wells that were drilled to the Trenton were perforated in the Devonian and Mississippian strata, which also served to increase the life and productiveness of the wells.

Stratigraphy:

A typical electric log is shown in Figure 5. This well was chosen for it's location near the crest of the Trenton anticline and the availability of continuous core in the Trenton, and good samples from the remainder. The Chouteau limestone is the last unit that is completely Mississippian in this area, as the lower most members of the New Albany Shale are thought to be Devonian in age. The New Albany Shale is the source rock for all of the oil in the Devonian and higher strata. The New Albany Shale unconformably overlies the Lingle Limestone, which is the upper most formation in the Hunton Megagroup. The Devonian reservoir unit is found at the base of the Grand Tower formation, which is marked by the sharp drop in SP and the reservoir unit is bounded by two inflections in the short normal resistivity. There is possibly a small section of Cayugan aged strata at the top of the Silurian section, but this analysis is based on logs alone, as there are no reliable samples from this section. The Niagaran aged section thickens up to 30 feet to the south of the Trenton structure, causing the structure to be extended stratigraphically throughout the deposition of the Hunton Megagroup. The Maquoketa shale also shows slight thickening, off of the Trenton structure, but the overall regional basinward thickening is much more significant, indicating that the thickening may be due to differential compaction rather than any depositional cause. The Trenton limestone is made up primarily of fossiliferous grainstone. There several porous zones that have been separated by mostly impermeable strata that were completely cemented. These porous zones also provided conduits for later hydrothermal alteration, which further increased the permeability within the original open zones.

Structural changes on the Centralia Anticline:

The structure of the Centralia Anticline is shown in detail in Figures 6 through 12. These seven figures are based on a similar data set, although there are significantly more completions in the Devonian than in the Trenton. Even with the lower data density, the Trenton structure is still well defined, but any structural features in the southern end of the field are poorly defined (Figure 13). Formations above the Middle Devonian have significantly better well control throughout the field and surrounding area (Figure 14).

The structure has evolved from a small dome-like structure during the Middle and late Ordovician time to a more elongated anticline in the Mississippian time. On the structural maps that have been modeled, it is difficult to see the thickening in individual formations due to poor sampling in the data. However, mapping thicker units such as the Hunton Megagroup shows the thickening quite clearly (Figure 15). The thickness of the upper Devonian through the Valmyrean series also has distinct thinning, although the relationship to the Devonian structure is less clear than the thickening in the Hunton Megagroup (figures 16 and 17). Two projected cross sections have been drawn, as shown in Figure 18. Thinning in individual formations is visible in the axial cross-section (Figure 19 and 20). The St. Clair formation is fairly uniform throughout the section, but the Moccasin Springs formation clearly thins across the top of the Trenton structure and extends the structure to the south (Figures 19 and 20). The Lower Devonian strata show a similar pattern, extending the structure further to the south than in the Silurian time (Figure 20). The cross axial cross sections show slight widening of the anticline, but the change is less than 5% (Figures 21 & 22). The differential deposition

continues on into the Lower Mississippian sequence, being evident in the section from the base of the New Albany to the top of the St. Genevieve formation (Figure 21 and 22). This has the effect of elongating the structure increasing the size of the closure from 2250 acres, to 3500 acres in the Devonian, to 4000 acres in the Mississippian. The main extension has occurred southward (over 2 miles additional length), with the northern end of the field remaining relatively unchanged from the Ordovician to the Mississippian time. The overall closure on the structure has decreased from 90 feet to 50 feet and the structure has broadened from 2 to 2.25 miles.

There has also been a lateral shift in the fold axis due to the inclined axial plane. The shift is clearly visible in figures 23, 24, and 25, which are separated by comparable amounts of section (roughly 1200 feet between each interval). The high points on the structure also show a distinct linear relationship, although it is difficult to determine if this pattern holds for all layers. It is also possible that this pattern is simply coincidence at this location, and not diagnostic for other Trenton structures, although if it were diagnostic, this would prove a valuable assessment tool.

Reservoir Characterization:

The Trenton pay zone is a small anticline that formed over a deeper seated fault. The total thickness of the Trenton is undetermined, but three main oil saturated zones are present in the upper 50 feet (Figure 23). The sections have been described in more detail by Crews (1985), but are generally fossiliferous grainstones (Figure 26), with secondary enhancement in layers that had an initial porosity greater than 5% (Figure 27). Impermeable layers have original porosities of 0-2%, with no solution enhancement of the porosity (Figure 28). The permeable layers are easily distinguishable in on geophysical logs, appearing as areas of slightly lower resistance than the surrounding units.

The Devonian pay was originally deposited as an interbedded sand and limestone ranging between 6-12 feet. The sandstone beds range from several inches thick to several feet thick, although there is often a significant amount of limestone present within the sandstone layers. The dolomite formed later at as a hydrothermal product, replacing 99-100% limestone present. The field is located near the Geneva Dolomite and the Dutch Creek Sandstone lateral contact.

The porosity observed in Devonian samples is up to 20% (Figures 29 and 30), in both the sandstone and the dolomite. The highest areas of the pay are almost water free, with higher water cuts down dip from the crest. The pay is elongated from the pay in the Trenton due to thickening of the Silurian section, but is most productive above the Trenton structure. Figures 31 and 32 both show a map of the Devonian initial production, and it is clear that while overall production mimics the Devonian structure, the highest production does not occur over the peak of the Devonian structure. The Trenton structure corresponds well with the highest values, indicating that there is some relationship between the paleostructure and production from higher units.

Conclusions:

The Centralia field is an excellent example of the potential of the Lower Paleozoic strata for oil production. The change in the structure from the Trenton to the Mississippian strata indicates one of the risks of drilling based on shallower structures. However, by mapping unit thicknesses and fold axis positions, it is possible to constrain the position of paleostructures. Further exploration into Devonian aged dolomites and sands along the DuQuoin Monocline could also be worthwhile due to the high porosities within these units.

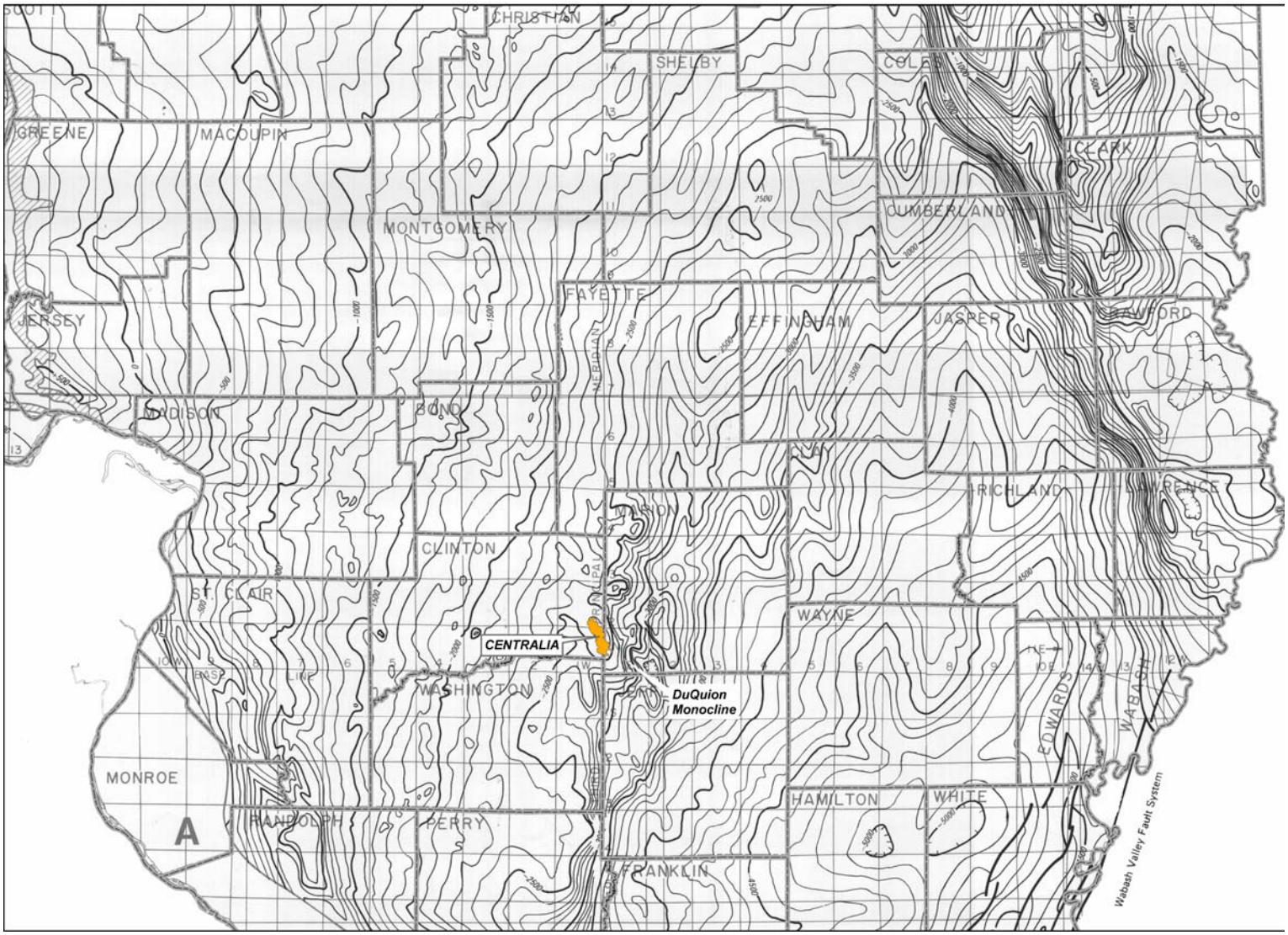

Figure 1. Structure contour map of the base of the New Albany Shale Group. Contour interval is 100 feet.

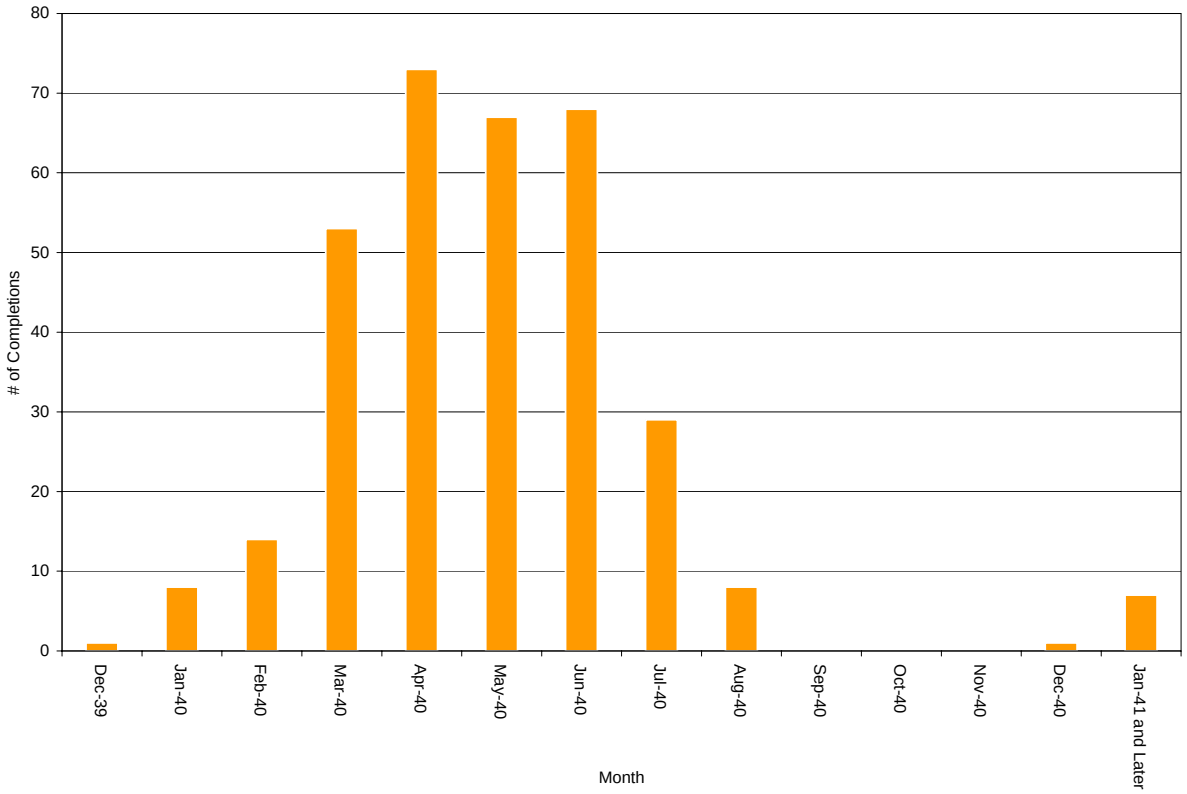

Figure 2. Chart showing the time of well completion within Devonian strata.

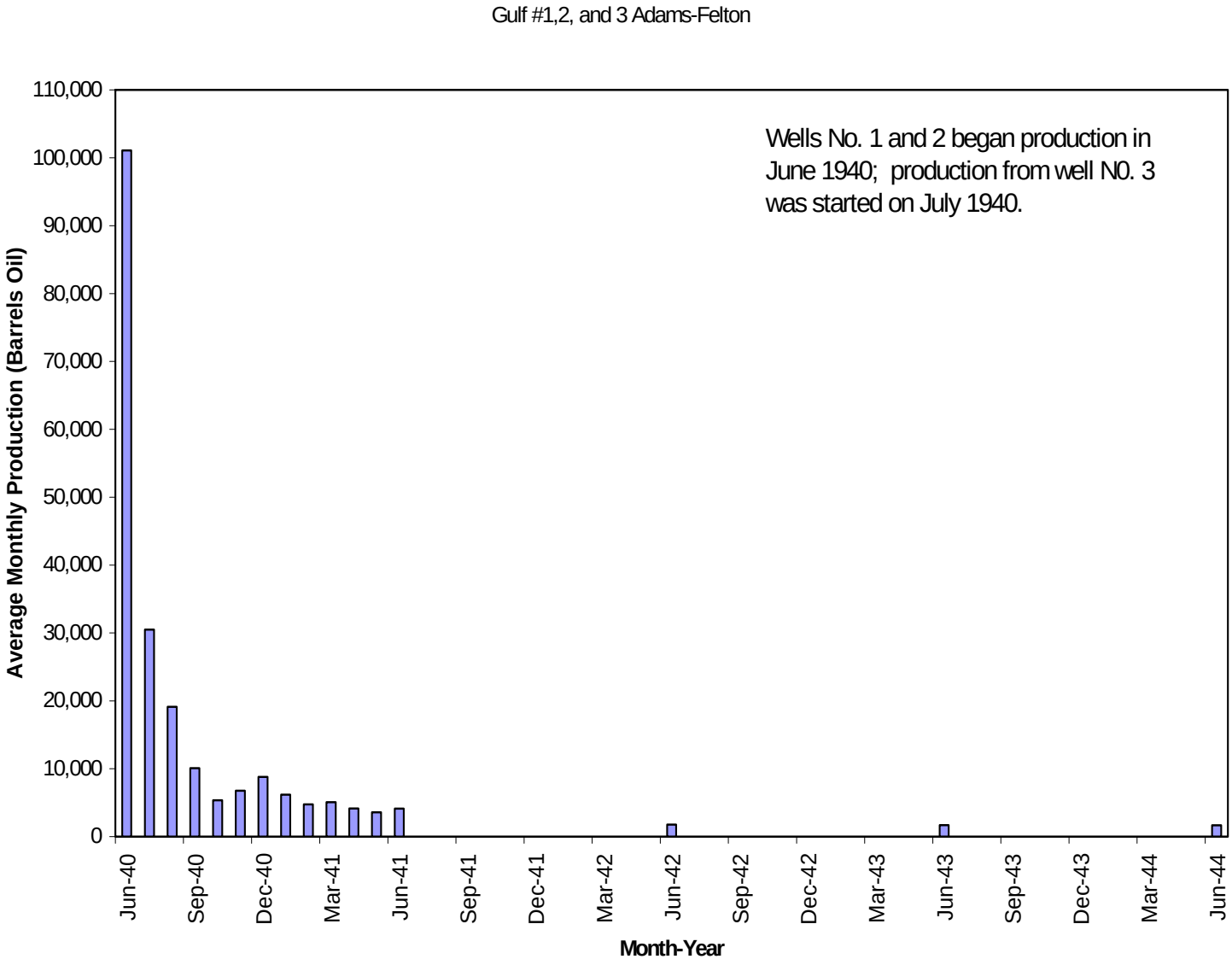

Figure 3. Chart showing a typical decline curve of Devonian wells. During the second month, even with the addition of a second well, production is less than 30% of the previous month, note that after the first year, monthly production is about 1% of the first month production.

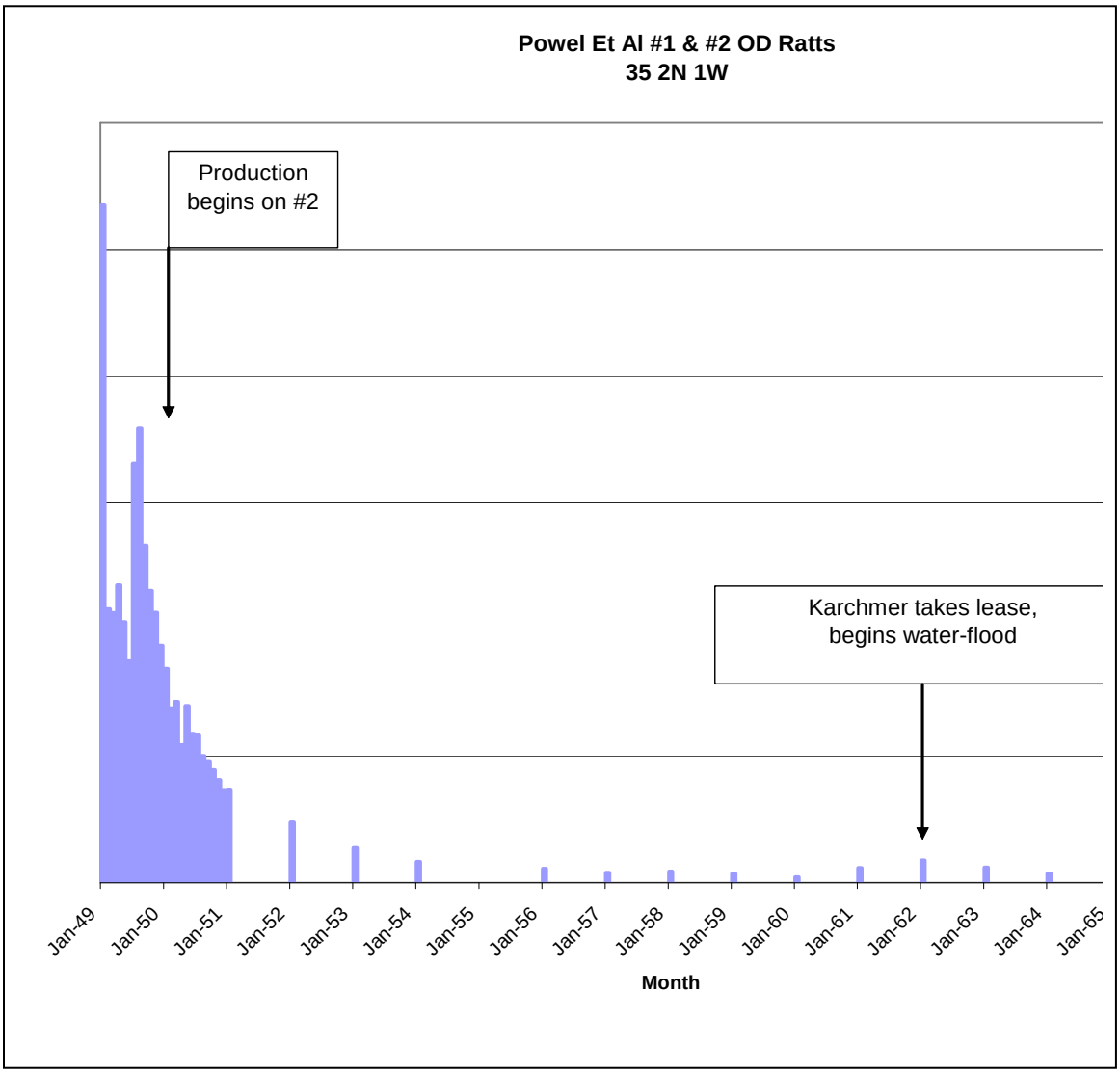

Figure 4. Chart showing a typical decline curve of a Trenton well in Centralia. Cumulative production for this lease was 74,000 barrels before a shallower zone was opened for production in 1968.

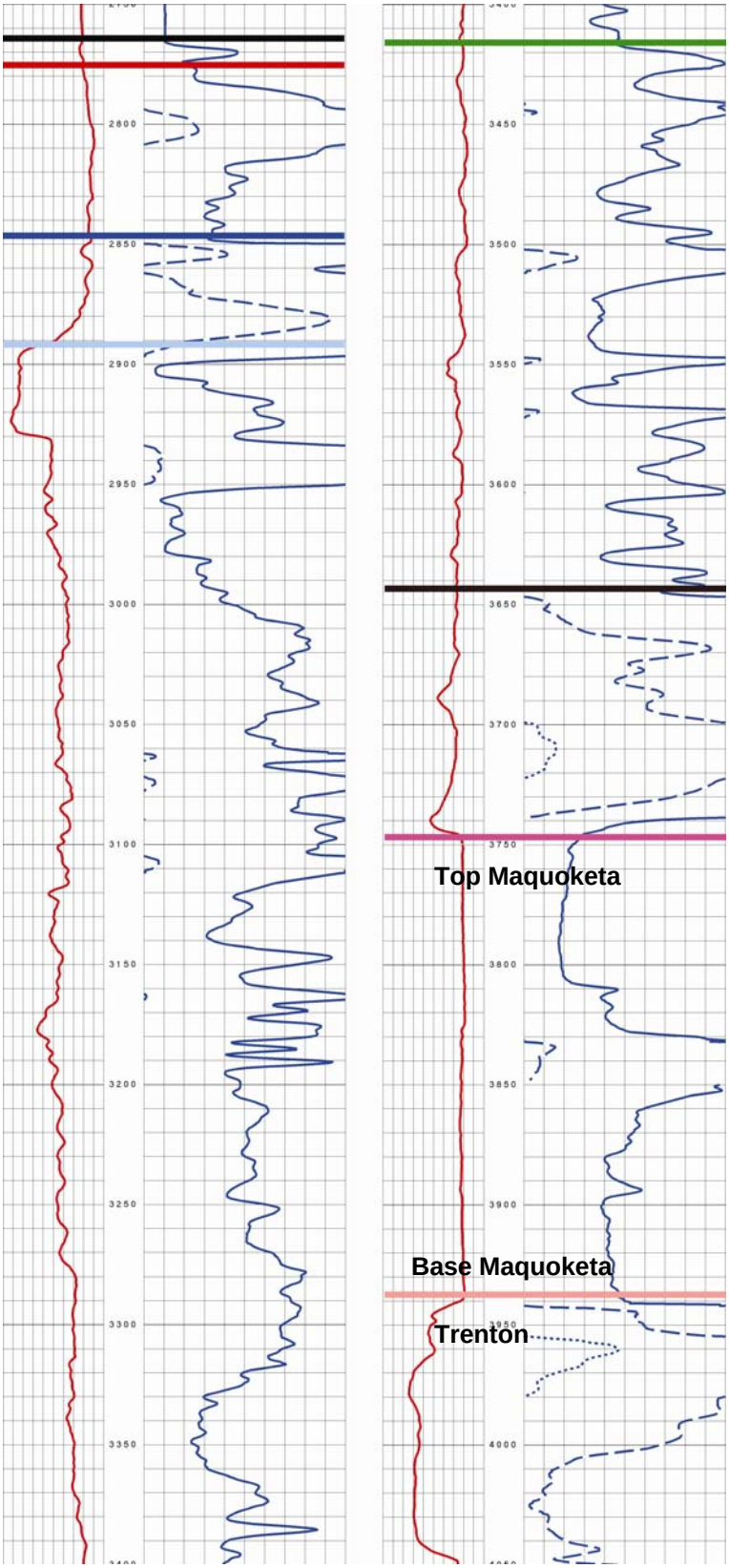

Figure 5. Electric log from the Shell #37-T Criley well. Log has been cut just below the top of the Silurian Section, and continued in the second column.

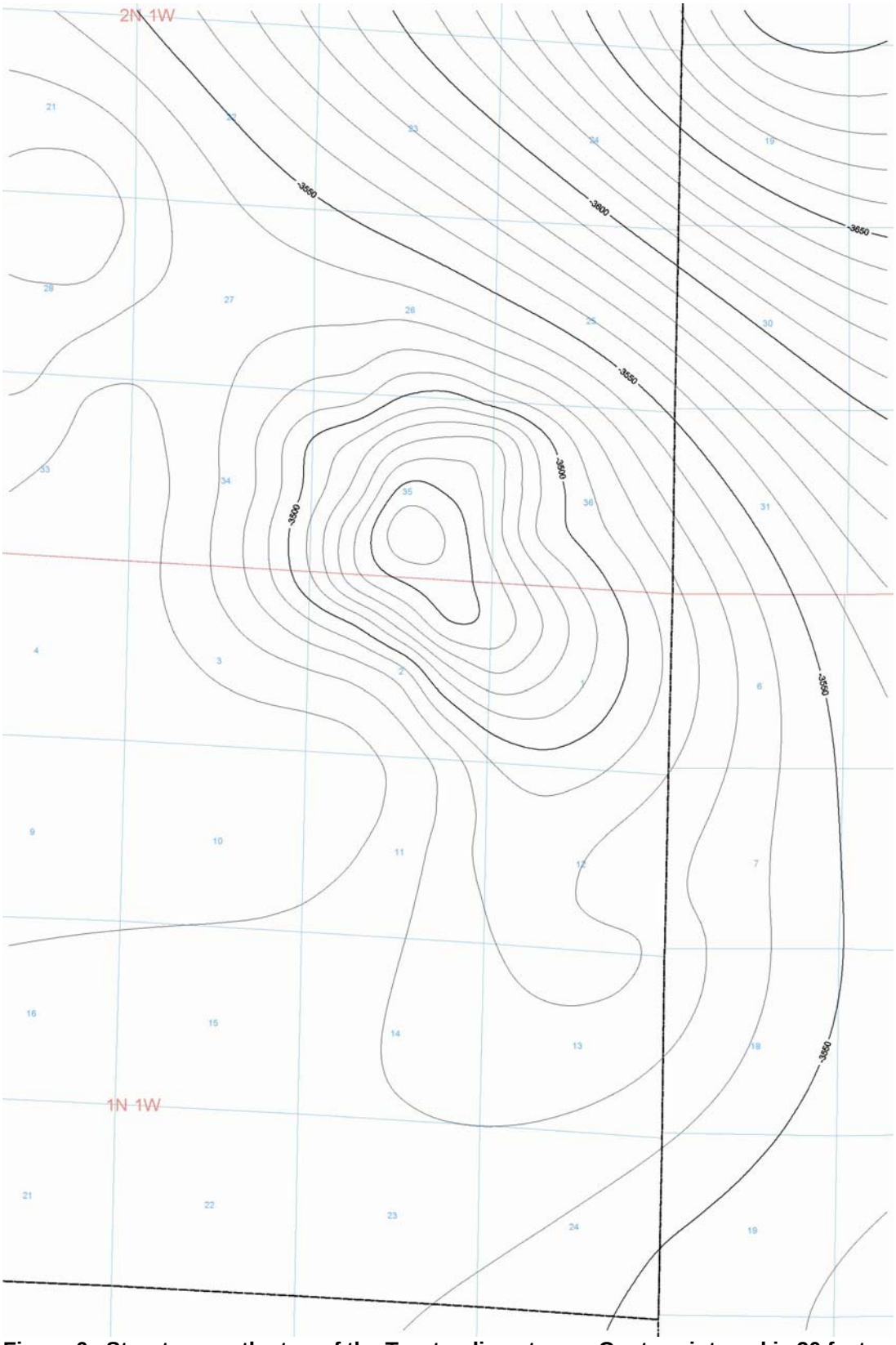

Figure 6. Structure on the top of the Trenton limestone. Contour interval is 20 feet.

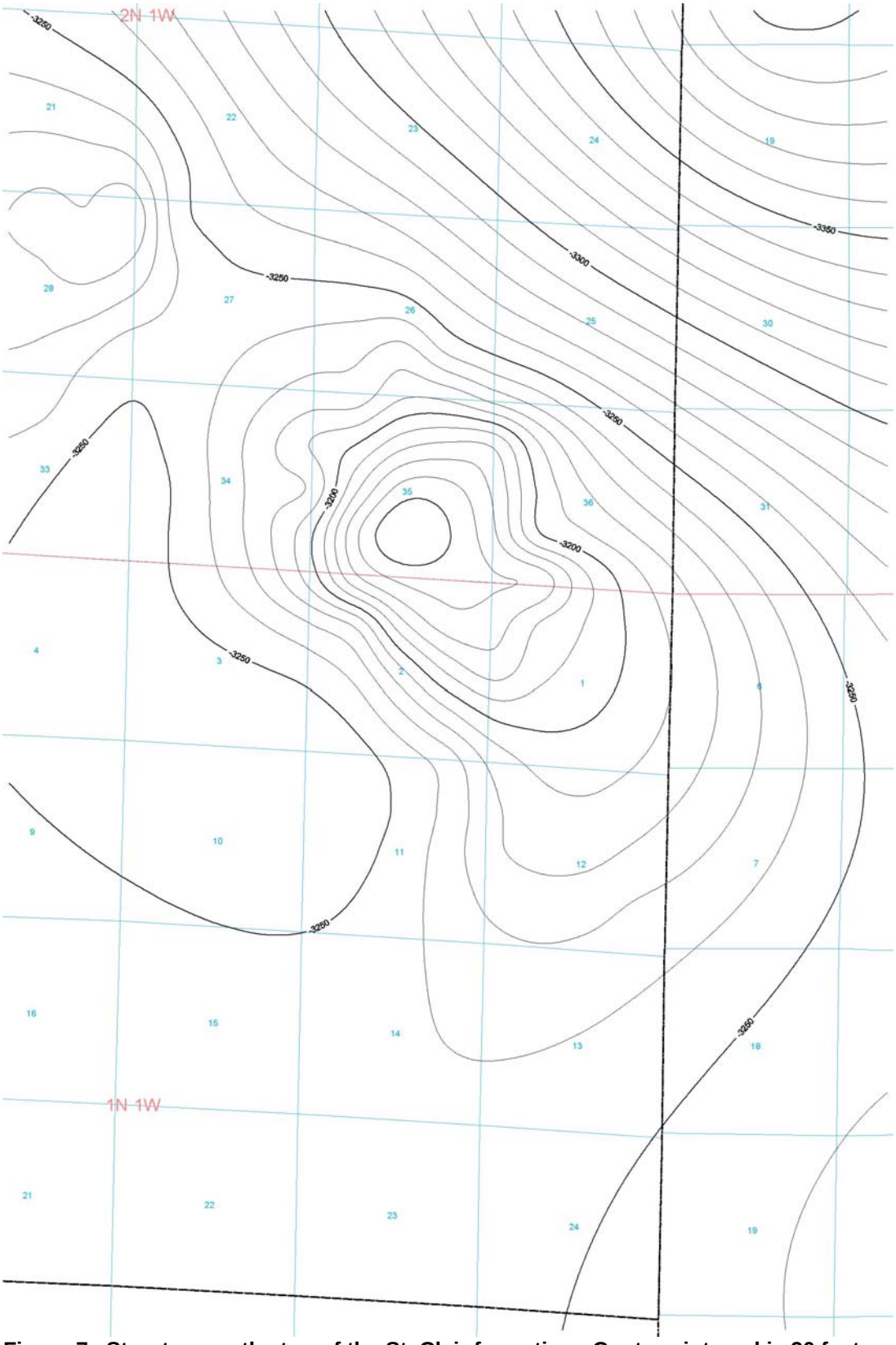

Figure 7. Structure on the top of the St. Clair formation. Contour interval is 20 feet.

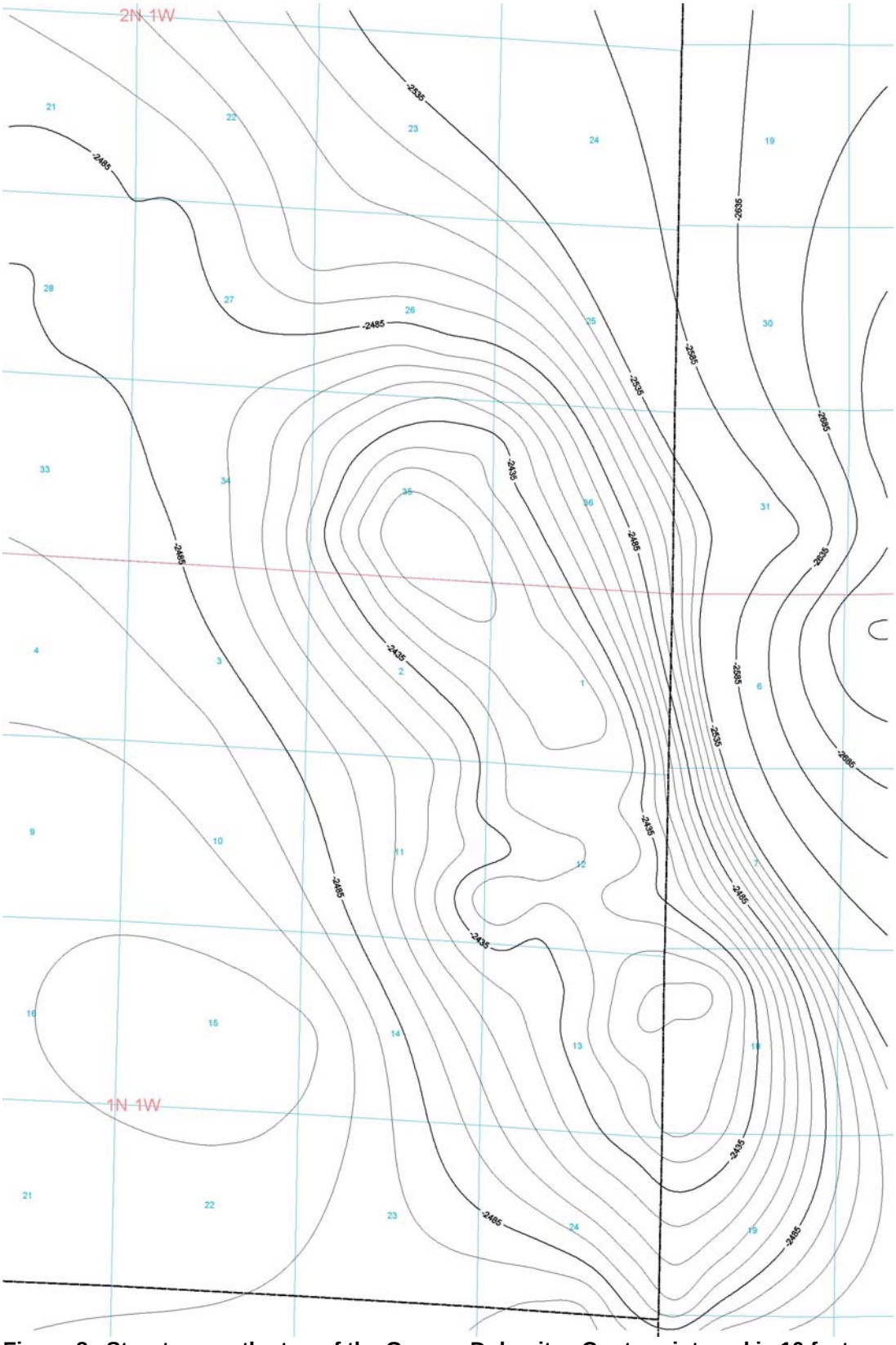

Figure 8. Structure on the top of the Geneva Dolomite. Contour interval is 10 feet.

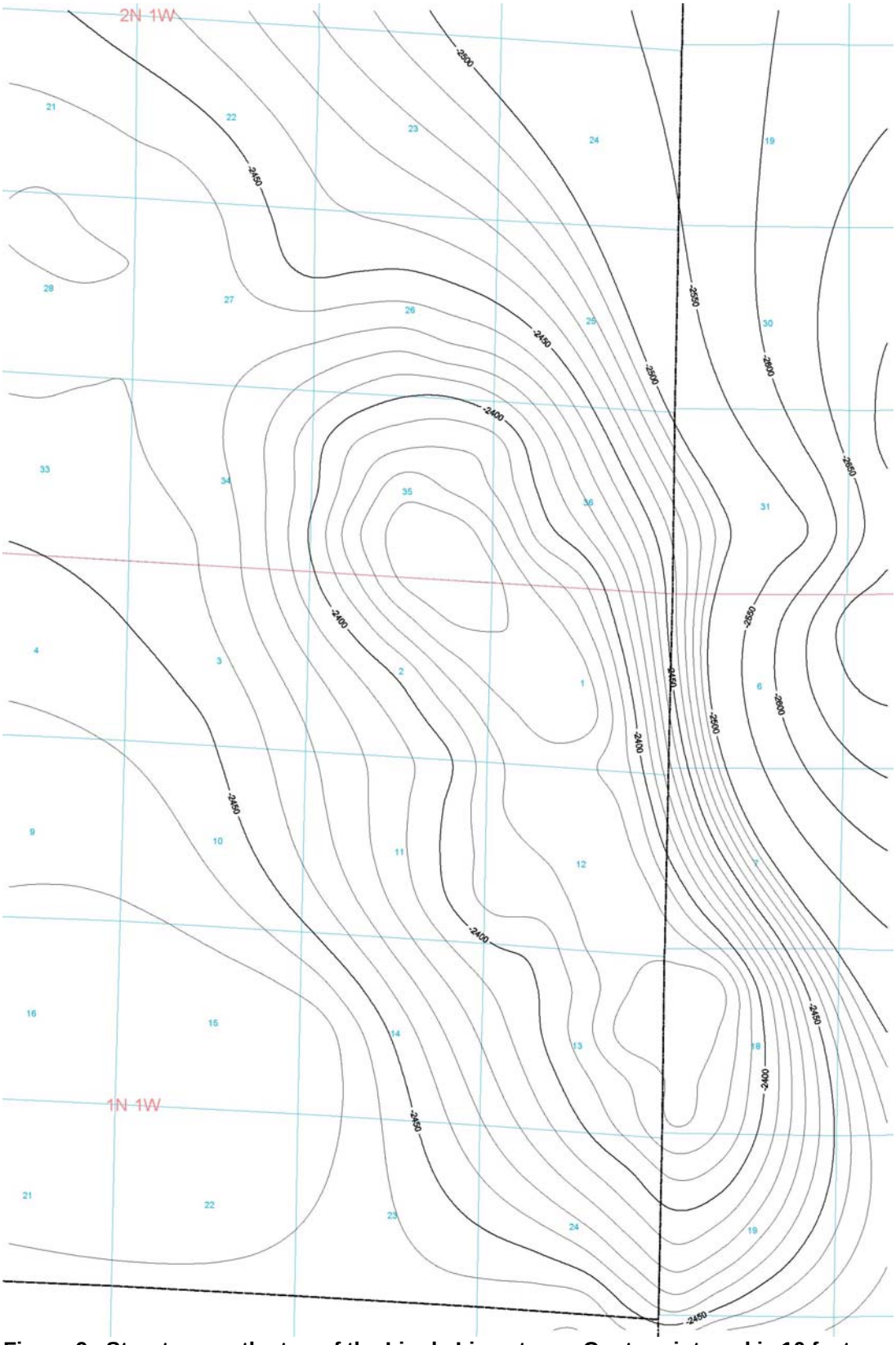

Figure 9. Structure on the top of the Lingle Limestone. Contour interval is 10 feet

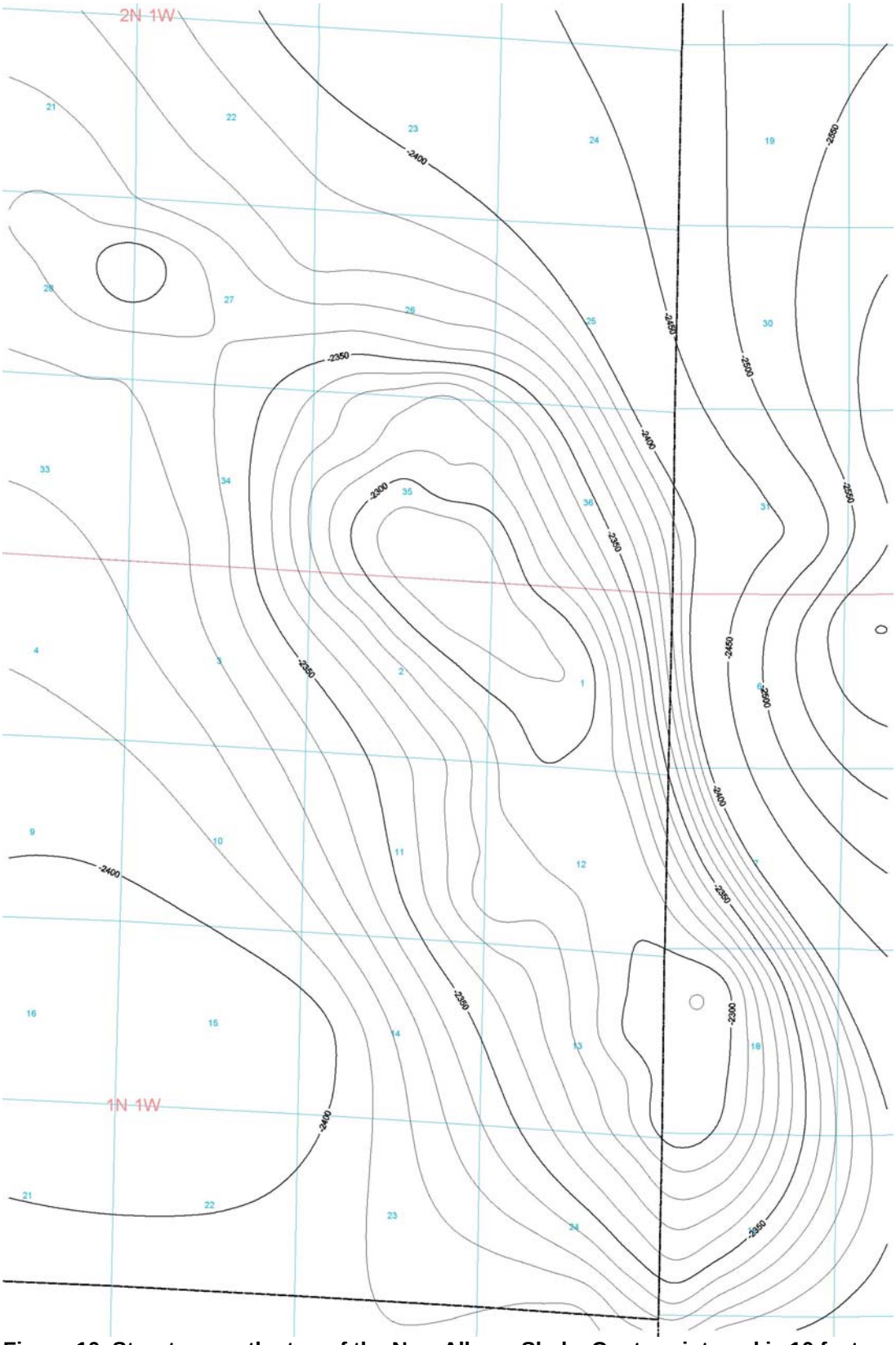

Figure 10. Structure on the top of the New Albany Shale. Contour interval is 10 feet.

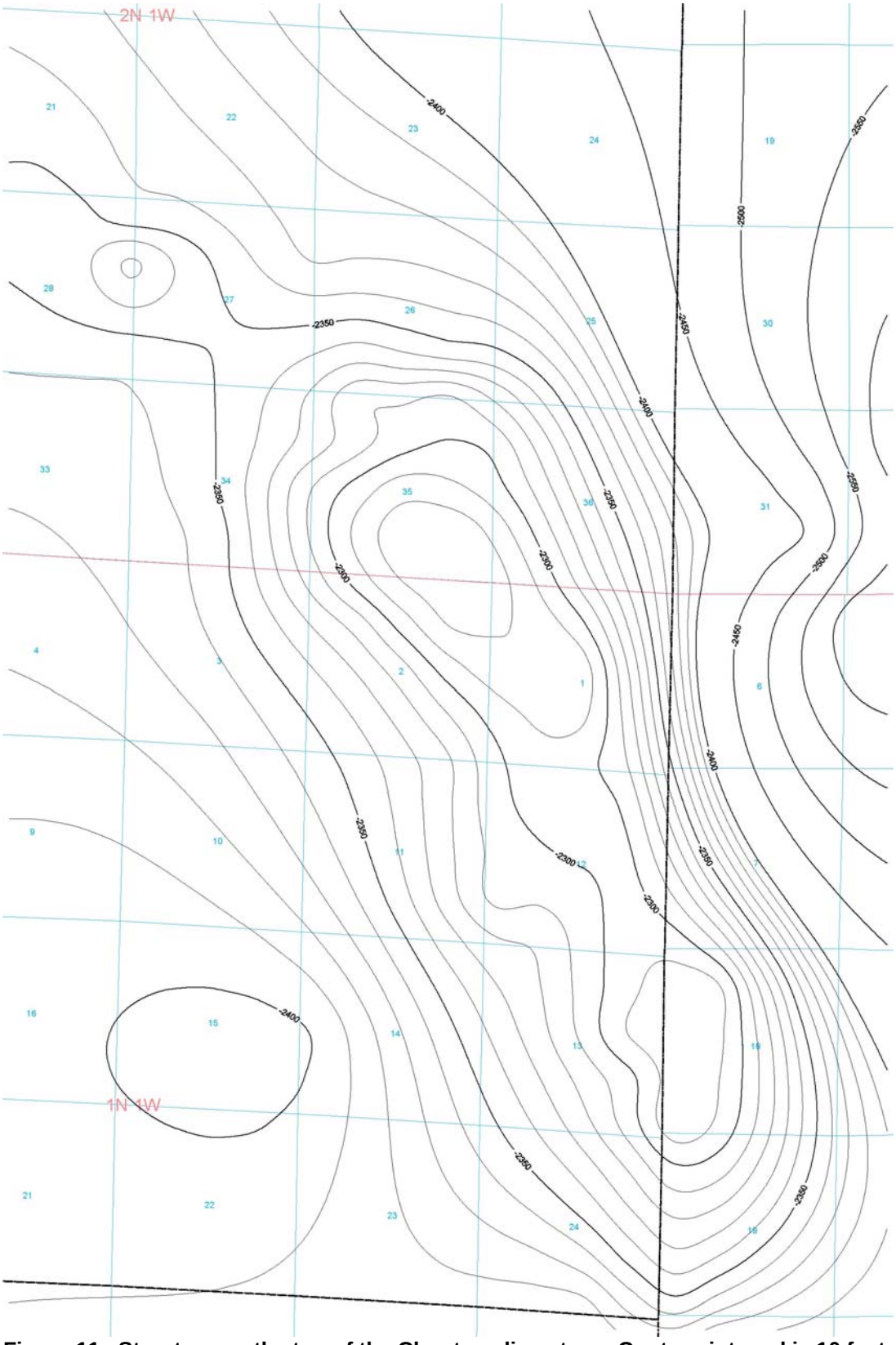

Figure 11. Structure on the top of the Chouteau limestone. Contour interval is 10 feet.

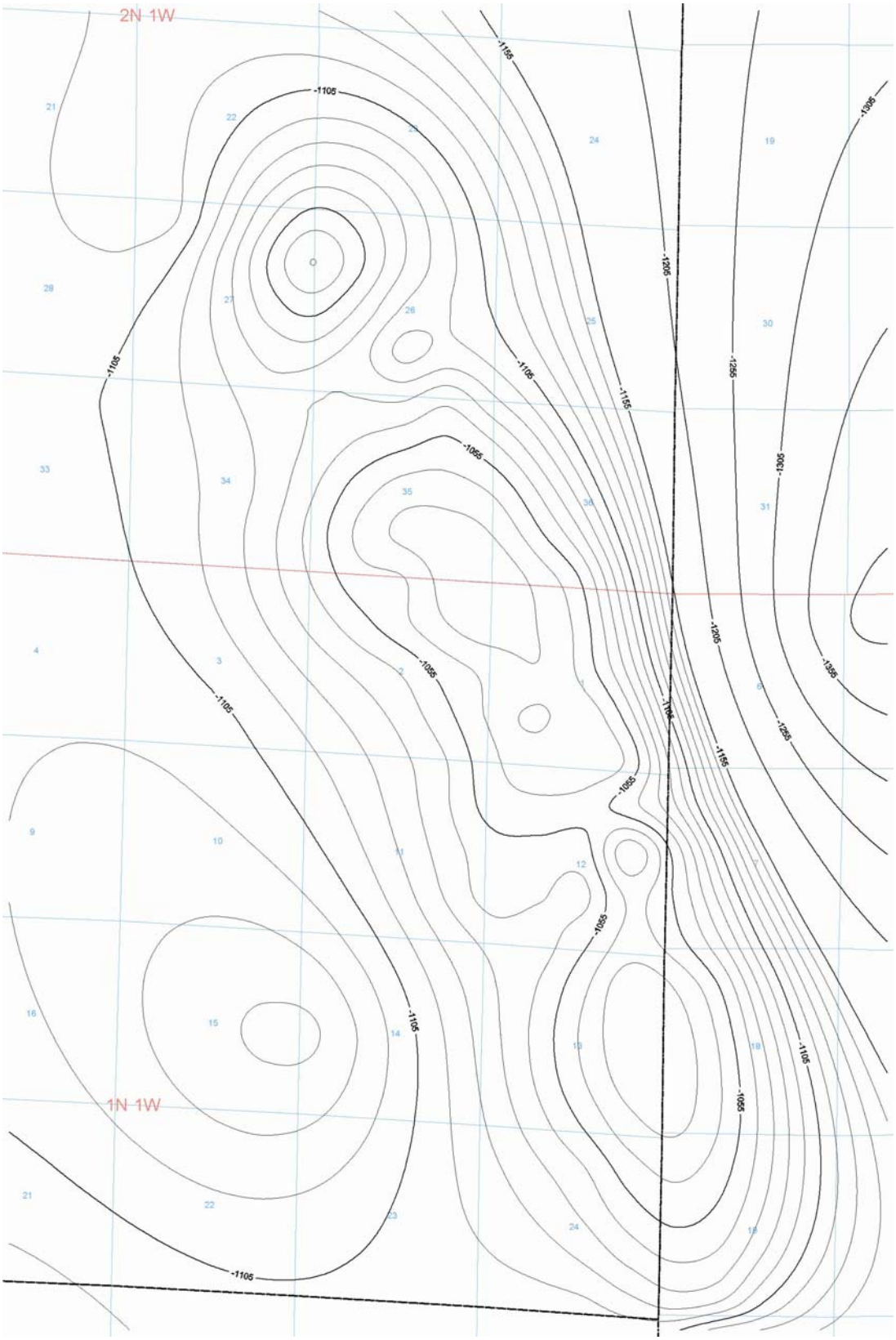

Figure 12. Structure on the top of the St. Genevieve formation. Contour interval is 10 feet.

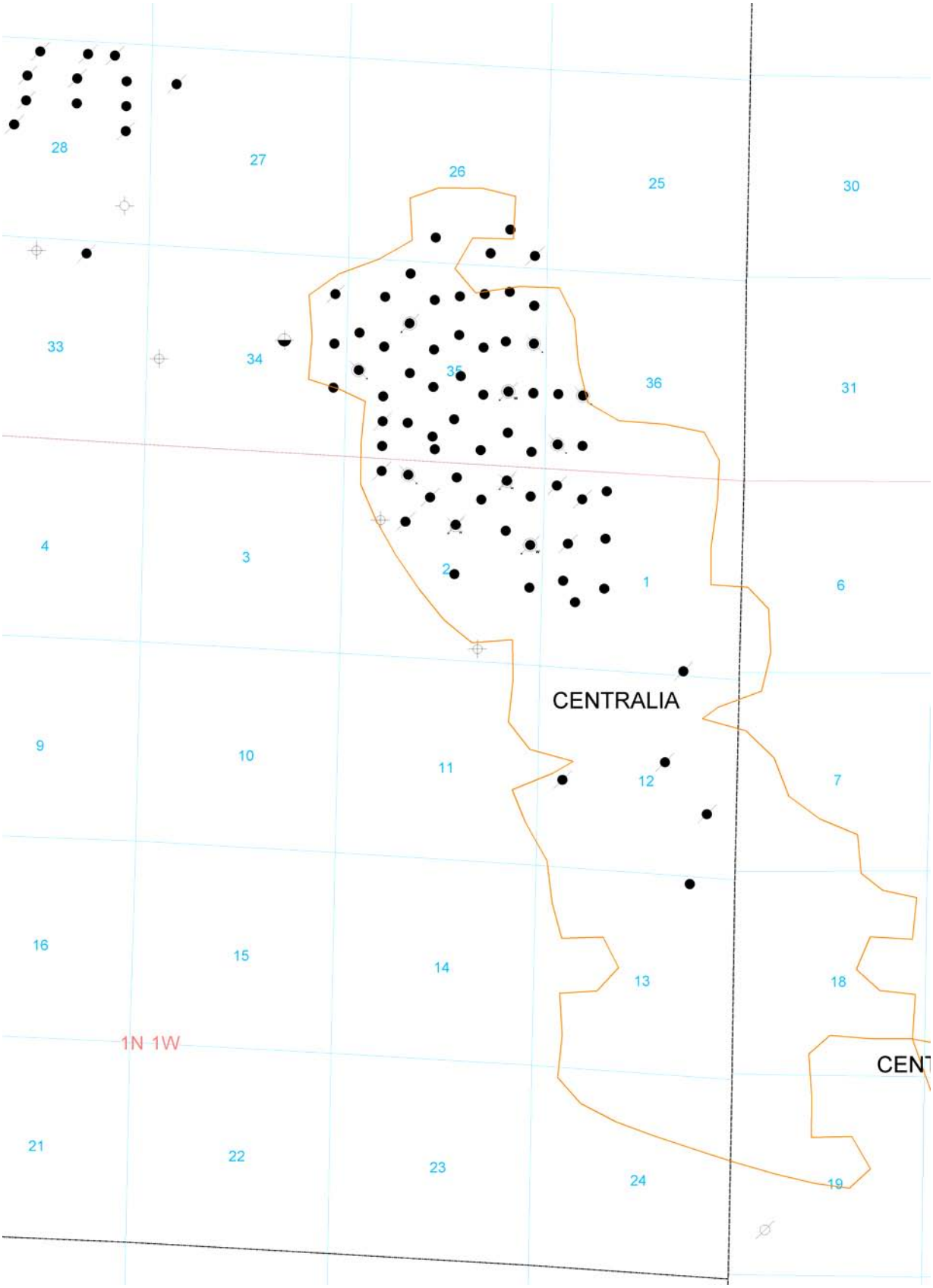

Figure 13. Map showing wells that have penetrated the Trenton Limestone.

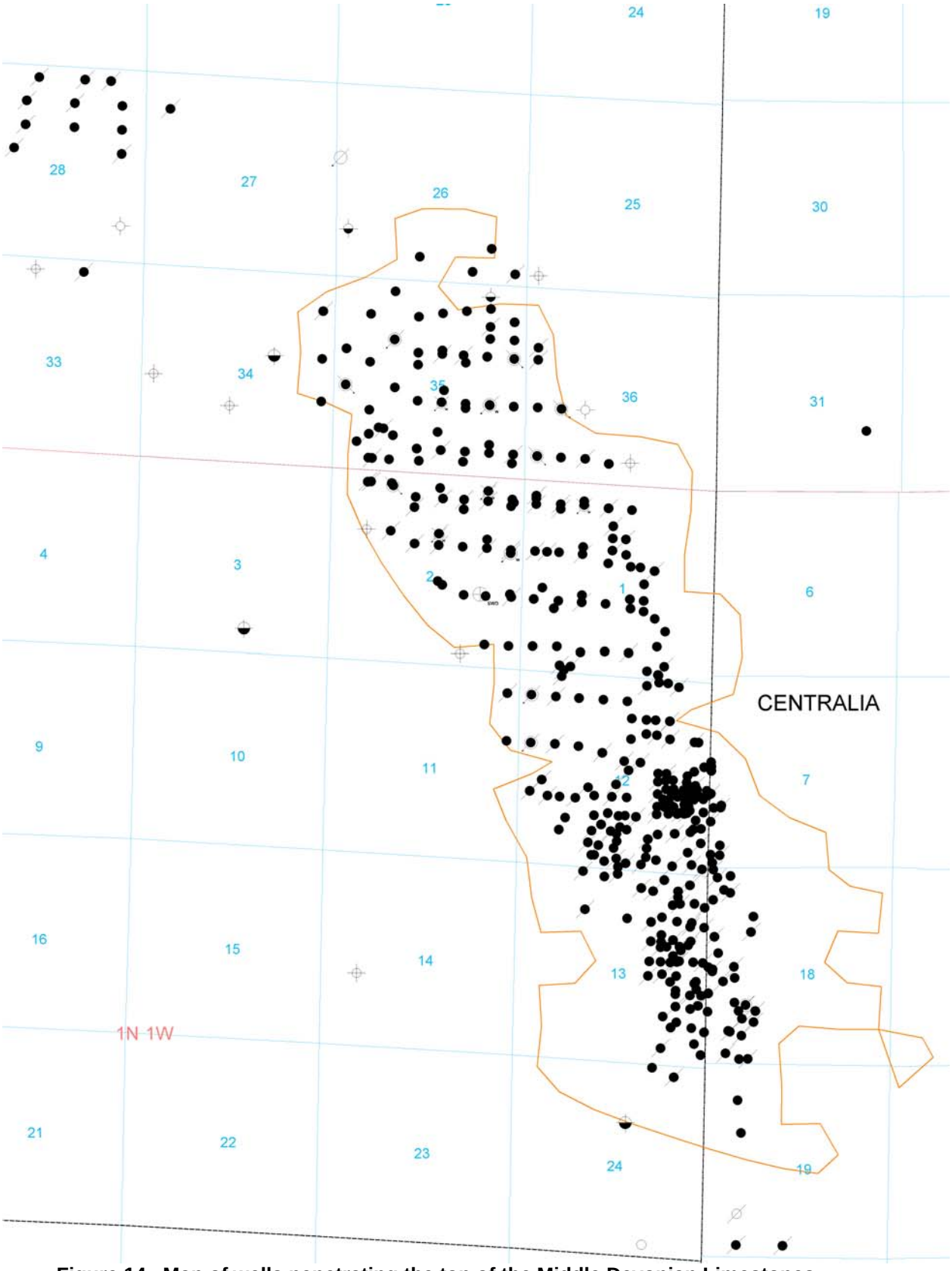

Figure 14. Map of wells penetrating the top of the Middle Devonian Limestones.

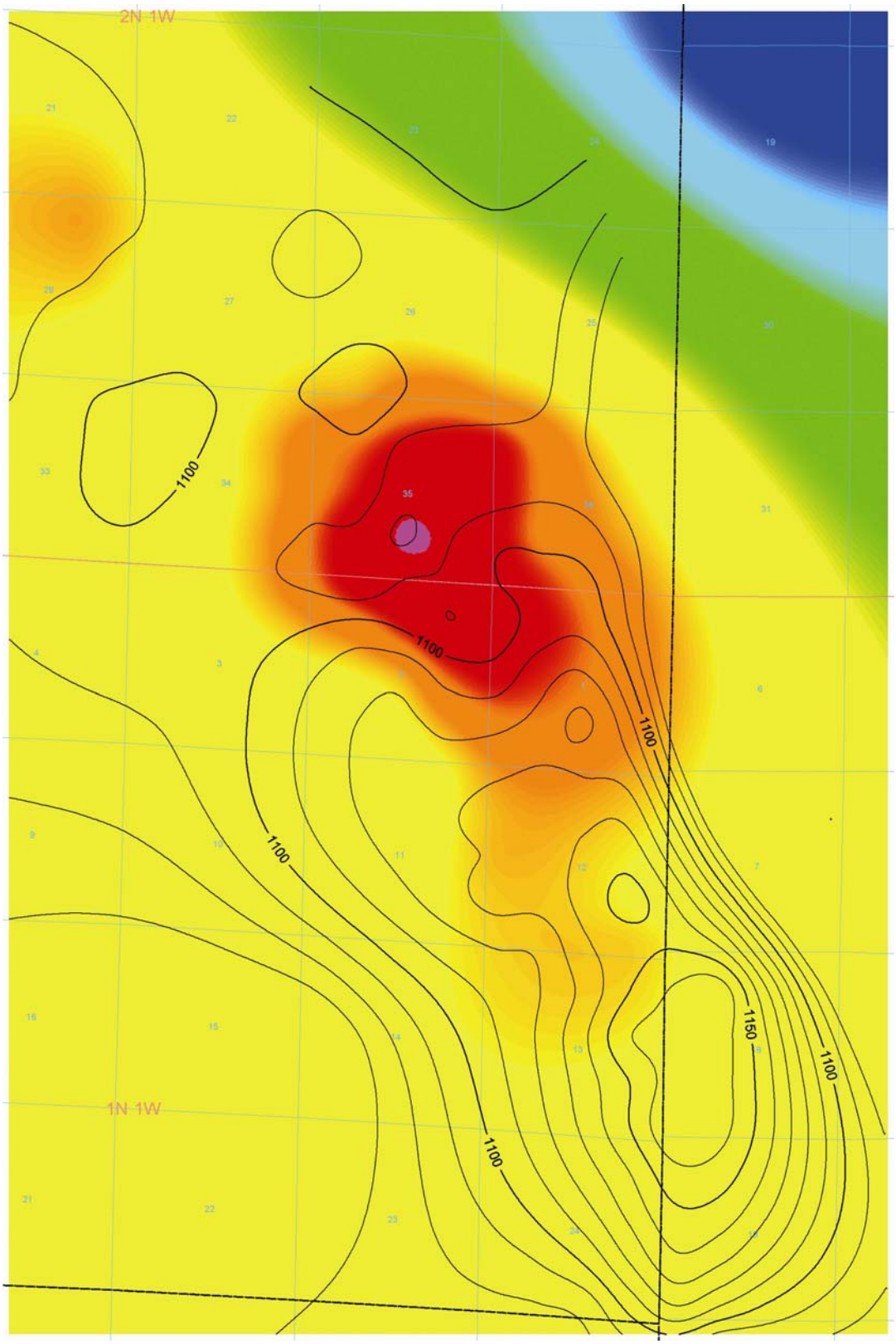

Figure 15. Isopach map of the Hunton Megagroup. Contour interval is 10 feet. Color background is the structure of the Trenton. The blue hues represent the lowest areas and the pink the highest.

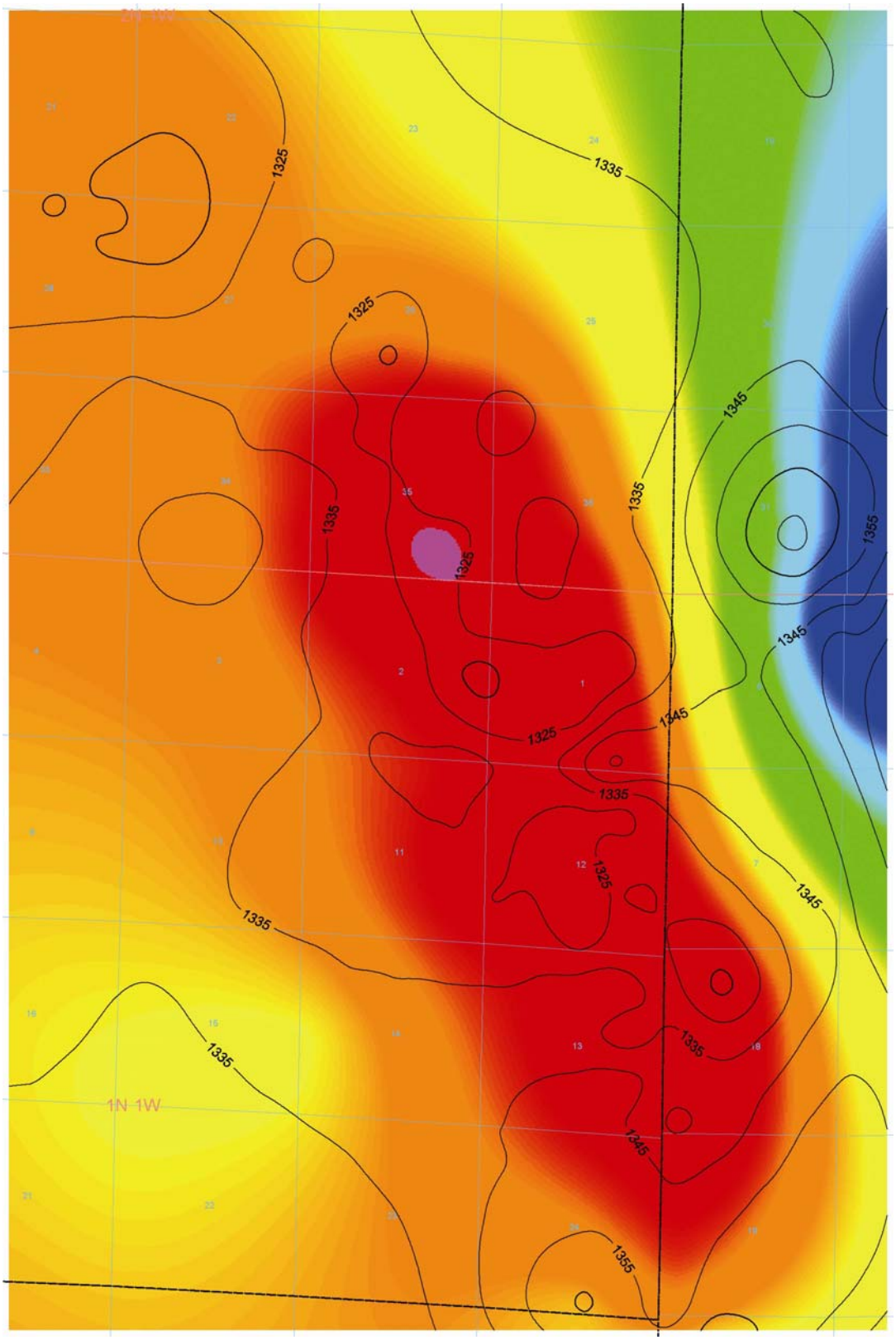

Figure 16. Map of the Valmeyeran thickness overlain on the color coded map of the base of the New Albany Shale. Color codes are the same as in Figure 4.

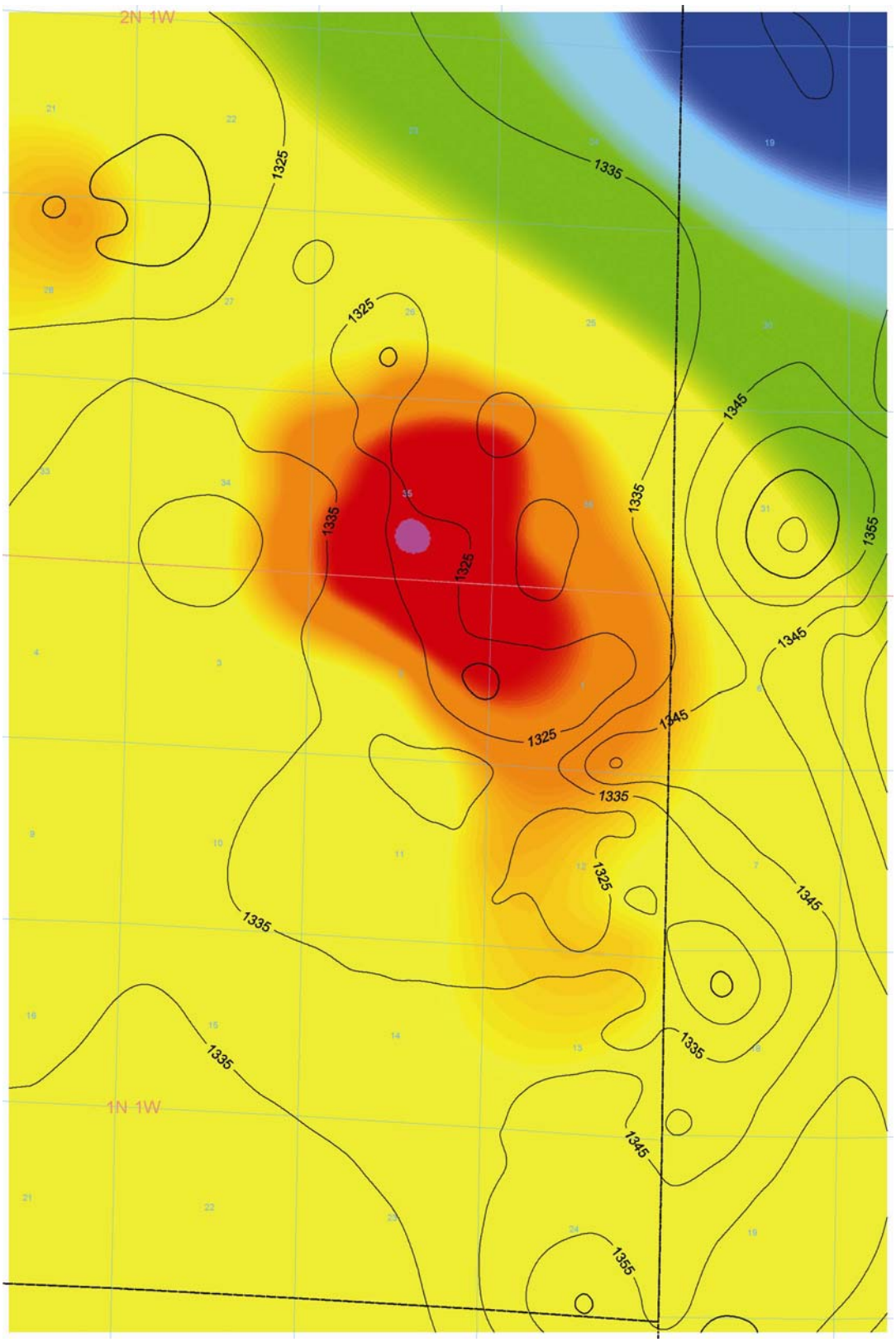

Figure 17. Map of the Valmeyeran thickness overlain on the color coded map of the top of the Trenton Limestone. Color codes are the same as in Figure 4.

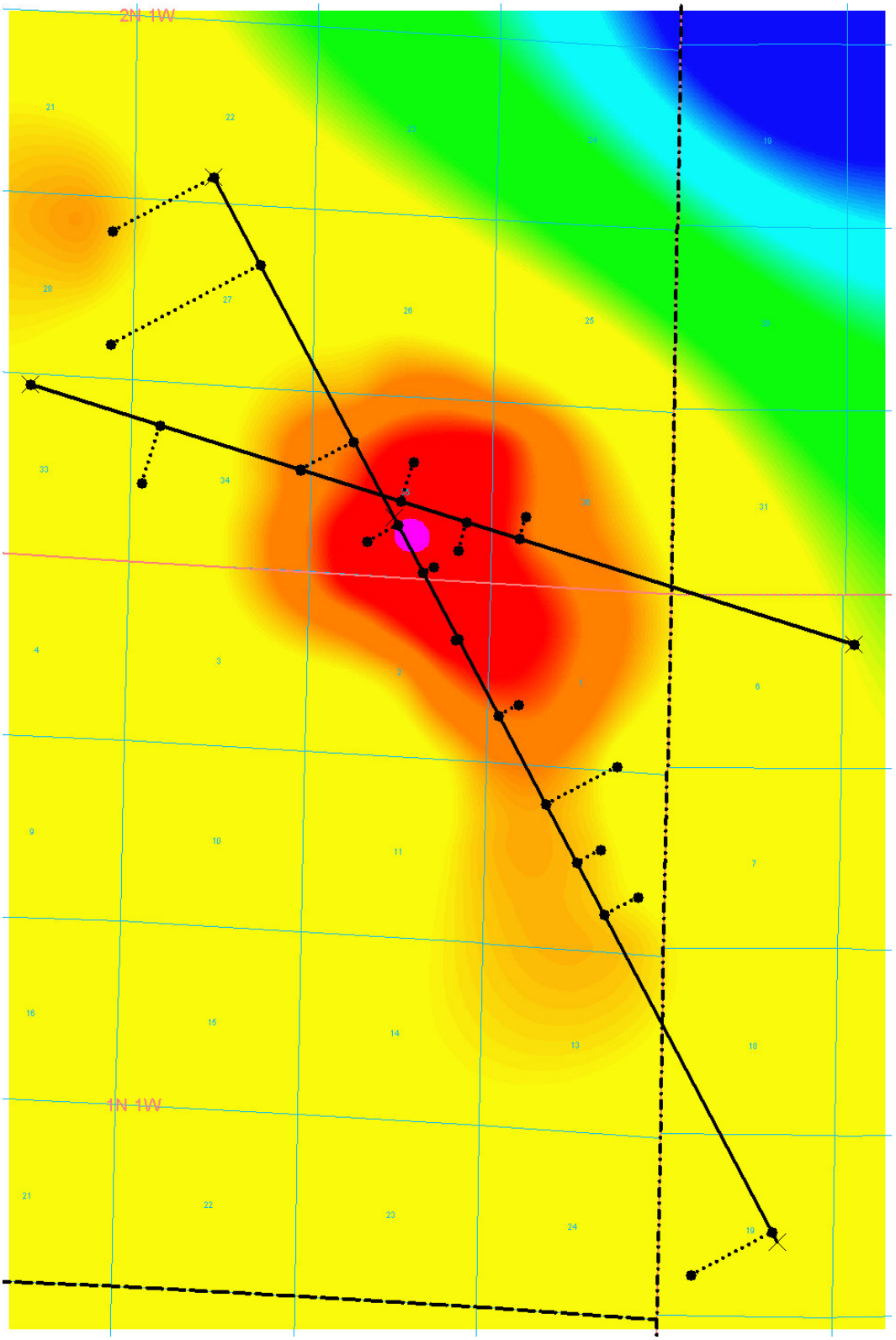

Figure 18. Map showing the two cross sections. All cross sections are projected onto the solid line and individual wells are show in actual positions, and projected placement on the line.

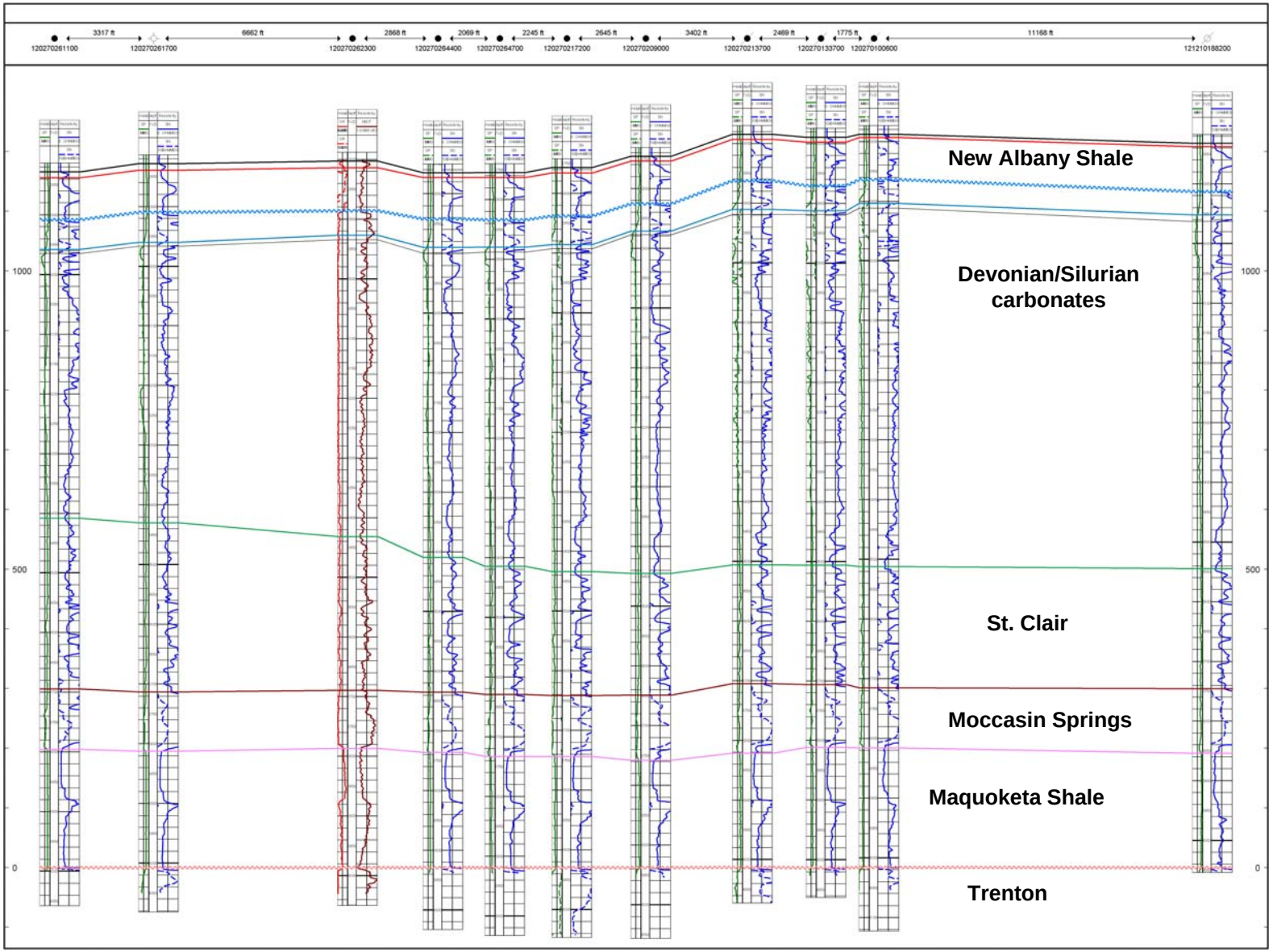

Figure 19. Stratigraphic cross section based on the top of the Trenton. Note thinning over the top of the Trenton structure, and the slight thickening visible in the St. Clair and Moccasin Springs formation to the south of the structure. Vertical exaggeration is 20X.

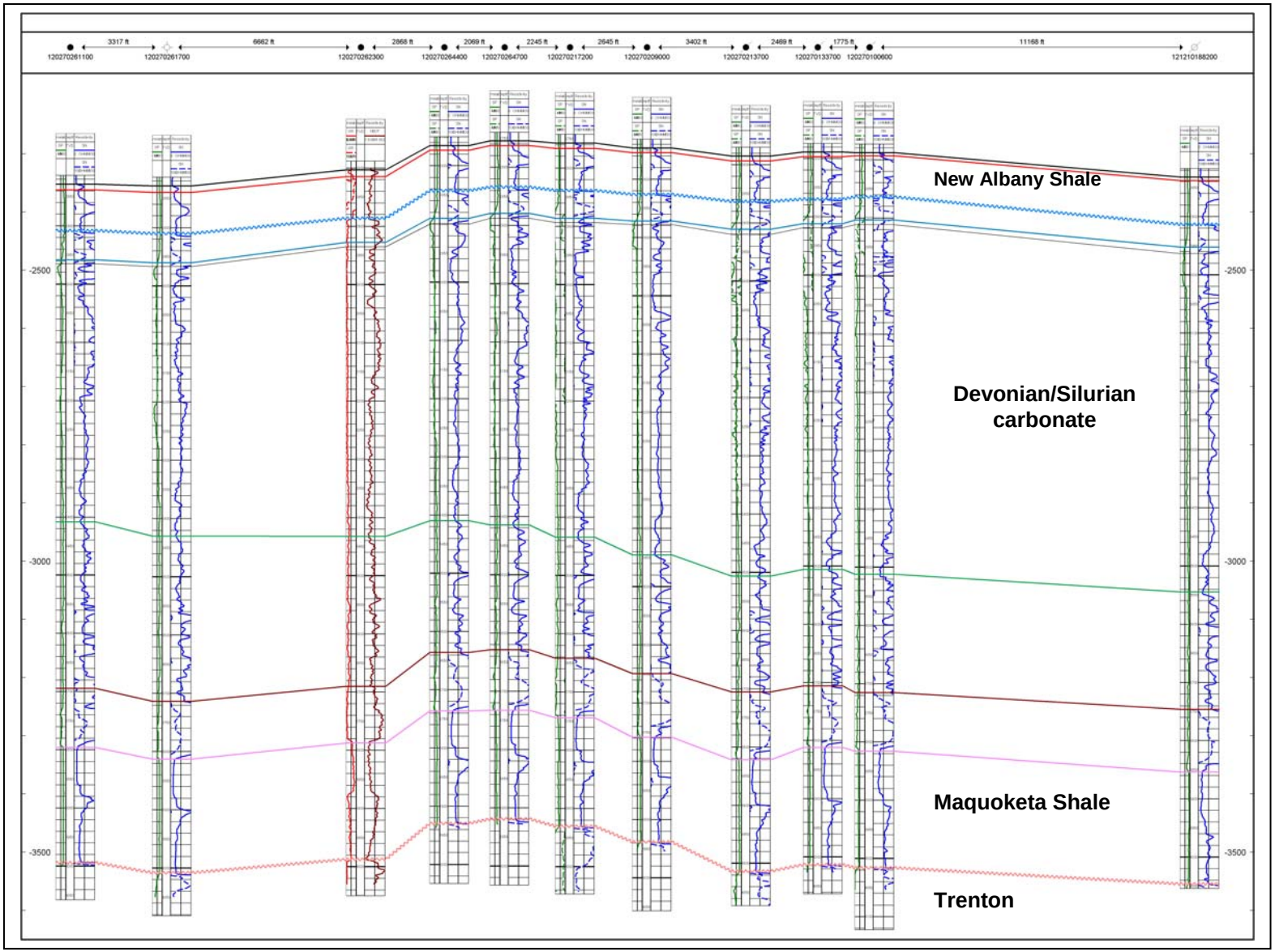

Figure 20. Structural cross section parallel to the fold axis. Note elongation of Devonian structure compared to the Trenton structure. See figure 12 for map view of cross section. Vertical exaggeration is 20X.

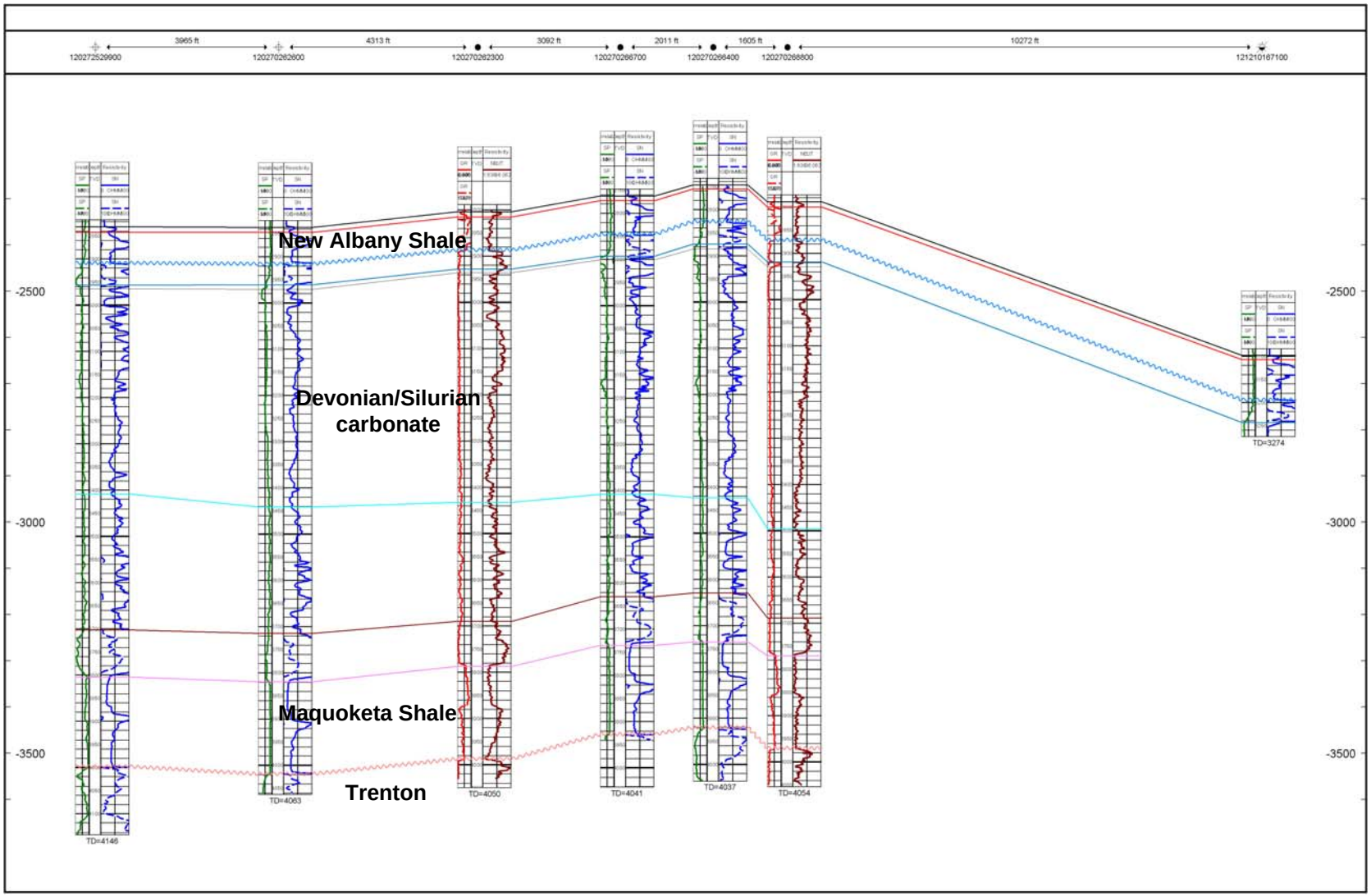

Figure 21. Cross-axial structural cross-section. The Rock Hill & Pure Oil #8 Buehler well is the farthest Trenton well to the east within the northern end of the field. Cross section indicates a steeper drop off than the contour model on the structural map.

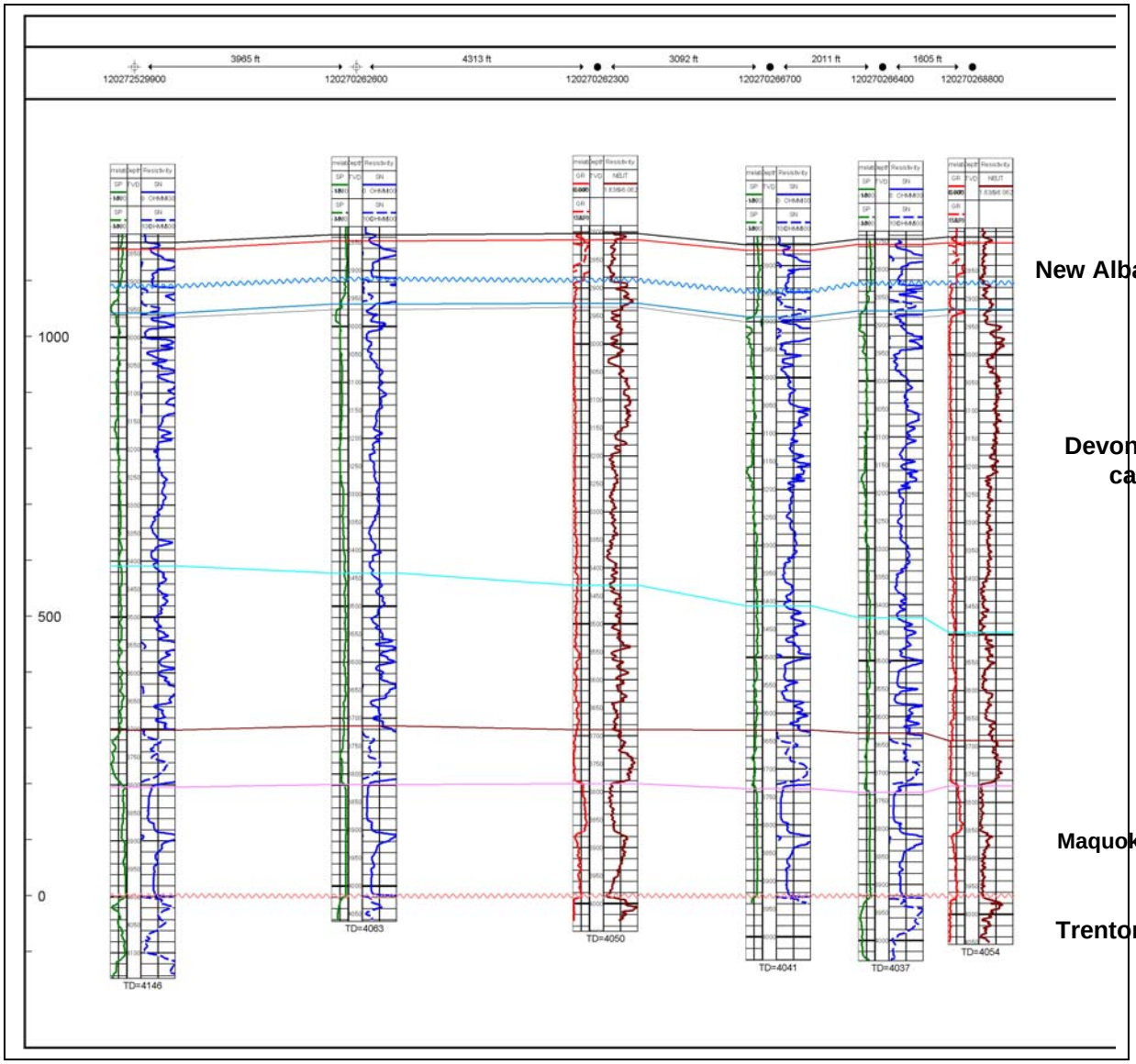

Figure 22. Cross-axial stratigraphic cross-section. The Murvin, John B. #1 Bridges P well is not displayed because it was drilled to the base of the Geneva. The Hunton is visibly thinned over the top of the cross section, but the individual Silurian units do not show the same correlation as in the axial cross-section.

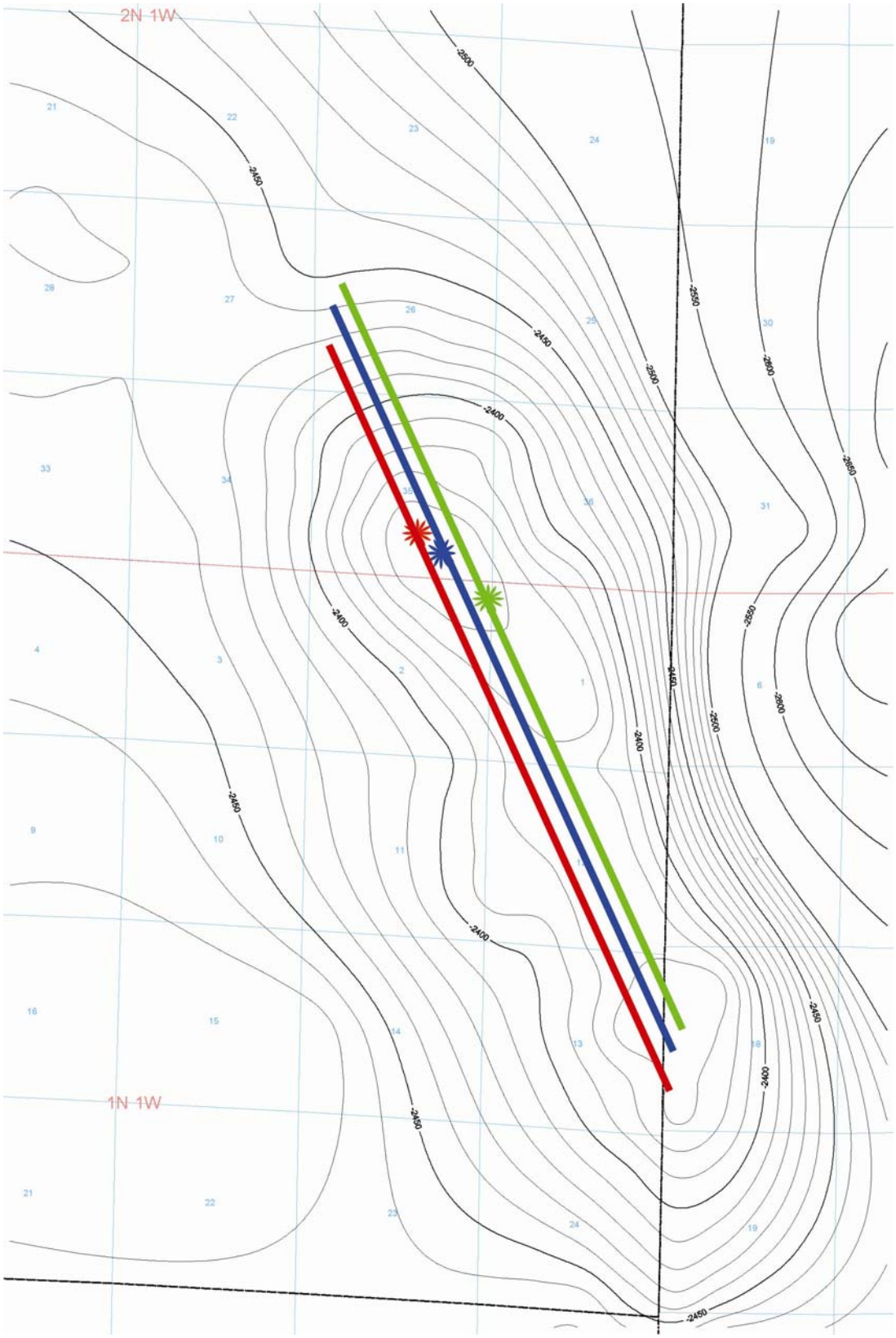

Figure 23. Map showing the structure on the top of the Lingle formation (blue line is the fold axis). Axis of the Trenton (red) and Ste. Genevieve (green) structures are shown for comparison.

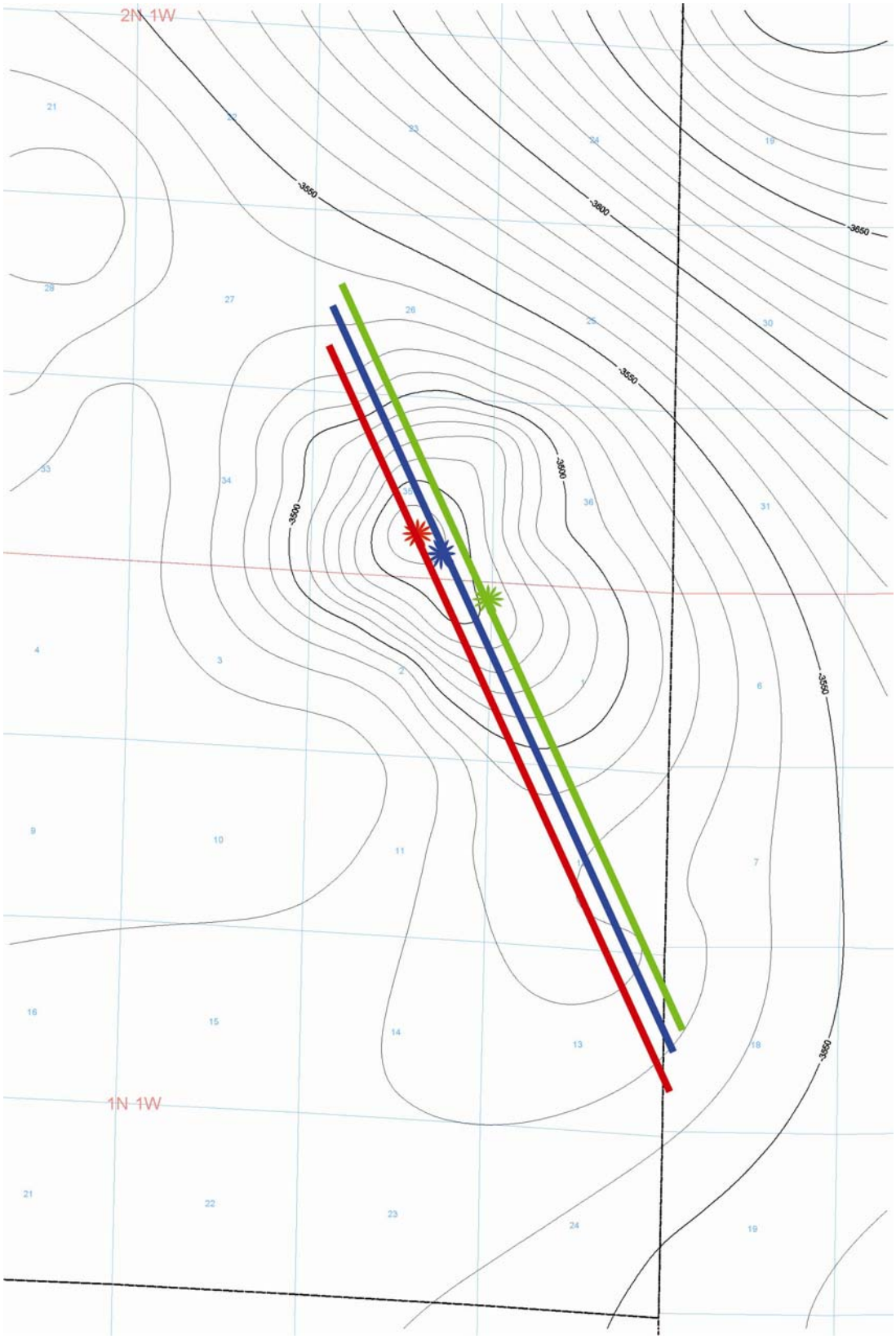

Figure 24. Map showing the structure of the top of the Trenton (Red line is the fold axis). Axis of Lingle (blue) and Ste. Genevieve (green) are shown for comparison.

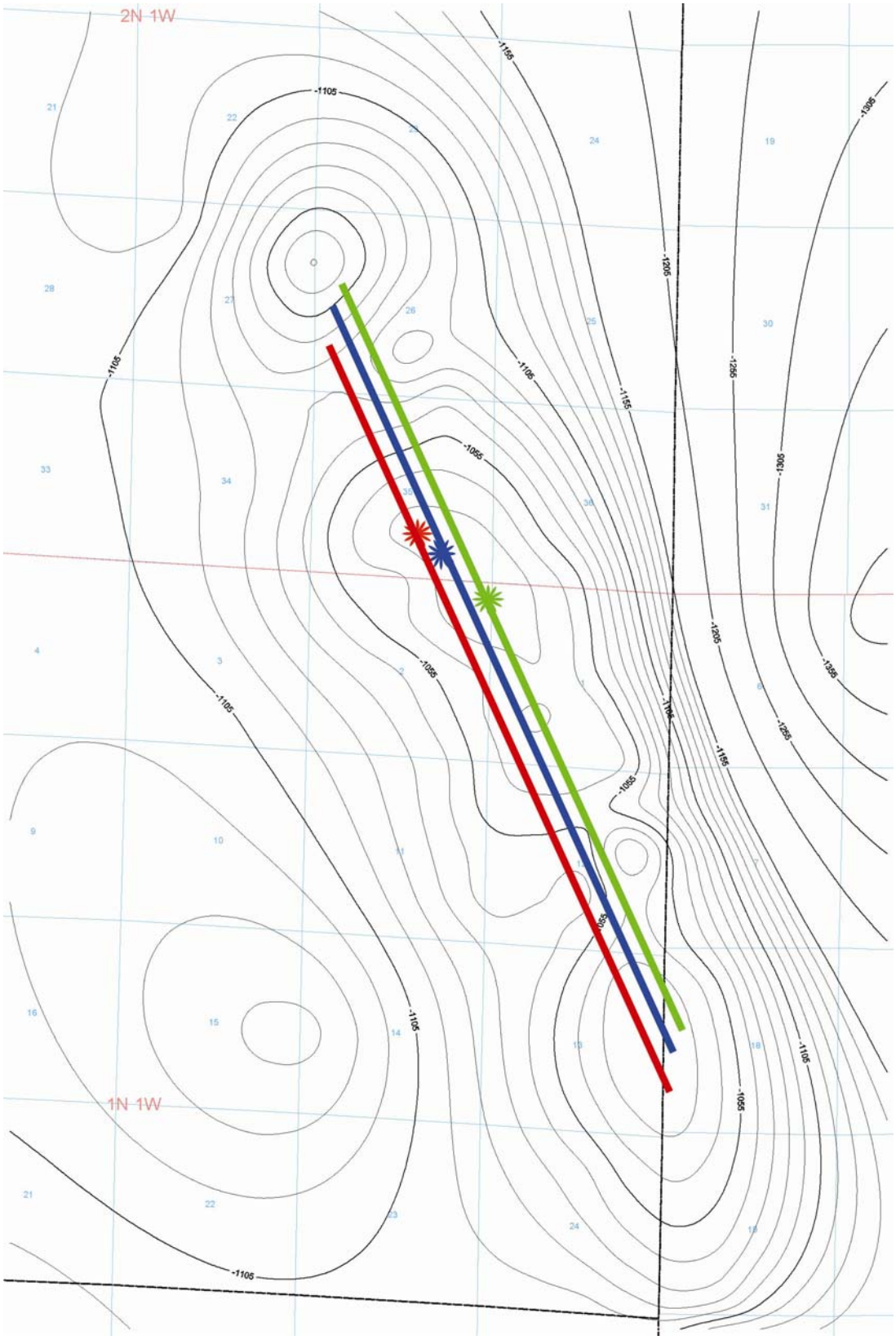

Figure 25. Map showing the structure on the Ste. Genevieve Formation (green line is the fold axis). Trenton (red) and Lingle (blue) fold axes are shown for comparison.

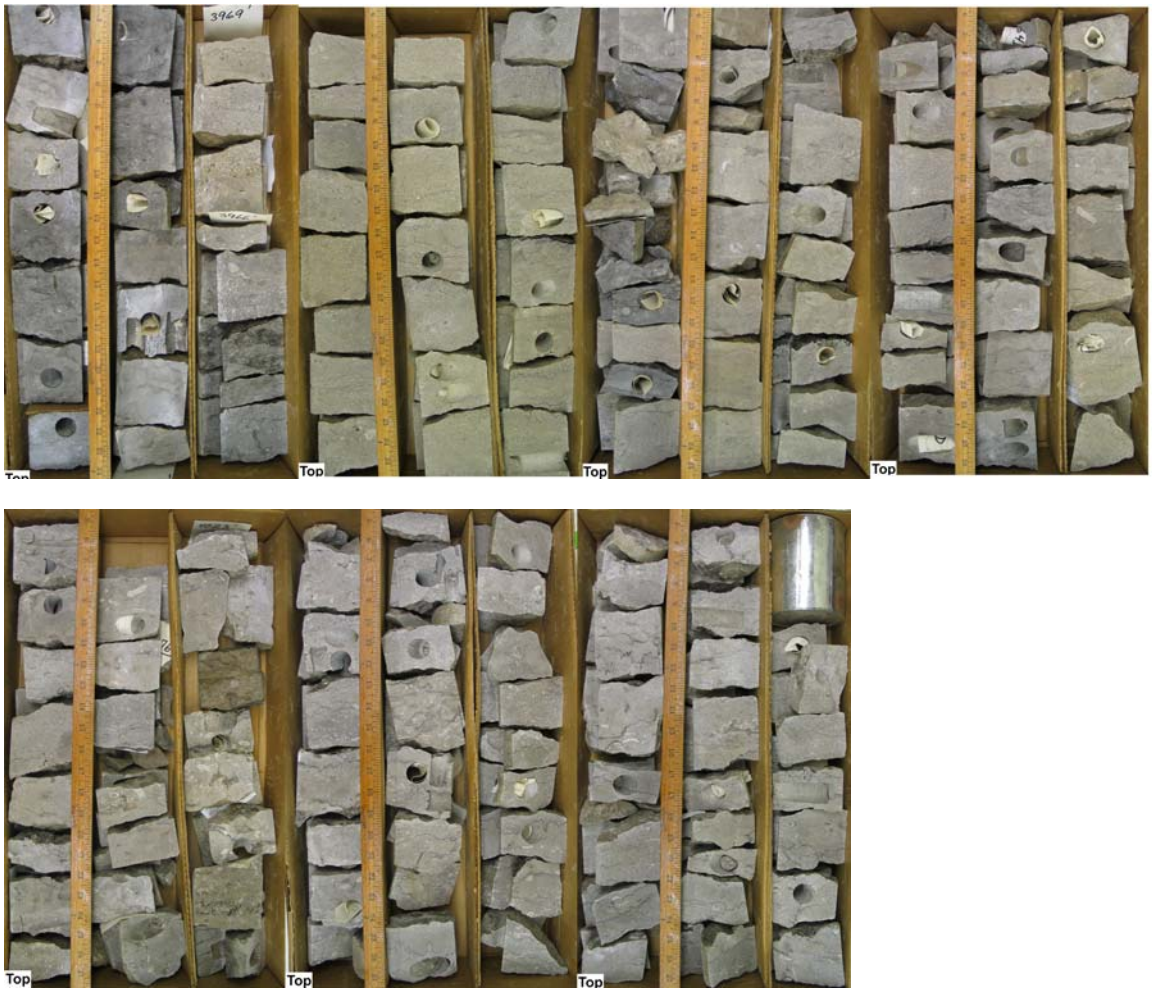

Figure 26. Core from the Shell #37-T Criley well. Note the three oil stained interval, upper interval (3968-3978 ft) is the most productive from this well. Middle oil stained zone is from 3988-3991 ft, and the lower zone is the fractured portion from 3998-4000 ft.

Figure 27. Sample of the Trenton Reservoir from the Criley 37-T well. Note the contact between the less porous layer below and the more porous grainstone above.

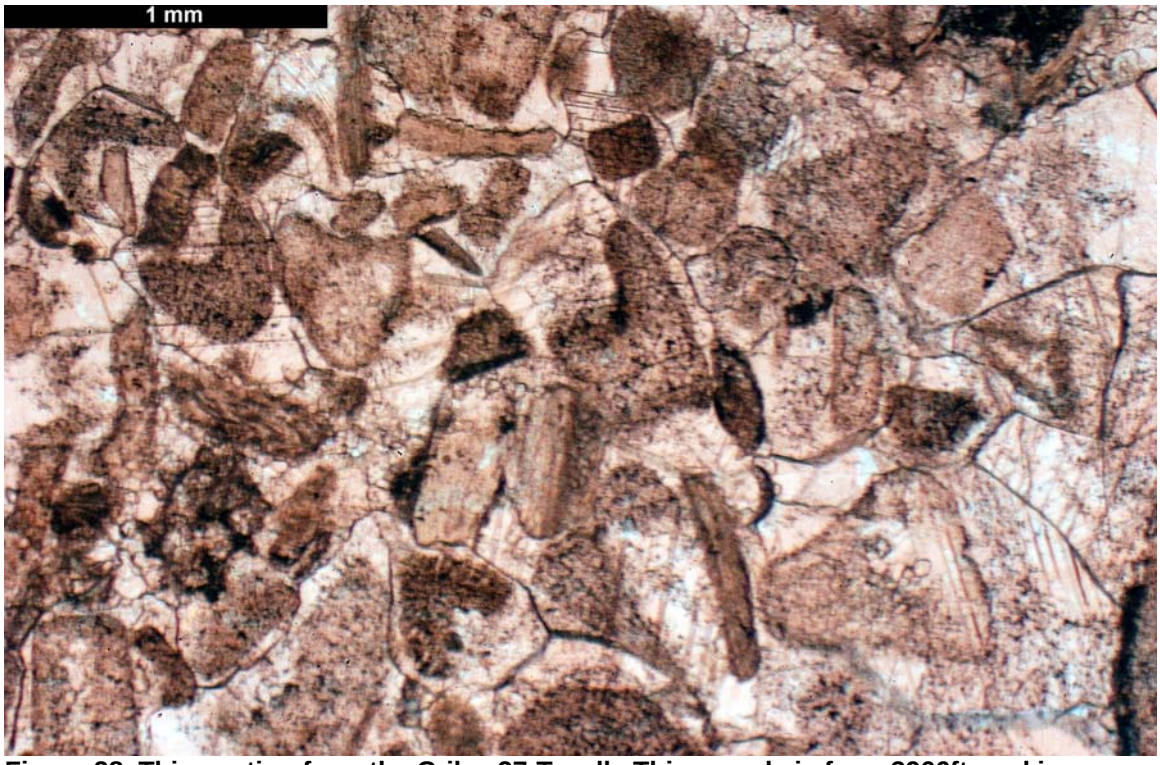

Figure 28. Thin section from the Criley 37-T well. This sample is from 3966ft, and is representative of the tight grainstones within the Trenton. Fossils are mainly crinoid fragments with lesser amounts of brachiopod and bryozoan fragments.

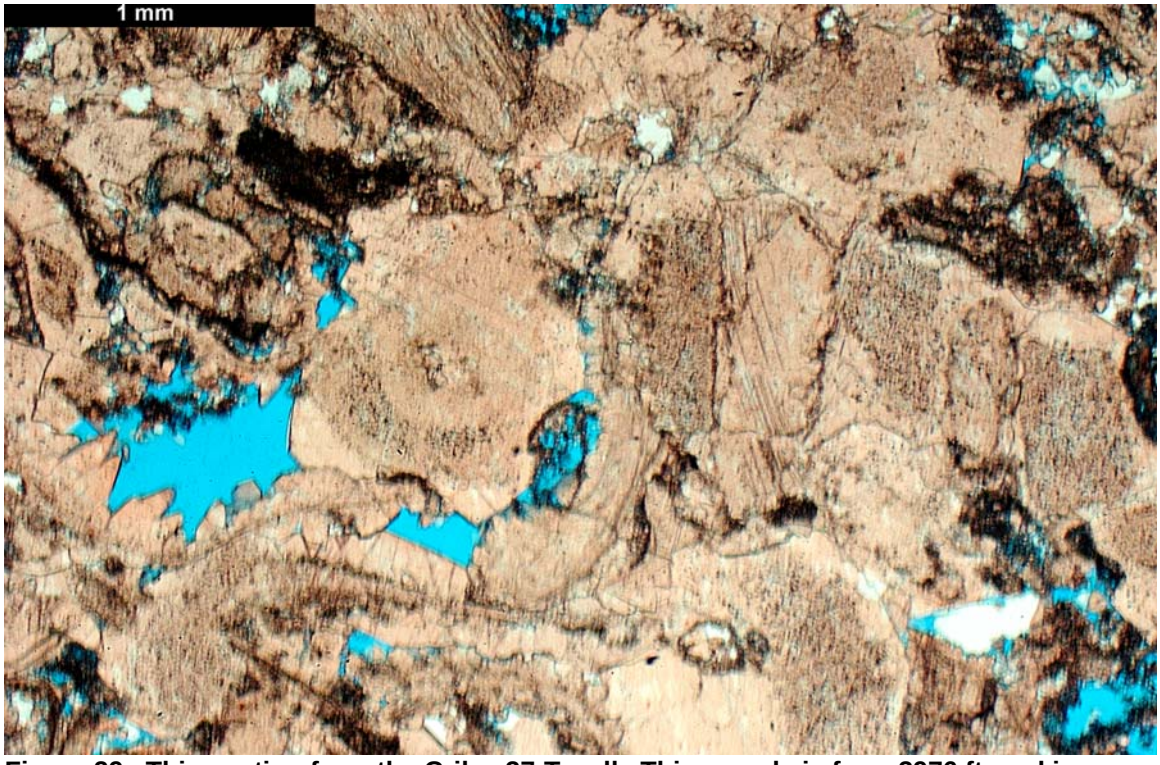

Figure 29. Thin section from the Criley 37-T well. This sample is from 3976 ft, and is representative of the reservoir units within the Trenton. Porosity is enhanced by dissolution of fossil grains.

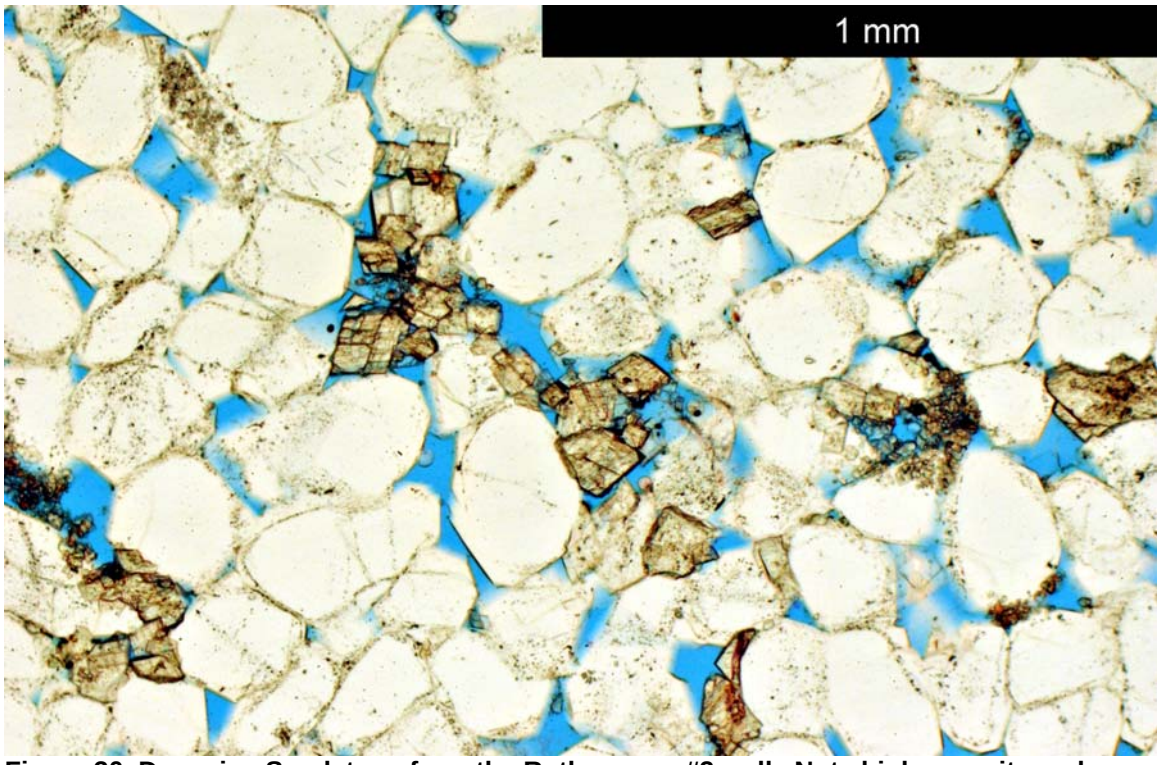

Figure 30. Devonian Sandstone from the Rothemeyer #2 well. Note high porosity and presence of dolomite crystals in this sample.

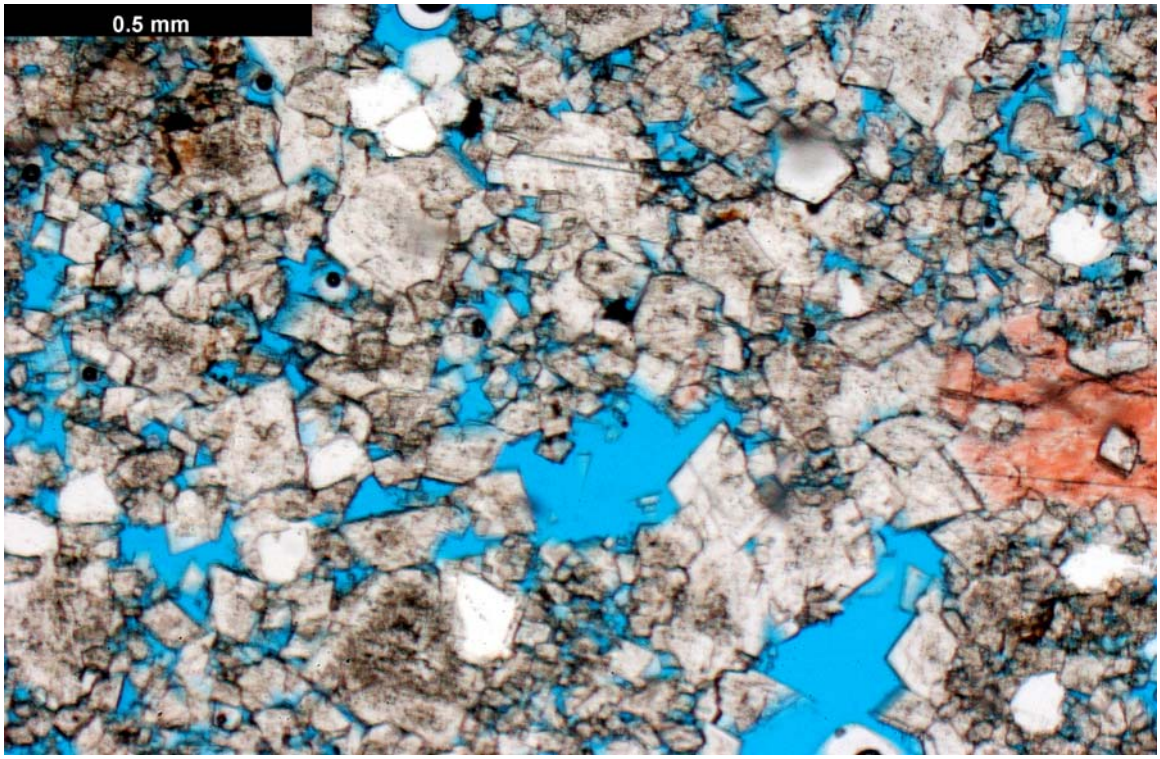

Figure 31. Devonian dolomite from the Baker #3 well. Note the calcite remaining in the sample which is stained pink. There is also some sand present, which are the bright white rounded grains with no visible cleavage.

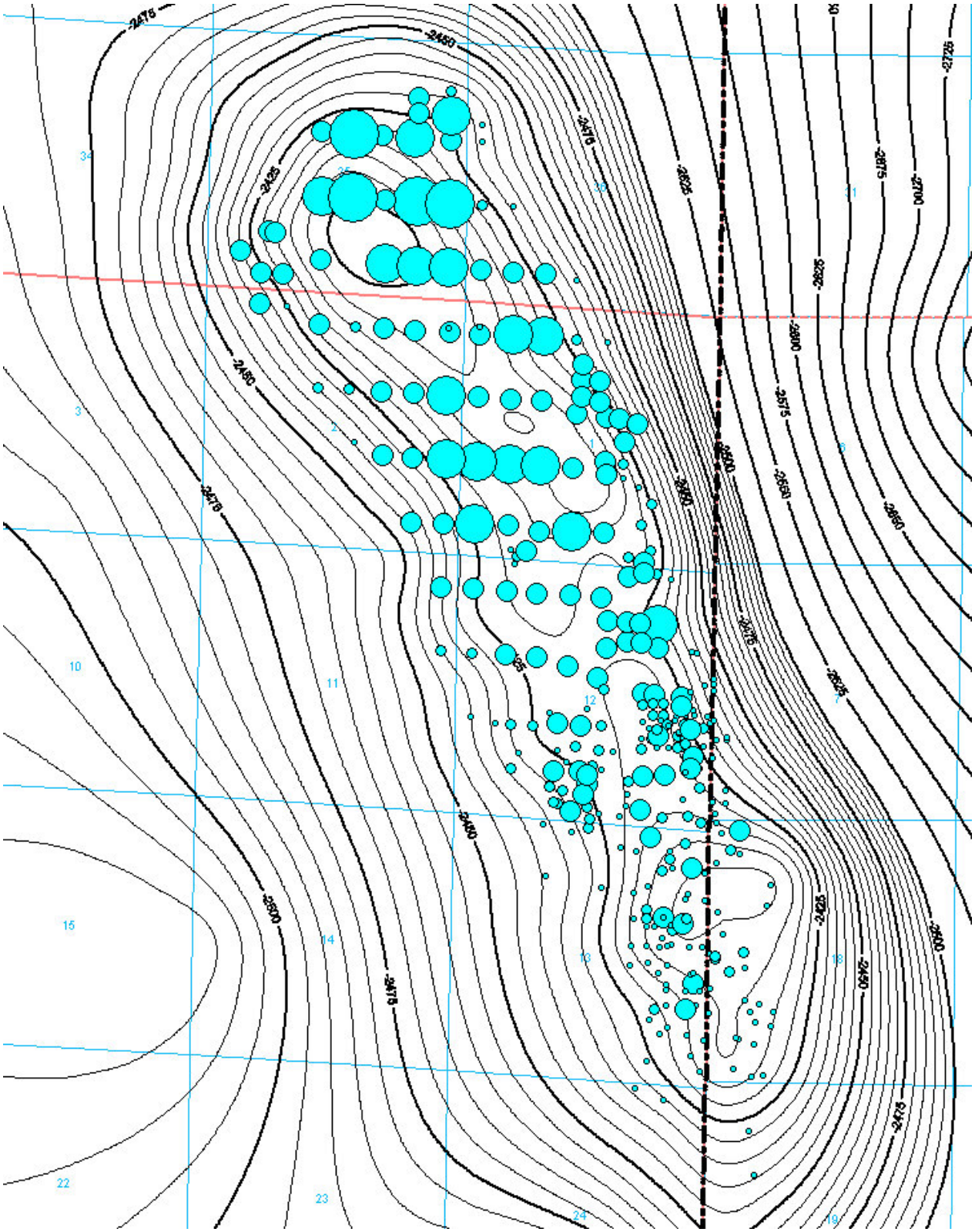

Figure 32. Map of reported initial production from Devonian wells shown over the Devonian structure. The Largest circles represent wells with rates over 10,000 barrels per day, the next size down represents wells more than 5,000 barrels per day, and the smallest circles represent wells with production less than 500 barrels per day.

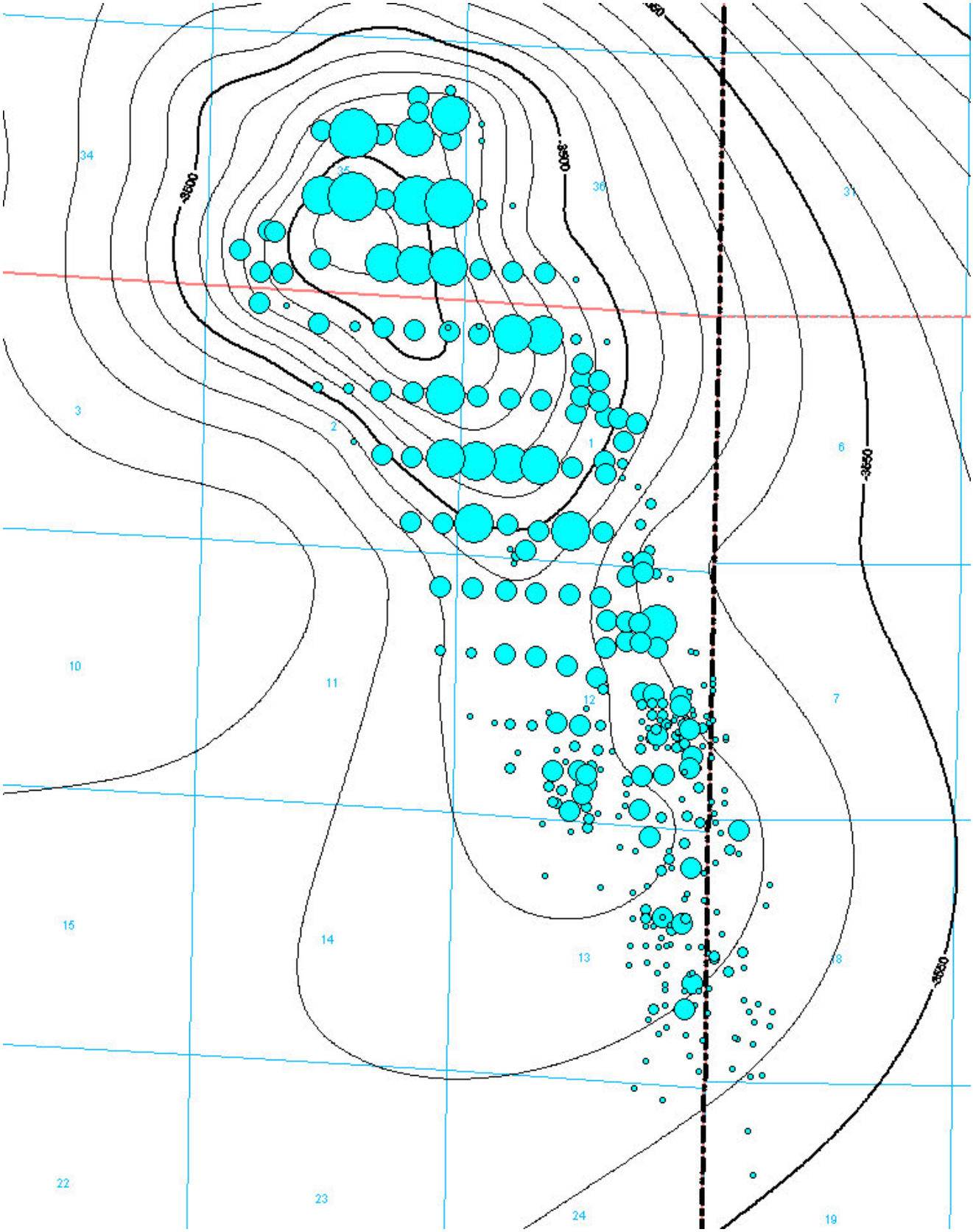

Figure 33. Map of reported initial production rates from Devonian wells shown on the Trenton structure. Symbol explanation is the same as the previous figure.

Westfield Trenton Production: **Jon Brenizer**

Geological Setting and Stratigraphy:

The Westfield field is located on the Westfield dome, a portion of the LaSalle Anticlinorium, in northwestern Clark County and parts of Coles and Cumberland Counties (see Figure 1). A typical log of Westfield is shown in Figure 2, as a guide to the stratigraphy of the field. The Mississippian strata have been eroded down into the Valmeyeran sequence to the base of the St. Genevieve and the top of the St. Louis Limestones. The Borden Siltstone has one or two distinctive lenses of Carper Sandstone which are productive if they are lenticular with no communication with water saturated units. The Chouteau Limestone is easily distinguished on the newer dual induction logs, and is between 12-15 feet thick throughout the area. The New Albany Shale directly underlies the Chouteau, and is 100 feet thick throughout the field. The Devonian limestones are not productive despite showing good porosity in logs. The Ordovician Maquoketa Shale is consistently 250 feet thick throughout the area. The Trenton Limestone is approximately 175 feet thick throughout the field and is comprised mainly of fossiliferous grainstones.

Production history:

Oil in the Trenton was discovered very early at Westfield with the first confirmed production coming from the Ohio Oil Company #79 Young, K&E well that was completed in 1910. Development of the field was slow with only 4 additional producers completed between 1922 and 1942 (Figure 3). In late 1948 through 1949, the first new wells were completed in the Trenton. There was no further Trenton development between 1949 and 1957, but 1957 marked the start of extensive drilling targeting the Trenton. Seventy-two wells were completed in the Trenton from 1957-1963, 64 being producers. This period also marked the beginning of water-flooding of the Trenton, which met with mixed success due to the proximity of some wells to large fracture systems. In 1983, a second round of development began and 52 production wells were drilled with no additional injection wells drilled. Development continued through the 1990's at a much slower pace, and in the mid-1990's horizontal drilling began. While the initial production of the wells has varied (from 909 bpd in the Lindley #5 to 32 bpd in the Huisinga 2-18), the average IP is about 50 barrels per day (excluding the Lindley #5) and the average water produced is less than 20 barrels per day. These values are remarkable because they are similar to the production level from 1957-1961, when the field was initially developed (Figure 4). Tests of the Devonian strata have produced no oil, but significant amounts of water.

Structural History:

The structure does not significantly change in shape or dimensions between Ordovician through Early Mississippian times (Figures 5, 6, 7, 8 and 9). The top of the bedrock in the area is in the middle of the Valmeyeran section, due to erosion. Much of this upper section has been highly altered and is difficult to recognize in logs. The Westfield Dome was described by Nelson (1995). "an asymmetrical box-fold with a long steep western limb (the Charleston Monocline), a gently dipping eastern limb, and a slightly domed crest."

The structure drops off drastically to the west of the mapped areas and there are no wells drilled to the Trenton in the next township to the west. Variations on the structure mapped on different stratigraphic units are relatively minor. Deeper stratigraphic units have

less well density than the shallower units, all of the maps and data for this project were based on the data available from wells penetrating the Trenton Limestone (Figure 10).

Cross sections were drawn along the lines shown in Figure 11. The East-West cross sections in Figures 12 and 13 show the structure and the particularly flat stratigraphic section with the Trenton as the datum. The North-South cross sections (Figures 14 and 15) show similar results to the East-West sections. The uniform thickness of the strata and the uniformity of the shape and size of the structure at each structural interval indicate that the uplift occurred both before and after the beginning of Pennsylvanian sedimentation (Nelson, 1995).

Reservoir Characterization:

The reservoir units of the Trenton in Westfield are similar to many Trenton reservoirs throughout the basin. The producing horizons are composed of porous grainstones (Crews, 1985). There are non porous tight grainstone intervals interbedded with the porous zones. After burial hydrothermal fluids may have moved through the porous units, dissolving mainly calcite cement, but also the brachiopods and bryozoans (Figure 16). Later, the fracturing occurred with additional fluids within the pore spaces resulted in partial dissolution of the carbonates along the fractures. Some time after the onset of fracturing formation of dolomite, probably of hydrothermal origin, began. There are several fractures that are filled with dolomite, and several instances where fractures cut through the dolomite and the dolomite bridged the fractures (Figure 17). The dolomite was precipitated more heavily in the larger fractures, indicating the best conduits for fluid migration and formation of porous intervals (Figure 18). A still later event deposited some calcite cement, and although it is not as pervasive as the dolomite, it is still present in most samples (Figure 19). This could be in part due to the reduction in magnesium concentration in the initial fluid due to the precipitation of dolomite.

On the basis of trends in initial production two fracture trends have been identified (Figure 20). These define fracture trends wider than the radius of a single well. The lack of oriented core makes it impossible to verify the orientation of field scale fractures, but they do indicate significant numbers, with openings up to 2 cm and significant dolomite mineralization. In the area of these trends, initial production values are 2-10 times higher than the areas of the field located outside of the fracture trends. The Lindley 5 well sits near the junction of two of the trends, and the two laterals cut across both of the trends. This would explain the remarkable initial production from this single well (909 barrels of oil, no water).

Completion methods:

All of the wells drilled prior to 1981 were completed as open holes. The main method of completing these wells was a fracture treatment with 40,000-80,000 gallons of water and 30,000-40,000 pounds of sand, with several of them flushed with acid. There were a very small number of wells that combined the two, but this was rare prior to the 1980s. Several fracture treatments were carried out using nitrogen after 1980. The wells with the fracture treatments initially produced more oil and water (8 barrels of oil and 13 barrels of water per day respectively) compared with the wells with combined treatments. The wells treated only with an acid flush made much less water (2 barrels per day on average) but produced about half of the oil compared to the wells with fracture treatment.

In the 1980's and later the preferred method was to case the entire well and then perforate the pay zones in the Trenton. The well treatments also changed, with combined acid and fracture treatments being used in 35 out of 61 completions. The combined treated wells made an average initial production of 66 barrels of oil and 14 barrels of water with a water cut of 18%. This is consistent with the combined treatments from the earlier development, but is much better than the single treatment method in modern wells (43% water cut for acid only and 47% water cut for fracture only wells).

Horizontal drilling also improves the recovery of oil with an average of 57 barrels per day recovered initially (not including the Lindley #5 well, including the Lindley #5 the average jumps to 178 barrels per day). Vertical wells drilled in the 1980's and 1990's averaged 44 barrels of oil initially. The vertical wells drilled before 1980 averaged 58 barrels per day initially. Horizontal drilling resulted in producing as much oil as the preceding 100 years of producing from the field.

Conclusions:

Several findings from this study can be applied to Trenton exploration and development throughout the Illinois Basin. First, the completion technique used in the Trenton must be carefully controlled, because fracturing the well too heavily or flushing the well with too much acid will ruin the well or increase the water cut. A moderate fracture treatment with a small acid flush will serve to better connect the existing fracture network without destroying it, and a light acid flush will remove the finer grained calcite, while leaving the calcite and dolomite bridges of existing fractures intact. Second, the presence of any fractures will improve production. Whether these fractures are caused by faulting, regional stress, or the stresses along the crest of the anticline, they directly increase the permeability directly. Finally, horizontal drilling in a fractured reservoir will increase production by 10 or 20%, even on a relatively short horizontal well.

Reference:

Nelson, J.W. *Structural Features in Illinois*. Bulletin 100, Illinois State Geological Survey, 1995.

Crews, G.A. *Carbonate Facies of the Kimmswick Limestone (Trenton/Galena) in Southwestern Illinois – Their Relations as Oil Reservoirs and Traps.* Thesis, University of Missouri-Rolla, 1985.

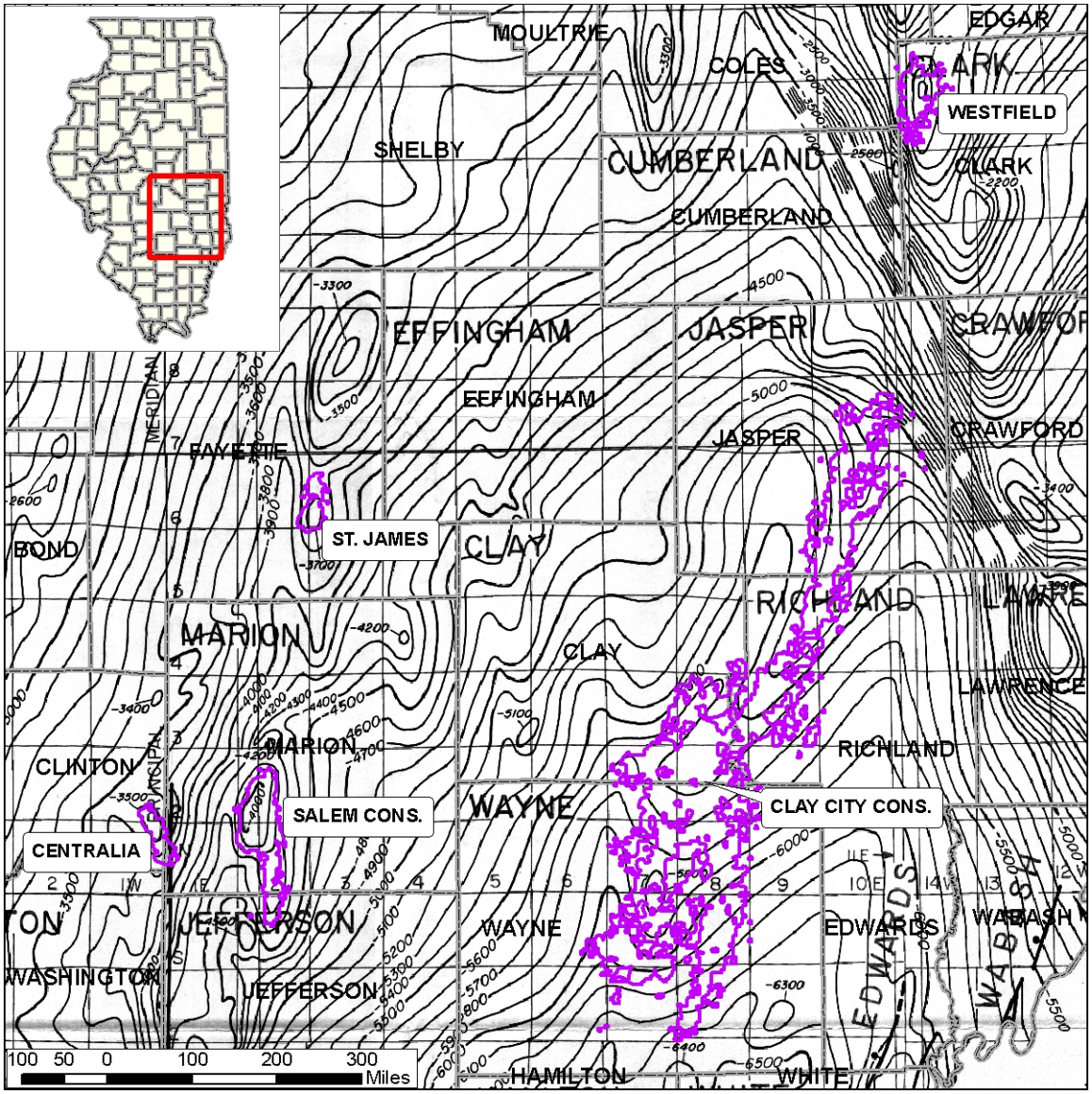

Figure 1. Map showing the location of Westfield (upper right corner). The map is contoured on the top of the Trenton Limestone and the contour interval is 100 feet (Bristol and Buschbach, 1973).

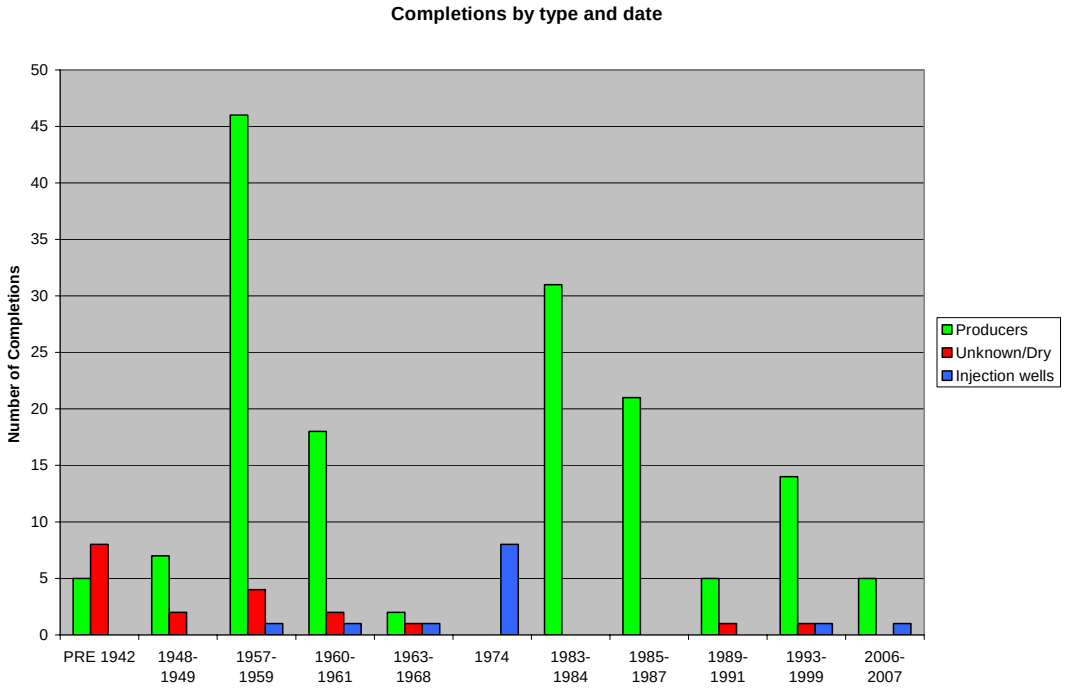

Figure 2. Graph of completions by type and date. Notice the three main periods of development within the field in the late 1950's -early 1960's, the mid 1980's and the late 1990's and early 2000's.

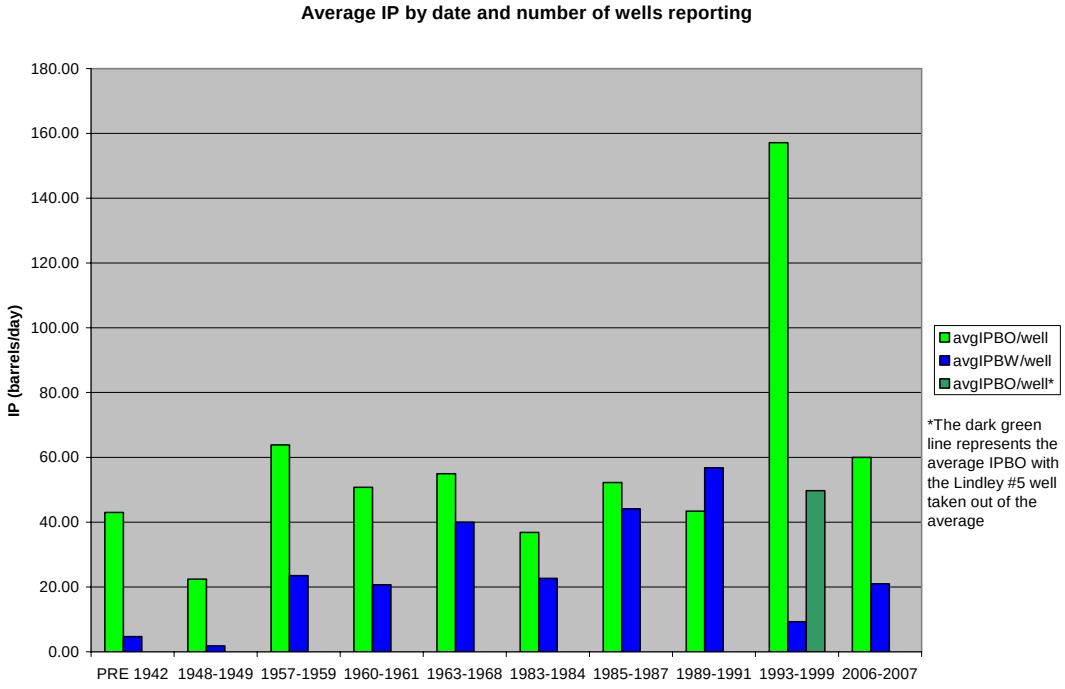

Figure 3. Graph showing average IP values per well drilled. The higher values from the late 1990's and early 2000's are due to the completion of several horizontal wells, which produce as much oil as the wells drilled in the 1950s.

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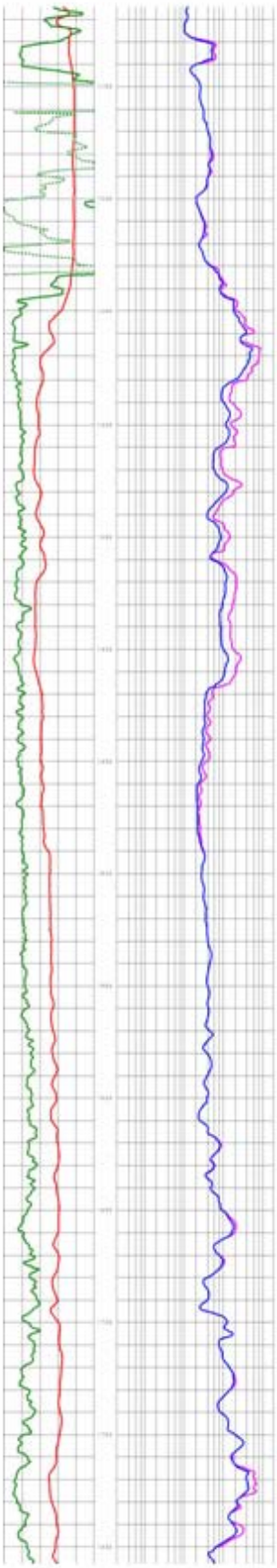
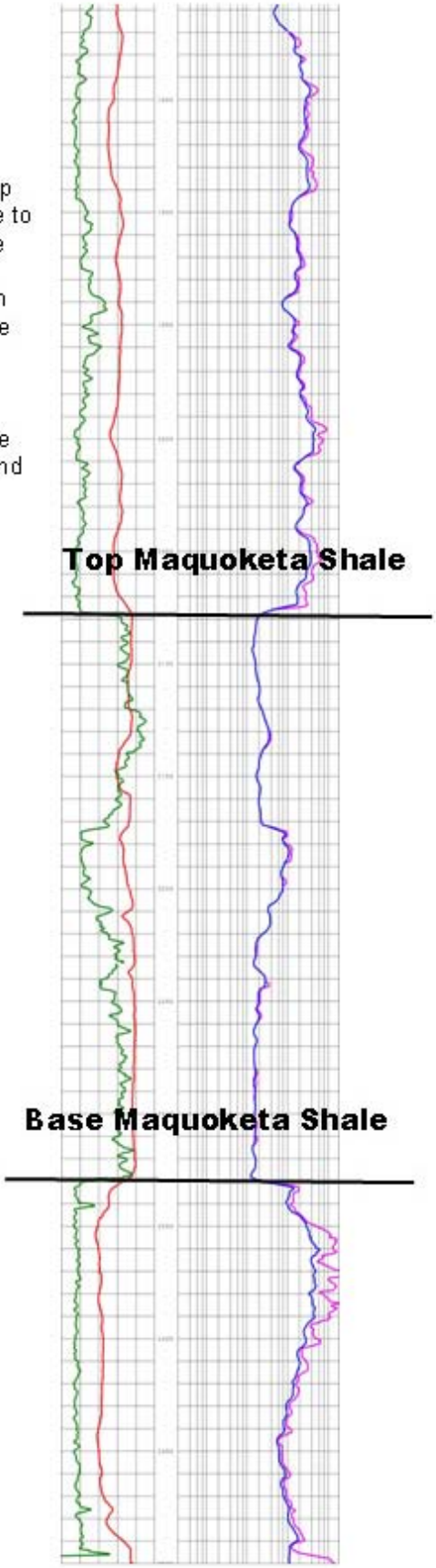


Figure 23. Left column shows a typical log from Westfield in Clark County Illinois, the Ashley Oil Husinga-McVey No. 4T in Sec. 6-T11N-R14W API 120232483800 from the top of the Chouteau Limestone to the top of the Silurian. The right column shows the continuation of the log from the top of the Silurian to the base of the Guttenberg Shale. The green line is gamma log, the red is the spontaneous potential, blue is the medium induction, and the pink line is the deep induction curve



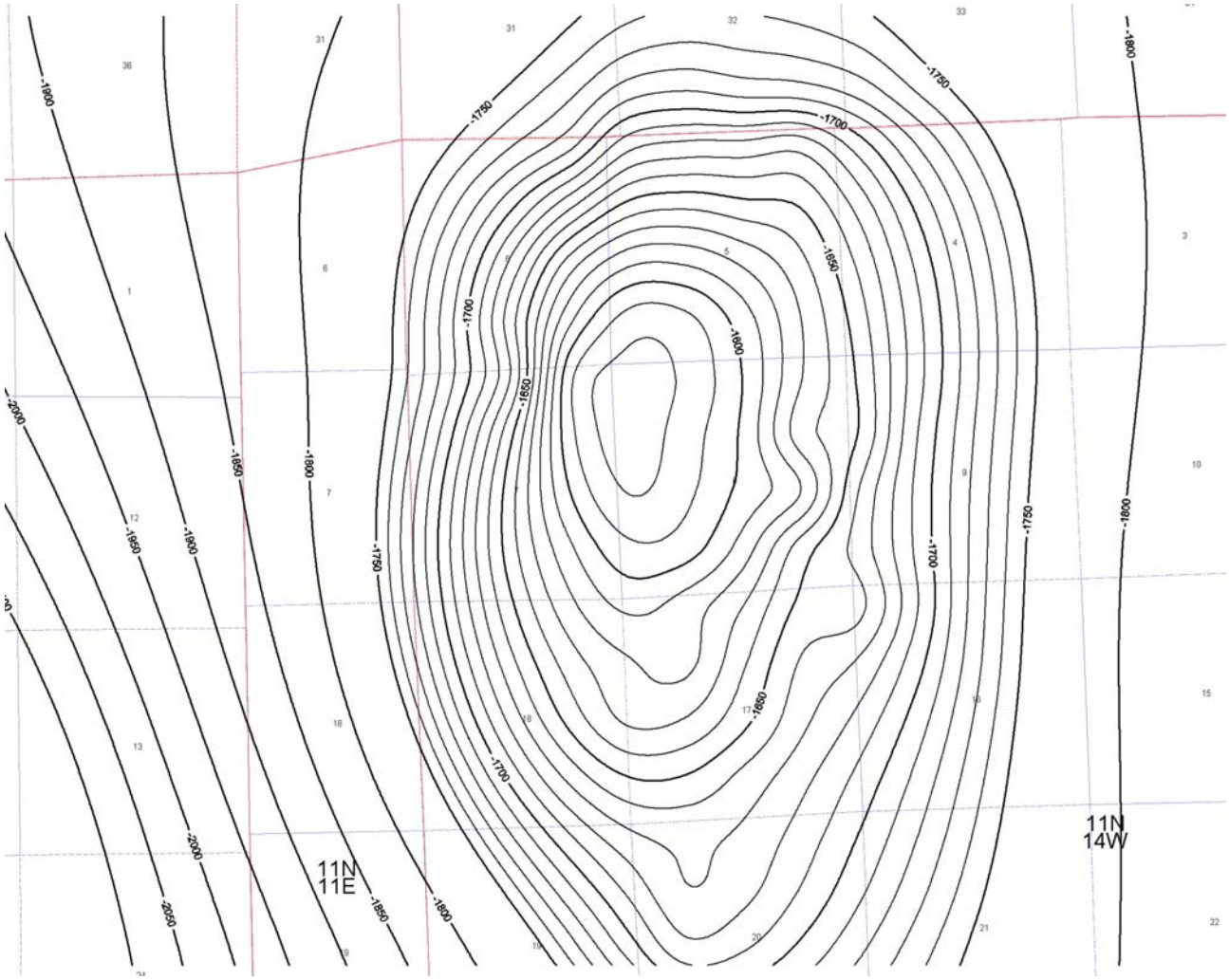


Figure 5. Map of the structure of the top of the Trenton Limestone.

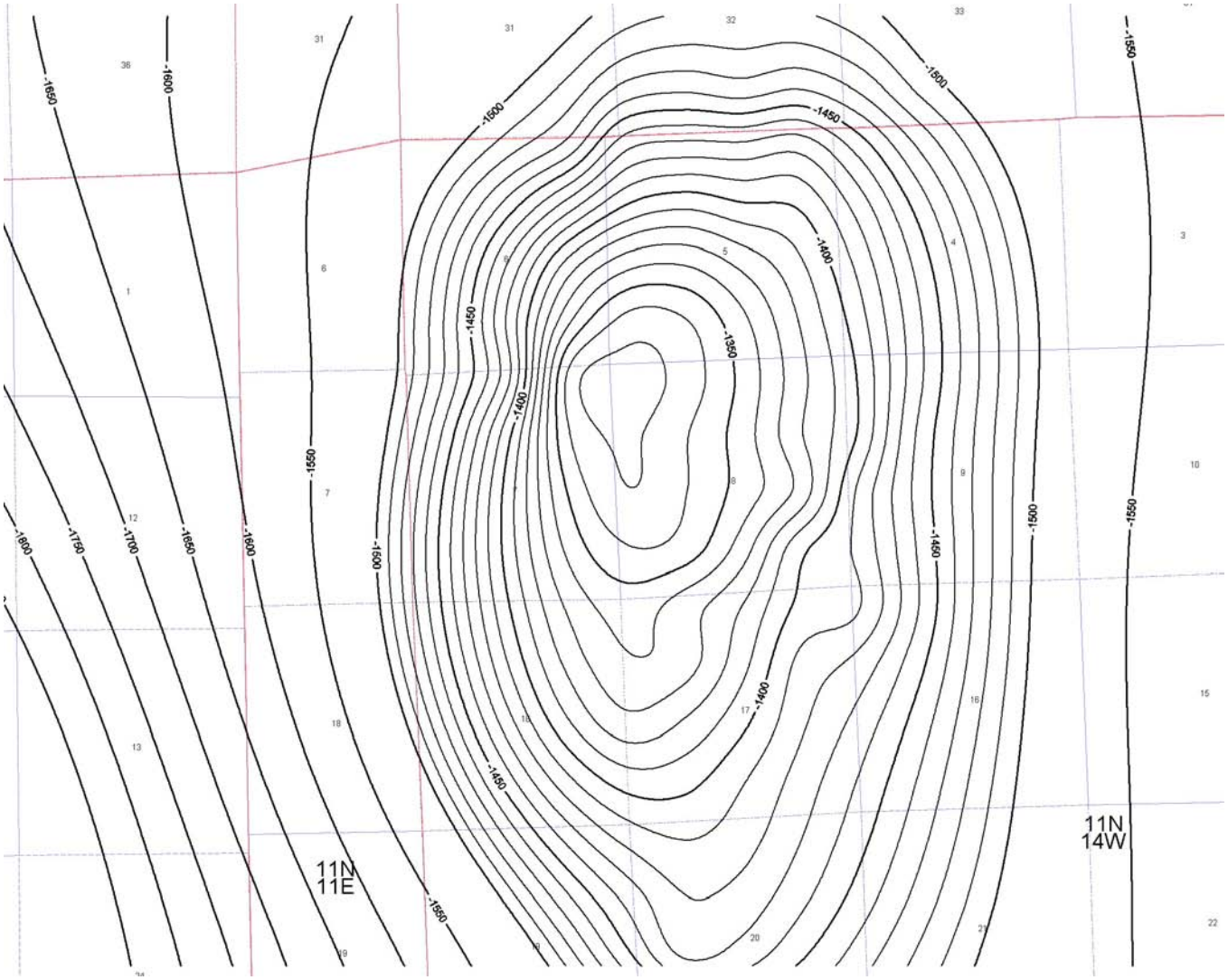


Figure 6. Map the structure on the top of the Maquoketa Shale.

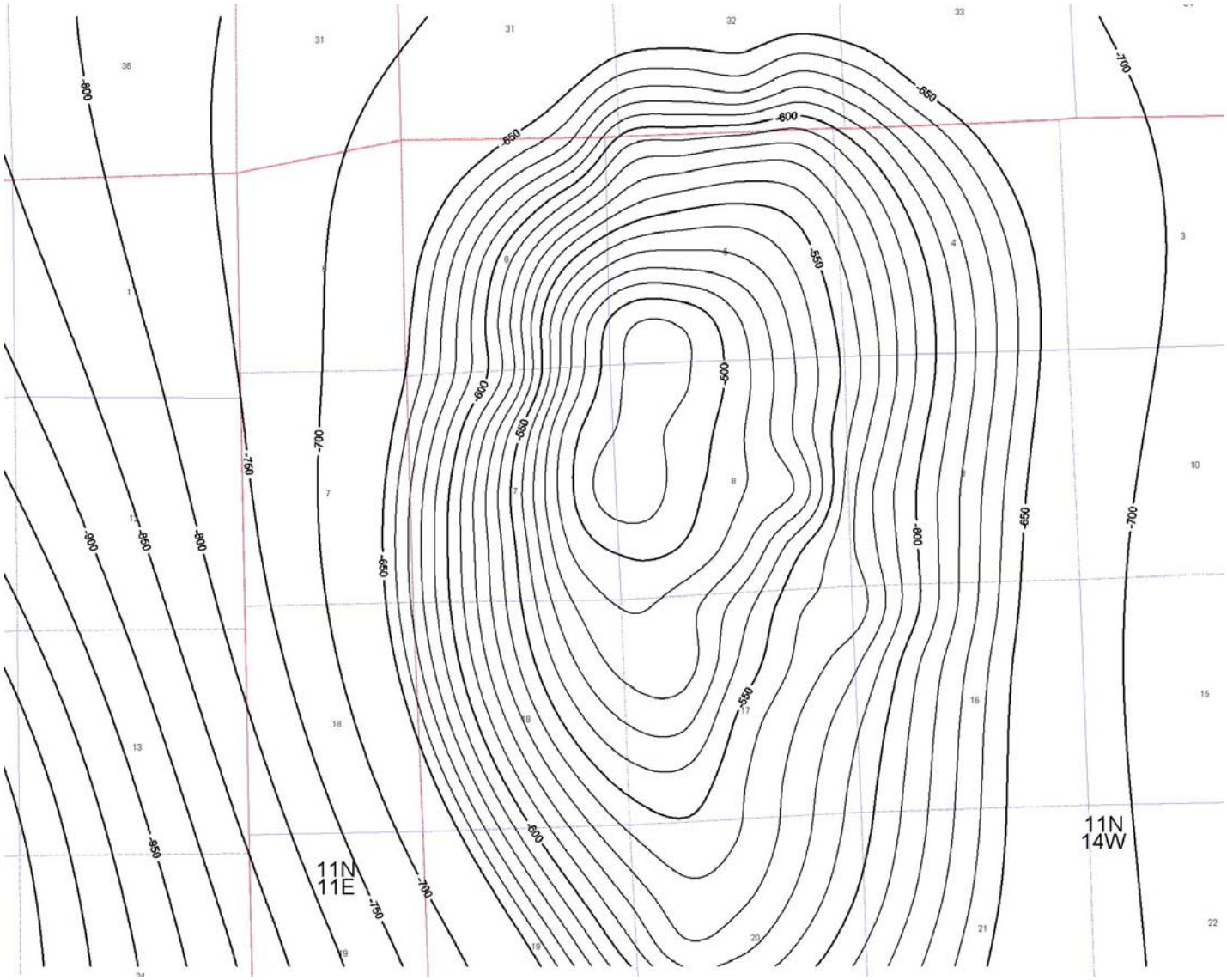


Figure 7. Structure on the top of the New Albany Shale.

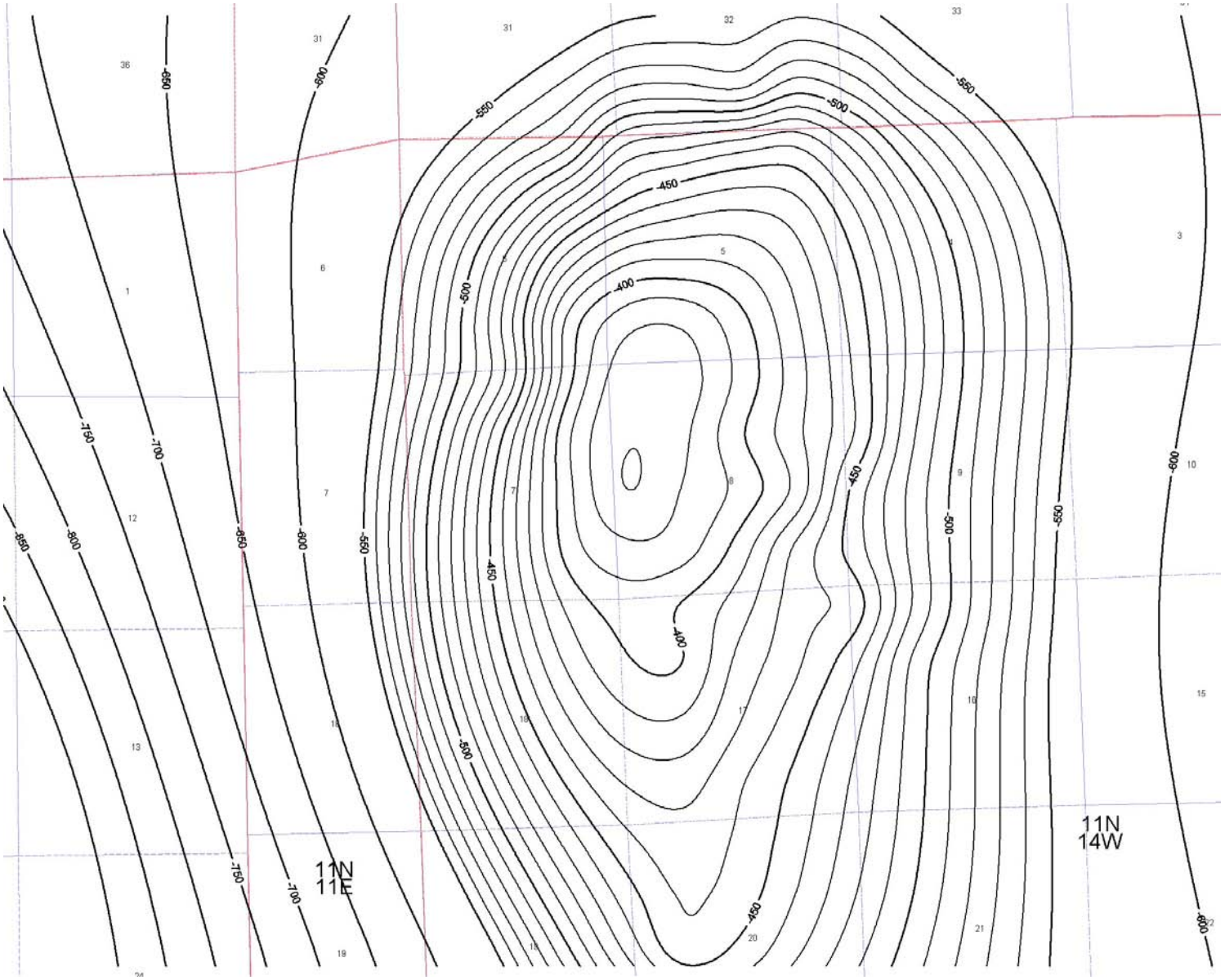


Figure 8. Map of the structure on the top of the Chouteau Limestone.

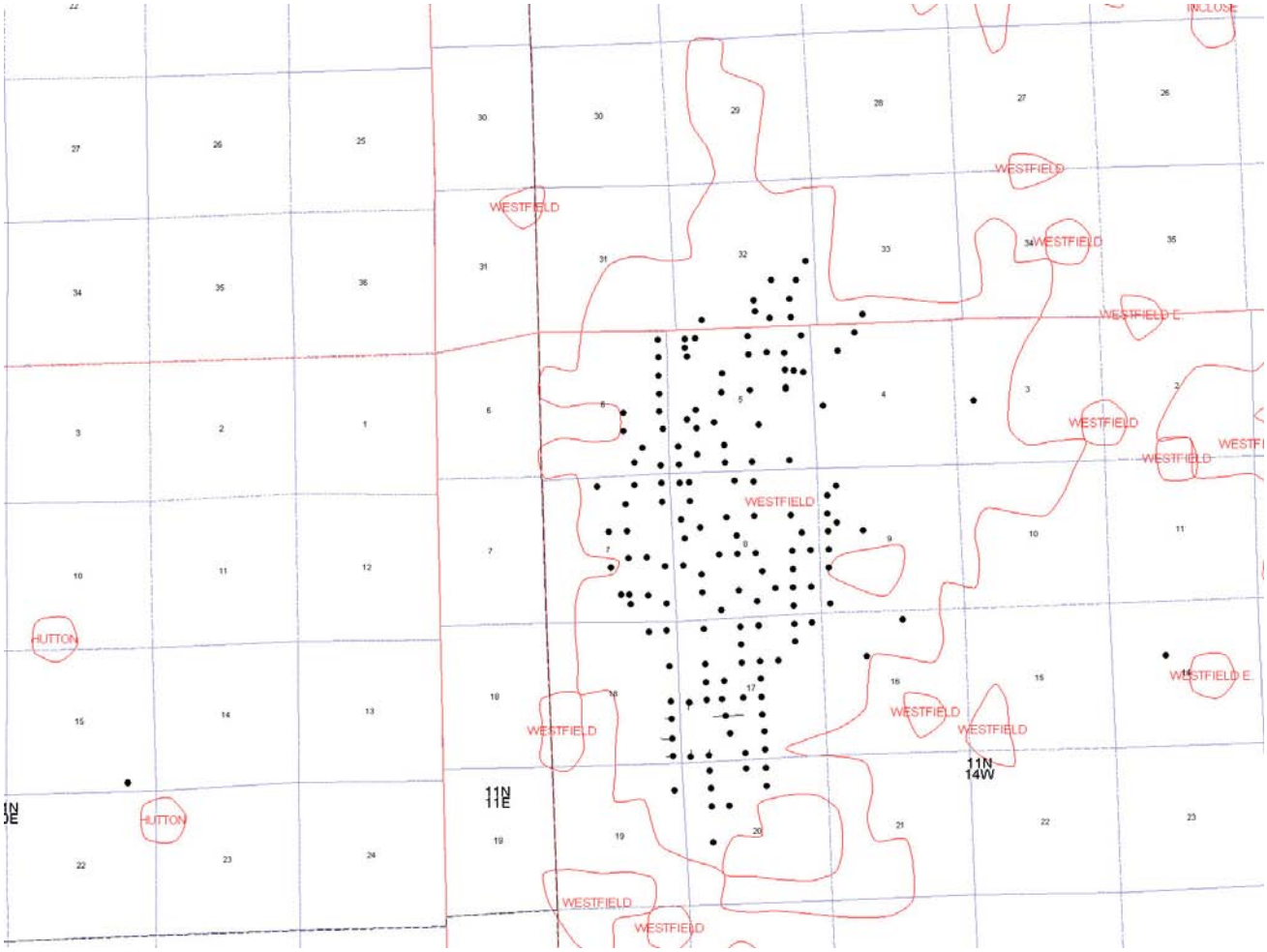


Figure 9. Map showing the location of logged wells penetrating the Trenton Limestone.

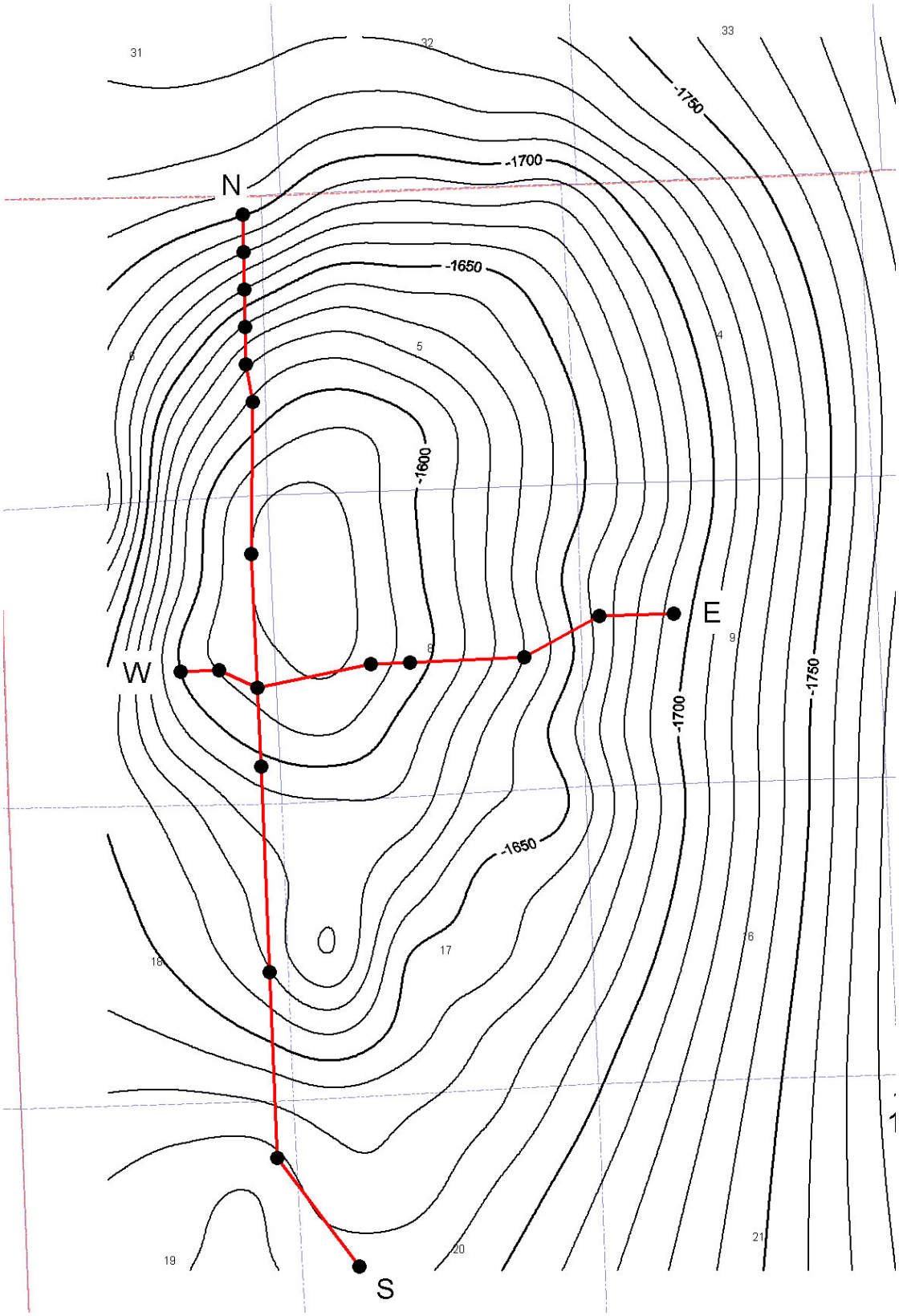


Figure 10. Map of cross sections shown on a contour map of the structure on the top of the Trenton Formation.

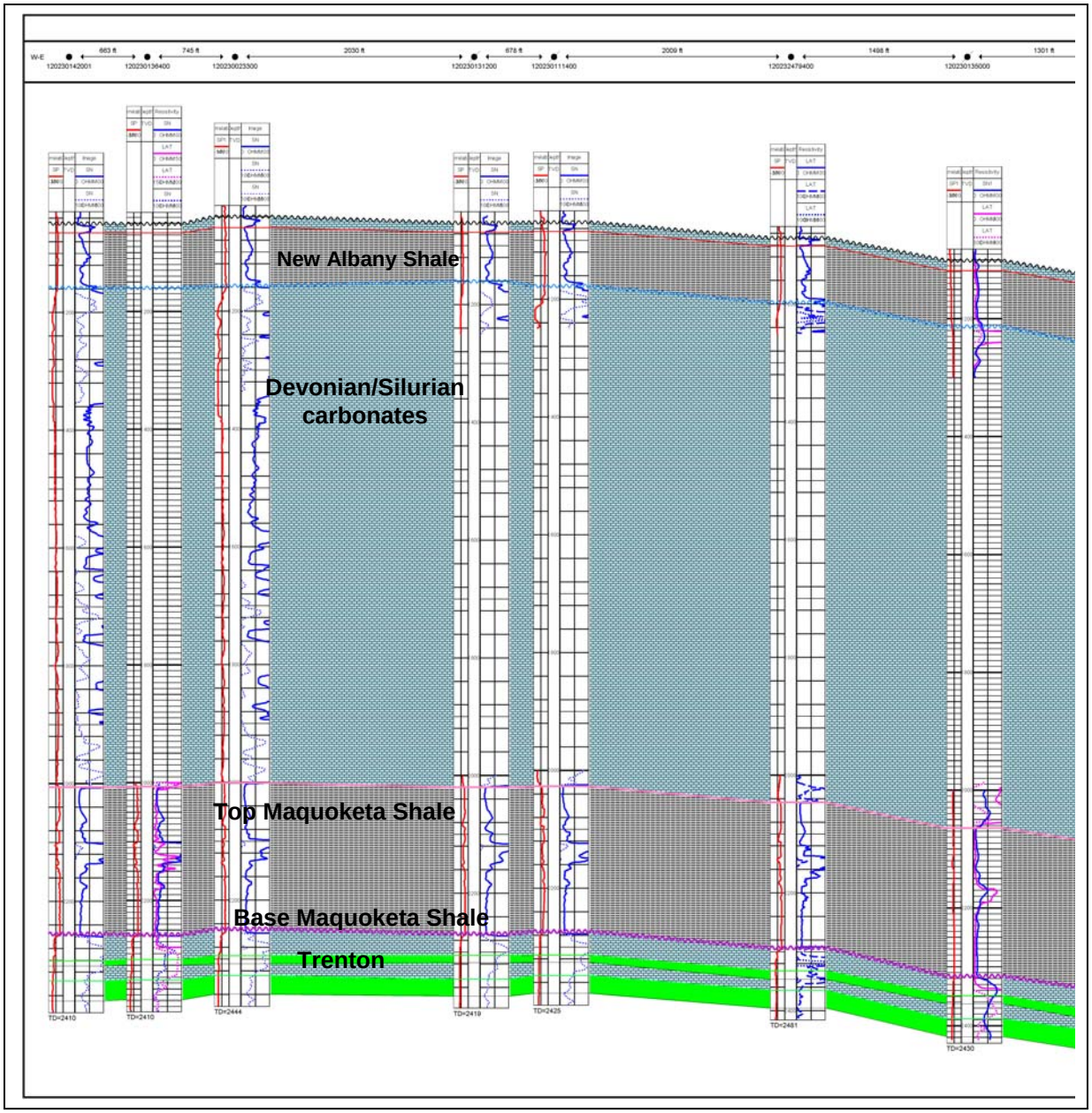


Figure 11.East- West structure cross section of Westfield. Vertical exaggeration is 5X. Index map is shown in Figure 7.

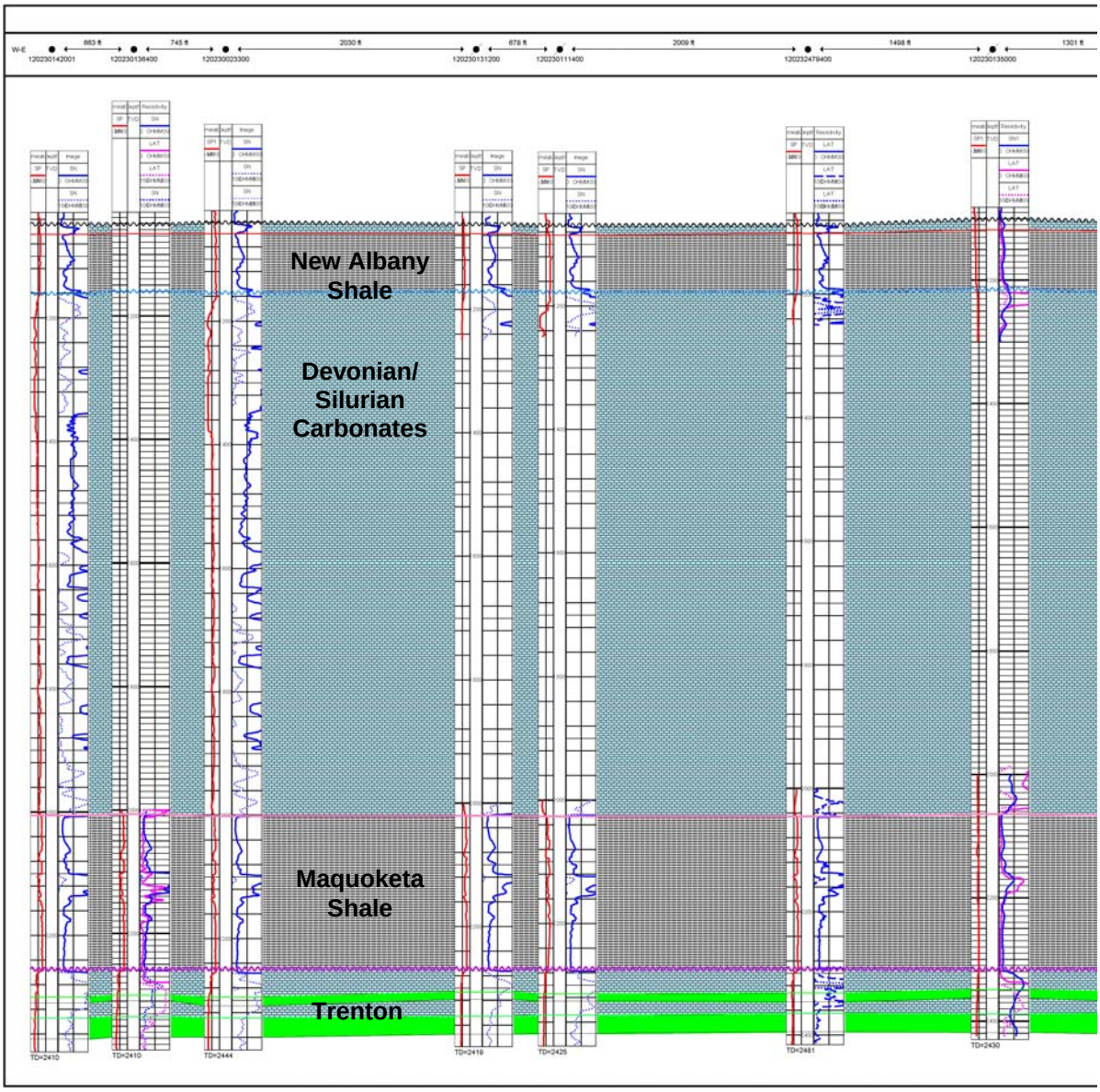


Figure 12. East-West stratigraphic cross section in Westfield. Vertical exaggeration is 5X. Index map is shown in figure 7. Green layers are reservoir intervals. Note the layers are all of relatively uniform size across the cross section

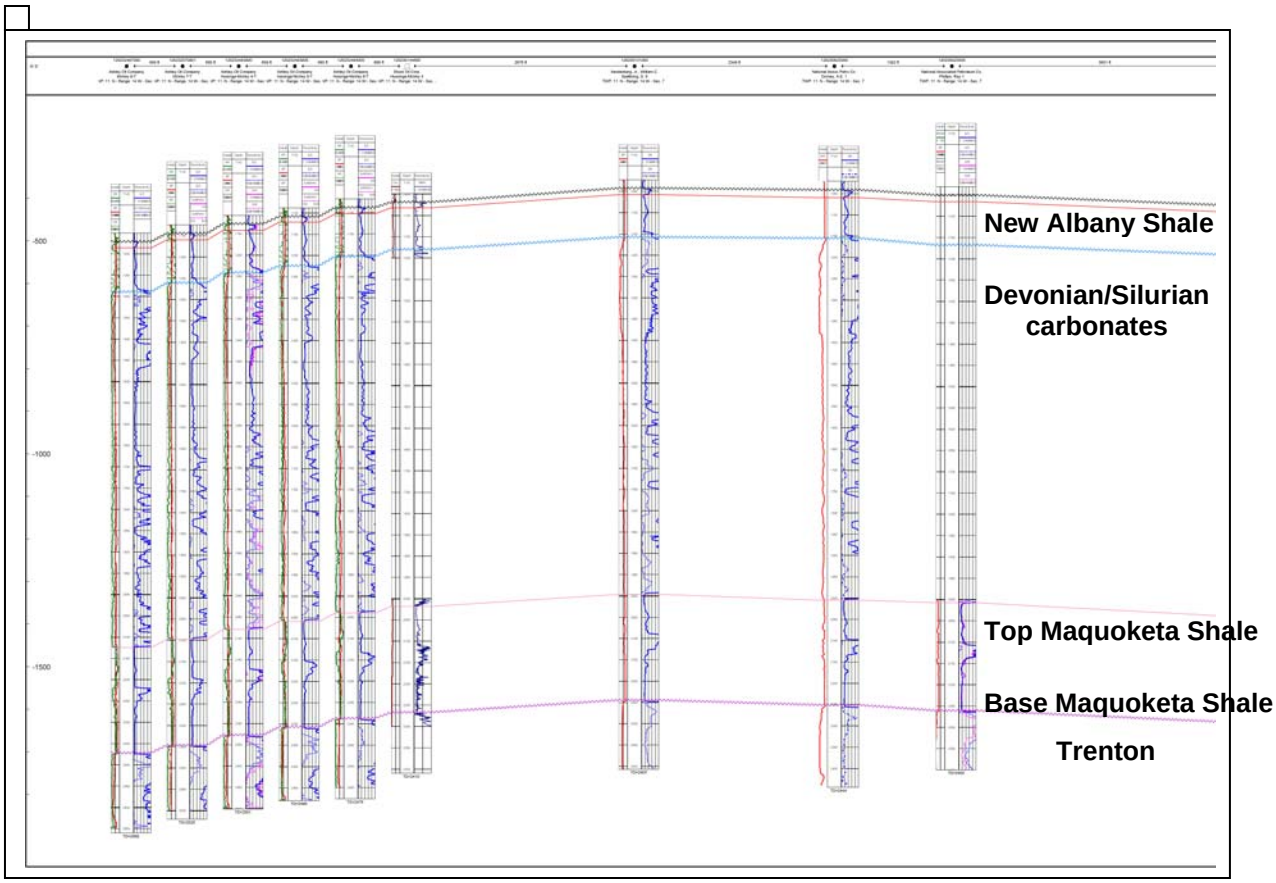


Figure 13. North-South structural cross section across the Westfield field. Vertical exaggeration is 5X.

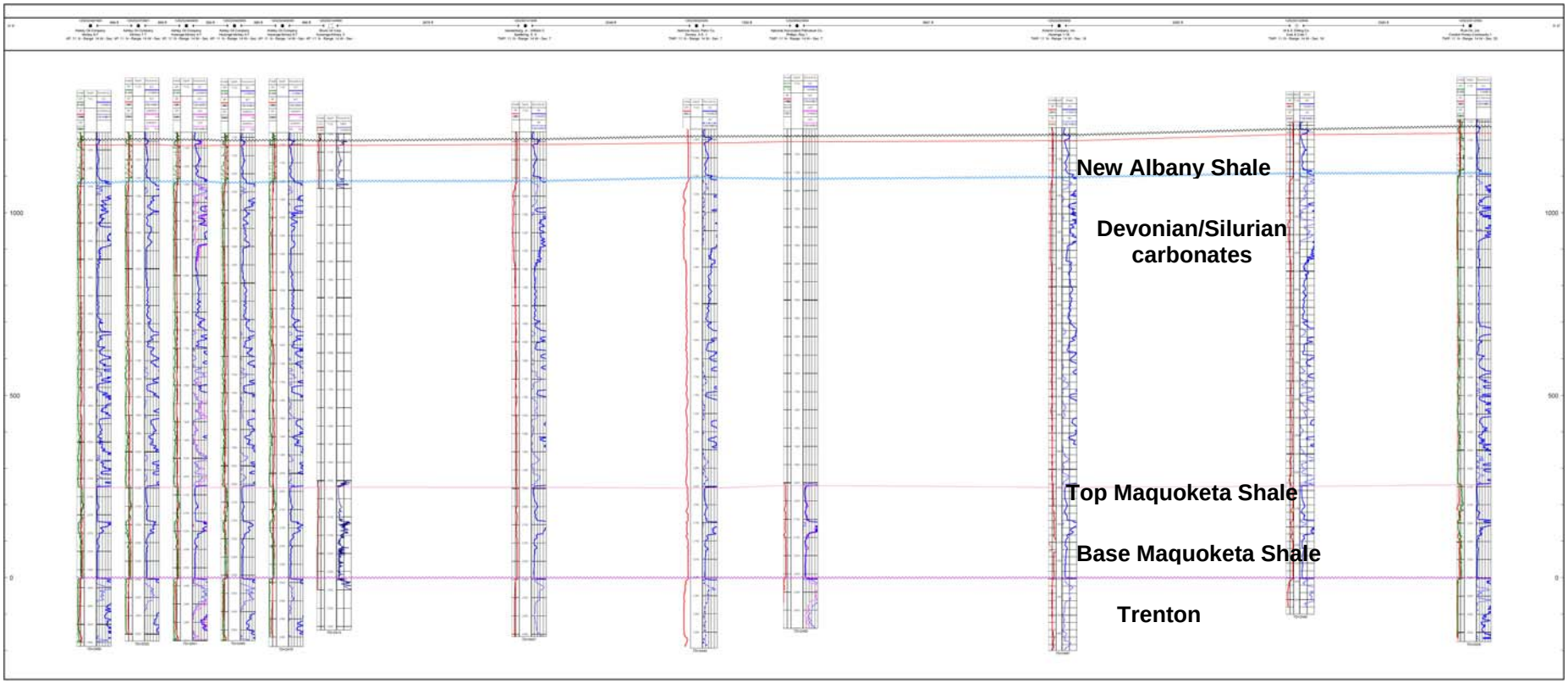


Figure 14. North-South stratigraphic cross section across Westfield. Vertical exaggeration is 5X. The Hunton section thickens towards the south along the "tongue" shaped feature along the southern end of the fold axis.

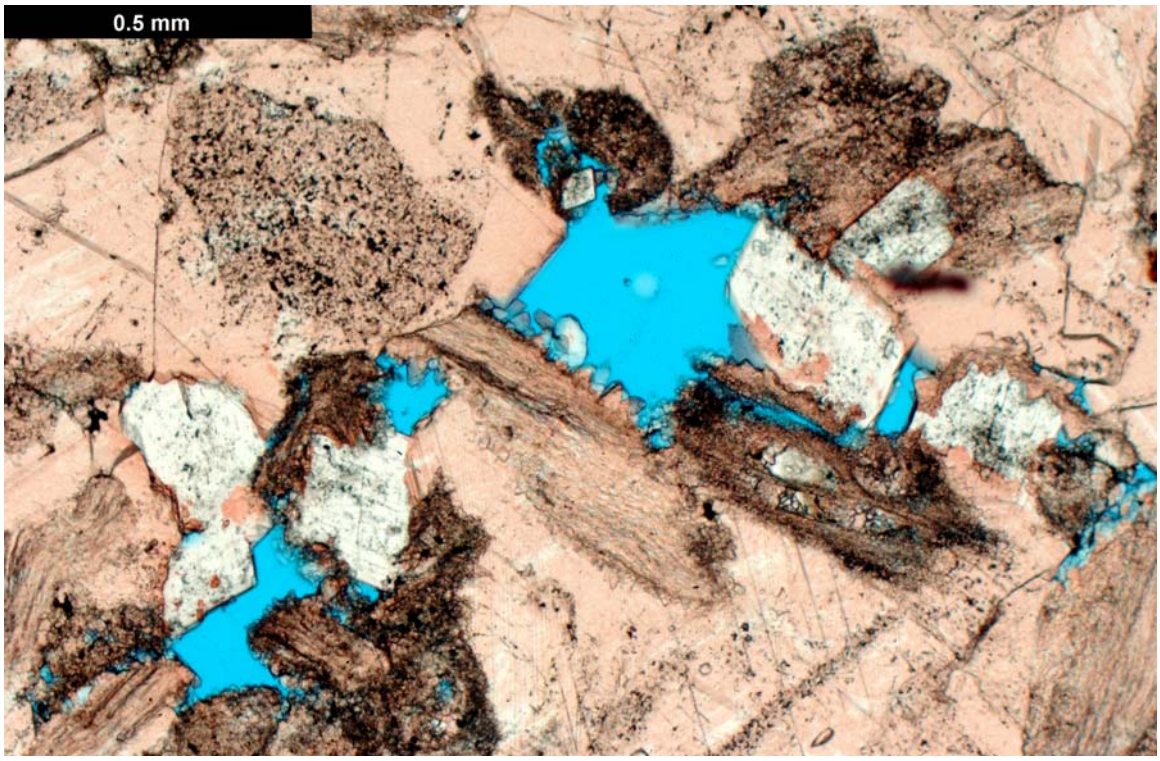


Figure 15. Picture of pore spaces present within parts of the Trenton. Note the sharp euhedral boundaries in several of the cement crystals, porosity appears to be the result of dissolution of carbonate grains and cement

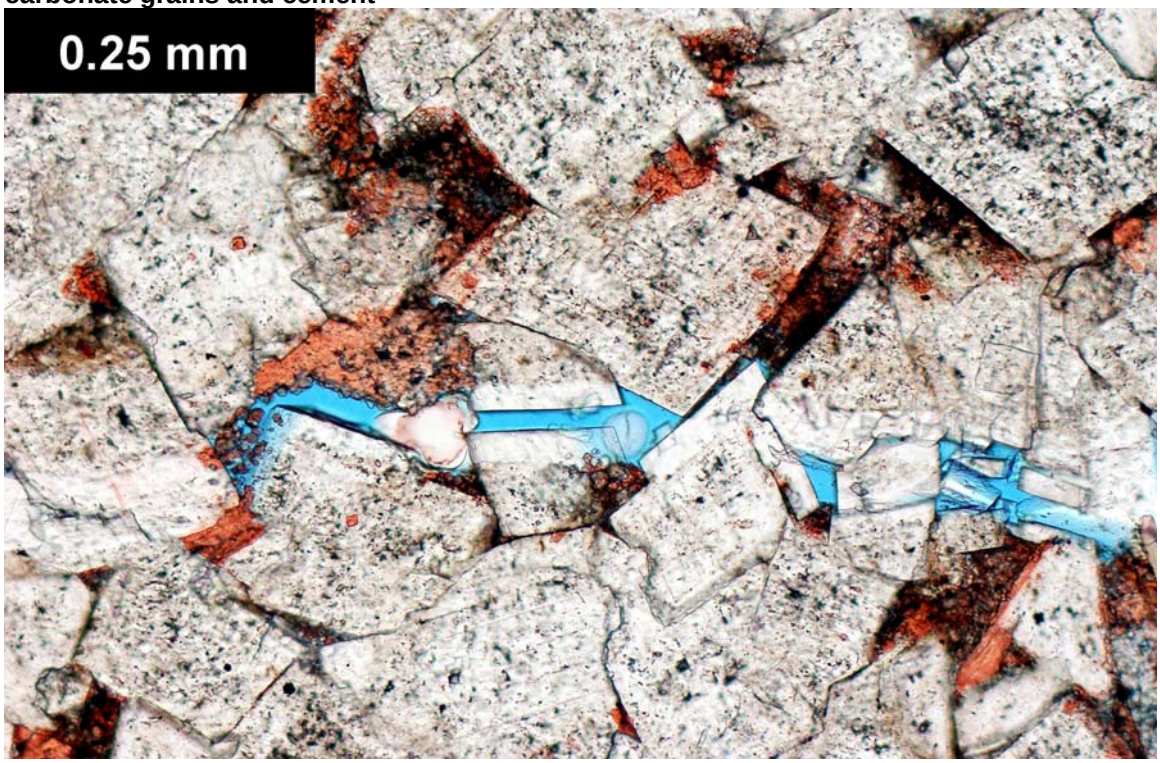


Figure 16. Fracture cutting though dolomite which was formed in a larger fracture (aperture of the larger fracture is about 1.5cm). Notice how the dolomite has grown into the space formed by the fracture.

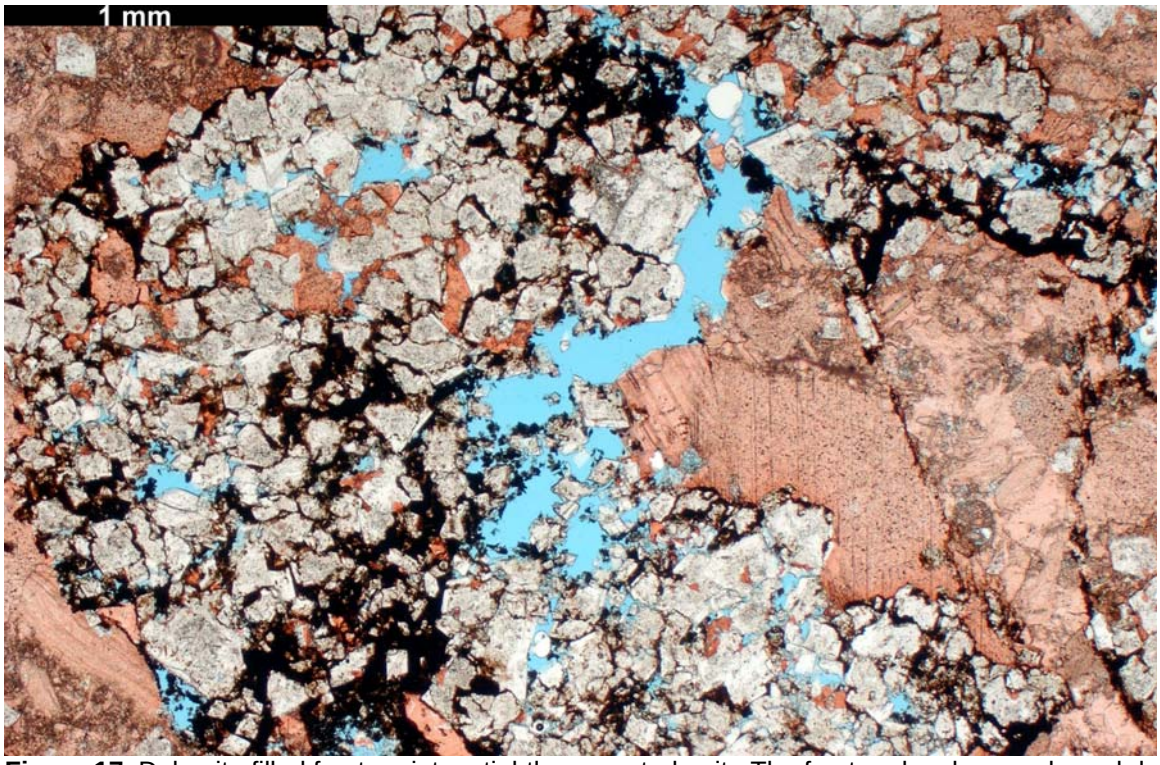


Figure 17. Dolomite filled fracture into a tightly cemented unit. The fracture has been enlarged due to dissolution prior to dolomite precipitation.

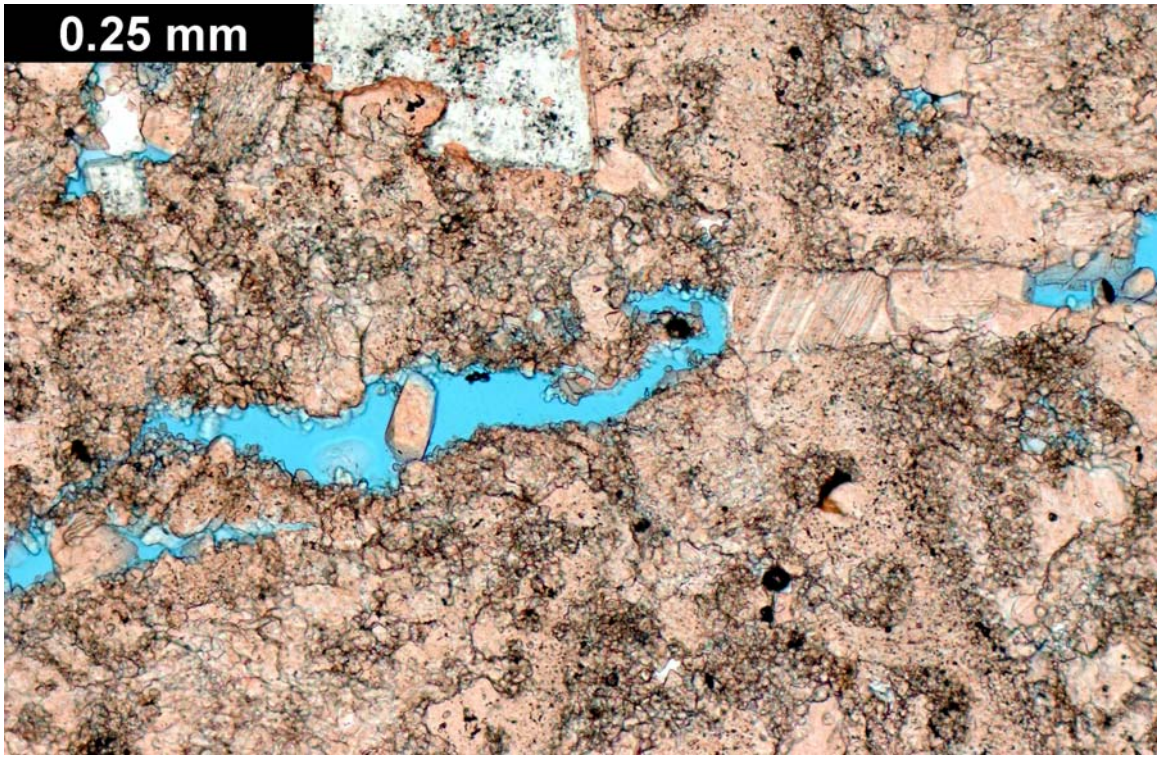


Figure 18. Calcite cement forming in fractures. The calcite cement is present in both a very fine grained lining, but also as a larger blocky cement that has completely bridged part of the fracture.

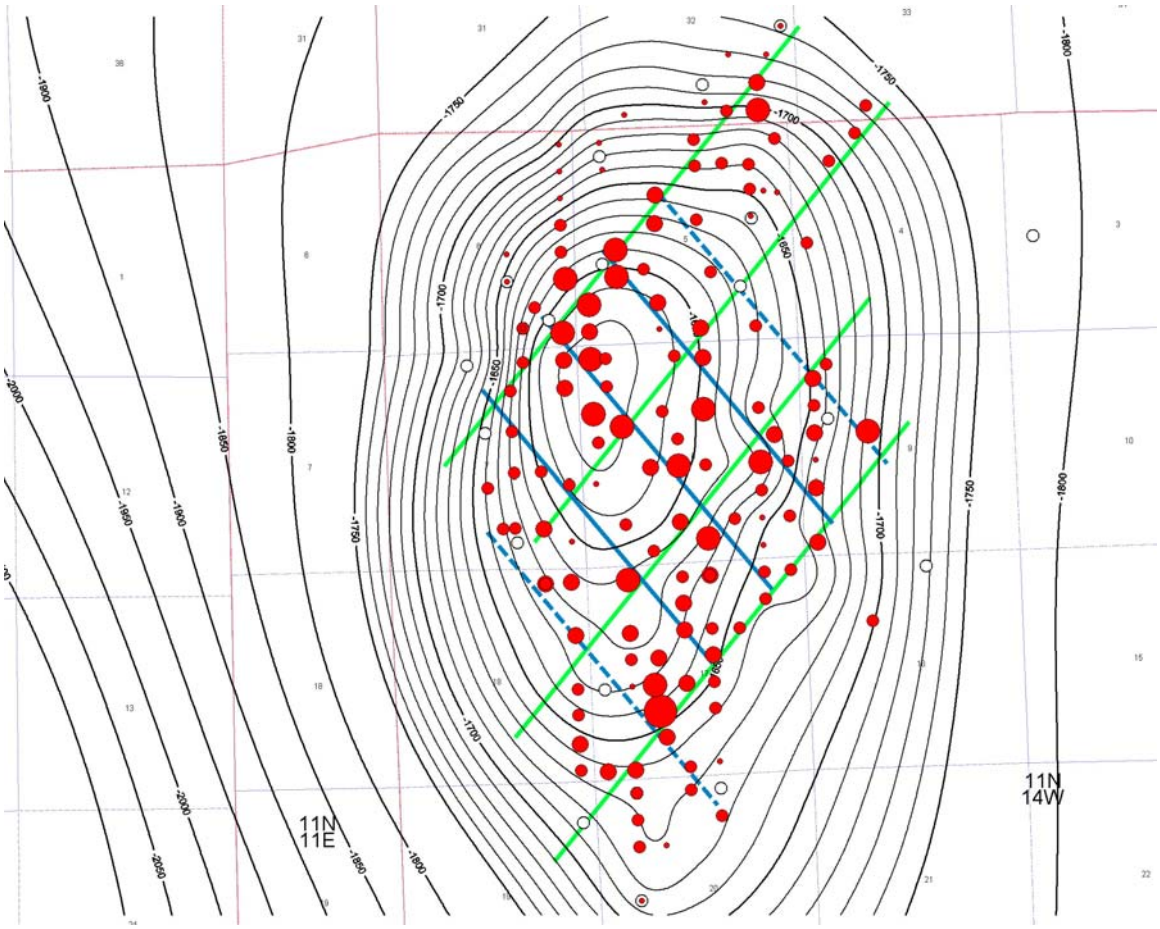


Figure 19. Fracture trends as determined by trends in Initial Production. Dashed lines represent possible fracture zones that lack significant data, but have similar spacing and a few data points.

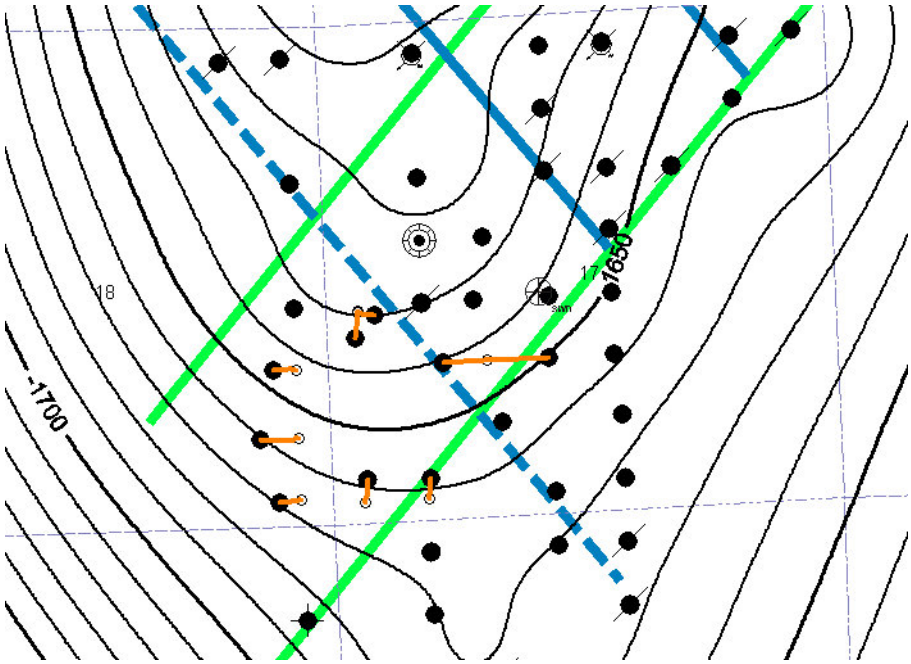


Figure 20. Fracture traces with horizontal wells shown. Well in section 17 with two long West-East horizontal legs is the Lindley #5 well.

Conclusions

Diagenetic alteration of carbonate accumulations to highly porous and permeable dolomite is a key factor in forming many Devonian, Silurian and Ordovician reservoirs in the Illinois Basin. This is not an important factor in younger Middle Mississippian carbonate reservoirs which are typically limestones that display little alteration. Prominent alteration is associated with unconformity surfaces related to the sub-Kaskaskia and sub-Tippecanoe unconformities although hydrothermal fluid alteration within the Ordovician may be widespread and a stratified brine reflux mechanism may be a significant component in the development of the Geneva Dolomite.

Many existing Lower Paleozoic fields in the Illinois Basin have pronounced structural closure, some are associated with differential compaction of younger strata over Silurian reefs which may themselves be related to paleotectonic features. Many of the major structures in the basin are also expressed in Lower Paleozoic strata and are likely to have expression as basement features.

There is a shift of closure with depth observed in some structural features. The location of the crest of structures changes with depth and structurally closed areas mapped on younger Middle Mississippian strata are not the same areas as those mapped on older Lower Paleozoic Devonian, Silurian and Ordovician strata. Therefore, the established exploration practice of drilling shallow structures to deeper depths is a strategy that must be refined to successfully explore for Lower Paleozoic reservoirs.

There is potential in the Illinois Basin for the discovery of hydrothermally altered fault/fracture based plays in the Ordovician Trenton Limestone similar to those found in the Michigan and Appalachian Basins. Analysis of porosity and permeability data from Trenton rocks shows generally low porosity in most samples however there is a smaller distribution of samples with very high porosity and permeability indicating sporadic development of intervals of excellent reservoir quality.

There are examples of combination traps with a strong stratigraphic component e.g. the Niagaran age Silurian production along the Sangamon Arch. The alteration of fossiliferous limestones to dolomites with moldic and vuggy porosity is a major factor in developing petroleum reservoirs in these units.

There is potential to more fully develop the subcrop play of Lower Devonian reservoirs in the deeper Fairfield portion of the Illinois Basin. Interpretation and analysis of available data for these units will assist exploration for stratigraphic traps.

Existing reservoirs in lower Paleozoic units in the Illinois Basin produced from pronounced structural closures. Recent research on the structural evolution of major features in the Illinois Basin suggests that the Illinois Basin was influenced by nearby late Paleozoic events related to the nearby Appalachian – Ouachita Orogenies (Kolata and Nelson 1991) as well as Ancestral Rockies events associated with compressive block style deformation (Marshak et al., 2003). These findings suggest the potential for fracture and fault related reservoir discoveries within lower Paleozoic units.

There has been a significant increase in permits issued to drill to Lower Paleozoic since the inception of this study. Staff at all three participating surveys have fielded numerous requests for information and advice regarding exploration and development in Lower Paleozoic units. Numerous test wells have been drilled with significant discoveries in the Mt. Auburn trend in Illinois and in other areas.

Source Rocks

It has been established by previous workers that Silurian and younger reservoirs in the Illinois Basin are sourced from the Devonian New Albany Black Shale. While the New Albany Shale contains intervals that exceed 10 percent Total Organic Carbon and some regions are in the oil window, there has been sparse exploration in this unit as a petroleum reservoir. The New Albany Shale has potential to become a producing horizon in the Illinois Basin.

The Upper Devonian New Albany Shale is a widespread, thick, organically-rich source rock that is present virtually everywhere that oil and gas are produced in the Illinois Basin. It is thickest in southern Illinois and western Kentucky, where it is more than 400 feet thick. The source rock is predominantly Type II Oil Prone material and is the major source of oil in Silurian through Pennsylvanian reservoirs in the Illinois Basin. Numerous studies of the New Albany Shale in Illinois (by Cluff et al., 1981, Cluff and Byrnes, 1991) describe an organic rich source rock that is generally in the oil window with some areas of intense generation that likely produced gas in the deep basin and in the Fluorspar District in southeastern Illinois. There has been recent gas exploration in the New Albany in Illinois, most gas discoveries to date have been marginal and are located on anticlinal structure domes, along the LaSalle Anticline trend, at Russellville and Westfield, and on the Clay City Anticline. Although the original gas wells drilled are vertical wellbores, it is believed that production can be improved using horizontal drilling programs, such as one recently undertaken at Russellville. In Indiana, exploration of the New Albany is predominantly on reef-drape structures along the Terre Haute Reef Bank and has resulted in several gas discoveries.

Gas chromatography analyses of oil from 4 Trenton reservoirs, 4 Silurian reservoirs and 3 Devonian reservoirs have been completed for the source rock-oil correlations studies. Interpretation of these gas chromatographs show strong similarities among Trenton samples and similarities among Silurian age oil but Silurian age oils are very different from Trenton age oils. Trenton age oils are largely devoid of n-C17 and higher components while the heavy end of the Silurian age oils taper off gradually.

Upper Middle Devonian Production

Lingle and Cedar Valley limestone reservoirs are the youngest Middle Devonian producing strata in Illinois. Lingle production is primarily associated with regional anticlinal structures (Assumption Field in Christian Co., at the northern toe of Louden Field in Fayette Co., and Woburn Field in Bond Co.). Hoing Sandstone occurs in the basal Cedar Valley limestone and is a prolific shallow pay at Colmar-Plymouth Field in western Illinois. The Hoing Sandstone lies at the sub-Kaskaskia unconformity and is composed of well rounded, highly porous, dolomite cemented sandstone similar to the Dutch Creek Sandstone.

Lower Middle Devonian Geneva Dolomite Miletus Field

The Geneva Dolomite is one of the most prolific reservoir units in the Illinois Basin. It produces from reef-drape areas (Miletus, Lillyville, and Tonti) and on regionally-extensive anticlines with strong elements of closure (Centralia, Salem, and Louden). It is formed from regional dolomitization of fossiliferous limestone deposits. Middle Devonian strata commonly have sand grains distributed throughout the predominantly carbonate lithology, but only occur as bedded layers in limited areas of the basin.

Production in Miletus Field in Marion County Illinois increased from 10,000 barrels per year to 100,000 barrels per year after the Geneva Dolomite discovery. A total

of 2 million barrels of oil were produced from the Geneva Dolomite in the first 2.5 years of production. Miletus is a typical example of a Geneva Dolomite field with closure created by differential compaction over an underlying Silurian Reef. Younger Devonian strata thin 20 feet or more over the top of the reef due to less deposition over the paleo-high. 3-D seismic exploration was successfully used to define this prolific extension reservoir beneath Forbes Lake to the south. Horizontal/directional drilling beneath Forbes Lake was also an element to the success at Miletus/Forbes Lake.

Middle Devonian Dutch Creek Sandstone Pays

Dutch Creek Sandstone reservoirs are located at the base of the Middle Devonian, at or just above the Sub-Kaskaskia unconformity. The reservoirs are quartz sand with dolomite cement. Sands are lenticular and grade laterally and vertically into sandy dolomite or limestone. The distribution of Dutch Creek reservoirs has been expanded in recent years to include production in Clay and Jasper Counties. Sands may be deposited in lows, sinkholes, or fractures on the unconformable Lower Devonian carbonate surface, and sand is not uncommon throughout the Grand Tower. All established fields are located on positive structural features. Although the deposits are thin (usually less than 15 feet), they may be prolific reservoirs. One Dutch Creek well in Aden Field has produced over 2.4 million barrels of oil from the Dutch Creek and shallower Mississippian pays.

Lower Devonian Reservoirs Sesser Field

The sequence of events leading to development of reservoir quality rock in Lower Devonian strata in central Illinois started with deposition of carbonates containing abundant sponges. Followed by dissolution of silica in some sponge spicules; re-precipitation of silica as microcrystalling chalcedony and quartz (chert nodules and bedded chert) leading to formation of porous chert. In Sesser Field uplift and erosion at sub-Kaskaskia unconformity has apparently removed upper Clear Creek deposits. All Clear Creek Fields have strong element of structural closure. The Clear Creek and the Grassy Knob Formations contain cherty intervals that are under-explored plays. All established Lower Devonian fields have a strong element of structural closure, there is indication that there is potential for a stratigraphic subcrop play in the region.

Lower Silurian Reservoir at Buckhorn Field in Western Illinois

Buckhorn Consolidated Field in Adams and Brown counties in Illinois is one of the most productive Lower Silurian fields in the Illinois Basin. The field was discovered in 1961 with a substantial field extension discovery in 1981 and has produced over 2 million barrels of oil from a depth of 650 feet. The producing horizon is a sucrosic dolomite located at the base of the Silurian carbonate section in the Kankakee Formation and directly overlies the sub-Kaskaskia unconformable surface on the Ordovician Maquoketa Shale. Kankakee carbonates accumulated in a regional drainage system eroded into the underlying Maquoketa Shale in response to the initial Silurian marine transgression. Later diagenetic events led to preferential dolomitization and dissolution of fossils to form moldic and vuggy porosity in the basal Silurian carbonates. Structure played a minor role in petroleum accumulation at the Buckhorn Consolidated Field. The Devonian New Albany Shale is the ultimate seal for the field.

Silurian Pinnacle Reef Play

Most of the Silurian reefs were discovered in the 1940s and 1950s, using traditional seismic and subsurface mapping to identify favorable positive structures for

drill sites. The New Albany Shale is in close contact with the reef and is the source rock as well as the reservoir seal. Production occurs from both fossil framework build-ups and flank deposits, as well as younger porous strata draped over the reefs. Most reef production occurs on the west side of the DuQuoin Monocline, in a region known as the Sparta Shelf. Diagenetic alteration and microfracturing likely contribute to reservoir quality. New reef production has been discovered as recently as 2002, when Vintage Resources re-entered an old test well and found oil in the Stone Church field. The Stone Church reef was discovered in 1994 using gravity, magnetics and 2-D seismic in addition to linear trend interpretation and lithology studies. The reef is associated with an underlying basement fault that dies out in the Maquoketa shale beneath the reef. East of the Du Quoin Monocline, the reefs are covered by thicker layers of Middle Devonian sediments, which is may prevent the Silurian reef from being charged with oil. These reefs have, however, contributed to the formation of several prolific Devonian reservoirs.

Sangamon Arch

The Sangamon Arch is a broad southwest-trending structure in west-central Illinois, which was formed as a result of upward warping during Late Silurian through Early-Middle Devonian times. The Silurian deposits of the Sangamon Arch are bounded by the pre-Middle Devonian (sub-Kaskaskia) and post Ordovician interregional unconformities. Oils are sourced from the New Albany shale, and reservoirs are charged where the Devonian sediments are absent due to erosion or non-deposition. Some reservoirs have been enhanced by hydrothermal and meteoric dissolution of fossils and dolomitization of sediments. Oil production from Silurian strata along the Sangamon Arch, includes two field study areas, the Springfield East Field and the Mt Auburn trend. The two fields depict the two main types of plays in the area. The channelized patch reefs such as Springfield East and the patchy barrier type reefs of the Mt. Auburn Consolidated field.

Silurian Patch Reefs: Springfield East

The Springfield East Field was discovered in 1960, and has produced 684,000 barrels of oil. Production correlates with deposition of Devonian sands, although the production is from the Silurian inter-reef sediments. Channels formed between reefs because reefs were more resistant to erosion. Payzone sediments are dolomitized, transported bioclasts have been dissolved, creating significant porosity and permeability. Silurian sediments underlying sands were karstified during the deposition of the Devonian sands, which served as a conduit for hydrothermal fluids and further alteration after burial by the New Albany Shale.

Silurian Carbonate Reservoirs: Mount Auburn Trend Along the Sangamon Arch:

The Silurian deposits of the Sangamon Arch are bounded by the pre-Middle Devonian (sub-Kaskaskia) and post Ordovician interregional unconformities. As a result of pre-Upper Devonian erosion, no Lower and Middle Devonian rocks are present on the Sangamon Arch. The Silurian rocks of the Sangamon Arch have produced for over 60 years with cumulative production being more than 20 million barrels of oil from dolomitized carbonates in the upper part of the Silurian succession. In the Mount Auburn trend, production thus far has been chiefly from the uppermost part of the Niagaran Series; most wells did not test the deeper reservoirs. This study identified permeability pinch outs at several horizons along the Mount Auburn trend in Macon, Christian and Sangamon Counties. The reservoirs display shallowing-upward cycles and include dolomitized bioclastic grainstone facies in the upper part and dolomitized coral

reef/rudstone facies in the lower part of the Niagaran succession. The reservoirs are of limited lateral extent. The highest production is associated with these lower reservoirs that most wells have not tested.

Trenton Oil Fields and Potential Production in Illinois

Trenton production in Illinois is confined to areas with pronounced structural closure at the base of the Ordovician Maquoketa Shale. Several fields produce from permeable grainstone intervals in which oil is trapped by overlying dense limestone. Production from dolomitized fractured intervals has been reported in other fields. There are 35 separate Trenton pools, most having been discovered from the early 1940s to the late 1960s. Size ranges from 20 – 2,000 acres at depths up to 4,000 feet. Up to 5 million barrels per field has been produced. All fields produce on structures and are most likely fractured. Most reservoirs have low porosity. Some reservoirs are dolomitic. There is potential for fault-based Trenton reservoirs in Illinois similar to the Albion Scipio Field 200 miles to the north in the Michigan Basin.

Trenton Production at Centralia and Westfield

In Centralia Oil field there is a shift in structural closure with depth. The Mississippian Barlow Limestone contoured structure map shows an elongate anticline with north and south regions of closure separated by a small saddle. The Trenton Limestone contoured structure map has closure on the north end of the anticline and the crest as mapped on Barlow has shifted to the south. Trenton production is confined to the anticlinal closure mapped on the Trenton. The reservoir interval is composed of grainstone containing dissolution-enhanced porosity.

There is potential for deeper Trenton grainstone reservoirs throughout the Illinois Basin. Trenton structural closure may not be reflected by shallower horizons. Westfield in eastern Illinois produces on a dome with 100 feet of closure on the Trenton. The reservoir is fractured limestone with dolomite reported in some intervals. There are three porous intervals in Westfield. Major fracture trends based on alignment of high initial production show fractures oriented northeast-southwest and another set oriented perpendicular to the primary set. Many wells exhibit flush production associated with fractures. Horizontal Trenton wells at Westfield generally have much higher production rates than surrounding vertical wells. East-west horizontal legs have higher production rates than north-south legs. Major fracture trends may be caused by basement faults. There is the potential for significant fault related oil discoveries on the flanks of structures.

Secondary Porosity in the Trenton (Galena) Dolomite of Northern Illinois

Outcrop study of the Trenton in Northern Illinois shows karstification along fractures. The porosity models and fracture patterns developed for the outcrop have application for exploration of Trenton reservoirs in the subsurface. Karstification in the Trenton occurred in the following sequence: Galena deposition (mid-Ord), uplift and meteoric karstification (mid-Ord), Maquoketa through Devonian deposition (mid-Ord thru Dev), hydrothermal karstification (late Paleozoic), uplift, erosion, and further meteoric karstification (late Paleozoic thru present). Secondary porosity occurs as conduits, fractures, and matrix vugs. Fractures and conduits are arranged in an orthogonal pattern with conduits forming at the fracture junctions. Primary fluid flow occurs through conduits, followed by flow from fractures, with fluid storage occurring in the matrix.

Source beds for the Trenton are the overlying Maquoketa shale and the underlying Guttenberg (Decorah) shale. Hydrocarbon can be trapped in faulted karst domes.

Technology Transfer

Website Development

Over 100 publications in the Illinois State Geological Survey Circular Series and 128 publications in the Illinois Petroleum series related to petroleum exploration and development in Illinois have been scanned and linked to the ISGS website for the public to view. Information is continually added to the website. To date over 140,00 scanned log images are available on the ILoil website, including all lower Paleozoic geophysical logs in Illinois. Data and previous studies pertaining to the New Albany Shale are available on line through the ISGS website which can be accessed at isgs.uiuc.edu. Much new data has been added to the ILoil website.

Presentations and Publications:

J.P. Grube, Seyler B., Huff, B. G. and Crockett, J. E., 2004, Trenton Oil Fields and Potential Production in Illinois, Program with Abstracts 2004 American Association of Petroleum Geologists 33rd Annual Eastern Section Meeting, p. 78-79.

H. E. Leetaru, 2005 Trend Surface analysis of the Trenton, presented at the Illinois Oil and Gas Association Meeting March, 2005 at Evansville, Indiana

Seyler B., J. P. Grube, J. E. Crockett, P. M. Johanek, B. G. Huff, R. A. Knepp., S. R. Gustison, R. D. Lipking, 2005, Petroleum Potential for the Lower Paleozoic Strata in the Illinois Basin, Eastern Section American Association of Petroleum Geologists Annual Meeting, Morgantown WV, Sept. 18-20, Abstracts Volume, p. 32-33

AAPG National Meeting Houston, Texas April 11, 2006
B. Seyler, J. P. Grube, J. E. Crockett, P. M. Johanek, B. G. Huff, R. A. Knepp, S. R. Gustison, and R. Lipking, 2006, Petroleum Potential of Under Explored Lower Paleozoic Strata in the Mature Illinois Basin, AAPG Program with Abstracts.

Eastern Section AAPG in Buffalo New York October 2006

J. E. Crockett and R. Lipking, Petroleum Potential of Lower Devonian Subcrop Play, Eastern AAPG Program with abstracts

B. Seyler, J. P. Grube, J. E. Crockett, P. M. Johanek, B. G. Huff, R. A. Knepp, S. R. Gustison, R. D. Lipking, Under Explored Lower Paleozoic Strata in Illinois, Eastern Section AAPG Program with abstracts

J. P. Grube, B. Seyler, B. G. Huff, J. E. Crockett, Selected Illinois Basin Lower Paleozoic Cores, Eastern Section AAPG Program with abstracts

Eastern Section AAPG in Lexington, Kentucky September 2007

Dean W. Ekberg, John P. Grube, and Joan E. Crockett, 2007, Secondary Porosity Development in the Galena (Trenton) Dolomite of Northern Illinois: Implications for Regional Fluid Flow and Hydrocarbon Accumulation, Program with abstracts 2007 Eastern Section American Association of Petroleum Geologists Annual Meeting, Lexington, Kentucky

B. Seyler and J. Crockett, 2007, Update of New Albany Shale Potential in Illinois, Program with abstracts 2007 Eastern Section American Association of Petroleum Geologists Annual Meeting, Lexington, Kentucky

Workshop March 5, 2008: Following Presentations were given at the Preconvention Illinois Oil and Gas Association PTTC Workshop in Evansville, Indiana

Secondary Porosity Development in the Galena/Trenton Dolomite of Northern Illinois Dean Ekberg

Trenton Oil Fields and Potential Production in Illinois: John Grube, Joan Crockett and Beverly Seyler

Trenton Production at Westfield and Centralia Fields Jon Brenizer

Siluro-Devonian Carbonates in Illinois: Play Analysis Hannes Leetaru

Western Illinois Shallow Silurian and Devonian Reservoirs at Buckhorn Consolidated and Colmar-Plymouth Fields Beverly Seyler and Joan Crockett

Sesser Oil Field Franklin County, IL Lower Devonian Clear Creek Chert Joan Crockett

Silurian Carbonate Reservoirs of the Mount Auburn Trend Along the Sangamon Arch Yaghoob Lasemi

Springfield East Oil Field Sangamon County, Illinois Bryan Huff

The Origin of Prolific Reservoirs in the Geneva Dolomite (Middle Devonian), West-Central Illinois Basin Beverly Seyler, John Grube and Zak Lasemi

Update of New Albany Shale Potential in Illinois Beverly Seyler and Joan Crockett

Tuscola Stone Quarry Fieldtrip and Core Workshop of Lower Paleozoic Reservoirs held April 17, 2008 at the Tuscola Stone Quarry in Tuscola, Illinois: Core Workshop held at the Illinois State Geological Survey Core Annex.

AAPG Presentations April 2008

Illinois Basin: Potential of Underexplored Lower Paleozoic Strata Beverly Seyler, Joan Crockett, Bryan Huff, Yaghoob Lasemi, Zoreh Askari, Jon Brenizer, John Grube

Ekberg, D.W. & Grube, J.P., 2008, Secondary Porosity Development in the Galena (Trenton) Dolomite of Northern Illinois: Implications for Regional Fluid Flow and Hydrocarbon Accumulation

GSA Presentation

Lasemi, Yaghoob and Seyler, B., 2008, Sangamon Arch Reef Play: An Important Exploration Target in Central Illinois

Kentucky Geological Survey subcontract
David Harris and John Hickman, Kentucky Geological Survey

A Systems Approach to Identifying Exploration and Development Opportunities in the Illinois Basin: Digital Portfolio of Play in Underexplored Lower Paleozoic Rocks

Kentucky Geological Survey subcontract from the Illinois State Geological Survey
Ms. Bev Seyler, Principal Investigator, Illinois State Geological Survey
Dave Harris and John Hickman, Kentucky Geological Survey

Interim Report: Nov. 19, 2008

Project Status

The western Kentucky portion of the Lower Paleozoic study has been delayed due to several reasons. Some of the final products resulting from this work are not complete. These delays have resulted partly from the interruption in DOE funding, which caused staff to be reassigned to other projects. In addition, the later renewal of the final year of funding coincided with the Kentucky Geological Survey (KGS) receiving significant state funding for a major carbon sequestration project resulting in delays for this project. KGS plans to continue work on this project to complete the various tasks defined at the start of the project. We plan to complete this work by June 30, 2009.

Project Outline

The work at KGS has focused on gaining a better understanding of the regional structure and stratigraphy in the Illinois Basin. The following tasks were proposed for the project at KGS:

1) **Interpretation of reflection seismic data.** Interpretation of 2D seismic data from western Kentucky available at KGS. This work was the primary task for KGS in the project, and was completed during the first phase of the project. A report is included below. Seismic data is not included in the report due to licensing restriction. Digital data derived from the seismic interpretation (horizon picks) are include with this report. The task was originally planned to include seismic data from Illinois and Indiana, but these data had not been received when funding was cut.
2) **Regional pre-New Albany stratigraphic interpretation.** This task involved interpretation of formation tops and construction of regional cross sections using digitized and scanned well logs. A subcrop map on the pre-Middle Devonian unconformity is an important part of this task. Key cores will be included. This task is still in progress.
3) **Catalog of Devonian, Silurian, and Upper Ordovician oil fields.** This task involves compiling a summary of fields and data for pools producing from the Devonian New Albany Shale down through the top of the Ordovician Knox Group. Some of this work is complete, but final pool summaries are in progress.
4) **Characterization of pre-New Albany hydrocarbon source rocks.** Compilation of existing source rock data for pre-Upper Devonian rocks.

Task summaries follow:

Interpretation of reflection seismic data, western Kentucky

Overview

The seismic/geophysics portion of this project included the interpretation of 41 regional 2-D seismic lines across southernmost Illinois Basin (Figure 1a-f). After a review of the seismic characteristics of the regional geology within the project area, six major reflection horizons were interpreted. These seismic reflections correspond to the stratigraphic horizons of the:

1) Top of the Devonian New Albany Shale
2) Base of the Devonian New Albany Shale
3) Top of the Upper Ordovician Maquoketa Shale
4) Top of the Middle Ordovician Trenton Formation
5) Top of the Middle Ordovician Black River Group
6) Top of the Lower Ordovician Knox Supergroup

Attempts were made to interpret shallower horizons, but due to data quality and "muting" of the near-surface data to remove interfering surface waves, this was not feasible within our area of data. Fault-cut maps also proved impractical to create due to both the data quality/spacing and the highly complex Rough Creek Graben fault zones that have been exposed to numerous periods of tectonic reactivization.

General Observations

The overall shape and orientation of the Rough Creek Graben and southernmost Illinois Basin can be observed from this data. The asymmetric patterns of stratigraphic packages become thicker and deeper to the west-northwest, away from western Kentucky and towards southern Illinois. While this is also evident from an analysis of the local well data (Figure 2), reflection seismology provides a 2-D view of regional trends, fault zones, etc.

The complicated, inverted nature of the Rough Creek Fault Zone (RCFZ) is also evident in the shallower (Devonian) horizons in this data. Even though the RCFZ is considered to be a down-to-south normal fault system, the top and base of the New Albany Shale horizons are dramatically elevated along and immediately south of the fault zone.

Although the extensional, basement-rooted faults of the Rough Creek Graben formed during the Early – Mid. Cambrian Era, this region of the Midcontinent has been exposed to regional tectonic stresses numerous times since then. The individual orogenies Taconic, Acadian, and Alleghanian that formed the Appalachian Mountains created far-field tectonic compressive stresses. These stresses reactivated this (and other) normal fault zones and created localized reverse faulting and inversion structures along the fault zone trend. The RCFZ was then further deformed during the regional extensional tectonics during the opening of the Gulf of Mexico (Triassic-Jurassic) and the creation of the Atlantic Ocean (L. Triassic – E. Cretaceous). The current RCFZ displays the deformation and offsets created through all six of these orogenies (3 compressive and 3 extensional).

Data Results

The file "LPIB_hrz.asc" comprises our seismic interpretations for this project. This file is an ASCII, column delimited data file with X, Y, and multiple Z values, grouped by individual seismic line names. Lines beginning with "!" are header and/or comment fields. X and Y values are Longitude and Latitude in decimal degrees based upon the NAD-83 datum. Z values are in milliseconds below a 500' above mean sea level datum. Lines processed with other datums were bulk shifted to a 500' datum before exporting. A null Z value of -999.25 is used if the horizon was absent and/or otherwise uncorrelatable. Locations (X, Y) w/o listed horizons (all nulls) were skipped from this output file.

Data file format:

Column 1 Latitude{(NAD83- Decimal Degrees, North)}
Column 2 Longitude{(NAD83- Decimal Degrees, East)}
Column 3 NALB [New Albany Sh]{Time (ms)}
Column 4 NALB_B [Base of New Albany Sh]{Time (ms)}
Column 5 MQKT [Maquoketa Sh]{Time (ms)}
Column 6 TRNT [Trenton Fm]{Time (ms)}
Column 7 BKRV [Black River Gp]{Time (ms)}
Column 8 KNOX [Knox SGp]{Time (ms)}

Also included are related GIS files for Kentucky. These include county outlines, 1:24K mapped surface faults, and oil and gas field outlines (both merged and separated by production type). All files are in Lat/Lon decimal degrees, based upon the NAD83 datum.

If you have any questions or comments, feel free to call me at 859-257-5500 ext.171, or email me at jhickman@uky.edu.

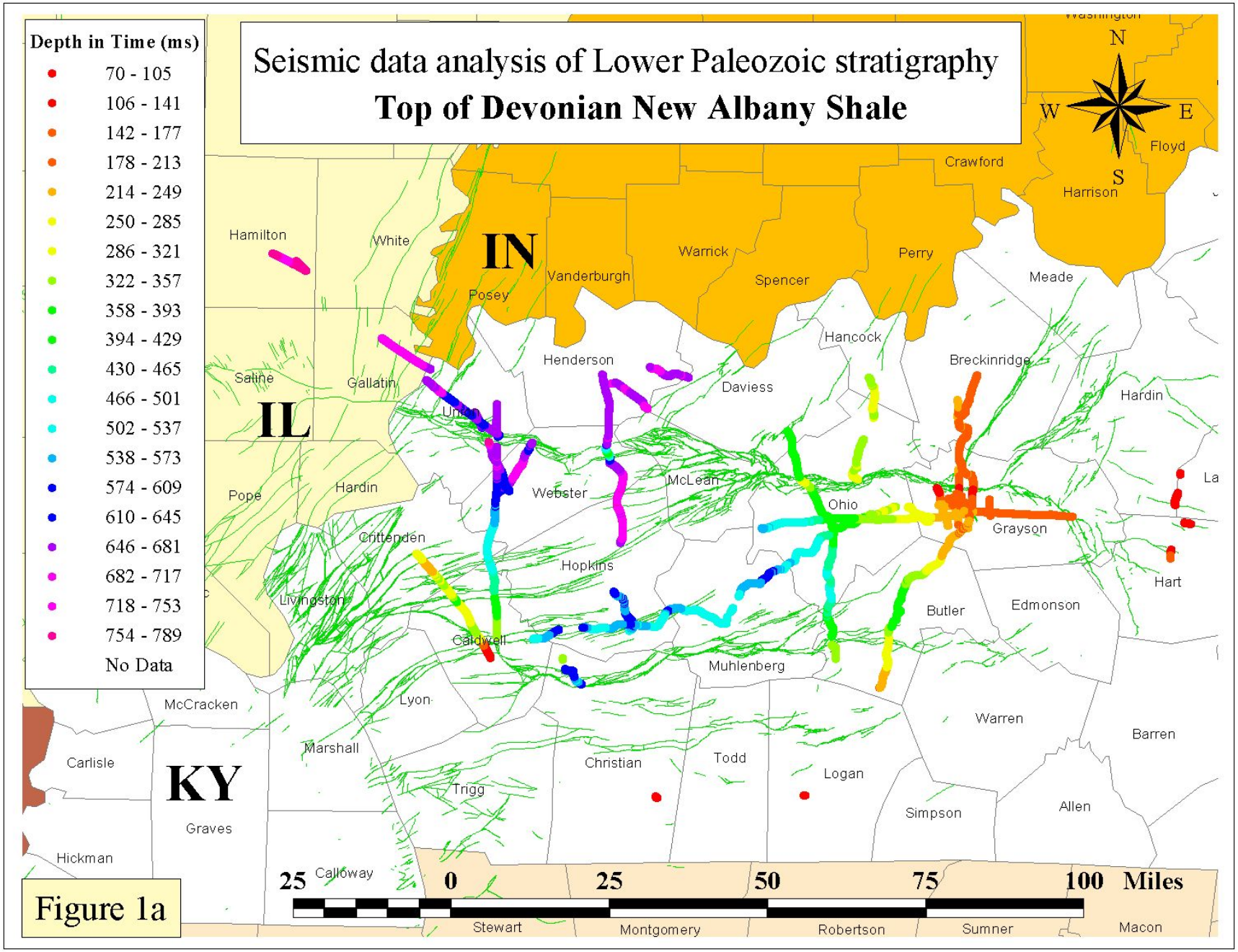
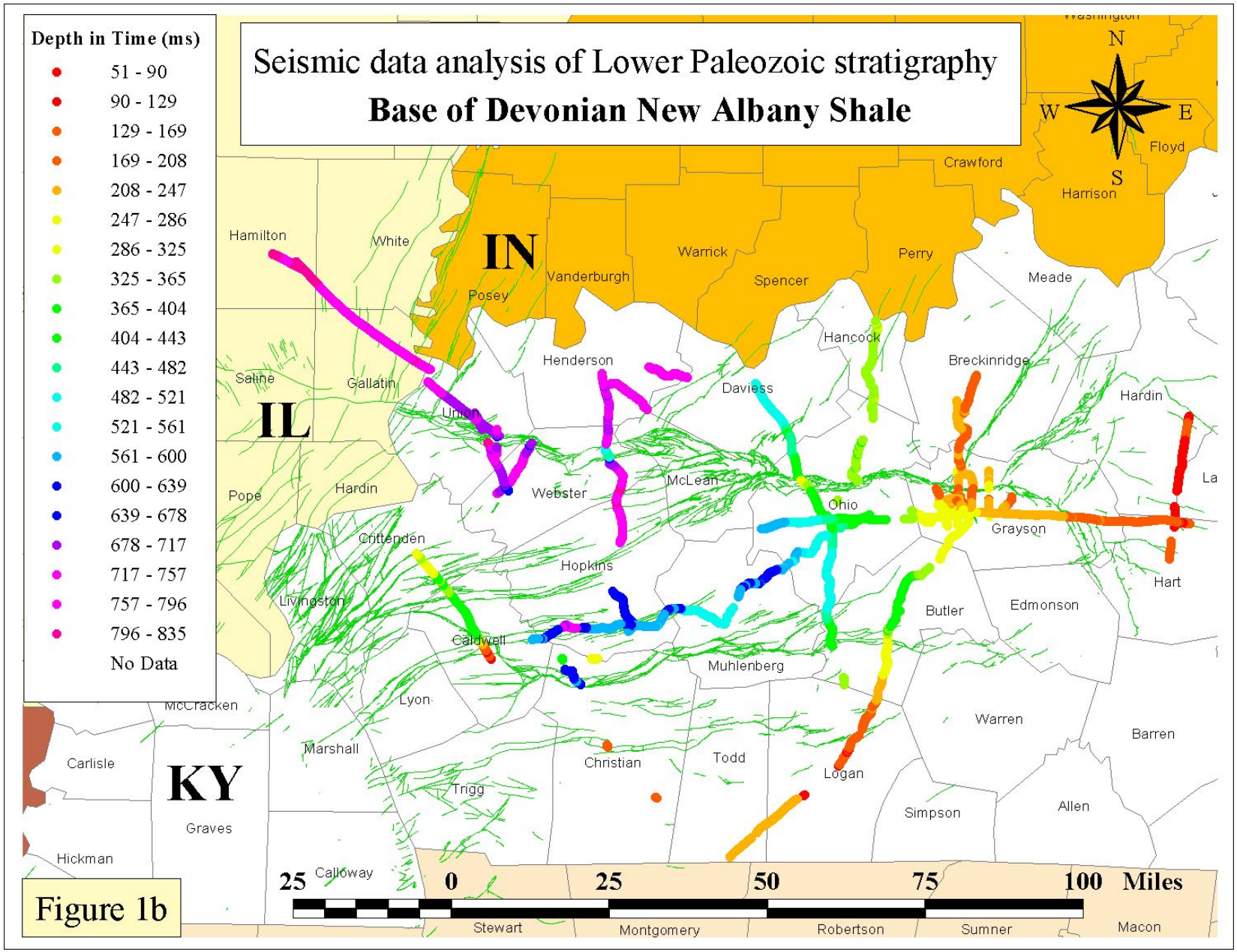

Seismic data analysis of Lower Paleozoic stratigraphy
Top of Devonian New Albany Shale
Depth in Time (ms)
70 - 105
106 - 141
142 - 177
178 - 213
214 - 249
250 - 285
286 - 321
322 - 357
358 - 393
394 - 429
430 - 465
466 - 501
502 - 537
538 - 573
574 - 609
610 - 645
646 - 681
682 - 717
718 - 753
754 - 789
No Data
N
W
E
S
IN
IL
KY
Hamilton
White
Posey
Vanderburgh
Warrick
Spencer
Perry
Crawford
Harrison
Floyd
Meade
Hancock
Henderson
Daviess
Breckinridge
Hardin
Saline
Gallatin
Union
Webster
McLean
Ohio
Grayson
La
Hart
Pope
Hardin
Crittenden
Hopkins
Livingston
Caldwell
Butler
Edmonson
Muhlenberg
Lyon
McCracken
Marshall
Carlisle
Christian
Todd
Logan
Warren
Barren
Trigg
Graves
Simpson
Allen
Hickman
Calloway
25 0 25 50 75 100 Miles
Stewart
Montgomery
Robertson
Sumner
Macon

Figure 1a


Depth in Time (ms)
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90 - 129
129 - 169
169 - 208
208 - 247
247 - 286
286 - 325
325 - 365
365 - 404
404 - 443
443 - 482
482 - 521
521 - 561
561 - 600
600 - 639
639 - 678
678 - 717
717 - 757
757 - 796
796 - 835
No Data
Seismic data analysis of Lower Paleozoic stratigraphy
Base of Devonian New Albany Shale
N
W
E
S
IN
IL
KY
Hamilton
White
Posey
Vanderburgh
Warrick
Spencer
Perry
Crawford
Harrison
Floyd
Meade
Hancock
Breckinridge
Hardin
Henderson
Daviess
Saline
Gallatin
Union
Webster
McLean
Ohio
Grayson
Pope
Hardin
Crittenden
Hopkins
Livingston
Caldwell
Muhlenberg
Butler
Edmonson
Hart
Lyon
McCracken
Marshall
Carlisle
Graves
Christian
Todd
Logan
Warren
Barren
Trigg
Simpson
Allen
Hickman
Calloway
25 0 25 50 75 100 Miles
Stewart
Montgomery
Robertson
Sumner
Macon

Figure 1b

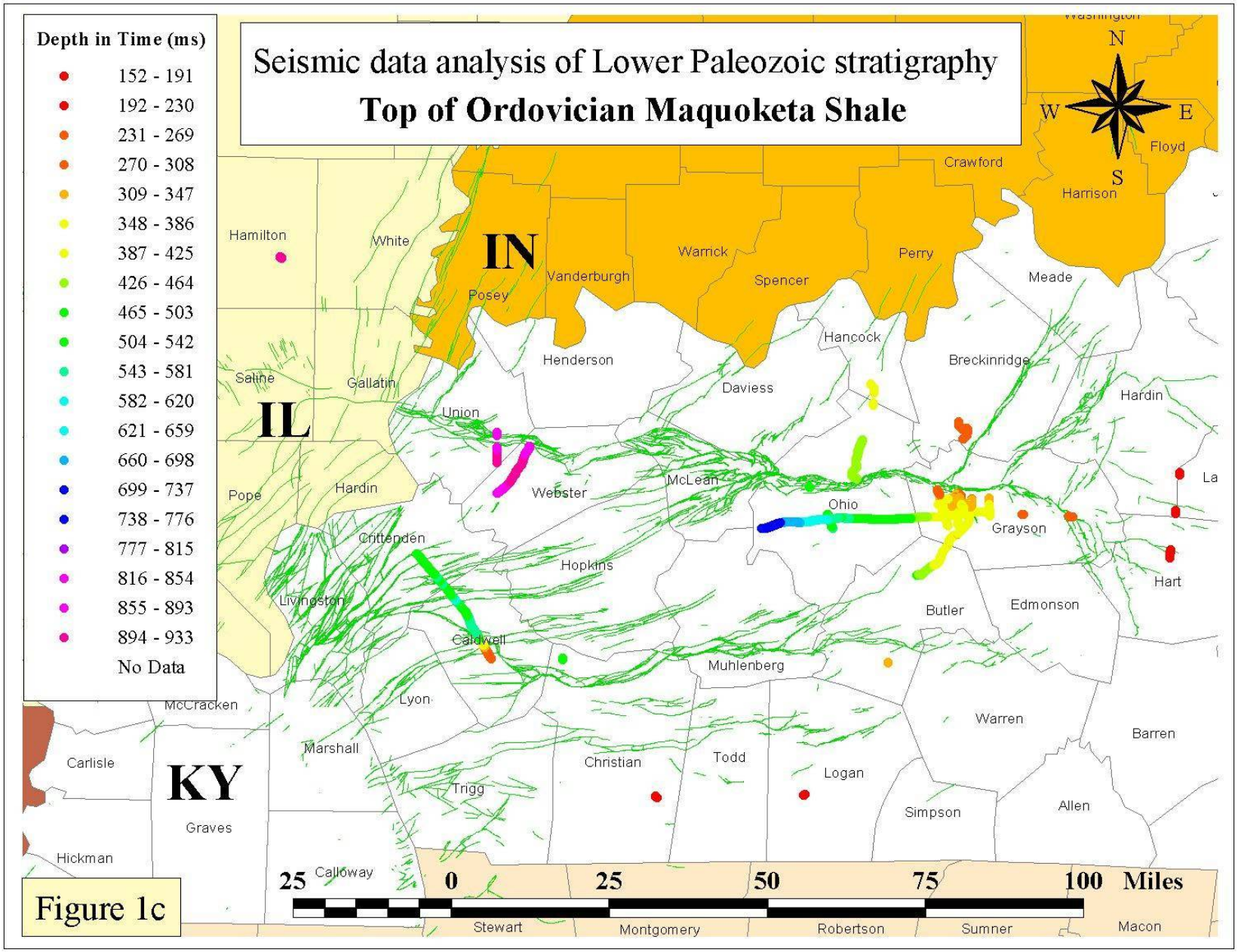
Depth in Time (ms)
152 - 191
192 - 230
231 - 269
270 - 308
309 - 347
348 - 386
387 - 425
426 - 464
465 - 503
504 - 542
543 - 581
582 - 620
621 - 659
660 - 698
699 - 737
738 - 776
777 - 815
816 - 854
855 - 893
894 - 933
No Data
Seismic data analysis of Lower Paleozoic stratigraphy
Top of Ordovician Maquoketa Shale
N
W
E
S
IN
IL
KY
Hamilton
White
Posey
Vanderburgh
Warrick
Spencer
Perry
Crawford
Harrison
Floyd
Meade
Hancock
Breckinridge
Henderson
Daviess
Hardin
Saline
Gallatin
Union
Webster
McLean
Ohio
Grayson
Pope
Hardin
Crittenden
Hopkins
Livingston
Caldwell
Butler
Edmonson
Hart
Muhlenberg
McCracken
Lyon
Warren
Barren
Carlisle
Marshall
Christian
Todd
Logan
Trigg
Simpson
Allen
Graves
Hickman
Calloway
25 0 25 50 75 100 Miles
Stewart
Montgomery
Robertson
Sumner
Macon

Figure 1c

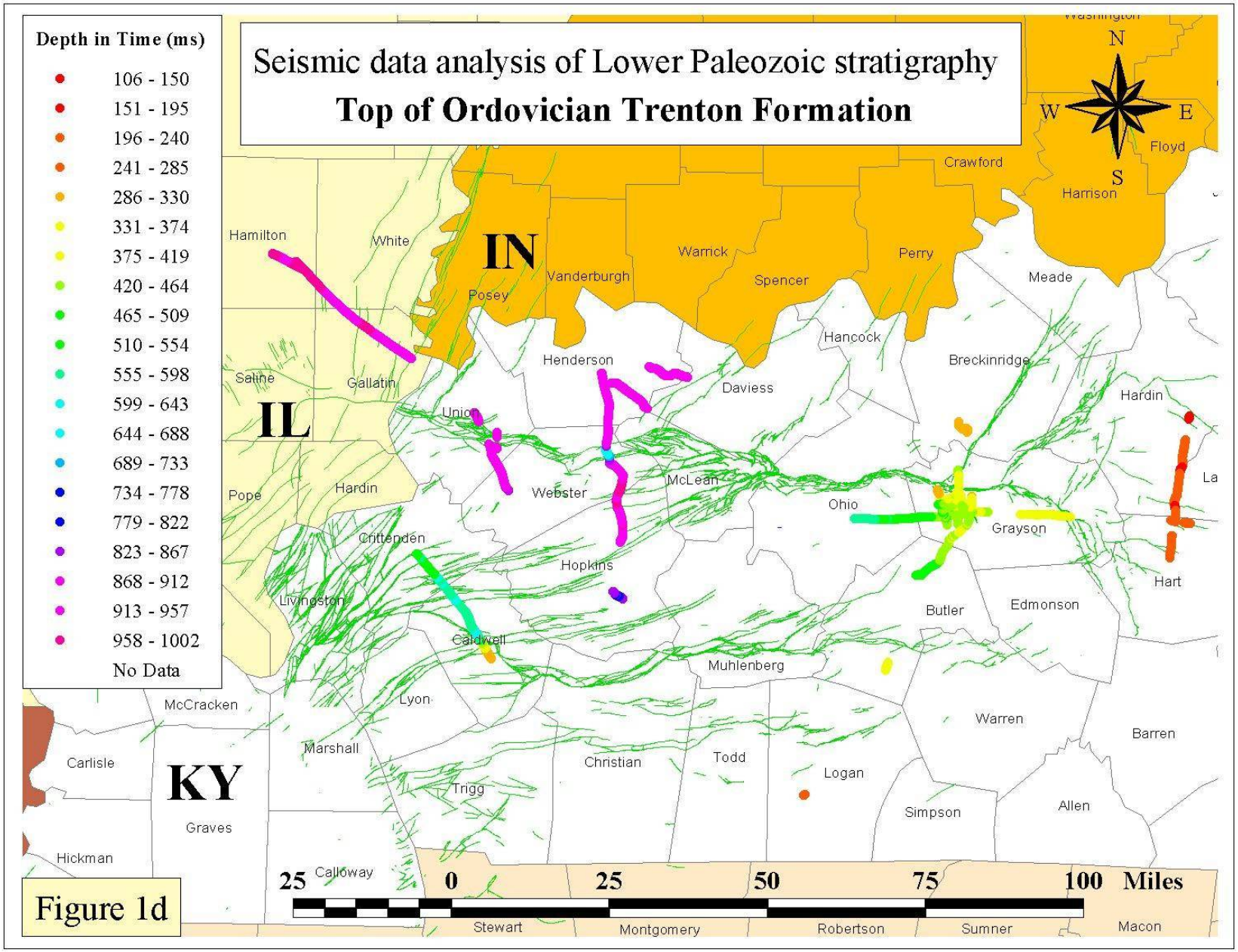
Depth in Time (ms)
106 - 150
151 - 195
196 - 240
241 - 285
286 - 330
331 - 374
375 - 419
420 - 464
465 - 509
510 - 554
555 - 598
599 - 643
644 - 688
689 - 733
734 - 778
779 - 822
823 - 867
868 - 912
913 - 957
958 - 1002
No Data
Seismic data analysis of Lower Paleozoic stratigraphy
Top of Ordovician Trenton Formation
N
W
E
S
IN
IL
KY
Hamilton
White
Crawford
Floyd
Harrison
Warrick
Perry
Spencer
Vanderburgh
Posey
Meade
Hancock
Breckinridge
Henderson
Daviess
Saline
Gallatin
Union
Hardin
Webster
McLean
Ohio
Grayson
Pope
Hardin
Crittenden
Hopkins
Livingston
Butler
Edmonson
Caldwell
Muhlenberg
McCracken
Lyon
Warren
Barren
Carlisle
Marshall
Christian
Todd
Logan
Trigg
Simpson
Allen
Graves
Hickman
Calloway
25 0 25 50 75 100 Miles
Stewart
Montgomery
Robertson
Sumner
Macon

Figure 1d

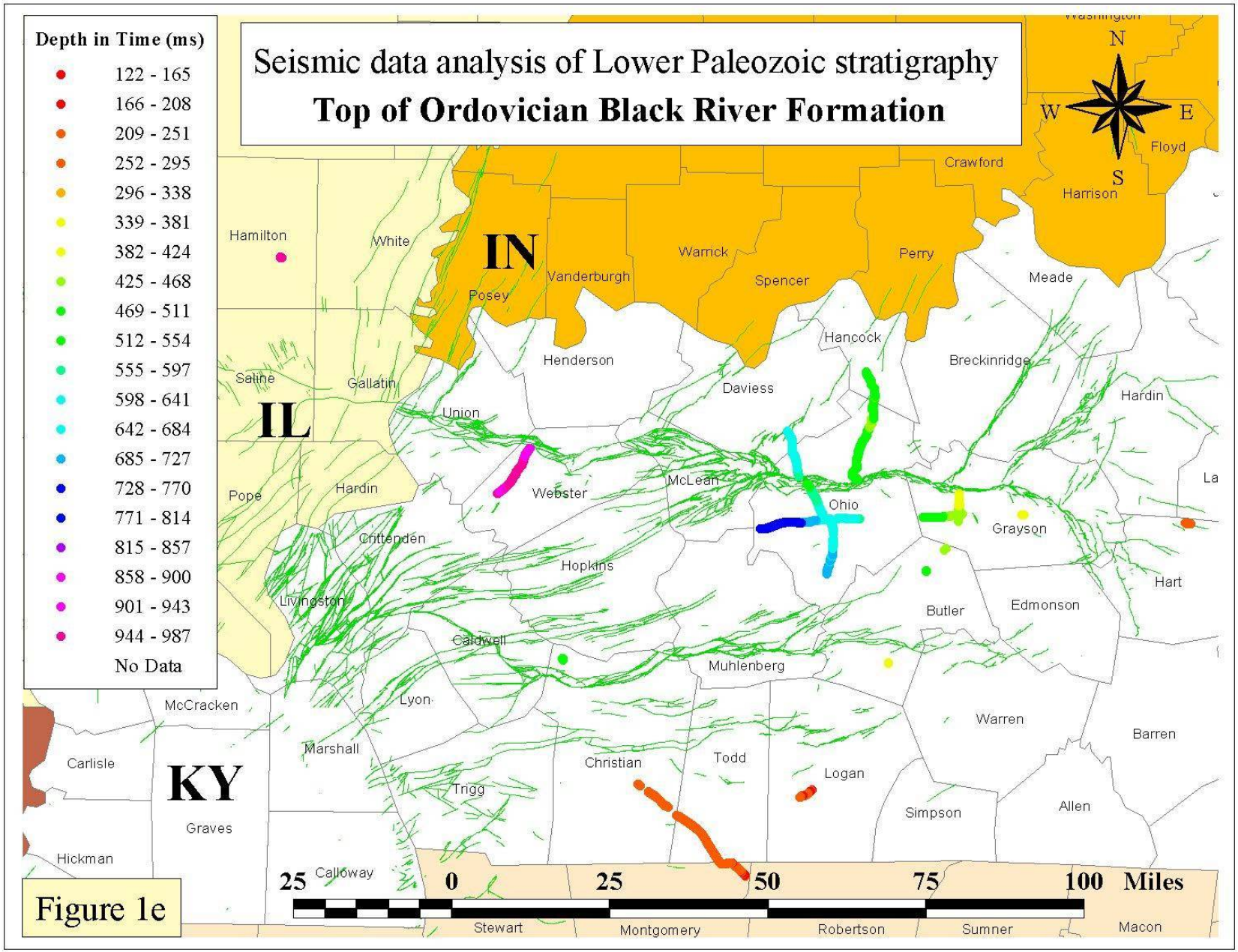
Depth in Time (ms)
122 - 165
166 - 208
209 - 251
252 - 295
296 - 338
339 - 381
382 - 424
425 - 468
469 - 511
512 - 554
555 - 597
598 - 641
642 - 684
685 - 727
728 - 770
771 - 814
815 - 857
858 - 900
901 - 943
944 - 987
No Data
Seismic data analysis of Lower Paleozoic stratigraphy
Top of Ordovician Black River Formation
N
W
E
S
IN
IL
KY
Hamilton
White
Posey
Vanderburgh
Warrick
Spencer
Perry
Crawford
Harrison
Floyd
Meade
Hancock
Breckinridge
Henderson
Daviess
Hardin
Saline
Gallatin
Union
Webster
McLean
Ohio
Grayson
Pope
Hardin
Crittenden
Hopkins
Butler
Edmonson
Hart
Livingston
Caldwell
Muhlenberg
McCracken
Lyon
Warren
Barren
Carlisle
Marshall
Christian
Todd
Logan
Trigg
Simpson
Allen
Graves
Hickman
Calloway
Stewart
Montgomery
Robertson
Sumner
Macon
25 0 25 50 75 100 Miles

Figure 1e

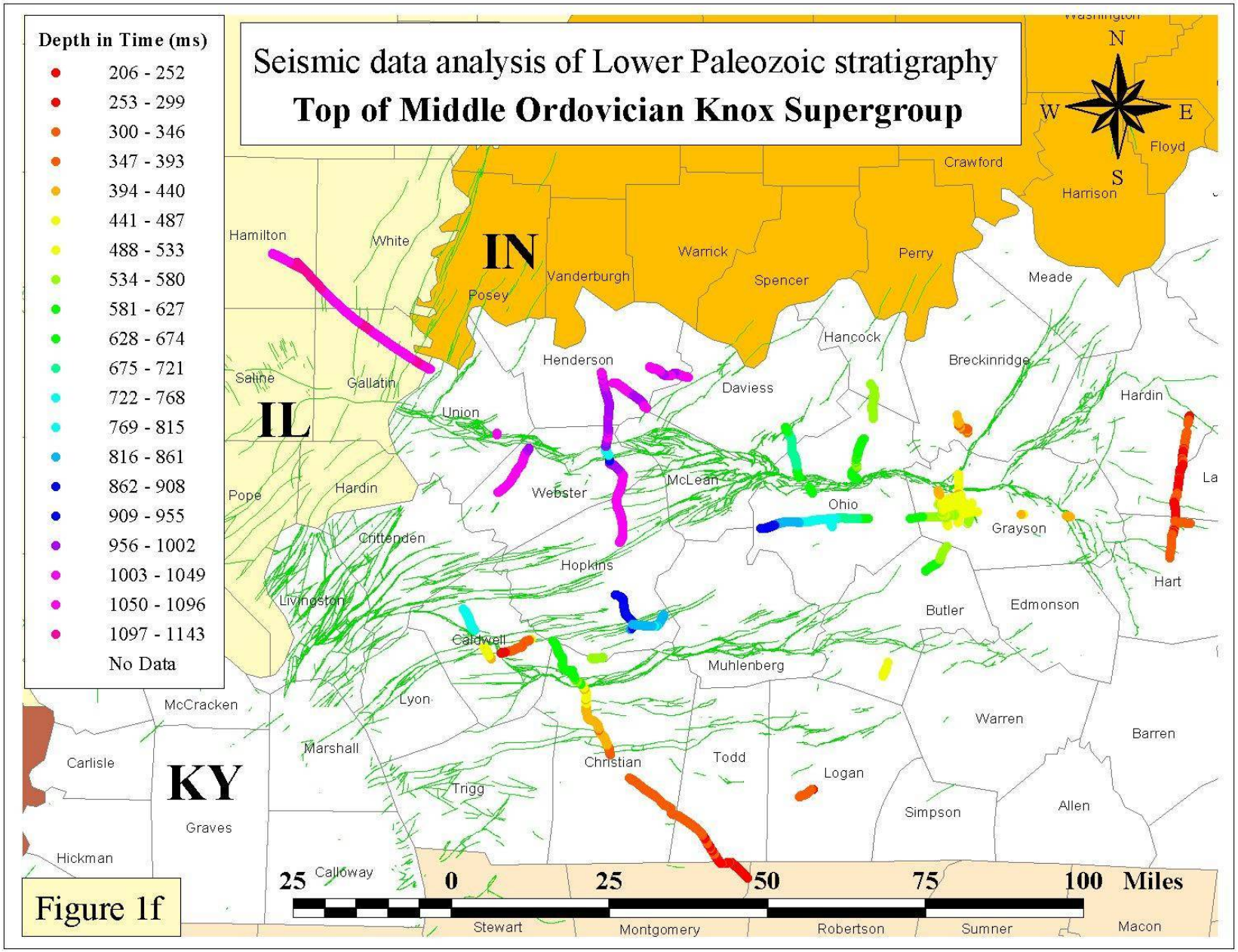
Depth in Time (ms)
206 - 252
253 - 299
300 - 346
347 - 393
394 - 440
441 - 487
488 - 533
534 - 580
581 - 627
628 - 674
675 - 721
722 - 768
769 - 815
816 - 861
862 - 908
909 - 955
956 - 1002
1003 - 1049
1050 - 1096
1097 - 1143
No Data
Seismic data analysis of Lower Paleozoic stratigraphy
Top of Middle Ordovician Knox Supergroup
N
W
E
S
IN
IL
KY
Hamilton
White
Posey
Vanderburgh
Warrick
Spencer
Perry
Crawford
Harrison
Floyd
Meade
Hancock
Breckinridge
Henderson
Daviess
Union
Saline
Gallatin
Hardin
Webster
McLean
Ohio
Grayson
Pope
Hardin
Crittenden
Hopkins
Livingston
Caldwell
Butler
Edmonson
Hart
Muhlenberg
McCracken
Lyon
Warren
Barren
Carlisle
Marshall
Christian
Todd
Logan
Trigg
Simpson
Allen
Graves
Hickman
Calloway
Stewart
Montgomery
Robertson
Sumner
Macon
25 0 25 50 75 100 Miles

Figure 1f

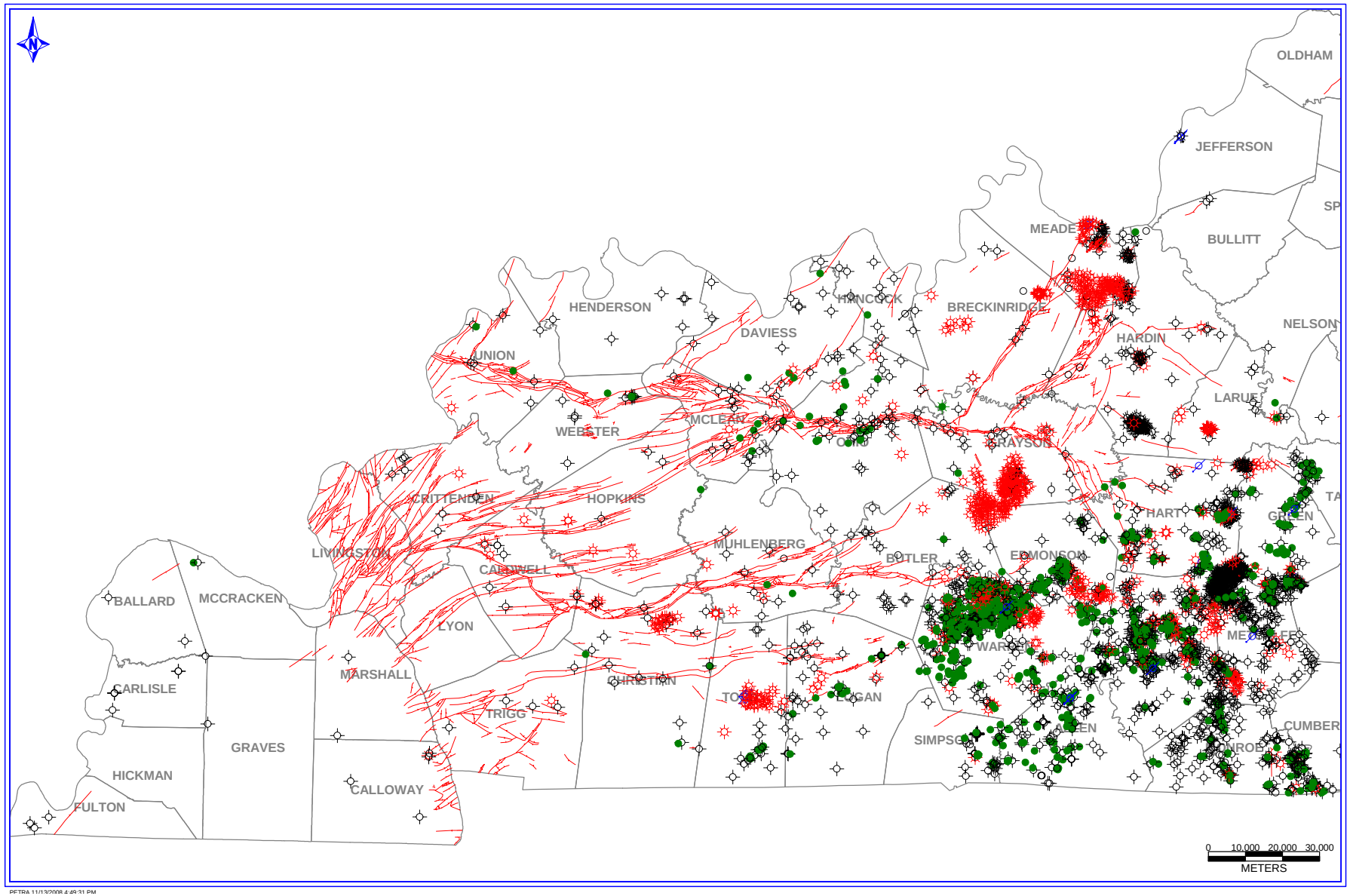

Figure 2. Location of wells with data used in this study. Dataset includes all wells deeper than the New Albany Shale with geophysical log data available at KGS.

Regional Pre-New Albany Stratigraphic Interpretation

The stratigraphic interval of interest in this study lies below the Upper Devonian New Albany Shale and the Lower Ordovician Knox Group. The work in Kentucky has focused on the Silurian and Devonian section, commonly referred to as "Corniferous" by drillers. Stratigraphic relationships in this interval, containing multiple unconformities, are not well understood. Most drilling records do not recognize individual formations, but lump everything below the New Albany Shale into the Corniferous. A main goal of this study is to resolve the distribution of Silurian-Devonian units and regional unconformities in the western Kentucky area.

Almost all of the oil production in the Silurian-Devonian section in western Kentucky has been from shallow carbonate fields on the west flank of the Cincinnati Arch (Fig. 3). Many of these pools are stratigraphic traps associated with unconformity truncations. The Cincinnati Arch was a positive feature during the Silurian and Devonian, and affected depositional and erosional patterns (Freeman, 1951). Multiple stacked unconformities occur along this eastern margin of the Illinois Basin, resulting in complex stratigraphic relationships. These stratigraphic correlations are difficult due to the similarity of log response of many of the carbonate units. A better understanding of the stratigraphy will be an important exploration tool, due to the subtle nature of many of the fields.

Header data and locations for 4,927 wells were obtained from the KGS oil and gas database and loaded into Petra, a geological interpretation program. Wells were selected for the study if they were drilled below the New Albany Shale and had at least one geophysical log. Existing digital well logs were loaded into the project and considerable additional geophysical well logs were digitized for the study. A total of 366 digital wells logs are now available (Fig. 4). In addition to digital logs, scanned logs (raster images) were used to fill in cross sections.

Eleven regional cross sections have been defined to interpret the stratigraphic framework for this interval (Figure 5). Stratigraphic correlations in this interval are continuing. Stratigraphic picks used in the study are illustrated in Table 1. A database of formation tops will be produced after cross sections are completed and correlations verified.

Once correlations are completed a new map of the pre-Middle Devonian unconformity surface (lower Kaskaskia sequence boundary) will be constructed. This subcrop map will be a valuable tool for visualizing stratigraphic patterns at this important unconformity.

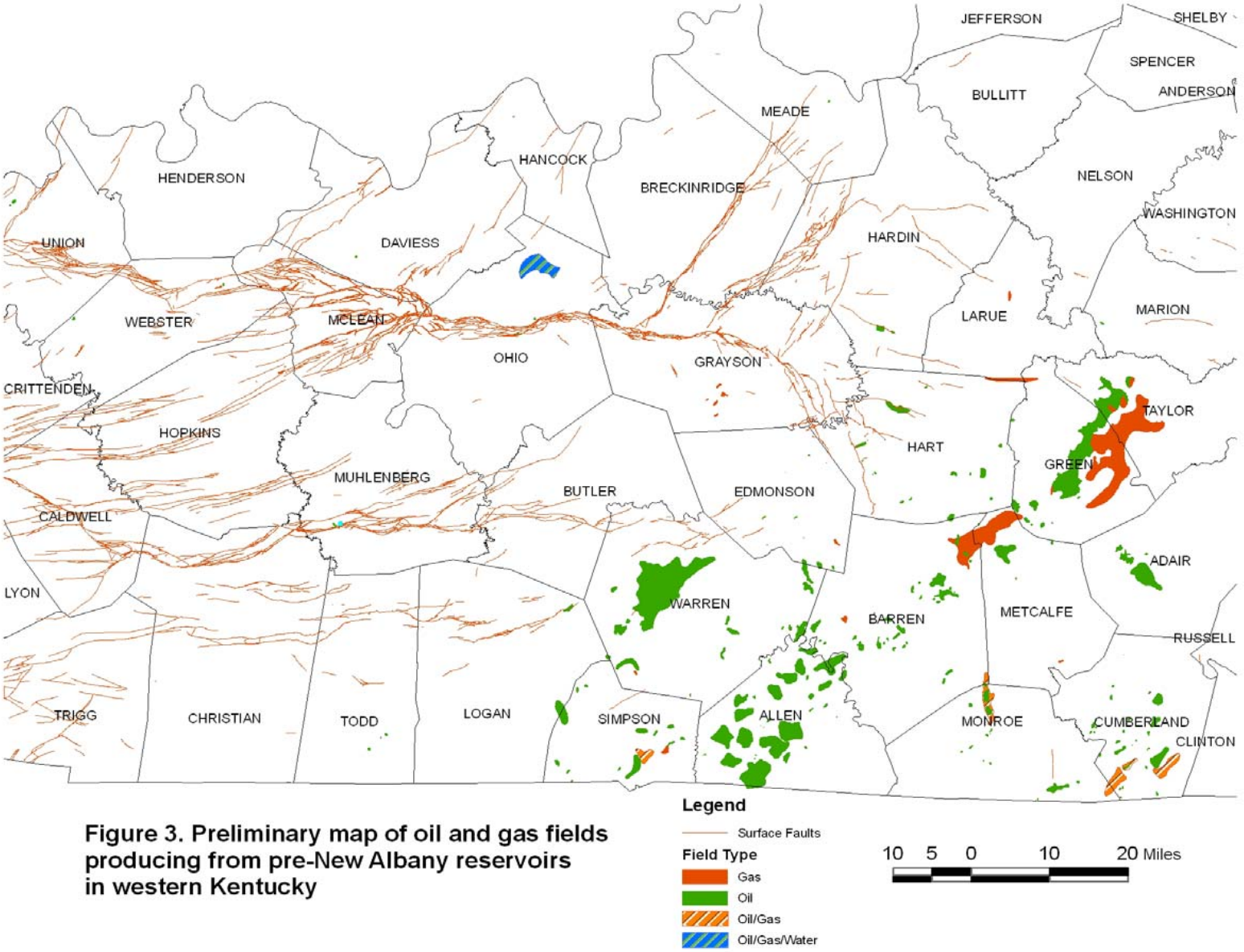

Figure 3. Preliminary map of oil and gas fields producing from pre-New Albany reservoirs in western Kentucky

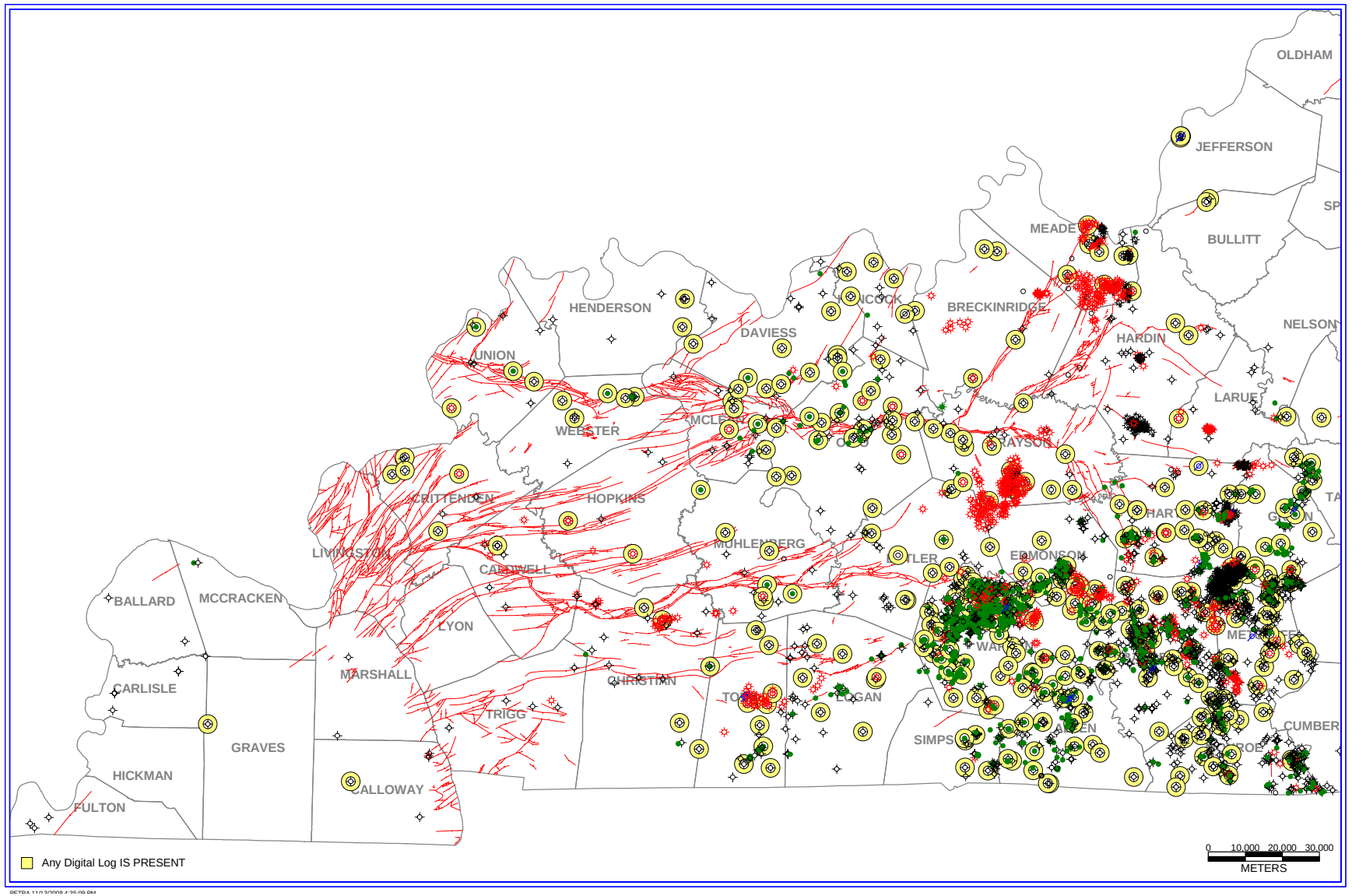

Figure 4. Locations of wells (highlighted in yellow) with digital well logs used in correlation and cross sections.

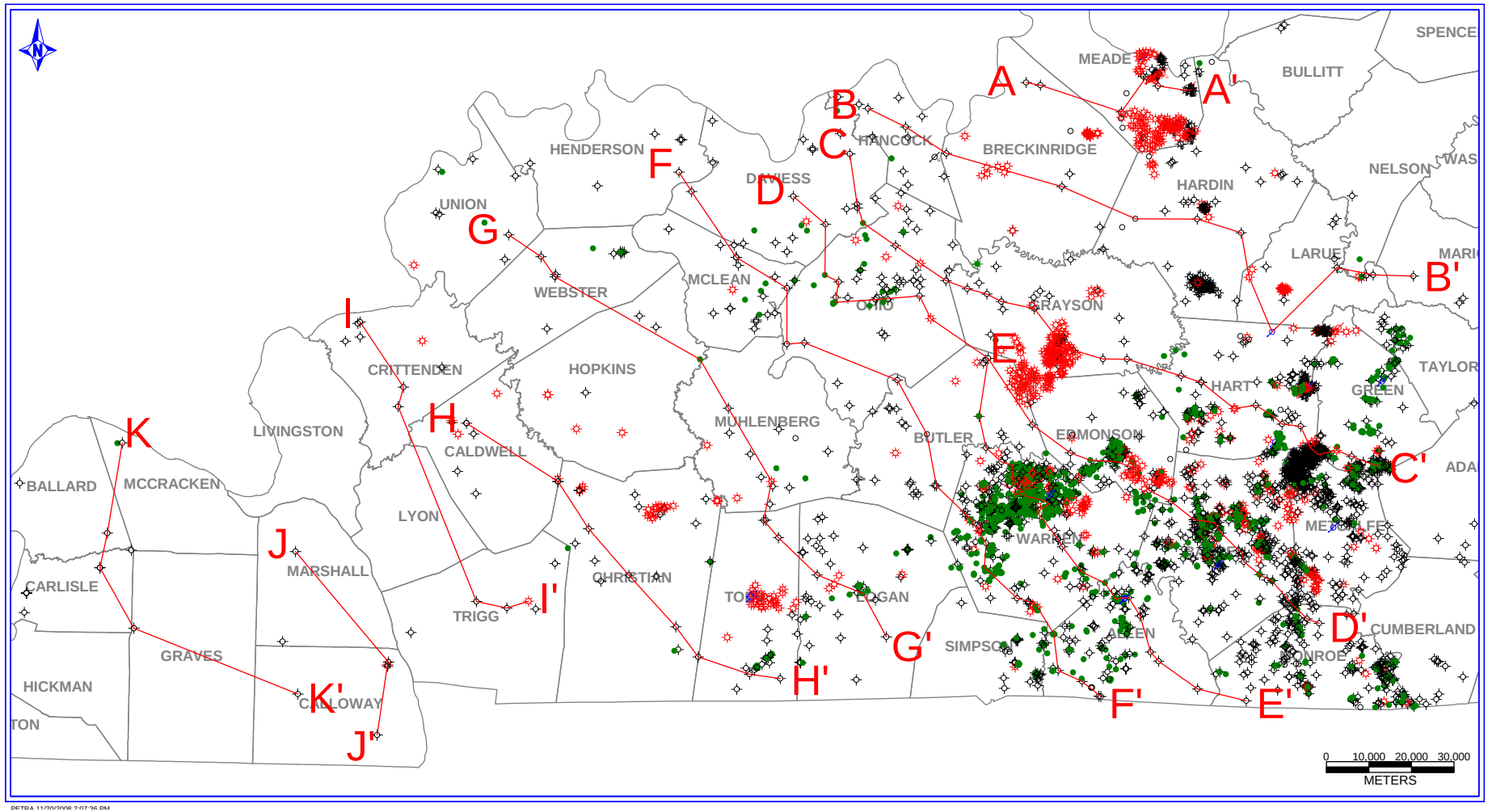

Figure 5. Cross section location map, western Kentucky.

Age	Primary Stratigraphic Units		Equivalent Units		Basinal Equivalents	
	Fm Code	Name	Fm Code	Name	Fm Code	Name
Upper Devonian	341NALB	New Albany Shale				
Middle Devonian	344SLBG	Sellersburg Ls				
	344JFVL	Jeffersonvlle Ls				
	344DCCK	Dutch Creek Ss				
Lower Devonian	347CCEK	Clear Creek Fm	347CCGK	Clear Creek/Grassy Knob Undiff		
	347BKBN	Backbone Ls				
	347GRKB	Grassy Knob Ls				
	347FLGP	Flat Gap Ls				
Upper Silurian	351BILY	Bailey Ls				
			351DCTR	Decatur Ls		
Middle Silurian	355BRPT	Brownsport Fm	355LBLV	Lobelville Ls. Mbr Brownsport Fm	355MSPG	Mocassin Springs Fm
			355BOB	Bob Ls. Mbr Brownsport Fm		
			355BCRV	Beech River Ls. Mbr Brownsport Fm		
	355DIXN	Dixon Ls				
	355LSVL	Louisville Ls	355LEGO	Lego Ls	355SCLR	St. Clair Ls
	355WLDR	Waldron Sh				
	355LAUR	Laurel Dol				
Lower Silurian	357OSGD	Osgood Sh				
	357BRSF	Brassfield Dol	357SXCK	Sexton Creek Ls		
U. Ord.	361MQKT	Maquoketa Sh				
Middle Ordovician	365TRNT	Trenton Ls				
	365BKRV	Black River Group				
	365DTCN	Dutchtown Fm				
	365STPR	St. Peter Ss				
	365EVRN	Everton Fm				
L. Ord.	368KNOX	Knox Group				

Table 1. Stratigraphic nomenclature used for western Kentucky study area. Unconformities are indicated by wavy red boundaries.

Catalog of Devonian, Silurian, and Upper Ordovician oil field data

This task has begun to compile available information on the major oil fields producing from pre-New Albany reservoirs in western Kentucky. Over 350 oil and gas pools produce from reservoirs below the New Albany Shale. While data is not available for all these fields, KGS is compiling summaries of the larger pools to serve as a reference. This will include scanned copies of published studies and data, as well as internal reservoir data at KGS.

Core Analysis Database

Part of this effort has been to build a comprehensive database of core analysis data for cores from pre-New Albany formations. Porosity and permeability data for 115 cored wells have been entered into a Microsoft Excel spreadsheet file and is included with this report. These data include a wide range of Devonian, Silurian and Ordovician cores. Cored intervals have been identified by specific formation, rather than the more generic "Corniferous" designation that was listed on most of the core reports. This reservoir data is now available for analysis by reservoir zone, which will help to delineate regional porosity trends as wells as reservoir characterization for enhanced oil recovery projects.

It is hoped that this pool data can be put in an interactive format and made available on the KGS or ISGS web site in the future.

Characterization of pre-New Albany hydrocarbon source rocks

Much of the oil production from pre-New Albany rocks in western Kentucky occurs along the flank of the Cincinnati Arch, where due to unconformity truncations the reservoirs are in close proximity to the organic-rich New Albany Shale. The New Albany is a known source rock for much of the oil produced in western Kentucky, particularly from Mississippian reservoirs. Even oils from Ordovician reservoirs on the crest of the Cincinnati Arch have been shown to be derived from Devonian source rocks (KGS data). The interpretation of a viable source rock below the New Albany would define a new petroleum system in this area, and make the deeper parts of the southern Illinois Basin much more prospective.

KGS is compiling what little source rock data is available from rocks older than the Devonian New Albany Shale. The most likely candidate for hydrocarbon source potential is the Upper Ordovician Maquoketa Shale. Very little data exists from the Maquoketa, but we recently obtained permission to release some analyses done by Conoco Inc. after they drilled 3 deep wells in the Rough Creek Graben. In a technical services report dated March 1993 (authorship redacted), Conoco reports a moderate total organic carbon value (TOC) of 0.44% in the Maquoketa Shale from 4,190-4,210 ft in the Conoco Turner well in McLean County. Conoco reported a calculated vitrinite reflectance (Ro) of 0.64 and determined the Maquoketa contained primarily Type III kerogen (gas prone, with some waxy oils). Based on the RockEval analysis, organic matter in the Maquoketa in the Turner well is mature. This suggests the Maquoketa has hydrocarbon source potential in western Kentucky and could have charged reservoirs in the Silurian and Lower/middle Devonian.

Additional source rock data is being sought from published and unpublished sources.

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Lower Paleozoic Fields in the Illinois Basin of Indiana

Oil, Natural Gas, and Gas Storage Fields in Devonian and Deeper Reservoirs

Prepared for U. S. DOE under subcontract to Illinois State Geological Survey
By Kuldeep Chaudhary and Brian D. Keith, Indiana Geological Survey at Indiana University

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October 2008

Introduction

This atlas is intended as a comprehensive listing of fields in southwestern Indiana that are part of the Illinois Basin and which contain wells with Devonian or deeper reservoirs that were completed for the production of oil and/or natural gas or as gas storage fields (Fig. 1). In some cases producing fields were converted to gas storage fields some time after discovery. Of the 70 fields listed (Table 1), all but Chrisney South have reservoirs in Middle Devonian rocks of the Muscatatuck Group (Fig. 2). Only three, Chrisney South, Portersville, and White Rose produce from the Lower Devonian New Harmony Group (Fig. 2). Three fields, Bartlettsville, Heltonville, and Unionville that all are along the Mt. Carmel Fault contain reservoirs in the Ordovician Trenton Limestone (Fig. 2). Only one field, Griffin Consolidated, produces from Cambrian/Ordovician Knox Super Group (Fig. 2). Fields or areas producing solely from the Devonian/Mississippian New Albany Shale (Fig. 2) were not included in this study.

Each field has a summary page report. For 13 fields information and well control was not adequate to compile any additional material beyond the summary report. Fields with sufficient well control have one or more of the items listed below in addition to the summary report.

Well location map showing Devonian wells, field outline, and line of cross section, if present.
Structure map on top of Muscatatuck Group.
Structure map on top of Jeffersonville Limestone.
Structure map on top of Geneva Dolomite Member of Jeffersonville Limestone.
Structure map on top of Silurian rocks.
Isopach map of North Vernon Limestone.
Isopach map of Vernon Fork Member of Jeffersonville Limestone.
Type log for field.
Structural cross section.
Porosity vs. permeability cross-plot.
Cumulative oil production curve.
List of wells used for structure maps.
Core description and photographs of Devonian section.

The amount of available information is highly variable from field to field. For two fields, Plummer and Simpson Chapel, more extensive reports were produced. Where information is not available or does not apply “na” has been used. It is also worth noting that cumulative gas production information is not available for Indiana, and is thus not shown for any natural gas fields. The structural closure mentioned on the summary report page may differ from that shown on structure maps. This is because county maps showing regional well control beyond the field limits were consulted for the summary report, and can show greater closure for the field structure than the more limited control in the immediate field area used for the report maps.

Table 1. List of fields and locations that are included in the atlas. Wells marked with * have insufficient well control for information beyond a summary report. Multiple ID numbers are for fields with gas storage designation in addition to oil or natural gas production.

Field	County & Location	IGS ID
Alfordsville Southwest*	Daviess 1N-5W	10008
Arlington*	Monroe 9N-1W	10011
Arney	Owen 9N-5W	10013
Arney North*	Owen 9N-5W	10014
Art	Clay 11N-7W	10015
Ashboro East	Clay 11N-6W	10019
Bartlettsville	Monroe & Lawrence 6&7N-1E	10032
Bartlettsville North*	Monroe, 7N-1E	10033
Blackhawk	Vigo 10N-8W	10050
Bowling Green	Clay 11N-6W	10057
Bowling Green South	Clay 11N-6W	10058
Carbon	Clay & Parke 13&14N-6W	10091
Carlisle North	Sullivan 6N-9&10W	10093
Carlisle West*	Sullivan 6N-10W	10094
Chrisney South	Spencer, 6S-5W	10109
Clay City North	Clay 10N-6W	10110
Coal City	Owen 9N-6W	10114
Coalmont West	Sullivan 9N-8W	10117
Cory Consolidated	Clay 11N-7W	10127
Cory South	Clay 10&11N-7W	10128
Dixon	Greene 7N-6W	10803
Dodds Bridge	Sullivan 8&9N-10W	10159

Dubois	Dubois County, 1S&1N-4W	10163
Elnora Central	Daviess 5N-6W	10185
Fairbanks	Sullivan 9N-10W	10196
Glendale	Daviess 2N-6W	10253
Griffin Consol.	Gibson &Posey 3S-13&14 W	10277
Heltonville*	Lawrence 6N-1E	10300
Howesville	Greene 8N-7W	10310, 10832
Leesville	Lawrence 5N-1&2E	10373, 10810
Leesville South*	Lawrence 4N-2E	10374
Lewis	Sullivan 9N-8W	10375
Linton	Greene 7N-7W	10382, 10812
Lonetree	Greene 8N-6&7W	10384, 10813
Lyons	Greene 6N-6W	10393
Lyons West*	Greene 7N-6W	10394
Marts	Sullivan 9N-9W	10409
Mineral City	Greene 6N-5W	10429, 10816
Montgomery North*	Daviess 3N-6W	10447
Newberry*	Daviess 5N-5&6W	10479
Oakland City Consol.*	Pike 2S-8W	10488
Odon East	Daviess 5N-5W	10495, 10820
Odon North	Daviess 5N-5W	10496
Odon South	Daviess 5N-5&6W	10497
Pennyville	Daviess 2N-5W	10532
Plainville	Daviess 4N-7W	10543
Plummer	Greene 6N-5W	10546

Portersville*	Daviess 1N-5W	10549
Portersville West	Daviess 1N-5W	10551
Prairie Creek	Vigo 10N-10W	10556
Riley	Vigo 11N-8W	10581
Riley South	Vigo 11N-8W	10582
Saline City	Clay 11N-7W	10605
Sandborn North	Greene 6N-7W	10608
Shelburne Consol.	Sullivan 8&9N-9&10W	10624
Simpson Chapel	Greene 6N-4&5W	10631, 10825
Siosi	Sullivan & Vigo 9&10N-10W	10632
South Martin*	Martin1N-4W	10645
Spencer Consol.	Posey 7&8S-14W	10649
Spring Hill	Vigo 11N-9W	10651
State Line	Vigo 12N-10W	10685, 10826
Staunton	Clay 12N-7W	10686
Switz City	Greene 7N-6W	10704, 10827
Terre Haute*	Vigo 12N-9W	10712
Terre Haute East	Vigo 12N-9W	10713
Terre Haute South	Vigo 11N-9W	10714
Unionville (Hindustan)	Monroe 9N-1E & 10N-1W	10734, 10829
White Rose	Greene 7N-7W	10783
Wilfred	Sullivan 9N-8W	10786, 10830
Worthington	Greene 8N-5W	10793

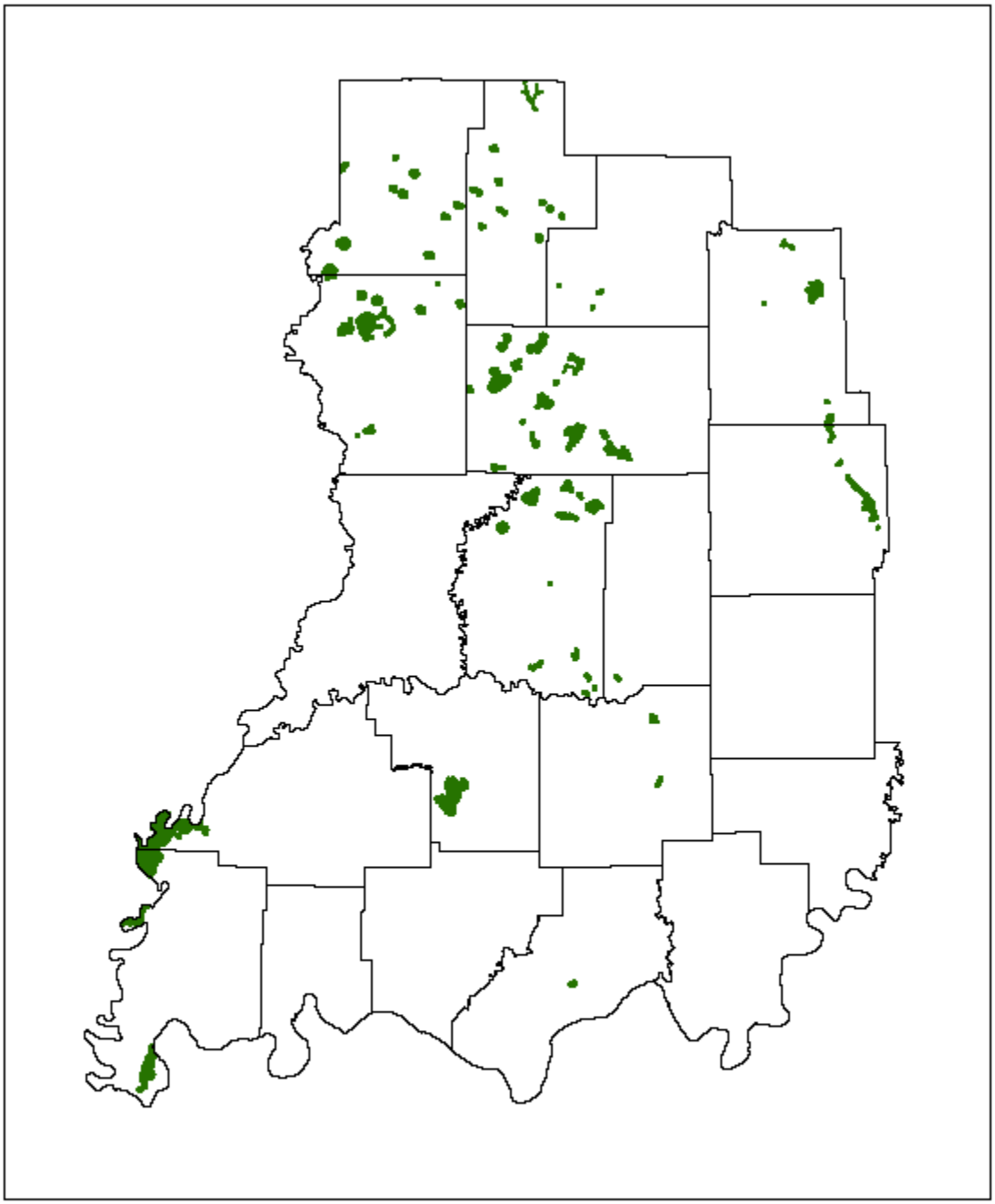

Figure 1. Map of southwestern Indiana showing oil, natural gas, and gas storage fields included in atlas.

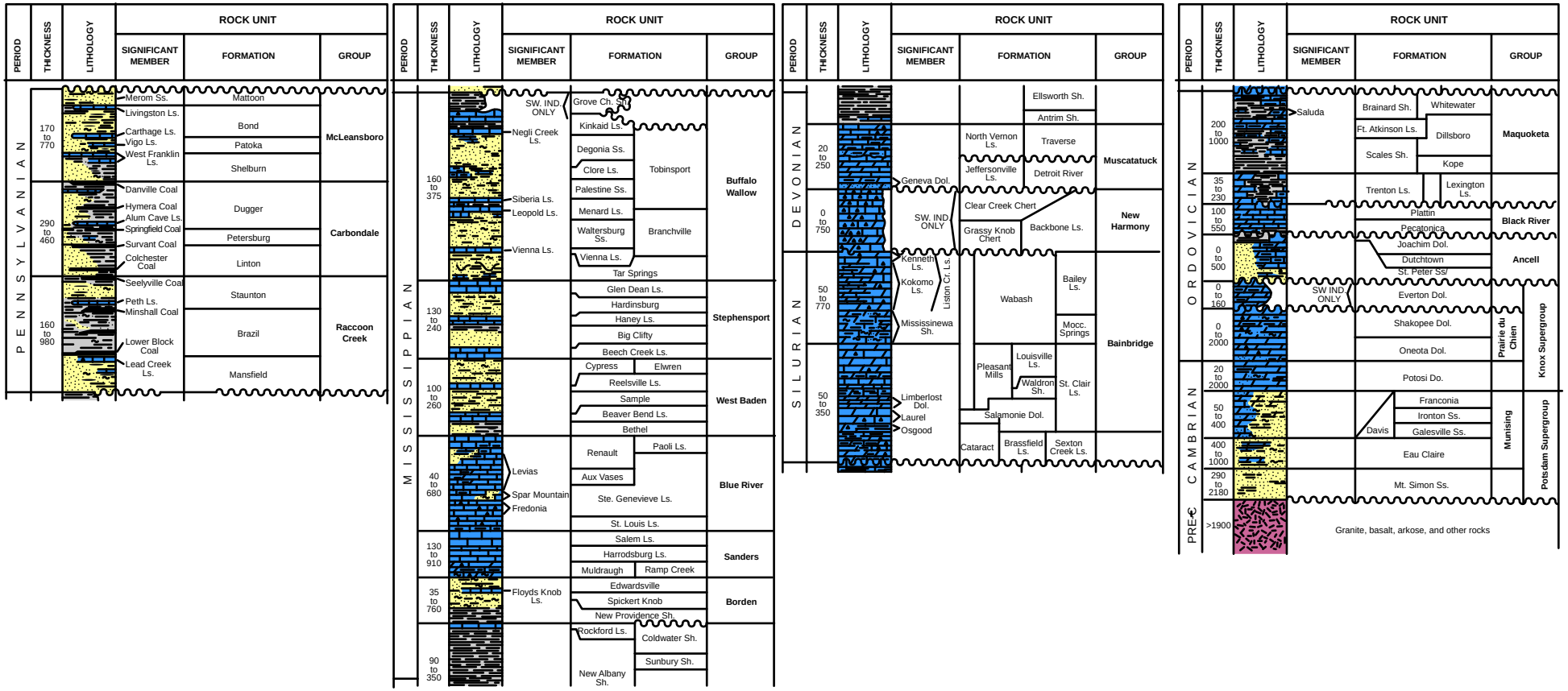

Figure 2. Generalized stratigraphic column for southern Indiana.

Field name: Alfordsville Southwest

IGS ID: 10008

DOE ID: 9650

Location: Daviess County, 1N-5W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls., (1,870 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (2,750 ft.)

Field characteristic: No structural closure observable.

Reservoir characteristics:

Porosity – 6.2 %

Permeability – 1.5 md

Reservoir thickness: 15 ft.

Field name: Arlington

IGS ID: 10011

DOE ID: na

Location: Monroe County, 9N-1W

Discovery date: 1960

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, na (873 ft.)

Field type: natural gas

Total number production wells: 1

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Muscatatuck (957 ft.)

Field characteristic: No structural closure observable.

Reservoir characteristics:

Field name: Arney

IGS ID: 10013

DOE ID: na

Location: Owen County, 9N-5W

Discovery date: 1951

Lower Paleozoic reservoir unit and depth: Devonian, Muscatatuck Group, na (1,314 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,467 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

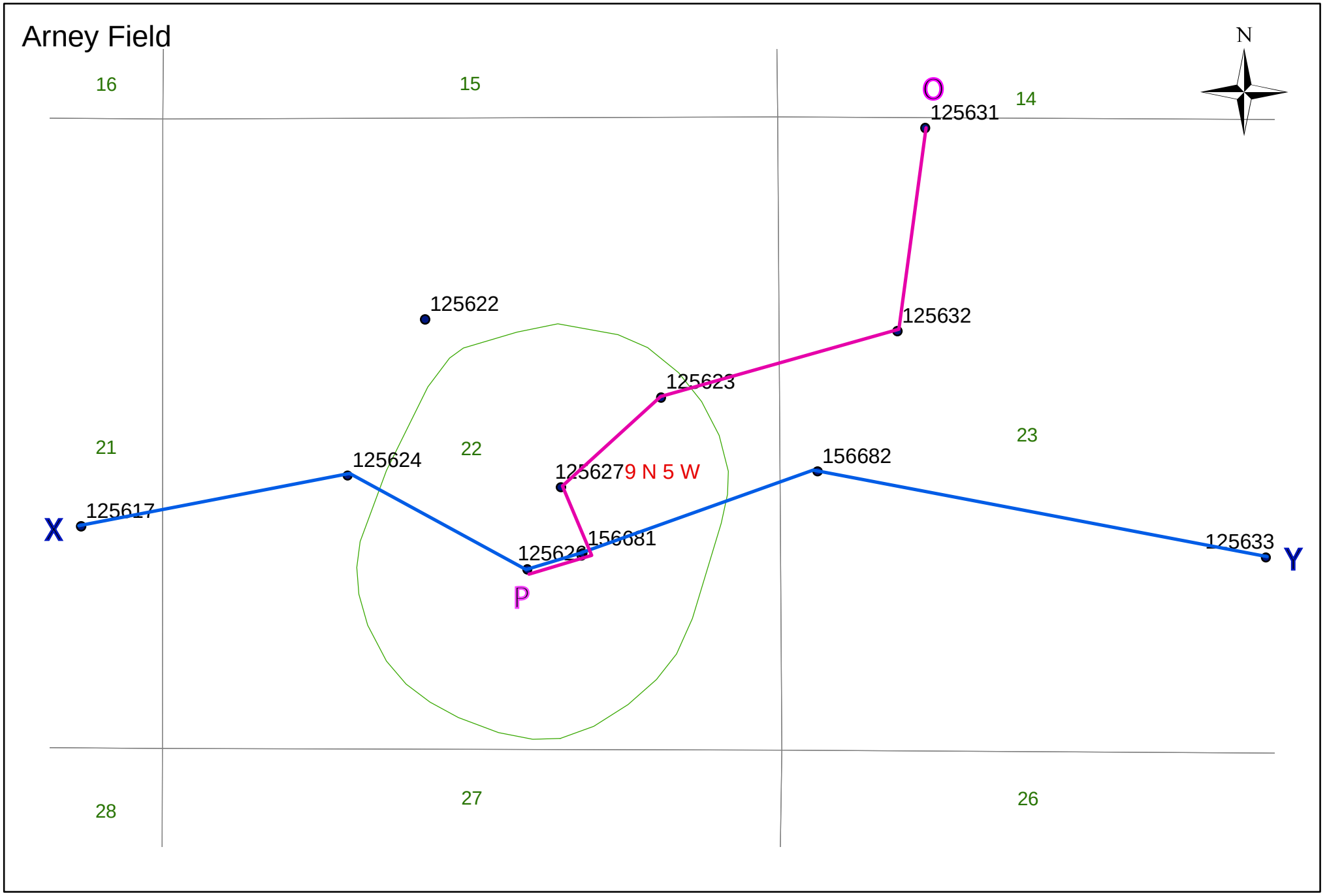

Figure 1: Map showing location and wells at Arney Field, Owen County. X-Y and P-O are the locations of the cross sections that show the subsurface Devonian structure in Figures 5 and 6.

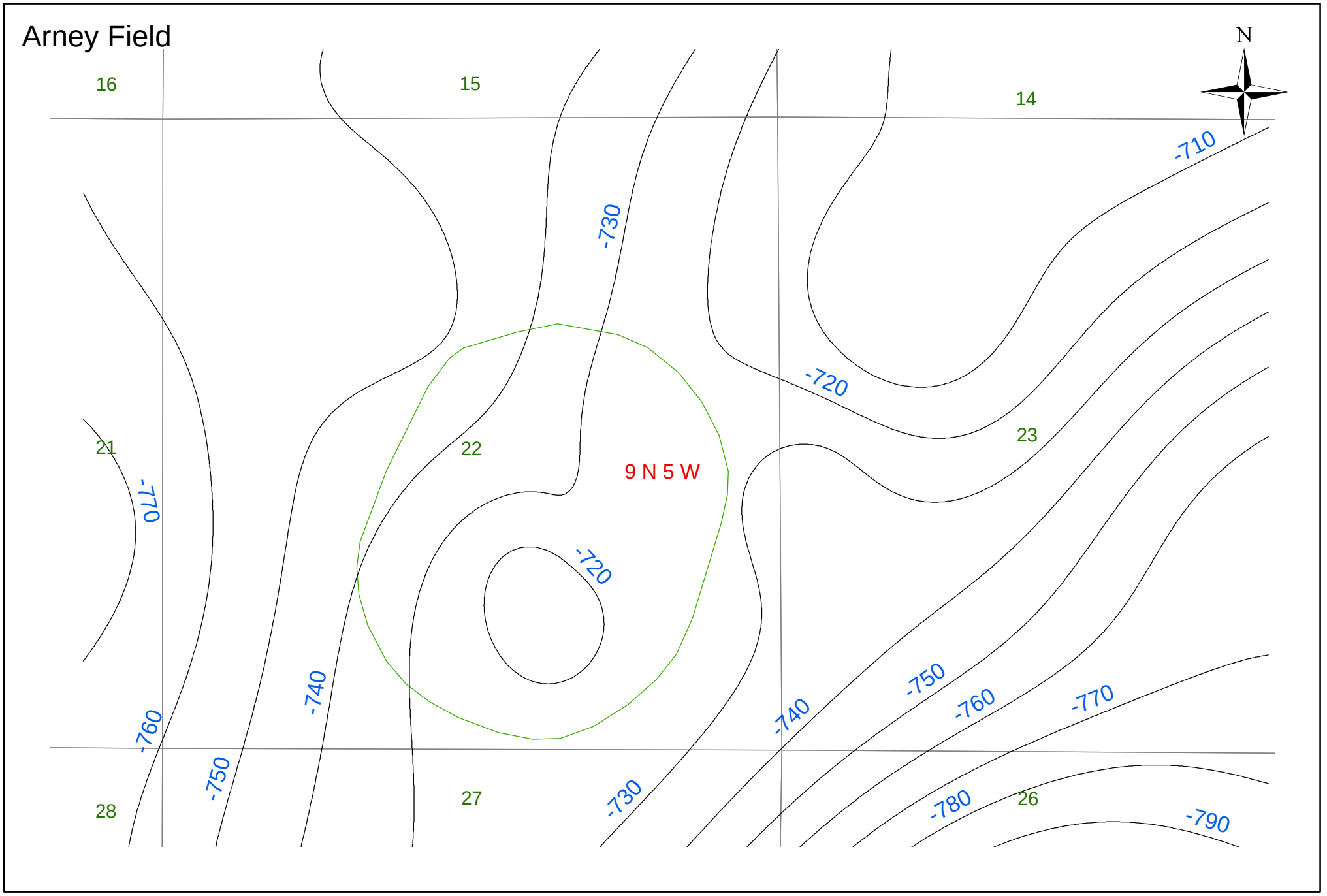

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in ArneyField, Owen County. Contours show values below sea level, contour interval is 10 ft .

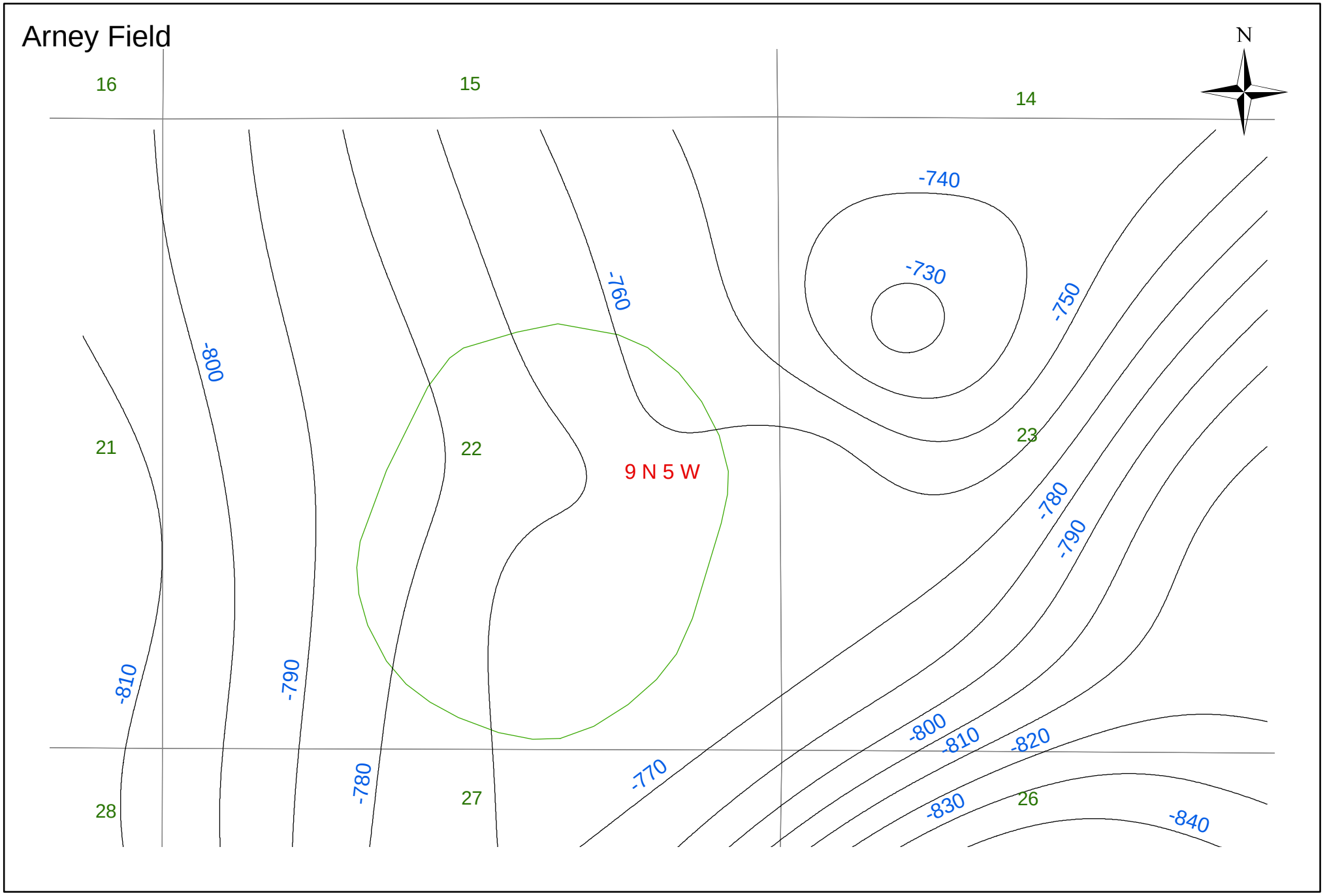

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Arney field, Owen County. Contours show values below sea level, contour interval is 10 ft .

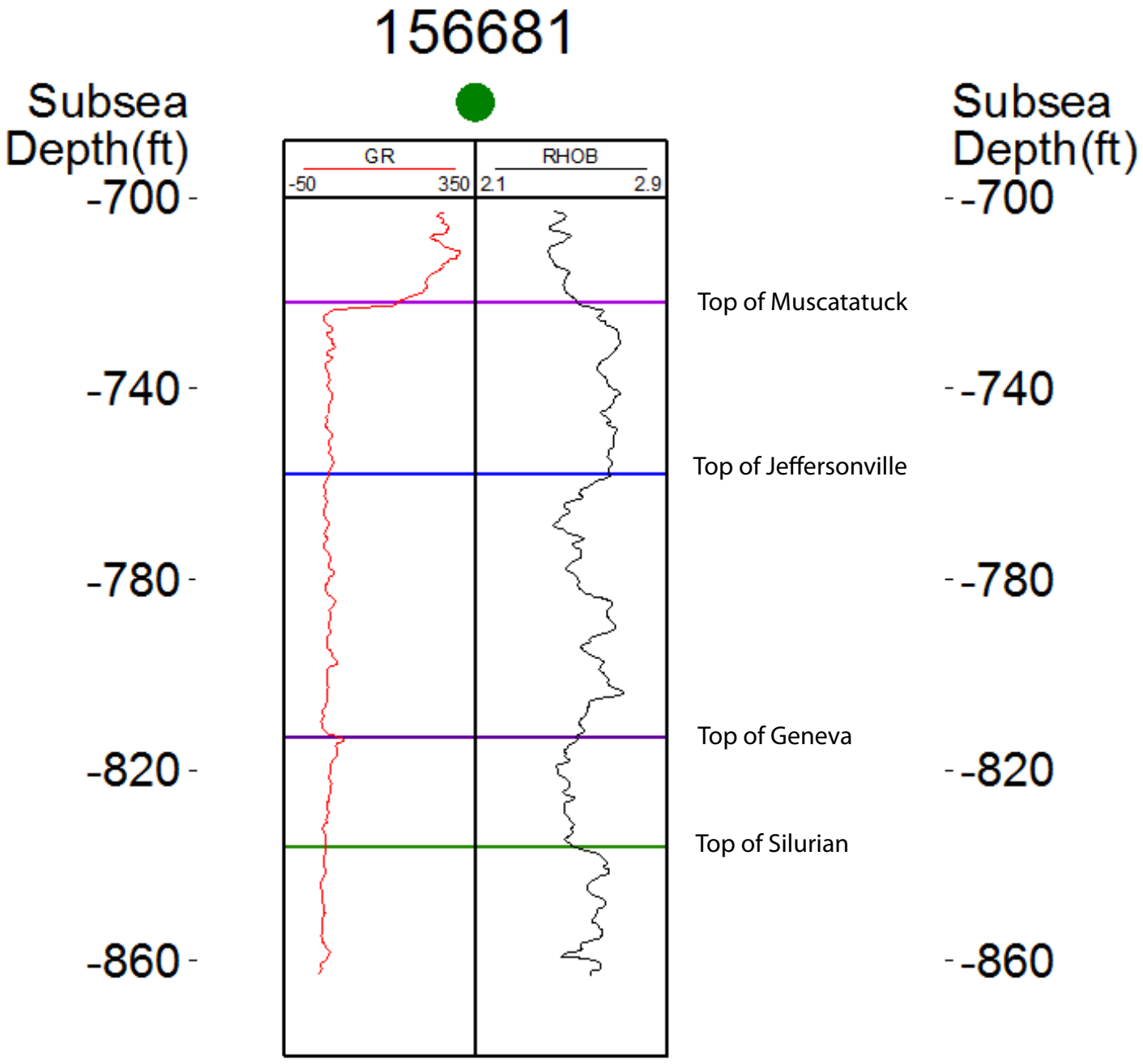

Figure 4: Type log section showing the Devonian formations at Arney Field, Owen County.

HS=1

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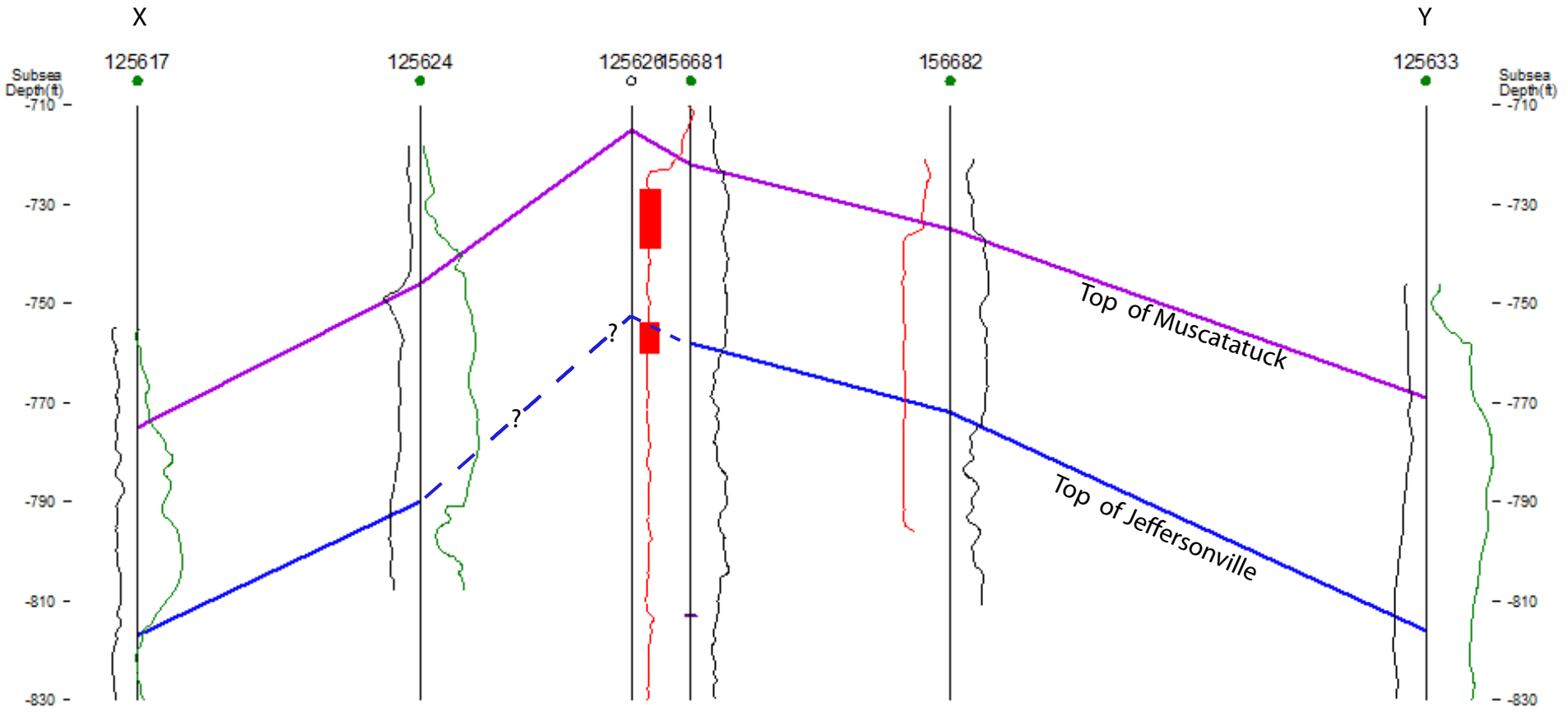

Figure 5: X-Y Cross section showing the Devonian subsurface structure across Arney Field, Owen County. The red color box shows the completion intervals for the gas production. For location of the cross section refer to Figure 1.

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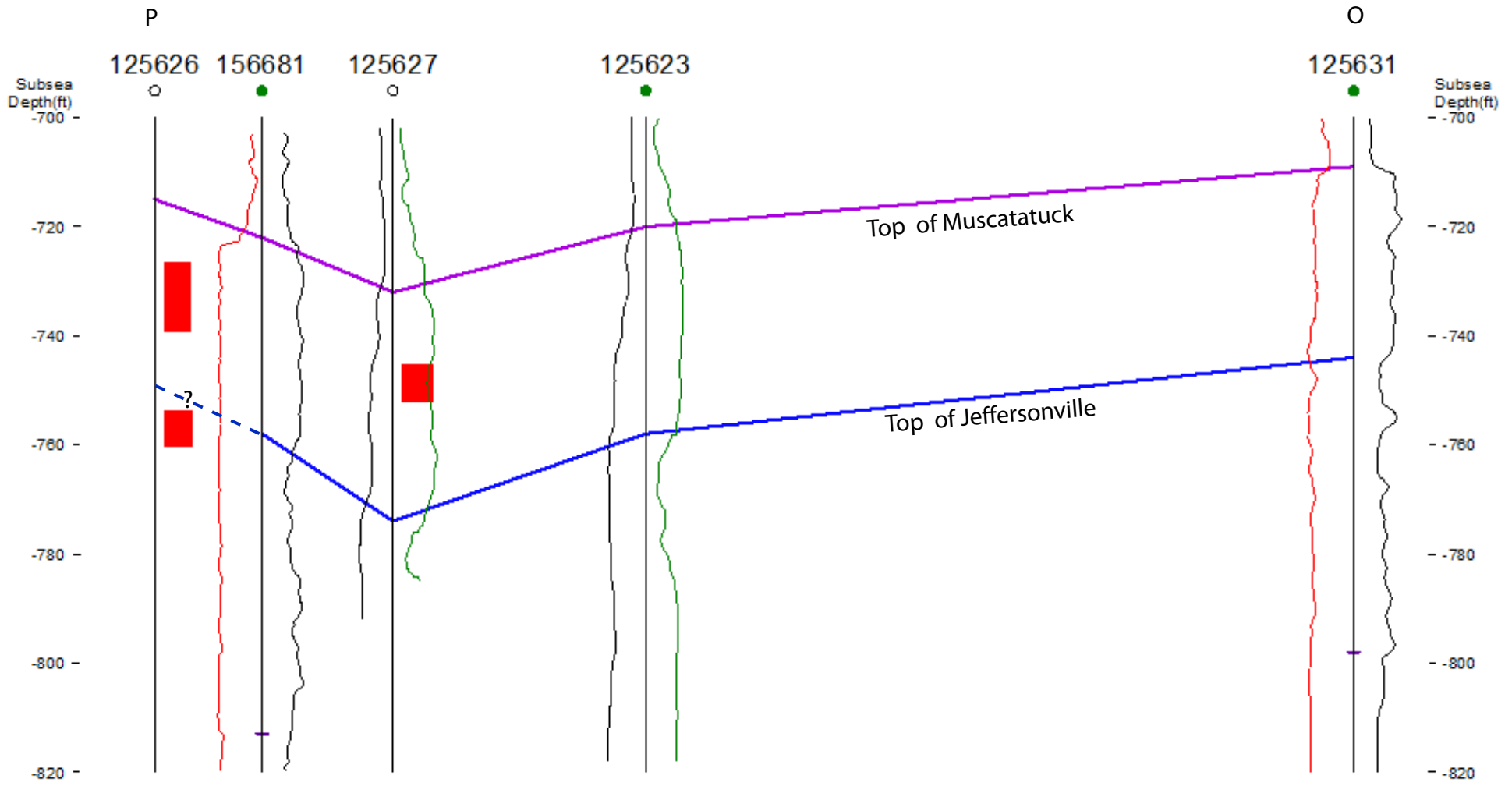

Figure 6: P-O Cross section showing the Devonian subsurface structure across Arney Field, Owen County. The red color box shows the completion intervals for the gas production. For location of the cross section refer to Figure 1.

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Table-1: List of the wells used for subsurface structure mapping in Arney Field, Owen County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
125617	9	N	5	W	21	670	1445	1487	1530	1596		
125622	9	N	5	W	22	642	1395					
125623	9	N	5	W	22	632	1354	1390				
125624	9	N	5	W	22	652	1398	1440				
125626	9	N	5	W	22	559	1274					1000
125627	9	N	5	W	22	568	1299	1342				1000
156681	9	N	5	W	22	597	1319	1358	1410	1433		
125631	9	N	5	W	23	668	1377	1412	1466			
125632	9	N	5	W	23	664	1364	1390	1440	1473		
125633	9	N	5	W	23	634	1403	1450	1520	1562		
156682	9	N	5	W	23	619	1354	1386				
156683	9	N	5	W	26	637	1446	1494				

Field name: Arney North

IGS ID: 10014

DOE ID: na

Location: Owen County, 9N-5W

Discovery date: 1977

Lower Paleozoic reservoir unit and depth: Devonian, Muscatatuck Group, na (1,330 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,700 ft.)

Field characteristic: Limited data available, but possible domal anticline with closure in excess of 60 ft.

Reservoir characteristics:

Field name: Art

IGS ID: 10015

DOE ID: 26716

Location: Clay County, 11N-7W

Discovery date: 1963

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls., (1,450 ft.)

Field type: oil

Total number production wells: 15

Area: 90 acres

Cumulative production: 71,885 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1,677 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

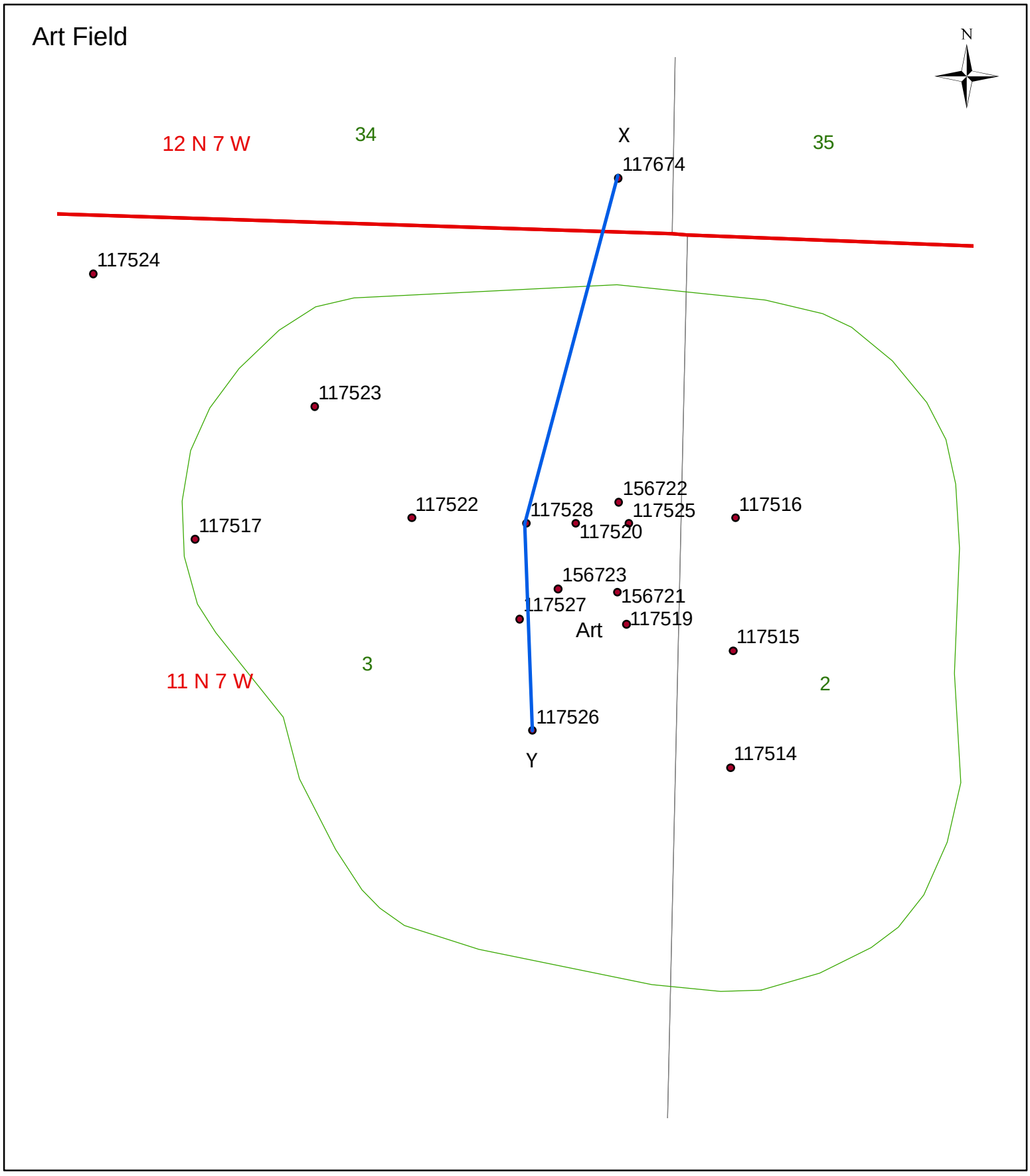

Figure 1: Map showing the location and wells at Art field, Clay County. X-Y is the location of cross section that showing the subsurface Devonian structure in Figure 4.

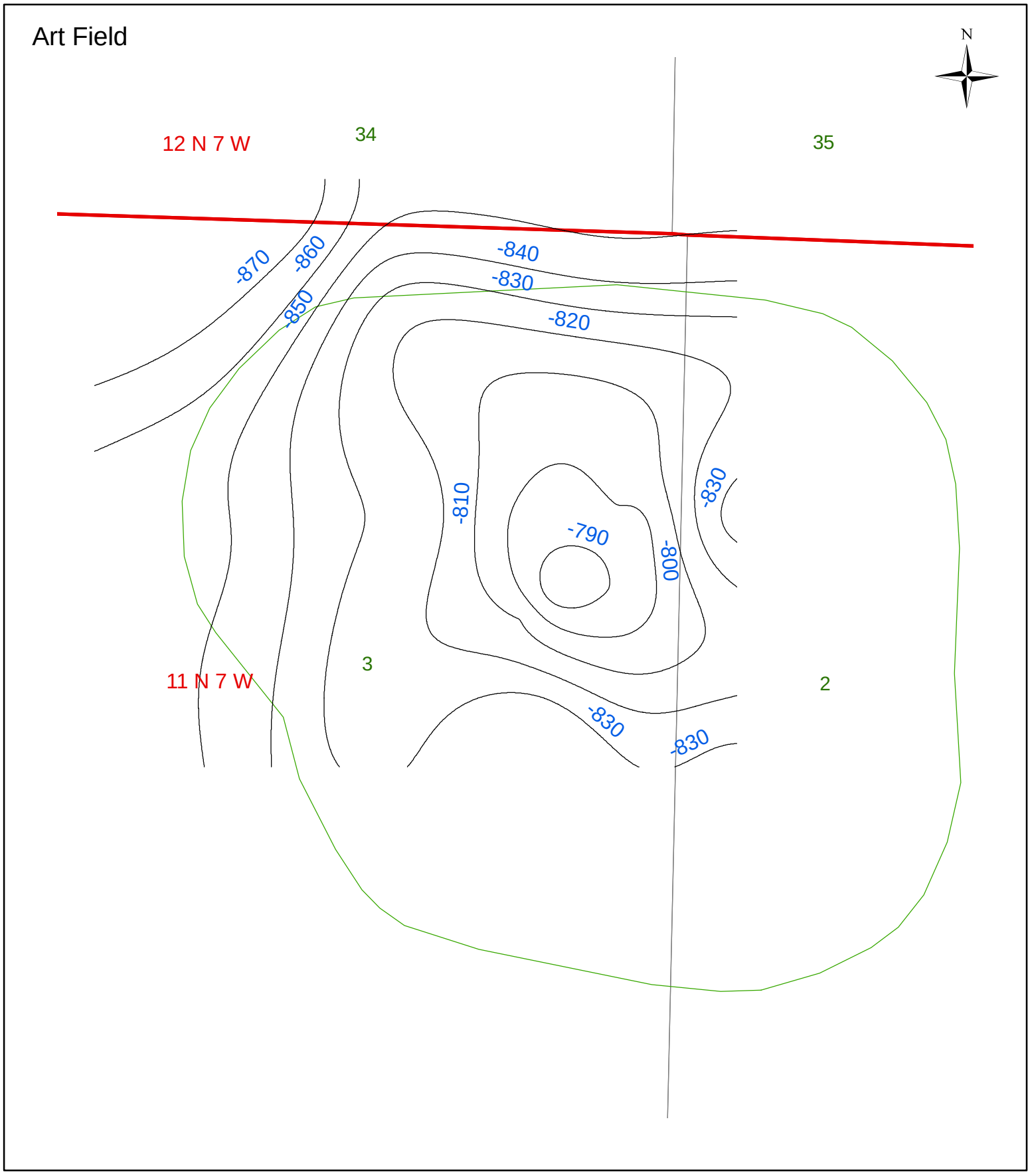

Figure 2: Structure map showing the top of Muscatatuck Limestone at Art Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

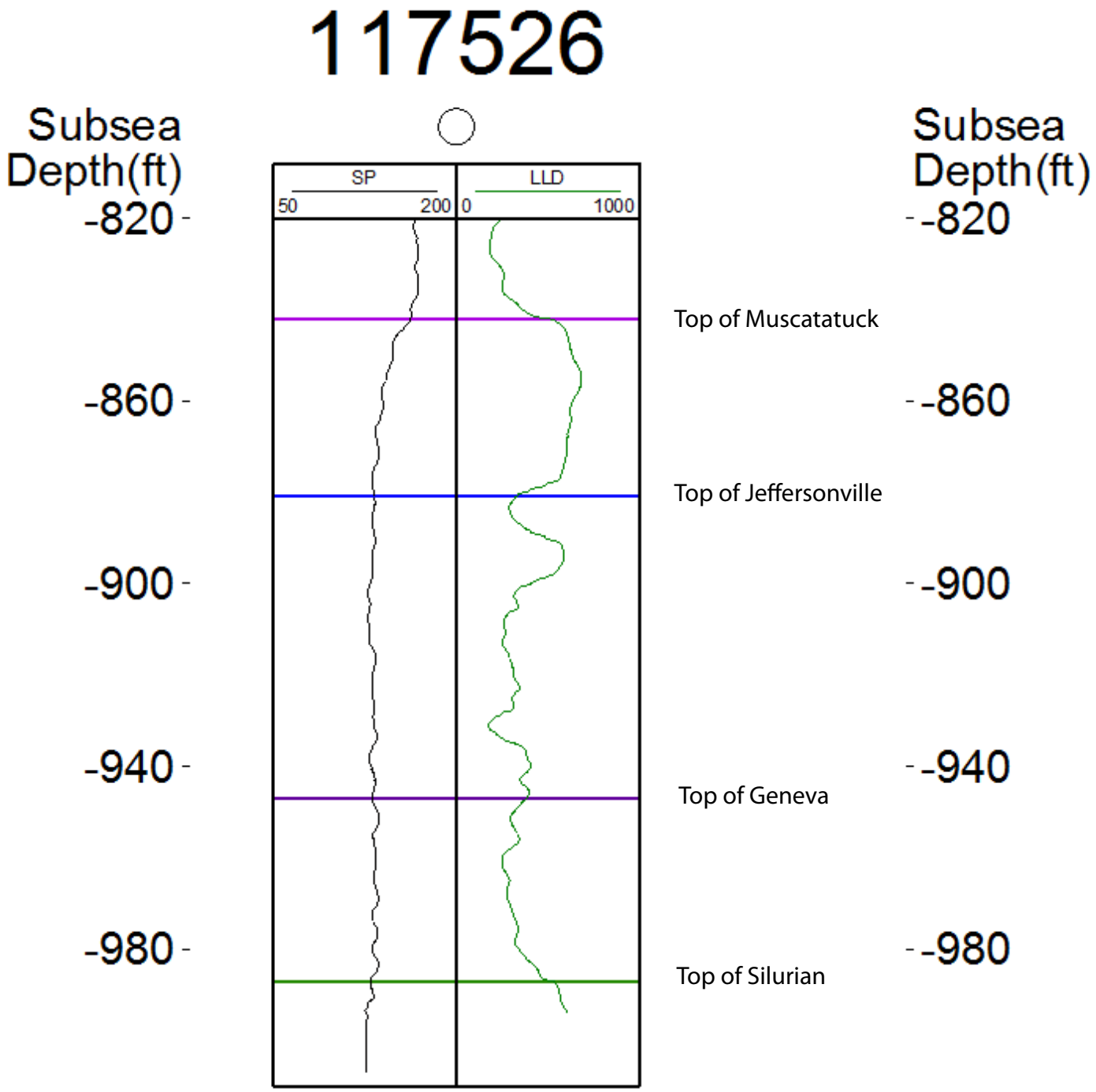

Figure 3: Type log section showing Devonian formations at Art Field, Clay County.

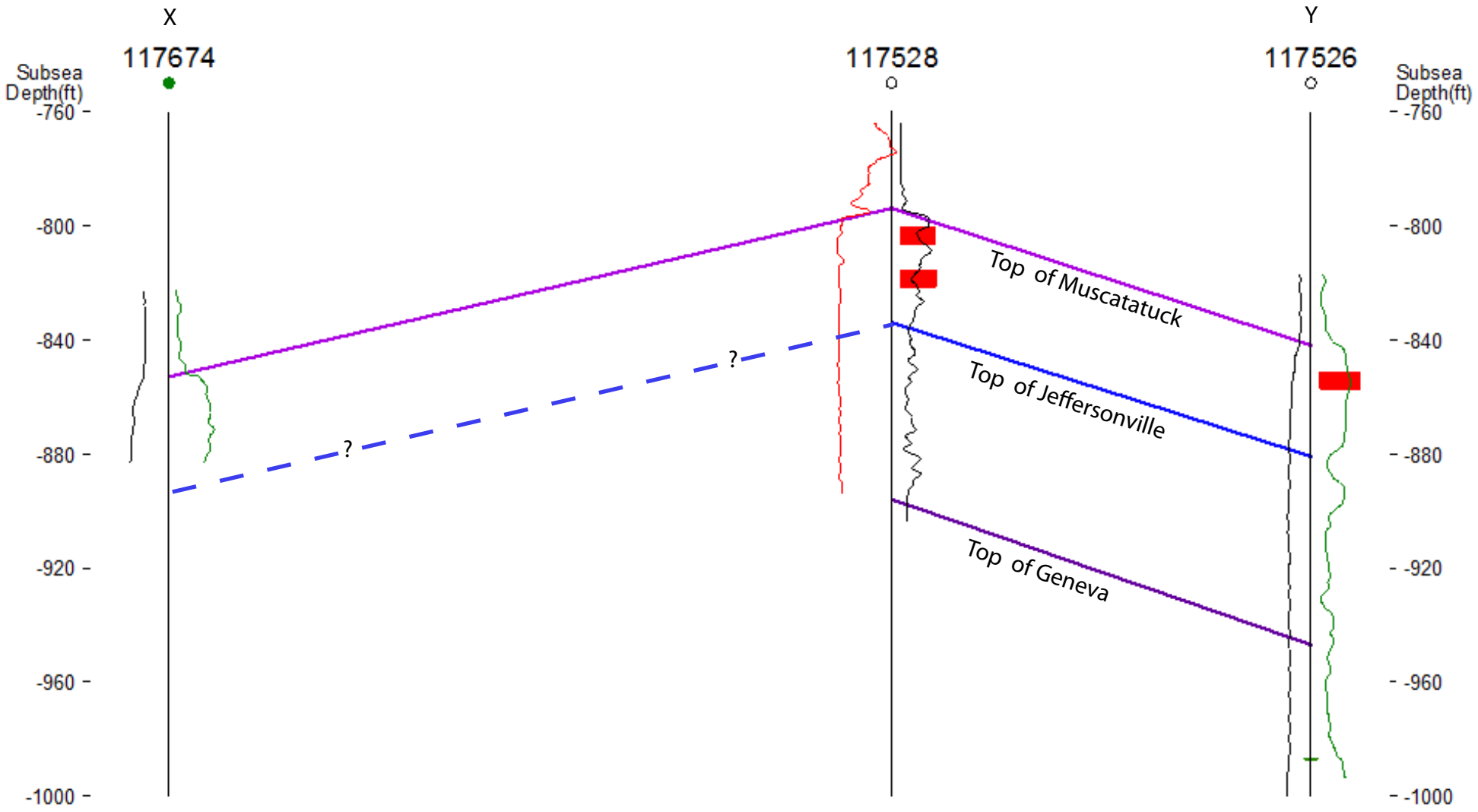

Figure 4: X-Y Cross section showing Devonian subsurface structure across Art Field, Clay County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

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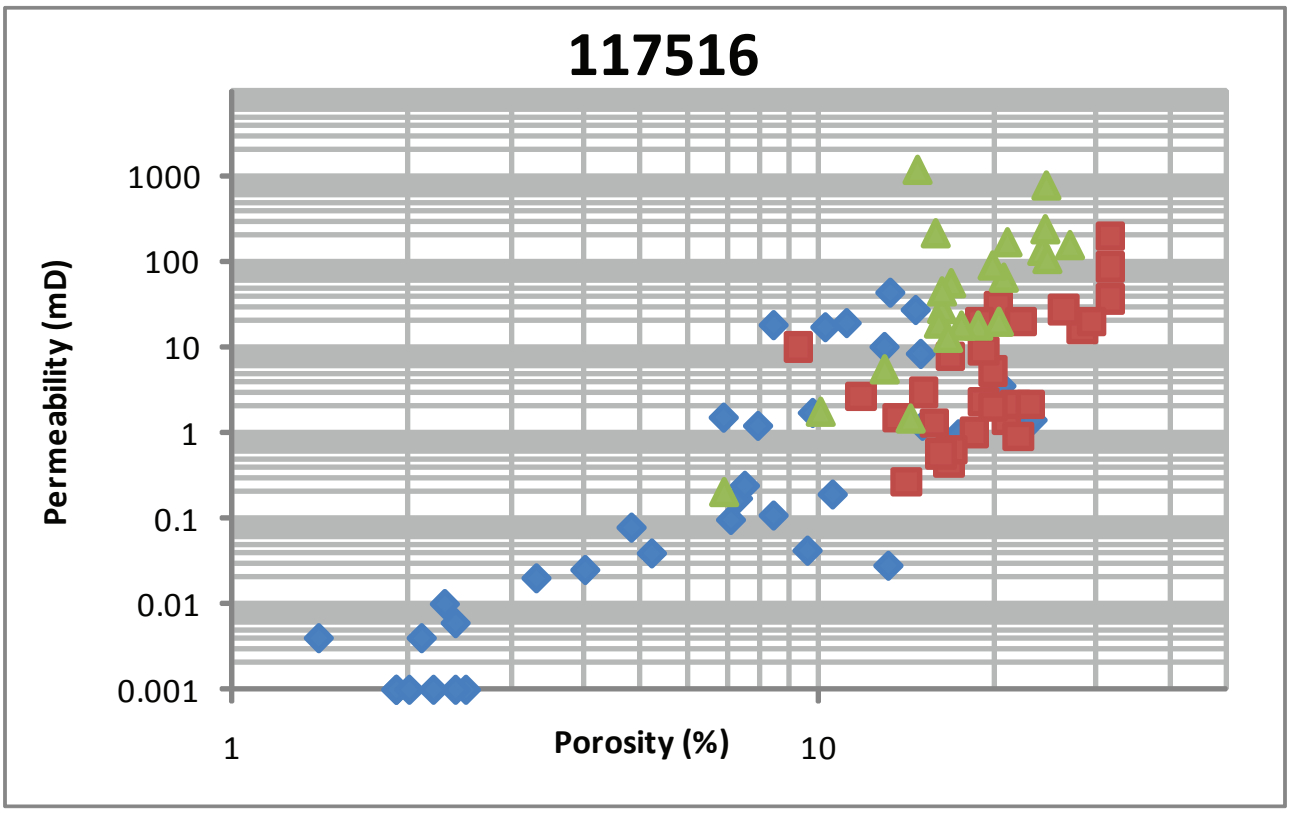

Figure 5: Porosity and permeability from core analysis from Art Field, Clay County. The blue points are from North Vernon, the red points from the Vernon Fork, the green triangles from the Geneva Dolomite. The chart title lists the IGS Well ID. For well location see Figure 1.

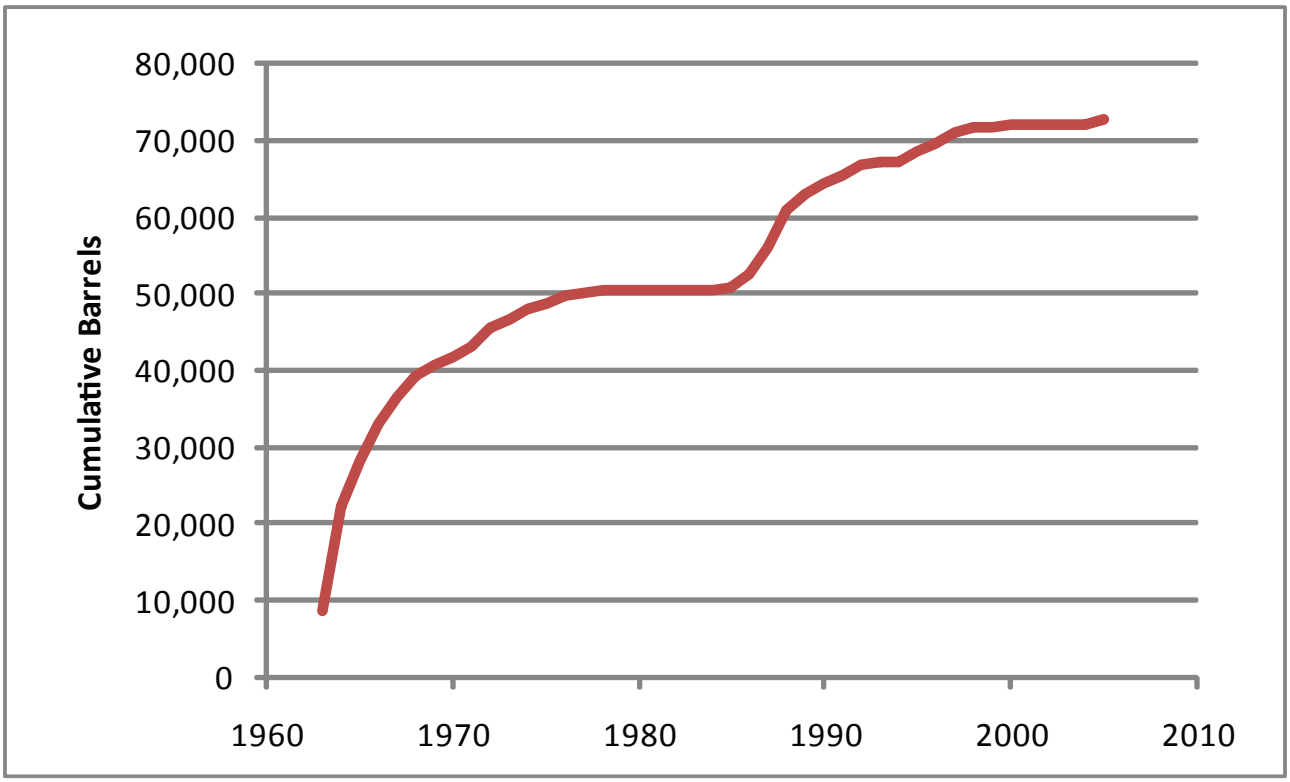

Figure - 6: Cumulative oil production history for Art Field, Clay County since 1963.

Table-1: List of the wells used for subsurface structure mapping in Art Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117513	11	N	7	W	1	603	1458	1498	1570	1629		
117514	11	N	7	W	2	630	1464				11	
117515	11	N	7	W	2	613	1426				26	
117516	11	N	7	W	2	629	1464	1500				
117517	11	N	7	W	3	636	1488	1520	1576	1620	10	
117519	11	N	7	W	3	620	1418				50/100	
117520	11	N	7	W	3	630	1423				85	
117522	11	N	7	W	3	629	1457				40	
117523	11	N	7	W	3	638	1496					
117524	11	N	7	W	3	654	1530					
117525	11	N	7	W	3	636	1430					
117526	11	N	7	W	3	633	1475	1514	1580	1620	36	
117527	11	N	7	W	3	614	1424				20	
117528	11	N	7	W	3	636	1432	1472	1532		48	
156721	11	N	7	W	3	623	1414				5	
156722	11	N	7	W	3	629	1430				8	
156723	11	N	7	W	3	618	1400				10	
117673	12	N	7	W	34	643	1509					
117674	12	N	7	W	34	617	1470					

Field name: Ashboro East

IGS ID: 10019

DOE ID: 3000

Location: Clay County, 11N-6W

Discovery date: 1980

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,338 ft.)

Field type: oil

Total number production wells: 6

Area: 110 acres

Cumulative production: 57,040 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,400 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

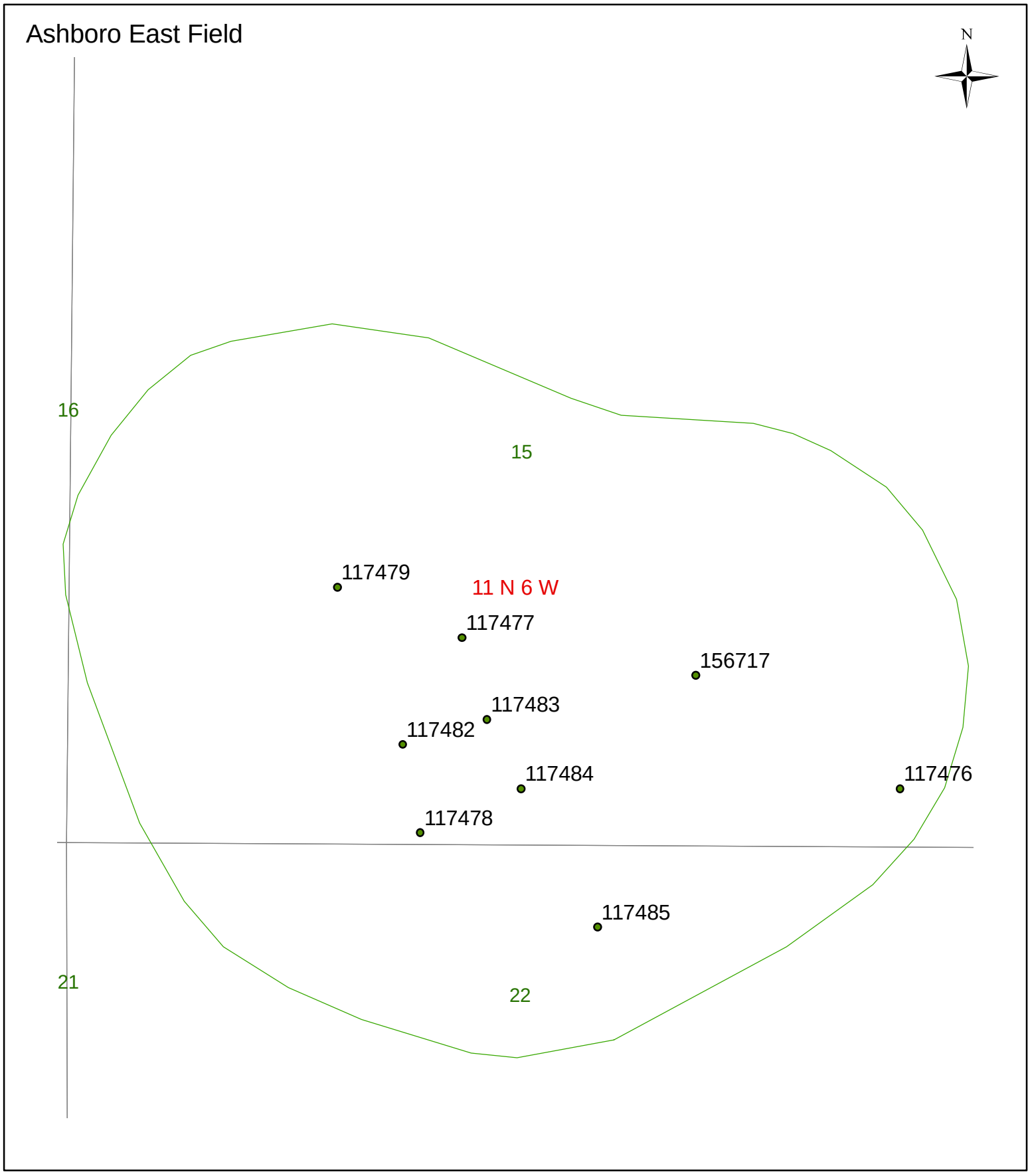

Figure 1: Map showing location and wells at Ashboro East Field, Clay County. The green points are the location of wells in the field.

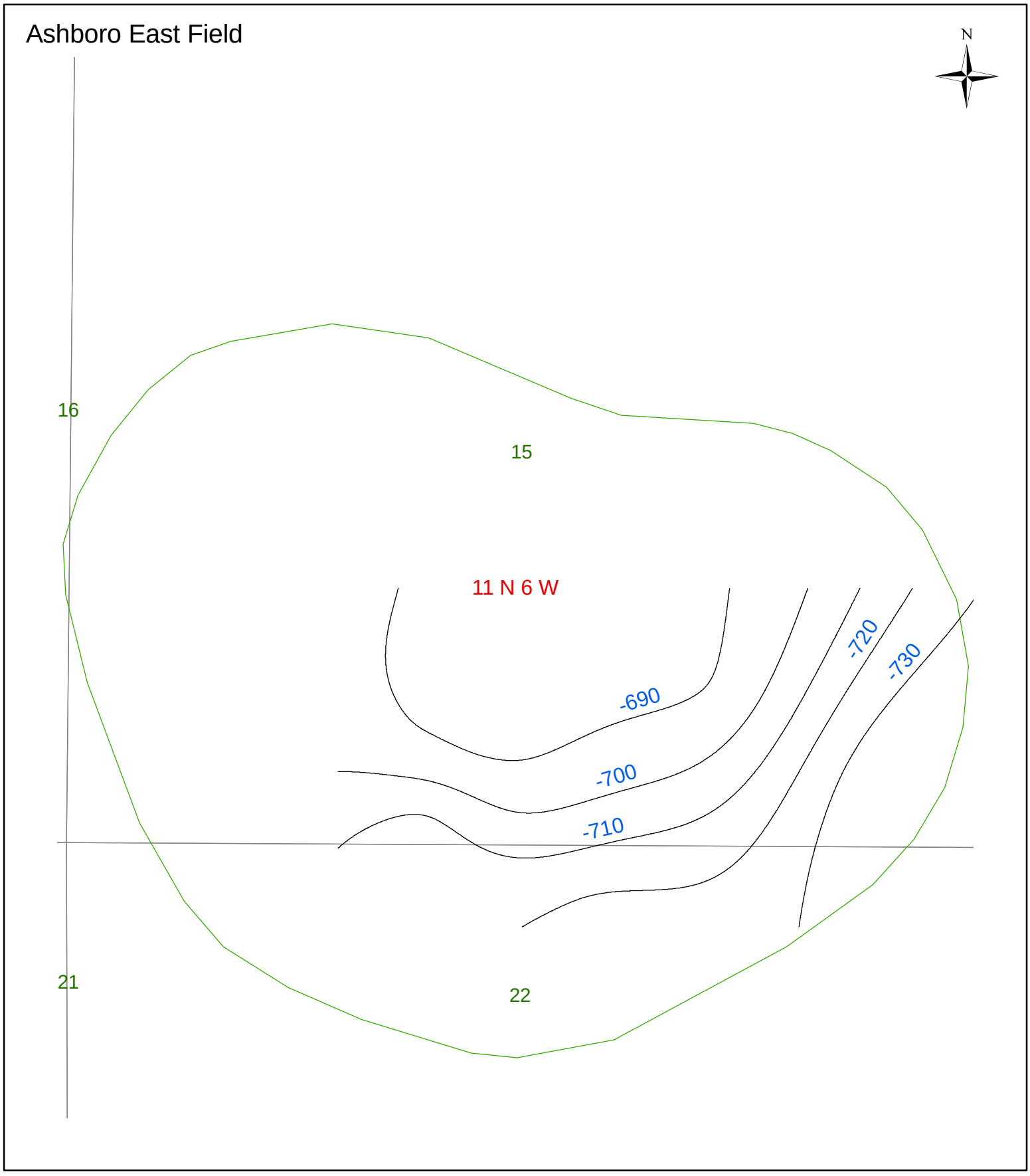

Figure 2: Structure map showing the top of Muscatatuck Limestone in Ashboro East Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

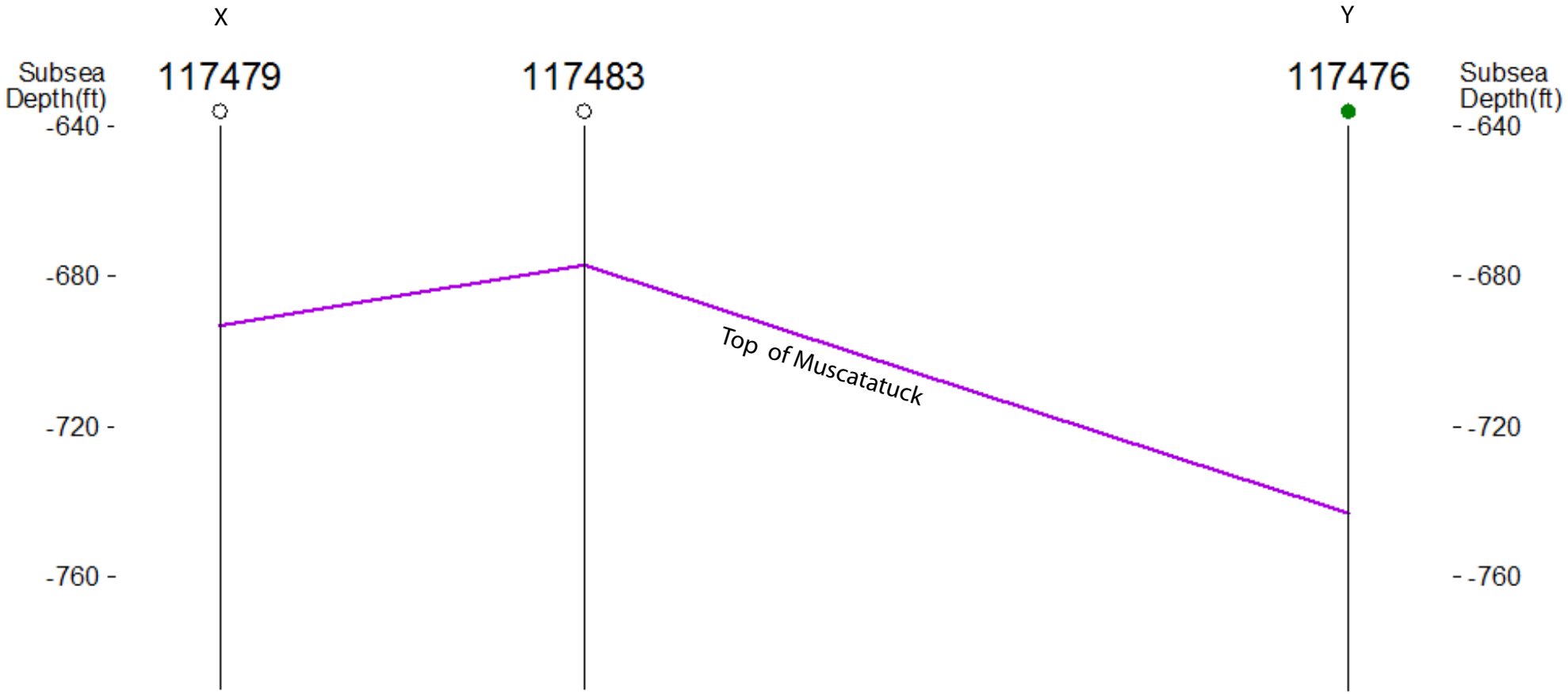

Figure 3: X-Y Cross section showing Devonian subsurface structure across Ashboro East field, Clay County. For location of the cross section refer to Figure 1.

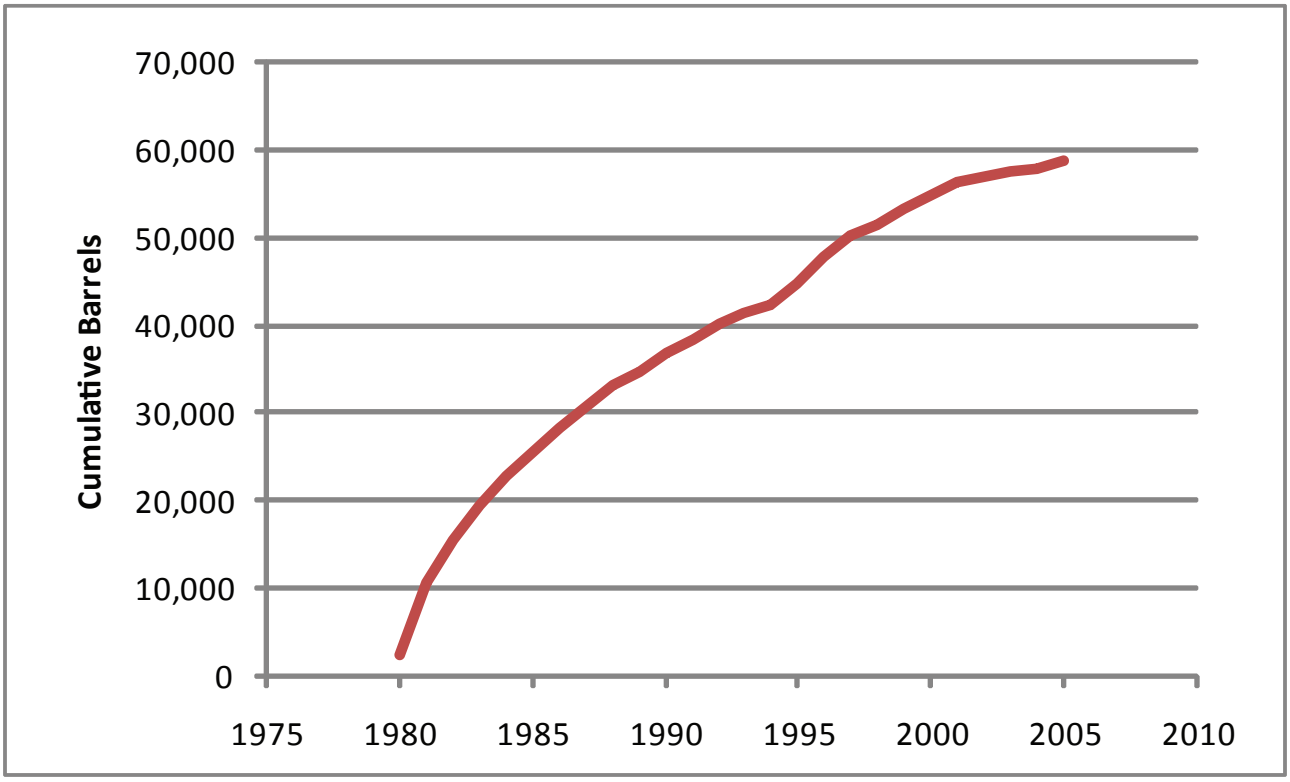

Figure - 3: Cumulative oil production history for Ashboro East Field, Clay County since 1980.

Table-1: List of the wells used for subsurface structure mapping in Ashboro East field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117475	11	N	6	W	14	586	1324	1360				
117476	11	N	6	W	15	629	1372					
117477	11	N	6	W	15	633	1320					
117478	11	N	6	W	15	631	1355				20	
117479	11	N	6	W	15	658	1351				10	
117482	11	N	6	W	15	631	1320				6	
117483	11	N	6	W	15	623	1300				2	
117484	11	N	6	W	15	626	1318				10	
156717	11	N	6	W	15	627	1312				8	
117485	11	N	6	W	22	626	1356					

Field name: Bartlettsville

IGS ID: 10032

DOE ID: 41675

Location: Monroe & Lawrence Counties, 6&7N-1E

Discovery date:

1929 (oil)

1935 (natural gas)

Lower Paleozoic reservoir units (depth):

Devonian, Muscatatuck Group (na) (natural gas)

Ordovician, Trenton Ls. (1691 ft.) (oil)

Field type: oil & natural gas

Total number production wells: 15 (oil), 4 (natural gas)

Area: 260 acres

Cumulative production: 56,413 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Cambrian/Ordovician Knox Supergroup (2,842 ft.)

Field characteristic: Anticline adjacent to Mt. Carmel Fault with structural closure in excess of 20 ft..

Reservoir characteristics:

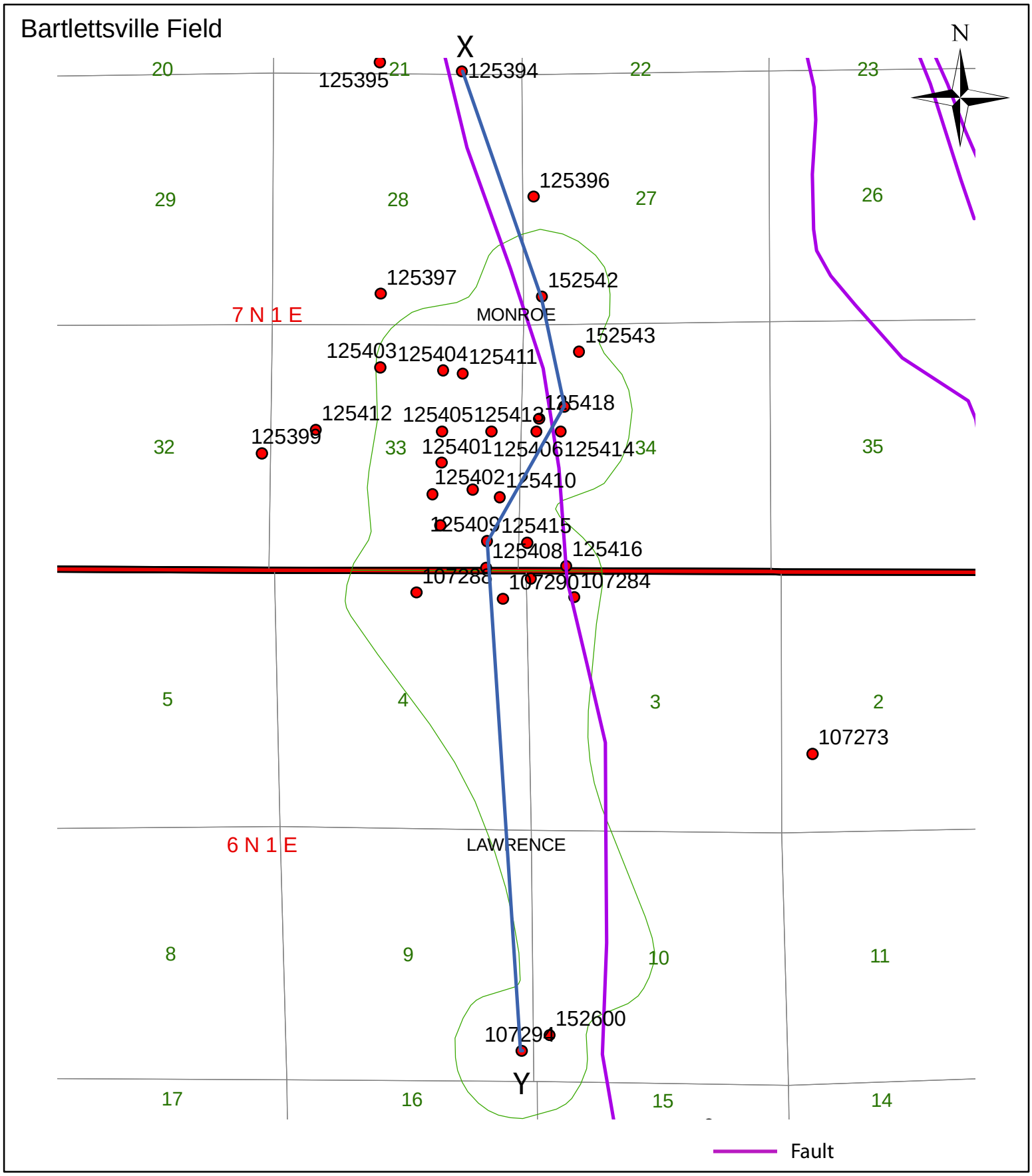

Figure 1: Map showing location and wells at Bartlettsville Field, Monroe County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 5. Mt. Carmel Fault traces are also shown.

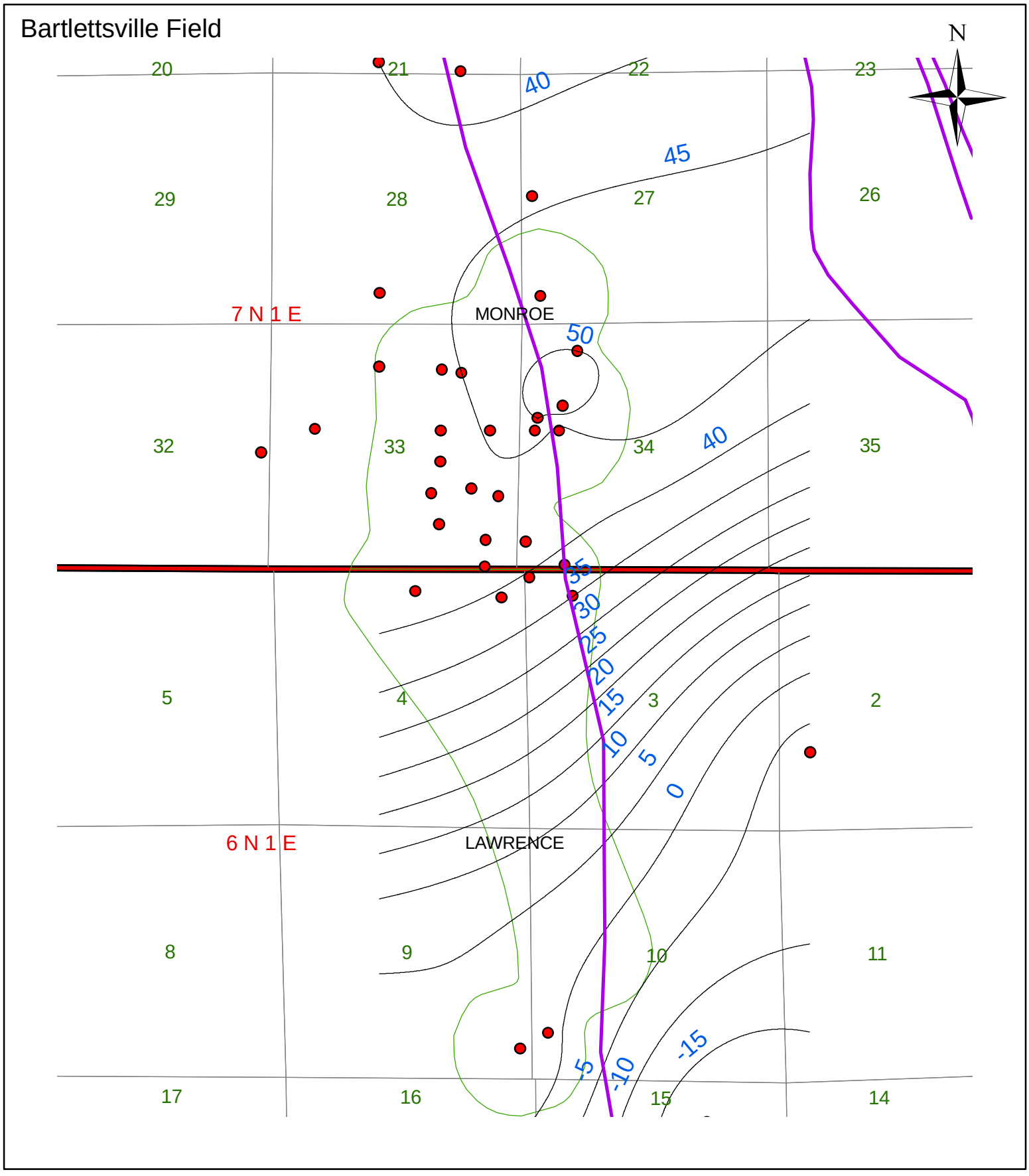

Figure 2: Structure map showing top of the Muscatatuck Limestone in the Bartlettsville Field, Monroe County. Contours show values below sea level, contour interval is 5 ft .

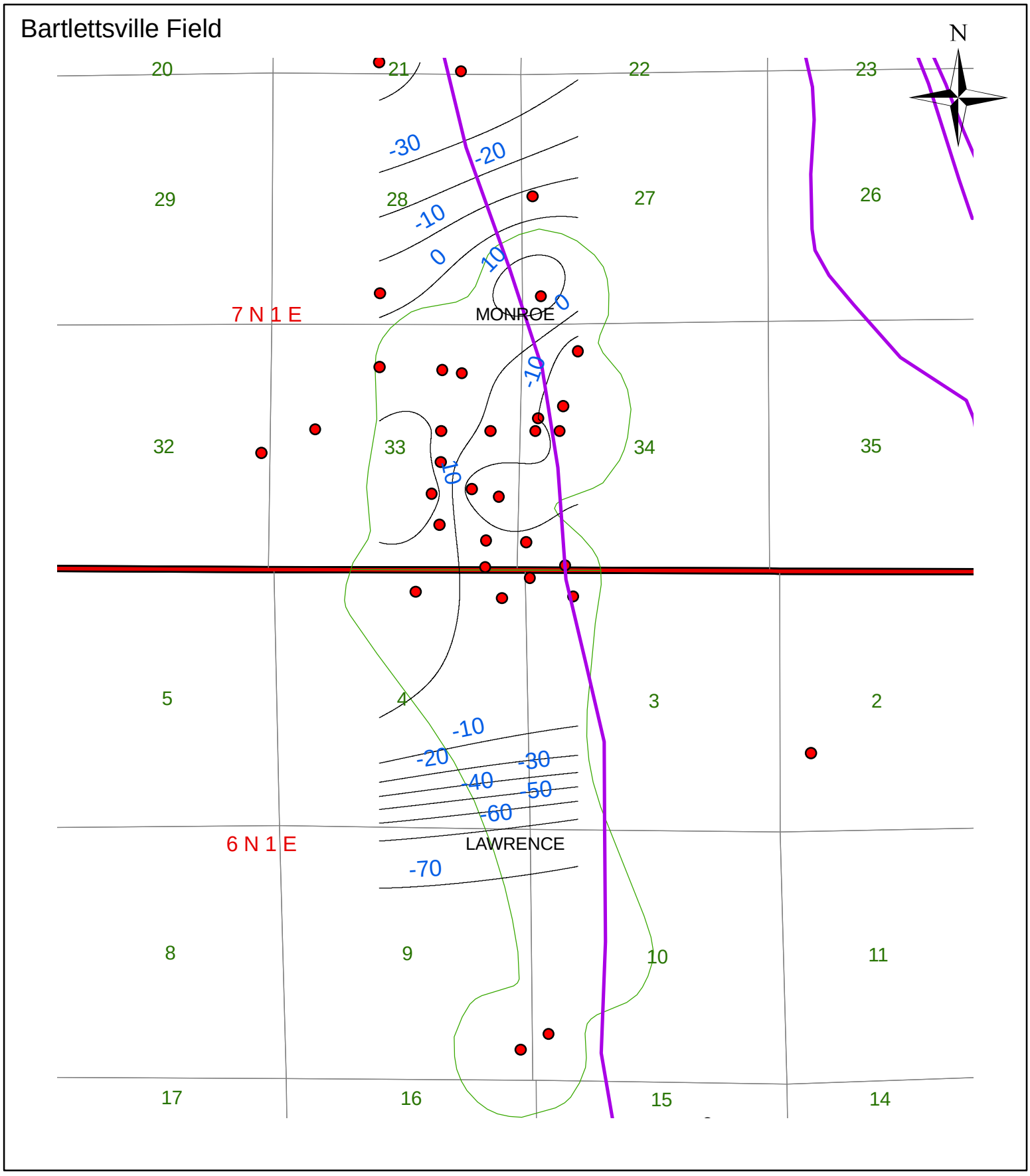

Figure 3: Structure map showing top of the Jeffersonville Limestone in Bartlettsville Field, Monroe County. Contours show values below sea level, contour interval is 10 ft .

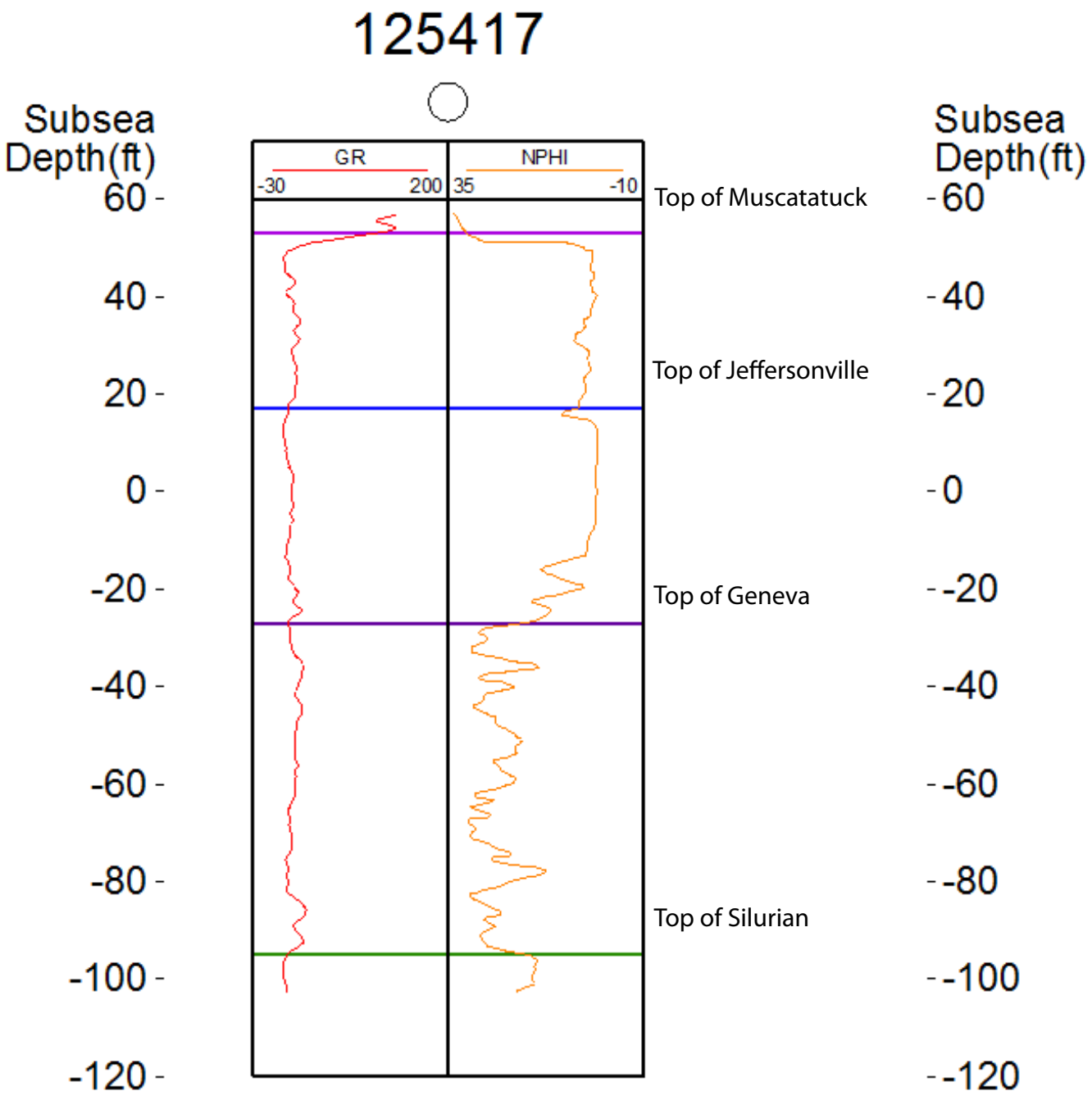

Figure 4: Type log section showing the Devonian formations at Bartlettsville Field, Monroe County.

HS=1

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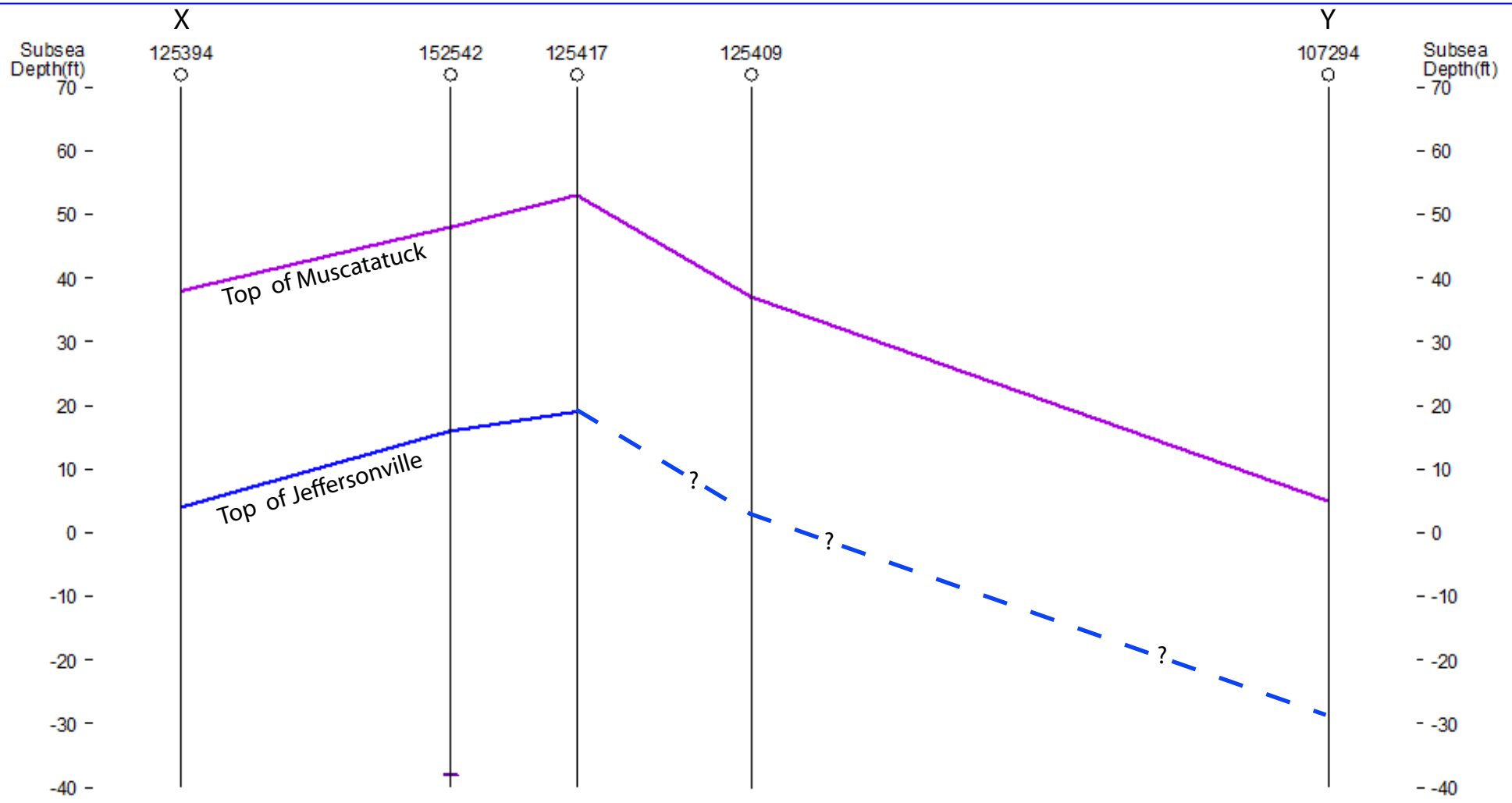

Figure 5: X-Y Cross section shows the Devonian subsurface structure across Bartlettsville Field, Monroe County. For location of the cross section refer to Figure 1.

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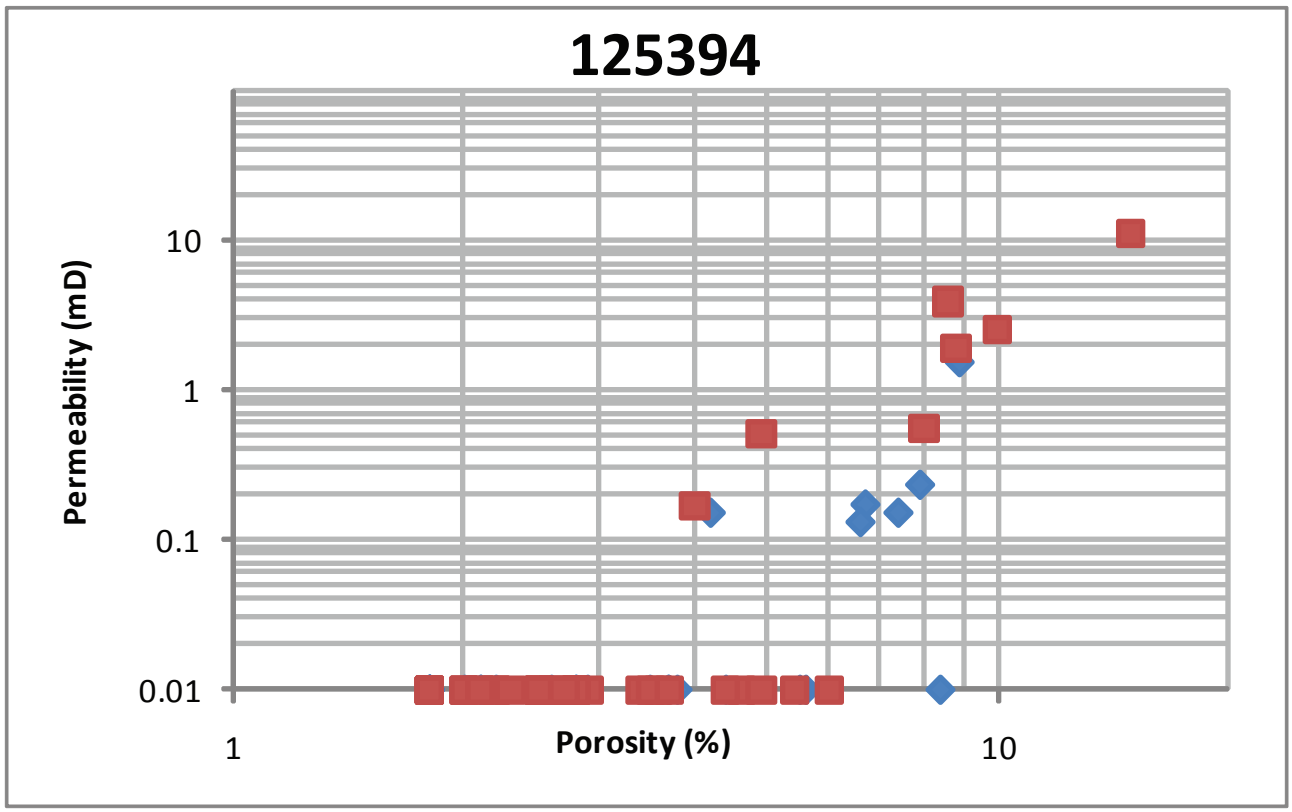

Figure 6: Porosity-permeability plot from core analysis from Bartlettsville Field, Monroe County. The blue points are from the North Vernon, the red points from the Vernon Fork. The chart title lists the IGS Well ID. For the well location see Figure 1.

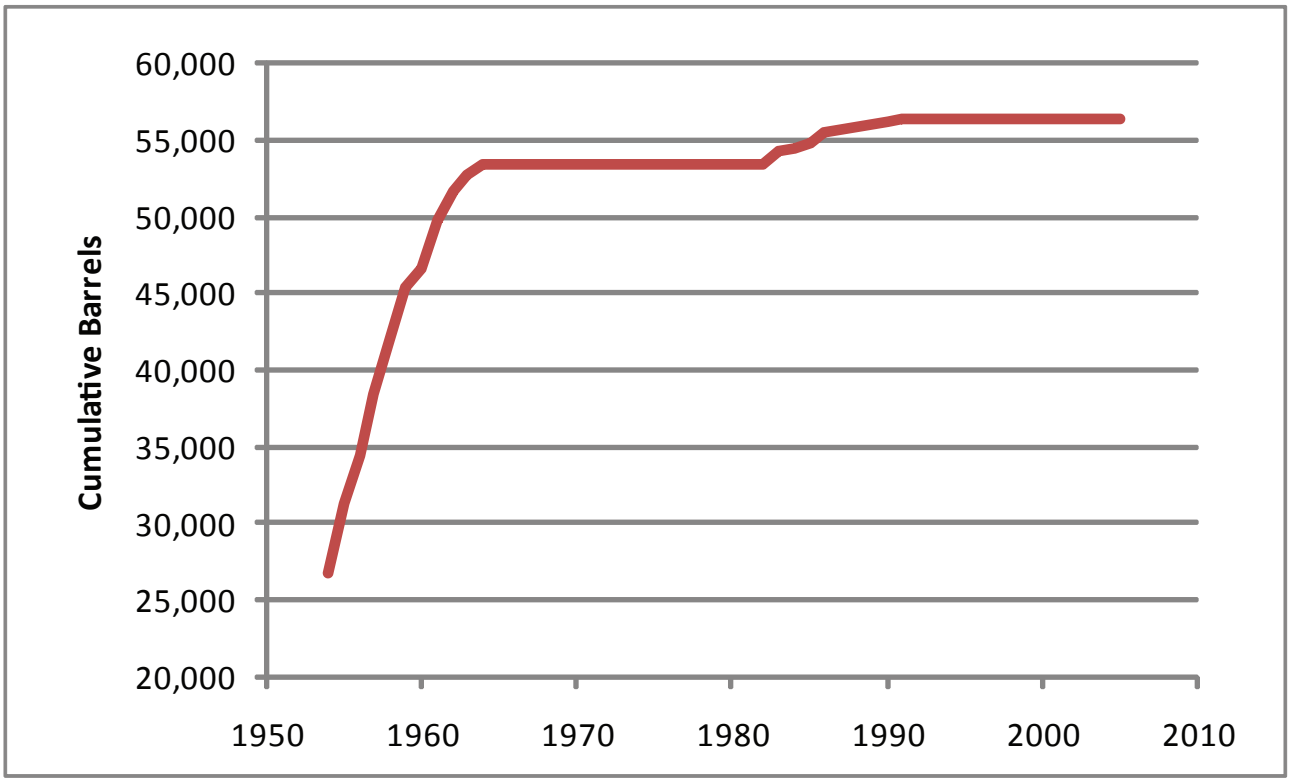

Figure - 7: Cumulative oil production history for Bartlettsville Field, Monroe County since 1954.

Table-1: List of the wells from Bartlettsville Field, Monroe County.

County	IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
Lawrence	107273	6	N	1	E	2	770	777			905		
Lawrence	107284	6	N	1	E	3	628	610					
Lawrence	107285	6	N	1	E	3	765						
Lawrence	107288	6	N	1	E	4	776	780				8	
Lawrence	107290	6	N	1	E	4	653						700
Lawrence	107294	6	N	1	E	9	567	562	638	710	770	5	3
Lawrence	152600	6	N	1	E	10	574	573					
Lawrence	107272	6	N	1	E	15	531						
Lawrence	152601	6	N	1	E	15	535	555			669		
Monroe	125391	7	N	1	E	15	804	788			922		
Monroe	125392	7	N	1	E	16	797	755					
Monroe	125394	7	N	1	E	21	802	764	840				
Monroe	125395	7	N	1	E	21	824	784	866		943		
Monroe	152540	7	N	1	E	21	699	670					
Monroe	125396	7	N	1	E	27	796	741					
Monroe	152542	7	N	1	E	27	823	775	807	861	900		
Monroe	125397	7	N	1	E	28	790	747			875		
Monroe	125399	7	N	1	E	32	625	612					
Monroe	125400	7	N	1	E	33	755	746	770	848	874	30	
Monroe	125401	7	N	1	E	33	809	766				25	
Monroe	125402	7	N	1	E	33	805	760	790	848	892	35	
Monroe	125403	7	N	1	E	33	800						
Monroe	125404	7	N	1	E	33	700	743				28	
Monroe	125405	7	N	1	E	33	797	755	788	846	900	23	
Monroe	125406	7	N	1	E	33	819	768				14	
Monroe	125407	7	N	1	E	33	785	748				30	
Monroe	125408	7	N	1	E	33	658	597					
Monroe	125409	7	N	1	E	33	671	634					
Monroe	125410	7	N	1	E	33	710						
Monroe	125411	7	N	1	E	33	805	776					
Monroe	125412	7	N	1	E	33	734	729					
Monroe	125413	7	N	1	E	34	802	764	810	855	894		
Monroe	125414	7	N	1	E	34	801	758					
Monroe	125415	7	N	1	E	34	768						
Monroe	125416	7	N	1	E	34	649						
Monroe	125417	7	N	1	E	34	797	744	810	858	892	6	
Monroe	125418	7	N	1	E	34	820	770	830	868	896	10	
Monroe	152543	7	N	1	E	34	824	774	840				

Field name: Bartlettsville North

IGS ID: 10033

DOE ID: na

Location: Monroe County, 7N-1E

Discovery date: 1986

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, na (693 ft.)

Field type: natural gas

Total number production wells: 1

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Devonian, Muscatatuck Group, na (768 ft.)

Field characteristic: Insufficient data available.

Reservoir characteristics:

Field name: Blackhawk

IGS ID: 10050

DOE ID: 69081

Location: Vigo County, 10N-8W

Discovery date: 1949

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,856 ft.)

Field type: oil

Total number production wells: 20

Area: 350 acres

Cumulative production: 584,406 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (2,110 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

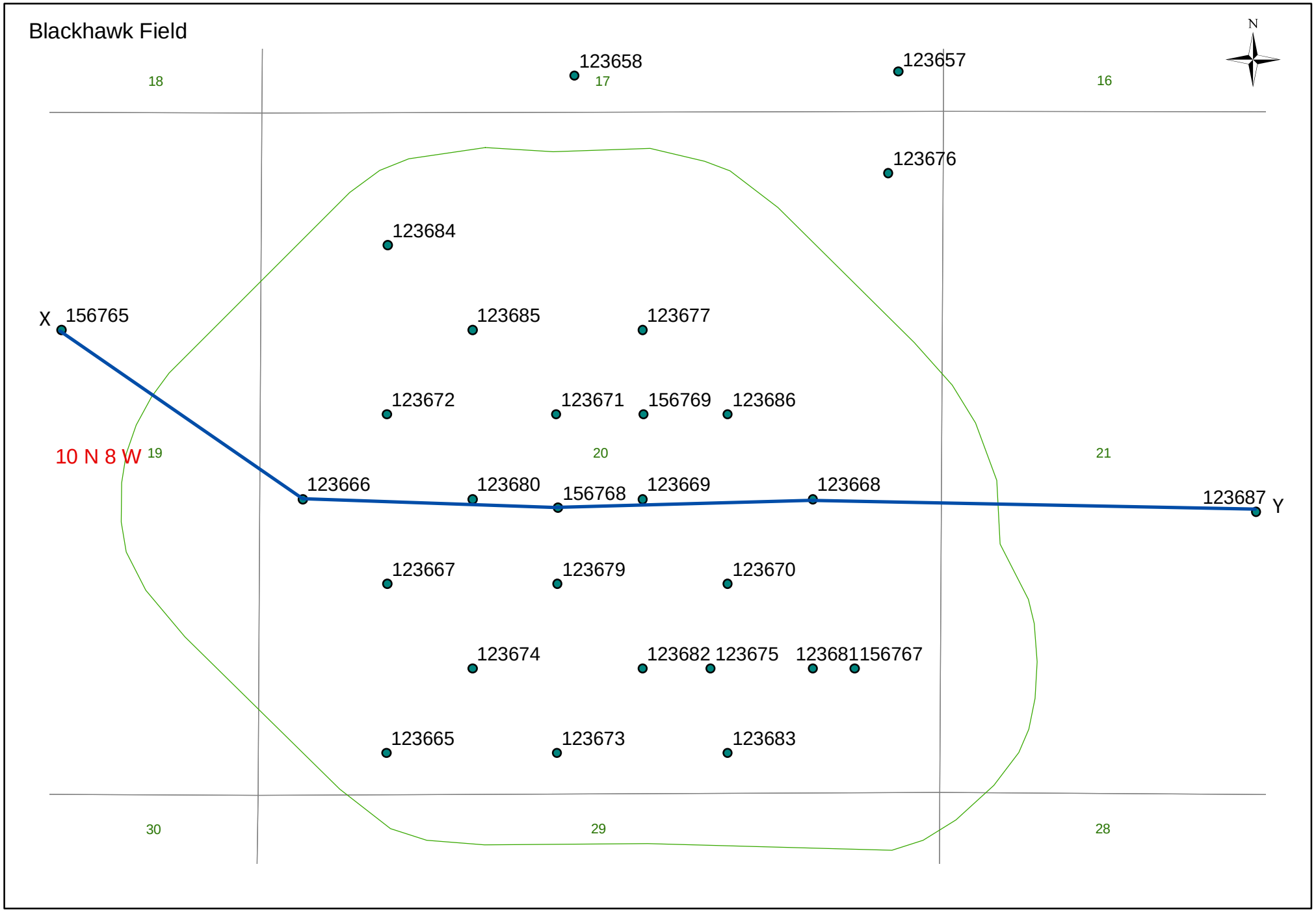

Figure 1: Map showing the location and wells at Blackhawk Field, Vigo County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 4).

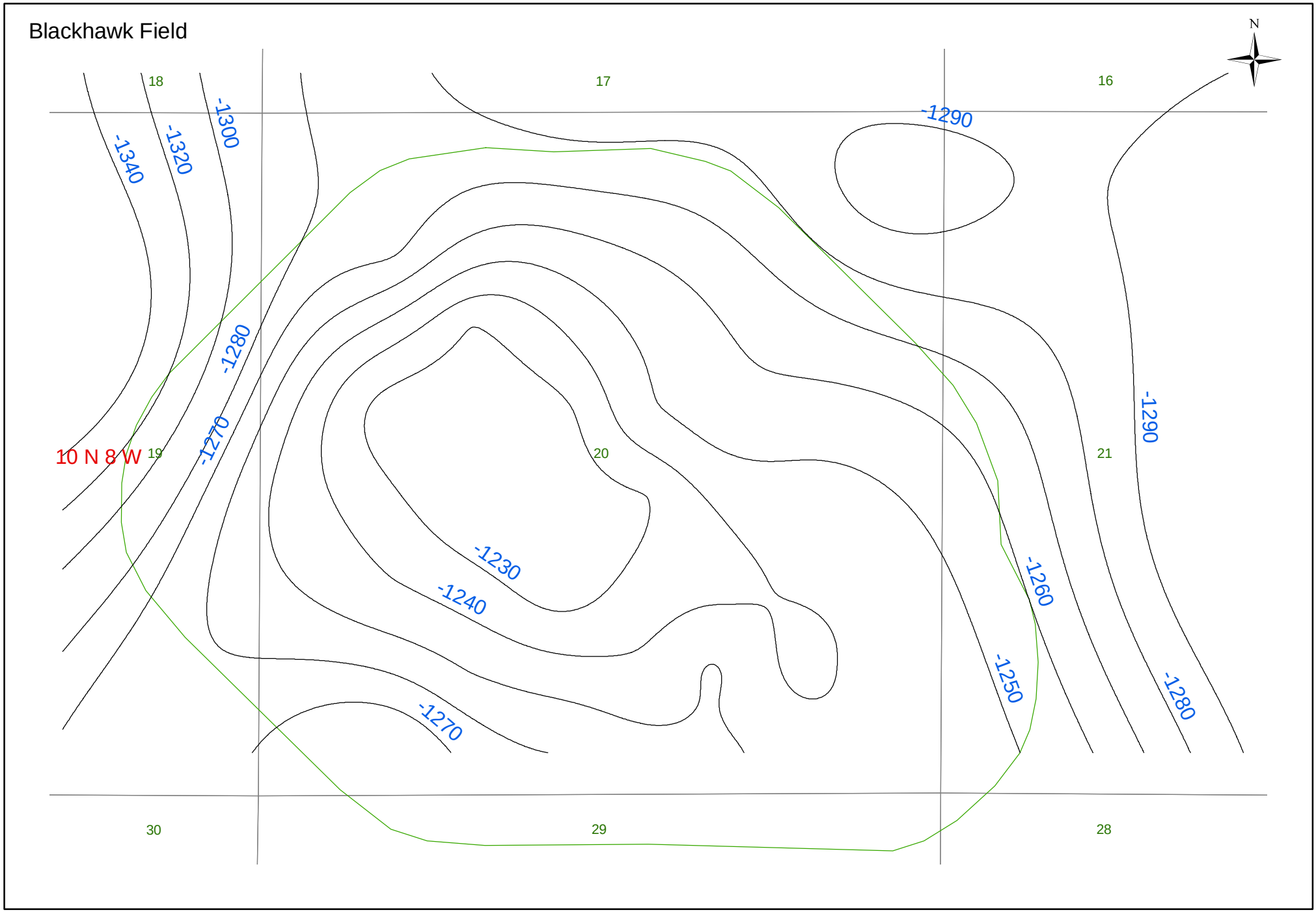

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Blackhawk Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

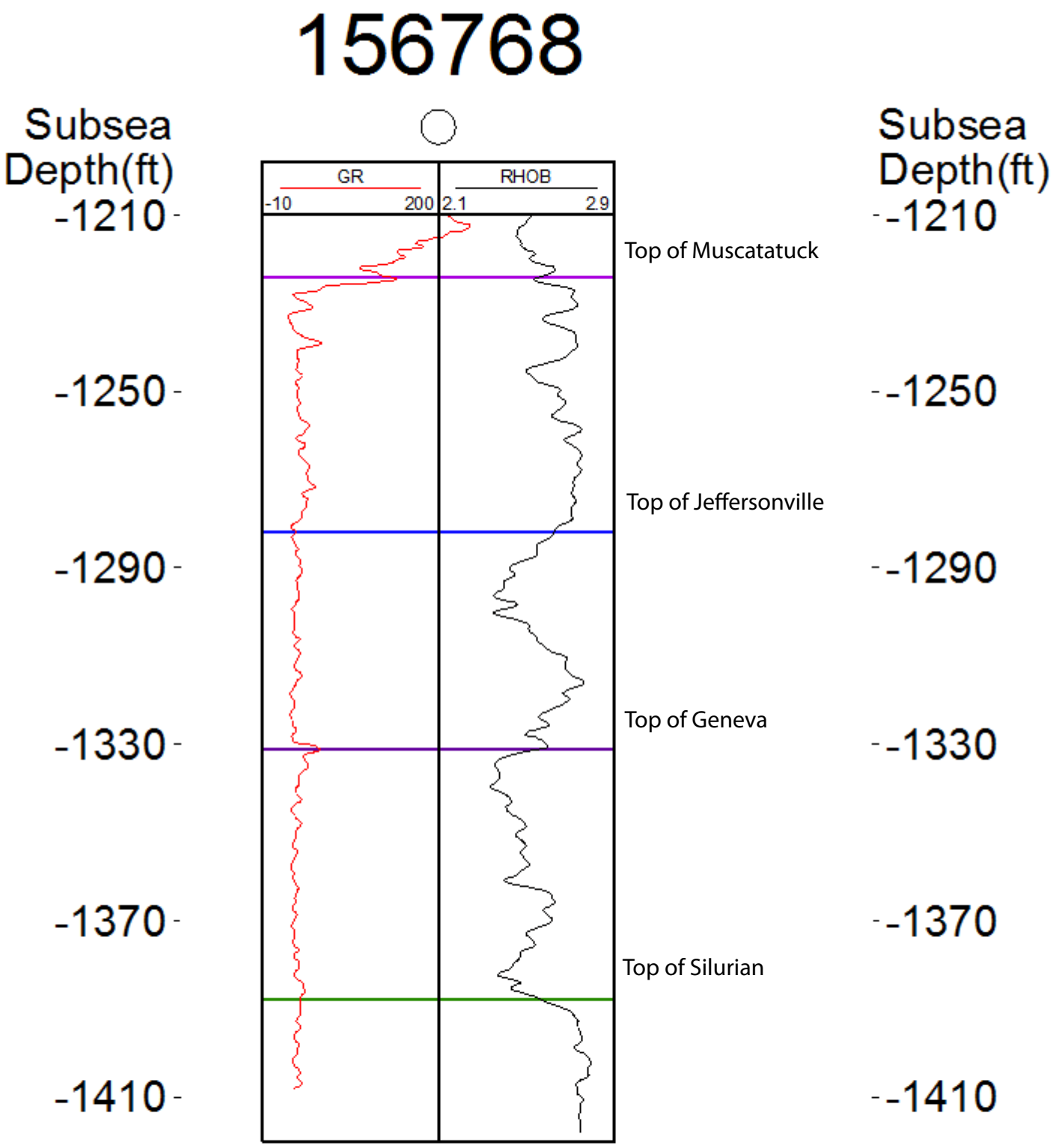

Figure 3: Type log section showing the Devonian formations at Blackhawk Field, Vigo County.

HS=1 240

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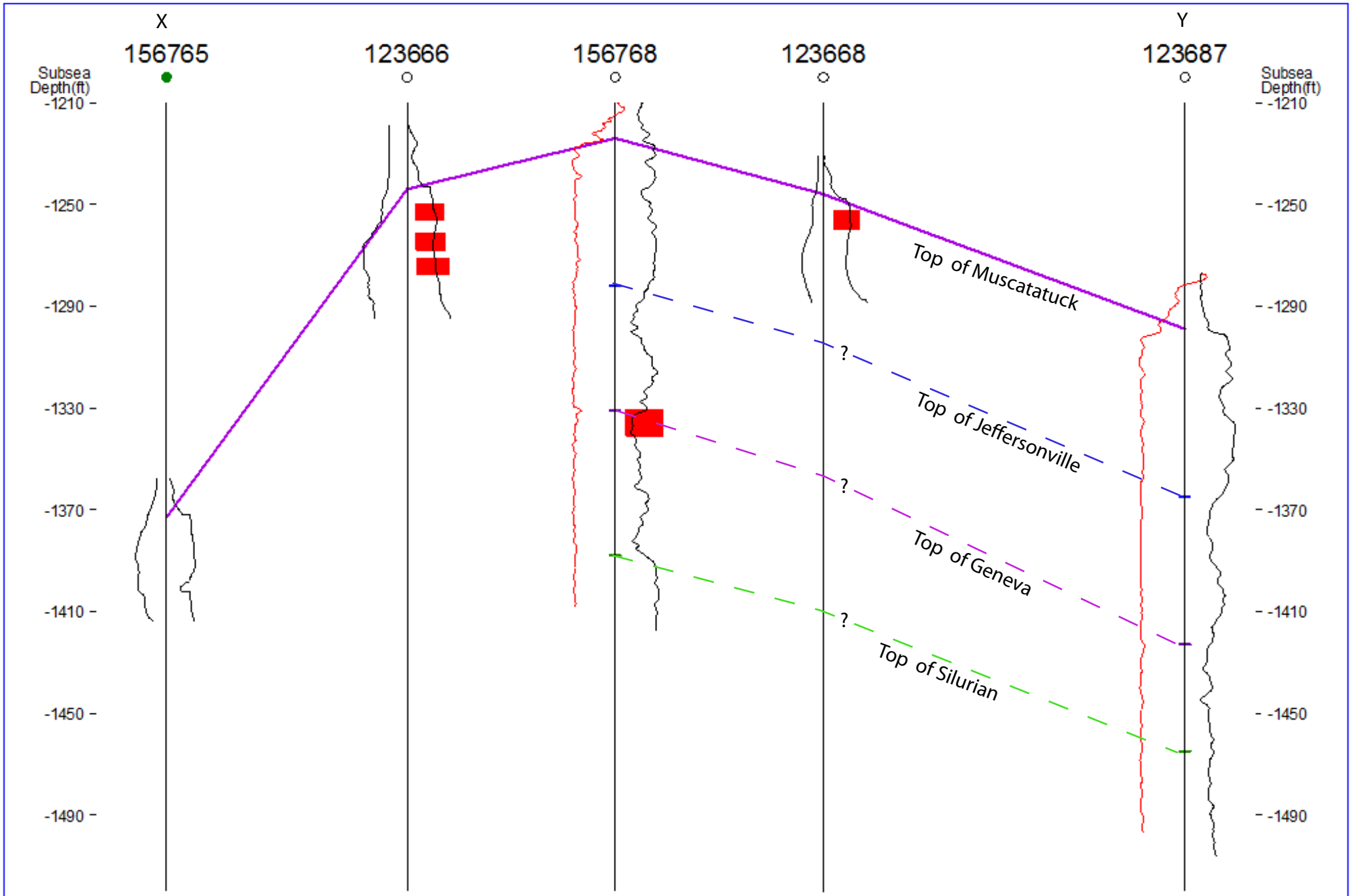


Figure 4: X-Y Cross section showing the Devonian subsurface structure across the Blackhawk Field, Vigo County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

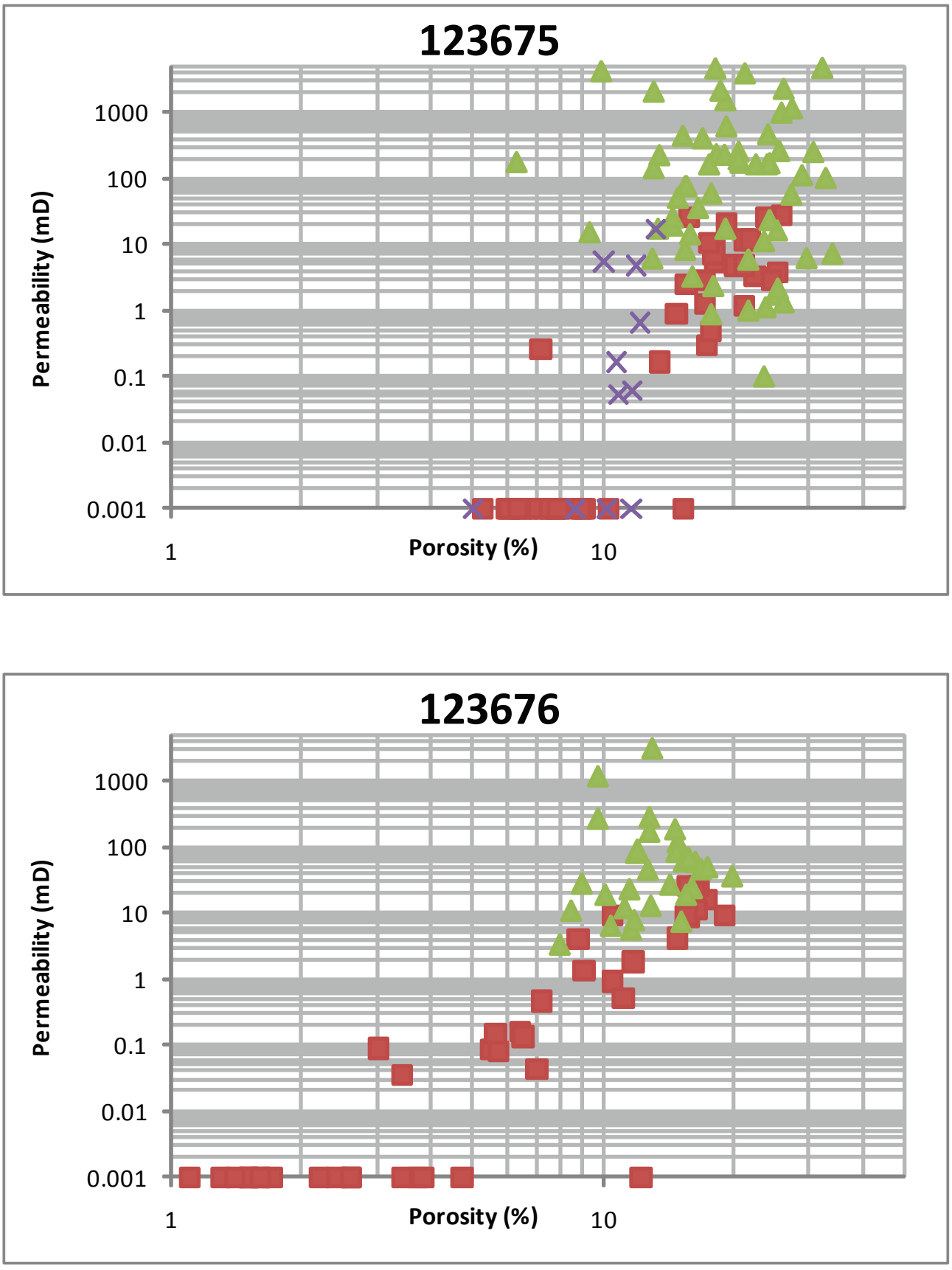
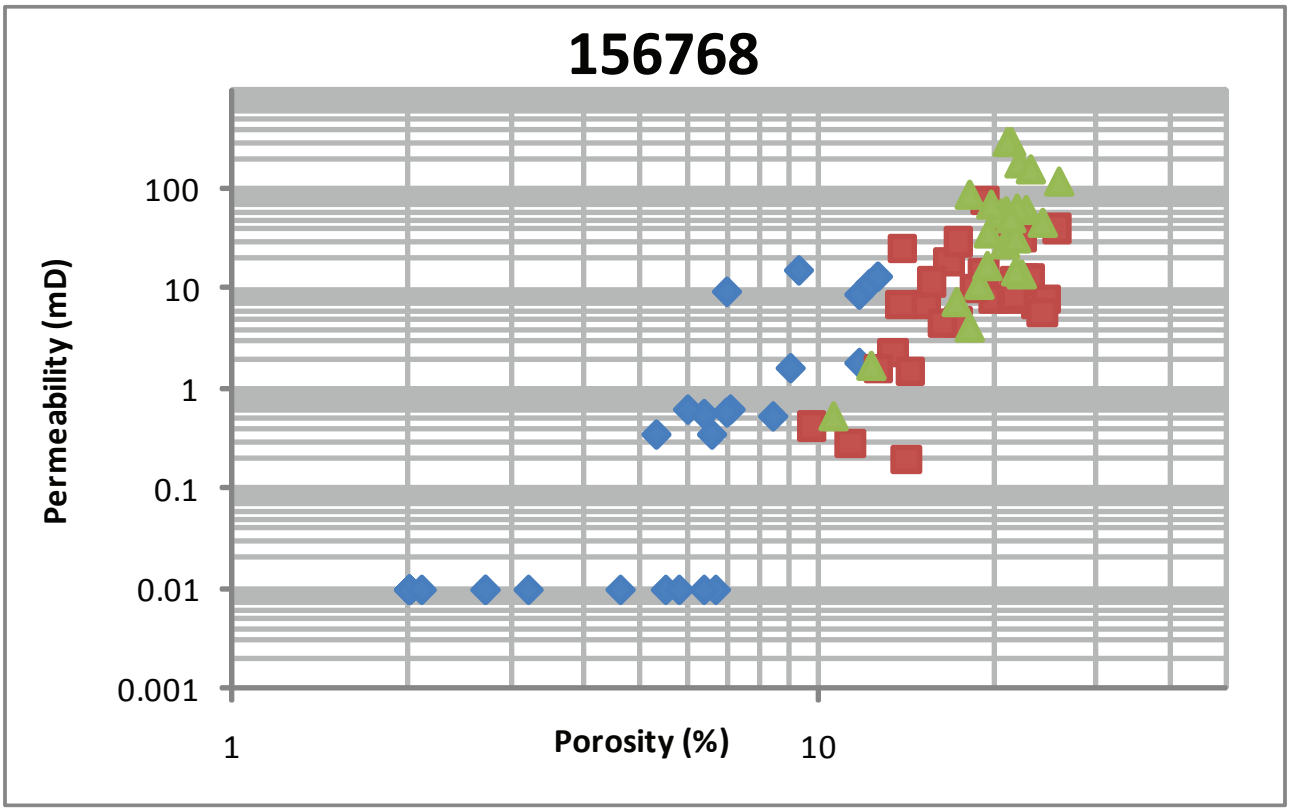


Figure 5: Porosity-permeability plots from core analysis from Blackhawk Field, Vigo County. The blue points are from North Vernon, the red points from the Vernon Fork, the green triangles from the Geneva Dolomite, and the crosses from the Silurian. The chart title lists the IGS Well ID. For the well locations see Figure 1.

Figure 5: Continued....



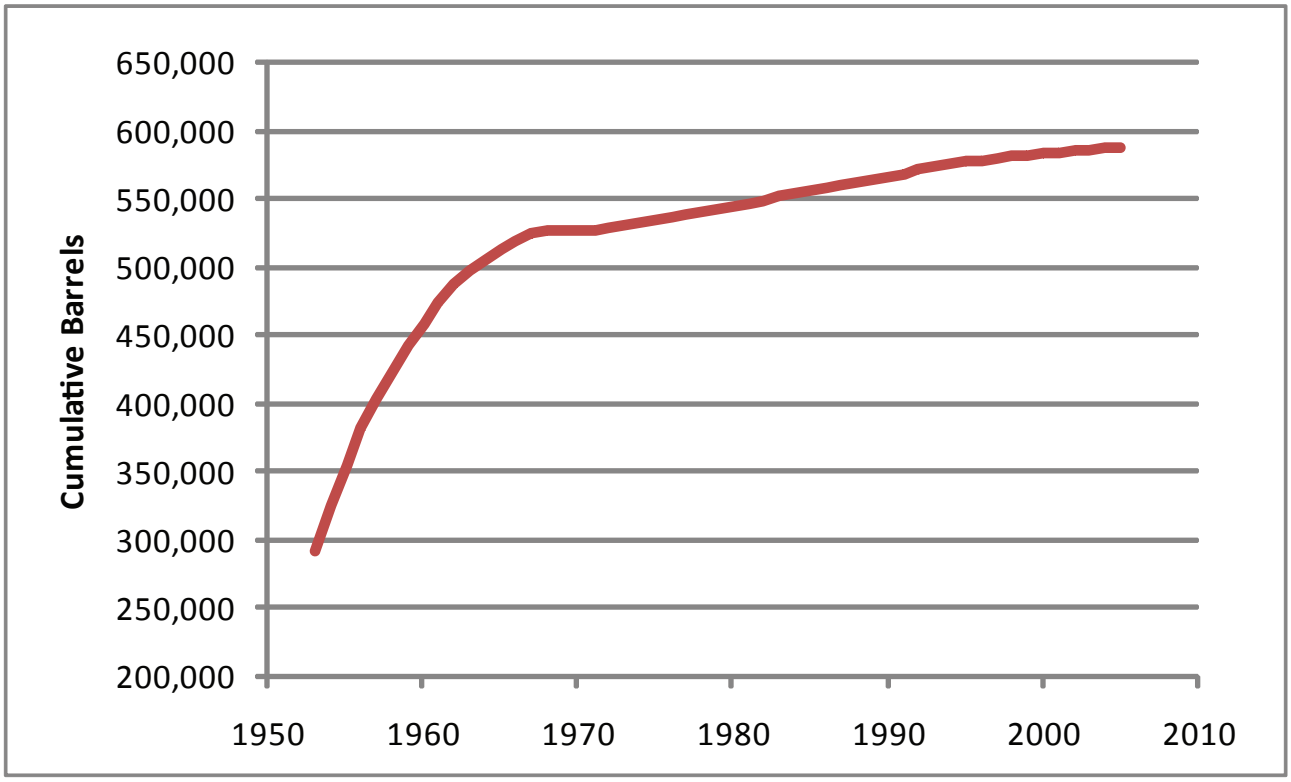


Figure - 6: Cumulative oil production history for Blackhawk Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Blackhawk Field, Vigo County. The wells selected have TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)	Core (P/A)
123657	10	N	8	W	17	619	1902						
123658	10	N	8	W	17	653	1943	2006	2071	2115			
156765	10	N	8	W	19	632	2005						
123665	10	N	8	W	20	629	1912						
123666	10	N	8	W	20	631	1875				100		
123667	10	N	8	W	20	633	1874				20		
123668	10	N	8	W	20	609	1855				61		Present
123669	10	N	8	W	20	620	1849	1906			100		
123670	10	N	8	W	20	596	1834				104		Present
123671	10	N	8	W	20	632	1858	1920			77		Present
123672	10	N	8	W	20	647	1872				161		
123673	10	N	8	W	20	638	1898						
123674	10	N	8	W	20	639	1888				36		
123675	10	N	8	W	20	619	1870	1922	1980	2040	5		Present
123676	10	N	8	W	20	612	1909	1968	2028	2065			Present
123677	10	N	8	W	20	648	1900				10		
123679	10	N	8	W	20	621	1845				70		
123680	10	N	8	W	20	635	1857				94		
123681	10	N	8	W	20	606	1841				144		
123682	10	N	8	W	20	633	1875				78		
123683	10	N	8	W	20	635	1886						
123684	10	N	8	W	20	662	1936						
123685	10	N	8	W	20	648	1877				103		
123686	10	N	8	W	20	617	1874	1936	2006	2049	45		Present
156767	10	N	8	W	20	598	1842						
156768	10	N	8	W	20	622	1847	1902	1944	2010	7		Present
156769	10	N	8	W	20	629	1877						
123687	10	N	8	W	21	583	1884	1948	2006	2048			

Field name: Bowling Green

IGS ID: 10057

DOE ID: 84600

Location: Clay County, 11N-6W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,274 ft.)

Field type: oil

Total number production wells: 10

Area: 120 acres

Cumulative production: 245,652 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, carper Ss.

Deepest unit penetrated (depth): Silurian (1,505 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

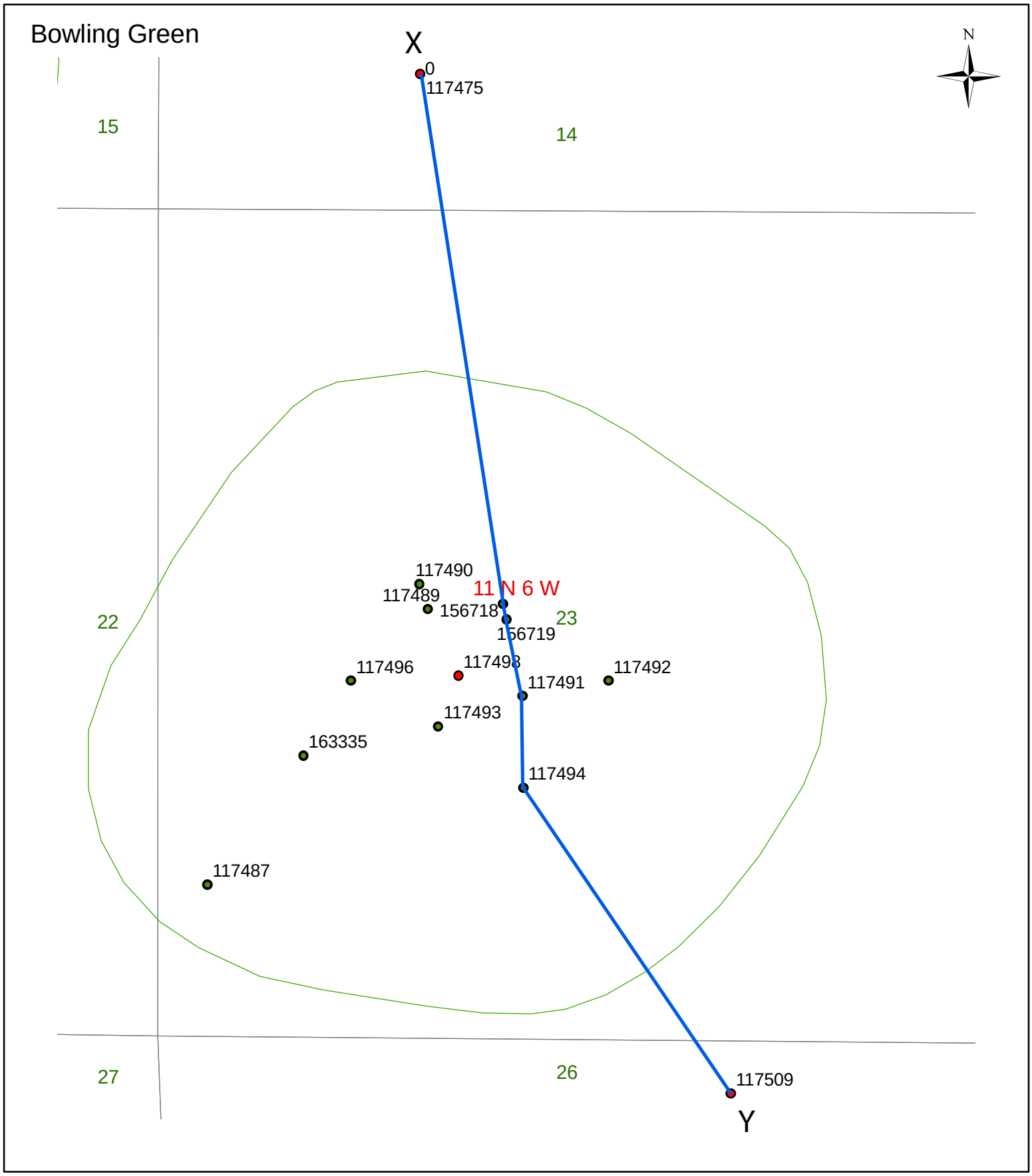


Figure 1: Map showing location and wells at Bowling Green Field, Clay County. X-Y is the location of cross section showing subsurface Devonian structure in Figure 4.

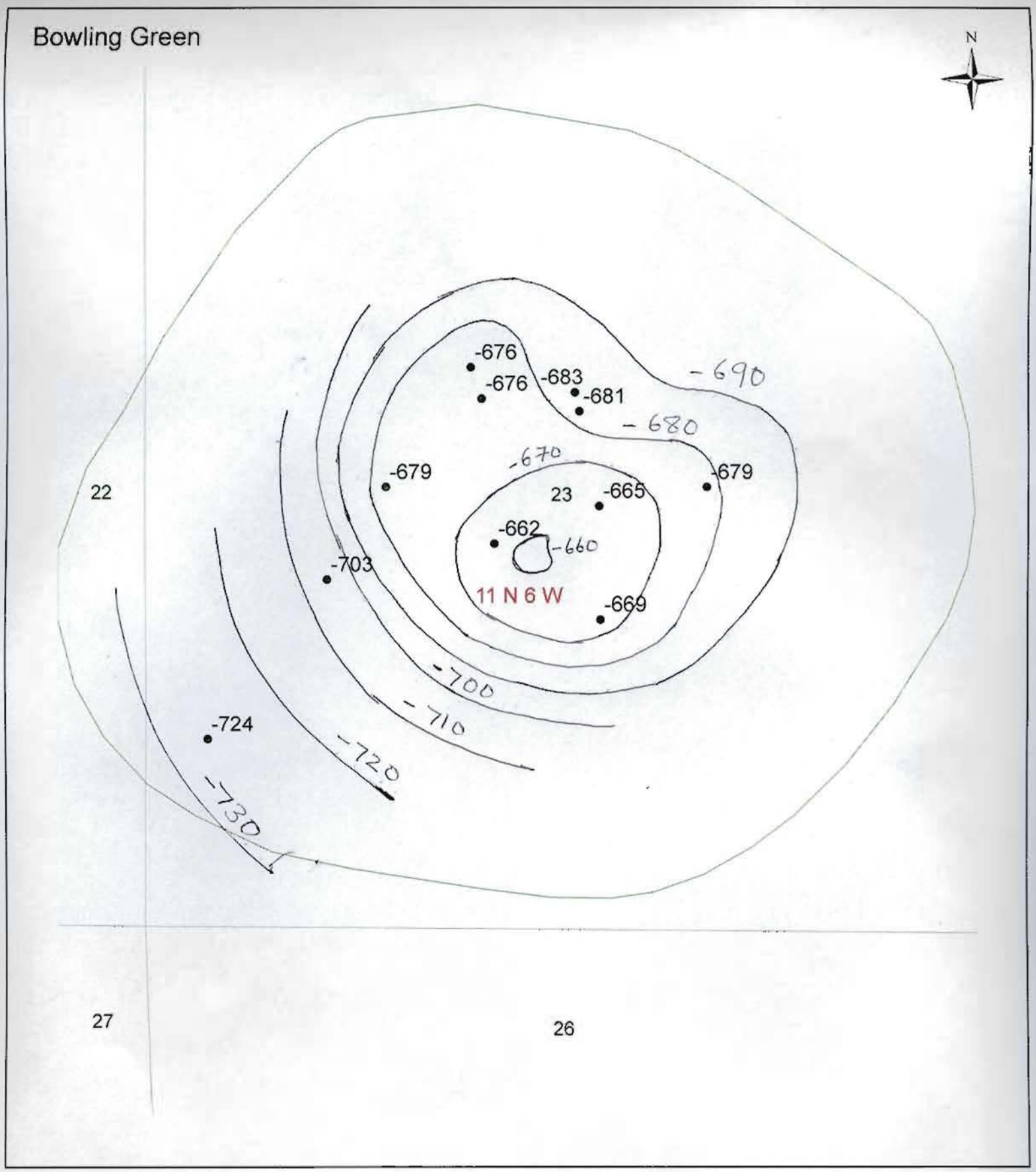


Figure 2: Structure map showing top of Muscatatuck Limestone in Bowling Green field, Clay County. Contours show values below sea level, contour interval is 10 ft .

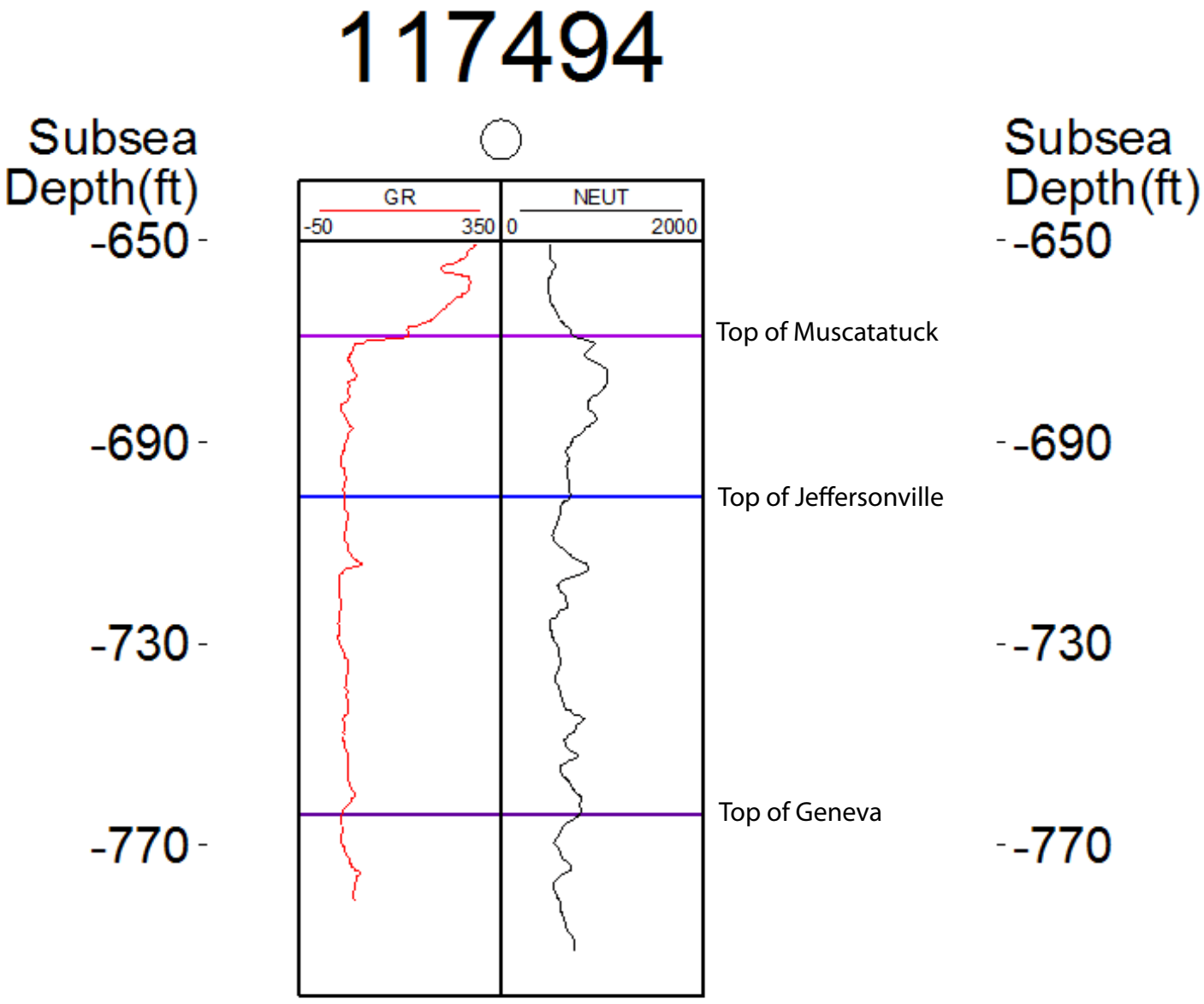


Figure 3: Type log section showing the Devonian formations from Bowling Green Field, Clay County.

HS=1

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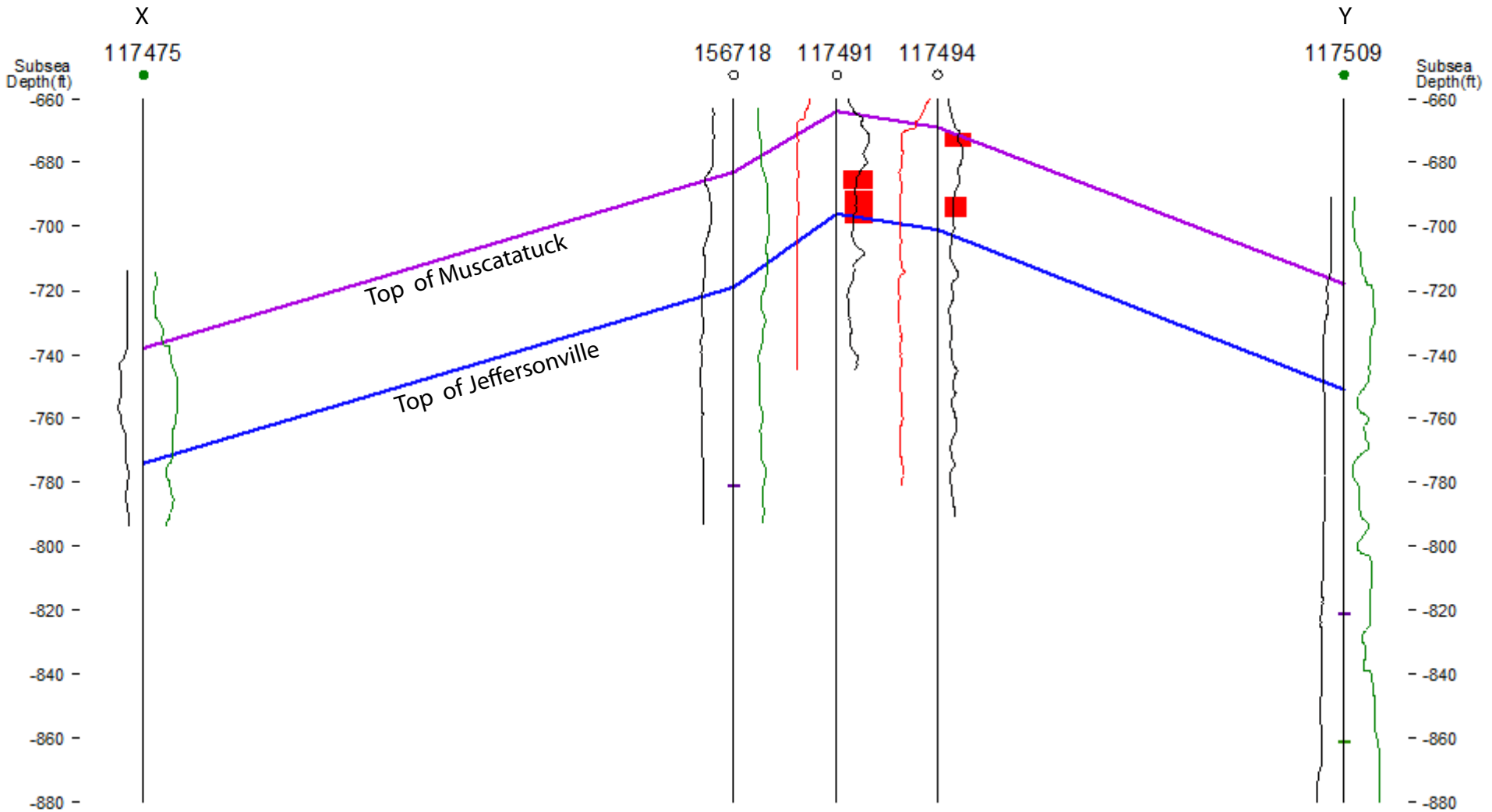

Figure 4: X-Y Cross section showing Devonian subsurface structure across Bowling Green Field, Clay County. The red color box shows completion intervals for oil production. For location of the cross section refer to Figure 1.

250

PETRA 6/20/2008 1:23:20 PM (XY.CSP)

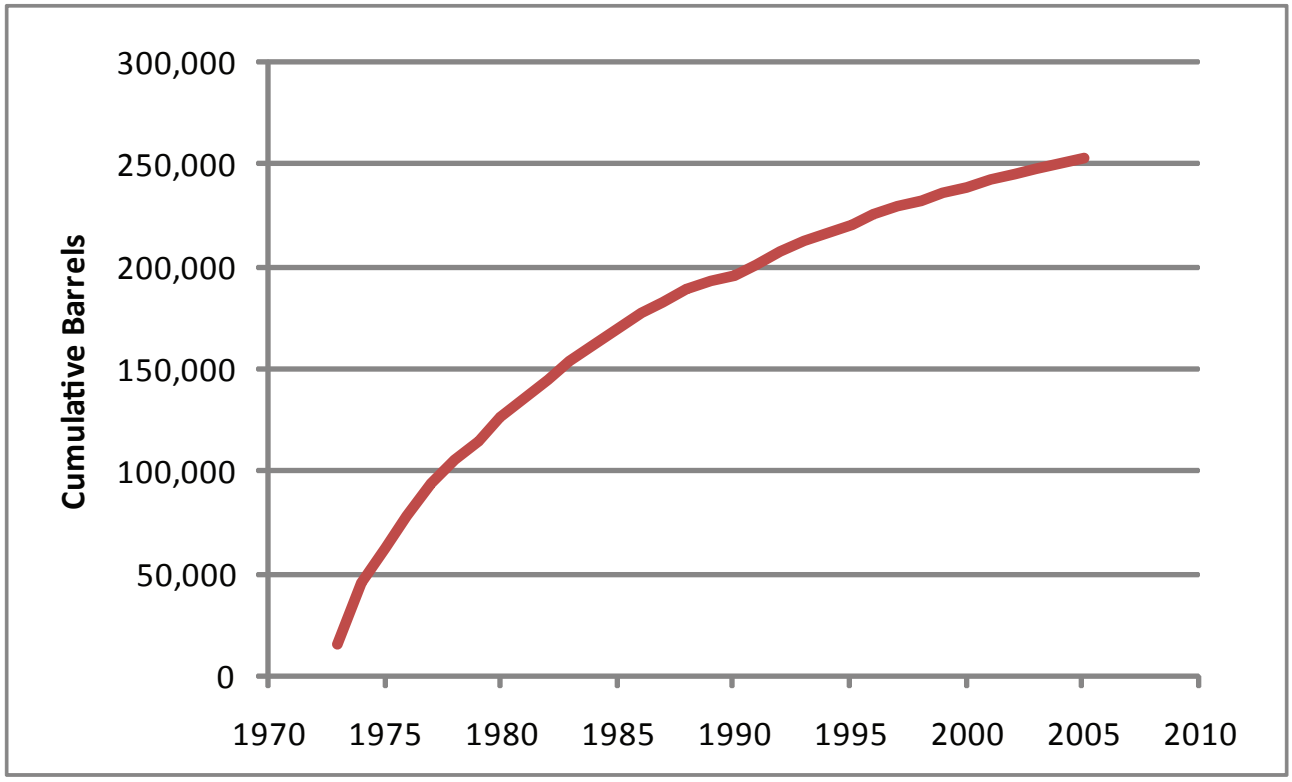

Figure - 5: Cumulative oil production history from Bowling Green Field, Clay County since 1973.

Table-1: List of the wells used for subsurface structure mapping in Bowling Green Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp _D	Rng	Rng_ D	Land _N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117475	11	N	6	W	14	586	1324					
117487	11	N	6	W	23	628	1352	1390	1462			
117489	11	N	6	W	23	623	1299					
117490	11	N	6	W	23	622	1298					
117491	11	N	6	W	23	625	1290	1336			160	
117492	11	N	6	W	23	595	1274				45	
117493	11	N	6	W	23	637	1299				90	
117494	11	N	6	W	23	649	1318	1340			15	
117496	11	N	6	W	23	637	1316				30	
117498	11	N	6	W	23	614	1297				2	
156718	11	N	6	W	23	607	1290	1324	1388			
156719	11	N	6	W	23	609	1290				8	
163335	11	N	6	W	23	632	1335	1368	1424	1482		
117509	11	N	6	W	26	579	1297	1330	1400	1440		

Field name: Bowling Green South

IGS ID: 10058

DOE ID: 84604

Location: Clay County, 11N-6W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,241 ft.)

Field type: oil

Total number production wells: 7

Area: 70 acres

Cumulative production: 78,997 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1,480 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

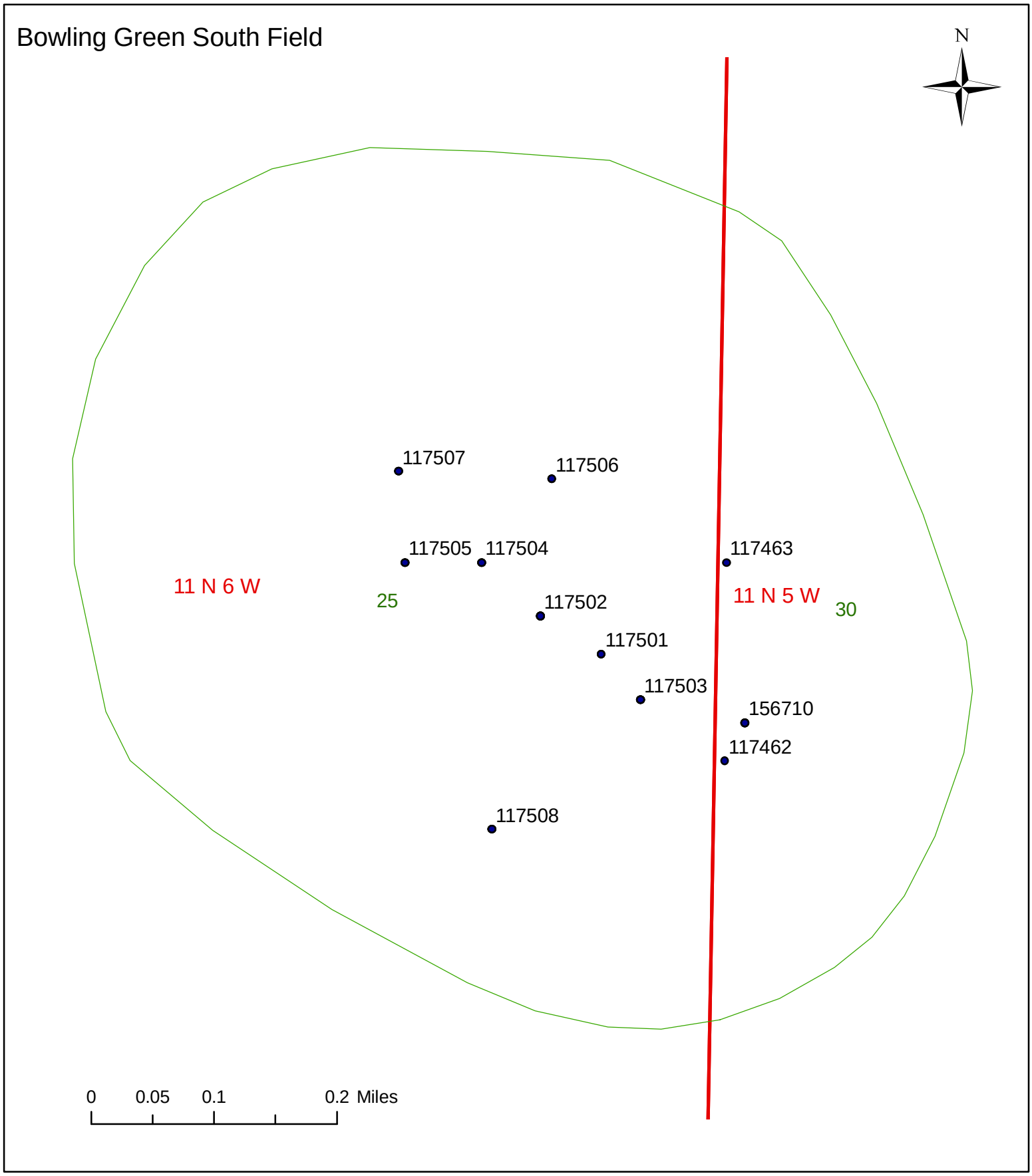

Figure 1: Map showing location aand wells at Bowling Green South Field, Clay County. Black circles are the location of wells in the field.

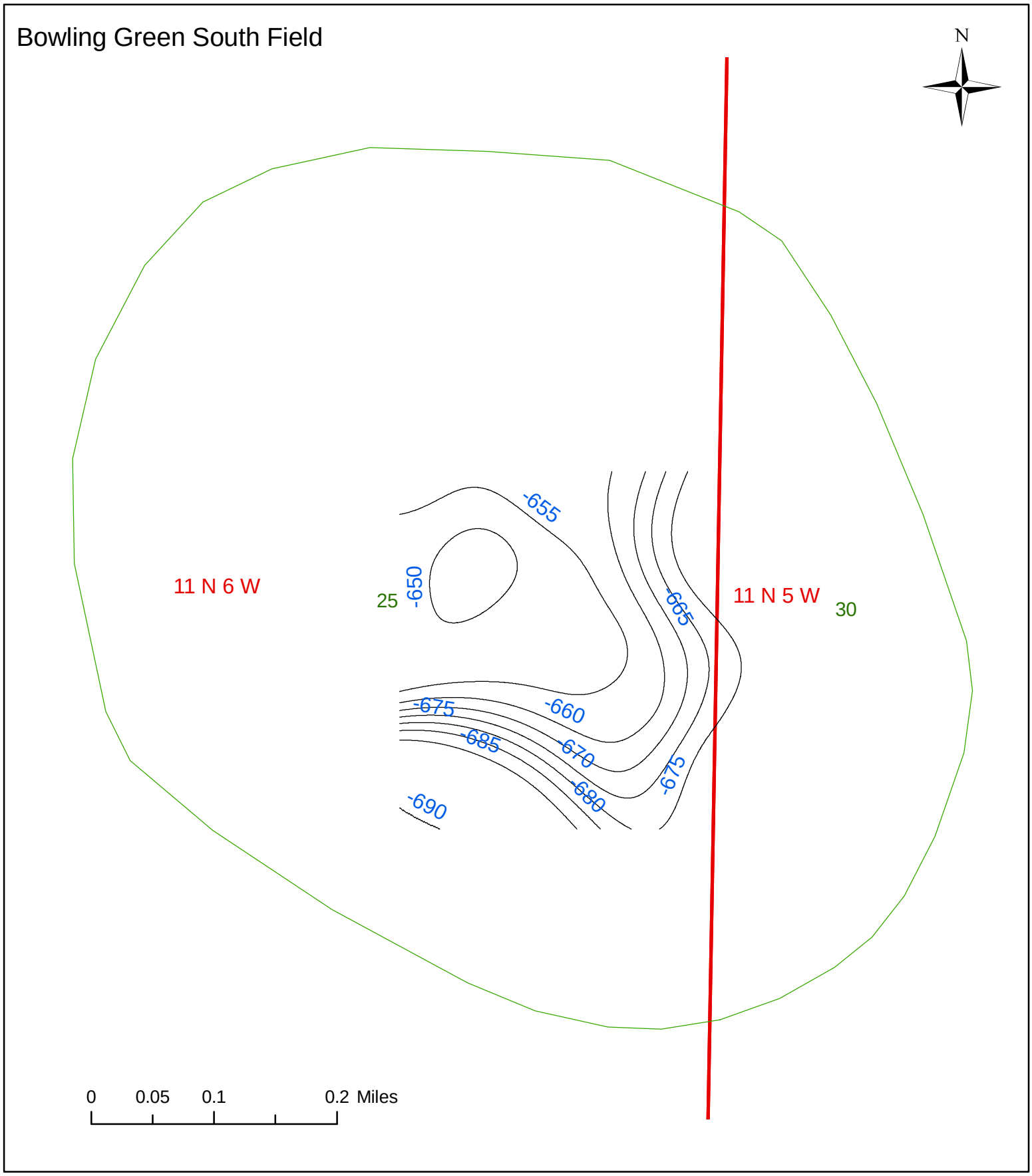

Figure 2: Structure map showing the top of Muscatatuck Limestone in Bowling Green South Field, Clay County. Contours show values below sea level, contour interval is 5 ft .

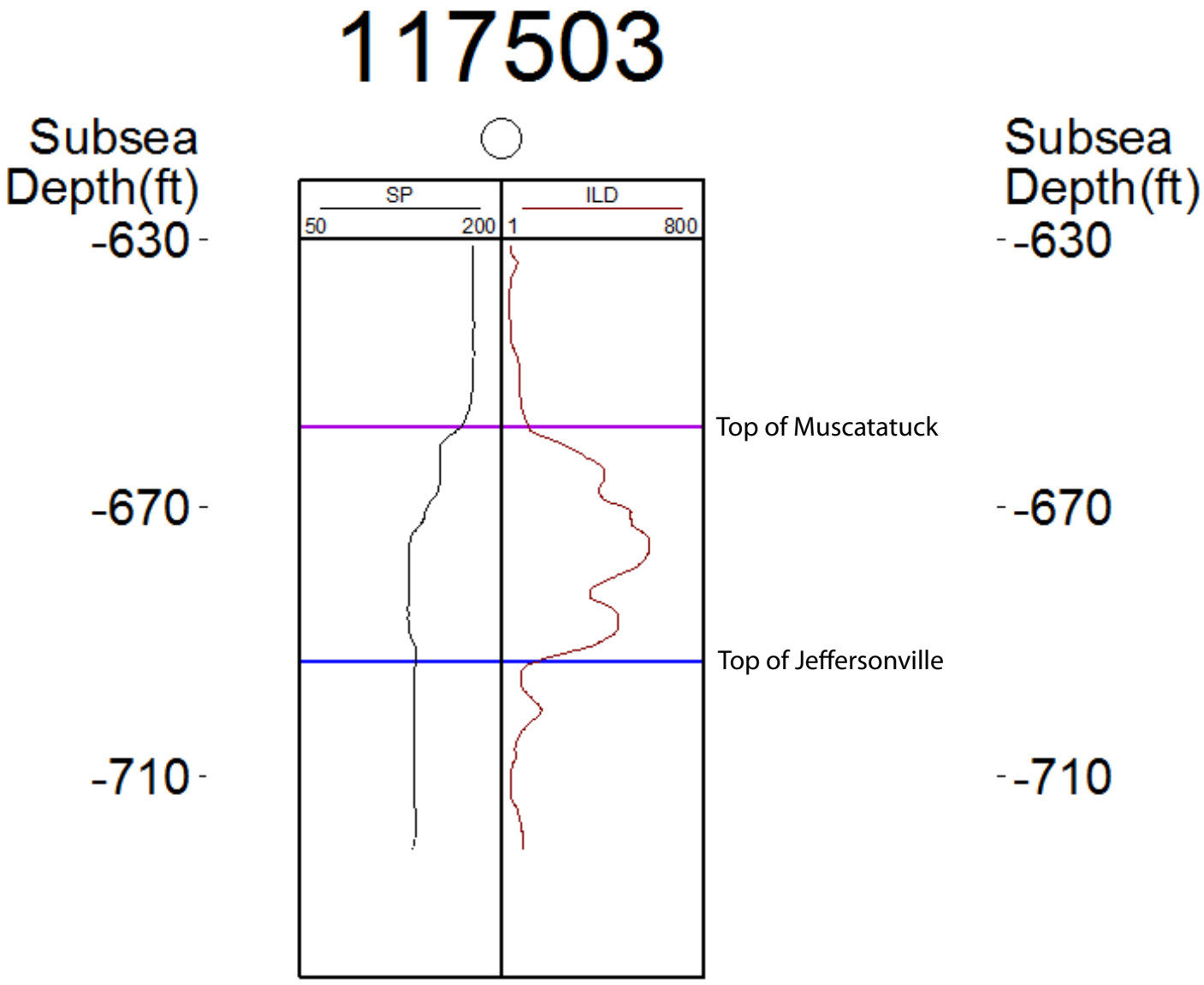

Figure 3: Type log section showing the Devonian formations from Bowling Green South Field, Clay County.

HS=1 256

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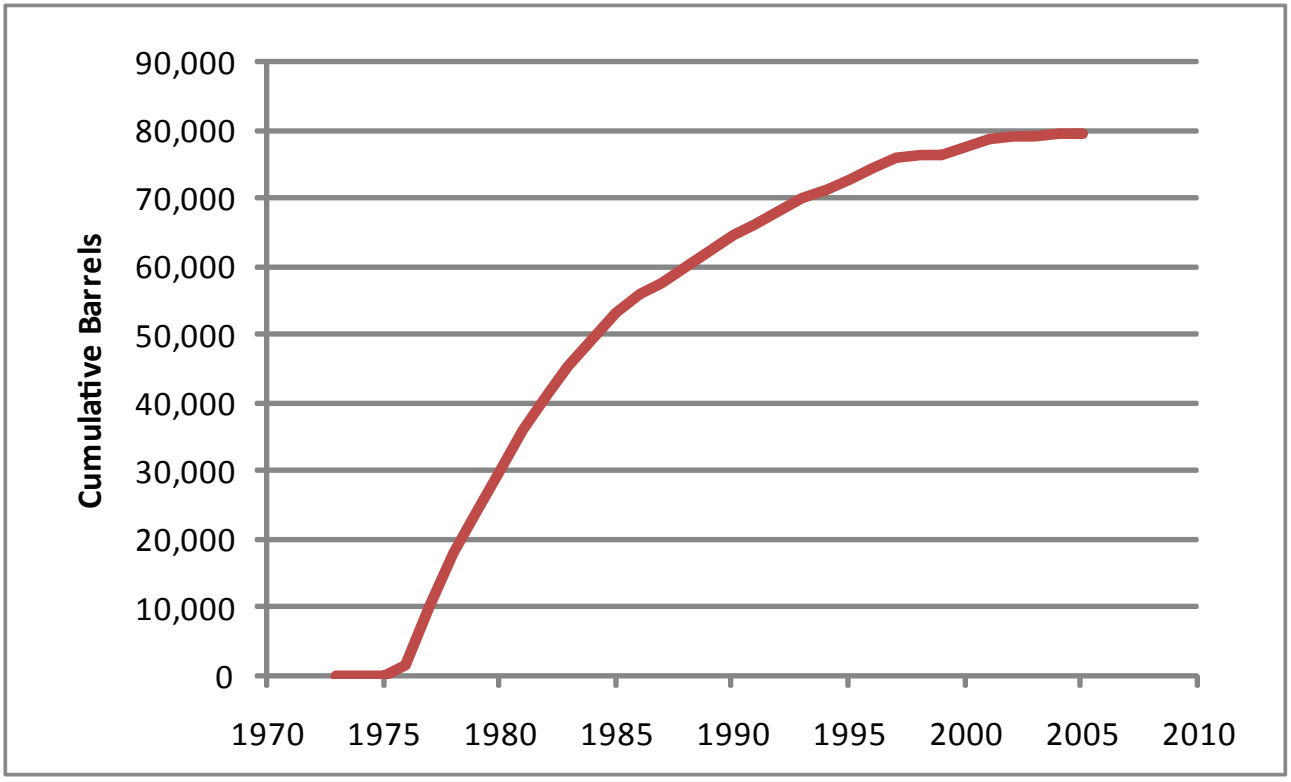

Figure - 4: Cumulative oil production history from the Bowling Green South Field, Clay County since 1976.

Table-1: List of the wells used for subsurface structure mapping in Bowling Green South Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
156708	11	N	5	W	19	659	1362					
117460	11	N	5	W	29	640	1348	1386	1456	1496		
117462	11	N	5	W	30	572	1251					
117463	11	N	5	W	30	565	1245					
117464	11	N	5	W	30	705	1398					
156710	11	N	5	W	30	567	1244			1380		
117501	11	N	6	W	25	563	1216				42	
117502	11	N	6	W	25	563	1216				62	
117503	11	N	6	W	25	569	1226	1262			200	
117504	11	N	6	W	25	563	1210				42	
117505	11	N	6	W	25	562	1213				12	
117506	11	N	6	W	25	563	1222				6	
117507	11	N	6	W	25	562	1221				42	
117508	11	N	6	W	25	597	1287					
117512	11	N	6	W	36	634	1383					

Field name: Carbon

IGS ID: 10091

DOE ID: na

Location: Clay & Parke Counties, 13&14N-6W

Discovery date: 1994 (storage initiation)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,275 ft.)

Field type: natural gas storage

Total number production wells: 19 storage, 16 observation

Area: na

Total capacity: na

Other reservoir units: na

Deepest unit penetrated (depth): Cambrian/Ordovician, Knox Supergroup (2,895 ft.)

Field characteristic: Subtle anticlinal feature with less than 20 ft. closure.

Reservoir characteristics:

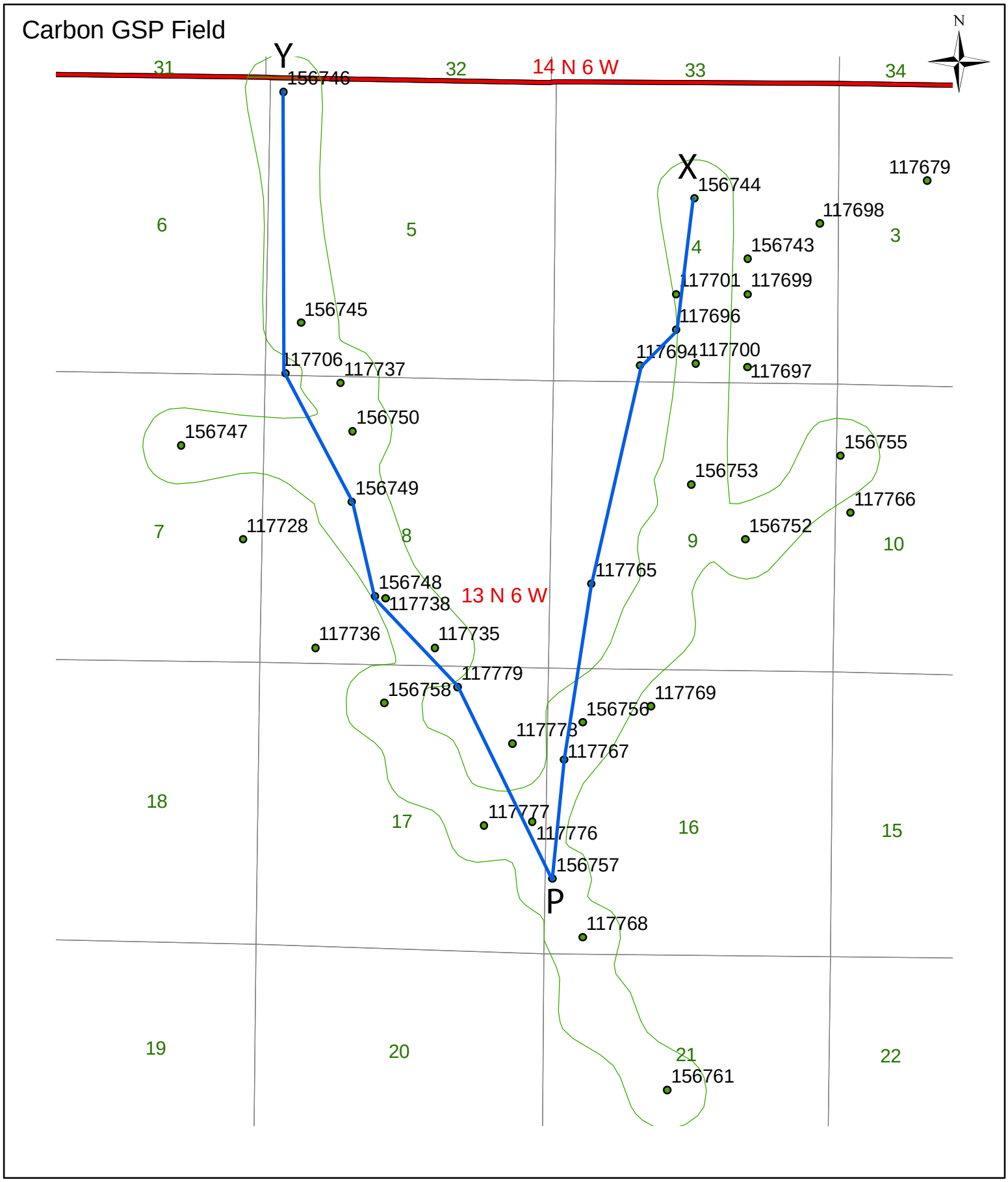

Figure 1: Map showing location and wells at Carbon GSP Field, Clay County. X-P and Y-P are the locations of the cross sections that show the subsurface Devonian structure in Figures 10 and 11.

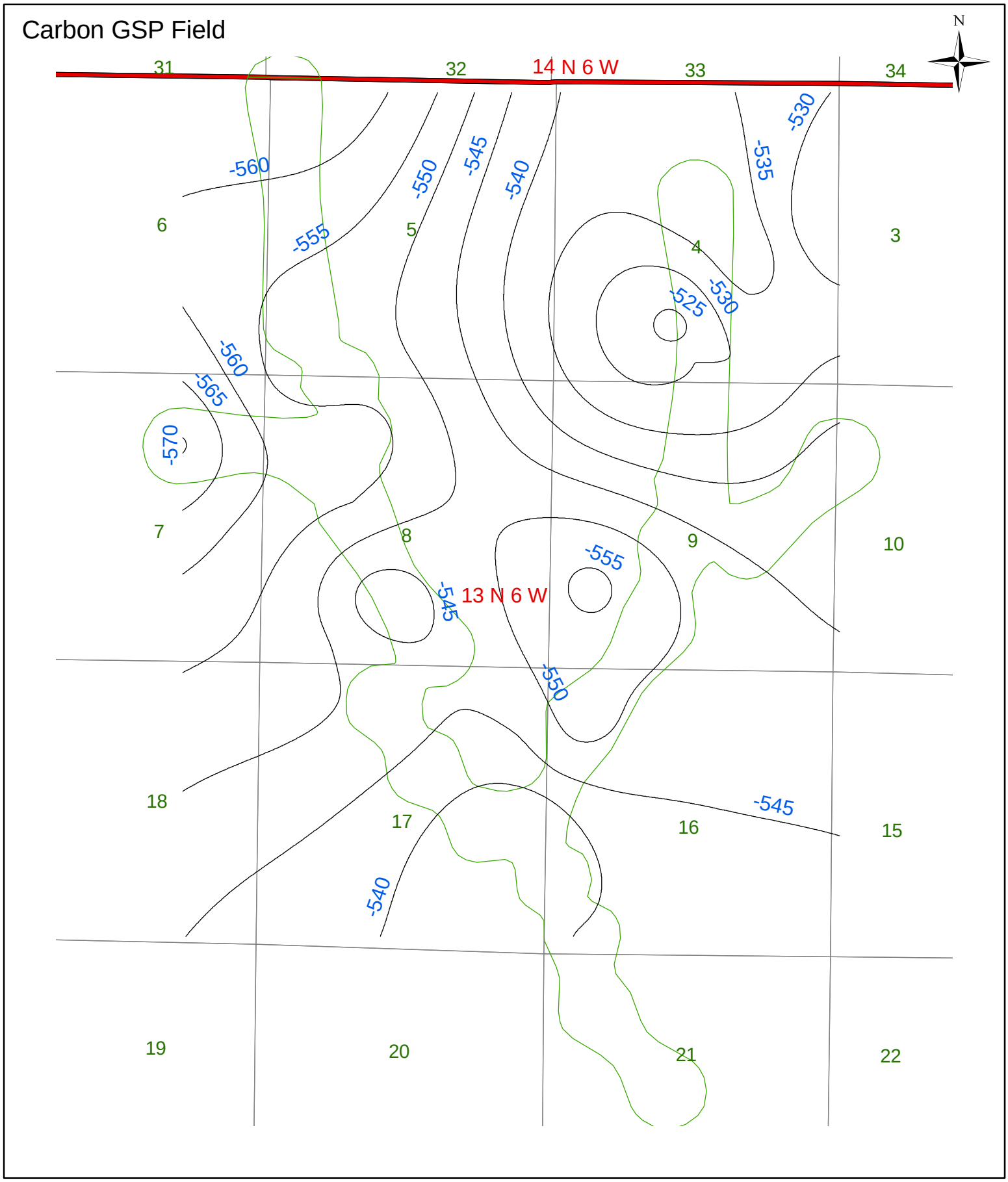

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Carbon GSP field, Clay County. Contours show values below sea level, contour interval is 5 ft .

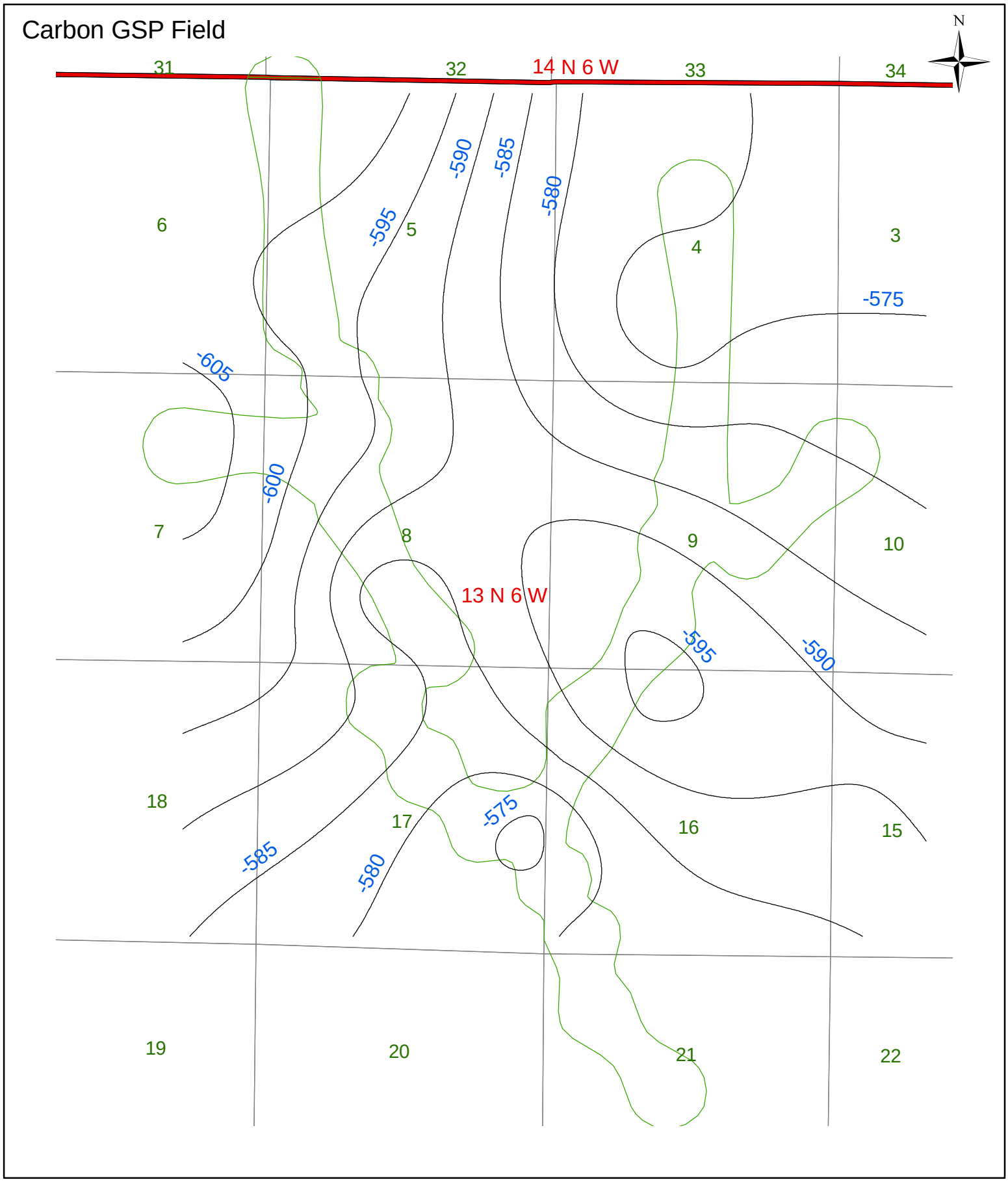

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Carbon GSP field, Clay County. Contours show values below sea level, contour interval is 5 ft .

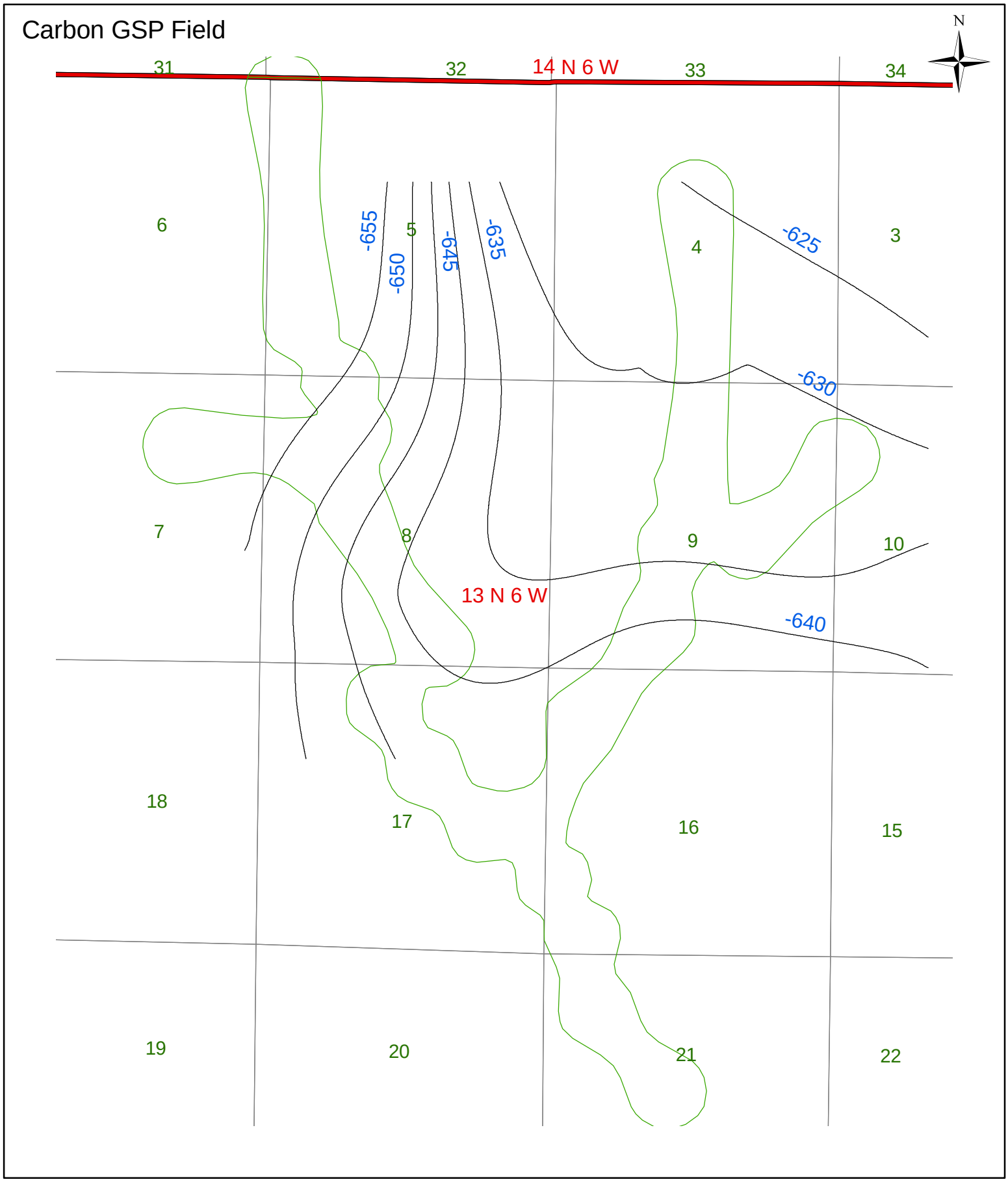

Figure 4: Structure map showing the top of subsurface Geneva Dolomite Member in Carbon GSP field, Clay County. Contours show values below sea level, contour interval is 5 ft .

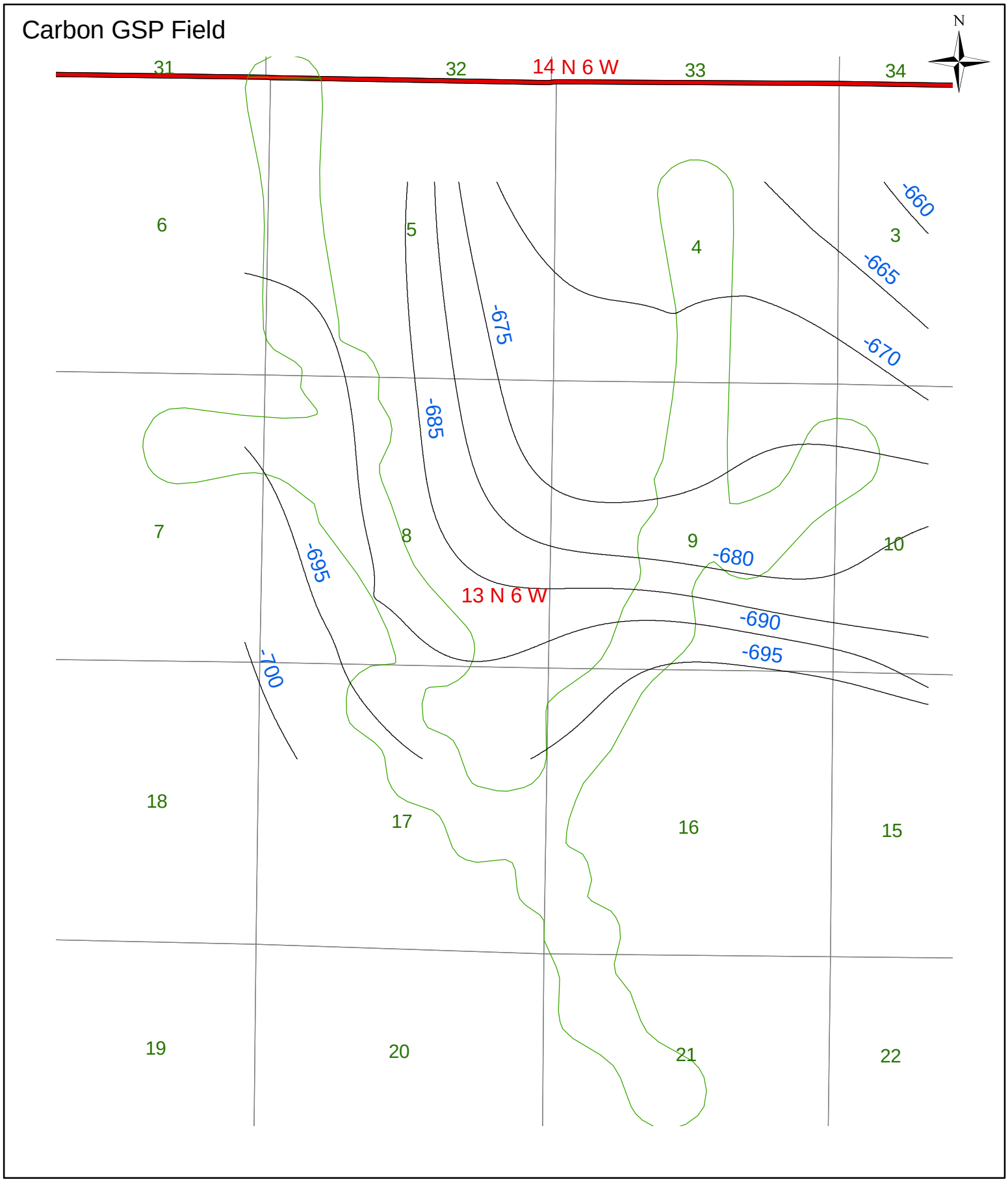

Figure 5: Structure map showing the top of subsurface Silurian formation in Carbon GSP field, Clay County. Contours show values below sea level, contour interval is 5 ft .

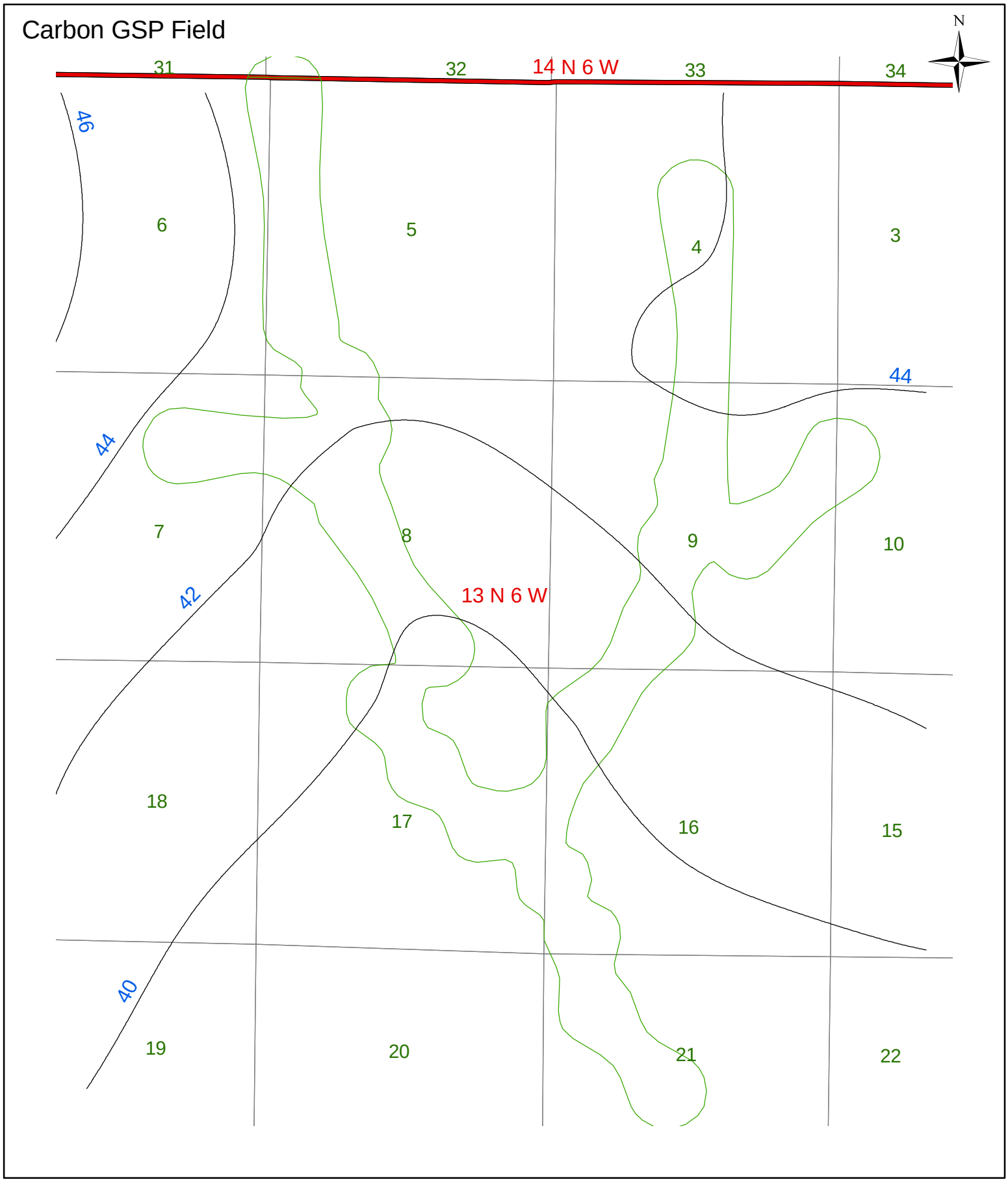

Figure 6: Isopach map of the North Vernon formation from Carbon GSP Field, Clay County. Contour interval is 2 ft.

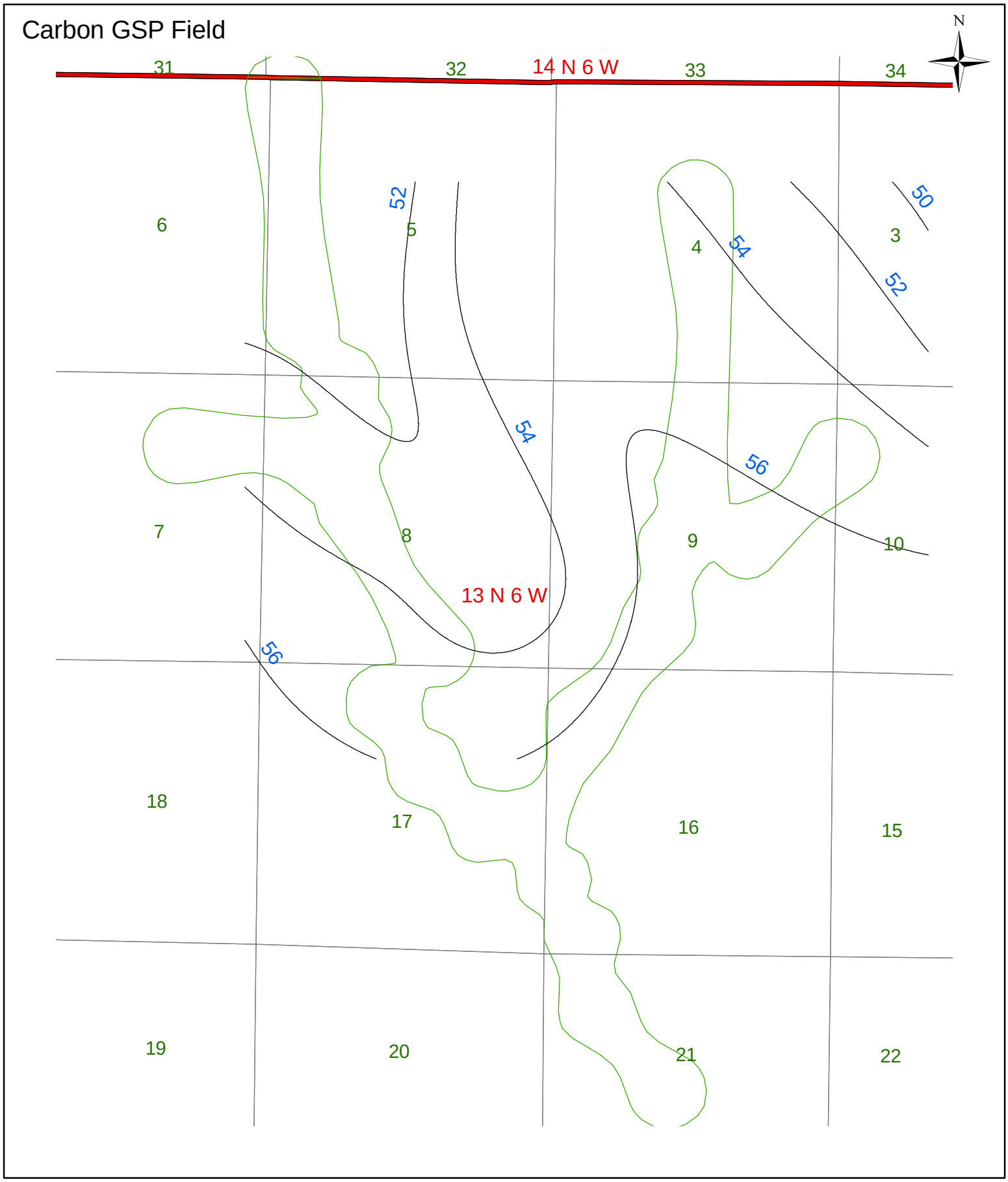

Figure 7: Isopach map of the Vernon Fork Member from Carbon GSP Field, Clay County. Contour interval is 2 ft.

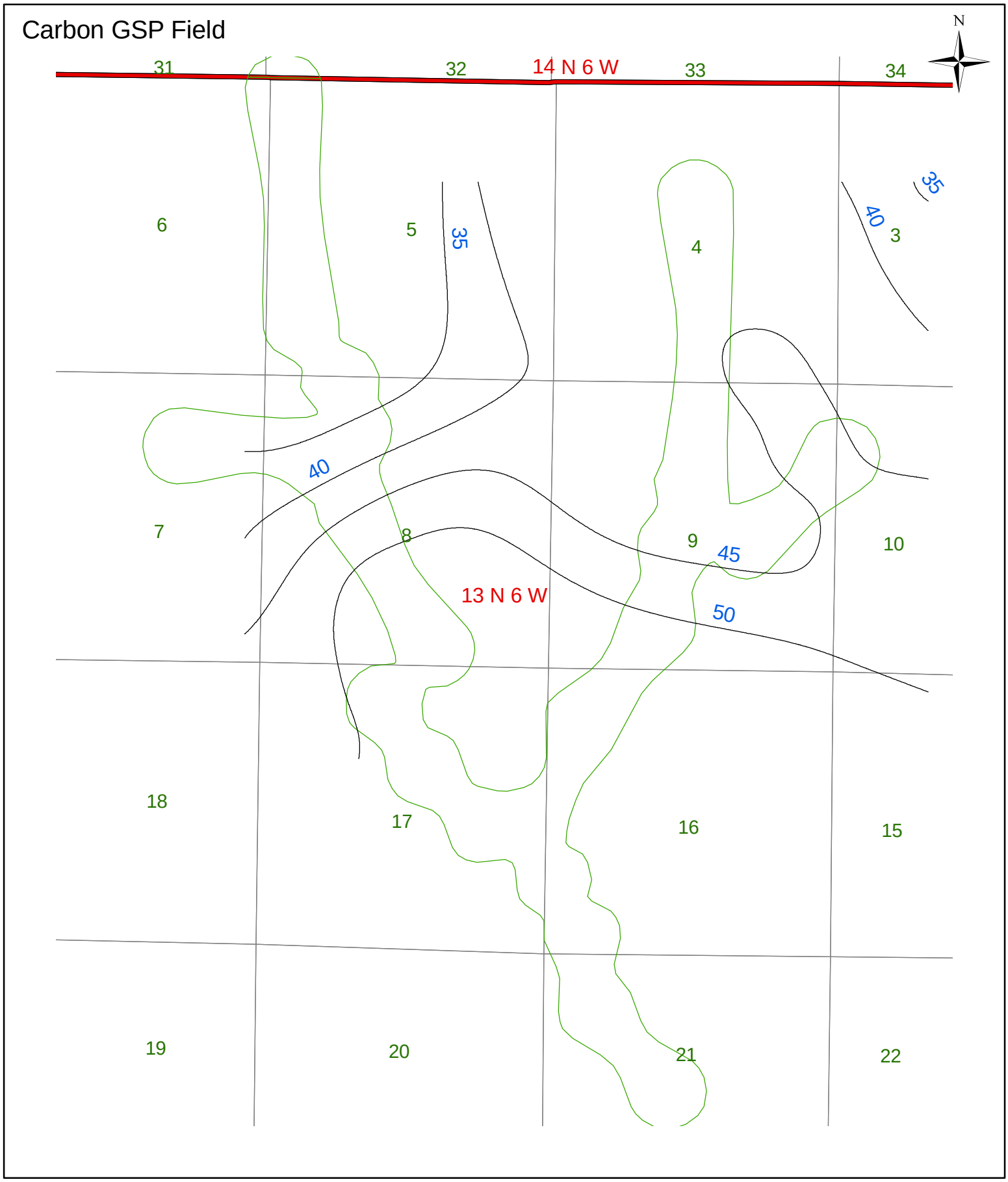

Figure 8: Isopach map of the Geneva Dolomite Member from Carbon GSP Field, Clay County. Contour interval is 5 ft.

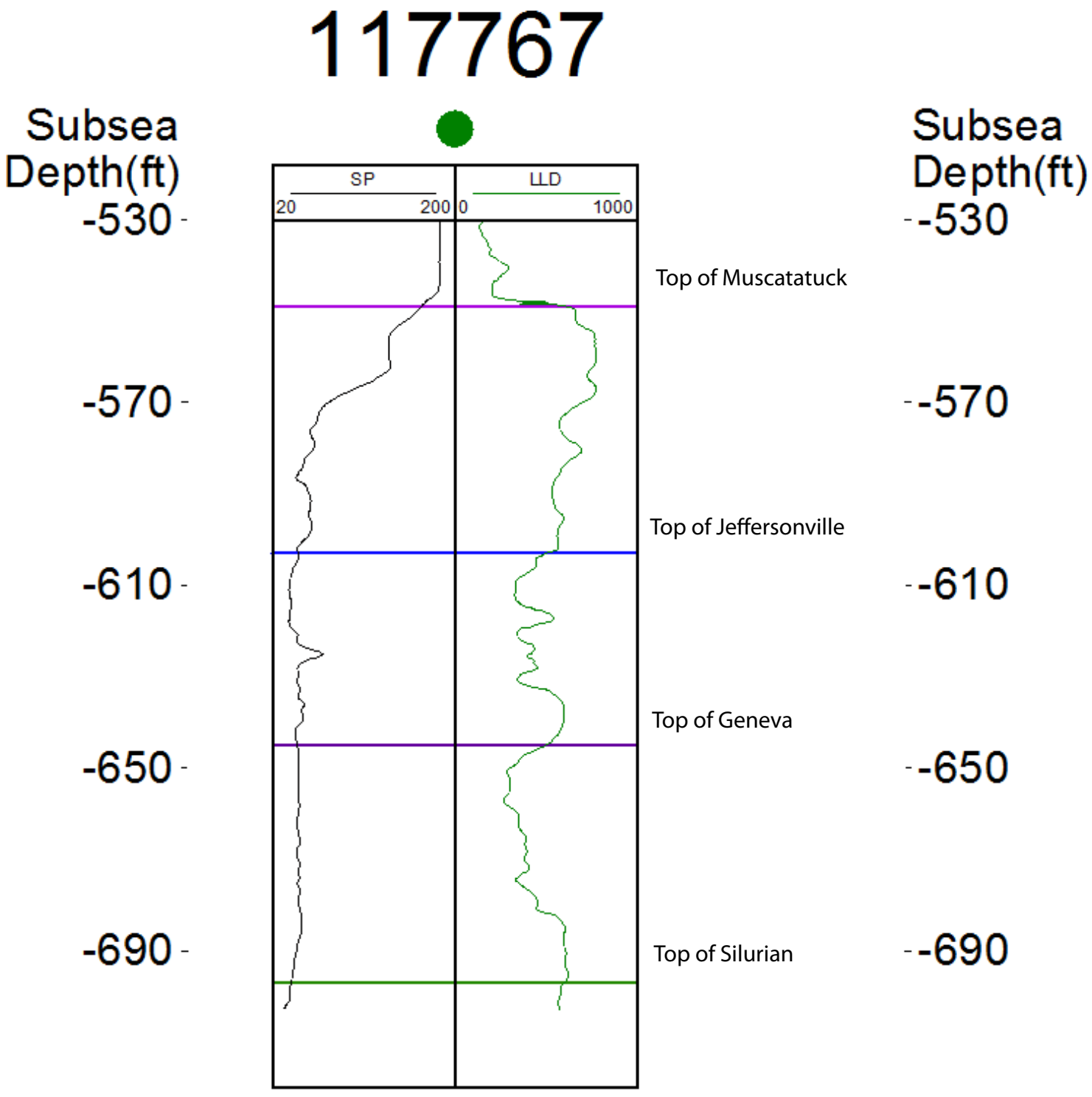

Figure 9: Type log section showing Devonian formations at Carbon GSP Field, Clay County.

HS=1

PETRA 6/14/2006 1:24:06 PM (TypeLog:CSP)

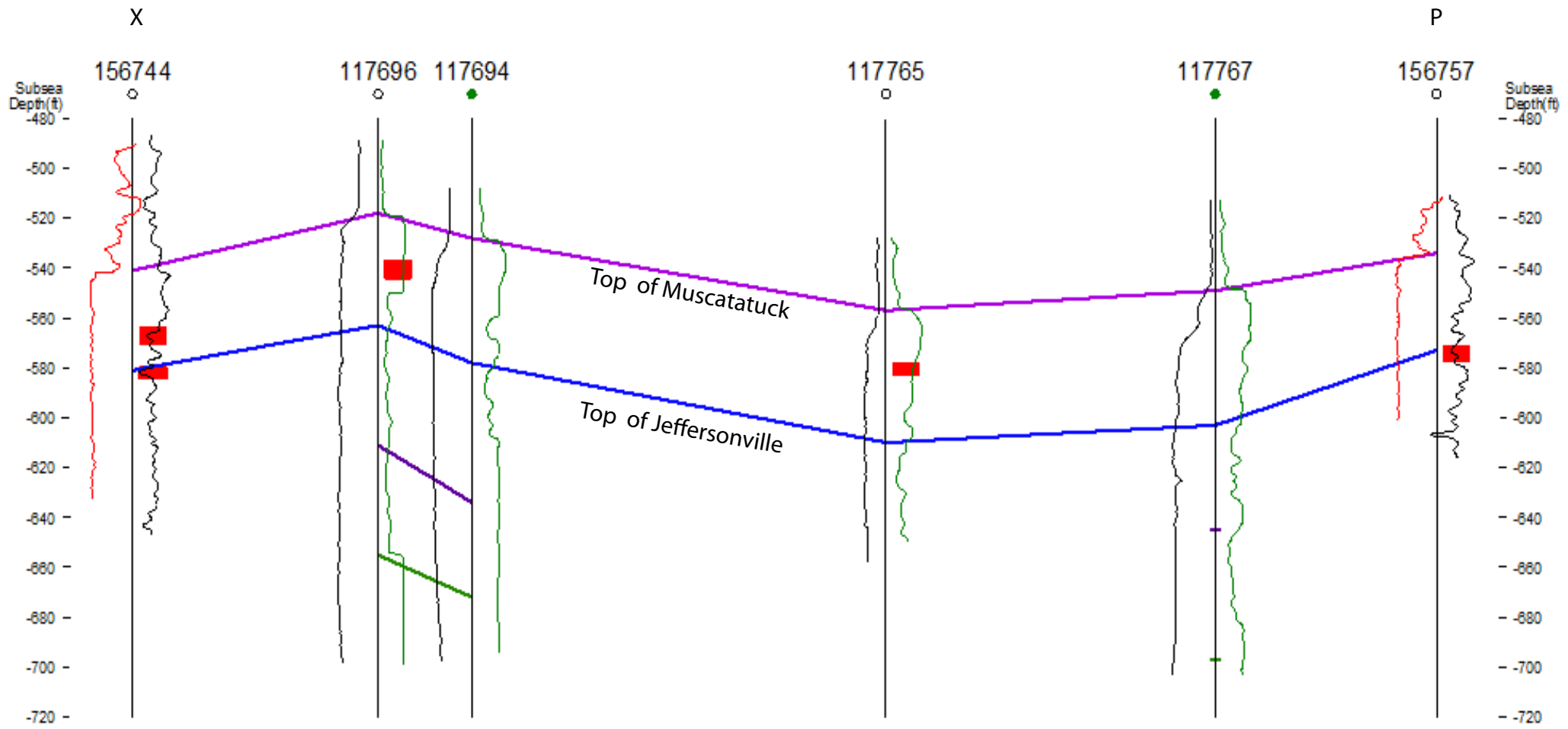

Figure 10: X-P Cross section showing the Devonian subsurface structure across Carbon GSP Field, Clay County. The red color box shows the completion intervals for the gas storage. For location of the cross section refer to Figure 1.

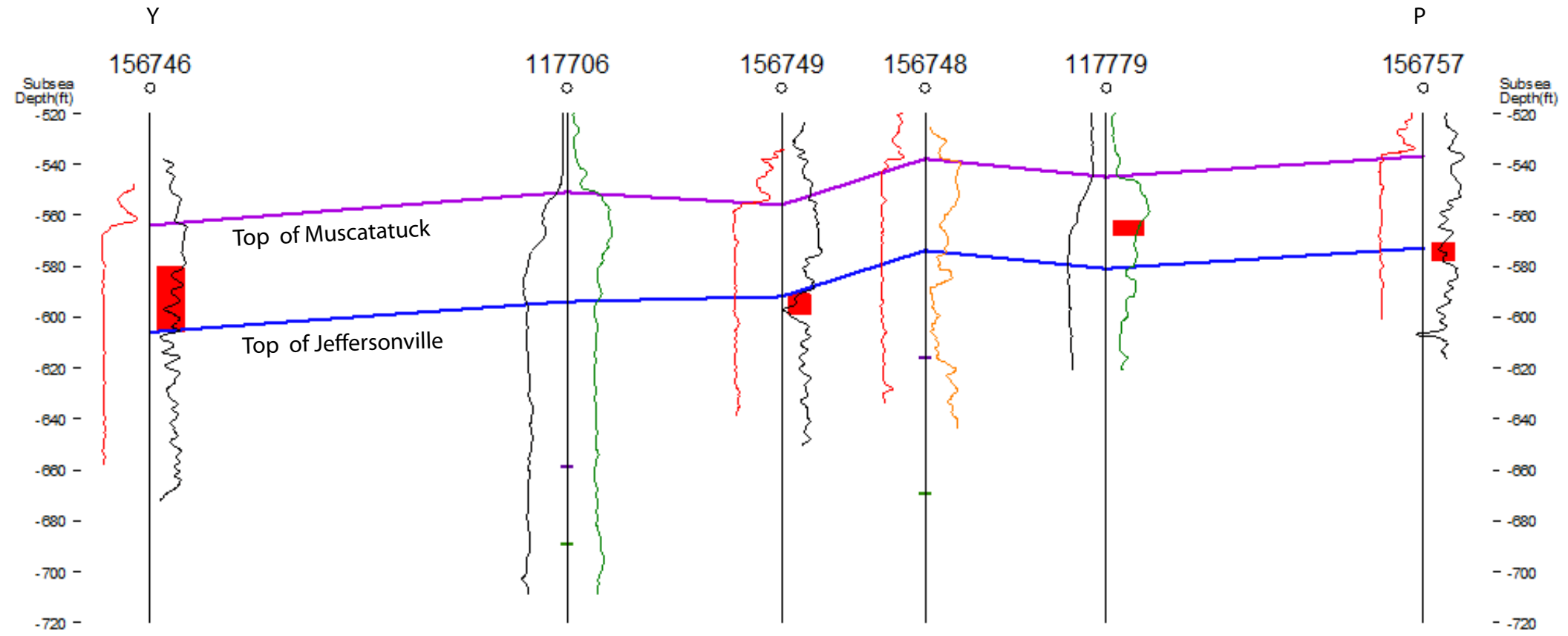

Figure 11: Y-P Cross section showing Devonian subsurface structure across Carbon GSP Field, Clay County. The red color box shows the completion intervals for the Gas storage. For location of the cross section refer to Figure 1.

Table-1: List of the wells used for subsurface structure mapping in Carbon GSP Field, Clay County.

IGS_ID	Twp	Twp _D	Rng	Rng _D	Land _N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Core (P/A)
117679	13	N	6	W	3	747	1271	1320	1366	1400	Present
117694	13	N	6	W	4	702	1230	1280	1342	1380	
117696	13	N	6	W	4	701	1219	1264	1312	1356	Present
117697	13	N	6	W	4	691	1219	1274	1330	1376	
117698	13	N	6	W	4	721	1243	1292	1340	1383	
117699	13	N	6	W	4	693	1229	1264	1324	1366	
117700	13	N	6	W	4	689	1222				
117701	13	N	6	W	4	702	1227				
156743	13	N	6	W	4	698	1241				
156744	13	N	6	W	4	713	1254	1292			
117706	13	N	6	W	5	691	1242	1300	1350	1380	
156745	13	N	6	W	5	691	1244	1284			
156746	13	N	6	W	5	692	1256	1298			
117723	13	N	6	W	6	674	1241	1294			
117728	13	N	6	W	7	681	1239	1288	1346	1386	Present
156747	13	N	6	W	7	676	1250	1286			
117735	13	N	6	W	8	687					
117736	13	N	6	W	8	642	1195	1240	1305	1354	
117737	13	N	6	W	8	688	1238	1280			
117738	13	N	6	W	8	690	1232	1270			
156748	13	N	6	W	8	696	1234	1270	1312	1365	
156749	13	N	6	W	8	656	1212	1248			
156750	13	N	6	W	8	686	1248	1286			
117765	13	N	6	W	9	692	1251	1290			
156752	13	N	6	W	9	703					
156753	13	N	6	W	9	692					
117766	13	N	6	W	10	704					
156755	13	N	6	W	10	690	1234	1270			
117767	13	N	6	W	16	697	1246	1284	1342	1394	
117768	13	N	6	W	16	731	1272	1316			
117769	13	N	6	W	16	705	1252	1306			
156756	13	N	6	W	16	699	1254	1290			
156757	13	N	6	W	16	699	1236	1272			
117776	13	N	6	W	17	694	1226	1260			
117777	13	N	6	W	17	691	1228	1266			
117778	13	N	6	W	17	686	1229	1270			
117779	13	N	6	W	17	689	1234	1270			
156758	13	N	6	W	17	686	1236	1278			
156761	13	N	6	W	21	738	1310	1346			

Field name: Carlisle North

IGS ID: 10093

DOE ID: 9021

Location: Sullivan County, 6N-9&10W

Discovery date: 1982

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville (2,567 ft.)

Field type: oil

Total number production wells: 8

Area: 100 acres

Cumulative production: 41,355 bbls. (2002)

Other reservoir units: Mississippian, Blue River Group, Ste. Genevieve Ls.

Deepest unit penetrated (depth): Devonian, New Harmony Group (2,806 ft.)

Field characteristic: Subtle anticlinal nose with no observable closure at top of Muscatatuck.

Reservoir characteristics:

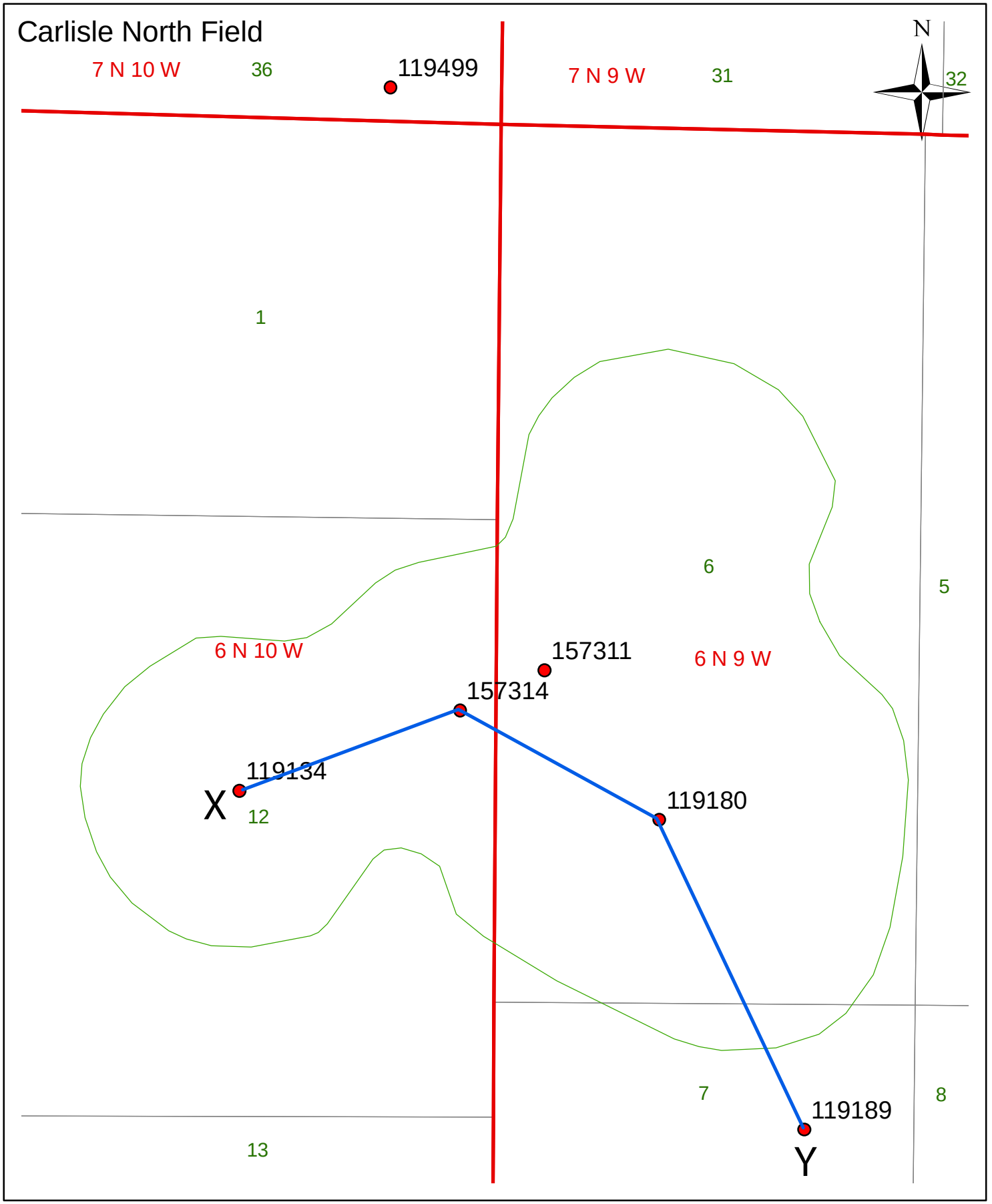

Figure 1: Map showing the location and wells at Carlisle North Field, Sullivan County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

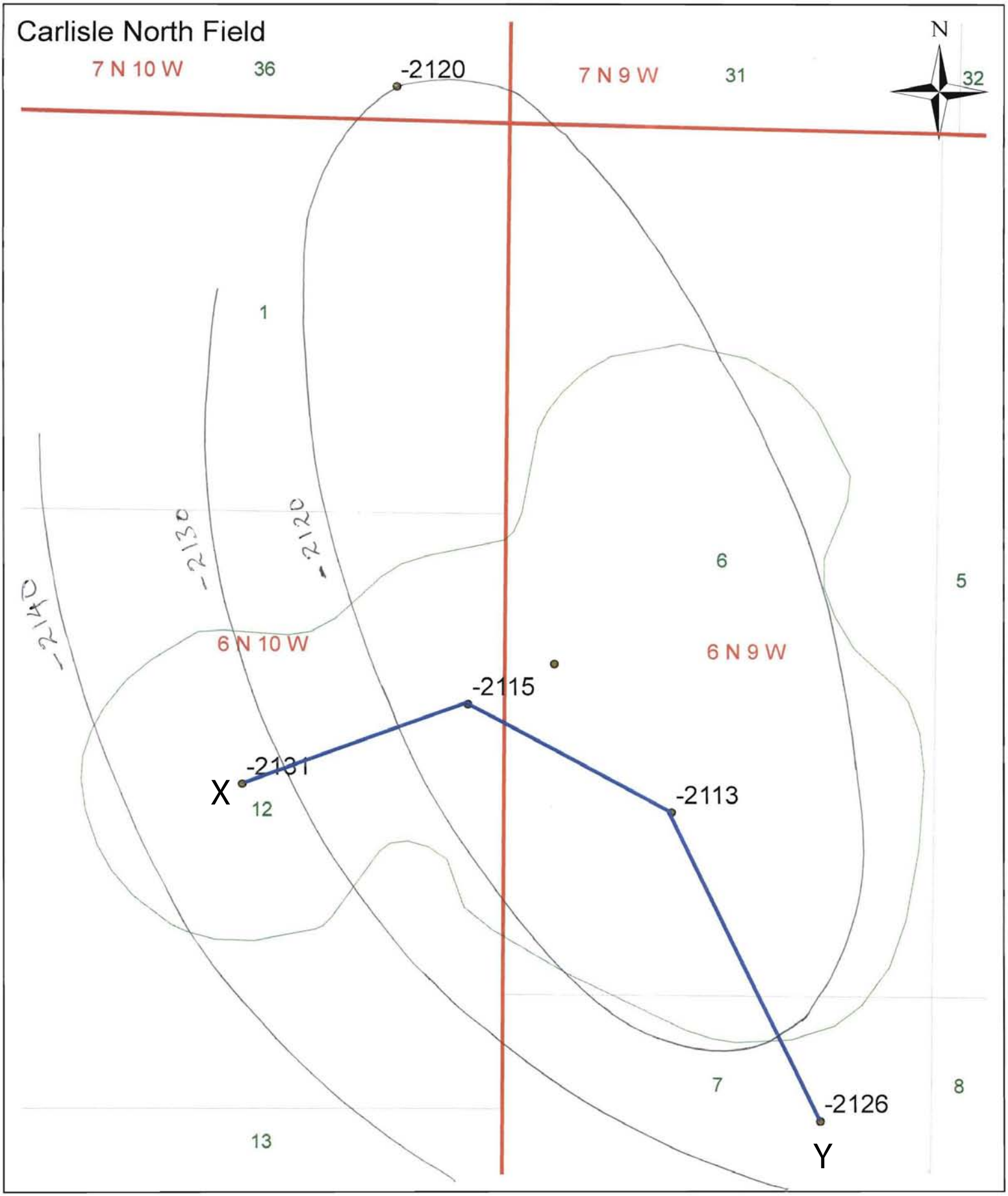

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Carlisle North Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

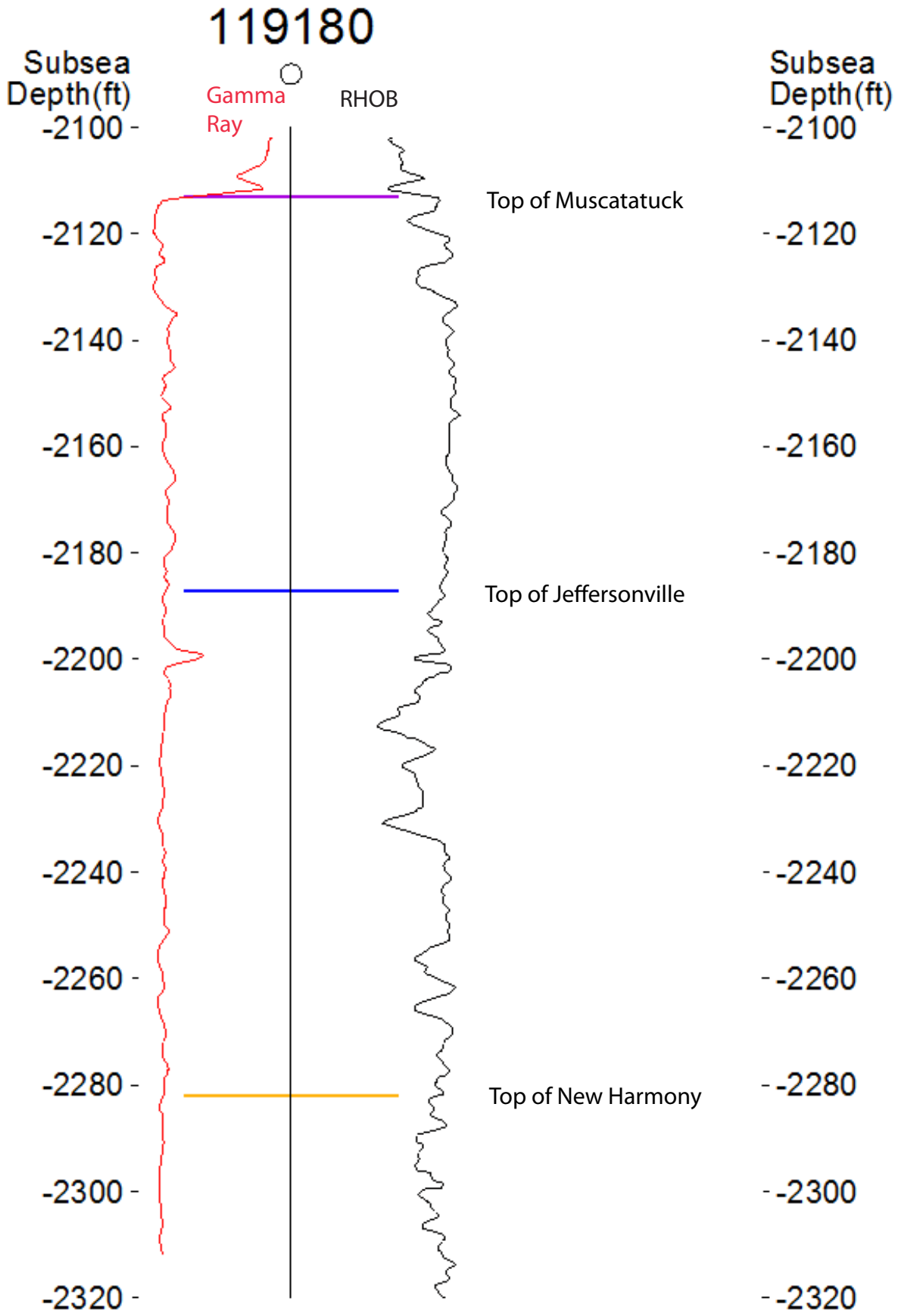

Figure 3: Type log section showing the Devonian formations at Carlisle North Field, Sullivan County.

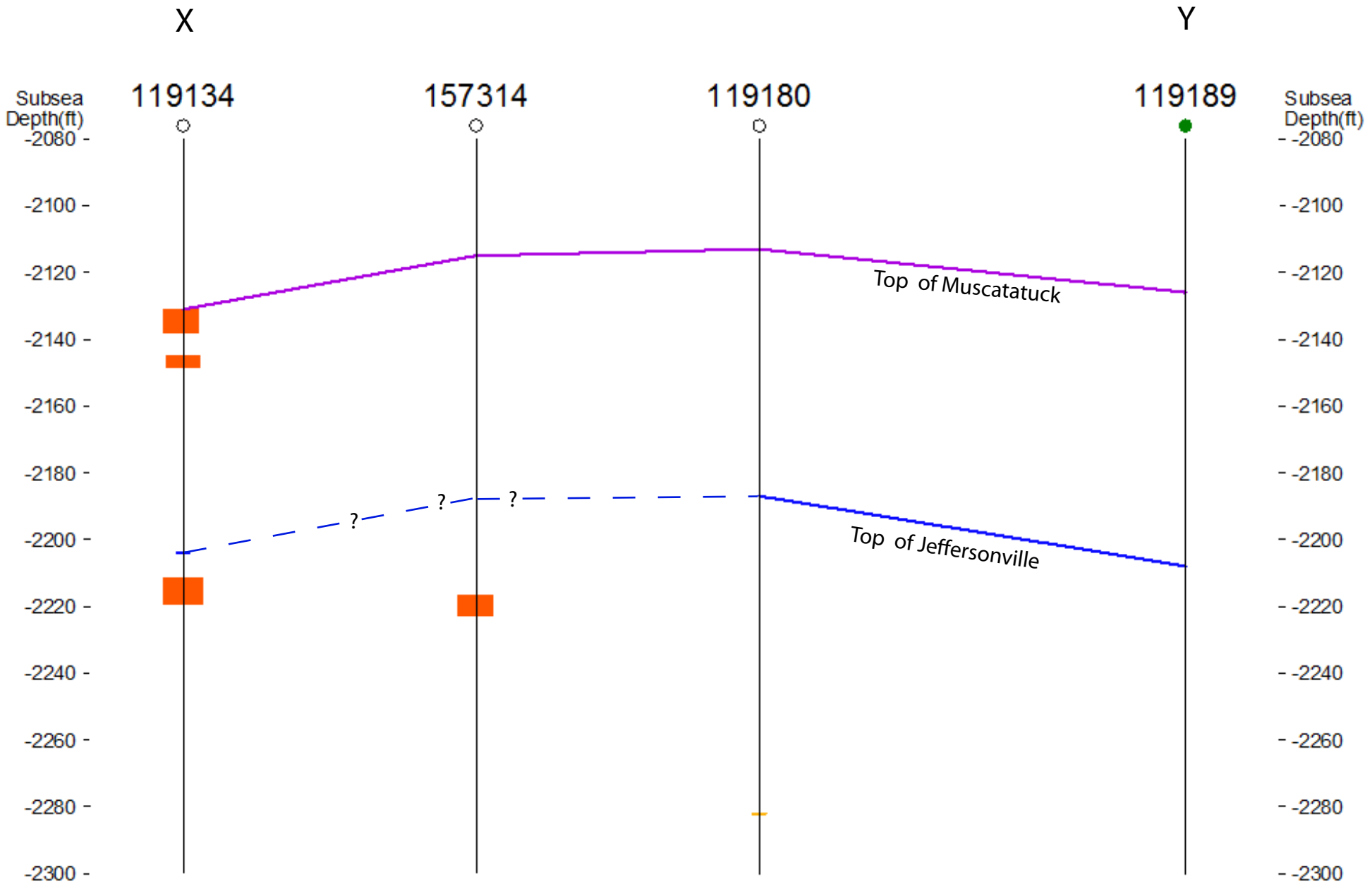

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Carlisle North Field, Sullivan County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for oil and gas production.

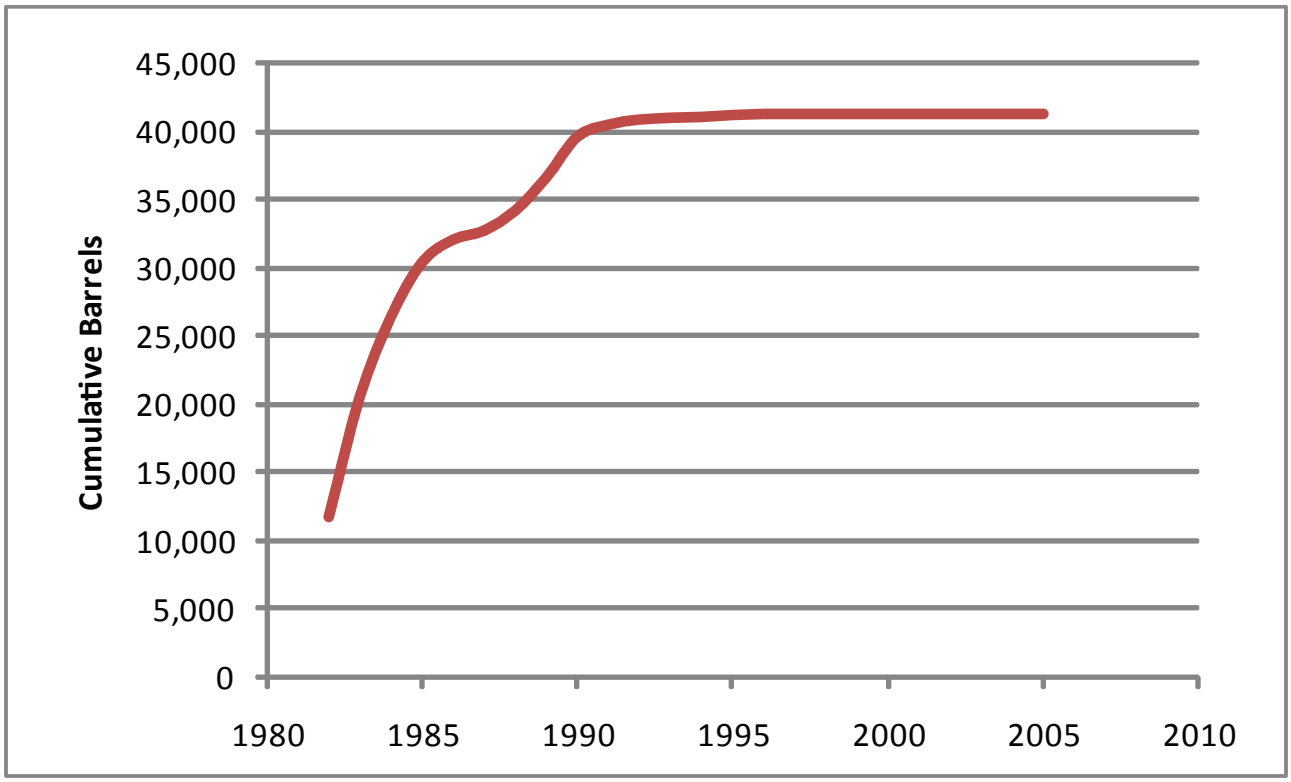

Figure - 5: Cumulative oil production history for Carlisle North Field, Sullivan County since 1983.

Table-1: List of the wells used for subsurface structure mapping in Carlisle North field, Sullivan County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
119180	6	N	9	W	6	468	2581	2655	2740		288	
157311	6	N	9	W	6	470						
119189	6	N	9	W	7	442	2568	2650				
119134	6	N	10	W	12	436	2567	2640	2758		2	
157314	6	N	10	W	12	462	2577					
119499	7	N	10	W	36	460	2580	2670				

Field name: Carlisle West

IGS ID: 10094

DOE ID: 102204

Location: Sullivan County, 6N-10W

Discovery date: 1976

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville (2,719 ft.)

Field type: oil (abandoned)

Total number production wells: 1

Area: 20 acres

Cumulative production: 674 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Devonian, New Harmony Group (2847 ft.)

Field characteristic: Subtle anticlinal nose with no observable closure at top of Muscatatuck.

Reservoir characteristics:

Field name: Chrisney South

IGS ID: 10109

DOE ID: 141370

Location: Spencer County, 6S-5W

Discovery date: 1958

Lower Paleozoic reservoir unit (depth): Devonian, New Harmony Group, Backbone (2,771ft.)

Field type: oil

Total number production wells: 9

Area: 100 acres

Cumulative production: 100,292 bbls. (2002)

Other reservoir units:

Mississippian, West Baden Group, Elwren (Cypress) & Sample Fms.

Mississippian, Sanders Group, Harrodsburg Ls.

Deepest unit penetrated (depth): Silurian (3,420 ft.)

Field characteristic: Complex domal anticline over probable Silurian reef with structural closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

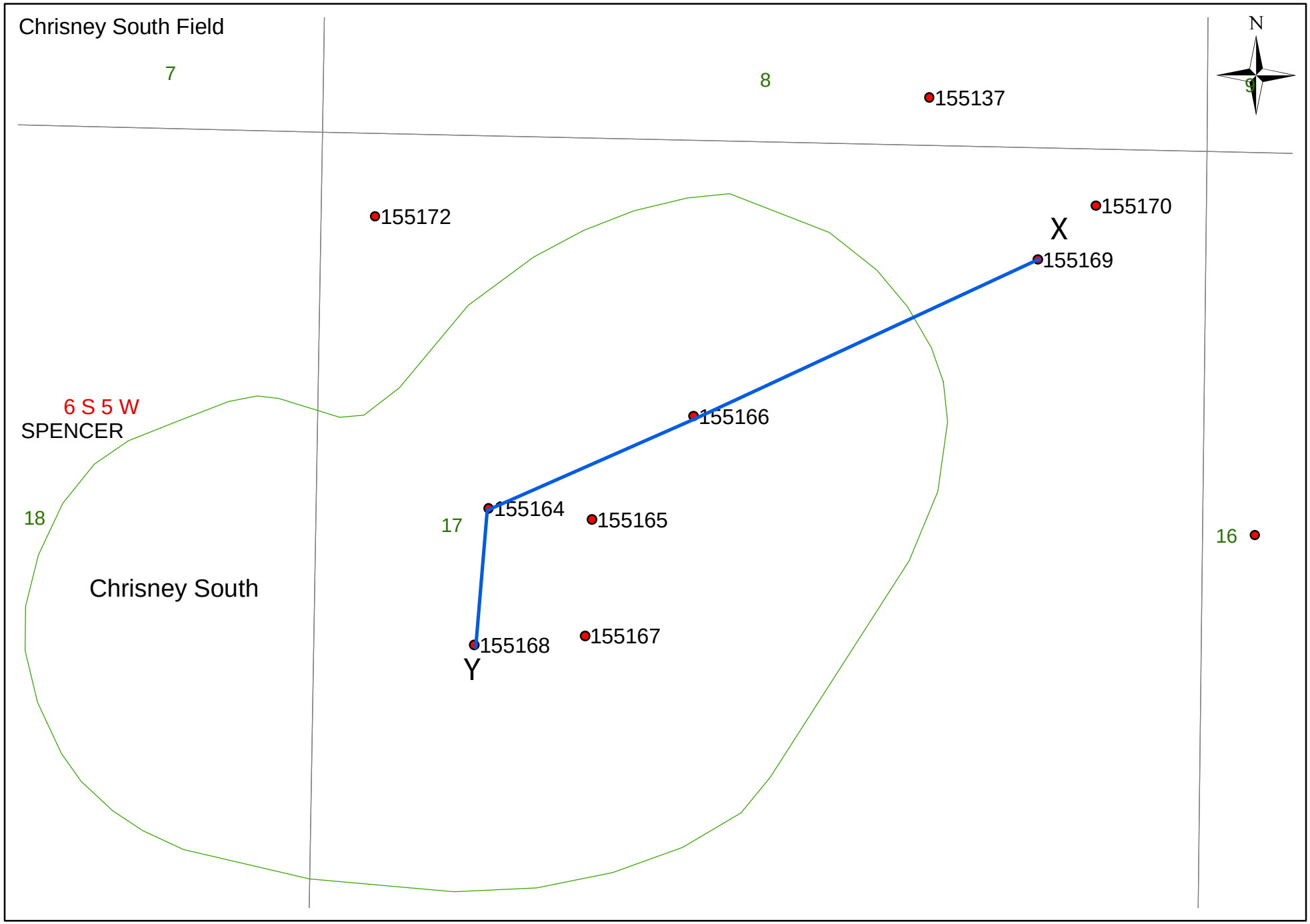

Figure 1: Map showing the location and wells at Chrisney South Field, Spencer County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 8.

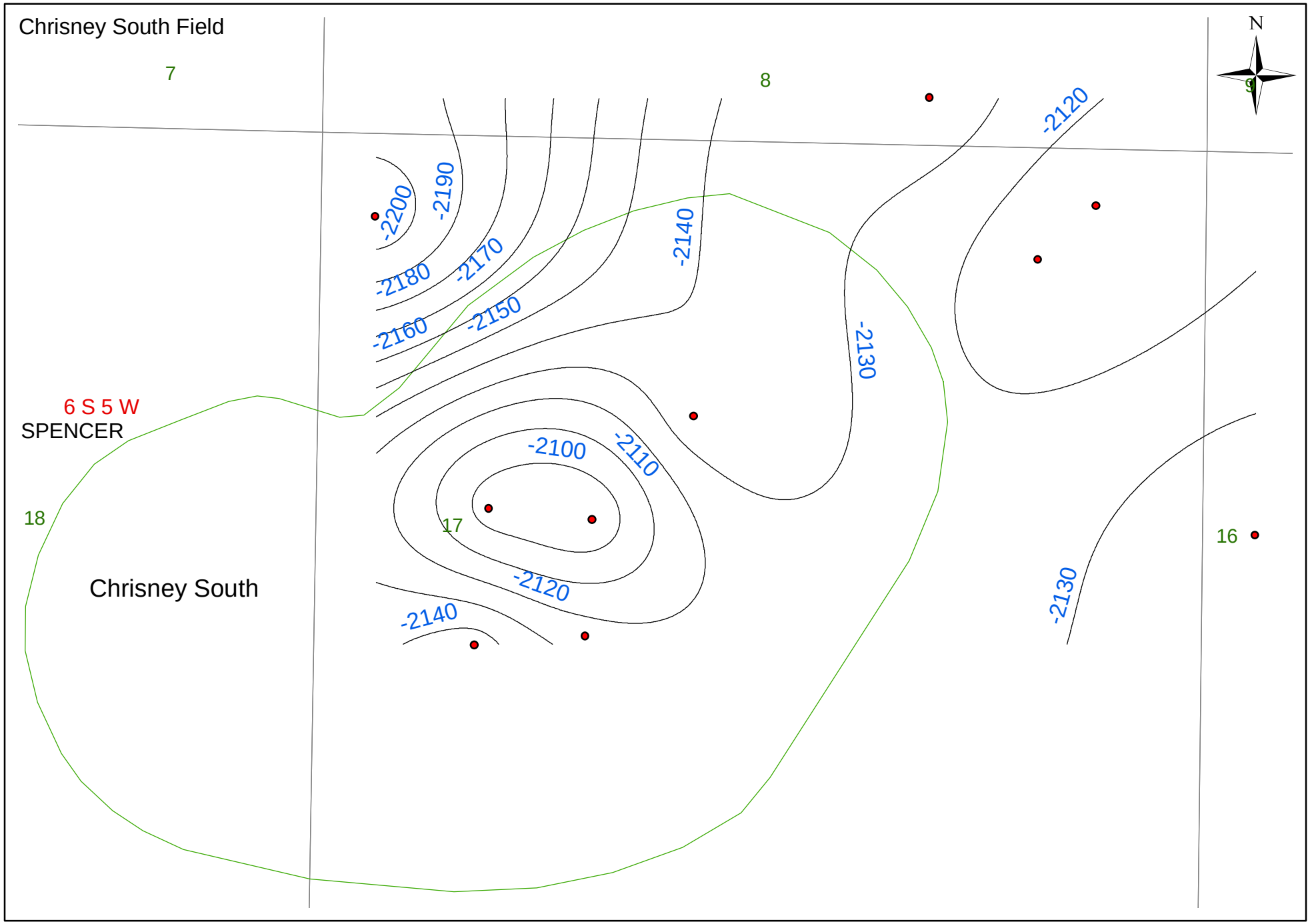

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Chrisney South Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

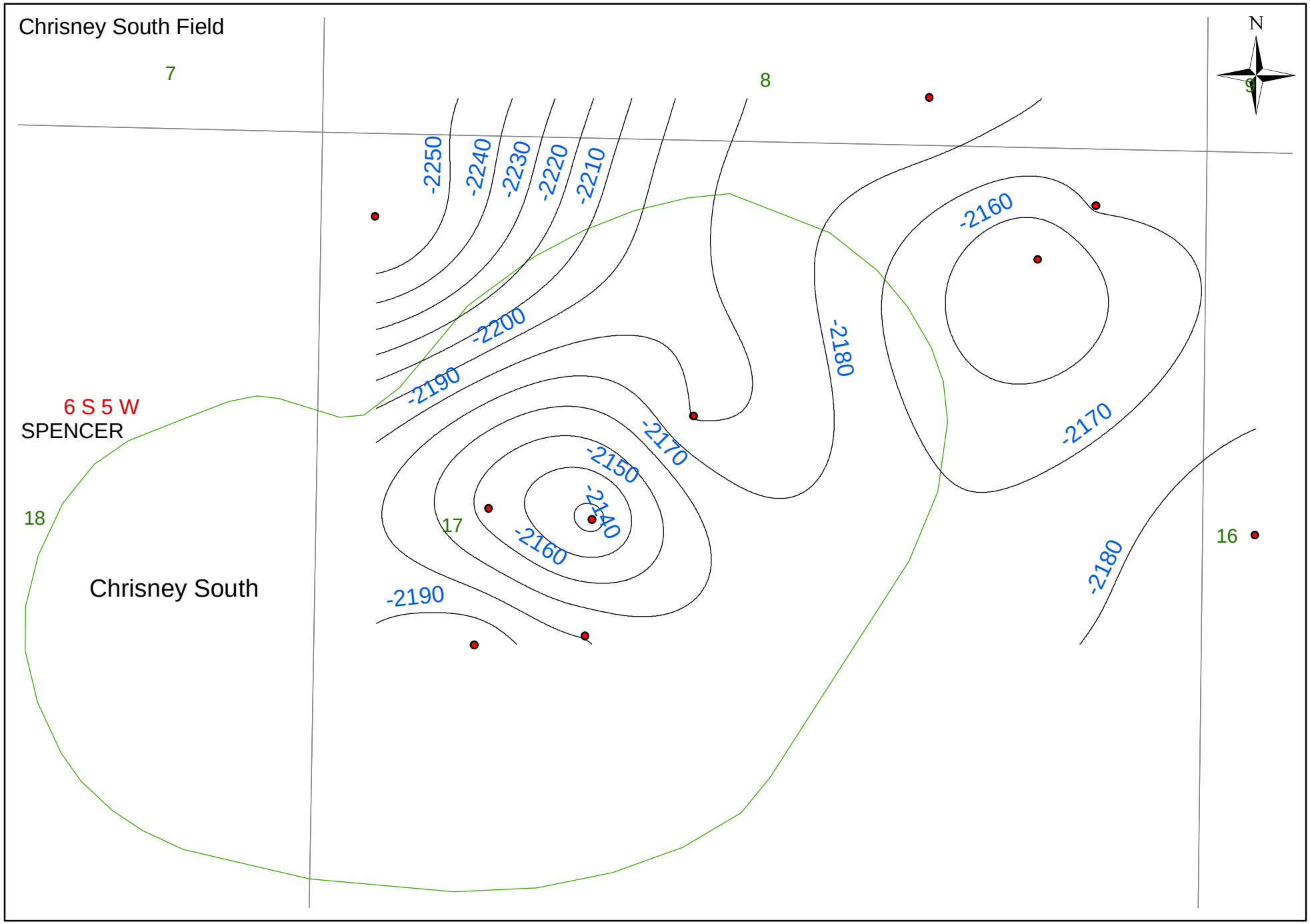

Figure 3: Structure map showing top of the Jeffersonville Limestone in Chrisney South Field, Spencer County. Contours show values below sea level, contour interval is 10 ft .

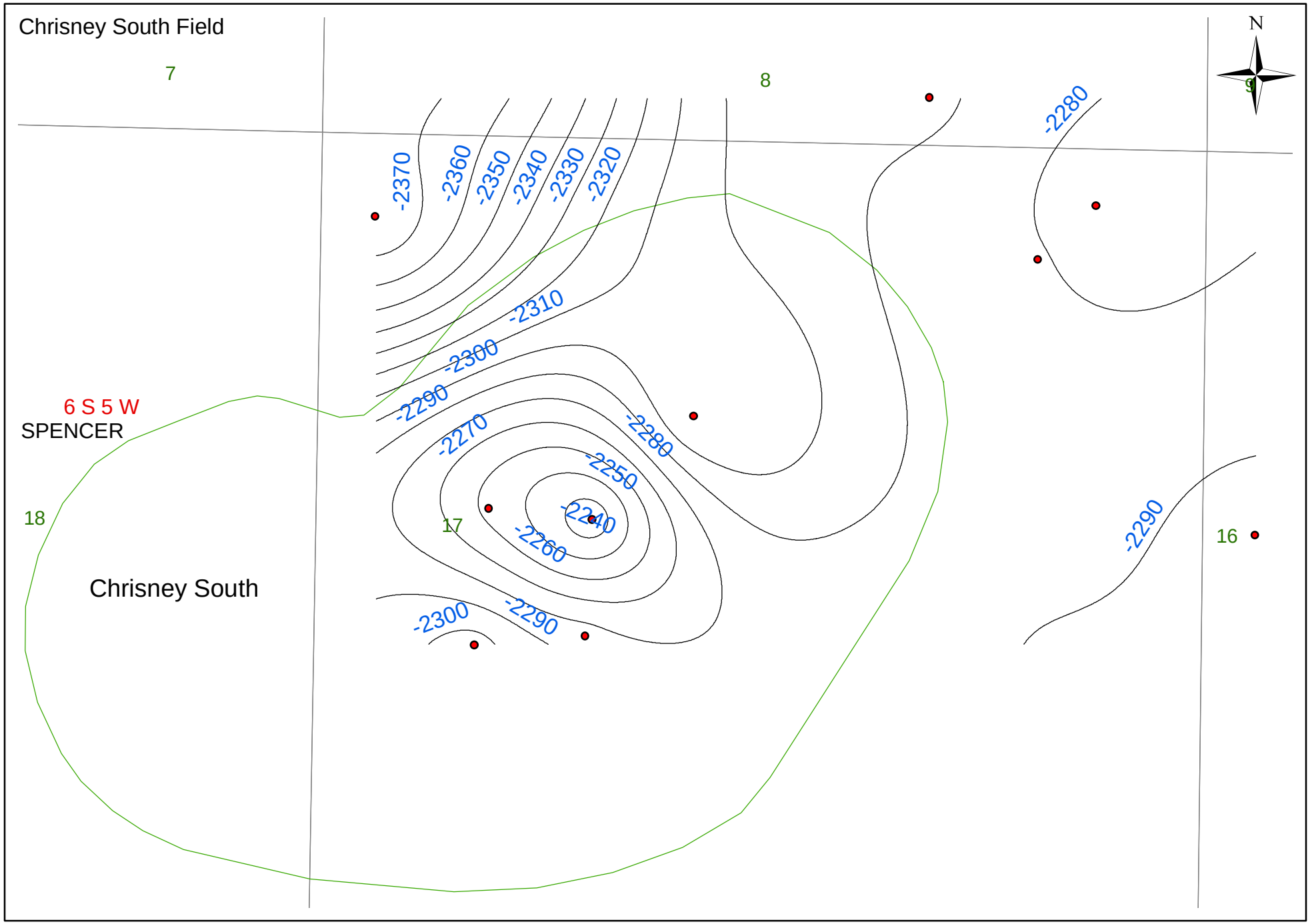

Figure 4: The structure map showing top of the New Harmony Limestone in the Chrisney South field, Spencer County. Countour shows values below sea level, contour interval is 10 ft .

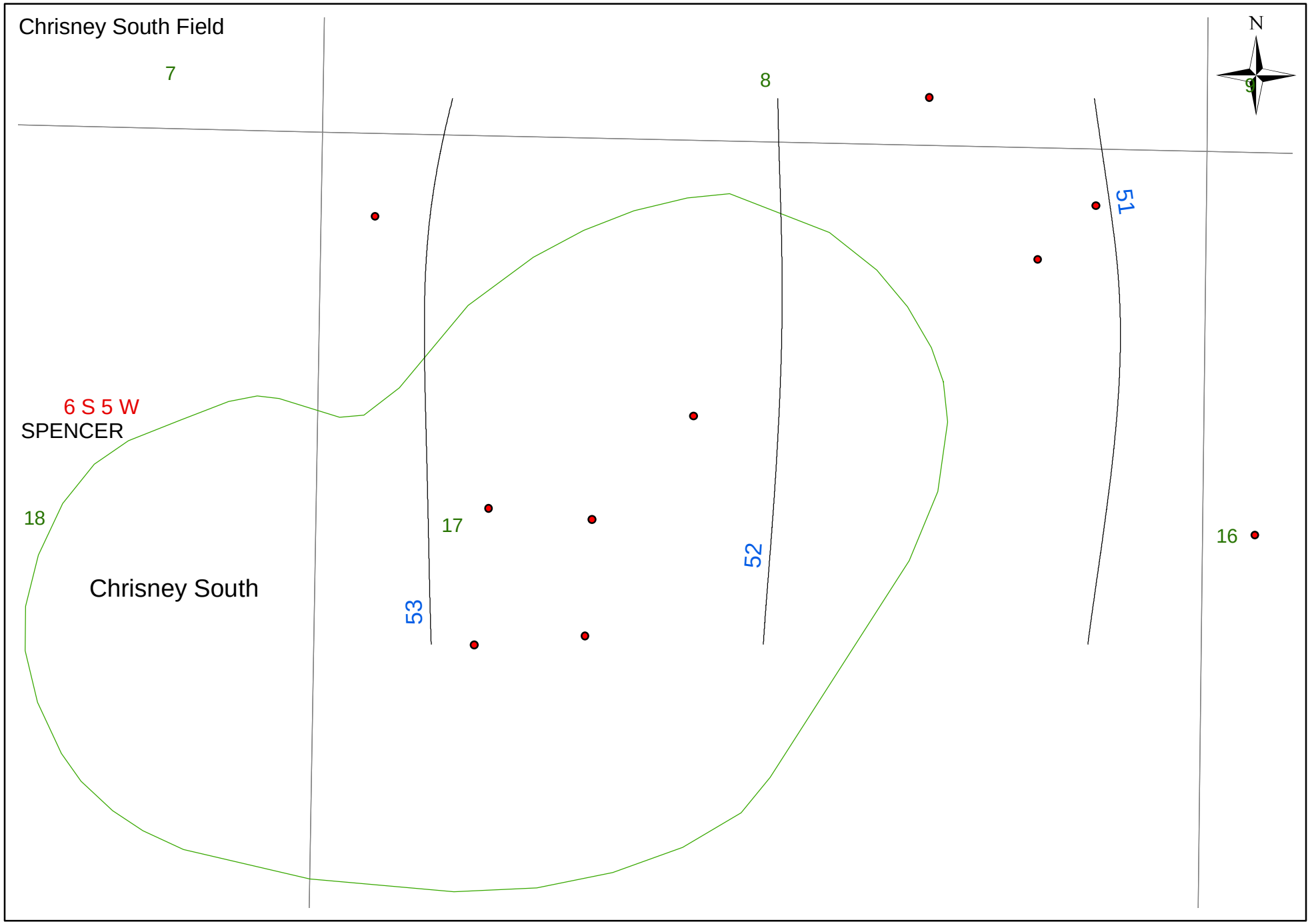

Figure 5: Isopach map showing the thickness of North Vernon Member in Chrisney South Field, Spencer County. Contour interval is 1 ft .

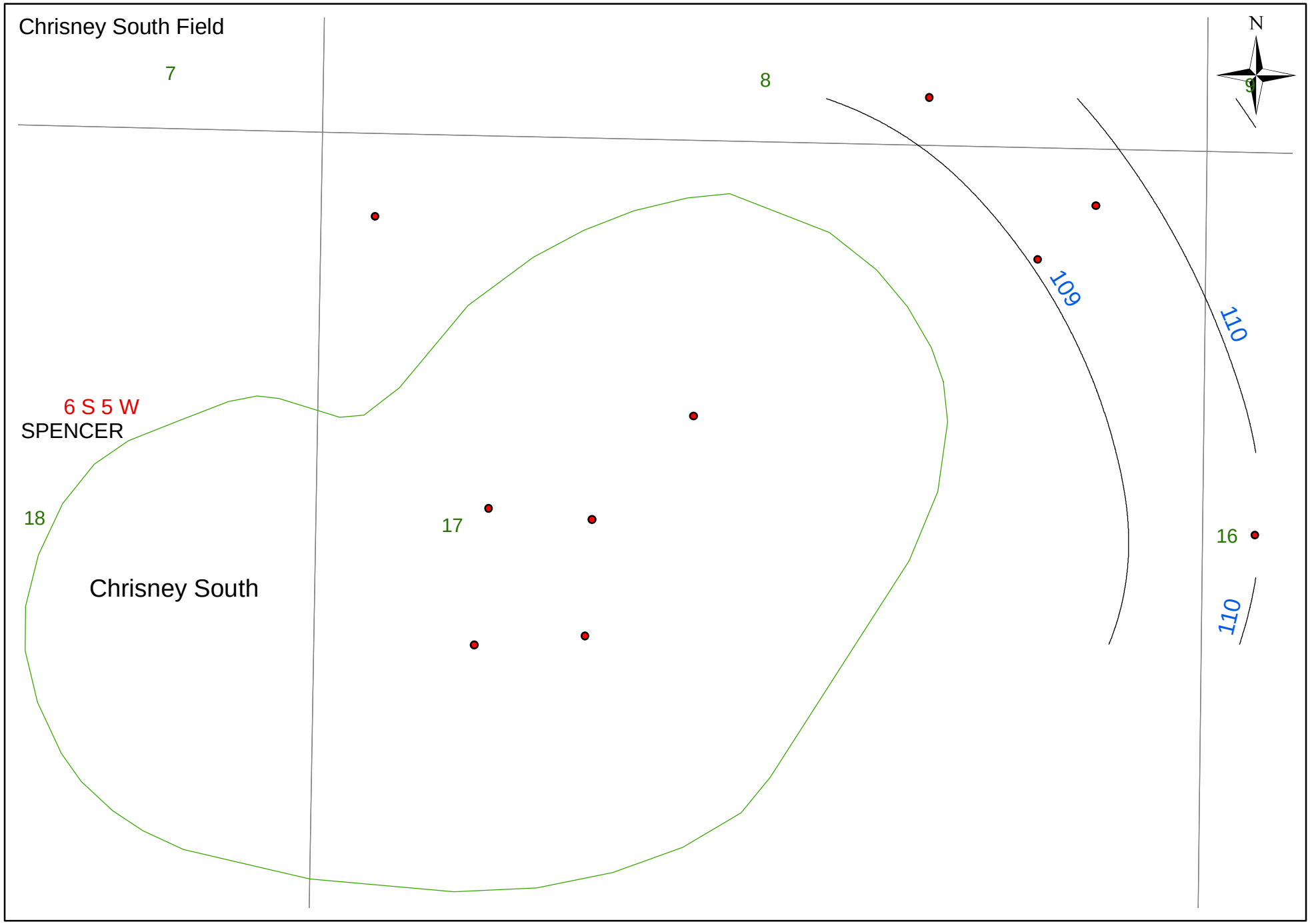

Figure 6: Isopach map showing the thickness of Jeffersonville Limestone in Chrisney South Field, Spencer County. Countour interval is 1 ft .

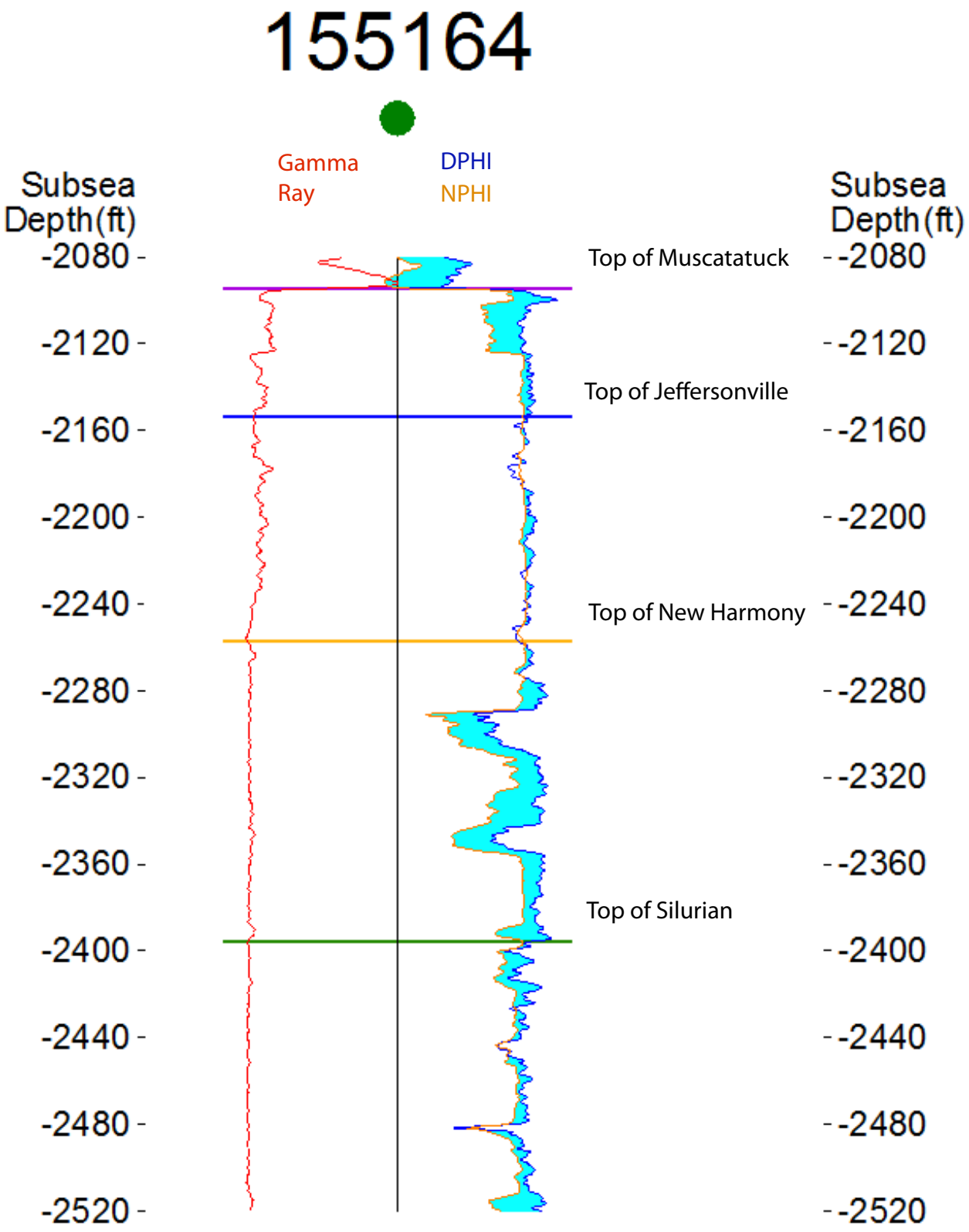

Figure 7: Type log section showing the Devonian formations at Chrisney South Field, Spencer County.

HS=1

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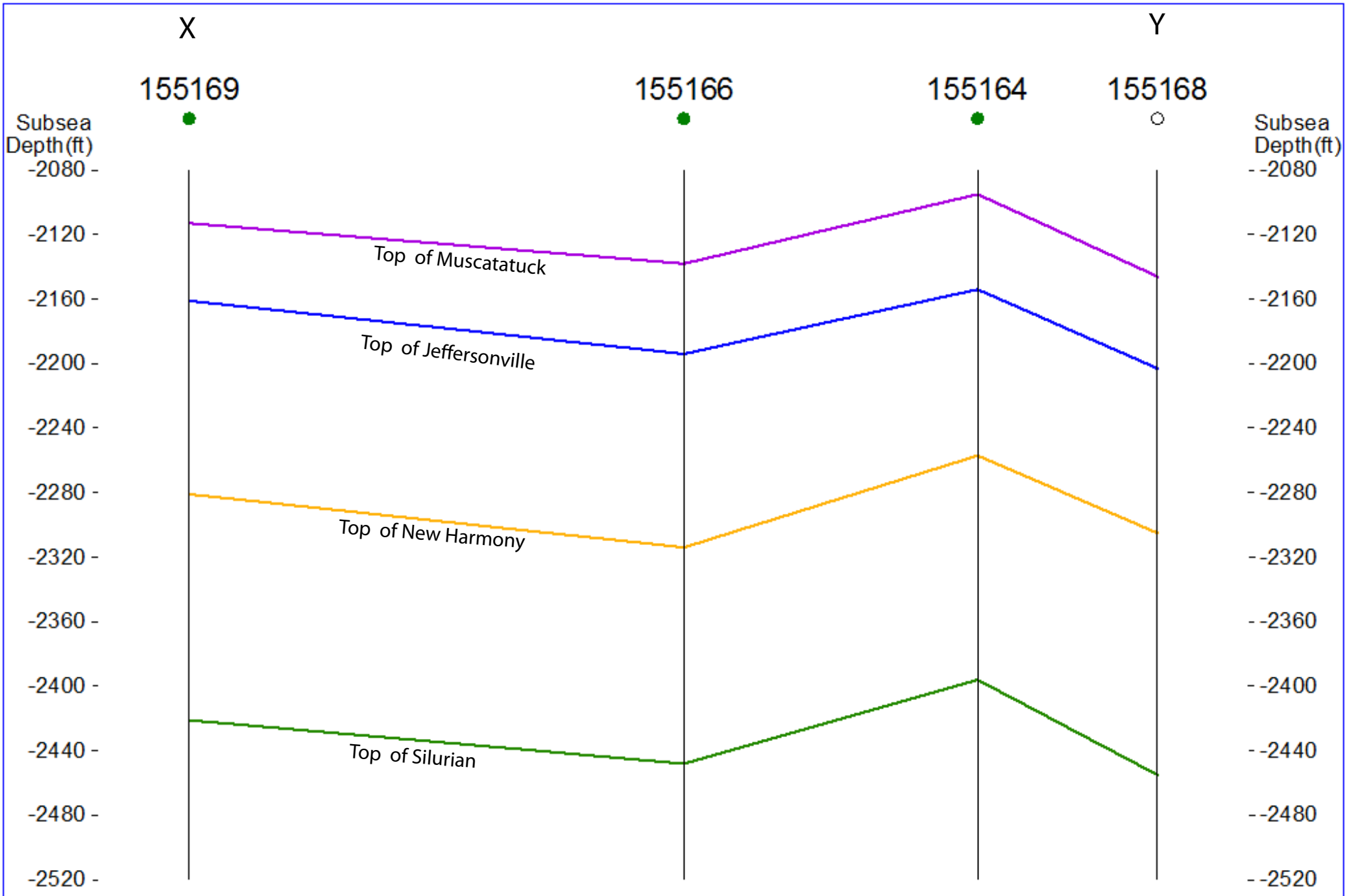

Figure 8: X-Y Cross section showing the Devonian subsurface structure across Chrisney South Field, Spencer County. For location of the cross section refer to Figure 1.

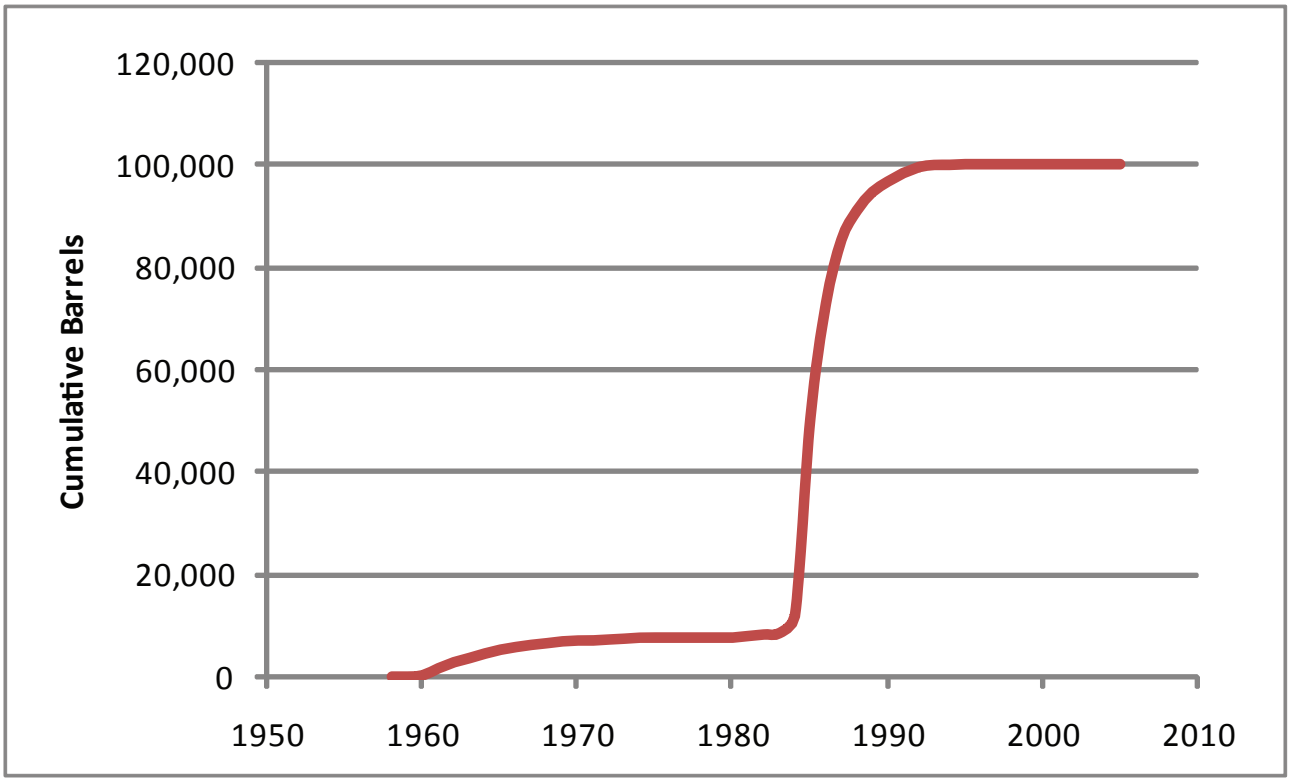

Figure - 9: Cumulative oil production history from Chrisney South Field, Spencer County since 1958.

Table-1: List of the wells used for subsurface structure mapping in Chrisney South Field, Spencer County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
155137	6	S	5	W	8	408	2546	2600	54			
155163	6	S	5	W	16	413	2550	2600	50	2920		
155164	6	S	5	W	17	468	2563	2622	59	2864		
155165	6	S	5	W	17	482	2573	2610	37		120	
155166	6	S	5	W	17	516	2654	2710	56	2964		
155167	6	S	5	W	17	487	2612	2668	56		60	
155168	6	S	5	W	17	495	2641	2698	57	2950	8	
155169	6	S	5	W	17	449	2562	2592	30	2870		
155170	6	S	5	W	17	416	2527	2590	63	2860		
155172	6	S	5	W	17	421	2629	2690	61			

Field name: Clay City North

IGS ID: 10110

DOE ID: 146439

Location: Clay County, 10N-6W

Discovery date: 1978

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,359 ft.)

Field type: oil

Total number production wells: 16

Area: 200 acres

Cumulative production: 260,420 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1,613 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

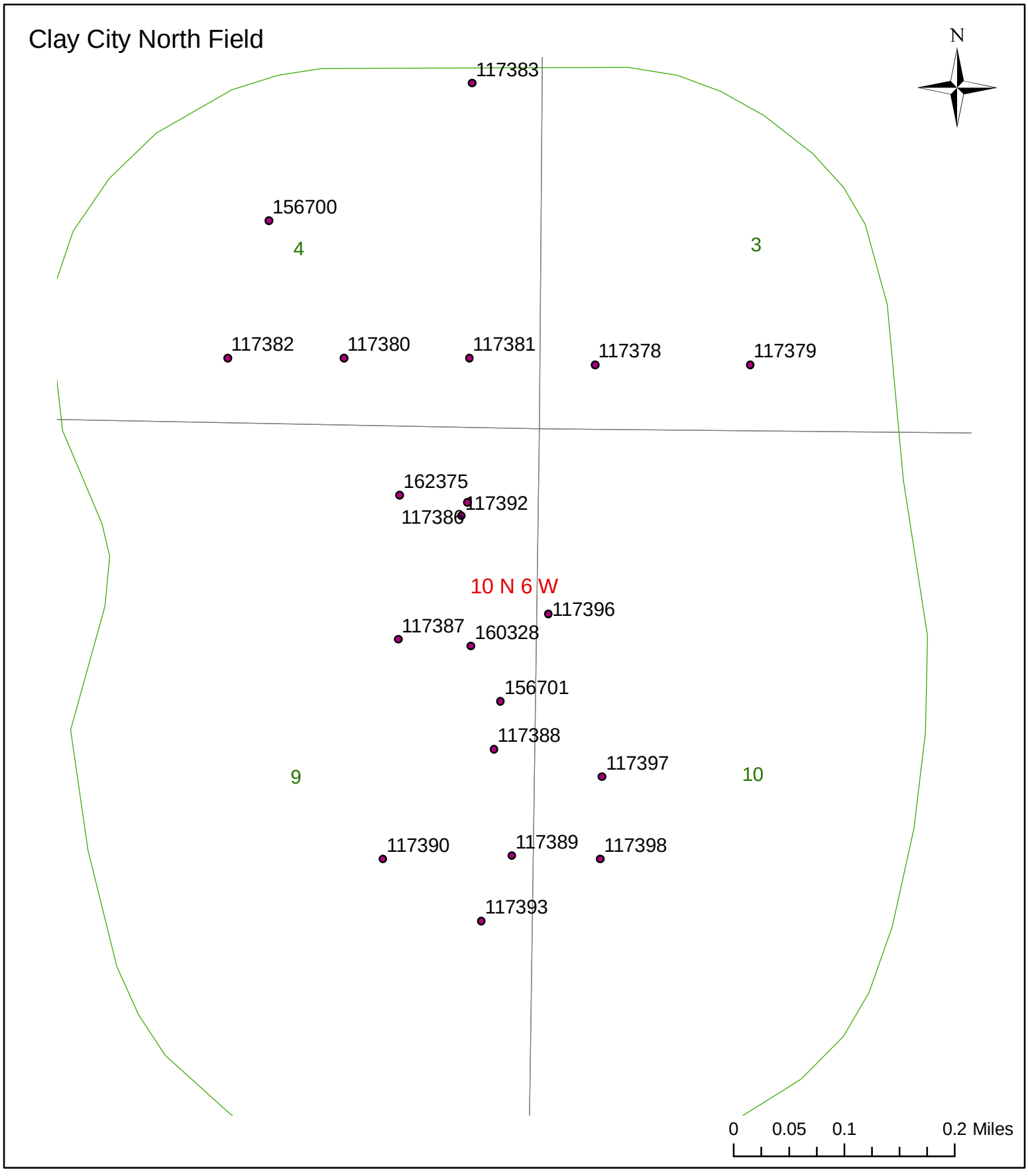

Figure 1: Map showing the location and wells at Clay City North Field, Clay County. Red points are the location of wells in the field.

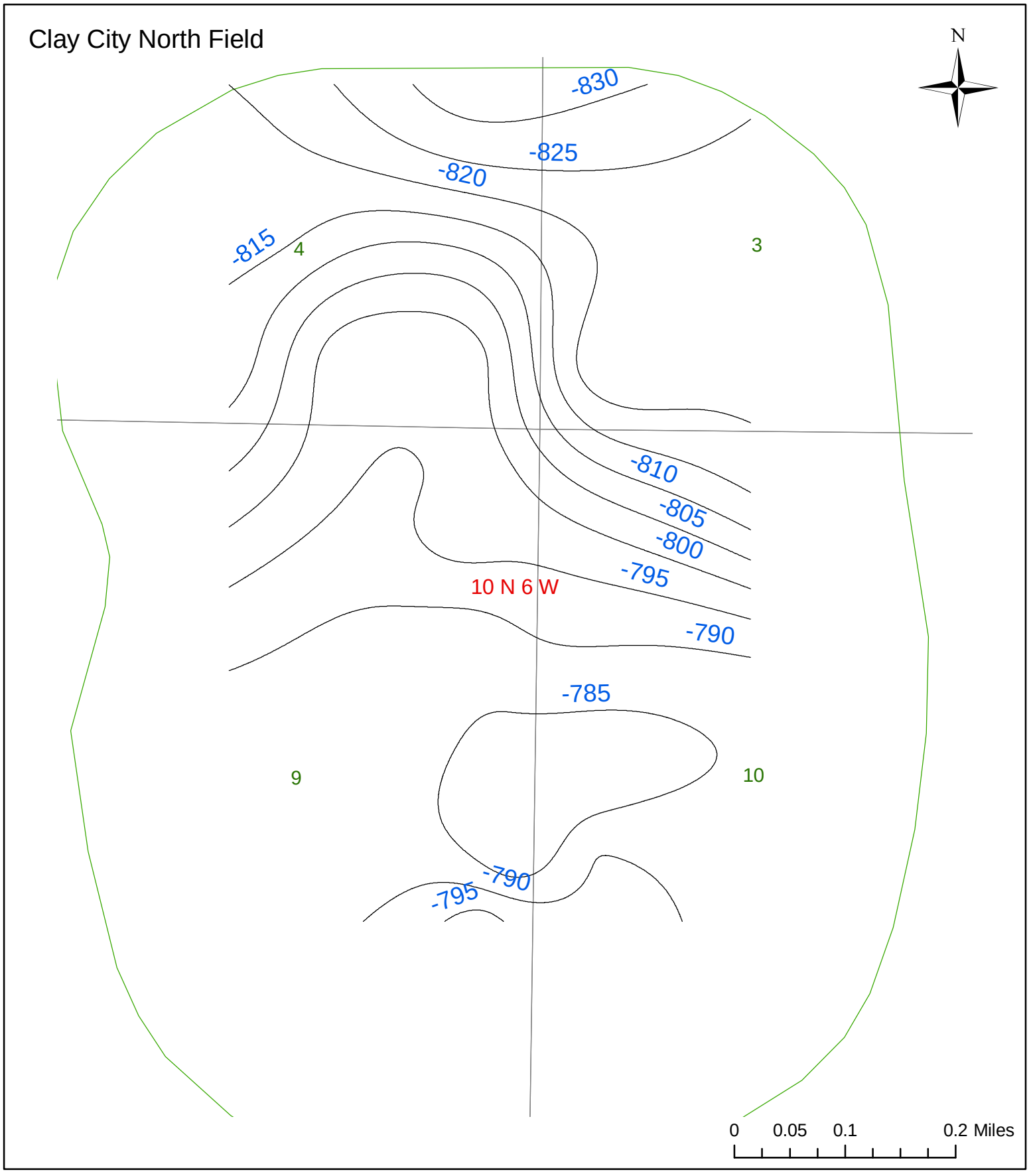

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Clay City North Field, Clay County. Contours show values below sea level, contour interval is 5 ft .

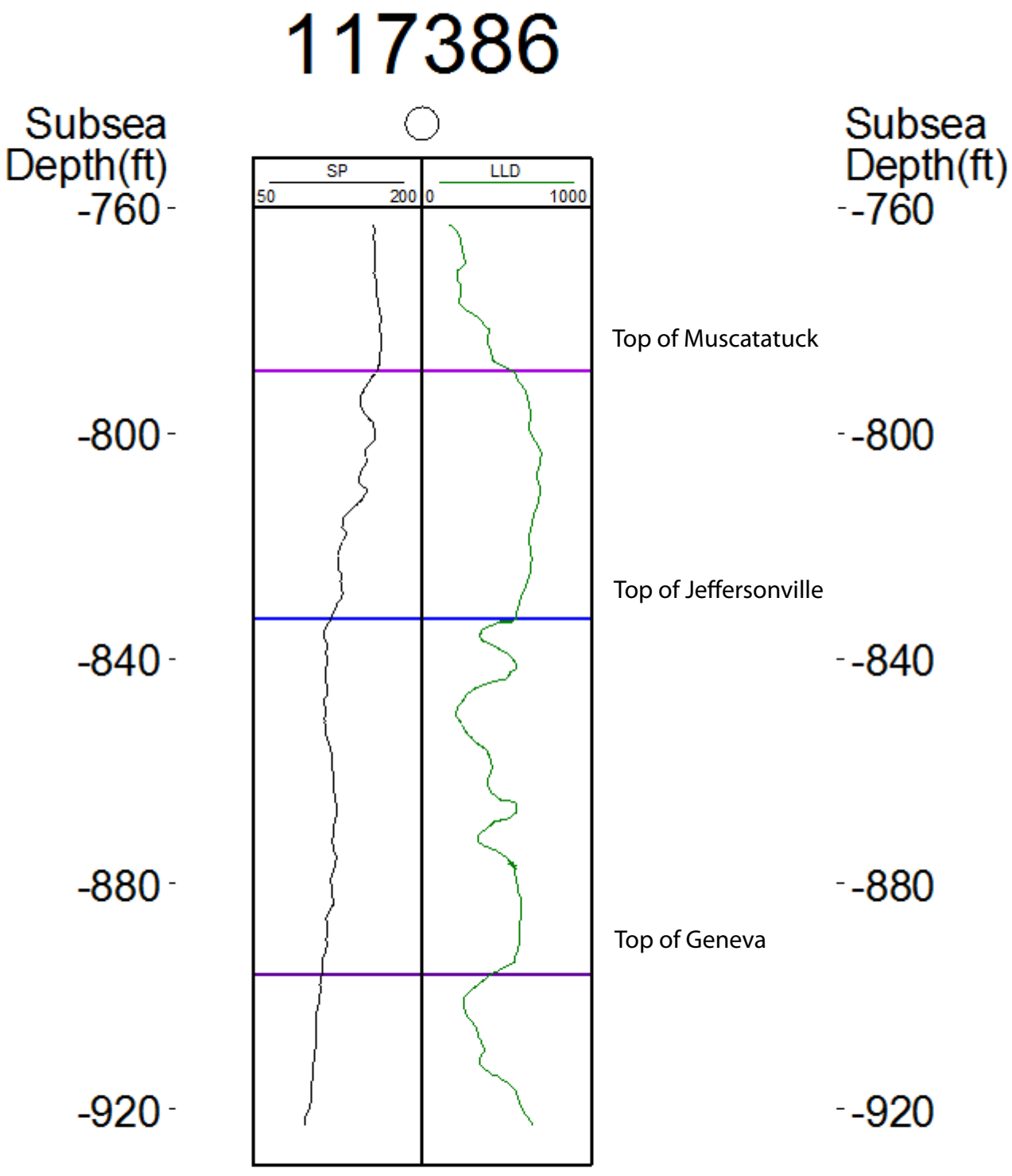

Figure 3: Type log section showing the Devonian formations from Clay City North Field, Clay County.

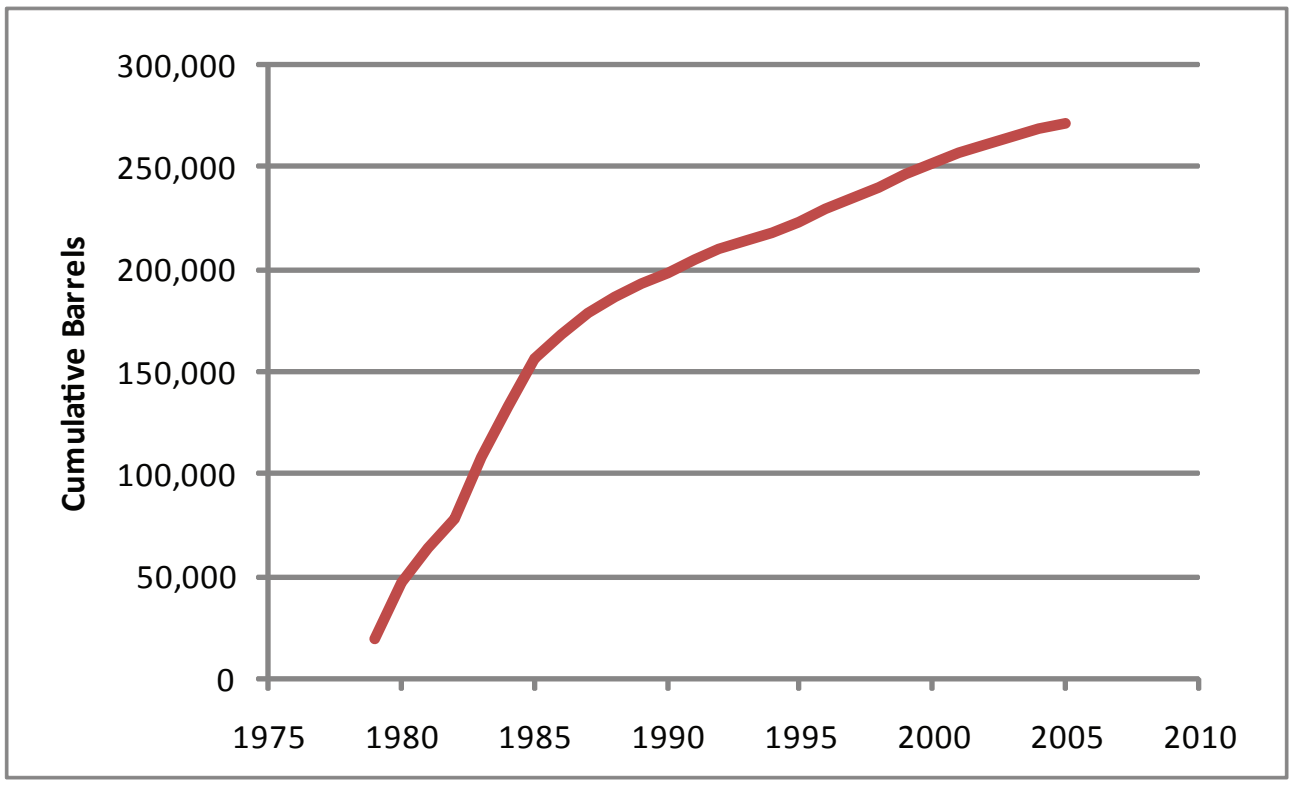

Figure - 4: Cumulative oil production history from Clay City North Field, Clay County since 1979.

Table-1: List of the wells used for subsurface structure mapping in Clay City North Field, Clay County. The wells selected have TD of Devonian or deeper.

IGS_ID	Twp	Twp _D	Rng	Rng_ D	Land _N	Elevation/ Kb	Top of Musca- tatcuk	Top of Jeffer- sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117378	10	N	6	W	3	558	1385				4	
117379	10	N	6	W	3	565	1386					
117380	10	N	6	W	4	555	1349				6	
117381	10	N	6	W	4	557	1352				12	
117382	10	N	6	W	4	555	1370	1408				
117383	10	N	6	W	4	567	1400					
156700	10	N	6	W	4	554	1373					
117386	10	N	6	W	9	577	1366	1410	1474			
117387	10	N	6	W	9	567	1355	1406			20	
117388	10	N	6	W	9	571	1343				35	
117389	10	N	6	W	9	586	1361				3\20	
117390	10	N	6	W	9	597	1384				10	
117392	10	N	6	W	9	572	1379				10	
117393	10	N	6	W	9	594	1396				10	
156701	10	N	6	W	9	575	1360			1520		
160328	10	N	6	W	9	575	1360				20	
162375	10	N	6	W	9	578	1371				15	
117396	10	N	6	W	10	581	1374				15	
117397	10	N	6	W	10	589	1369				5\12	
117398	10	N	6	W	10	587	1380				15	

Field name: Coal City

IGS ID: 10114

DOE ID: na

Location: Owen County, 9N-6W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,448 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,695 ft.)

Field characteristic: Insufficient data.

Reservoir characteristics:

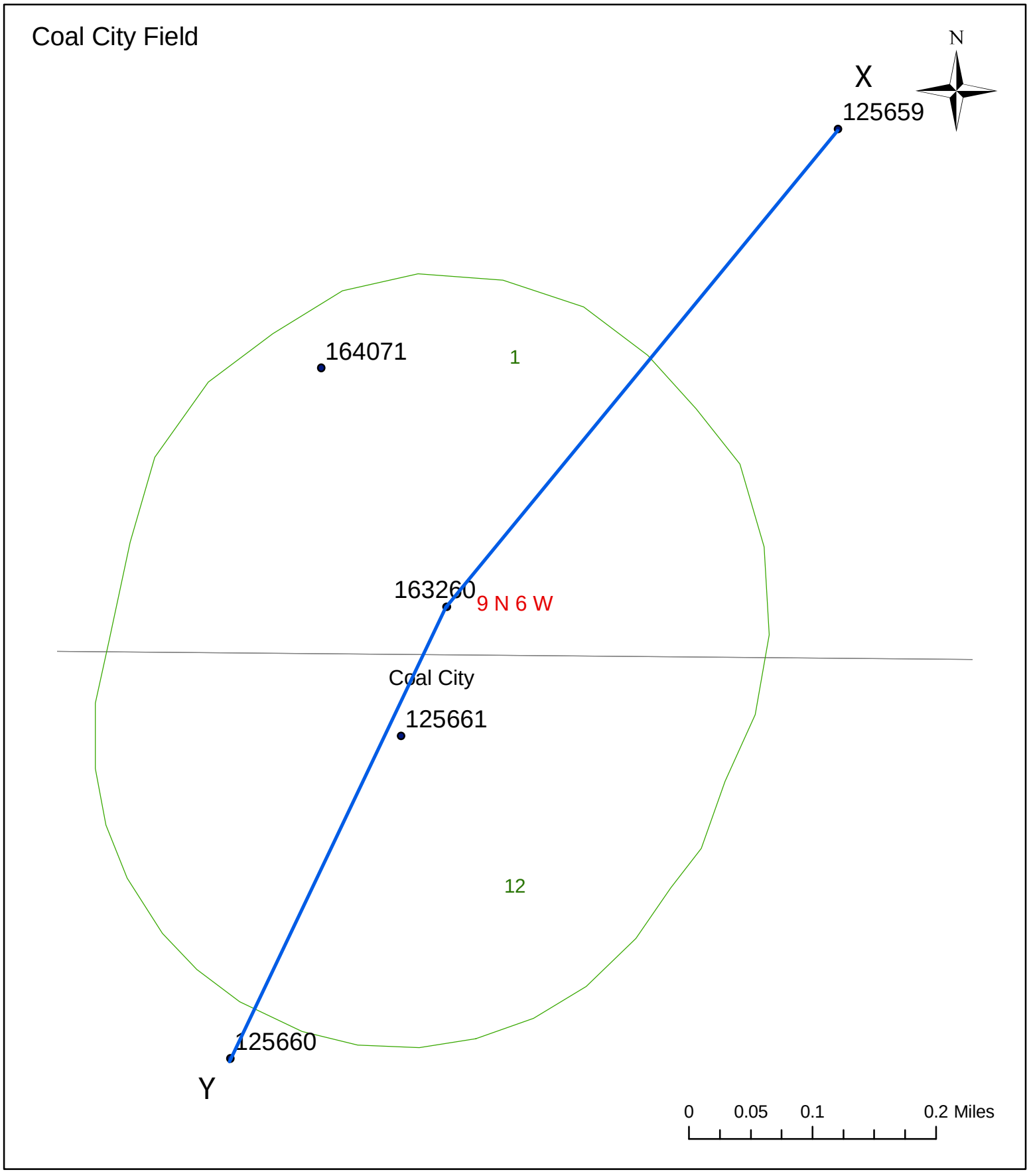

Figure 1: Map showing the location and wells at Coal City Field, Owen County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

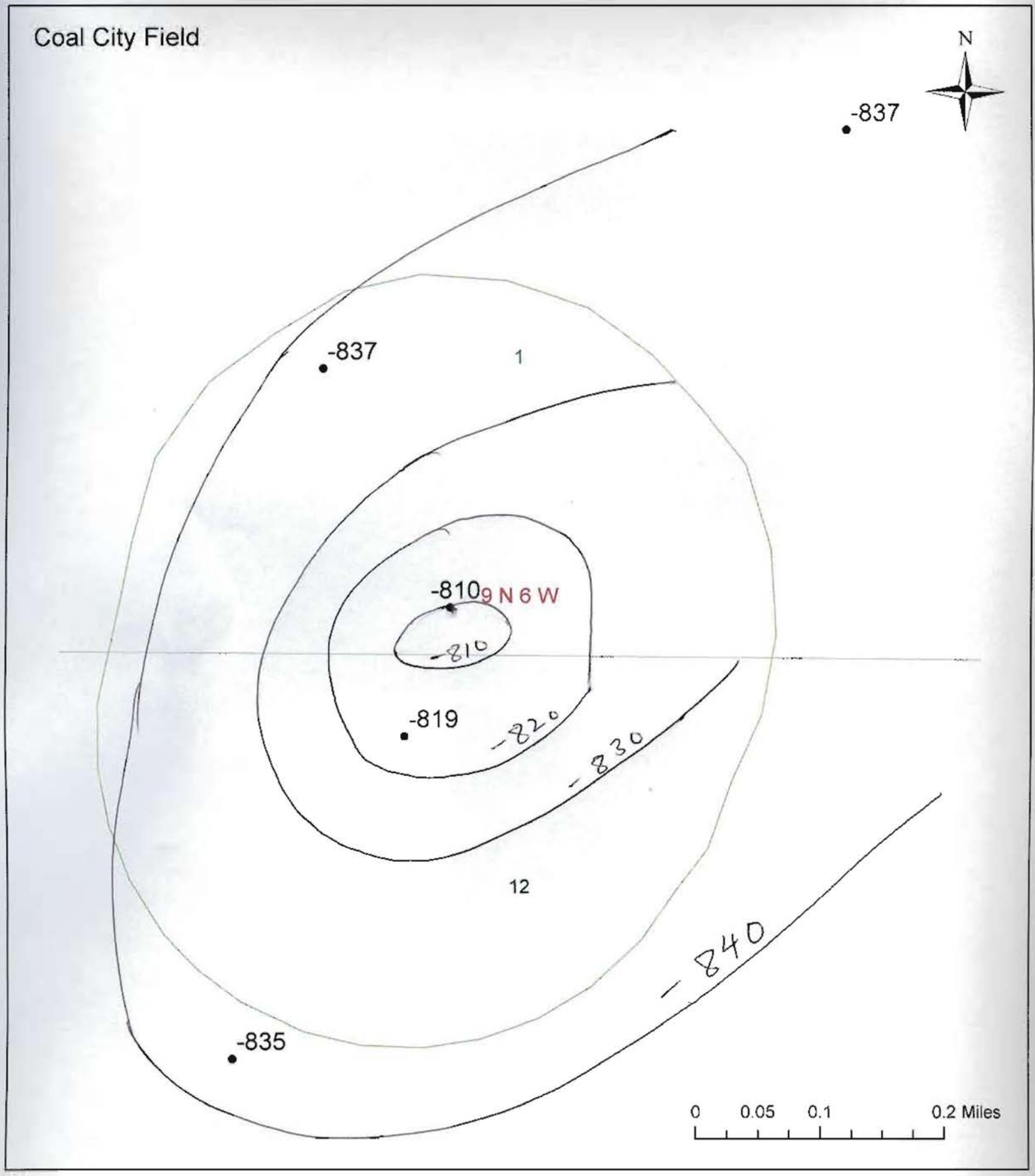

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Coal City Field, Owen County. Contours show values below sea level, contour interval is 10 ft .

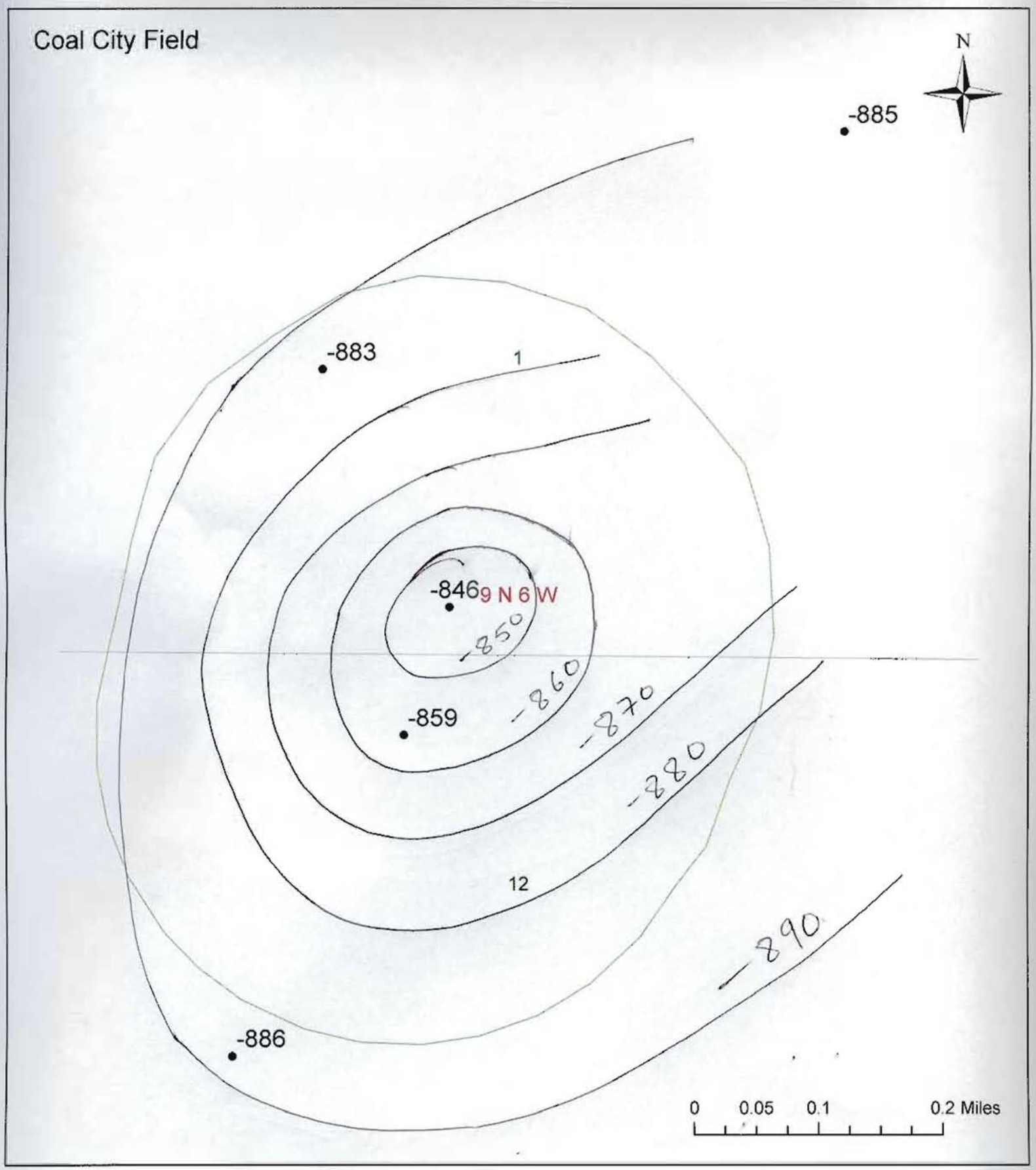

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Coal City Field, Owen County. Contours show values below sea level, contour interval is 10 ft .

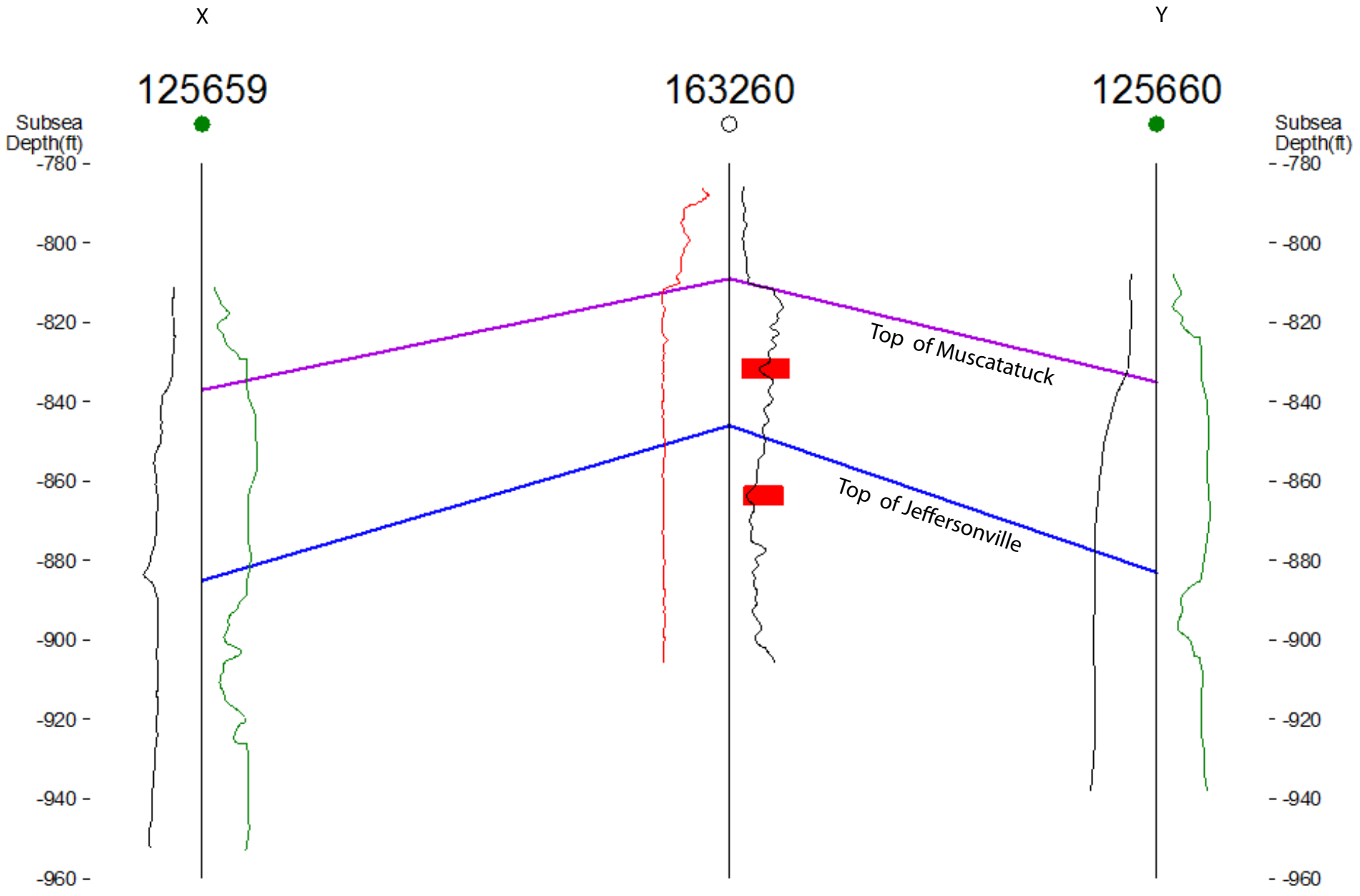

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Coal City Field, Owen County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

HS=121
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Table-1: List of the wells used for subsurface structure mapping in Coal City Field, Owen County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Muscatatcuk	Top of Jeffersonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
125659	9	N	6	W	1	539	1376	1424				
163260	9	N	6	W	1	644	1454	1490				
164071	9	N	6	W	1	617	1454	1500	1570			1500
125660	9	N	6	W	12	612	1447	1498				
125661	9	N	6	W	12	611	1430	1470	1532			112

Field name: Coalmont West

IGS ID: 10117

DOE ID: 13356

Location: Sullivan County, 9N-8W

Discovery date: 1988

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,863 ft.)

Field type: oil & natural gas

Total number production wells: 7 oil, 3 natural gas

Area: na

Cumulative production: na

Other reservoir units: Devonian/Mississippian, New Albany Sh.

Deepest unit penetrated (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,988 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

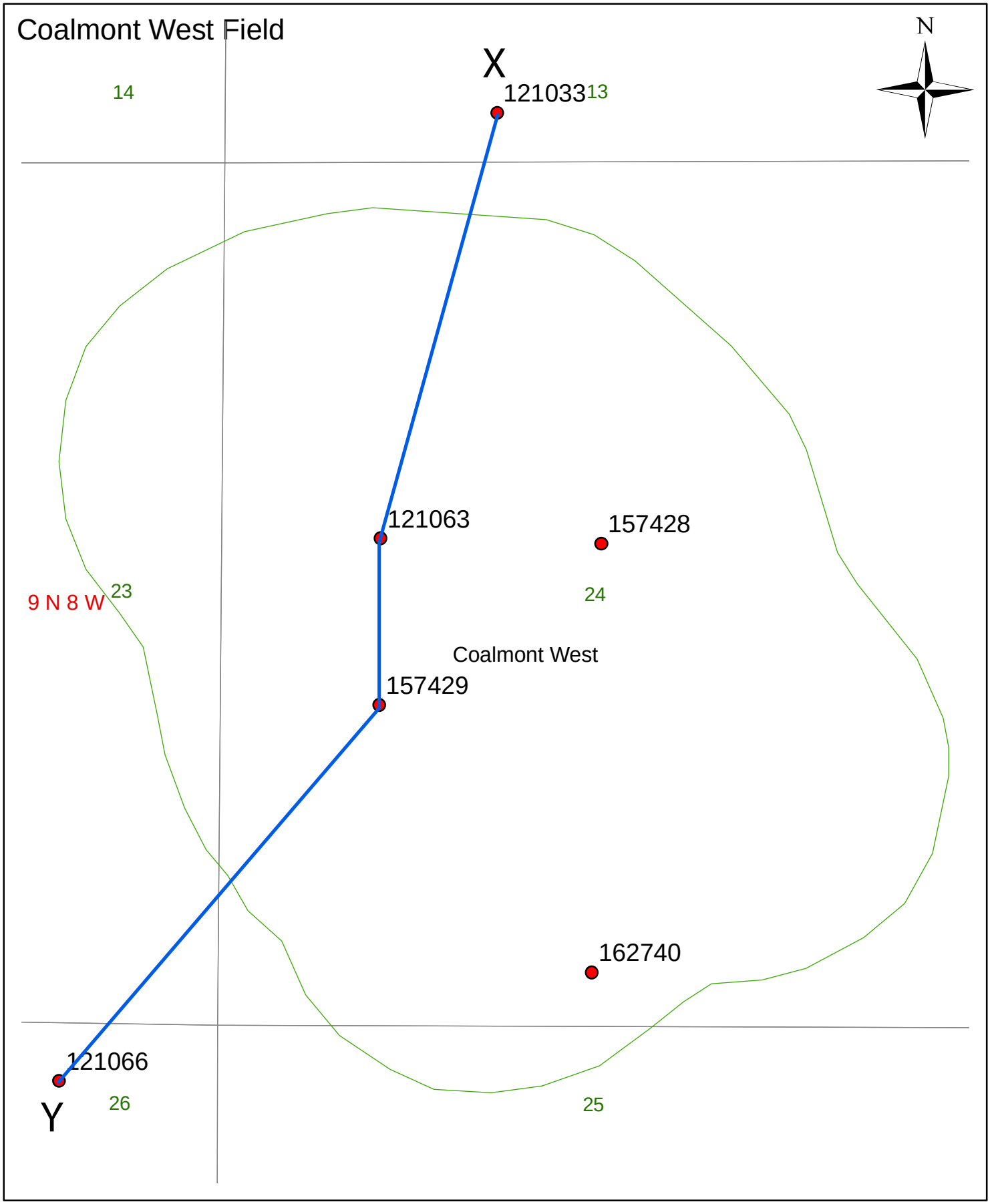

Figure 1: Map showing the location and wells at Coalmont West Field, Sullivan County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

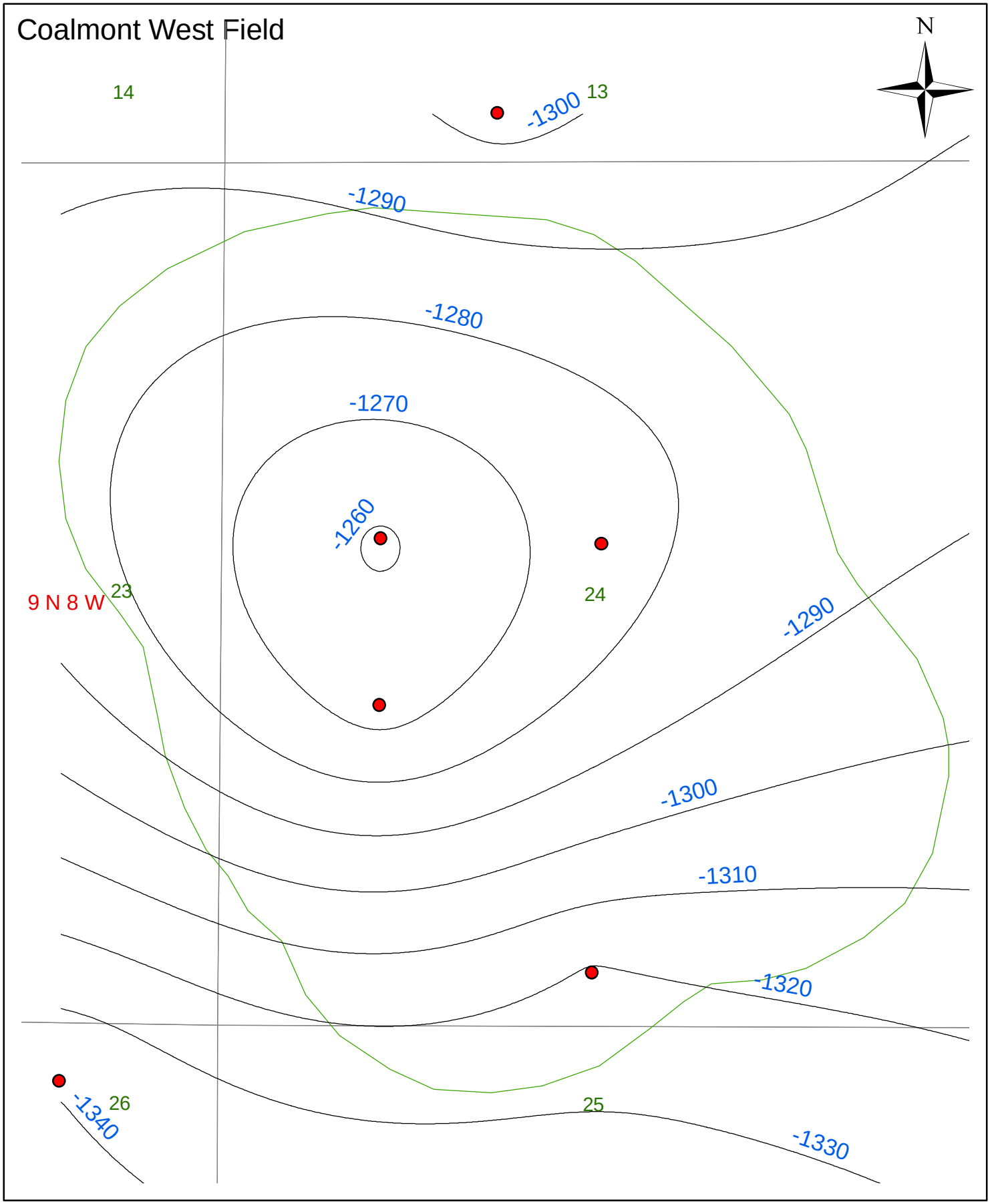

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Coalmont West Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

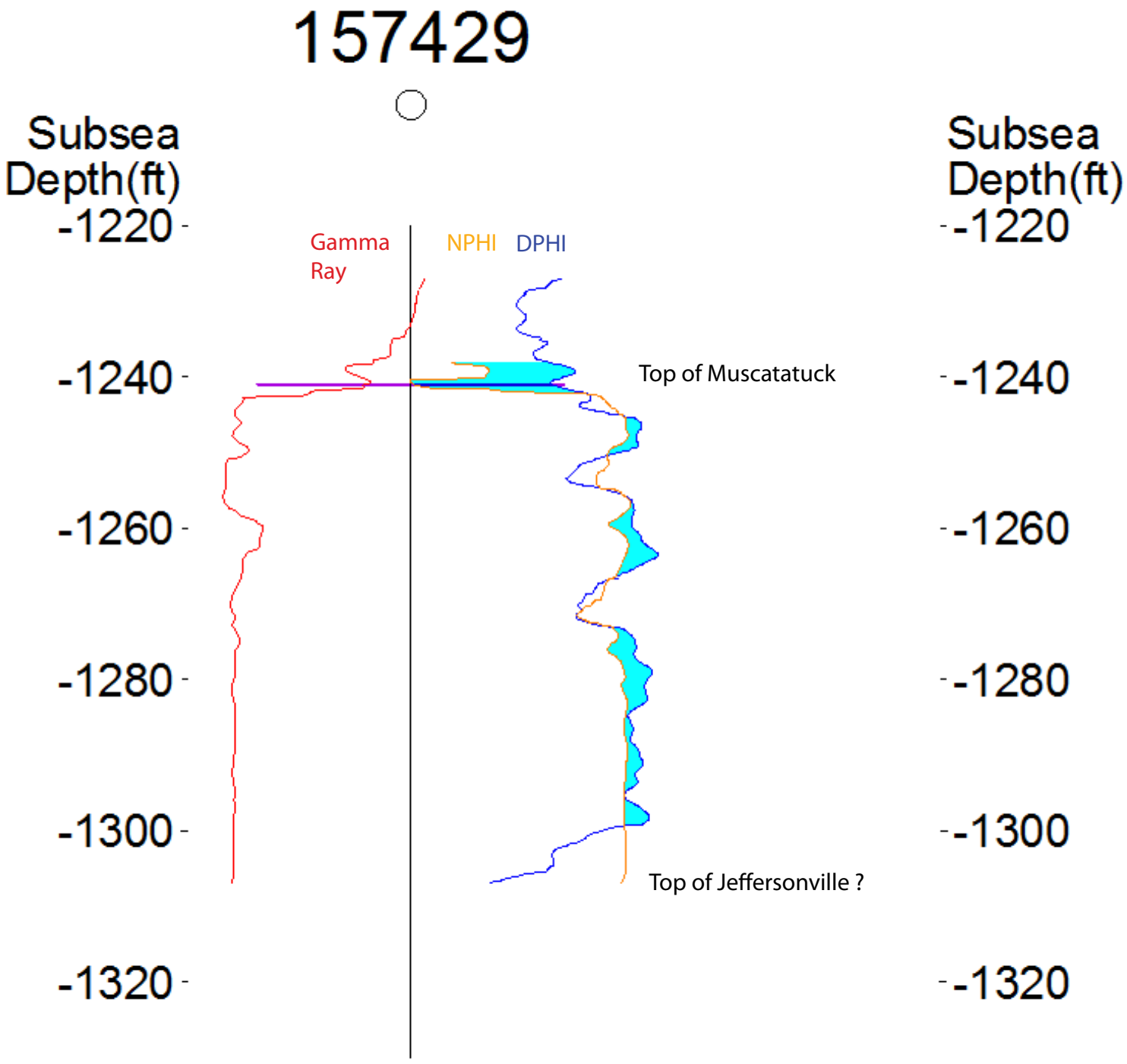

Figure 3: Type log section showing the Devonian formations from Coalmont West Field, Sullivan County.

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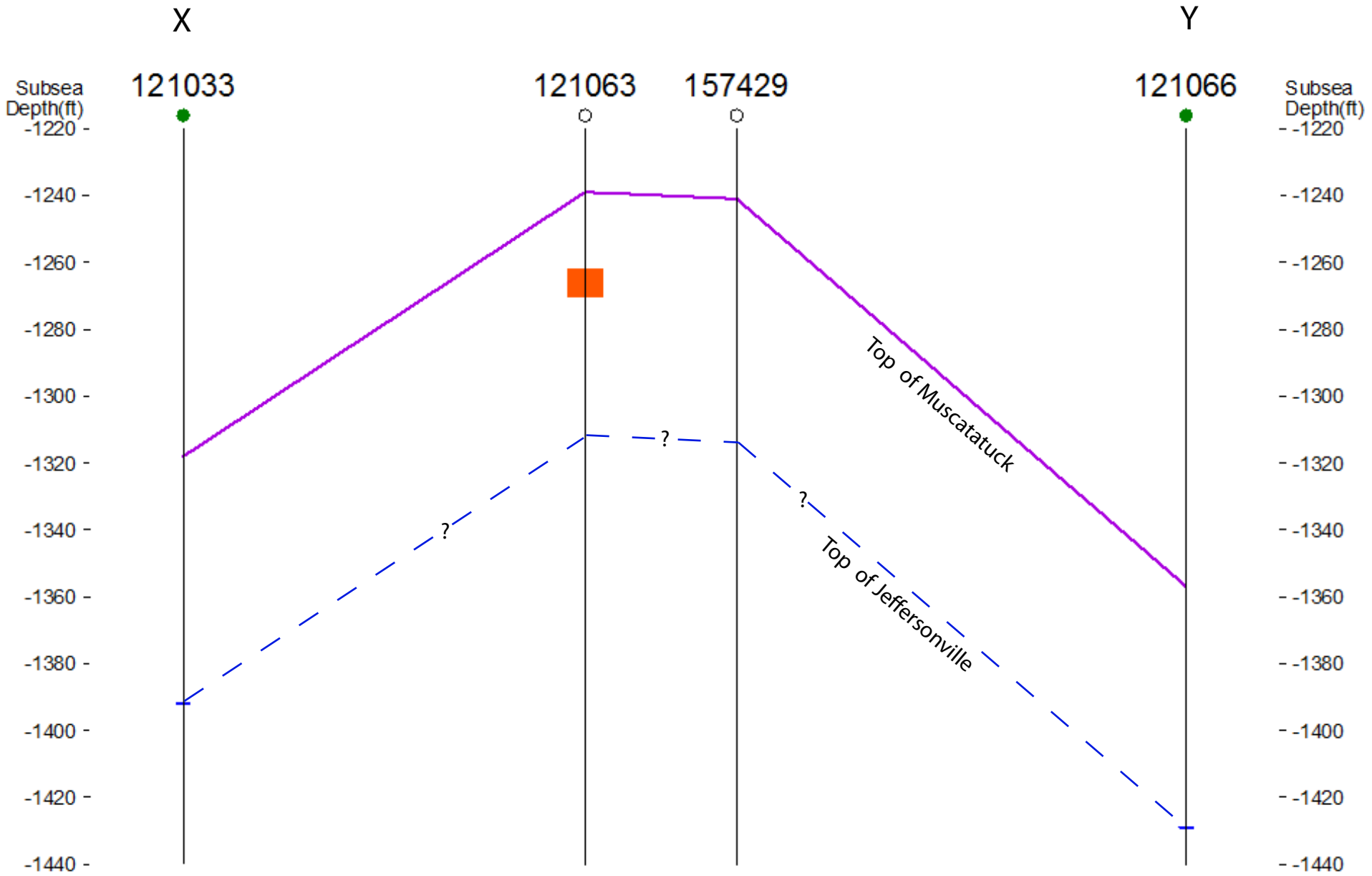

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Coalmont West Field, Sullivan County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for gas production.

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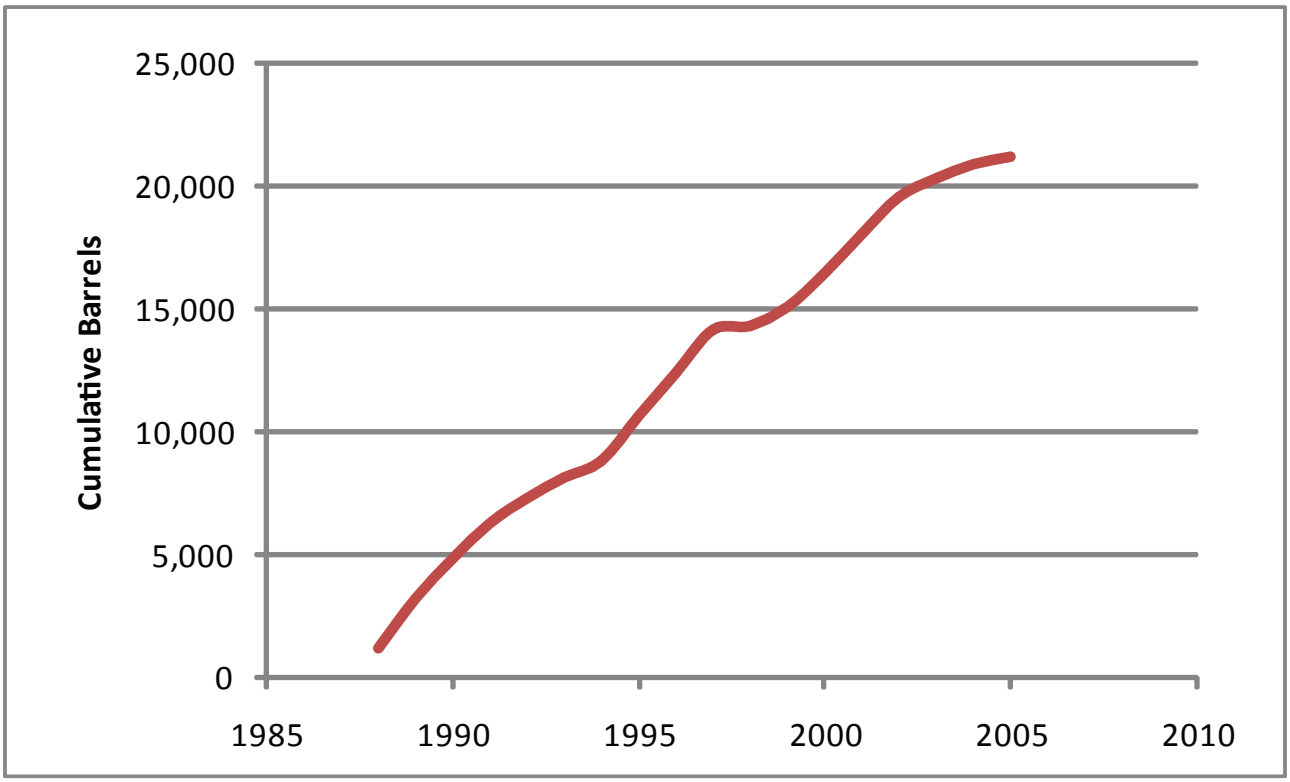

Figure - 5: Cumulative oil production history for Coalmont West Field, Sullivan County since 1988.

Table-1: List of the wells used for subsurface structure mapping in Coalmont West Field, Sullivan County.

IGS_ID	Twp	Twp _D	Rng	Rng_ D	Land _N	Elevation/ Kb	Top of Musca- tatcuk	Top of Jeffer- sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
121033	9	N	8	W	13	608	1926	2000				
121062	9	N	8	W	24	614	1896					
121063	9	N	8	W	24	599	1838					400
157428	9	N	8	W	24	596	1872					454
157429	9	N	8	W	24	593	1834					115
162740	9	N	8	W	24	591	1928			2130		
121065	9	N	8	W	25	590	1947	2024				
121066	9	N	8	W	26	551	1908	1980				

Field name: Cory Consolidated

IGS ID: 10127

DOE ID: 163102

Location: Clay County, 11N-7W

Discovery date: 1958

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,521 ft.)

Field type: oil (abandoned)

Total number production wells: 17

Area: 250 acres

Cumulative production: 177,151 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,738 ft.)

Field characteristic: Irregular domal anticline over probable Silurian reef with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

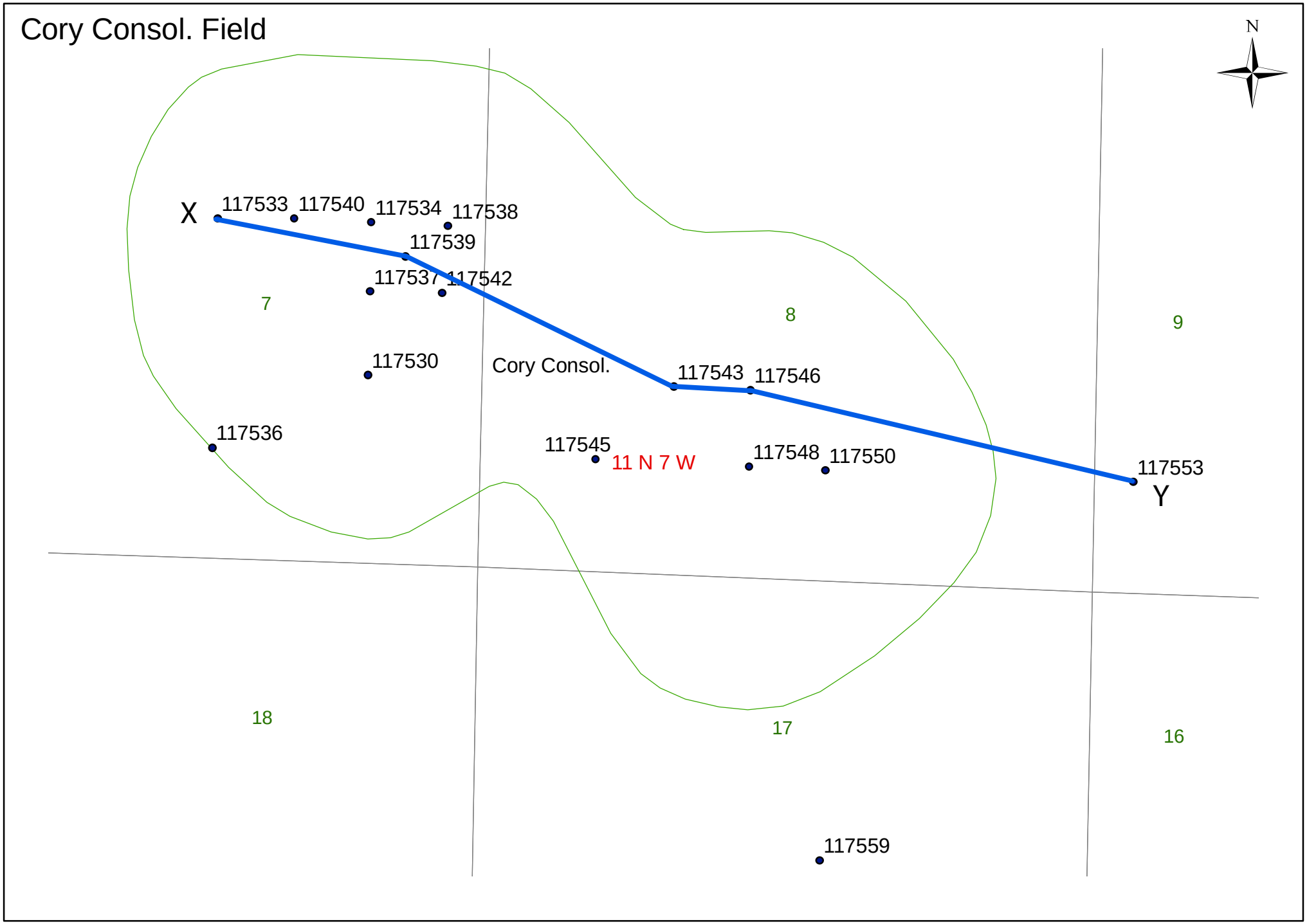

Figure 1: The map shows the location and wells at Cory Consolidated Field, Clay County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

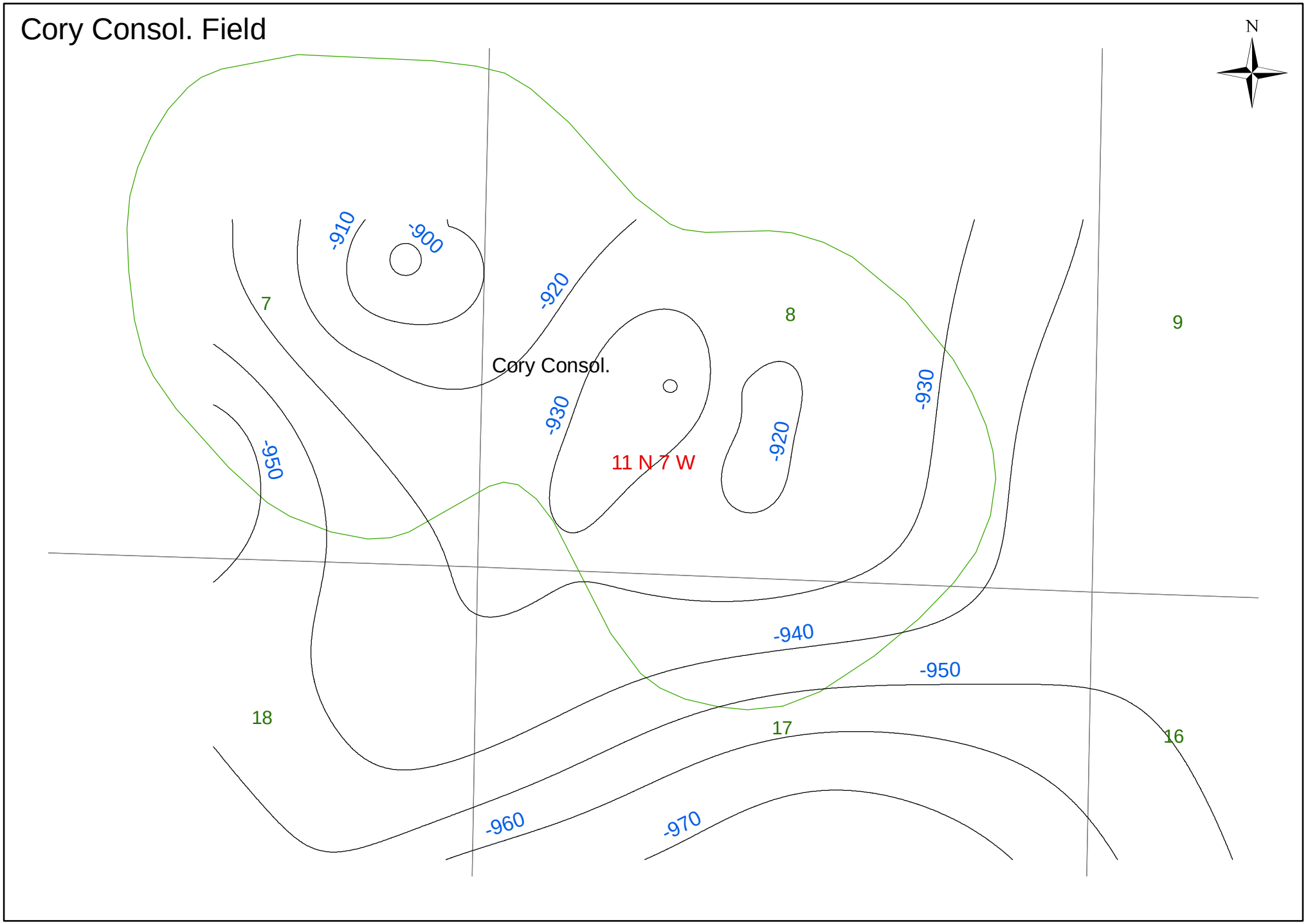

Figure 2.32 Structure map showing the top of subsurface Muscatatuck Limestone in Cory Consol. Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

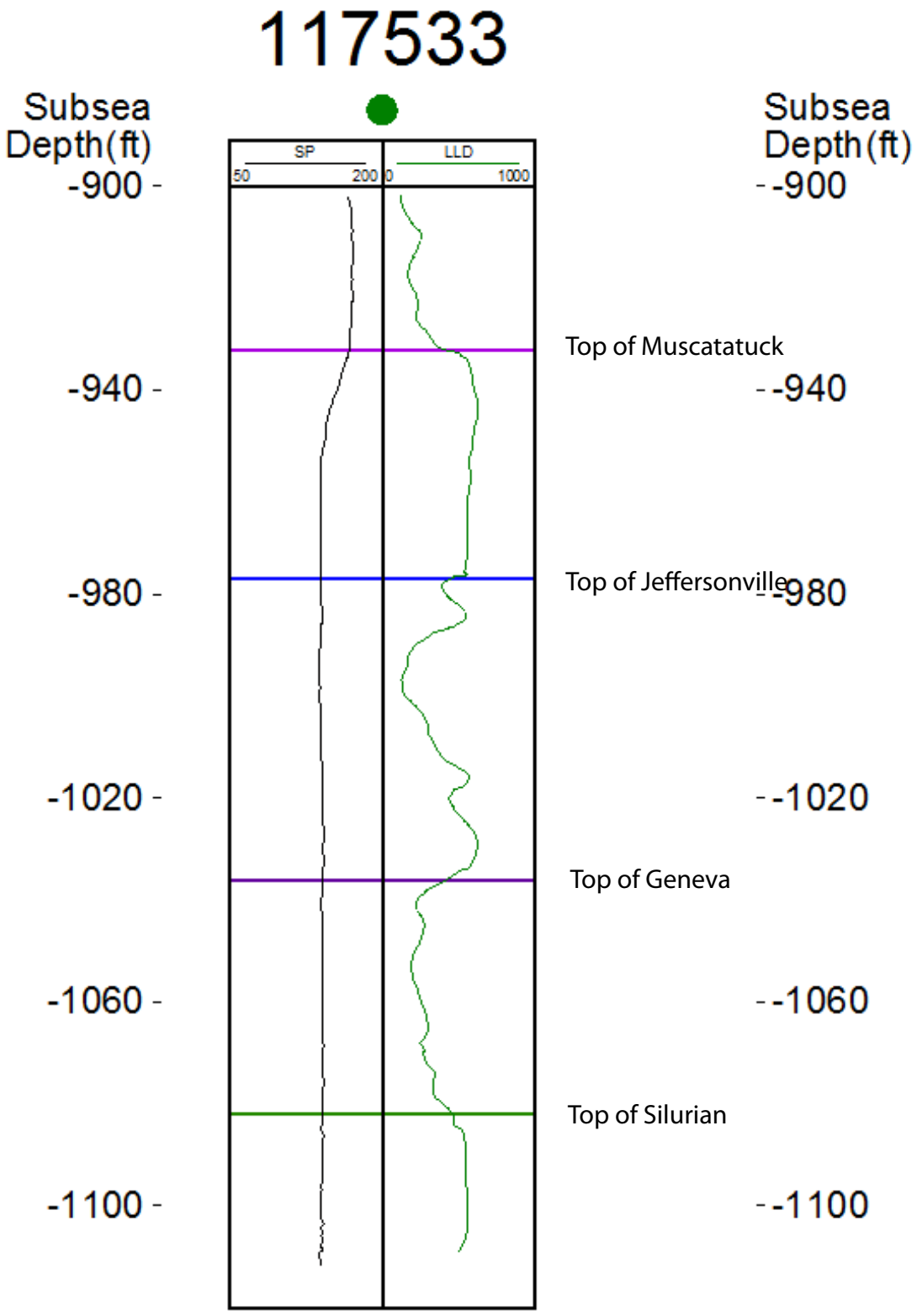

Figure 3: Type log section showing the Devonian formations from Cory Consol. Field, Clay County.

HS=1

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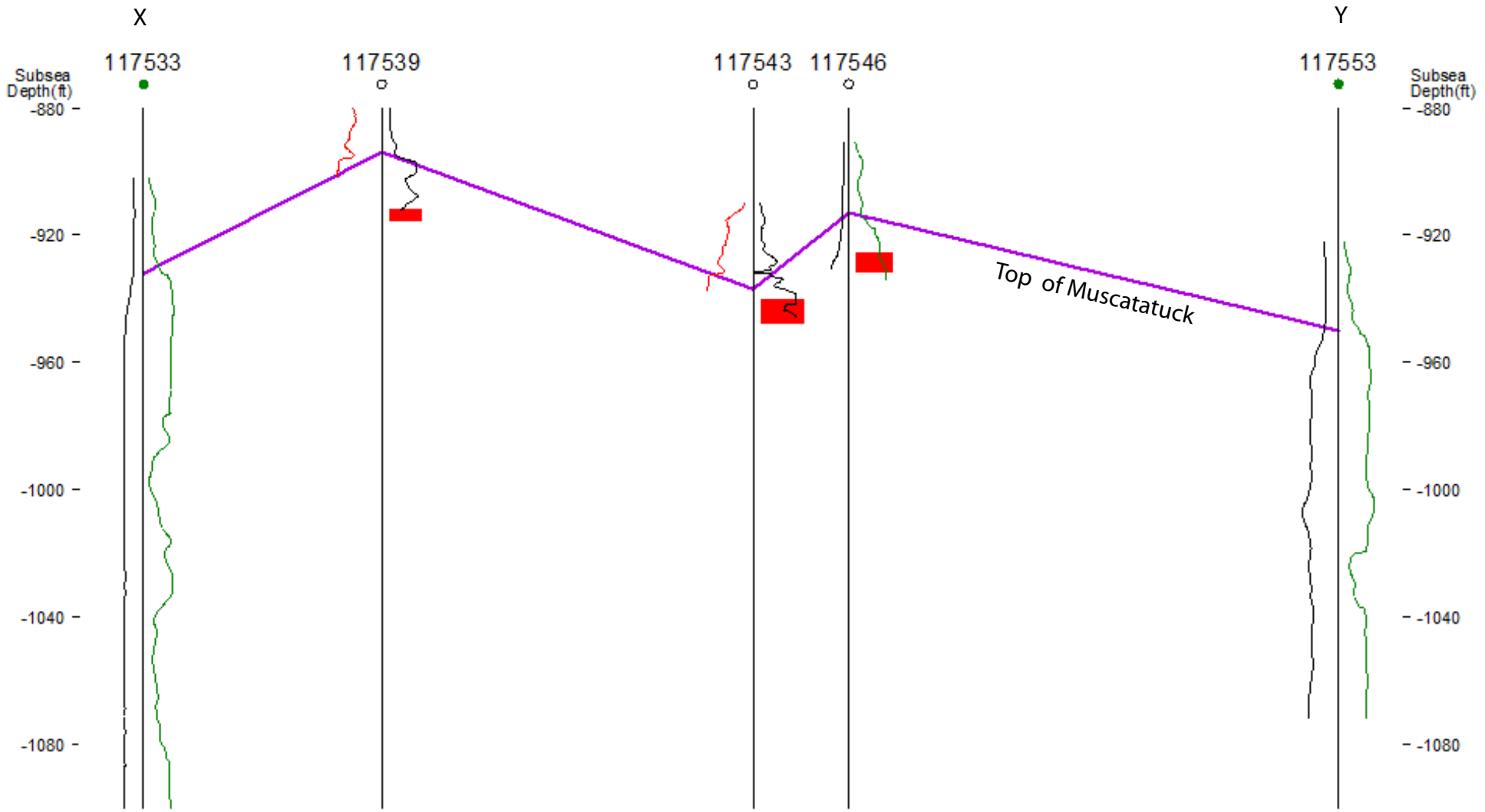

Figure 4: X-Y Corss section showing the Devonian subsurface structure acorss the Cory Consol. field, Clay County. The red colour box shows the completion intervals for oil production. For location of the cross section refer to Figure 1.

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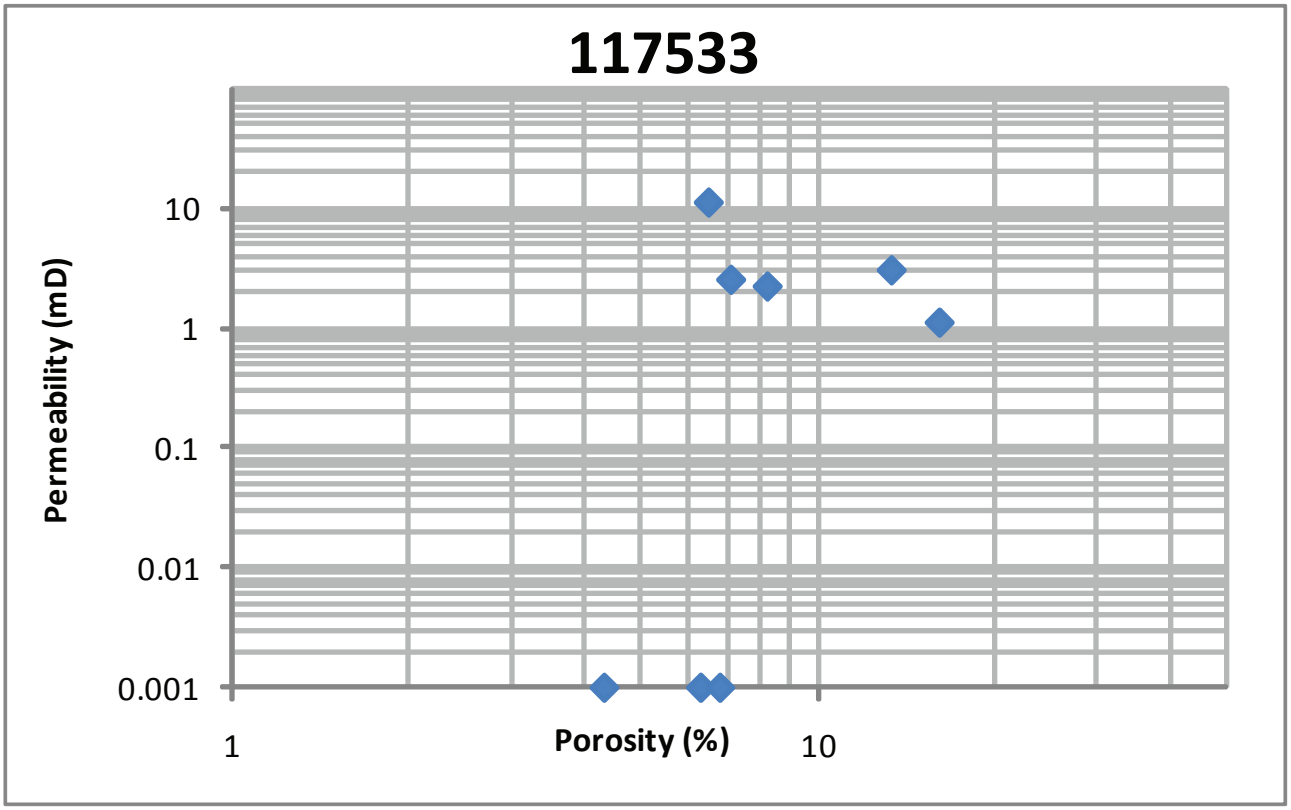


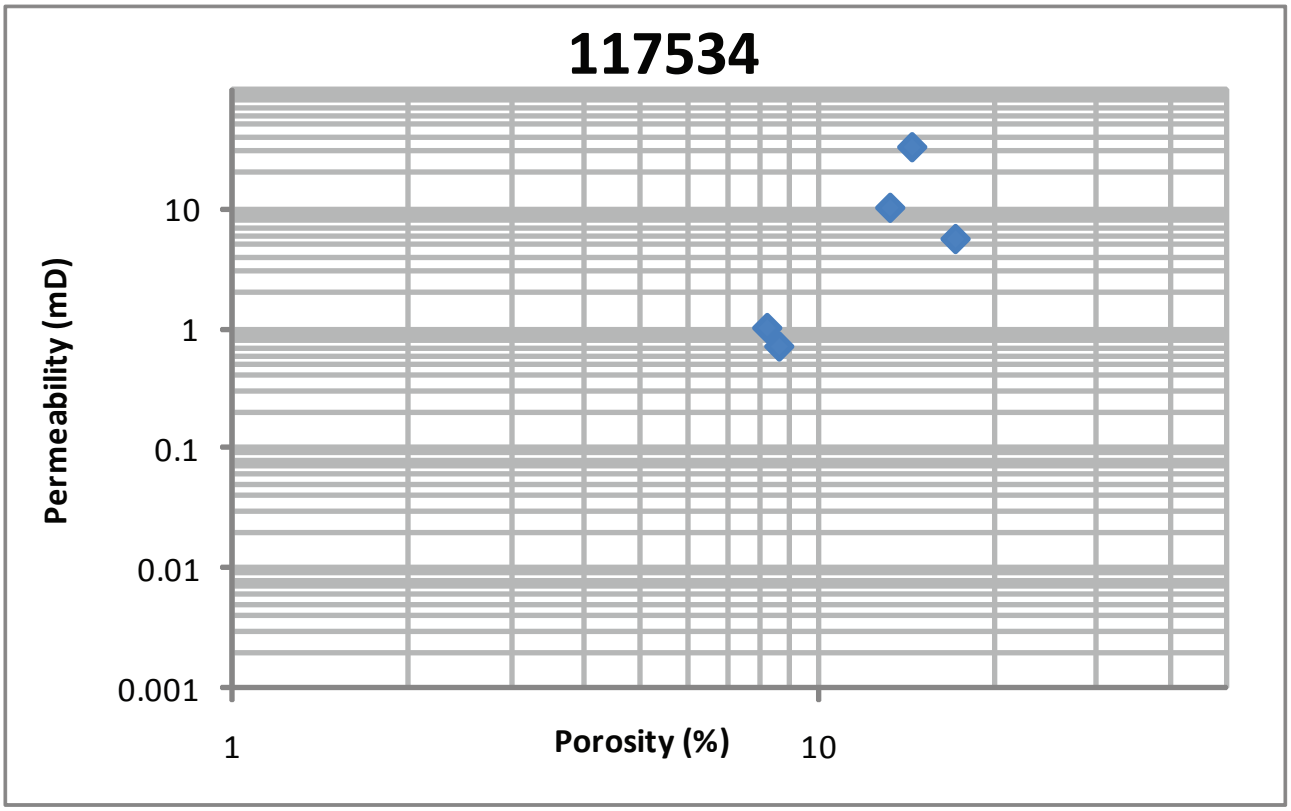


Figure 5: Porosity and permeability plot from core analysis from Cory Consol. Field, Clay County. The blue points are from North Vernon. The chart title lists the IGS Well ID. For the well locations see Figure 1.

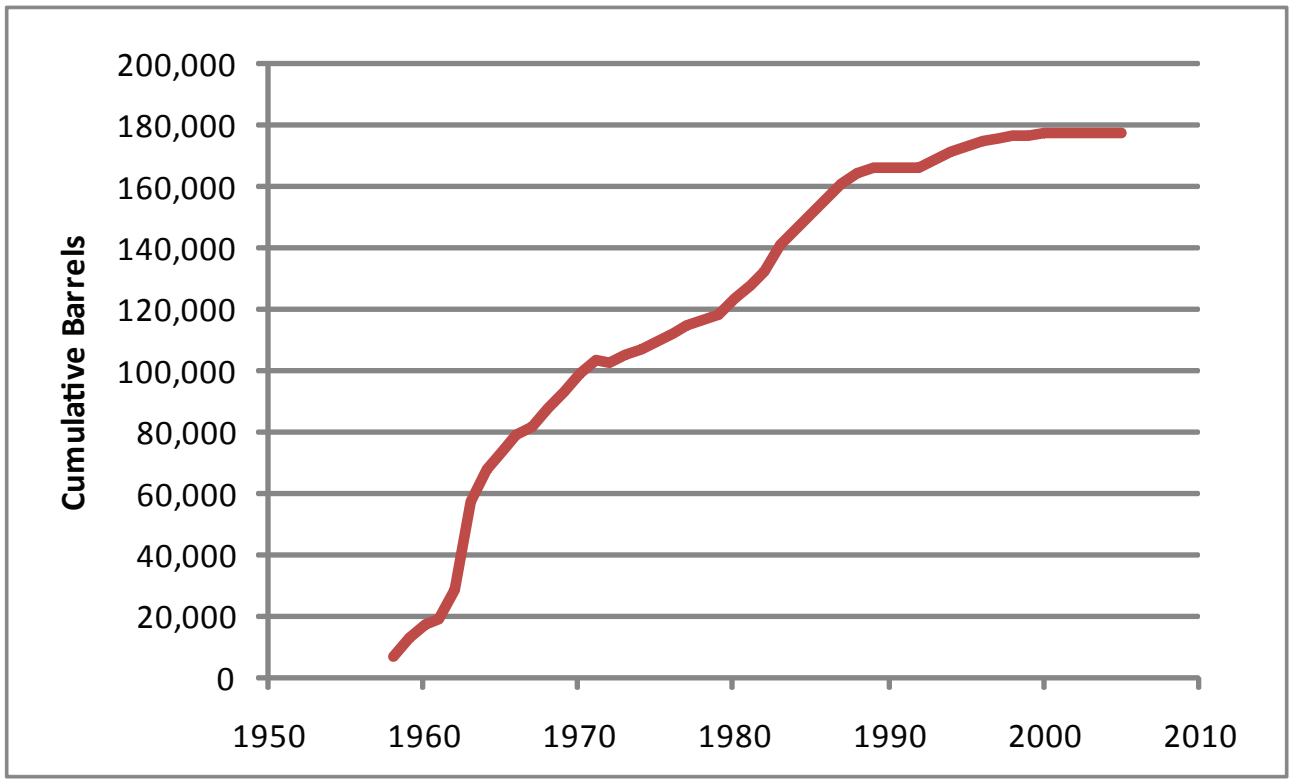


Figure - 6: Cumulative oil production history from Cory Consol. Field, Clay County since 1958.

Table-1: List of the wells used for subsurface structure mapping in Cory Consol. Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117530	11	N	7	W	7	605	1528				10	
117531	11	N	7	W	7	617						
117533	11	N	7	W	7	628	1560	1605	1664	1710		
117534	11	N	7	W	7	611	1520				62	
117535	11	N	7	W	7	599					34	
117536	11	N	7	W	7	636	1593					
117537	11	N	7	W	7	598	1504				16	
117538	11	N	7	W	7	608	1518				42	
117539	11	N	7	W	7	608	1504				10	
117540	11	N	7	W	7	615	1536	1578			60	
117542	11	N	7	W	7	603	1509				10	
156724	11	N	7	W	7	618						
117543	11	N	7	W	8	610	1551				36	
117544	11	N	7	W	8	615					10	
117545	11	N	7	W	8	638	1570	1614	1686	1720		
117546	11	N	7	W	8	639	1557	1620			15	
117547	11	N	7	W	8	628						
117548	11	N	7	W	8	611	1527				175	
117549	11	N	7	W	8	629					35	
117550	11	N	7	W	8	633	1557				2	
117551	11	N	7	W	8	614					8	
117552	11	N	7	W	8	638					7	
117553	11	N	7	W	9	648	1598	1636				
117556	11	N	7	W	16	638	1586					
117559	11	N	7	W	17	638	1613					

Field name: Cory South

IGS ID: 10128

DOE ID: 163133

Location: Clay County, 10&11N-7W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,543 ft.)

Field type: oil (abandoned)

Total number production wells: 5

Area: 100 acres

Cumulative production: 31,664 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,717 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

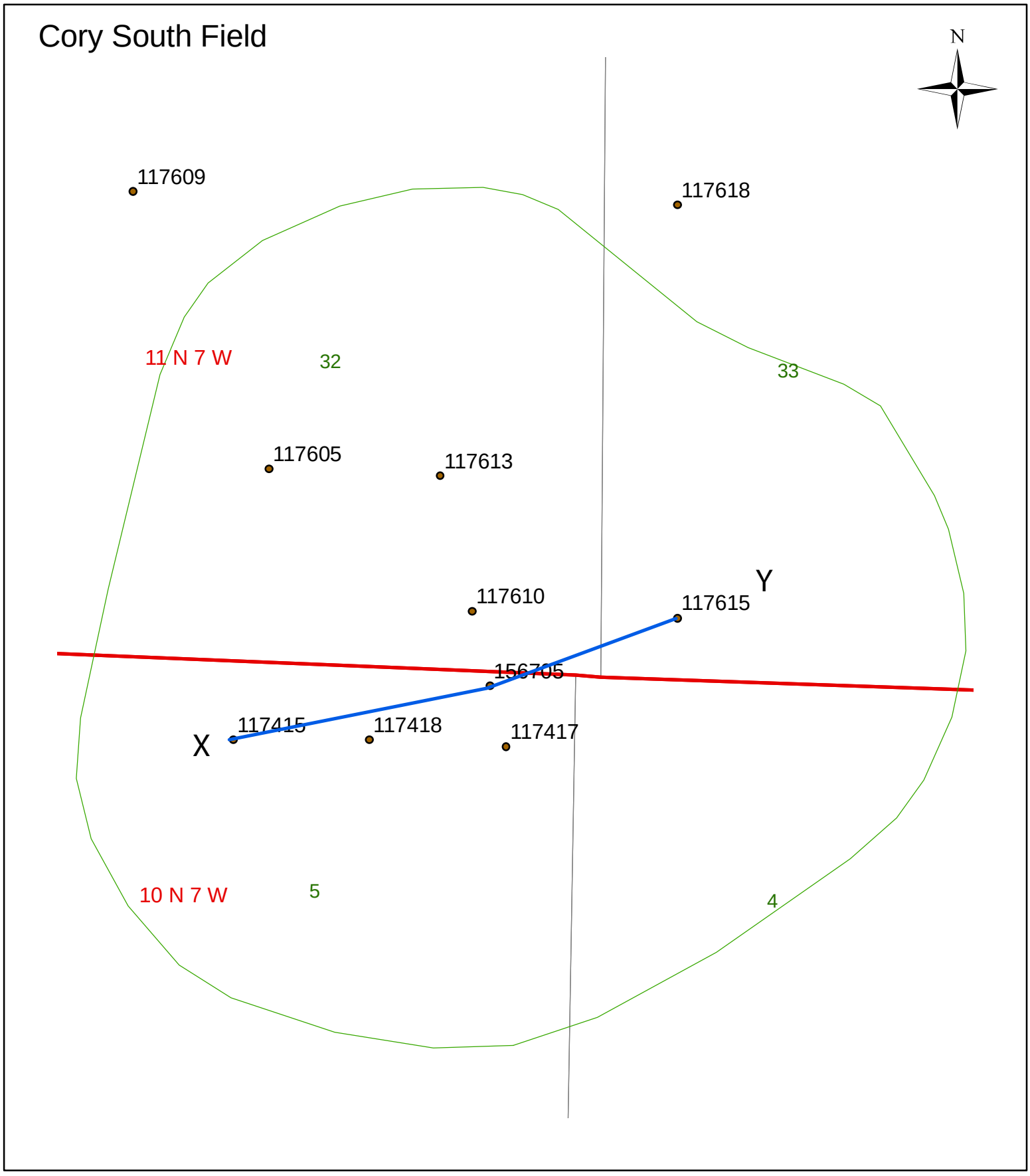


Figure 1: Map showing the location and wells at Cory South Field, Clay County. X-Y is the location of cross section that shows the subsurface Devonian structure in Figure 4.

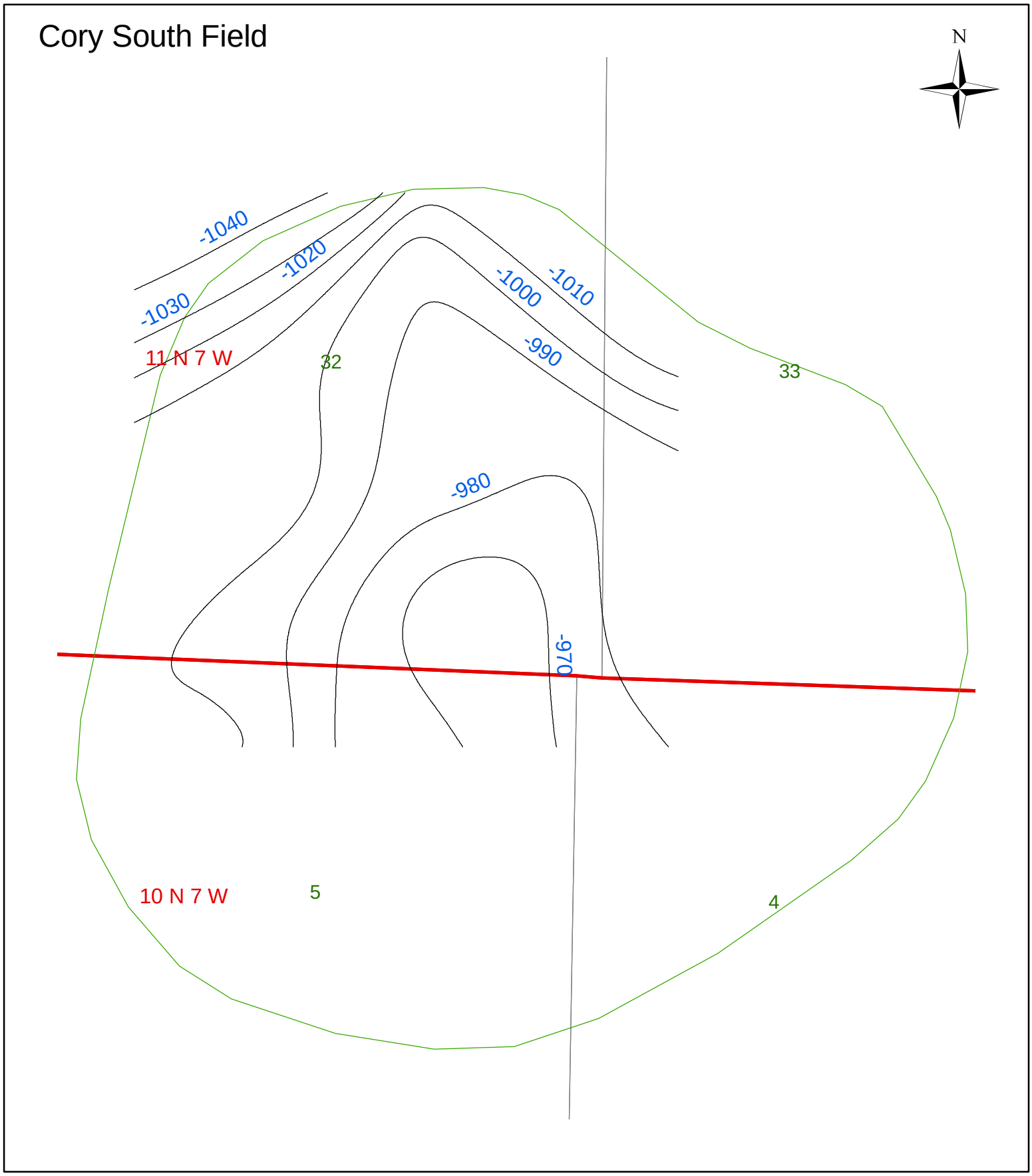


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in the Cory South Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

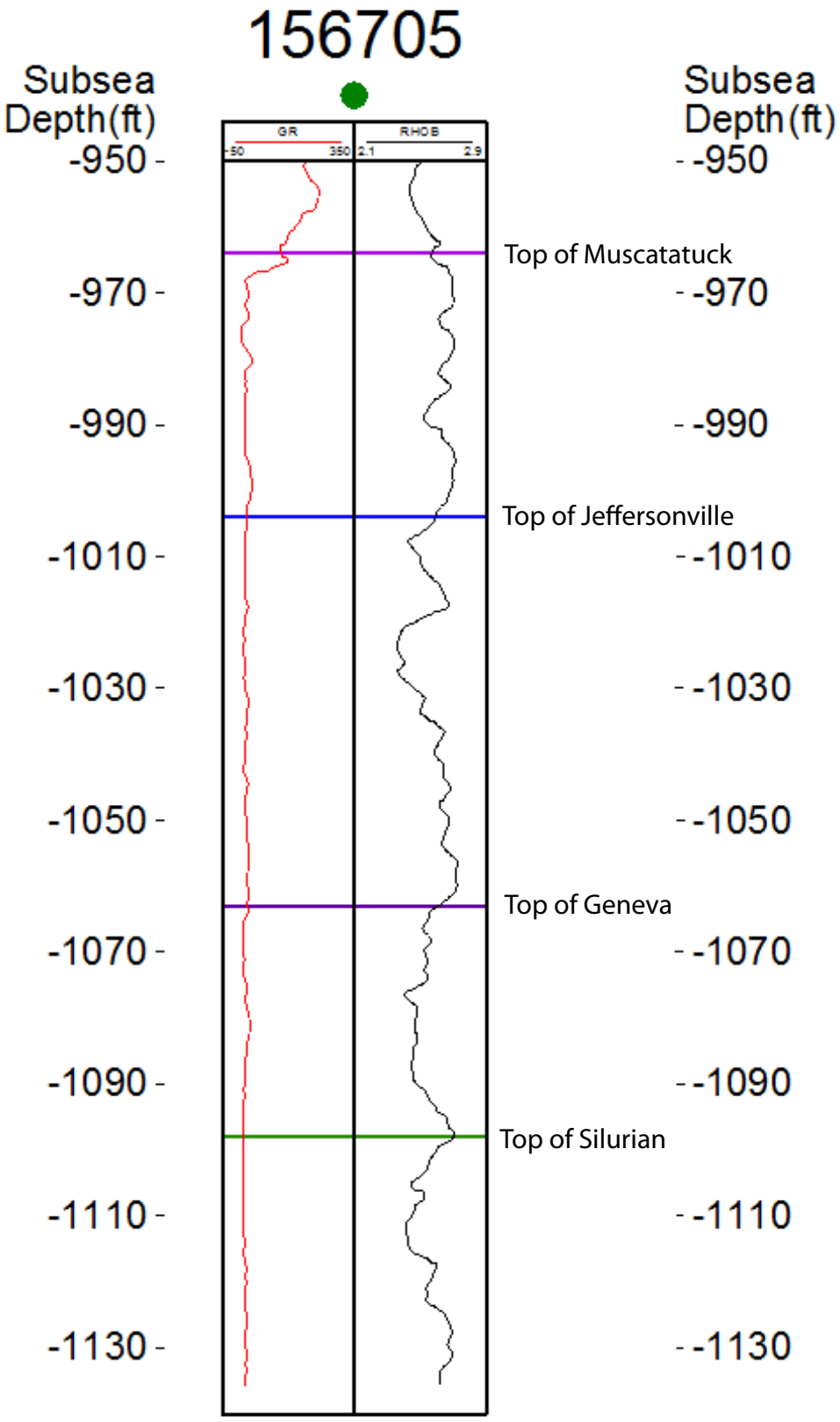


Figure 3: Type log section showing the Devonian formations at Cory South Field, Clay County.

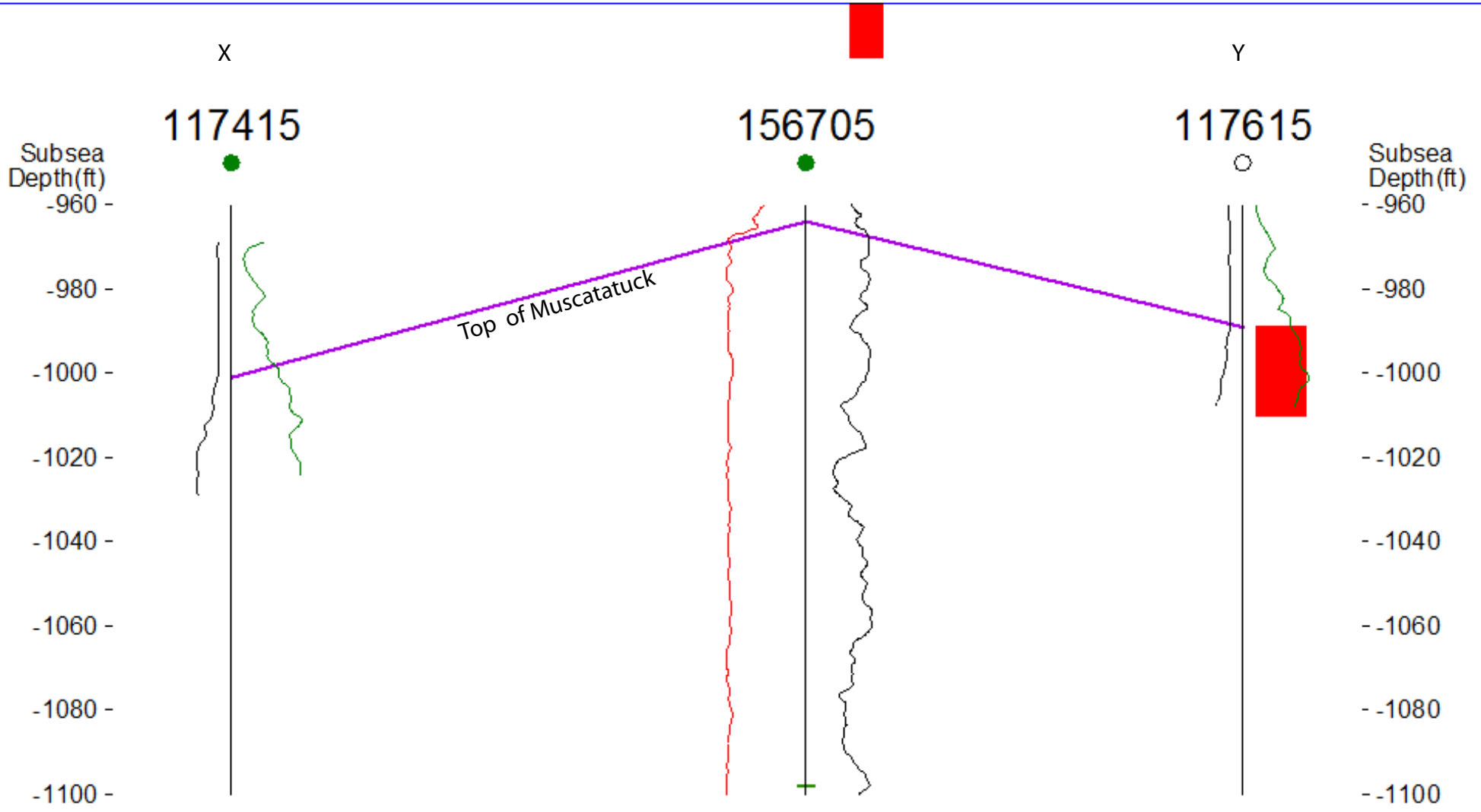


Figure 4: X-Y Cross section showing the Devonian subsurface structure across Cory South Field, Clay County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

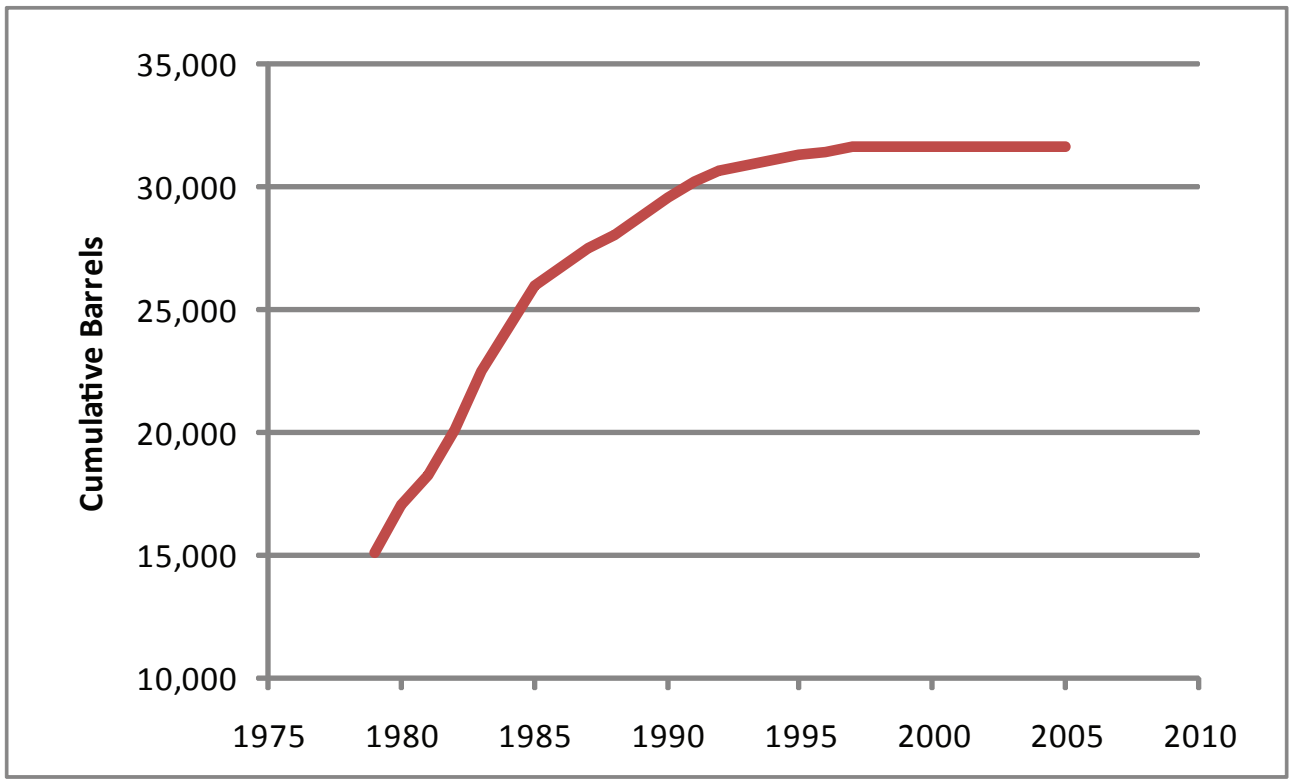


Figure - 5: Cumulative oil production history from Cory South Field, Clay County since 1979.

Table-1: List of the wells used for subsurface structure mapping in the Cory South Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117413	10	N	7	W	4	555	1590					
117415	10	N	7	W	5	581	1582					
117417	10	N	7	W	5	586	1555				35	
117418	10	N	7	W	5	566	1541				10	
156705	10	N	7	W	5	582	1549	1586	1645	1680		
117423	10	N	7	W	9	571	1662			1839		
117602	11	N	7	W	29	599						
117605	11	N	7	W	32	596	1601					
117609	11	N	7	W	32	609	1652					
117610	11	N	7	W	32	582	1544				10	
117613	11	N	7	W	32	593	1577				25	
117615	11	N	7	W	33	592	1581				2	
117616	11	N	7	W	33	574	1604					
117617	11	N	7	W	33	621	1642					
117618	11	N	7	W	33	596	1613	1652				

Field name: Dixon

IGS ID: 10803

DOE ID: na

Location: Greene County, 7N-6W

Discovery date: 1965 (gas storage initiated 1966)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,850 ft.)

Field type: natural gas & gas storage

Total number production wells: 15 storage, 6 observation

Area: 362 acres

Total capacity: 2,827,500 mcf

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,780 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 100 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 16 %

Average permeability – 35 md

Approximate reservoir thickness: 43 ft.

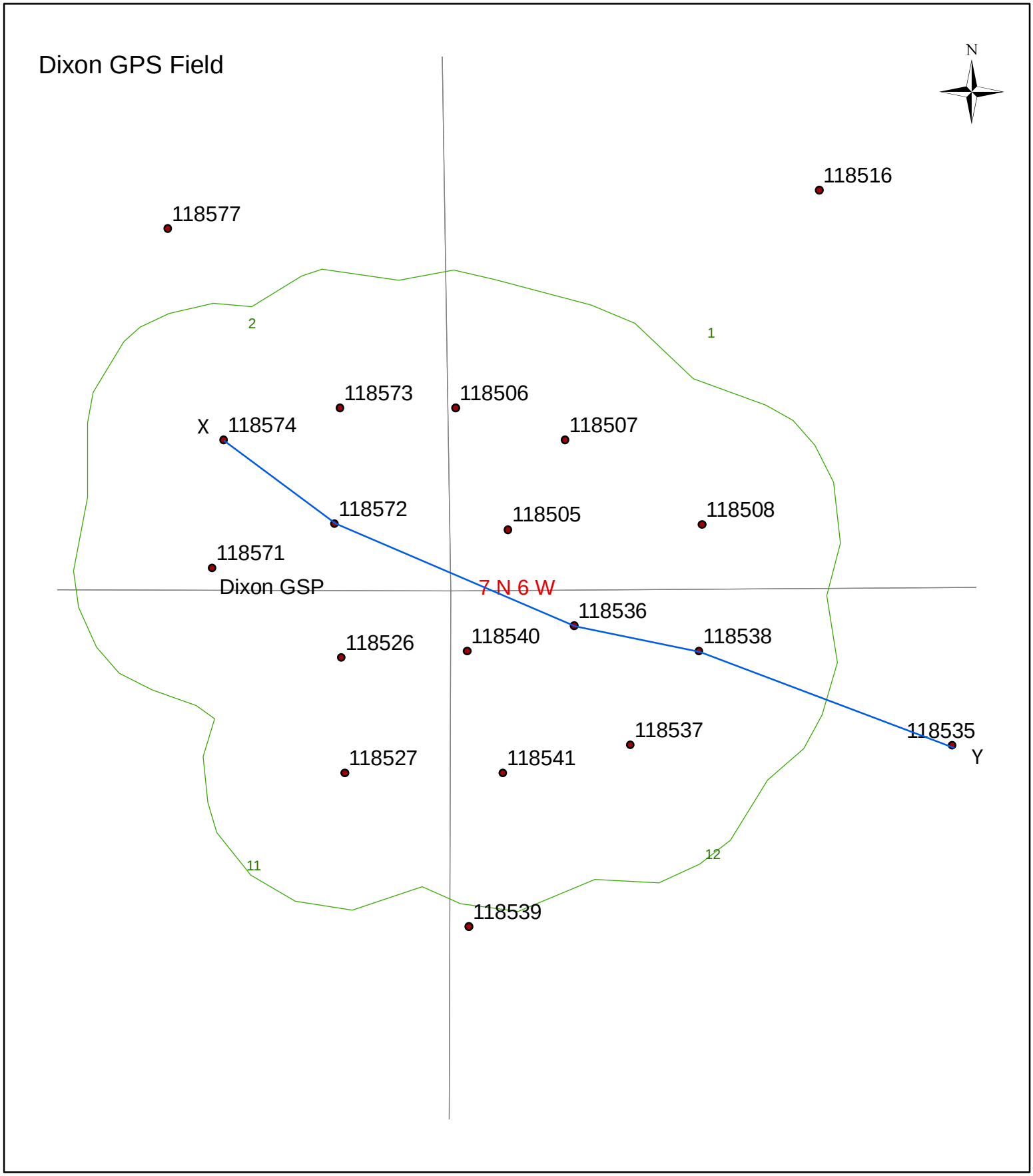


Figure 1: Map showing the location and wells at Dixon GSP Field, Greene County. X-Y is the location of the cross sections that shows the subsurface devonian structure (Fig. 11). The wells depicted were used for subsurface maping and had a total depth (TD) of Devonian or deeper.

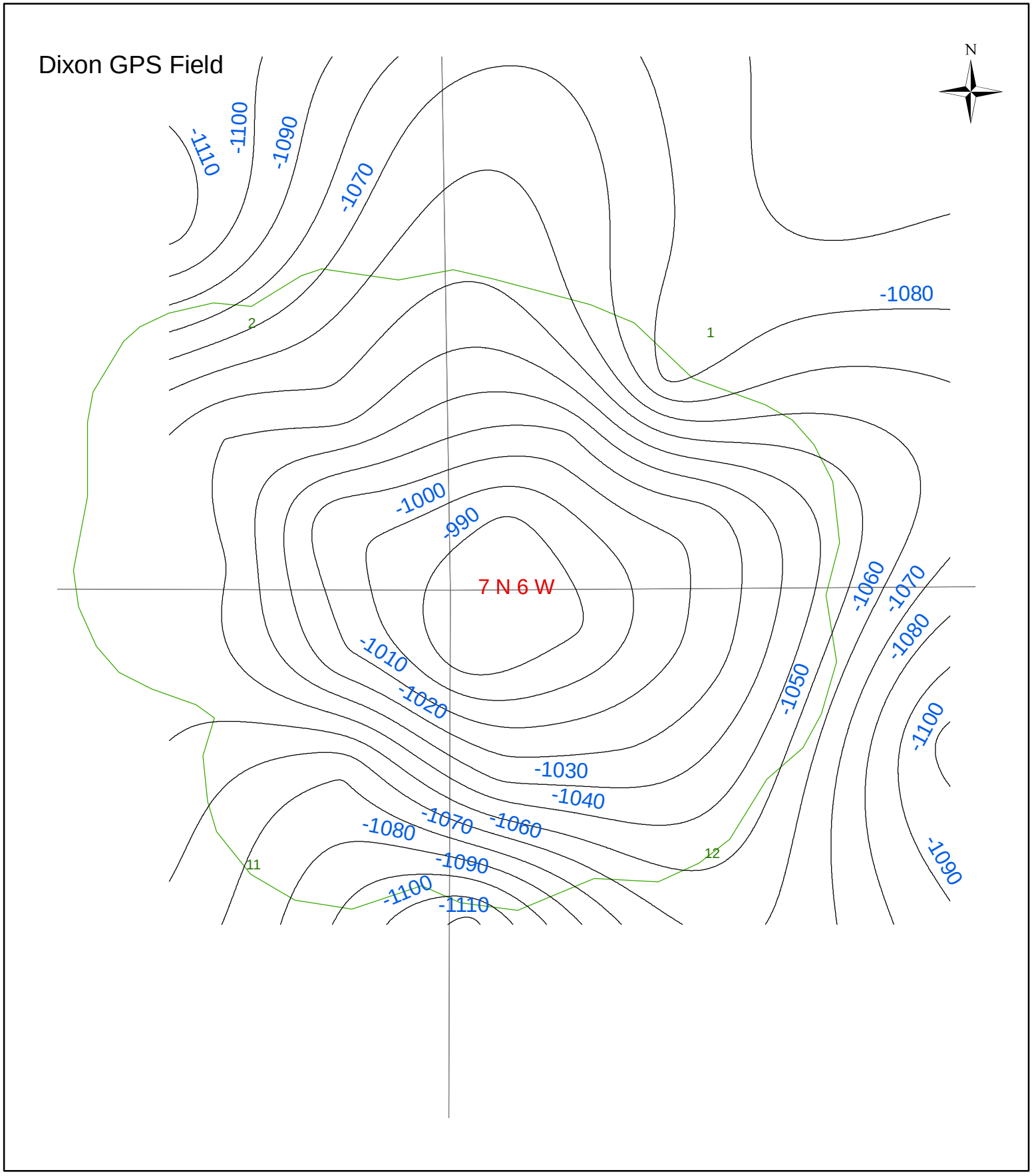


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Dixon GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

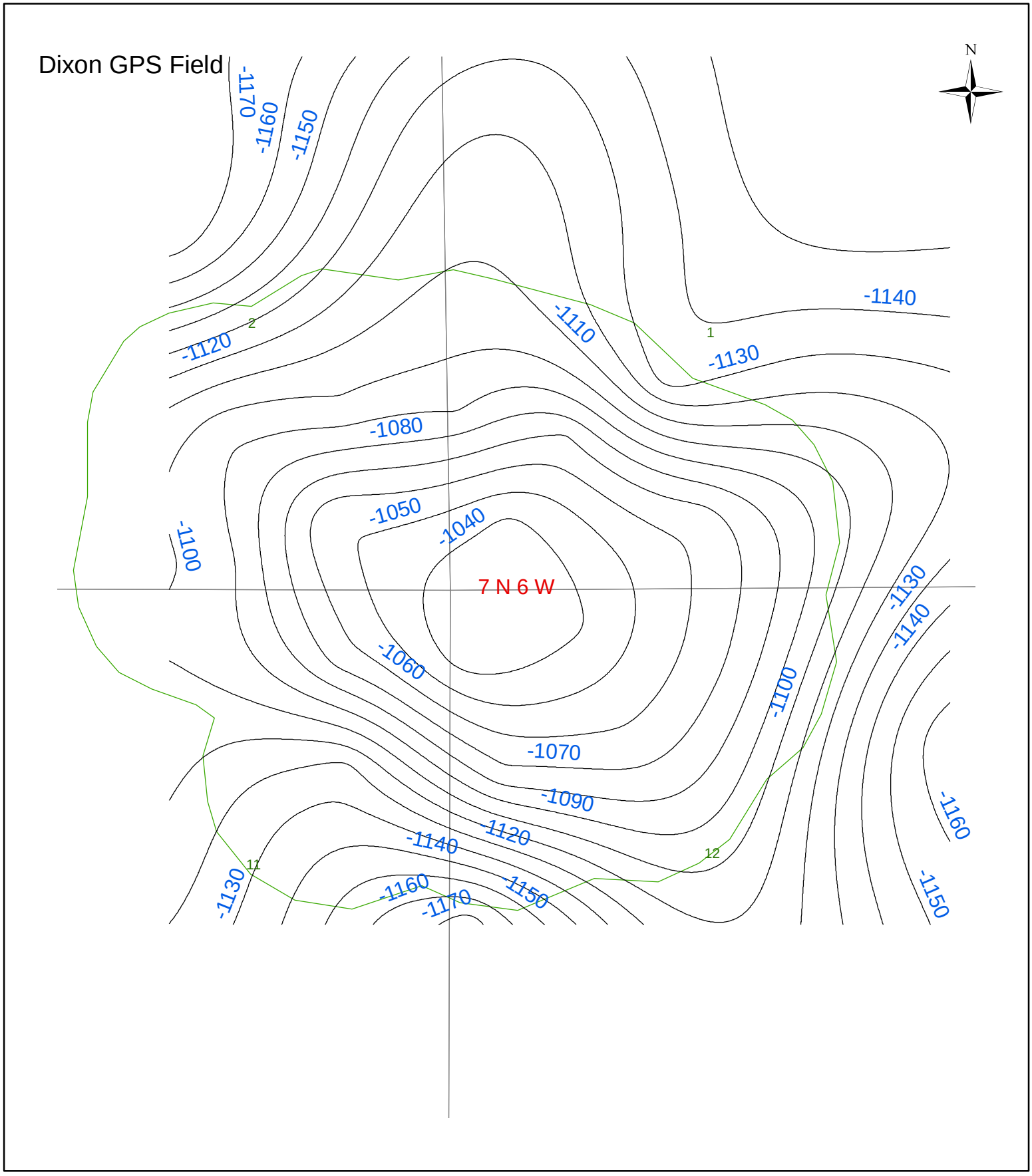


Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Dixon GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

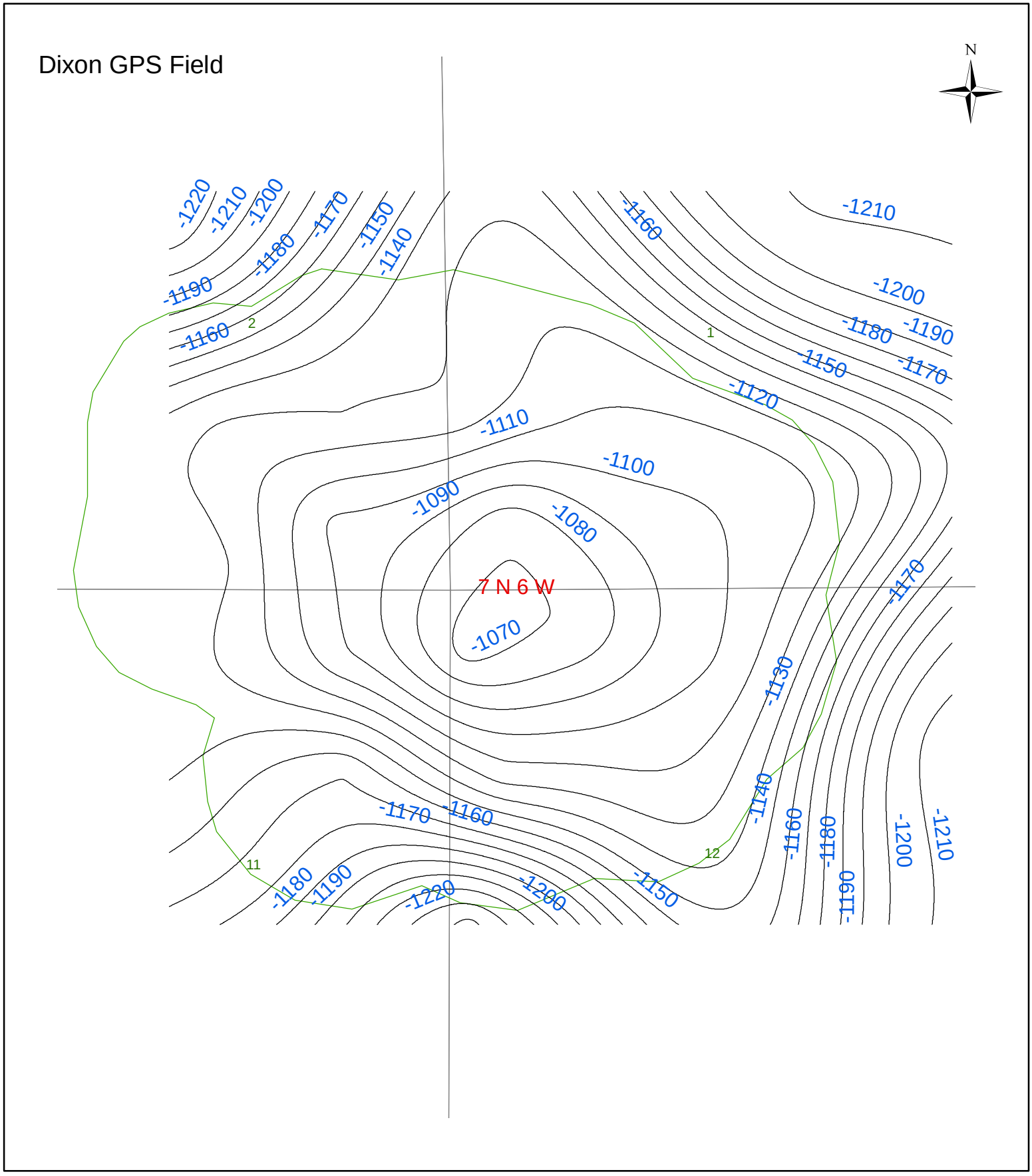


Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Mbr. in Dixon GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

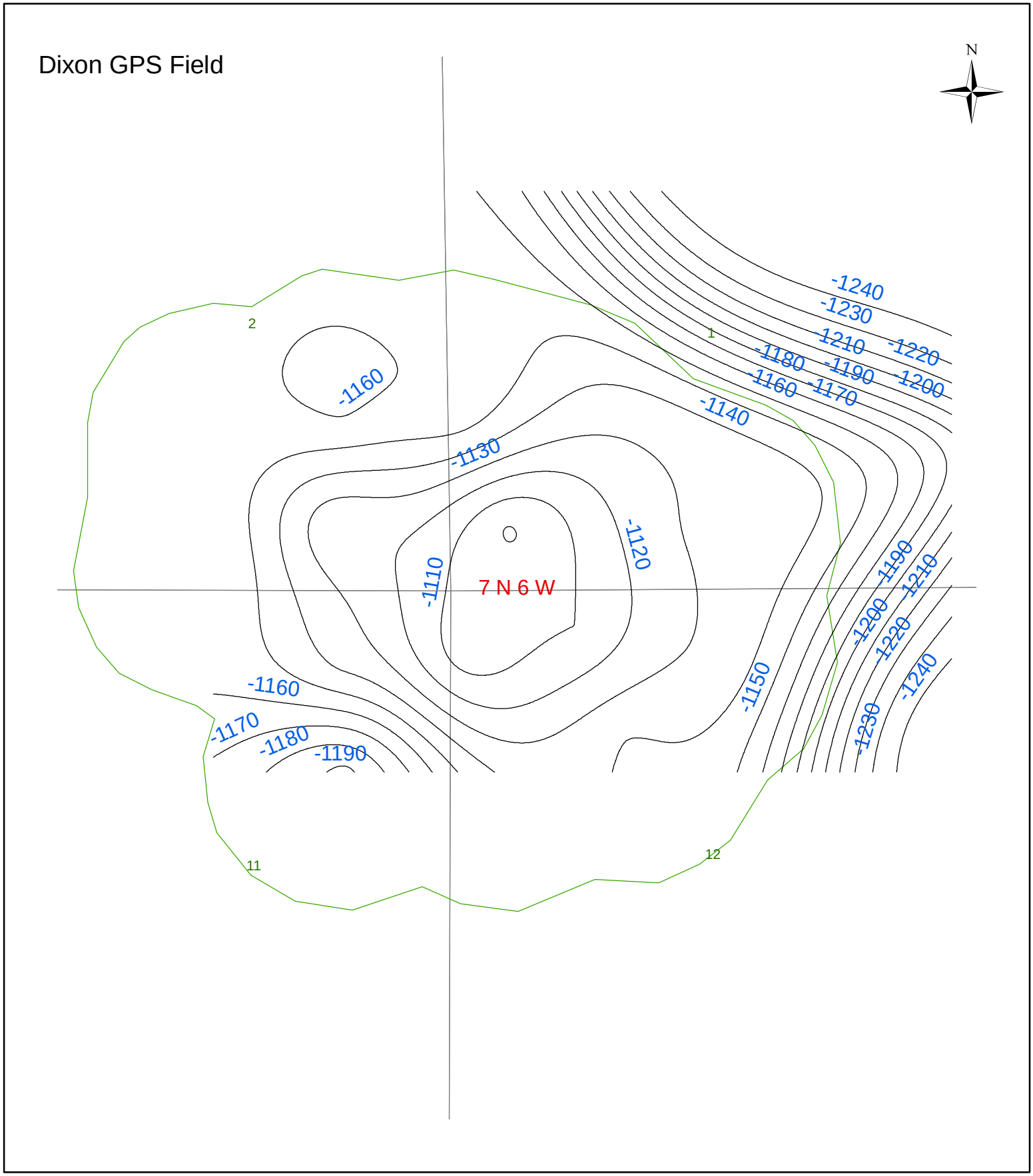


Figure 5: Structure map showing the top of the subsurface Silurian formation in Dixon GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

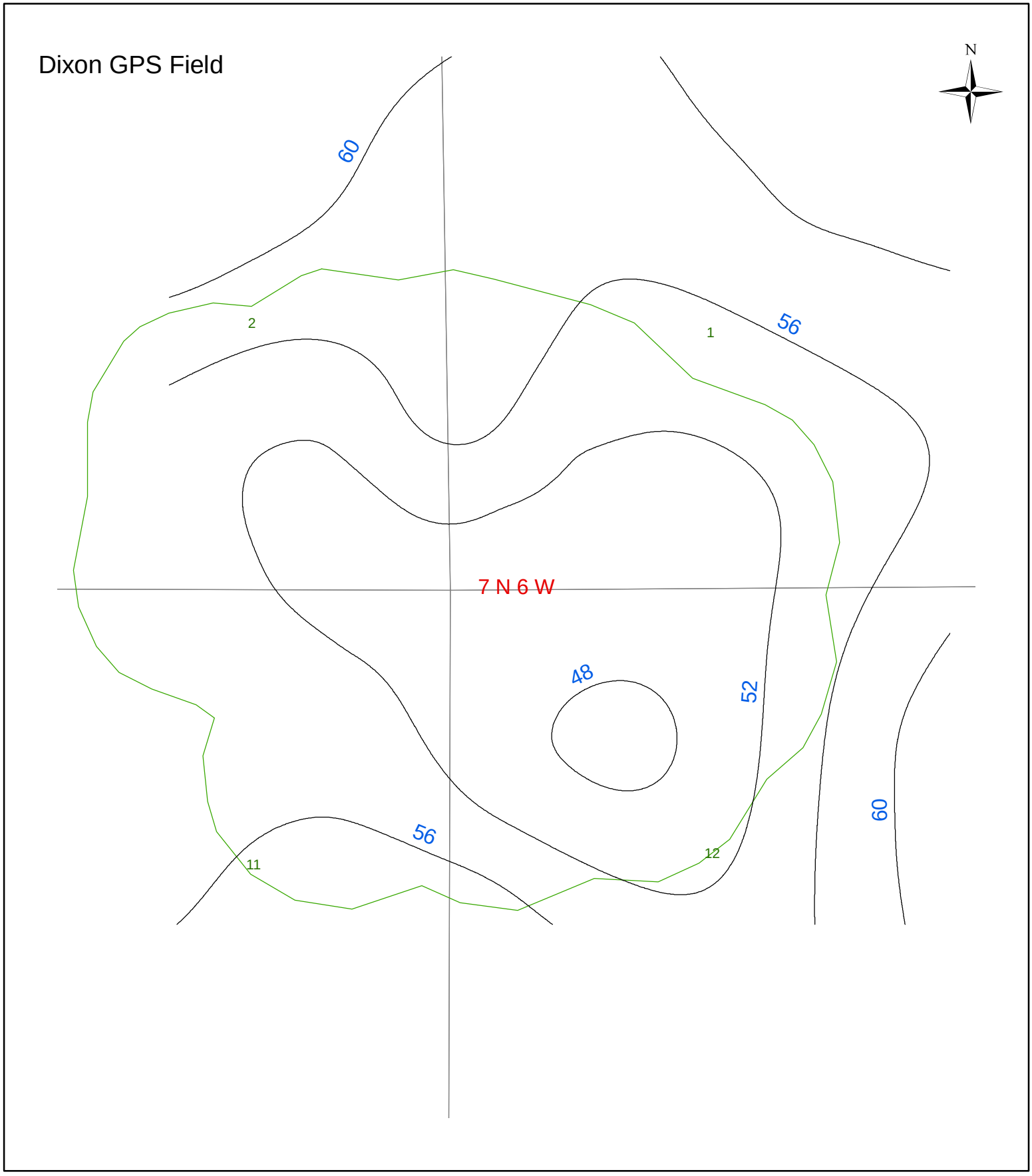


Figure 6: Map showing isopach of the North Vernon Limestone at Dixon GSP Field, Greene County. Contour interval is 4 ft.

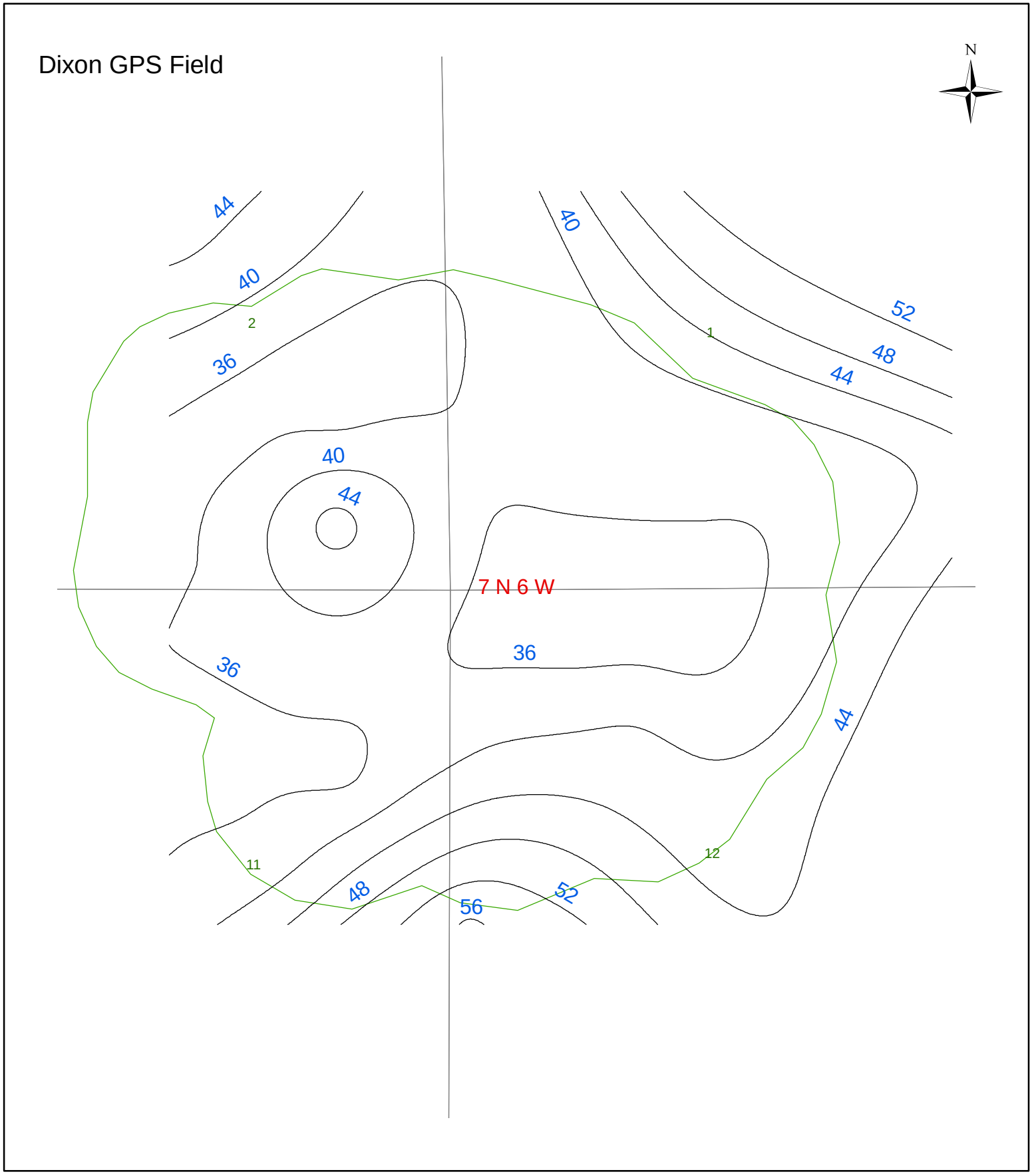


Figure 7: Map showing isopach of the Vernon Fork Member from Dixon GSP Field, Greene County. Contour interval is 4 ft.

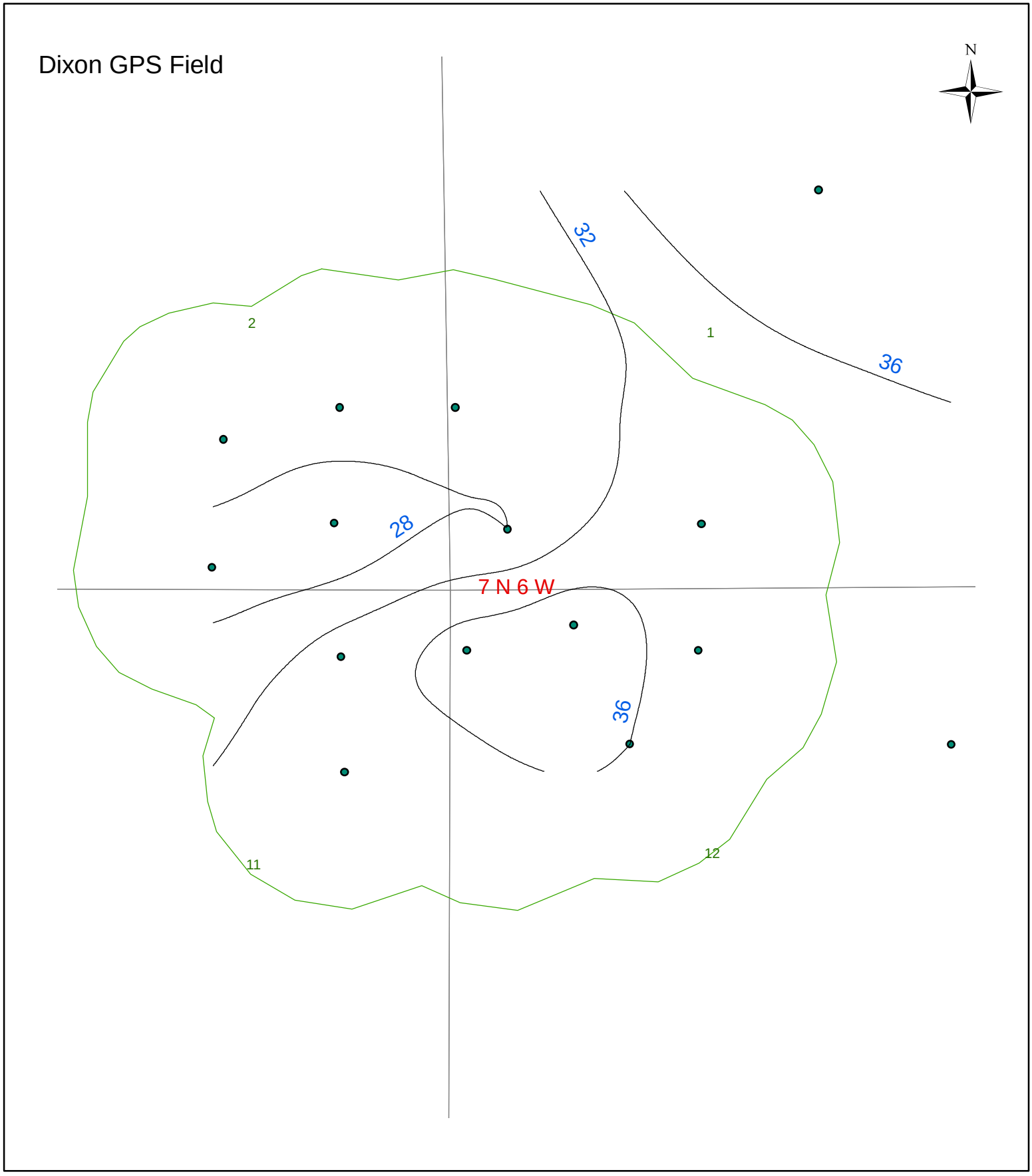


Figure 8: Map showing isopach of the Geneva Dolomite Member in Dixon GSP Field, Greene County. Contour interval is 4 ft.

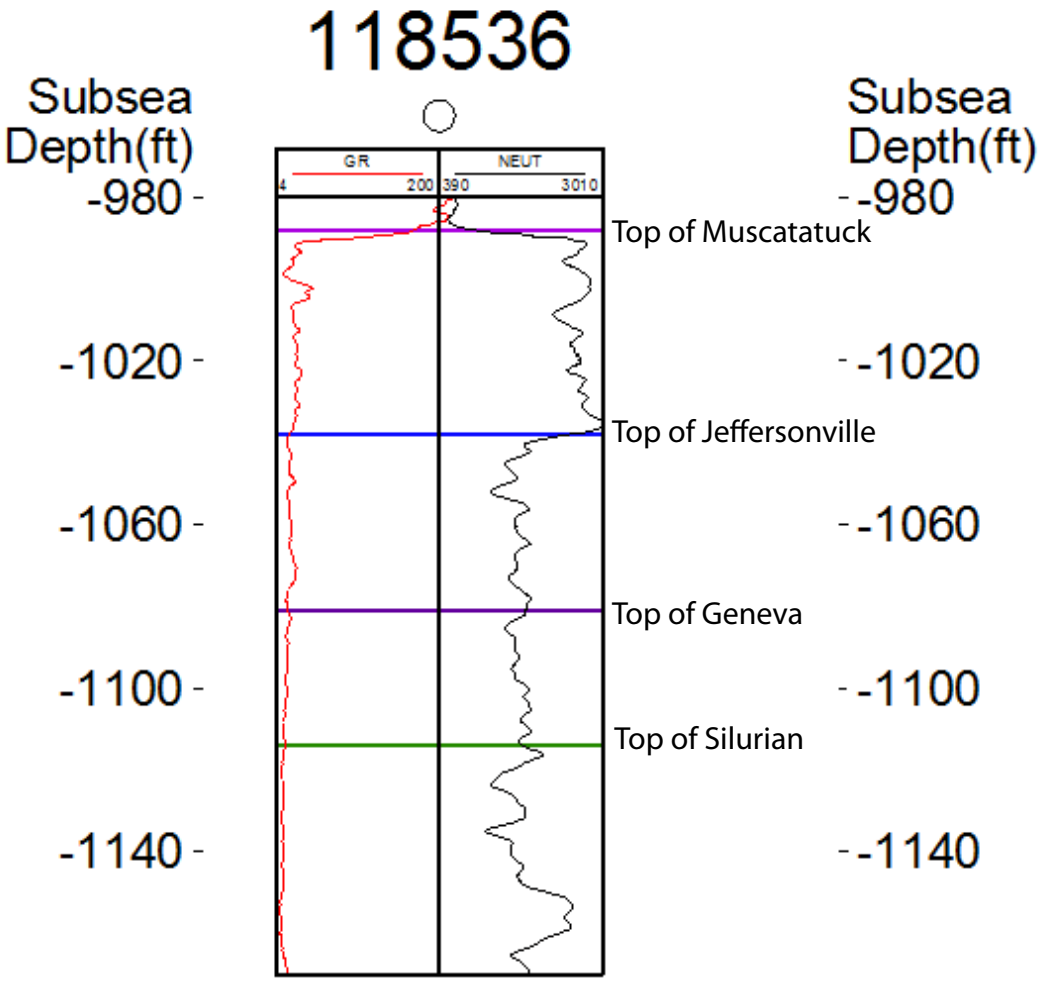
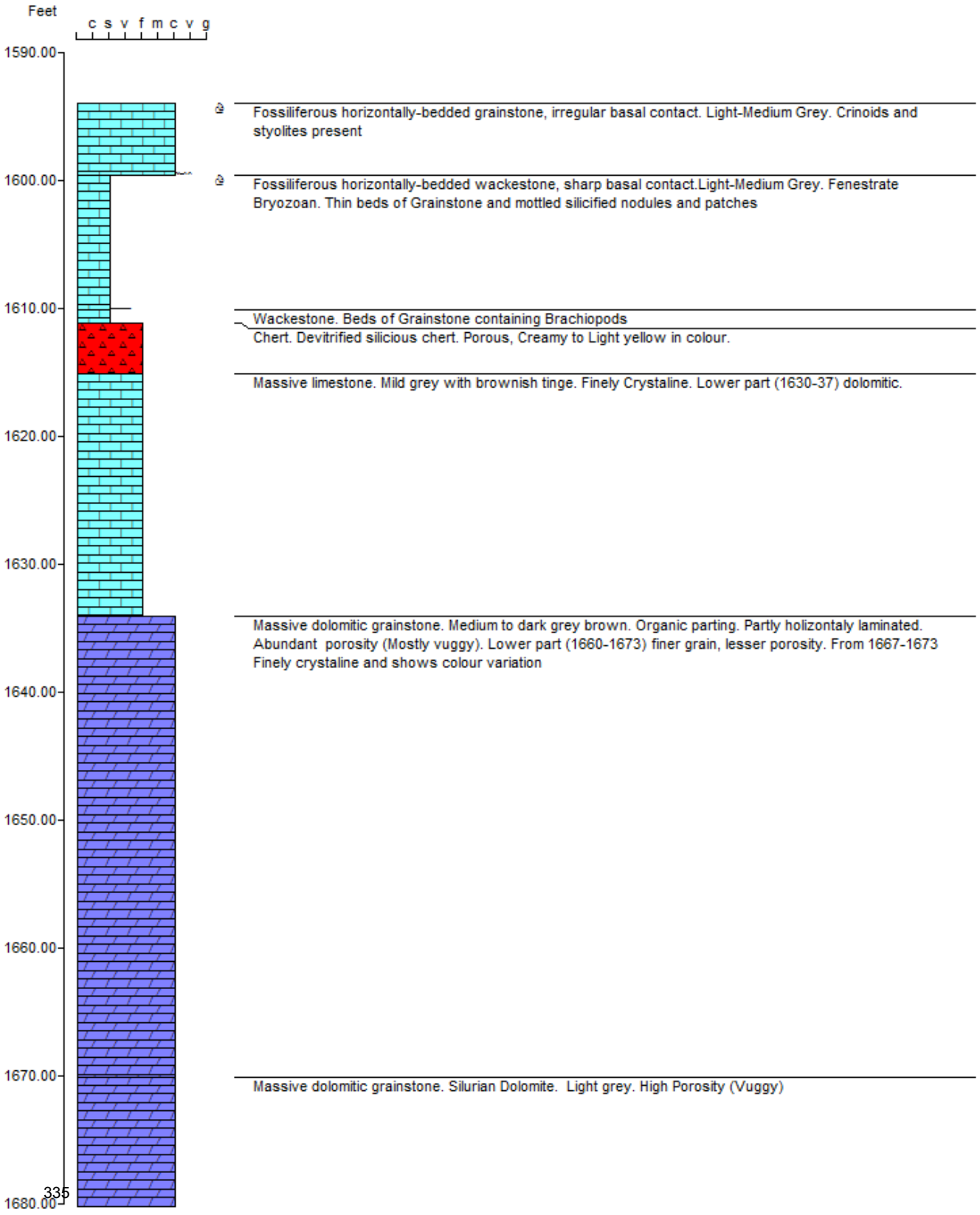


Figure 9: Type log section showing the Devonian formations at Dixon GSPField, Greene County.

PETRA 4/14/2008 11:02:00 AM

Figure 10: Core description and the litholog of IGS well ID 118540, Dixon GSP Field, Greene County.

ID Number:	118540	Date:	3/18/2008
Site Name:		By:	No User Name Entered
Location:	Greene	Notes:	
Elevation:	0.0000 Feet		



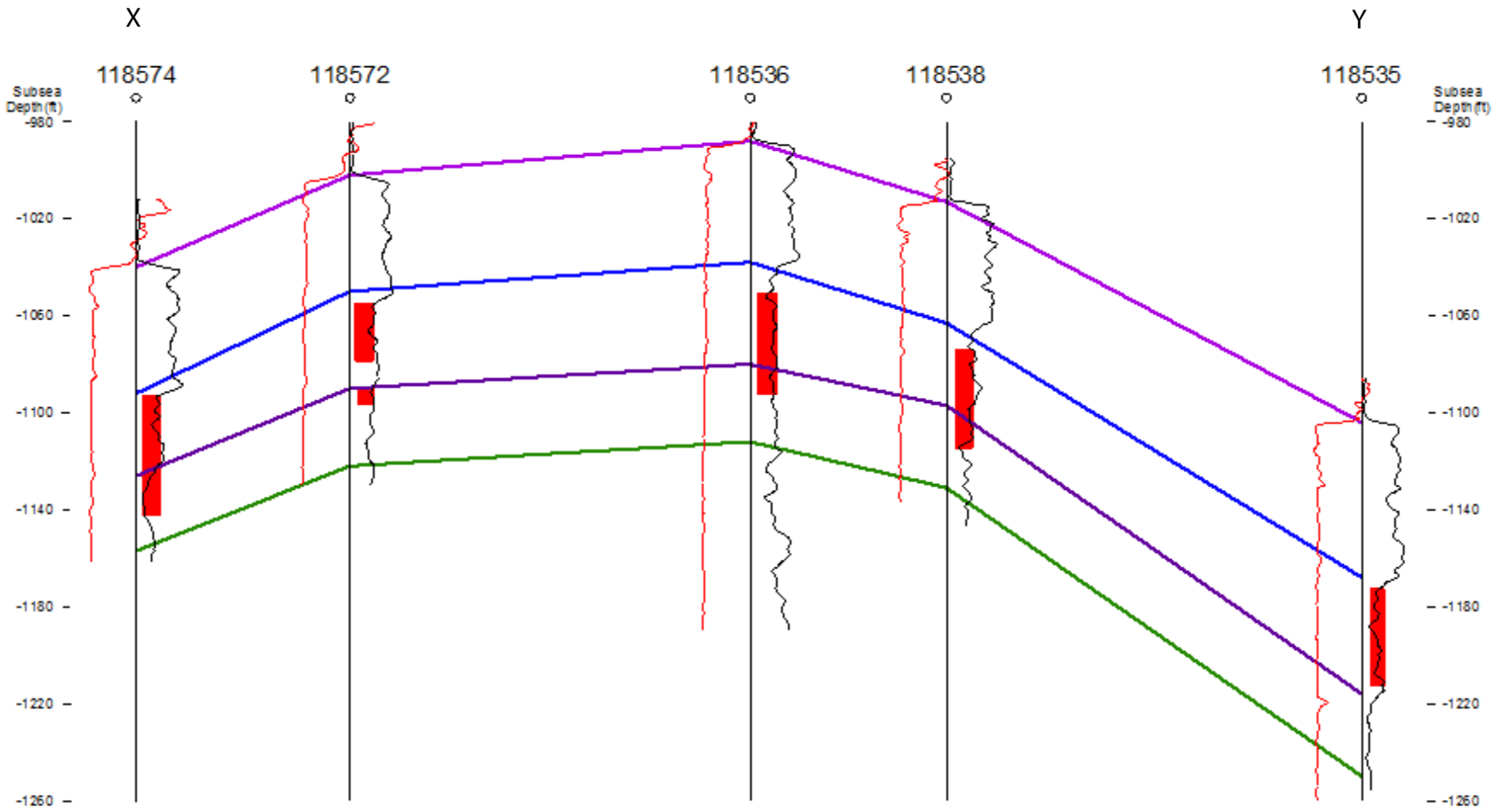


Figure 11: X-Y Cross section showing the Devonian subsurface structure across Dixon GSP Field, Greene County. The red color box shows the completion intervals for the gas storage, production or observation. For location of the cross section refer to Figure 1.

PETRA 4/14/2005 9:19:25 AM (XY.CSP)

Table-1: List of the wells used for subsurface structure mapping in Dixon GSP Field, Greene County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Core
118505	7	N	6	W	1	591	1577	1627	1662	1690	
118506	7	N	6	W	1	602	1630	1694	1730	1760	
118507	7	N	6	W	1	583	1600	1651	1690		
118508	7	N	6	W	1	609	1622	1672	1708	1741	
118509	7	N	6	W	1	566	1650	1703			
118516	7	N	6	W	1	551	1646	1708	1762	1800	
118571	7	N	6	W	2	566	1610	1664	1700	1726	
118572	7	N	6	W	2	570	1572	1620	1668	1692	
118573	7	N	6	W	2	600	1647	1698	1731	1762	
118574	7	N	6	W	2	588	1628	1680	1714	1745	
118576	7	N	6	W	2	610	1720	1787			
118577	7	N	6	W	2	580	1695	1760	1806		
118526	7	N	6	W	11	554	1566	1618	1656	1690	
118527	7	N	6	W	11	541	1610	1666	1700	1734	
118535	7	N	6	W	12	514	1618	1682	1730	1764	
118536	7	N	6	W	12	560	1548	1598	1631	1670	
118537	7	N	6	W	12	537	1556	1600	1642	1678	
118538	7	N	6	W	12	575	1588	1638	1672	1706	
118539	7	N	6	W	12	520	1634	1696	1754		Present
118540	7	N	6	W	12	569	1549	1600	1635	1673	
118541	7	N	6	W	12	536	1561	1608	1650		

Figure 1: Photo of the core ID 317, IGS ID # 118540 from Dixon GSP Field, Greene County.

Figure 12: Continued....

2

1618 ft

Figure 12: Continued....

1628 ft

1639 ft

1639 ft

1649 ft

1650 ft

1657 ft

Figure 12: Continued....

1650 ft

7

344

1657 ft

Figure 12: Continued....

1668 ft

8

1681 ft

1684 ft 1686 ft 1690 ft 1692 ft

1682 ft 1684 ft 1687 ft 1690 ft

Figure 12: Continued....

Field name: Dodds Bridge

IGS ID: 10159

DOE ID: 194507

Location: Sullivan County, 8&9N-10W

Discovery date: c.1913 (oil), c.1915 (natural gas)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,265 ft.)

Field type: oil & natural gas

Total number production wells: 126 oil, 3 natural gas

Area: 960 acres

Cumulative production: 2,554,506 bbls. (2002)

Other reservoir units:

Pennsylvanian

Mississippian, Sanders Group, Salem Ls.

Deepest unit penetrated (depth): Silurian (2,600 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

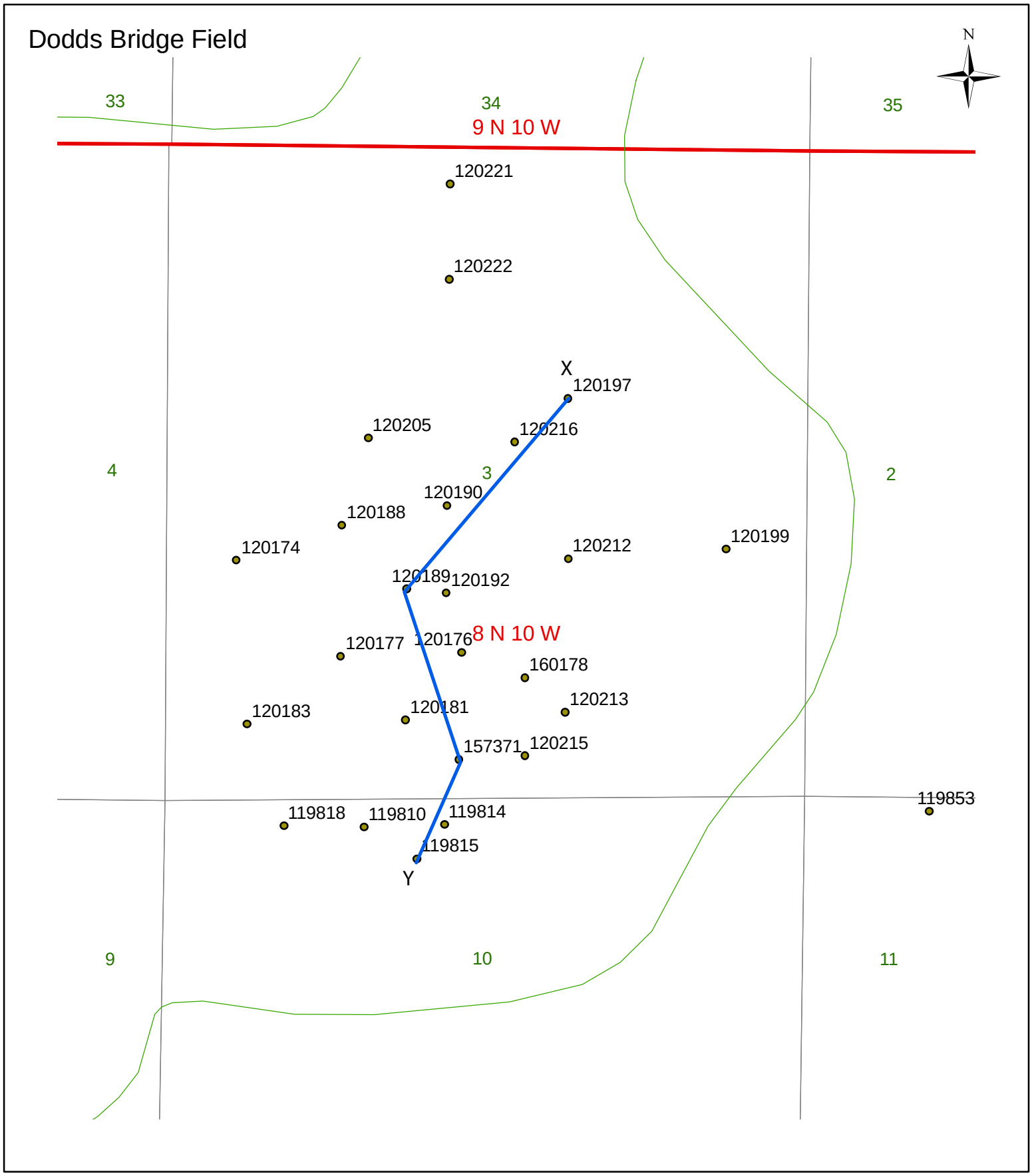


Figure 1: Map showing the location and wells at Dodds Bridge Field, Sullivan County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 9).

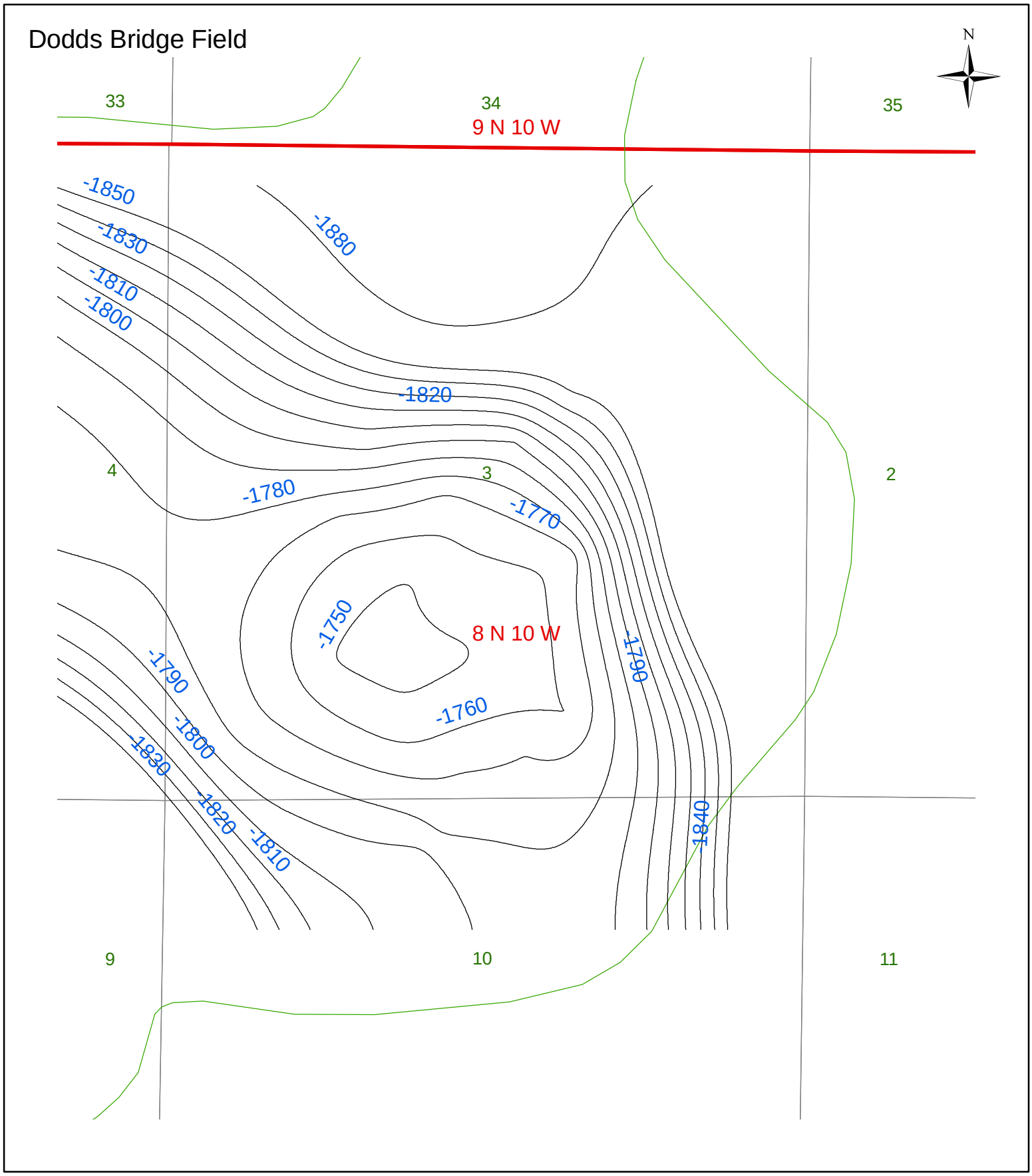


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Dodds Bridge Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

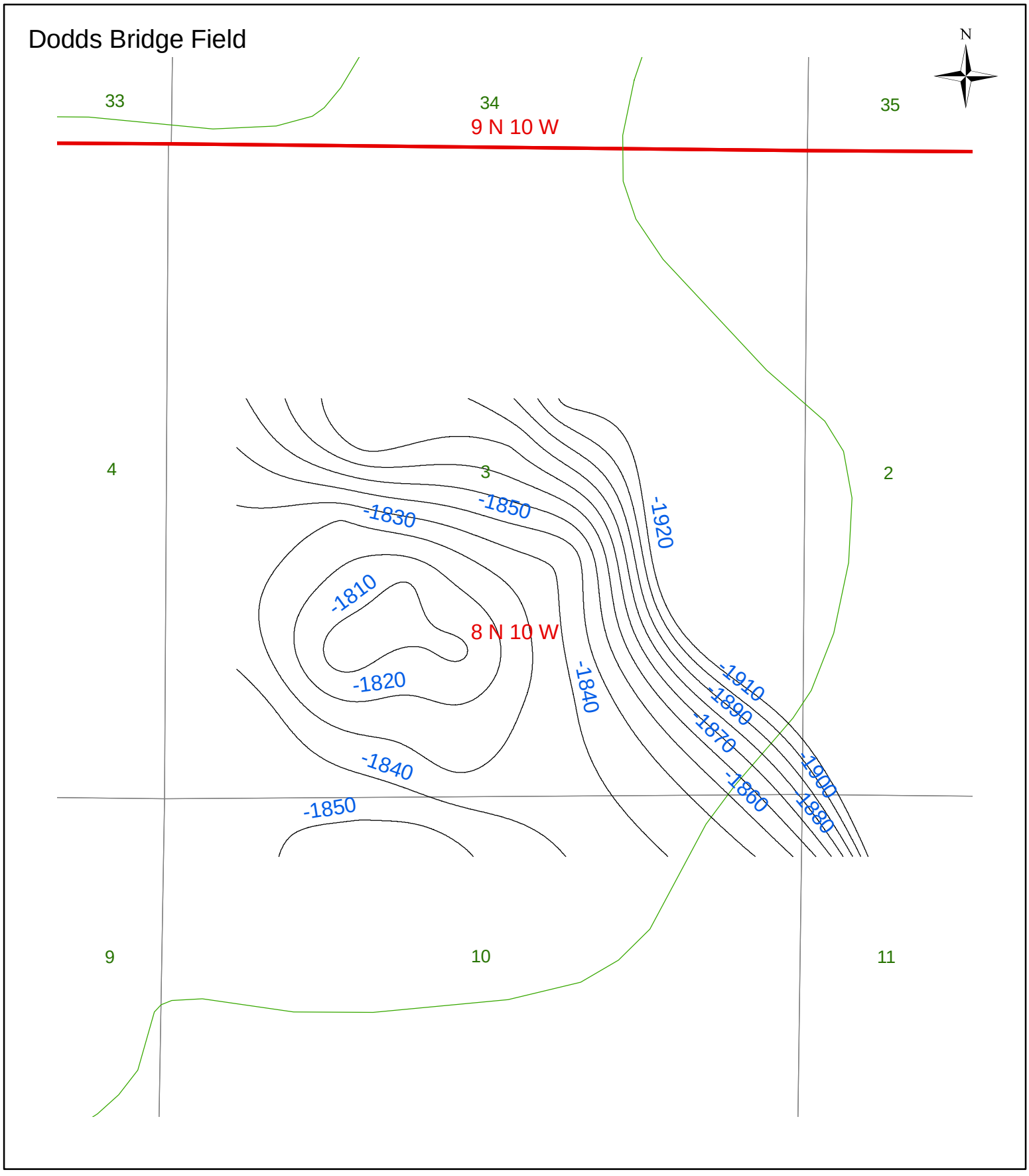


Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Dodds Bridge Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

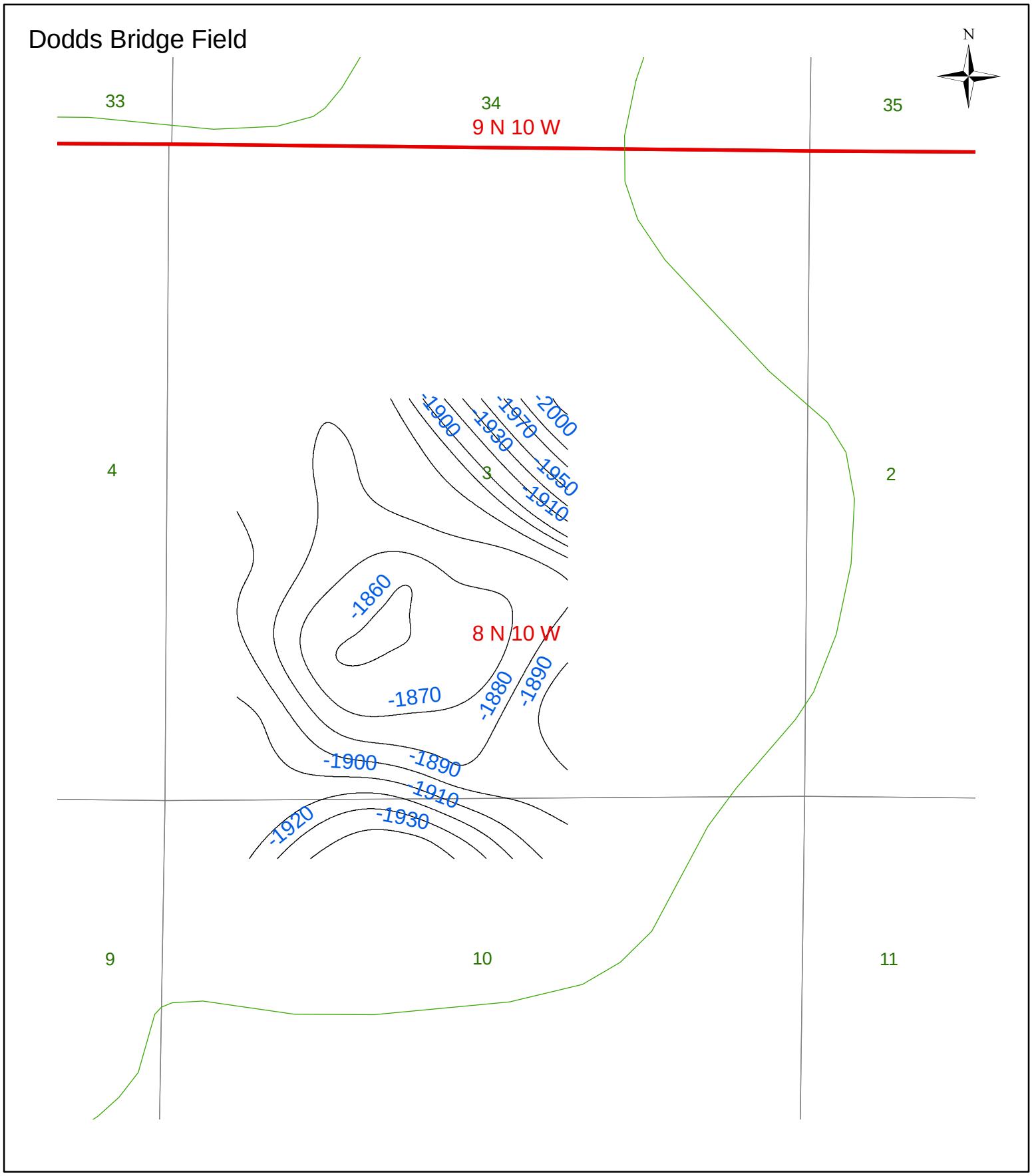


Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Mbr. in Dodds Bridge Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

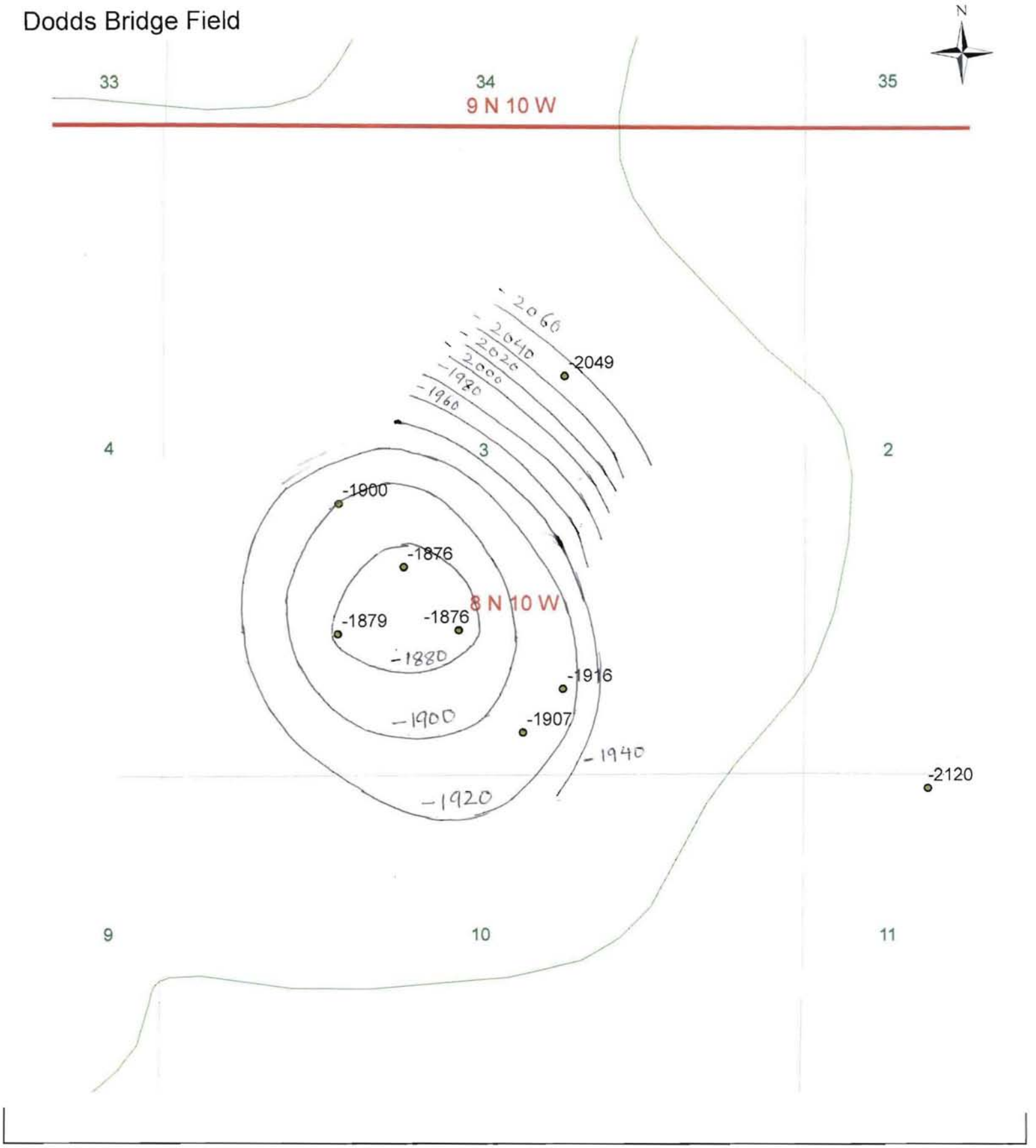


Figure 5: Structure map showing the top of the subsurface Silurian formation in Dodds Bridge Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

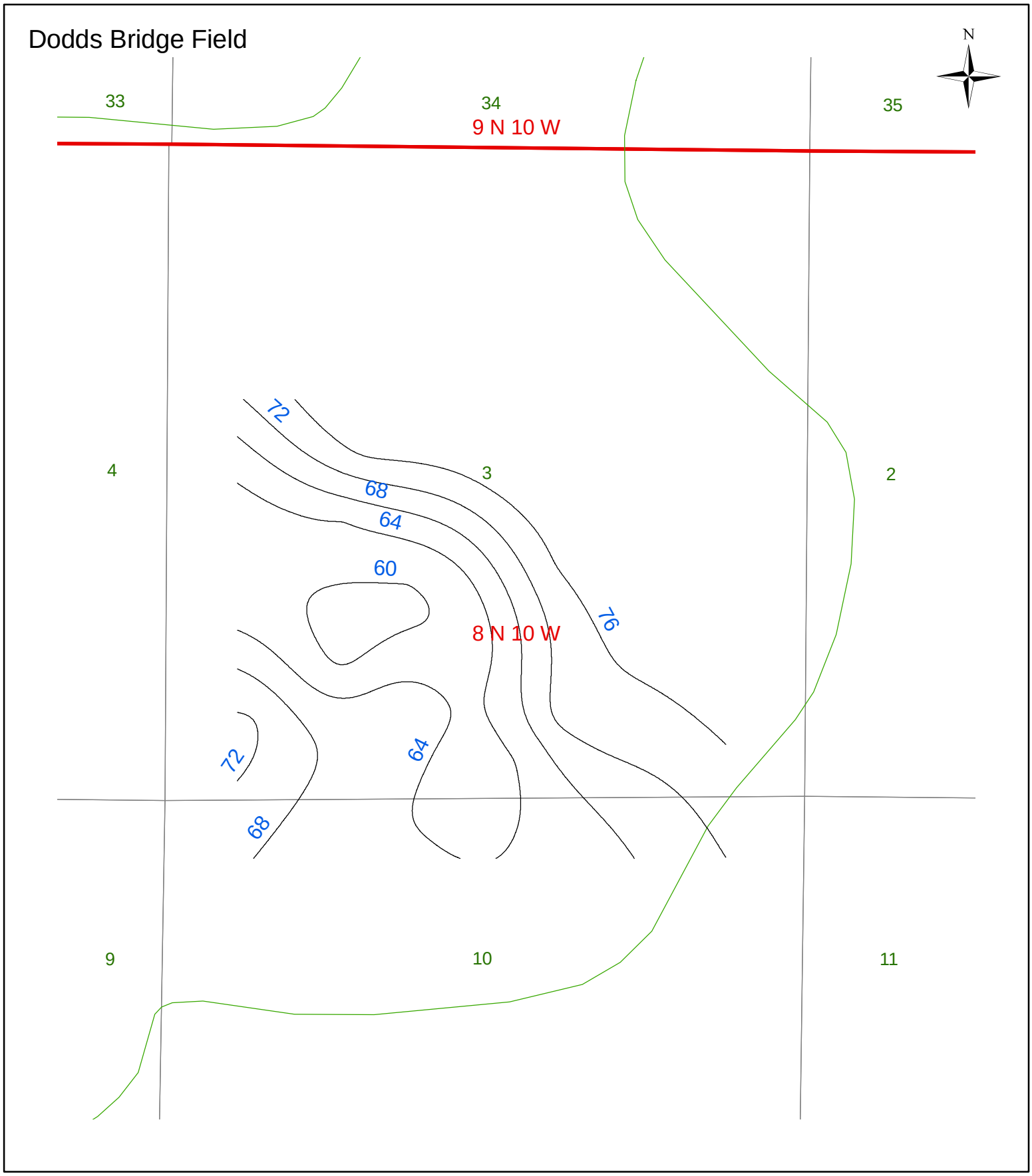


Figure 6: Isopach map showing the thickness of the North Vernon Limestone at Dodds Bridge Field, Sullivan County. Contour interval is 4 ft.

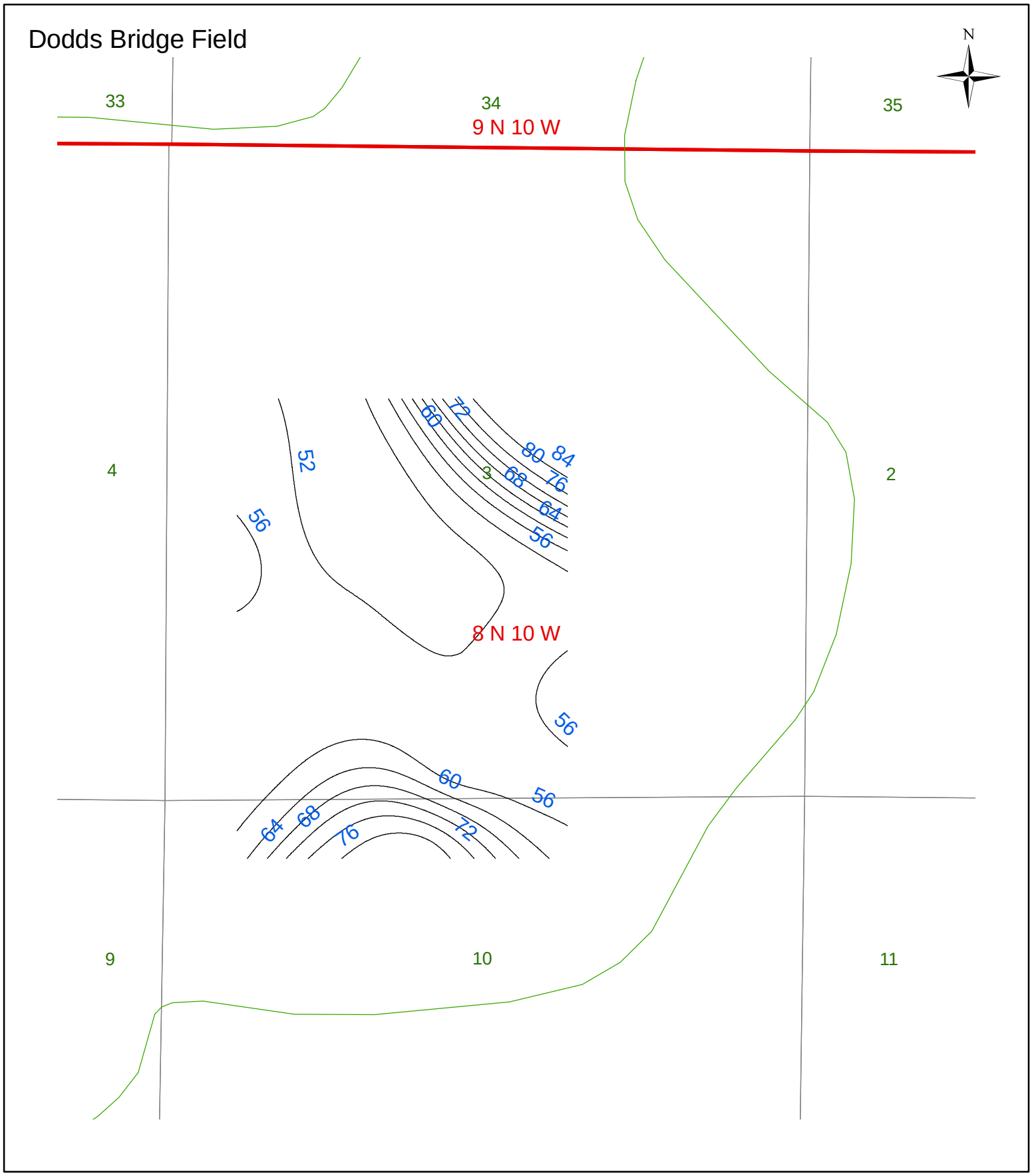


Figure 7: Isopach map showing the thickness of the Vernon Fork Member at Dodds Bridge Field, Sullivan County. Contour interval is 4 ft.

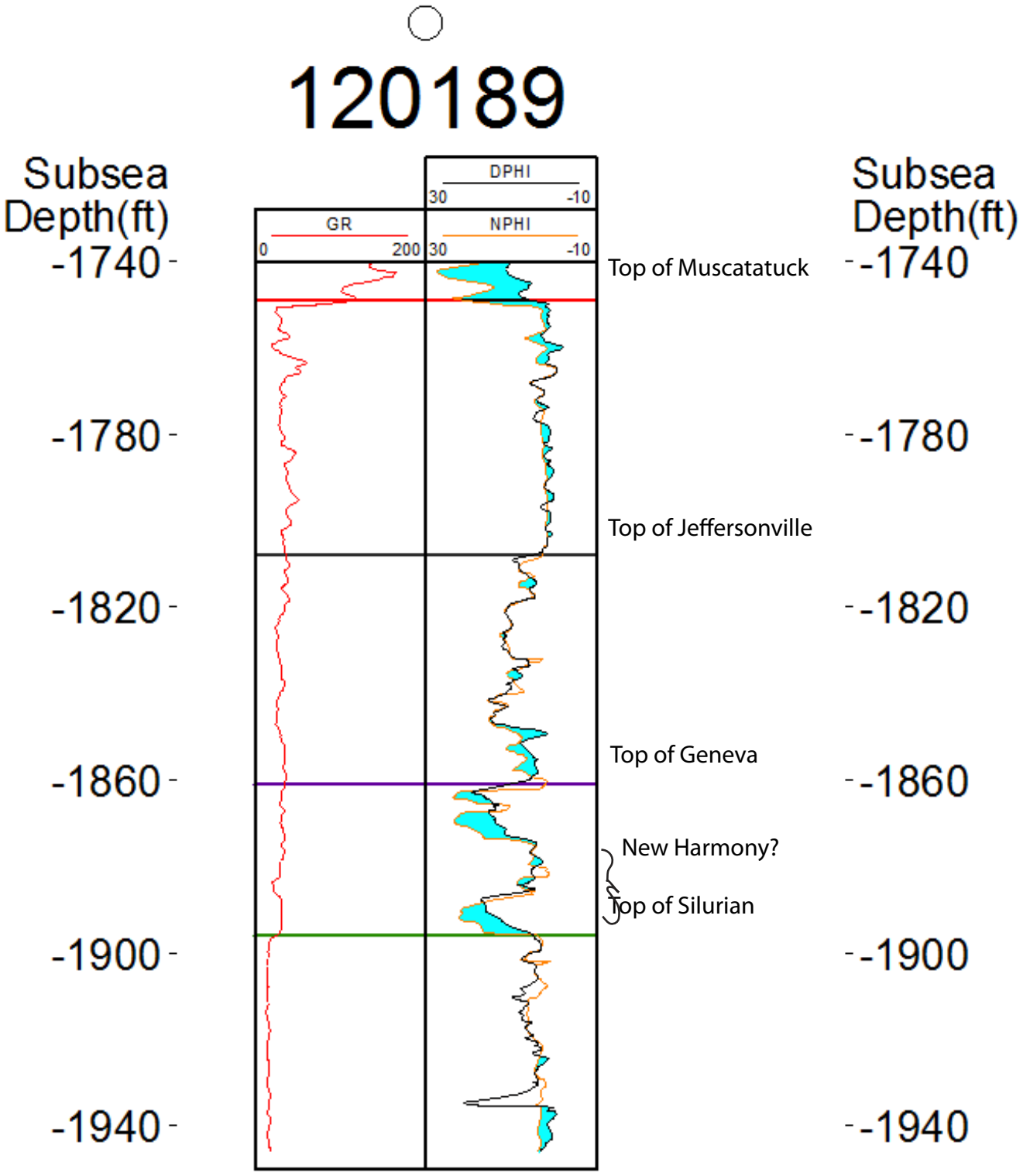


Figure 8: Type log section showing the Devonian formations at Dodds Bridge Field, Sullivan County.

HS=1

PETRA 4/30/2008 11:52:11 AM (TypeLog.CSP)

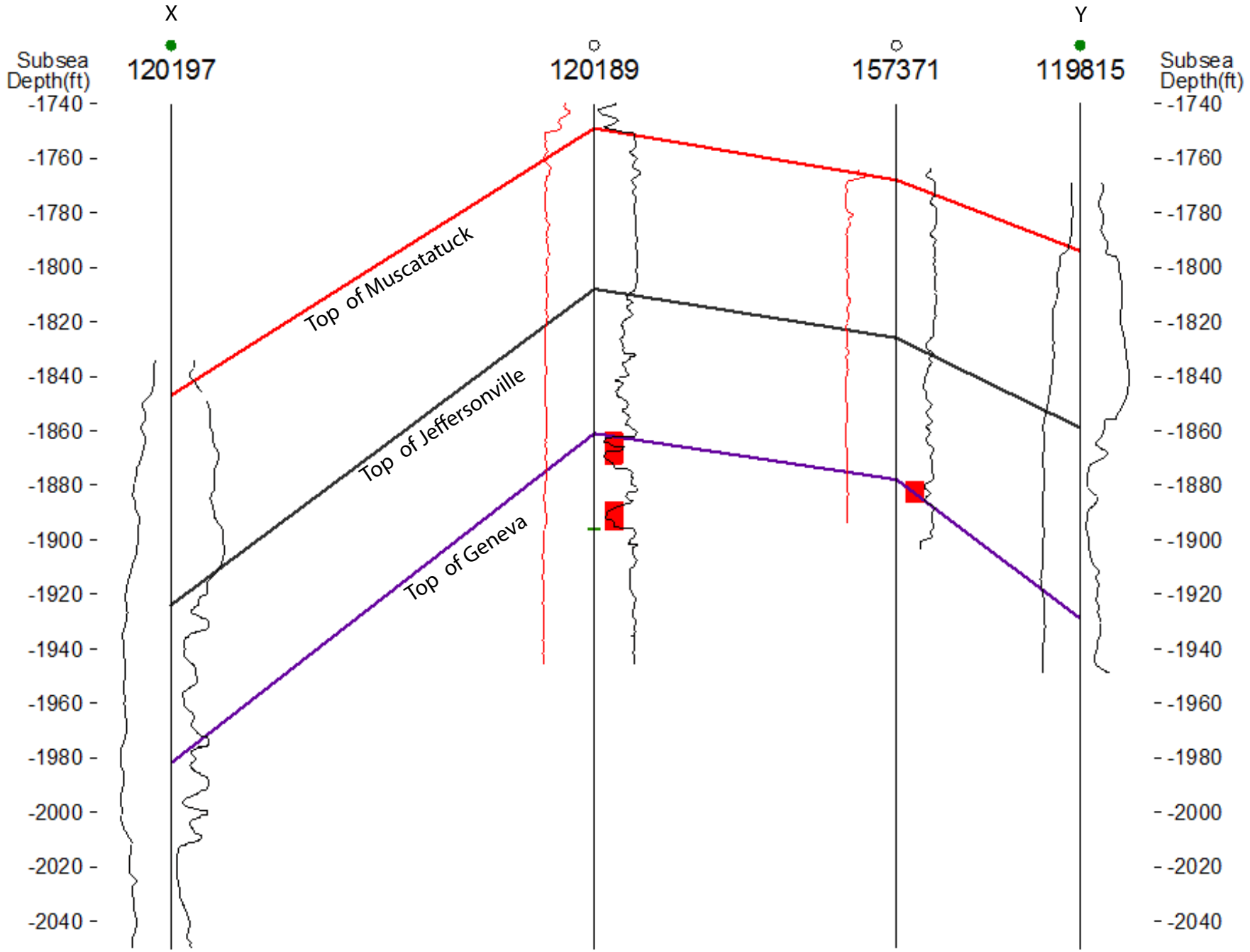


Figure 9: X-Y Cross section showing the Devonian subsurface structure acorss Dodds Bridge Field, Sullivan County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

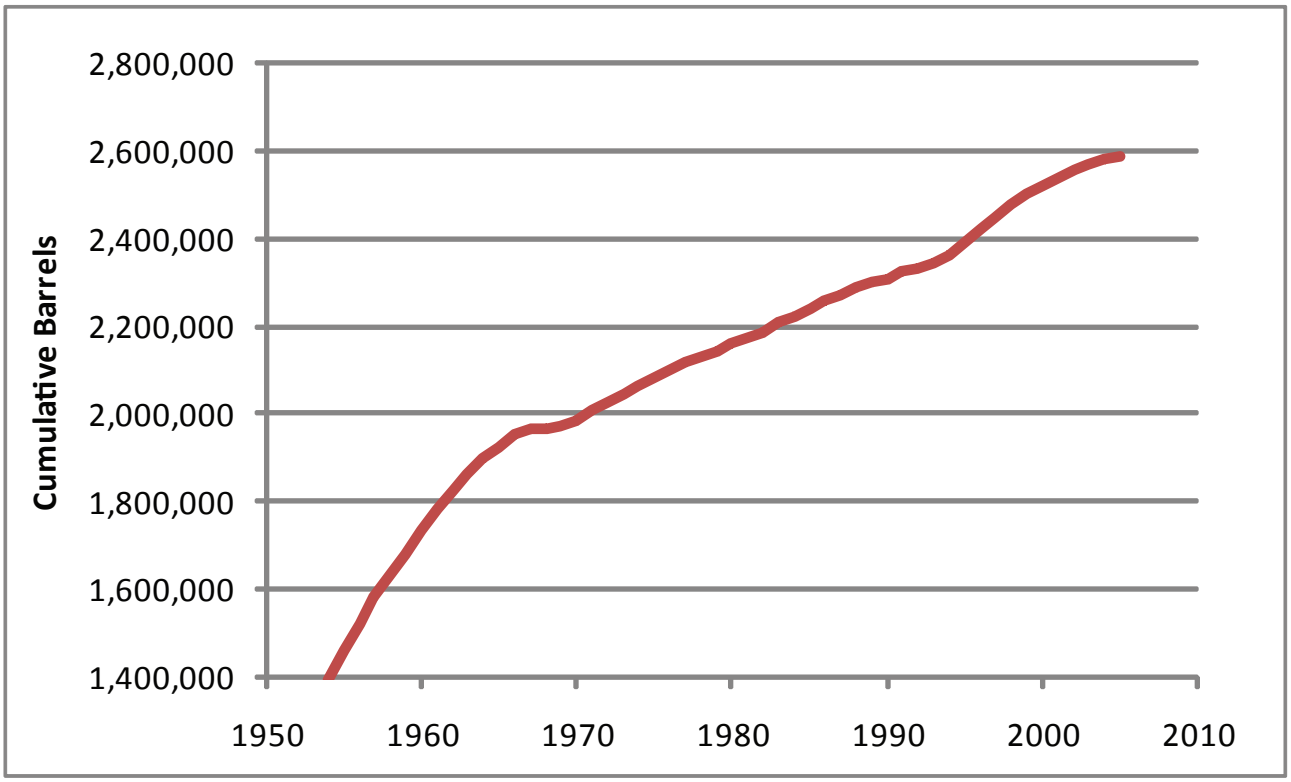


Figure - 10: Cumulative oil production history for Dodds Bridge Field, Sullivan County since 1954.

ID Number:	120189	Date:	5/1/2008
Site Name:		By:	
Location:	Dodds Bridge	Notes:	
Elevation:	0.0000 Feet		

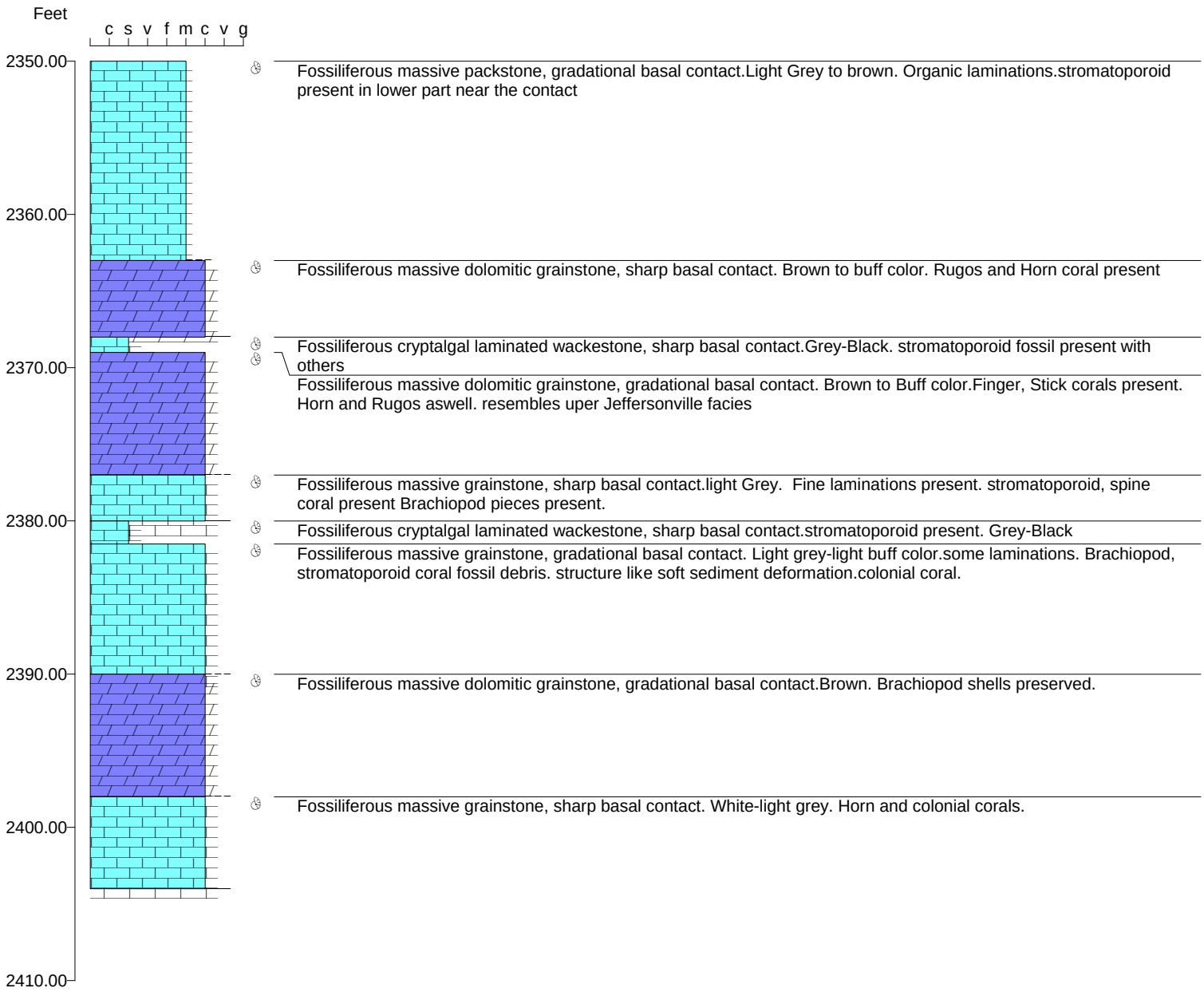


Figure 11: Core description of IGS well ID 120189, Dodds Bridge Field, Sullivan County.

Table-1: List of the wells used for subsurface structure mapping in Dodds Bridge Field, Sullivan County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
120174	8	N	10	W	3	468	2243	2303	2360		143	
120176	8	N	10	W	3	504	2253	2312	2364	2380	58	
120177	8	N	10	W	3	513	2262	2318	2372	2392	15	
120181	8	N	10	W	3	489	2242	2315			13	
120183	8	N	10	W	3	501	2275	2350	2404			
120188	8	N	10	W	3	472	2238	2300	2350	2372	20	
120189	8	N	10	W	3	504	2253	2312	2363	2380		
120190	8	N	10	W	3	489	2254		2376		5	
120192	8	N	10	W	3	497	2254	2314	2365		35	
120197	8	N	10	W	3	466	2313	2390	2478	2515		
120199	8	N	10	W	3	496	2404	2484				
120205	8	N	10	W	3	462	2268	2350			20	
120212	8	N	10	W	3	503	2267	2346			385	
120213	8	N	10	W	3	506	2266	2344	2402		16	
120215	8	N	10	W	3	487	2257	2320	2373		33	
120216	8	N	10	W	3	490	2290	2372				
120221	8	N	10	W	3	469	2370					
120222	8	N	10	W	3	463	2373					
157371	8	N	10	W	3	506	2274	2332	2384		9	
160178	8	N	10	W	3	491					22	
120547	8	N	10	W	9	461	2429			2542		
119810	8	N	10	W	10	509	2296	2360			8	
119814	8	N	10	W	10	483	2260				235	
119815	8	N	10	W	10	511	2305	2370	2450			
119818	8	N	10	W	10	505	2299					
119853	8	N	10	W	11	504	2453			2624		

Figure 12: Photo of the core ID 654, IGS ID # 120189 from Dodds Bridge Field, Sullivan County.

Fig 12: Continued...

Fig 12: Continued...

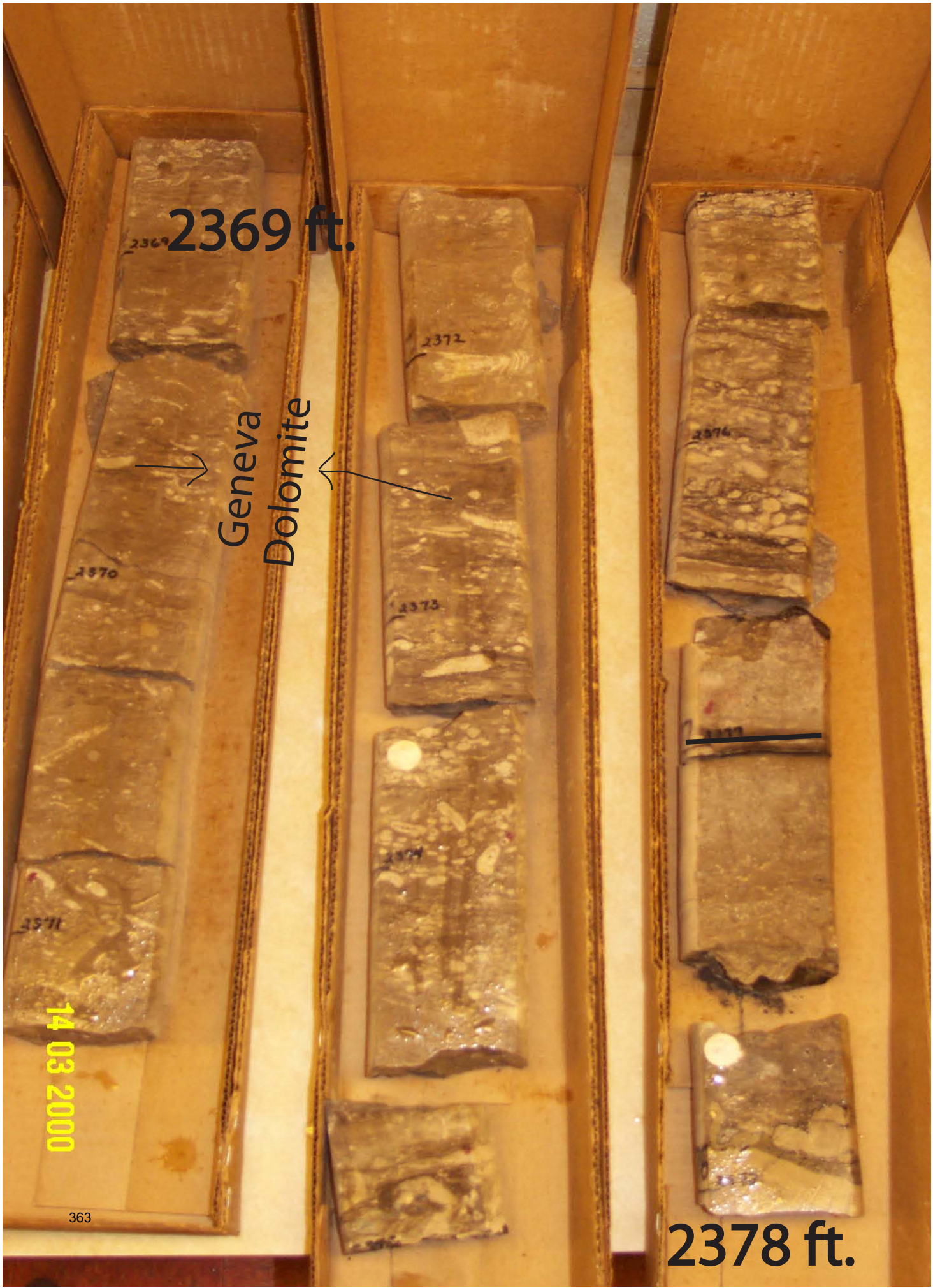


Fig 12: Continued...

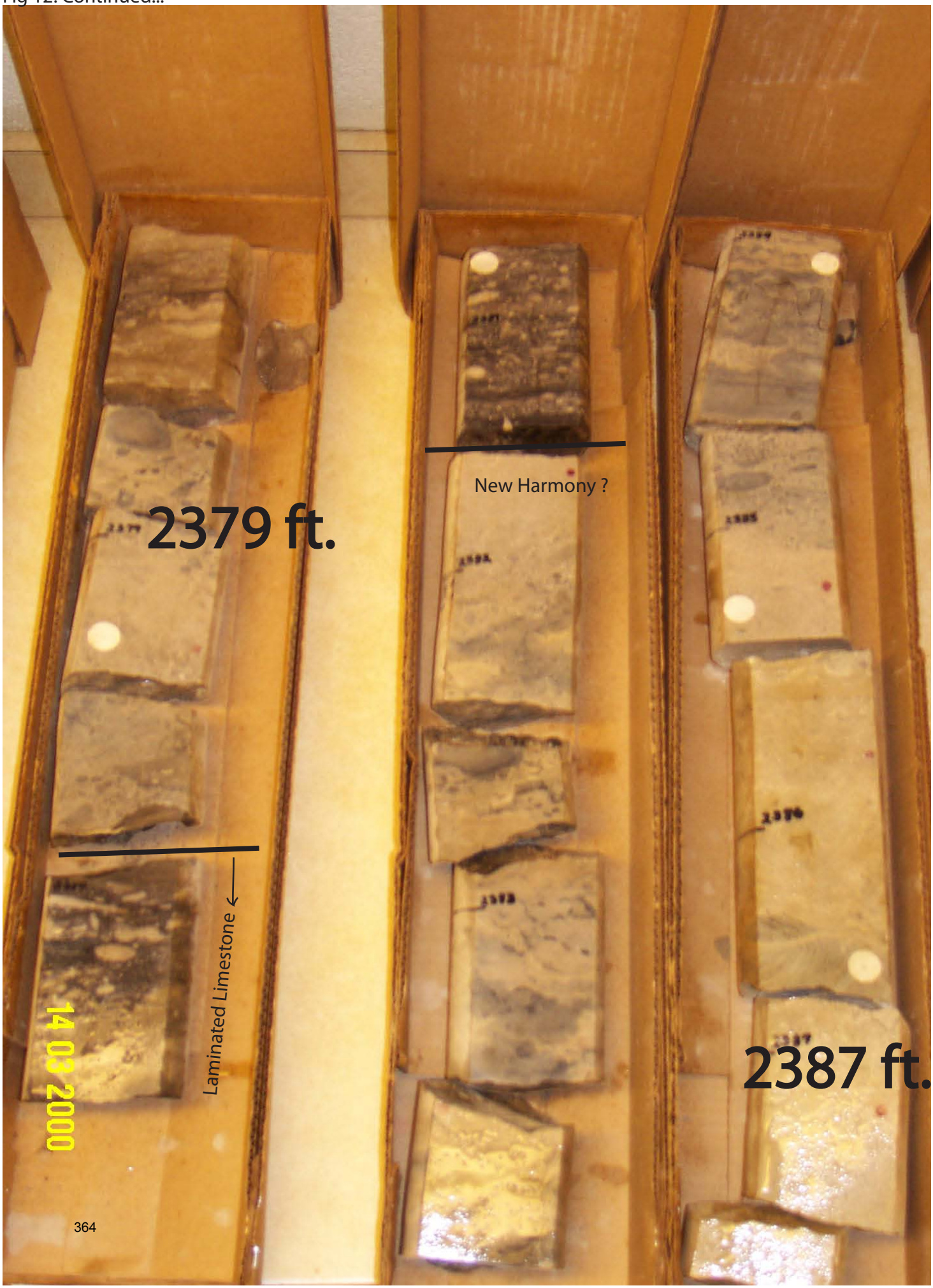


Fig 12: Continued...

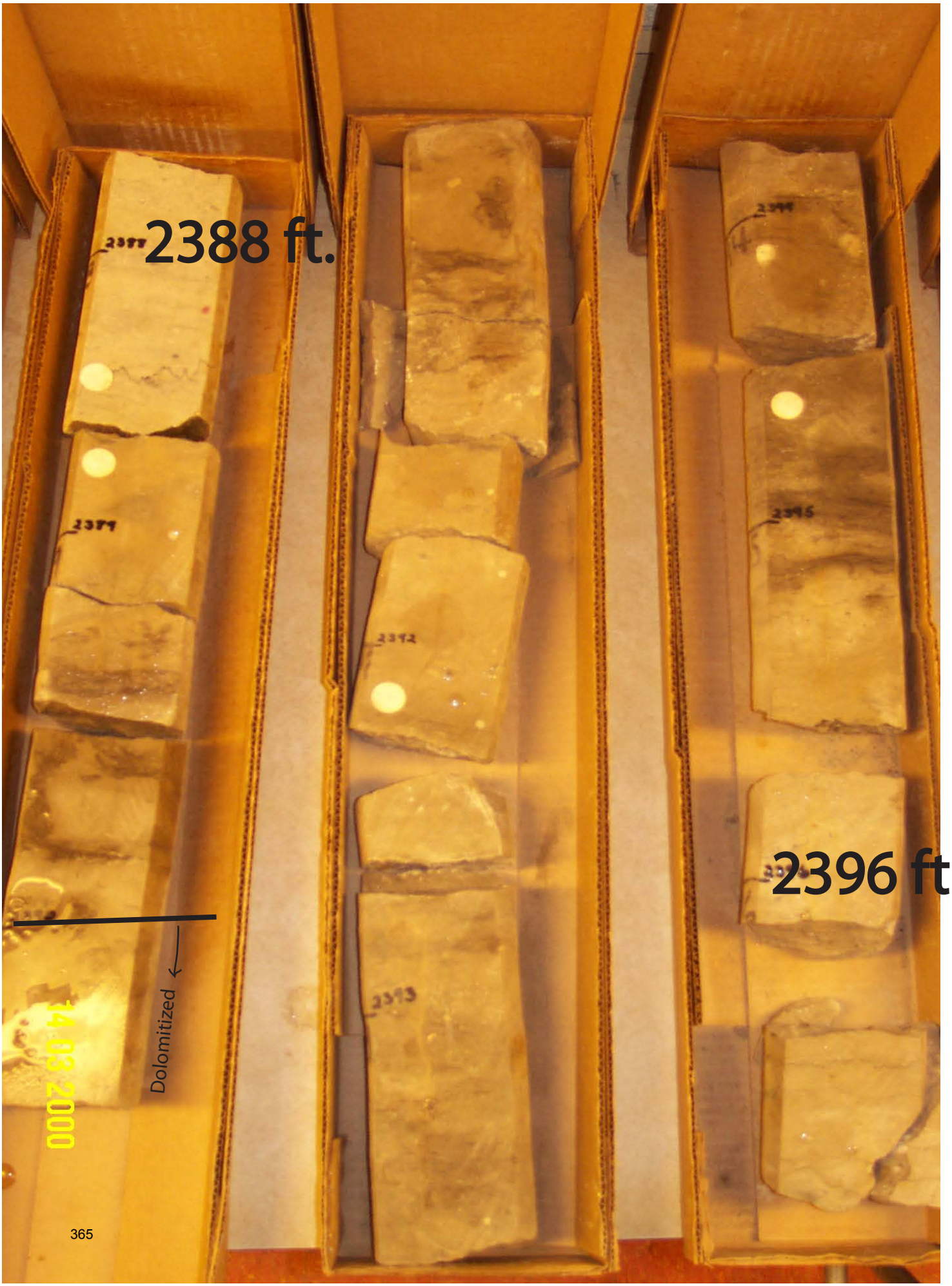


Fig 12: Continued...

Field name: Dubois

IGS ID: 10163

DOE ID: 204114

Location: Dubois County, 1S&1N-4W

Discovery date: 1987

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,596 ft.)

Field type: oil & natural gas

Total number production wells: 3 (oil), 1 (natural gas)

Area: na

Cumulative production: 183 bbls. (2002)

Other reservoir units:

Mississippian, Sanders Group, Salem Ls.

Mississippian, Sanders Group, Harrodsburg Ls.

Deepest unit penetrated (depth): Ordovician, Black River Group (3,100 ft.)

Field characteristic: na

Reservoir characteristics:

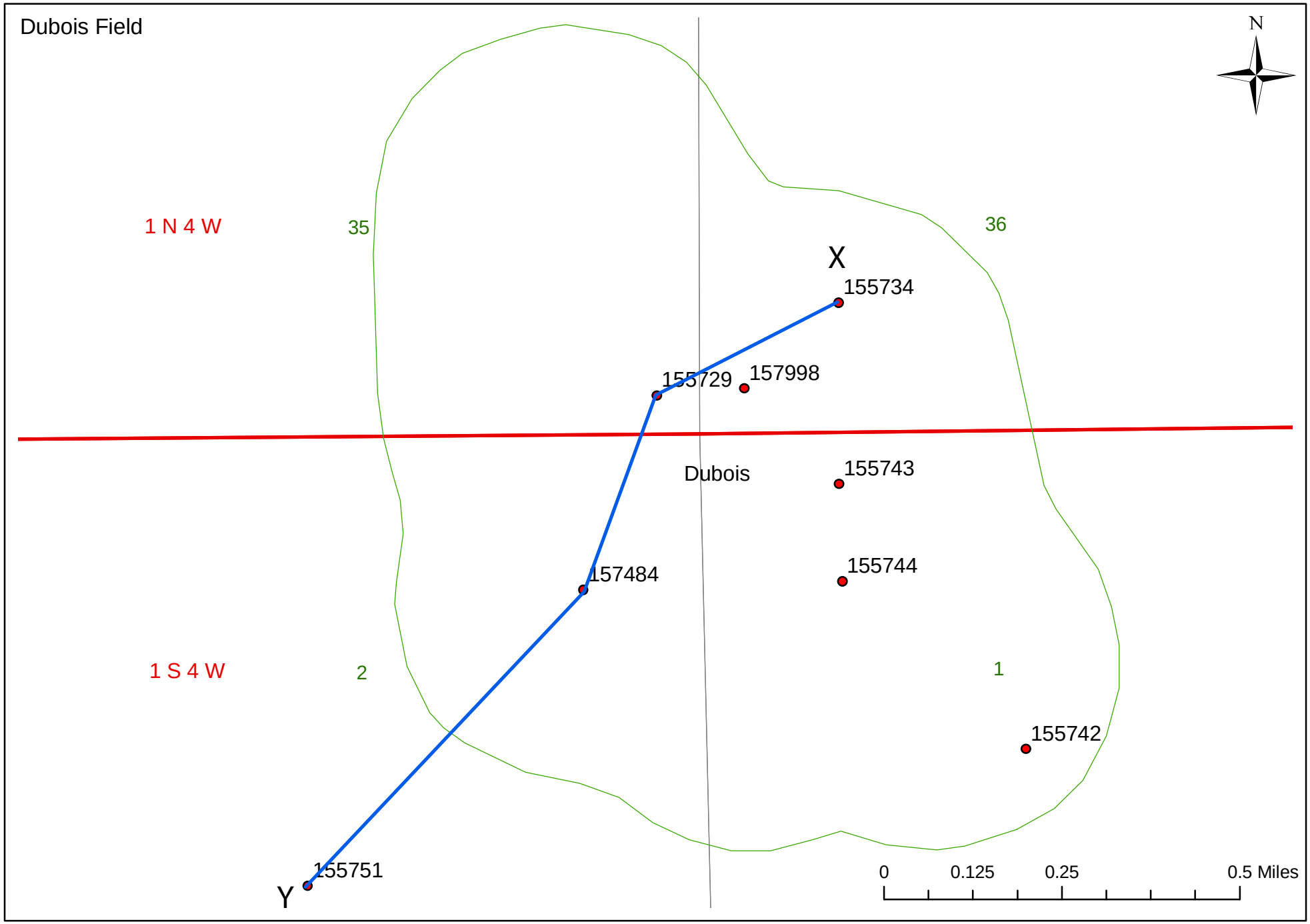


Figure 1: Map showing the location and wells at Dubois Field, Dubois County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 5.

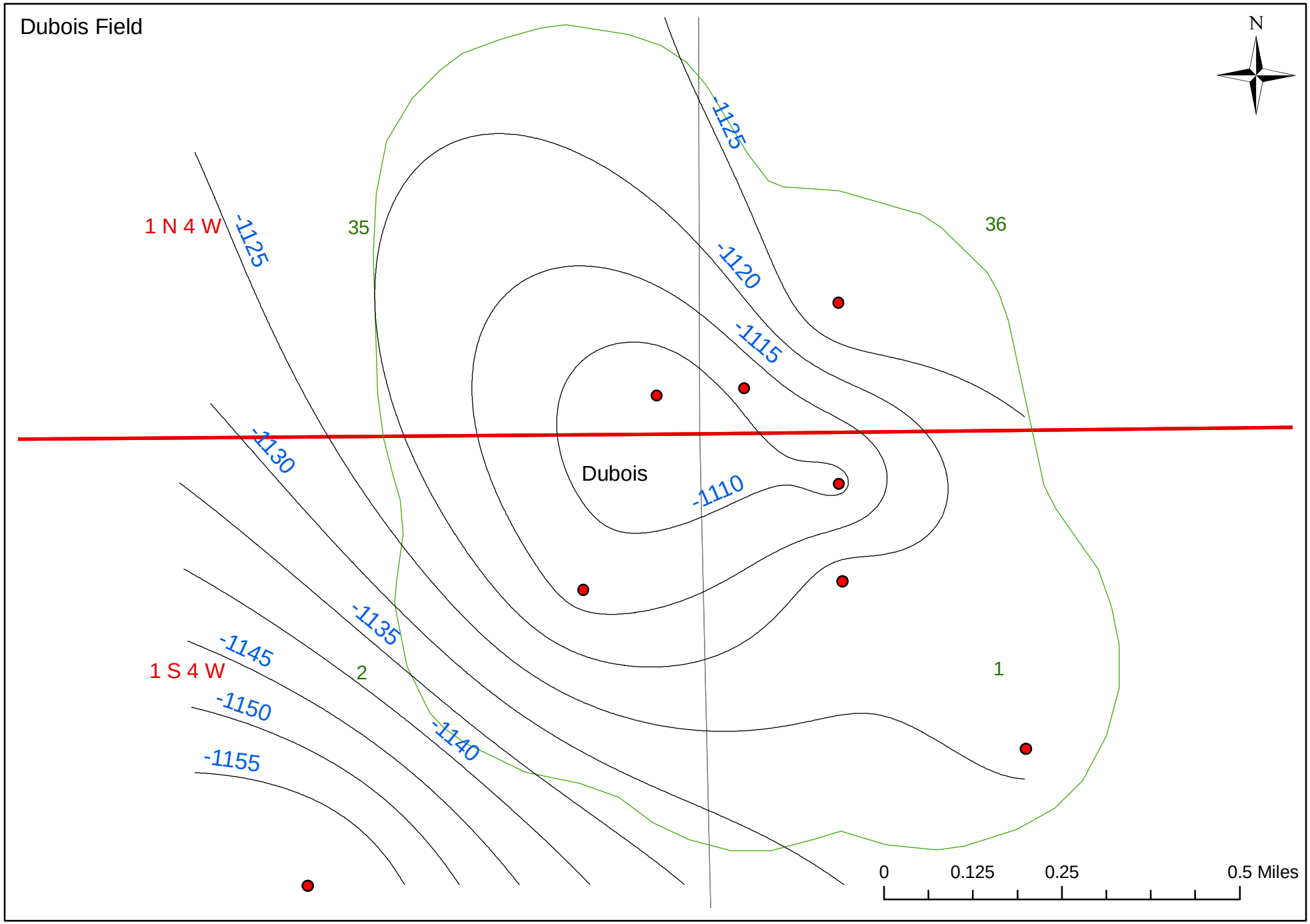


Figure 2: Structure map showing top of the Muscatatuck Limestone in Dubois field, Dubois County. Contours show values below sea level, contour interval is 5 ft .

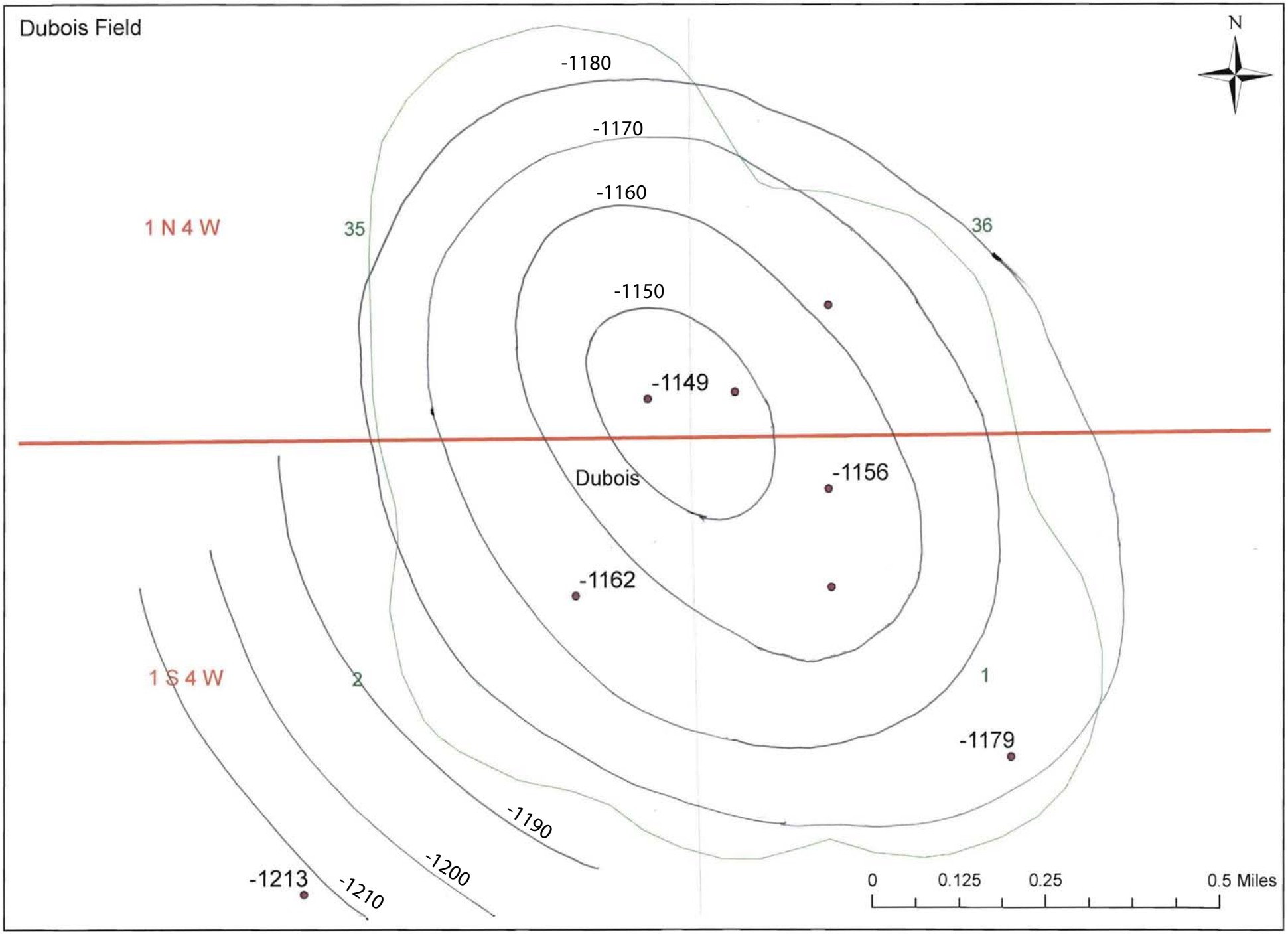


Figure 3: Structure map showing top of the Jeffersonville Limestone in Dubois Field, Dubois County. Contours show values below sea level, contour interval is 10 ft .

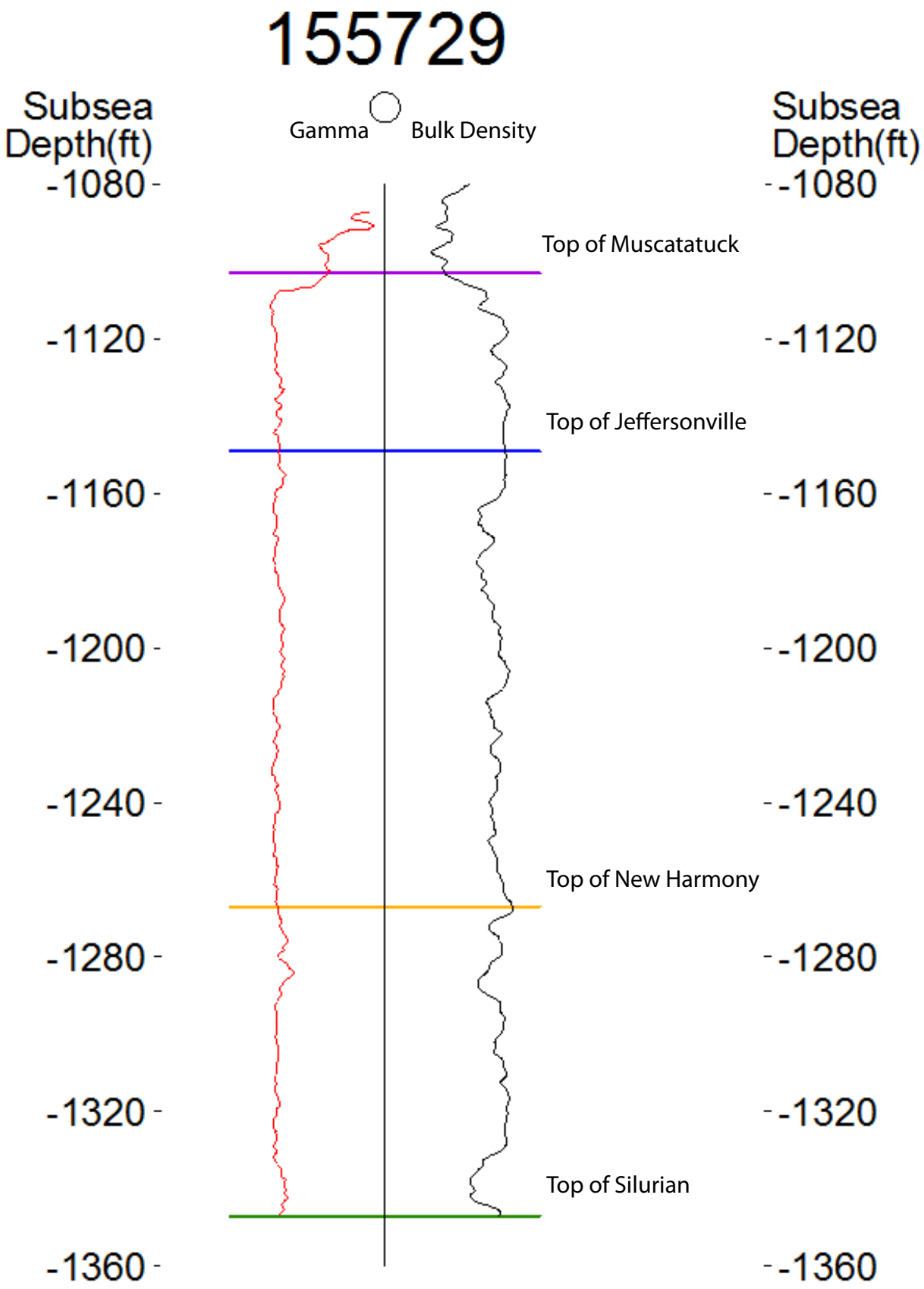


Figure 4: Type log section showing the Devonian formations at Dubois Field, Dubois County.

HS=1

PETRA 5/3/2005 4:05:57 PM (Type-Log.CSP)

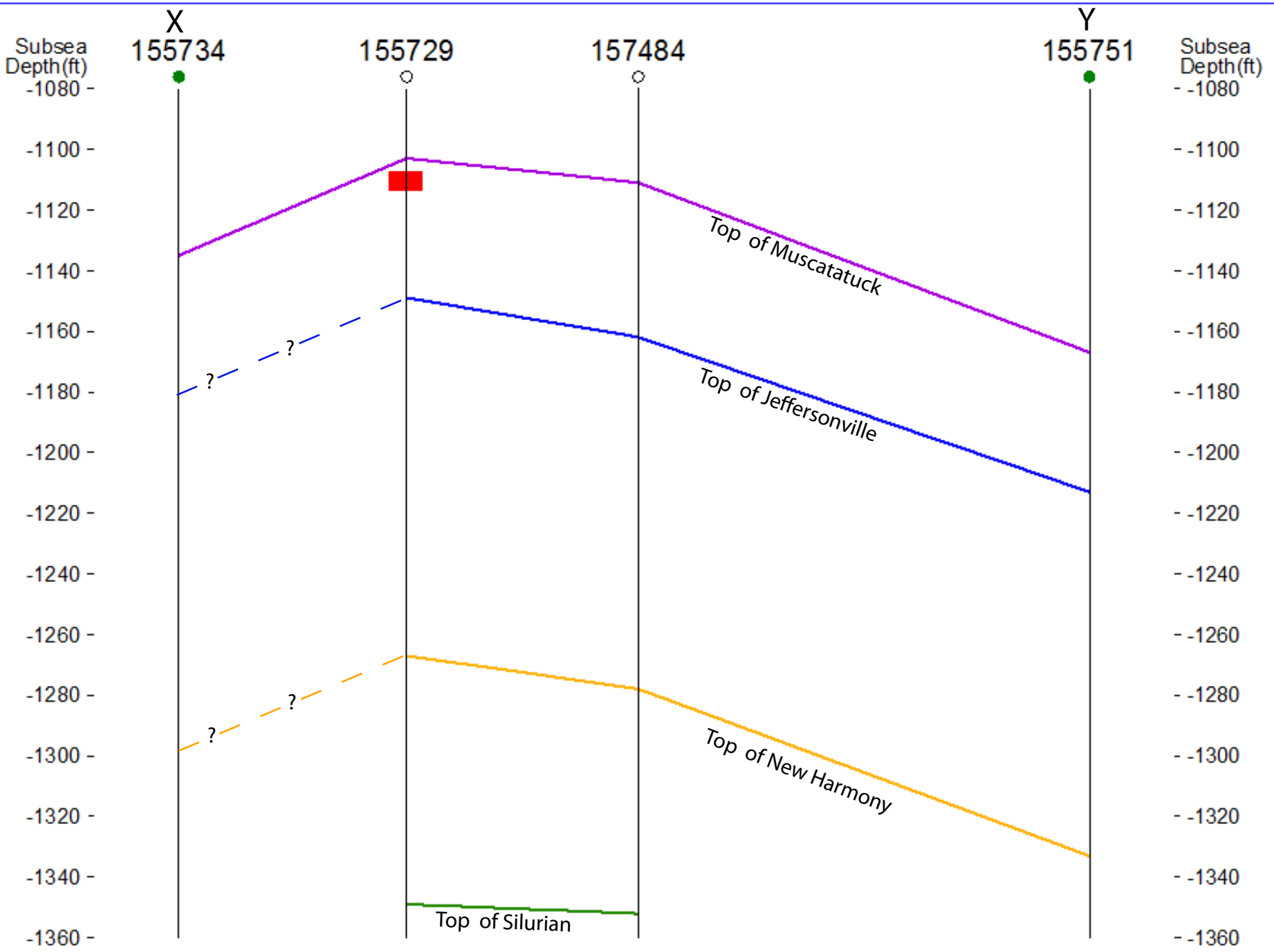


Figure 5: X-Y Cross section showing the Devonian subsurface structure across Dubois Field, Dubois County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for oil and gas production.

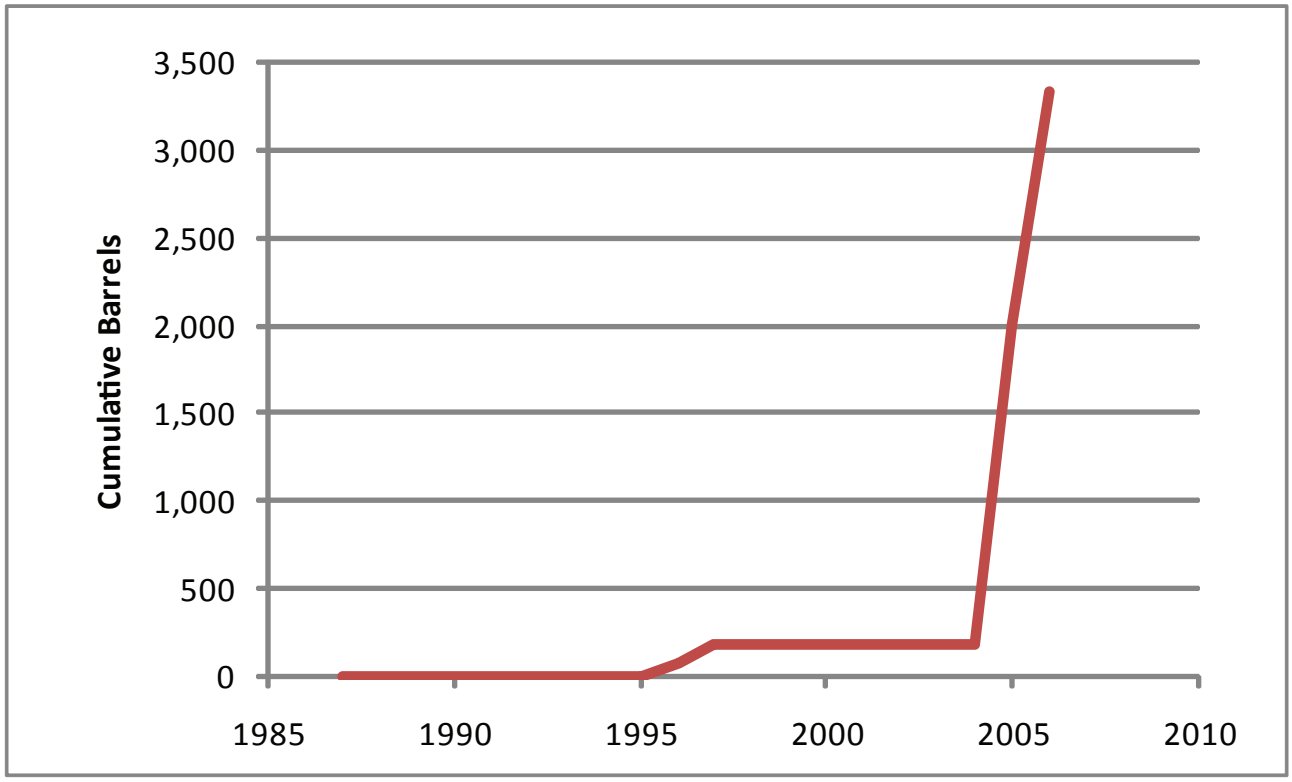


Figure - 6: Cumulative Oil production history from Dubois Field, Dubois County since 1987.

Table-1: List of the wells used for subsurface structure mapping in Dubois Field, Dubois County.

IGS_ID	Twp	Twp _D	Rng	Rng_ D	Land _N	Elevation/ Kb	Top of Musca-	Top of Jeffer-	Top of New	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
155729	1	N	4	W	35	503	1606	1652	1770	1852		
155734	1	N	4	W	36	490	1625					
157998	1	N	4	W	36	493	1604				5	
155742	1	S	4	W	1	551	1675	1730	1840	1900		
155743	1	S	4	W	1	486	1590	1642	1746			750
155744	1	S	4	W	1	487	1614					
155751	1	S	4	W	2	537	1704	1750	1870			
157484	1	S	4	W	2	568	1679	1730	1846	1915		

Field name: Elnora Central

IGS ID: 10185

DOE ID: 222134

Location: Daviess County, 5N-6W

Discovery date: 1972

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,847 ft.)

Field type: oil & natural gas

Total number production wells: 88 (oil), 3 (natural gas)

Area: 1,090 acres

Cumulative production: 2,145,984 bbls. (2002)

Other reservoir units:

Mississippian, Blue River Group, Aux Vases Fm.

Mississippian, Blue River Group, Ste. Genevieve Ls.

Deepest unit penetrated (depth): Silurian (2,030 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 60 ft. at top of Muscatatuck.

Reservoir characteristics:

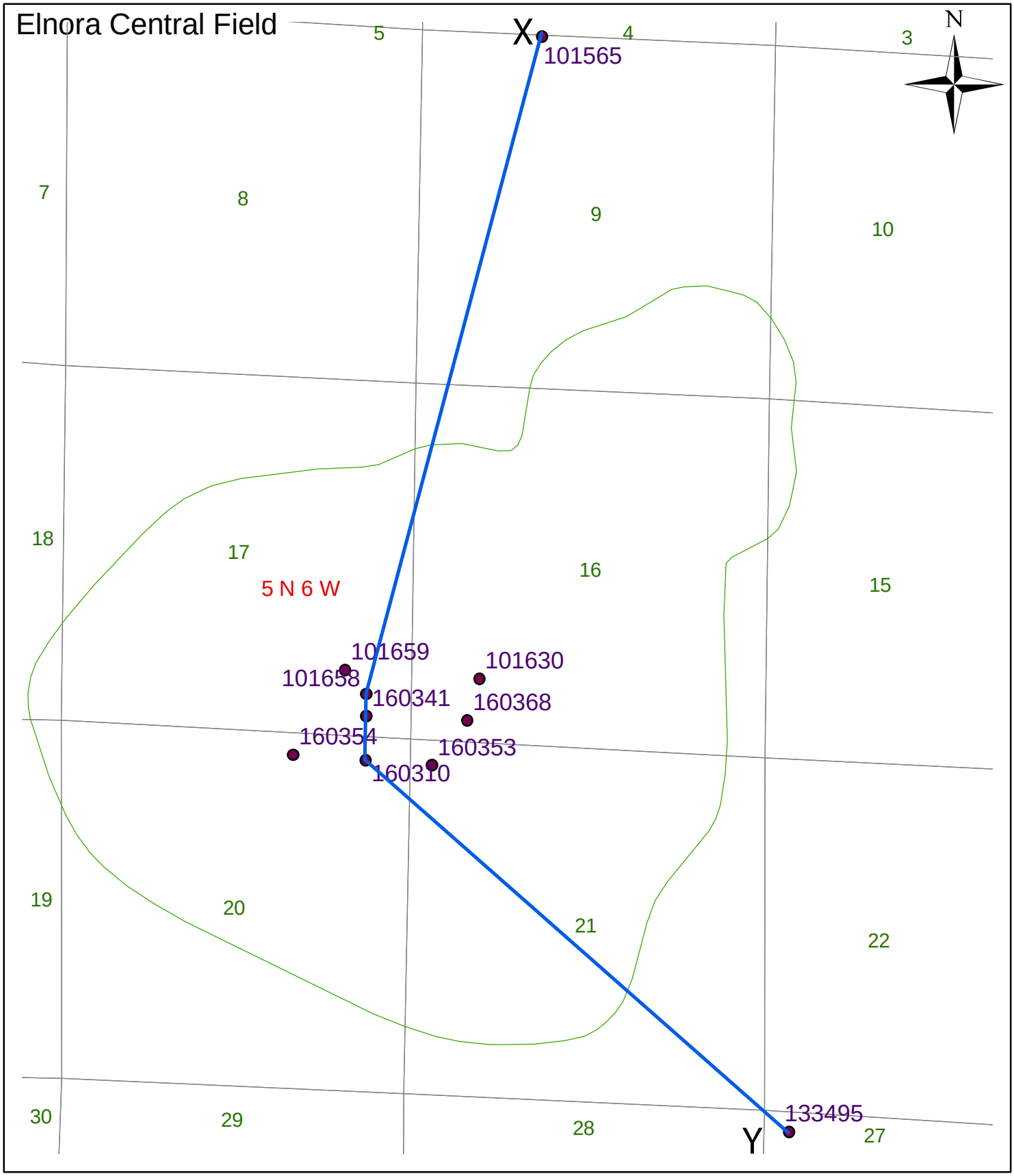


Figure 1: Map showing the location and wells at Elnora Central Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

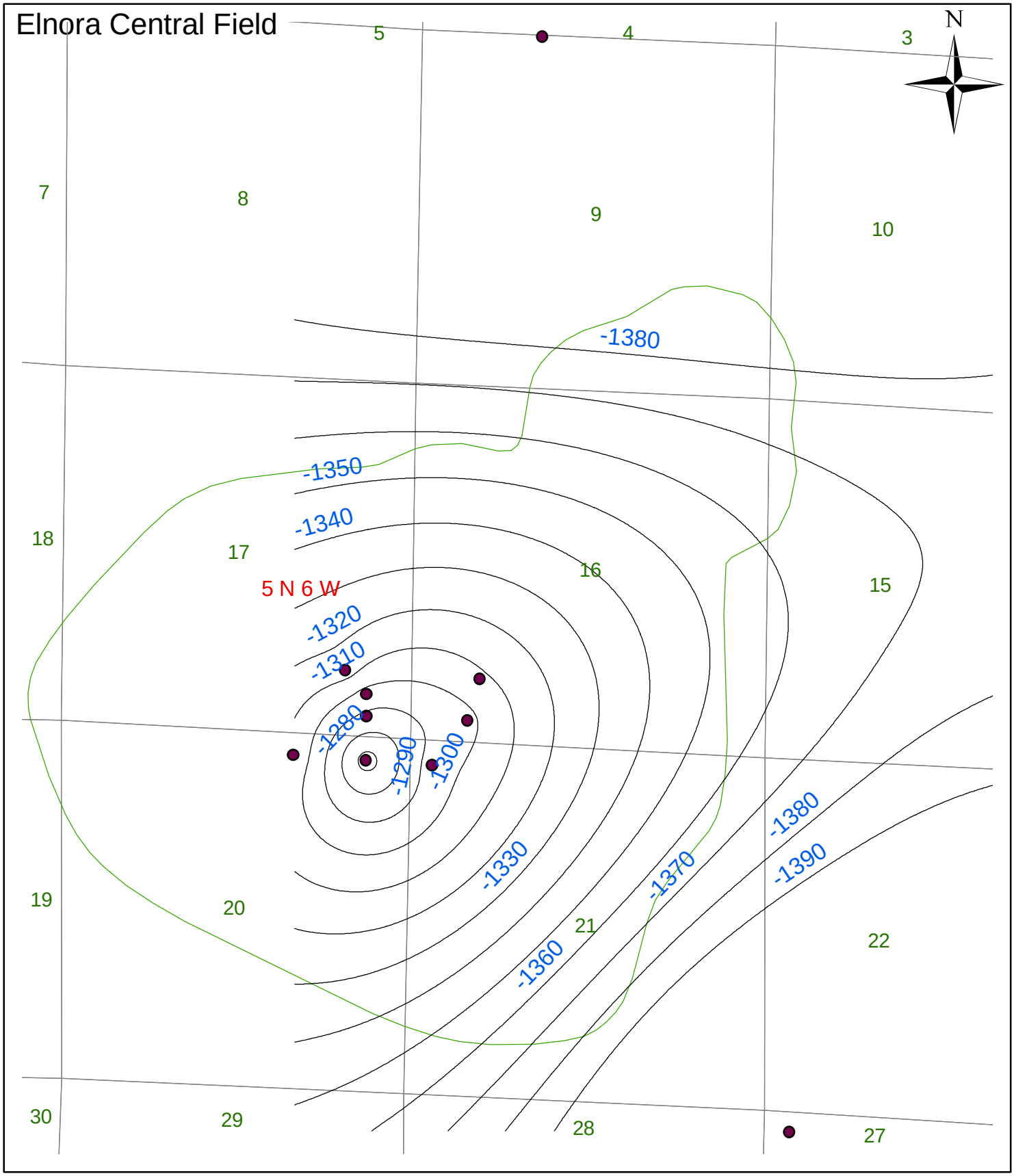


Figure 2: Structure map showing top of the Muscatatuck Limestone in Elnora Central field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

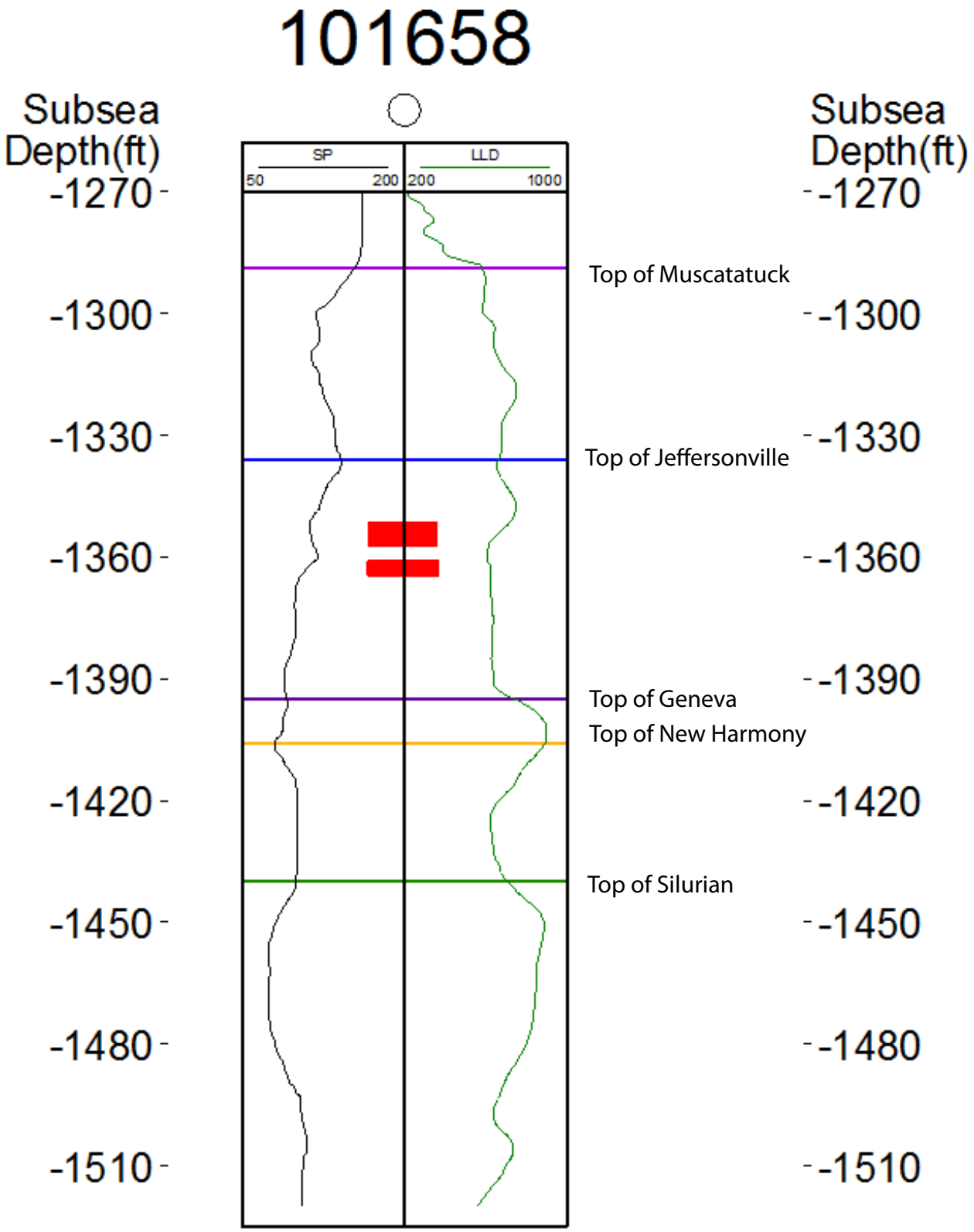


Figure 3: Type log section showing the Devonian formations from Elnora Central Field, Daviess County. Red box show the completion interval for oil production.

HS=1

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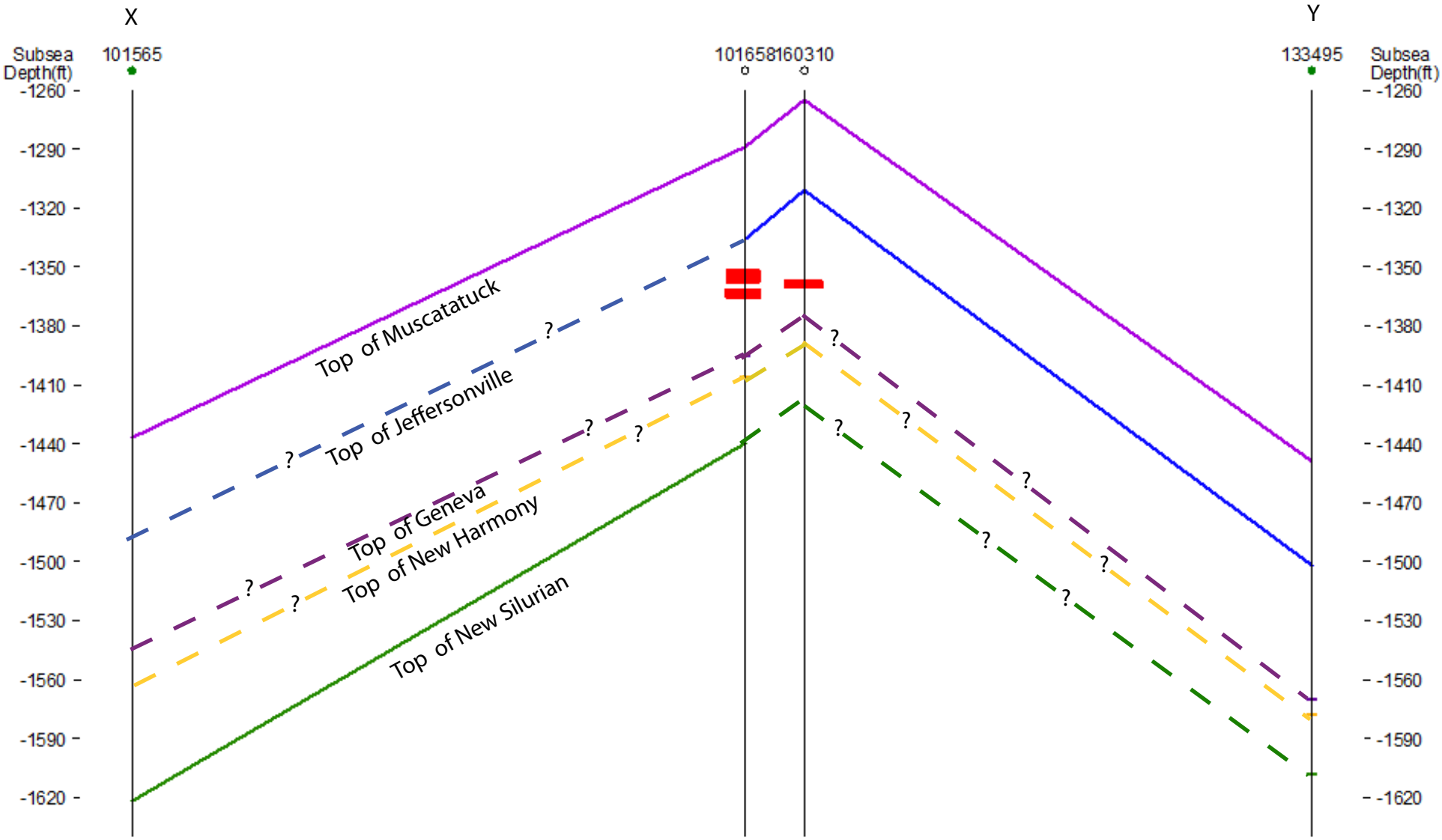

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Elnora Central Field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for oil production.

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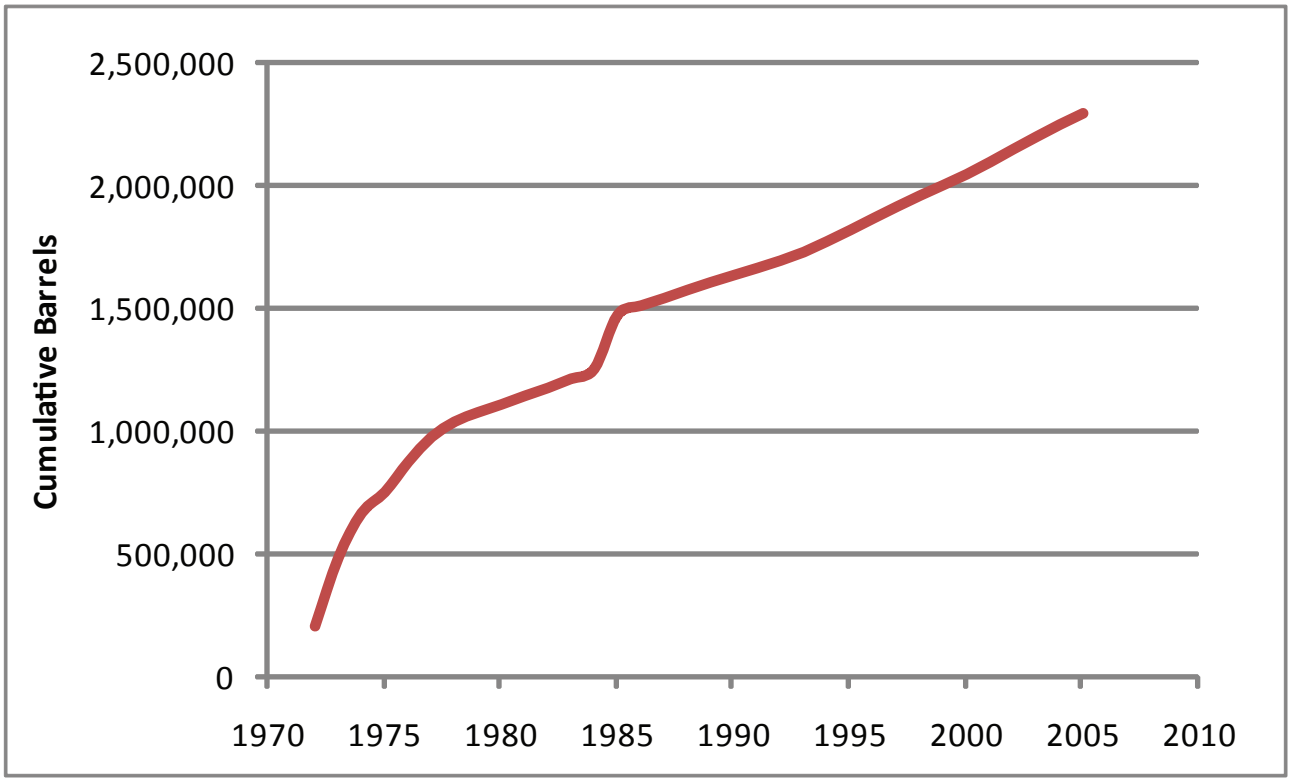

Figure - 5: Cumulative oil production history from Elnora Central Field, Daviess County since 1972.

Table-1: List of the wells used for subsurface structure mapping in Elnora Central Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_ N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
101565	5	N	6	W	4	473	1910				2095		
101600	5	N	6	W	15	542	1916						
101630	5	N	6	W	16	484	1792	1834	1910	1915	1945	21	
160368	5	N	6	W	16	495	1792	1834				32	
101658	5	N	6	W	17	510	1806	1850	1905	1916	1950	14	
101659	5	N	6	W	17	491	1806					120	
160341	5	N	6	W	17	514	1802					96	
160352	5	N	6	W	17	503							
160310	5	N	6	W	20	523	1788	1834				30	
160354	5	N	6	W	20	510	1819	1868				70	
160353	5	N	6	W	21	495	1790						35
133495	5	N	6	W	27	482	1931	1984	2052	2060	2090		

Field name: Fairbanks

IGS ID: 10196

DOE ID: 233444

Location: Sullivan County, 9N-10W

Discovery date: 1950

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (2,225 ft.)

Field type: oil

Total number production wells: 28

Area: 440 acres

Cumulative production: 3,247,727 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (3,075 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

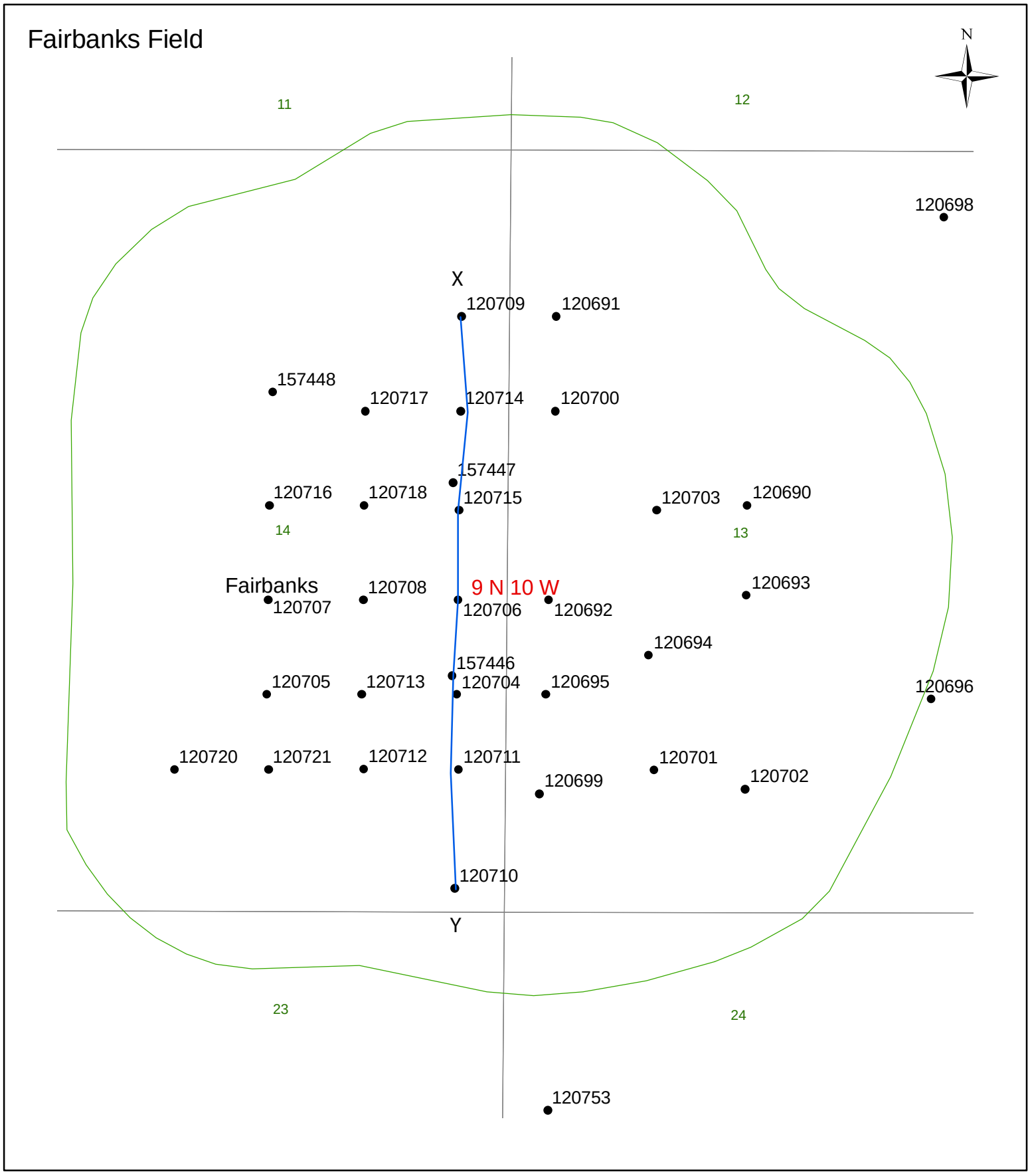

Figure 1: Map showing the location and wells at Fairbanks Field, Sullivan County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 6). The wells depicted were used for subsurface maping and have a total depth (TD) of Devonian or deeper.

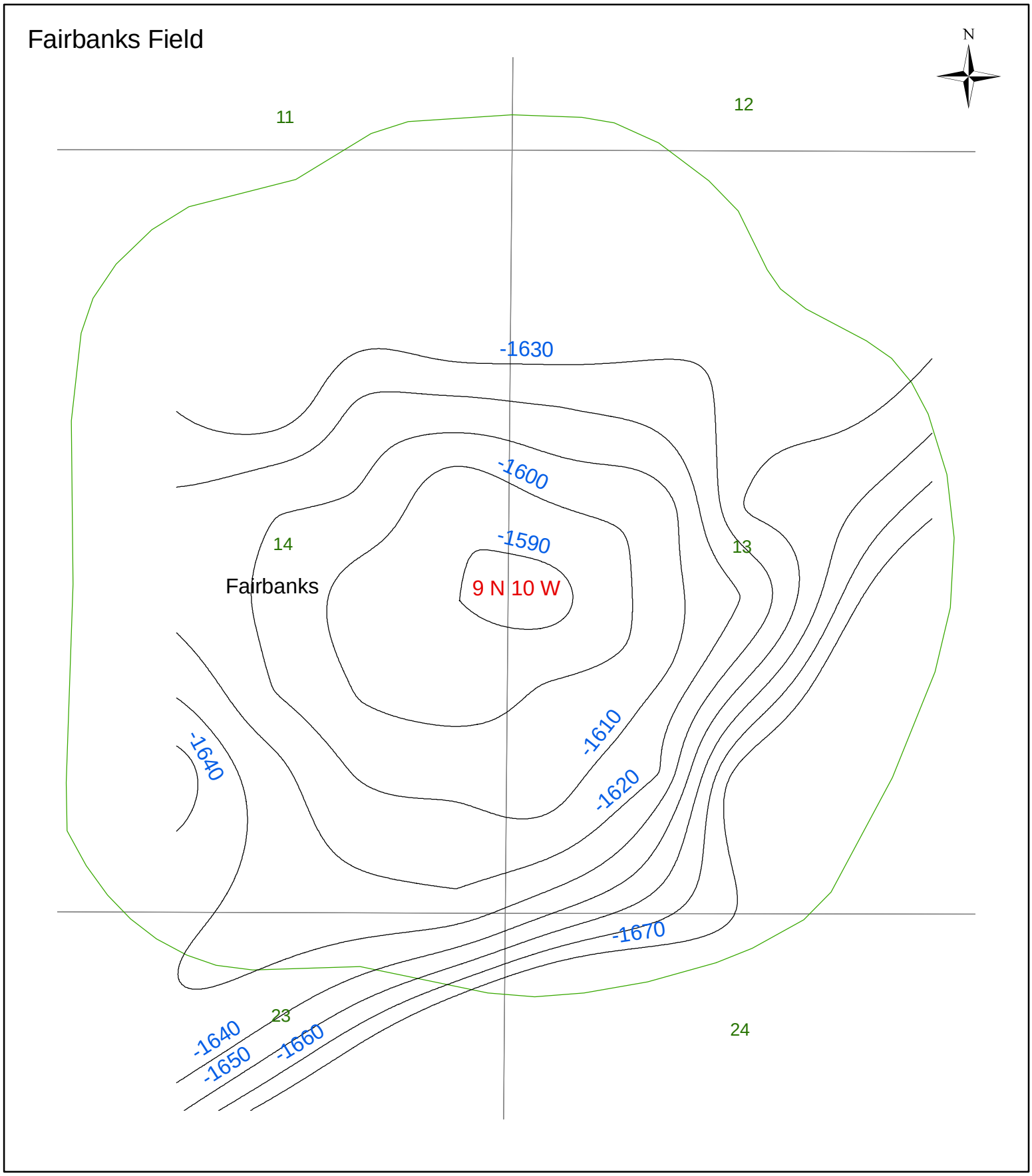

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Fairbanks Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

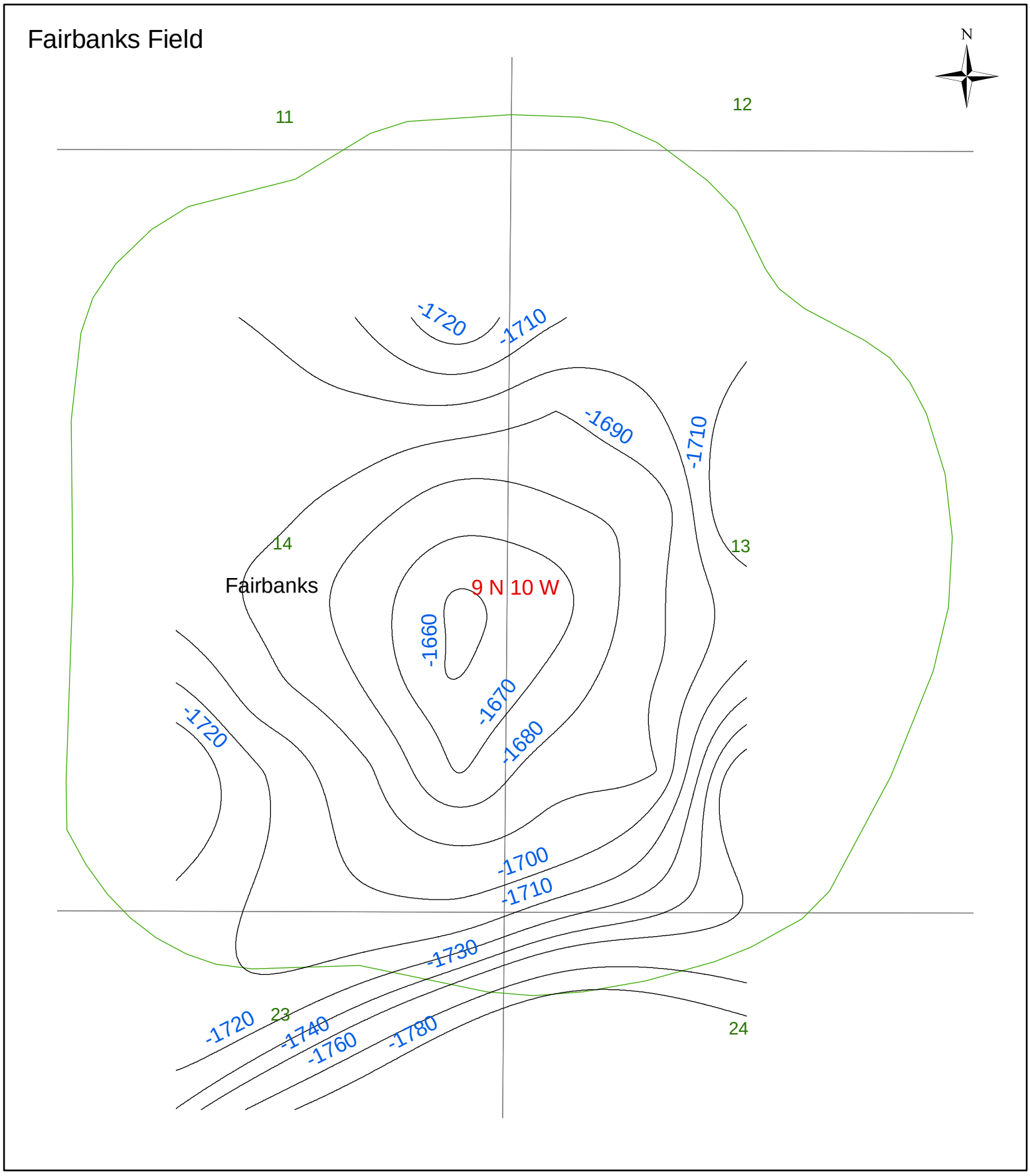

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Fairbanks Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

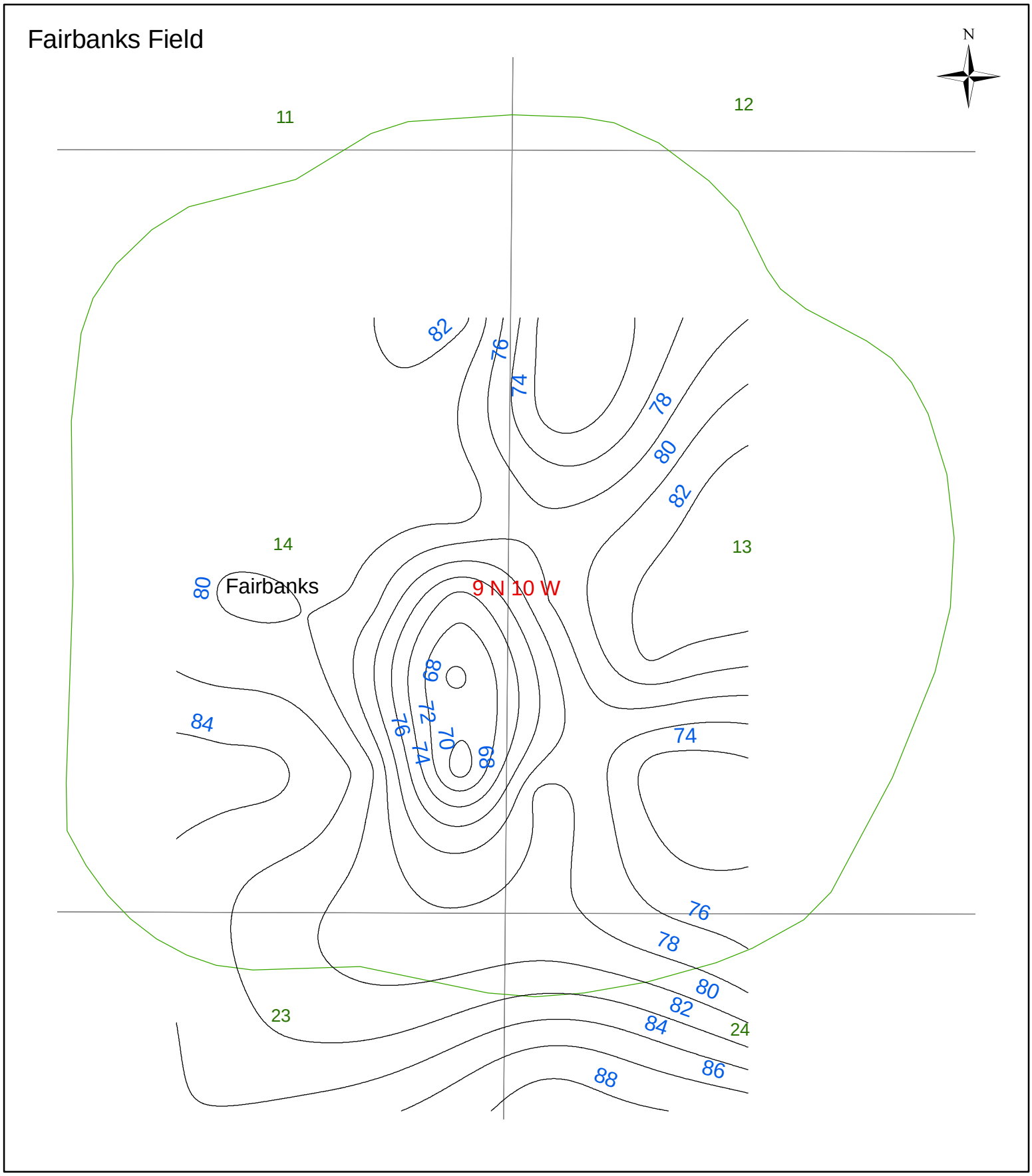

Figure 4: Isopach map showing the thickness of the North Vernon Member from Fairbanks Field, Sullivan County. Contour interval is 2 ft.

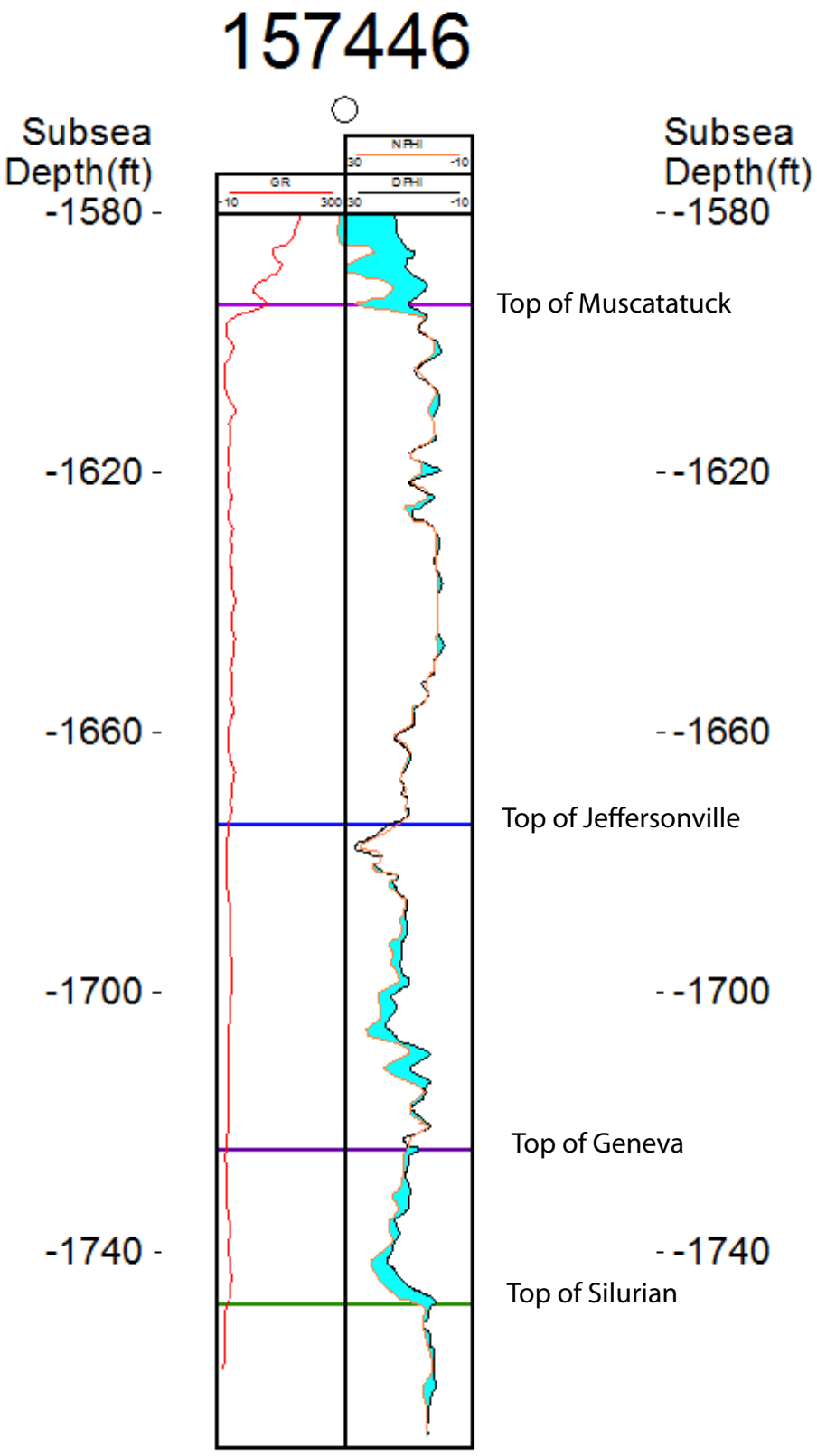

Figure 5: Type log section showing the Devonian formations at Fairbanks Field, Sullivan County.

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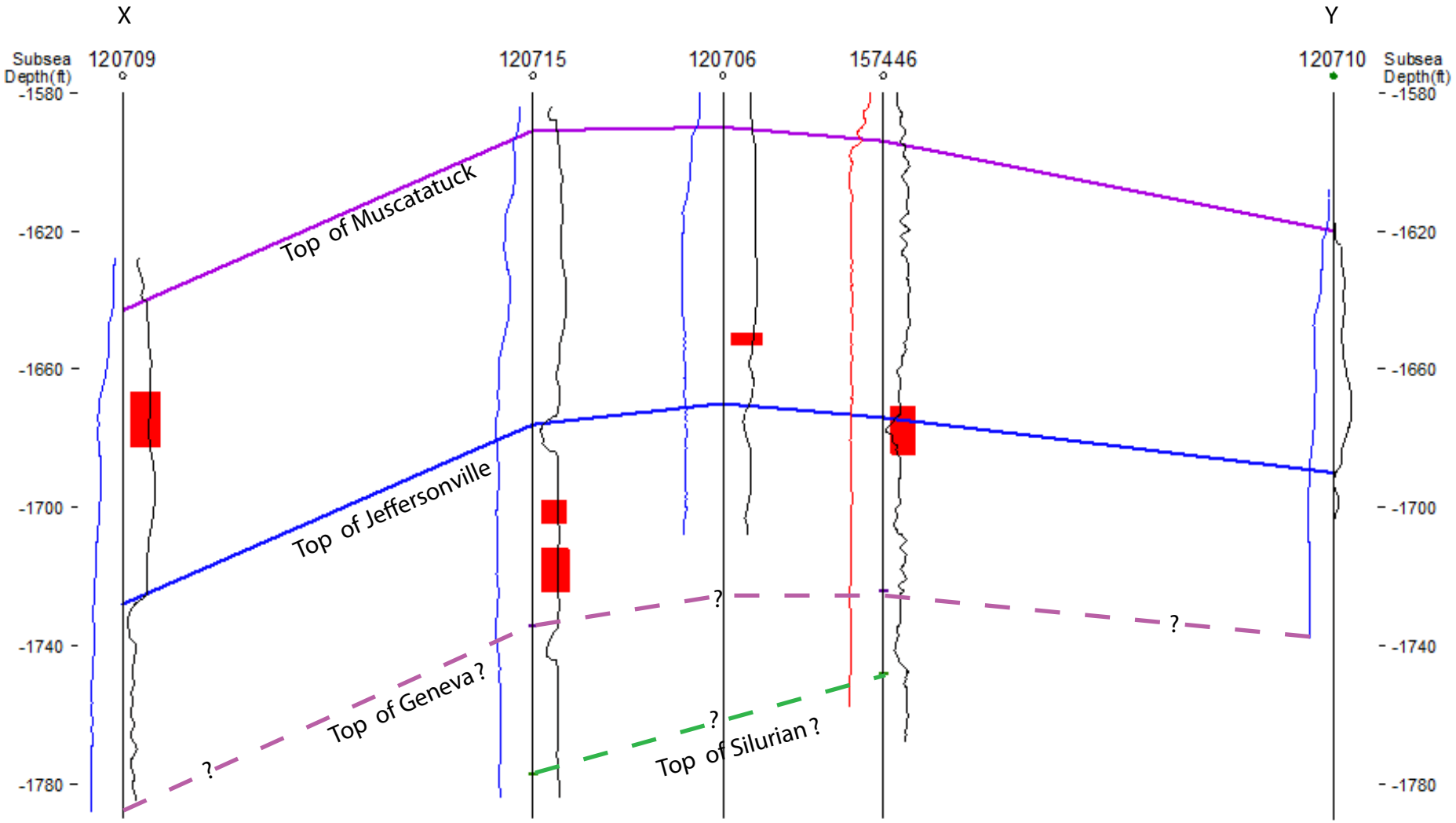

Figure 6: X-Y Cross section showing the Devonian subsurface structure across Fairbanks Field, Sullivan County. The red color box shows the completion intervals for the oil or gas production. For location of the cross section refer to Figure 1.

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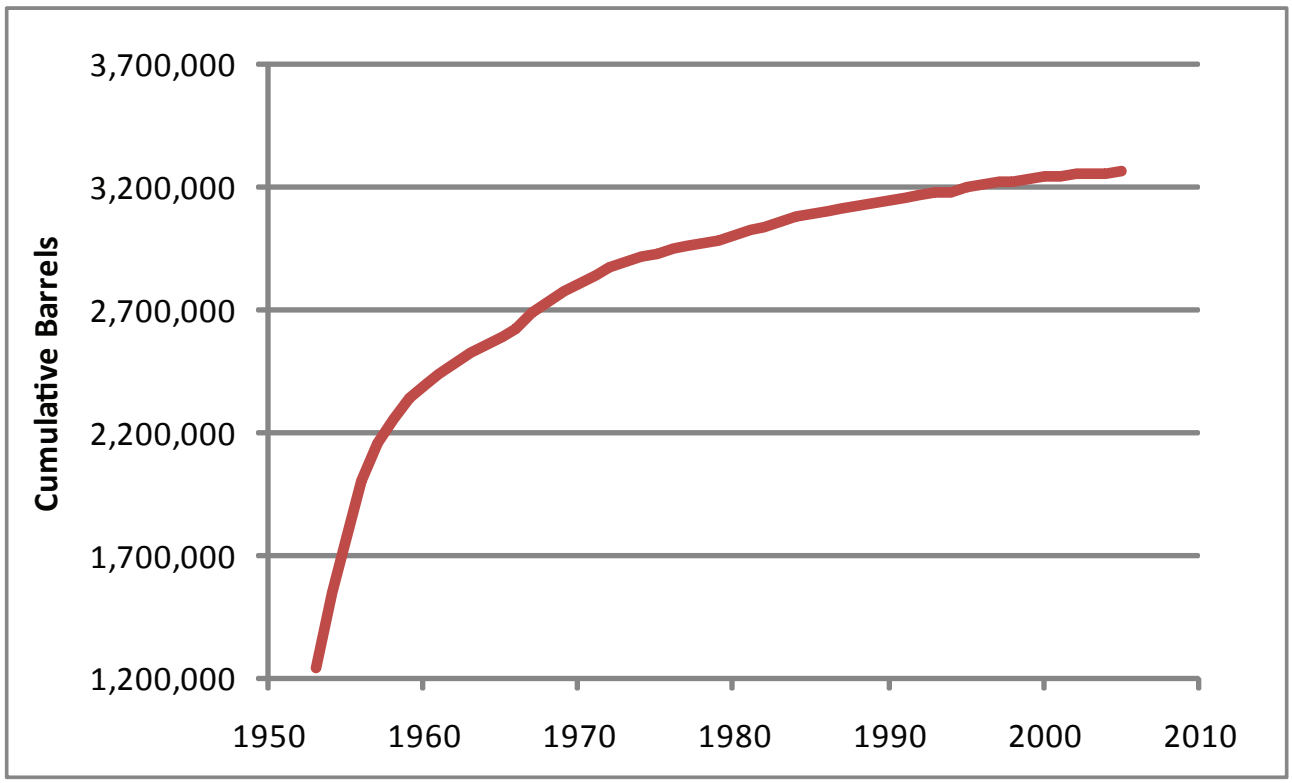

Figure - 7: Cumulative oil production history for Fairbanks Field, Sullivan County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Fairbanks Field, Sullivan County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
120690	9	N	10	W	13	533	2175	2260			432	
120691	9	N	10	W	13	509	2150	2220			62/17	
120692	9	N	10	W	13	501	2087	2166			210	
120693	9	N	10	W	13	535	2156	2240			120/40	
120694	9	N	10	W	13	517	2120	2204			258	
120695	9	N	10	W	13	496	2098				85	
120696	9	N	10	W	13	542	2270					
120698	9	N	10	W	13	546						
120699	9	N	10	W	13	502	2108	2190			233	
120700	9	N	10	W	13	514	2133	2204				
120701	9	N	10	W	13	519	2137	2208			54/38	
120702	9	N	10	W	13	524	2208	2280				
120703	9	N	10	W	13	526	2129	2210	2270		240	
120704	9	N	10	W	14	508	2103	2172	2248	2300	142	
120705	9	N	10	W	14	521	2132	2214	2270		126	
120706	9	N	10	W	14	512	2102	2170			105	
120707	9	N	10	W	14	523	2131	2210			126	
120708	9	N	10	W	14	525	2119	2200	2260		198	
120709	9	N	10	W	14	512	2155	2240			109	
120710	9	N	10	W	14	512	2132	2210				
120711	9	N	10	W	14	511	2118	2180			192	
120712	9	N	10	W	14	528	2136	2220			180	
120713	9	N	10	W	14	525	2124				87	
120714	9	N	10	W	14	510	2126				15	
120715	9	N	10	W	14	516	2107	2190	2254	2293	280	
120716	9	N	10	W	14	525	2136	2218			294	
120717	9	N	10	W	14	524	2140	2222			270	
120718	9	N	10	W	14	520	2128				100	
120720	9	N	10	W	14	519	2164	2250				
120721	9	N	10	W	14	521	2145	2230			70	
157446	9	N	10	W	14	512	2106	2171	2236	2260		
157447	9	N	10	W	14	518	2113				15	
157448	9	N	10	W	14	520	2161				9	
120753	9	N	10	W	24	515	2280	2370	2440	2469		

Field name: Glendale

IGS ID: 10253

DOE ID: na

Location: Daviess County, 2N-6W

Discovery date: 1930

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (2,181ft.)

Field type: natural gas

Total number production wells: 1

Area: na

Cumulative production: na

Other reservoir units: Devonian/Mississippian, New Albany Shale

Deepest unit penetrated (depth): Silurian (2,576 ft.)

Field characteristic: No observable structural closure.

Reservoir characteristics:

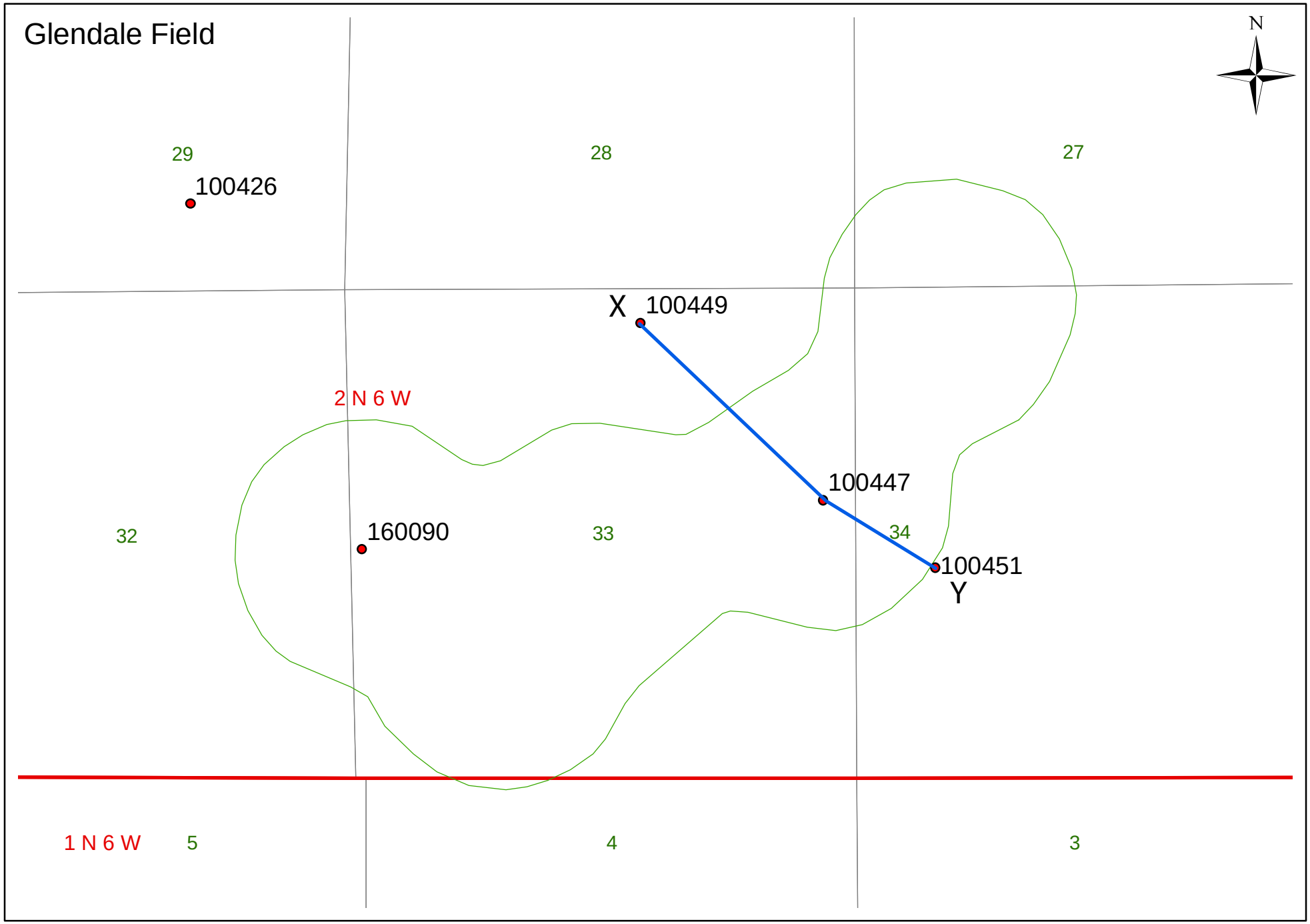

Figure 1: Map showing the location and wells at Glendale Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

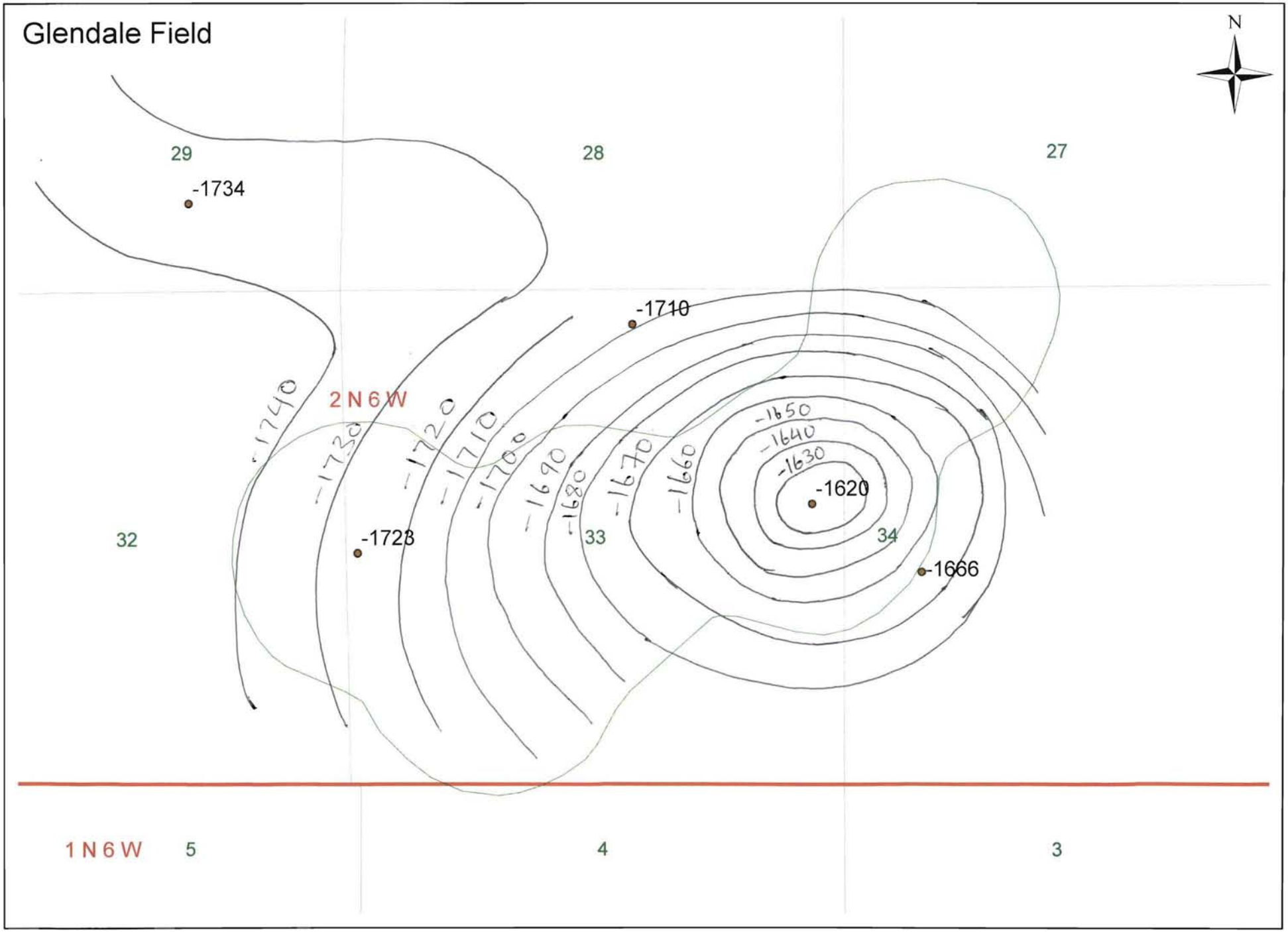

Figure 2: Structure map showing top of the Muscatatuck Limestone in Glendale Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

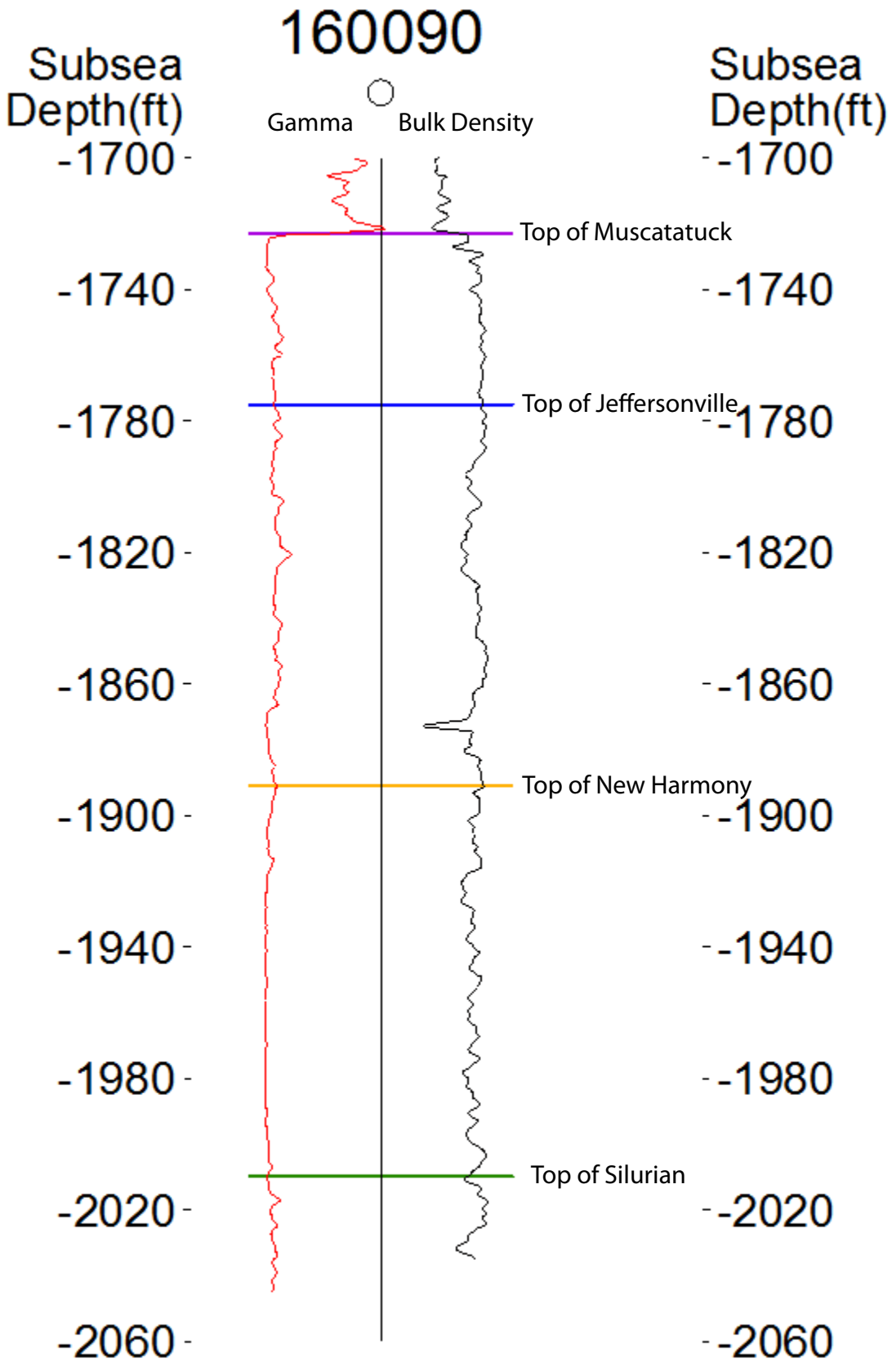

Figure 3: Type log section showing the Devonian formations from Glendale Field, Daviess County.

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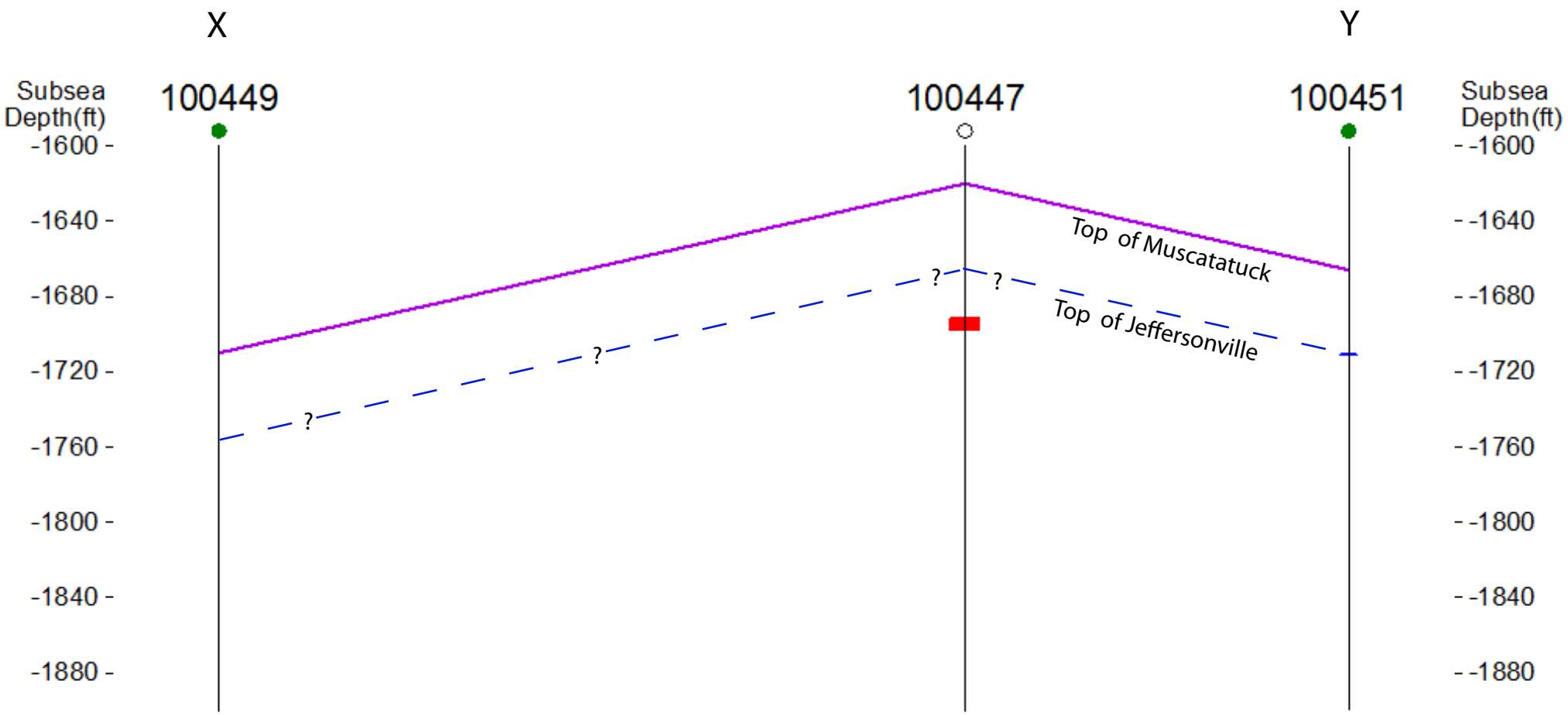

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Glendale Field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for gas production.

Table-1: List of the wells used for subsurface structure mapping in Glendale Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
100418	2	N	6	W	22	502	2130						
100426	2	N	6	W	29	481	2215	2263					
100447	2	N	6	W	33	559	2179						750
100449	2	N	6	W	33	541	2251						
160090	2	N	6	W	33	505	2228	2280		2396	2515		10
100451	2	N	6	W	34	521	2187	2232					

Field name: Griffin Consolidated

IGS ID: 10277

DOE ID: 291313

Location: Gibson &Posey Counties, 3S-13&14 W

Discovery date: 1938

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (4,870 ft.)

Field type: oil & natural gas

Total number production wells: 1,106 (oil), 4 (natural gas)

Area: 9,240 acres

Cumulative production: 84,162,274 bbls. (2002)

Other reservoir units:

Pennsylvanian

14 Mississippian reservoir units

Devonian/Mississippian, New Albany Shale

Deepest unit penetrated (depth): Ordovician, Black River Group (6,408 ft.)

Field characteristic: Anticline associated with Wabash Valley Fault System with structural closure in excess of 120 ft, at Mississippian, limited well data available at Devonian.

Reservoir characteristics:

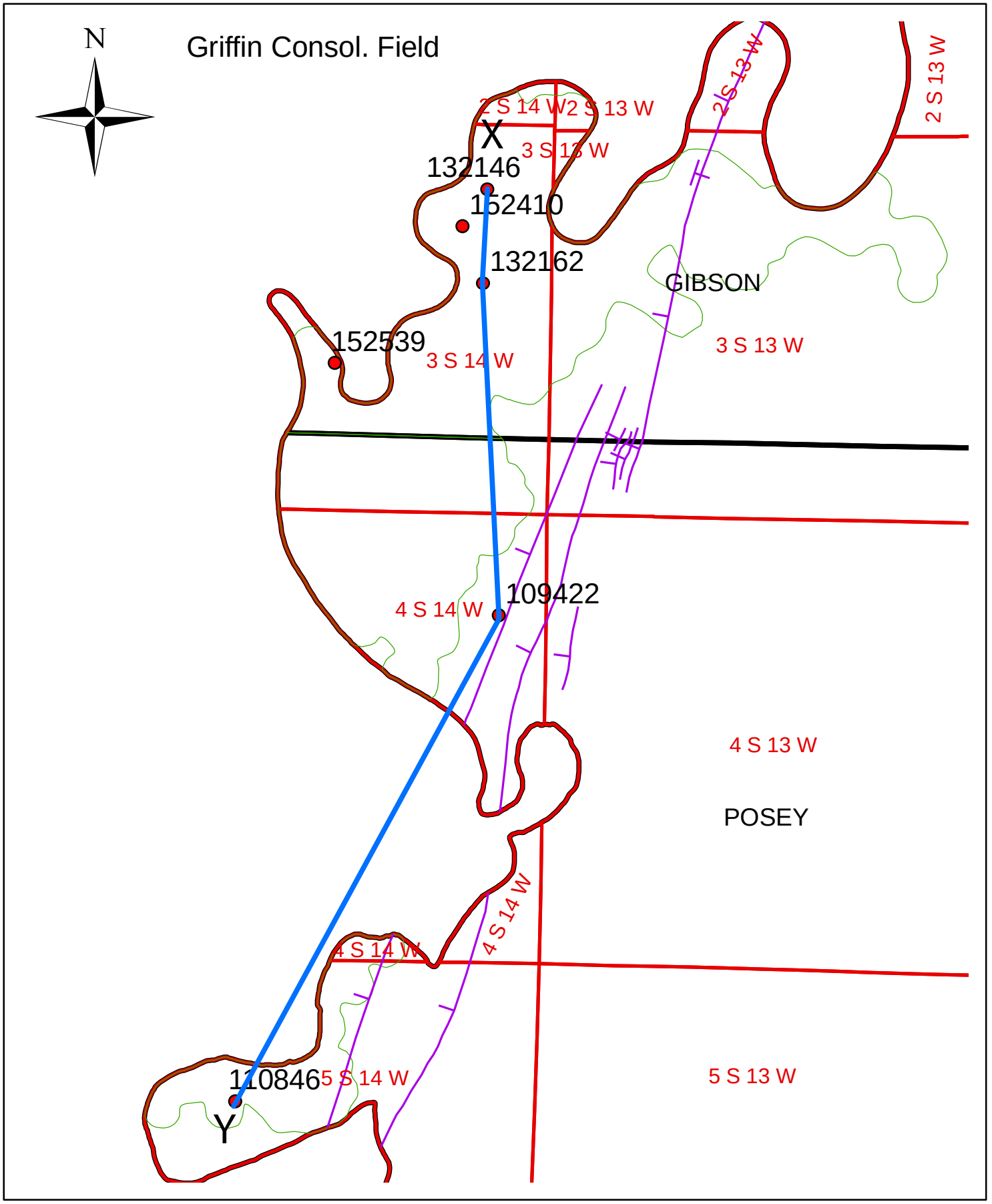

Figure 1: Map showing the location and wells at Griffin Consolidated Field, Gibson and Posey County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 3.

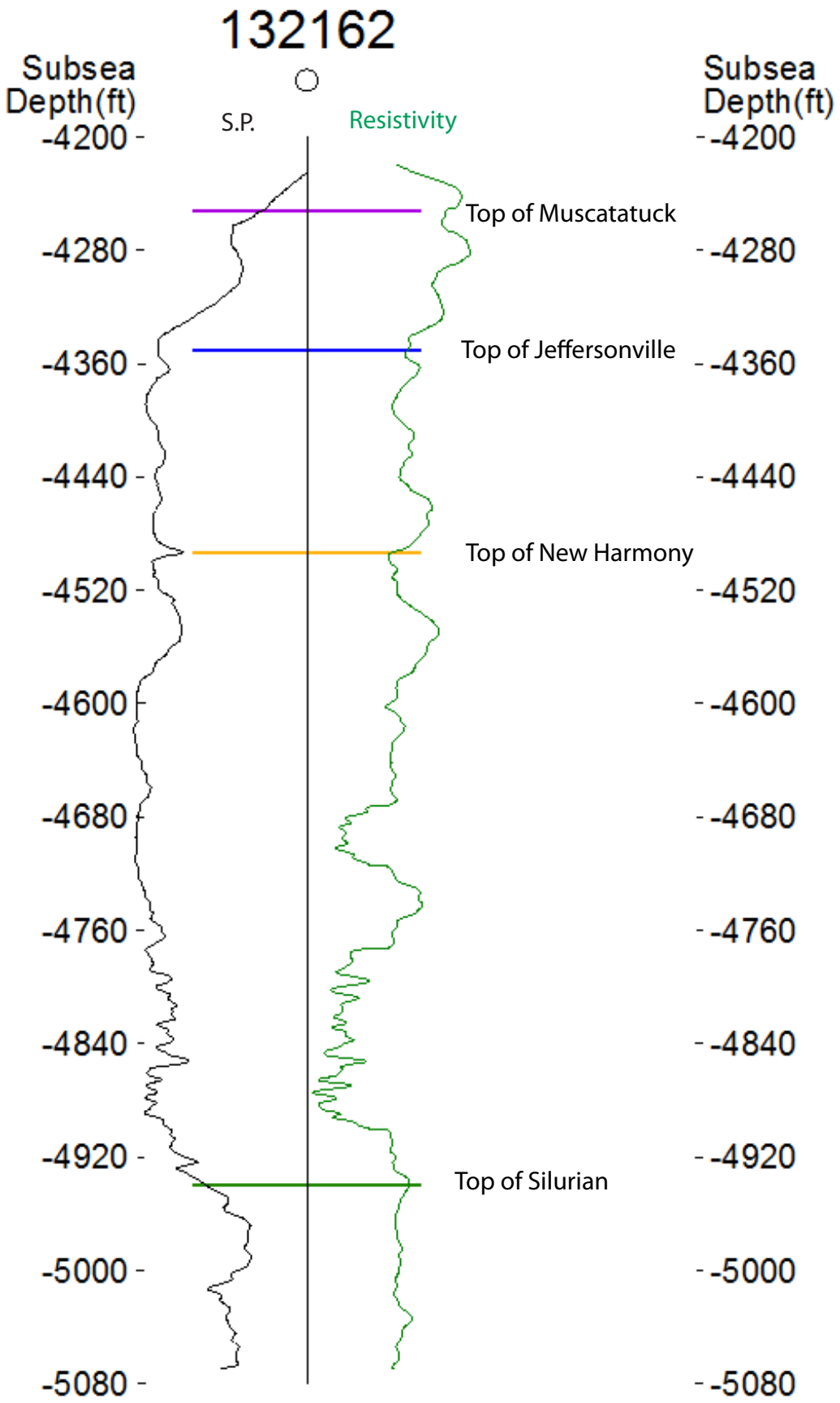

Figure 2: Type log section showing the Devonian formations at Griffin Consol. Field, Gibson and Posey County.

HS=1

PETRA 5/10/2005 8:36:36 PM (TYpeLog.CSP)

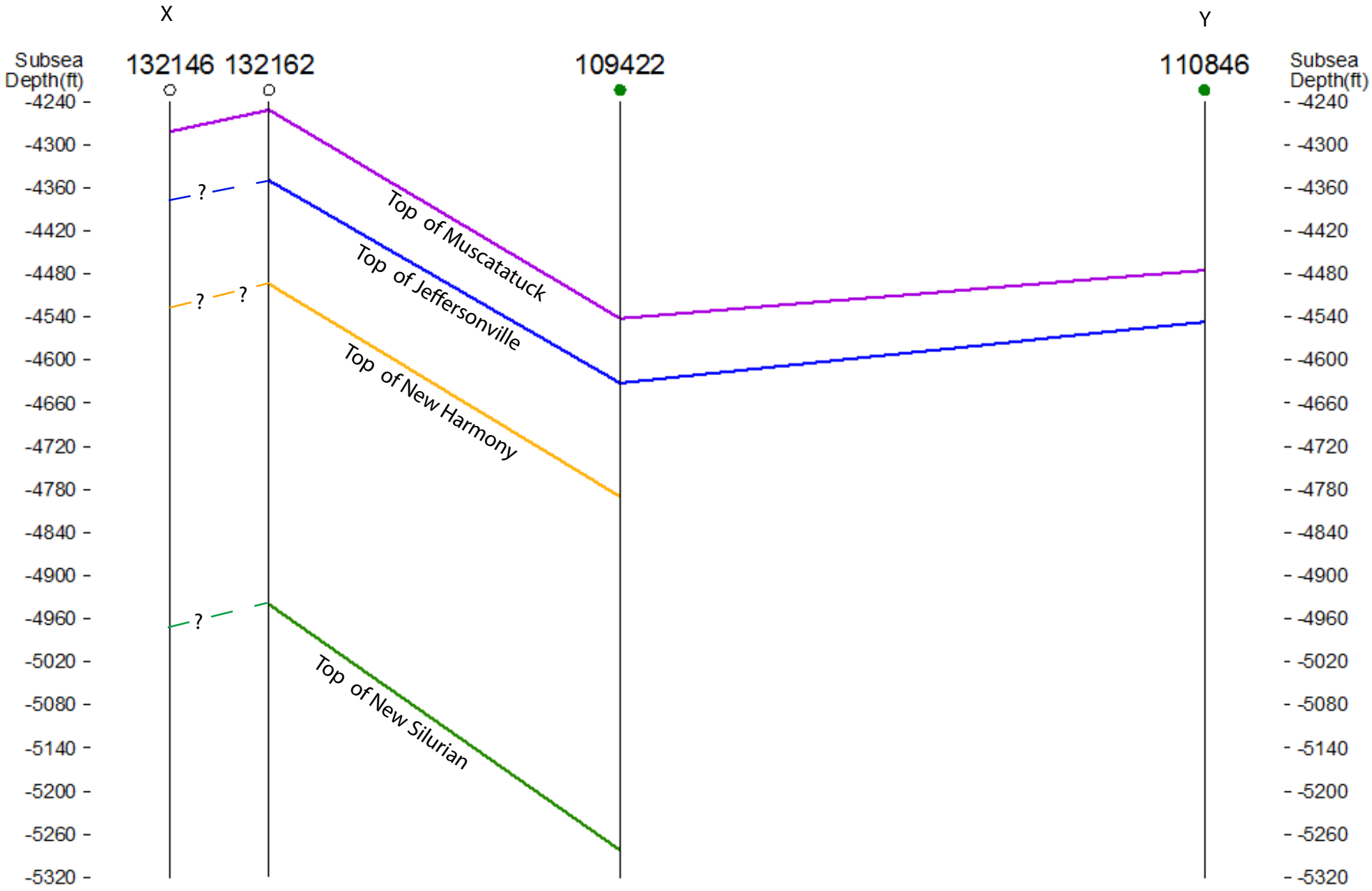

Figure 3: X-Y Cross section showing the Devonian subsurface structure across Griffin Consol. Field, Gibson and Posey Counties. For location of the cross section refer to Figure 1.

400

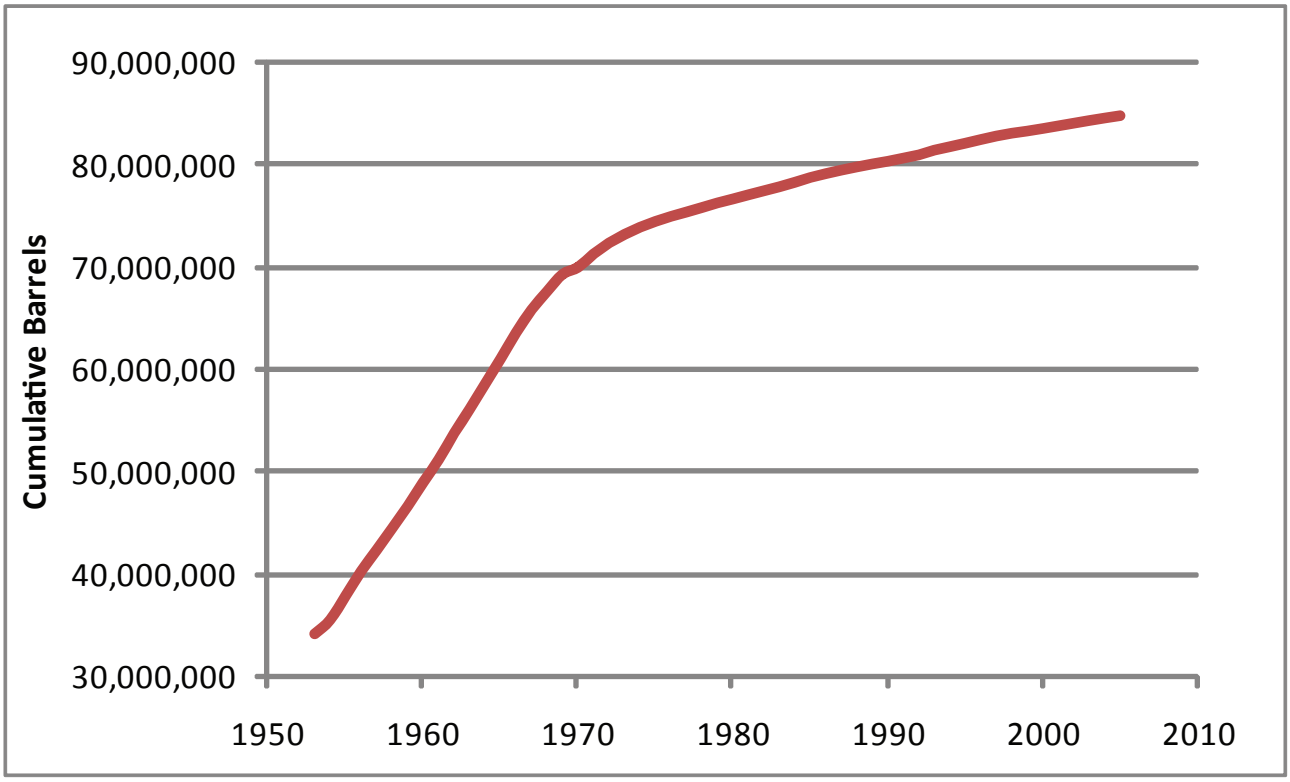

Figure - 4: Cumulative oil production history from Griffin Consol. Field, Gibson and Posey Counties since 1953.

Table-1: List of the wells used for subsurface structure mapping in Griffin Consol. field, Gibson and Posey Counties.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
132146	3	S	14	W	12	378	4660				7	
132162	3	S	14	W	13	380	4632	4730	4874	5320	11	
152410	3	S	14	W	14	384	4649	4734	4890		10	17
152539	3	S	14	W	27	374	4675	4772	4904		110	
109422	4	S	14	W	12	398	4940	5030	5188	5680		
110846	5	S	14	W	9	369	4844	4916				

Field name: Heltonville

IGS ID: 10300

DOE ID: na

Location: Lawrence County, 6N-1E

Discovery date: 1912

Lower Paleozoic reservoir unit (depth):

Devonian, Muscatatuck Group, (na)

Ordovician, Trenton Ls. (na)

Field type: natural gas (abandoned)

Total number production wells: 3

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Ordovician, Black River Group (1,780 ft.)

Field characteristic: Anticline adjacent to Mt. Carmel Fault with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

Field name: Howesville

IGS ID: 10310 (natural gas) 10832 (gas storage)

DOE ID: na

Location: Greene County, 8N-7W

Discovery date: 1952 natural gas, 1961 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,690 ft.)

Field type: natural gas & gas storage

Total number production wells: 10 (gas), 18 (storage), 7 (observation)

Area: 500 acres

Total capacity: 4,250,000 mcf

Other reservoir units: na

Deepest unit penetrated (depth): Cambrian/Ordovician, Knox Supergroup (3,527 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 60 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 16%

Average permeability – 35 md.

Approximate thickness – 70 ft.

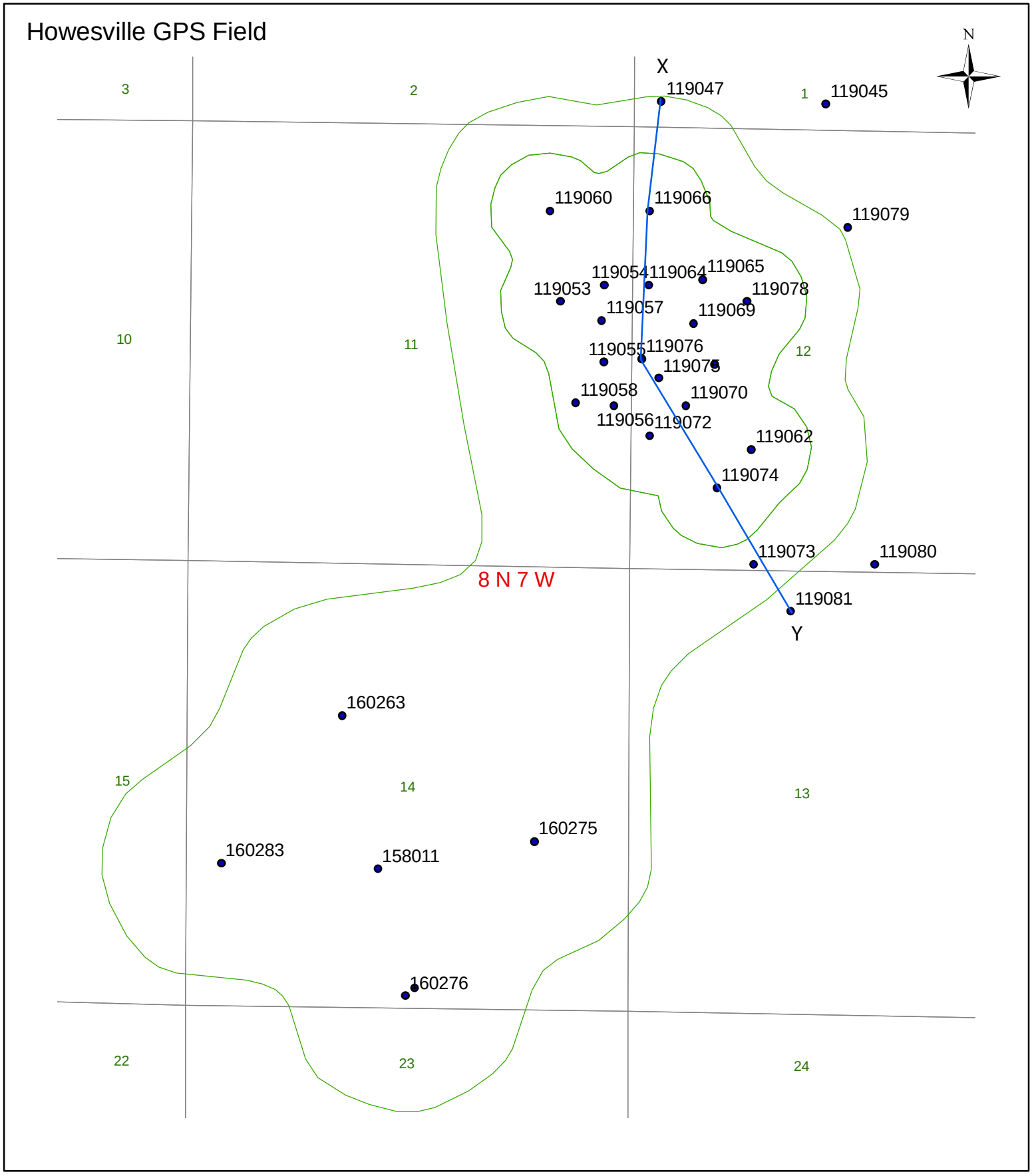

Figure 1: Map showing the location and wells at Howesville GSP Field, Greene County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 10). The wells depicted were used for subsurface mapping and had a total depth (TD) of Devonian or deeper .

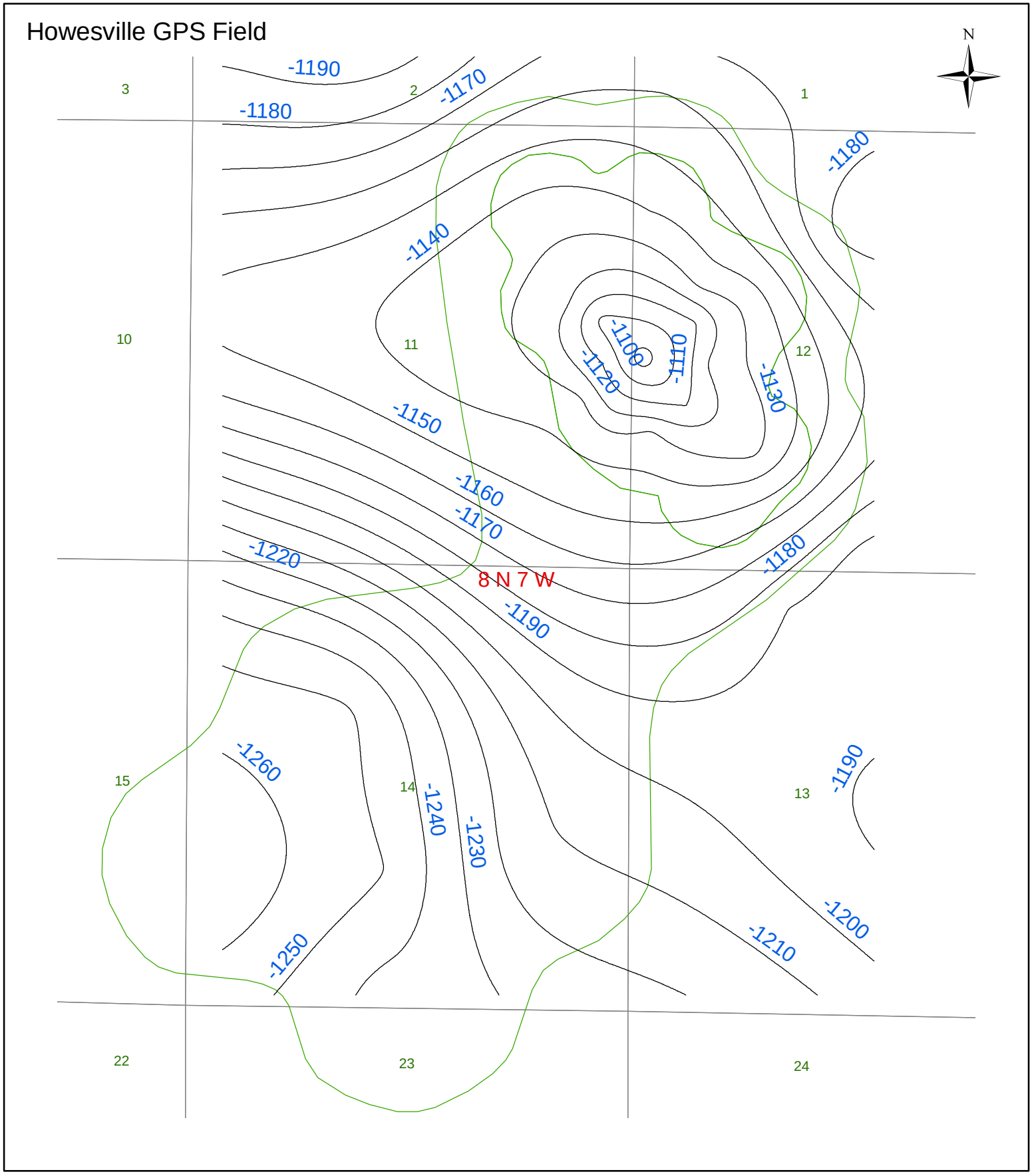

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Howesville GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

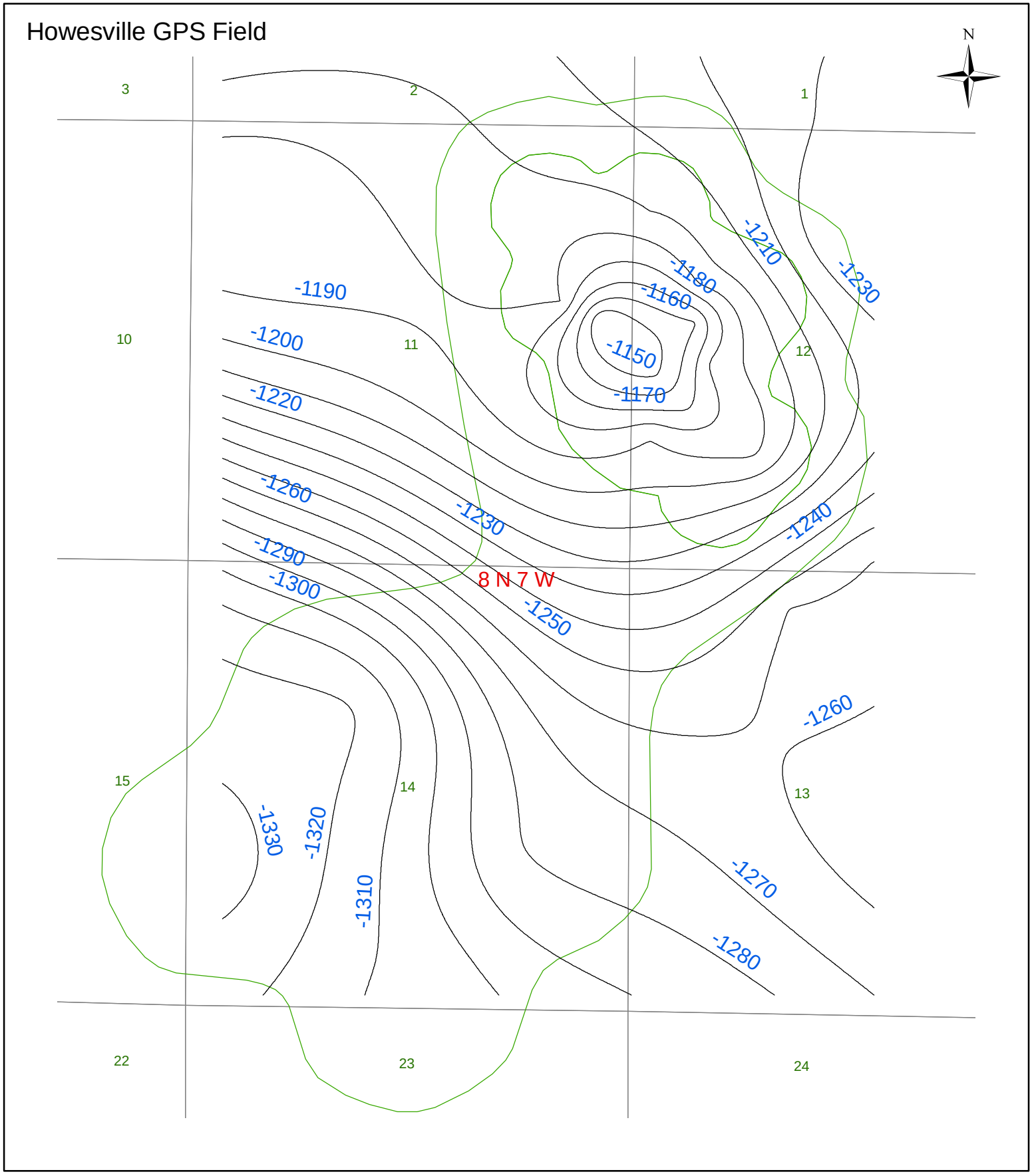

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Howesville GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

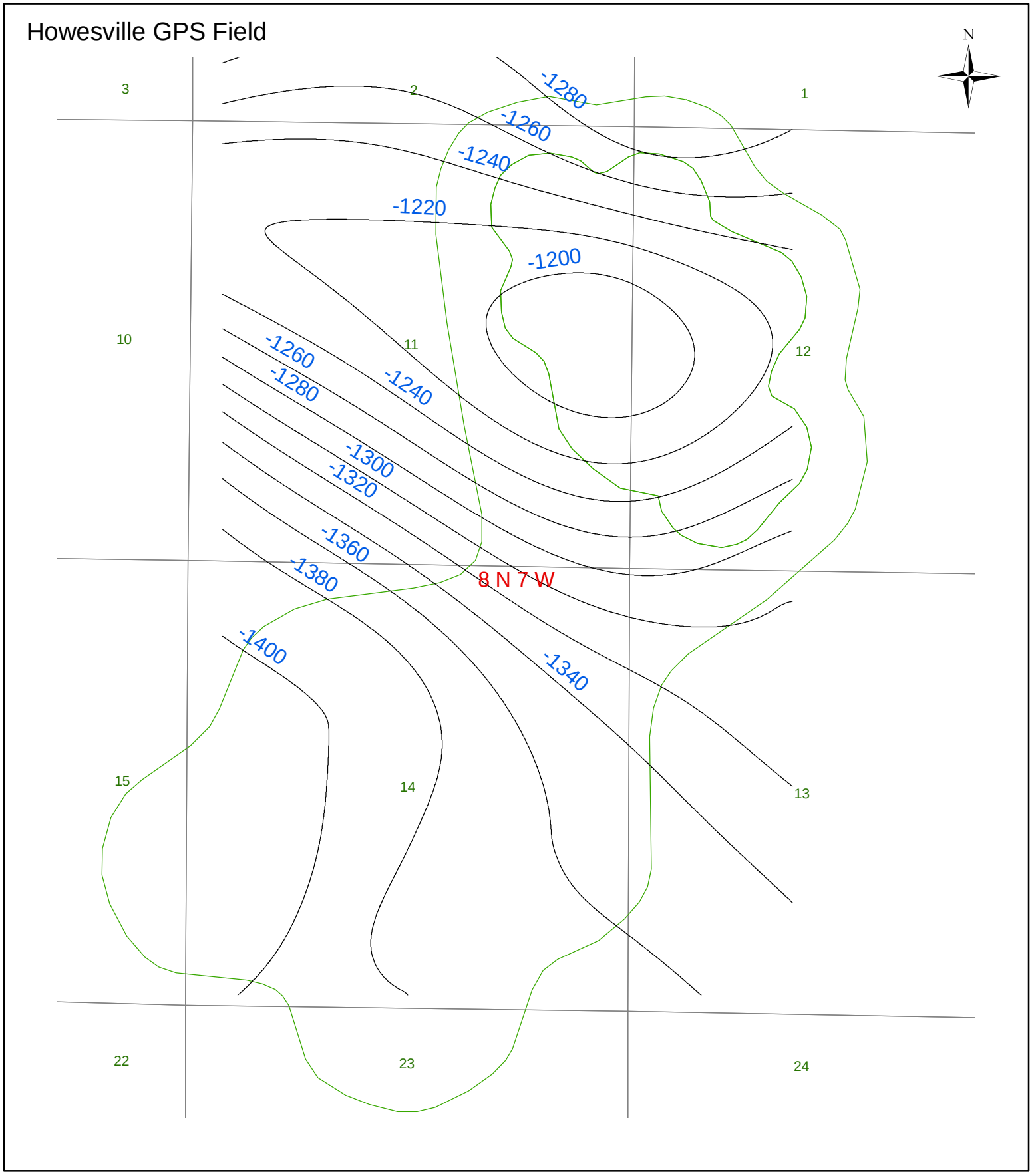

Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Mbr. in Howesville GSP Field, Greene County. Contours show values below sea level, contour interval is 20 ft .

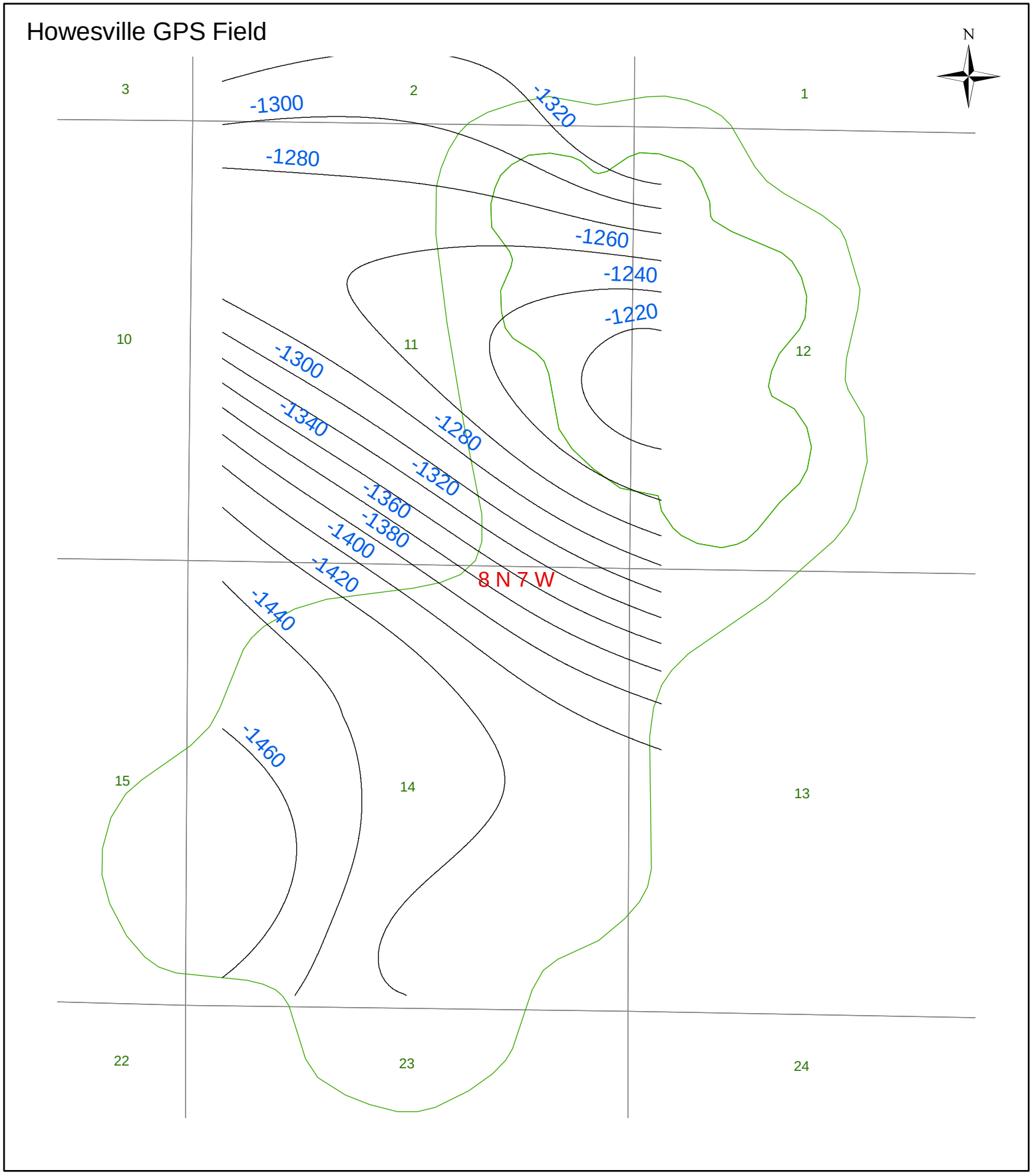

Figure 5: Structure map showing the top of the subsurface Silurian in Howesville GSP Field, Greene County. Contours show values below sea level, contour interval is 20 ft .

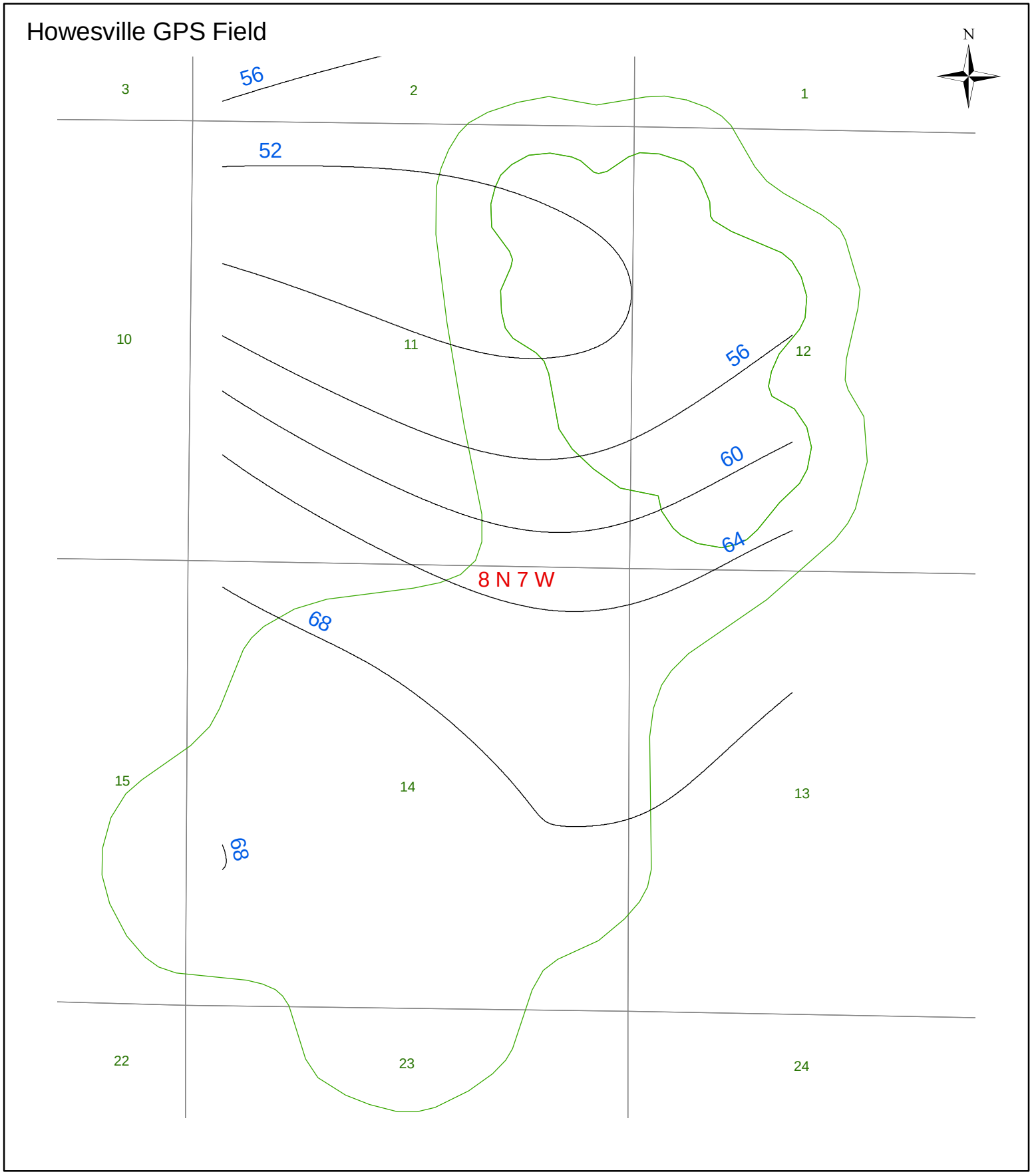

Figure 6: Map showing isopach of the North Vernon Ls. from Howesville GSP Field, Greene County. Contour interval is 4 ft.

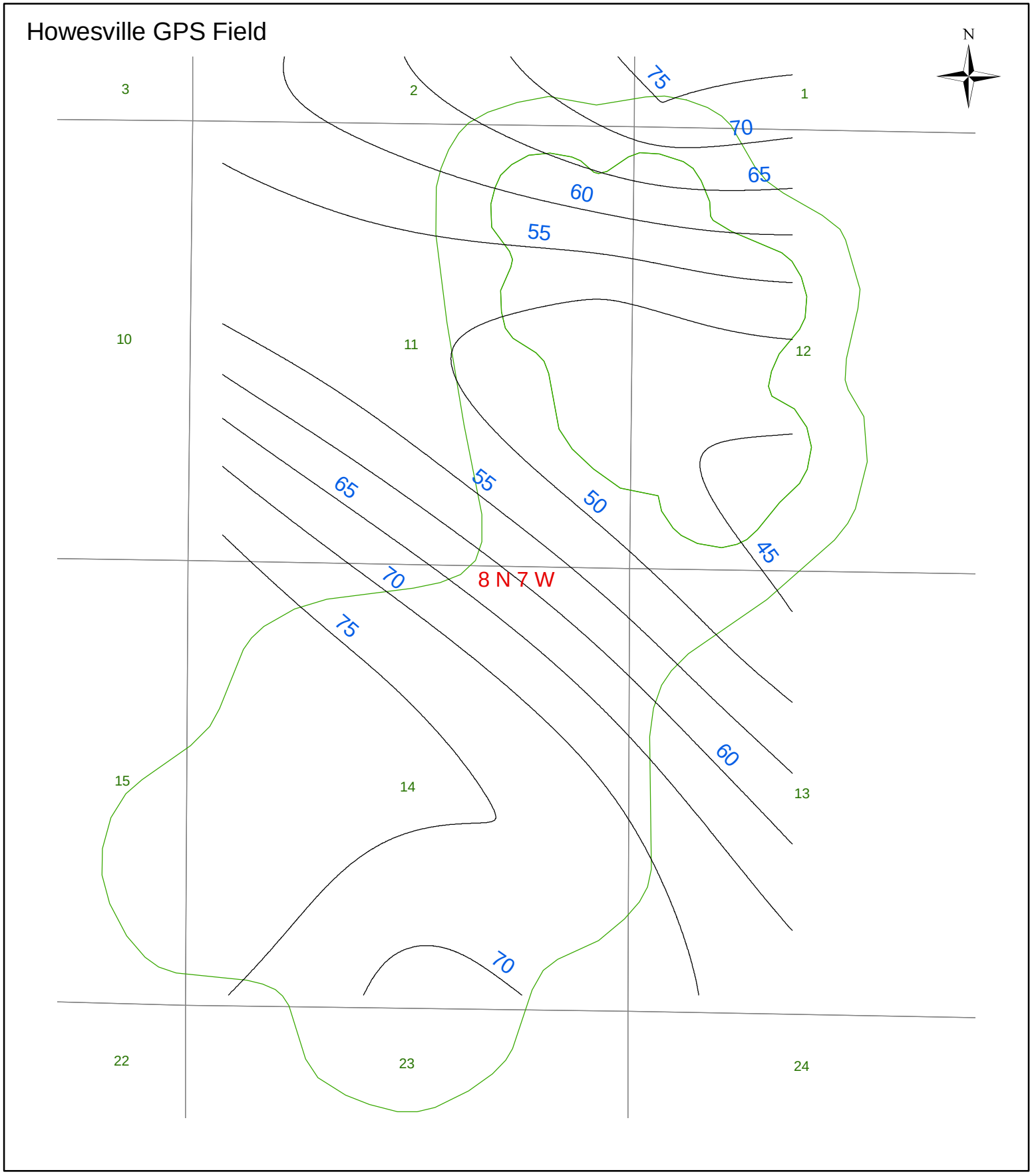

Figure 7: Map showing isopach of the Vernon Fork Member from Howesville GSP Field, Greene County. Contour interval is 5 ft.

A

B

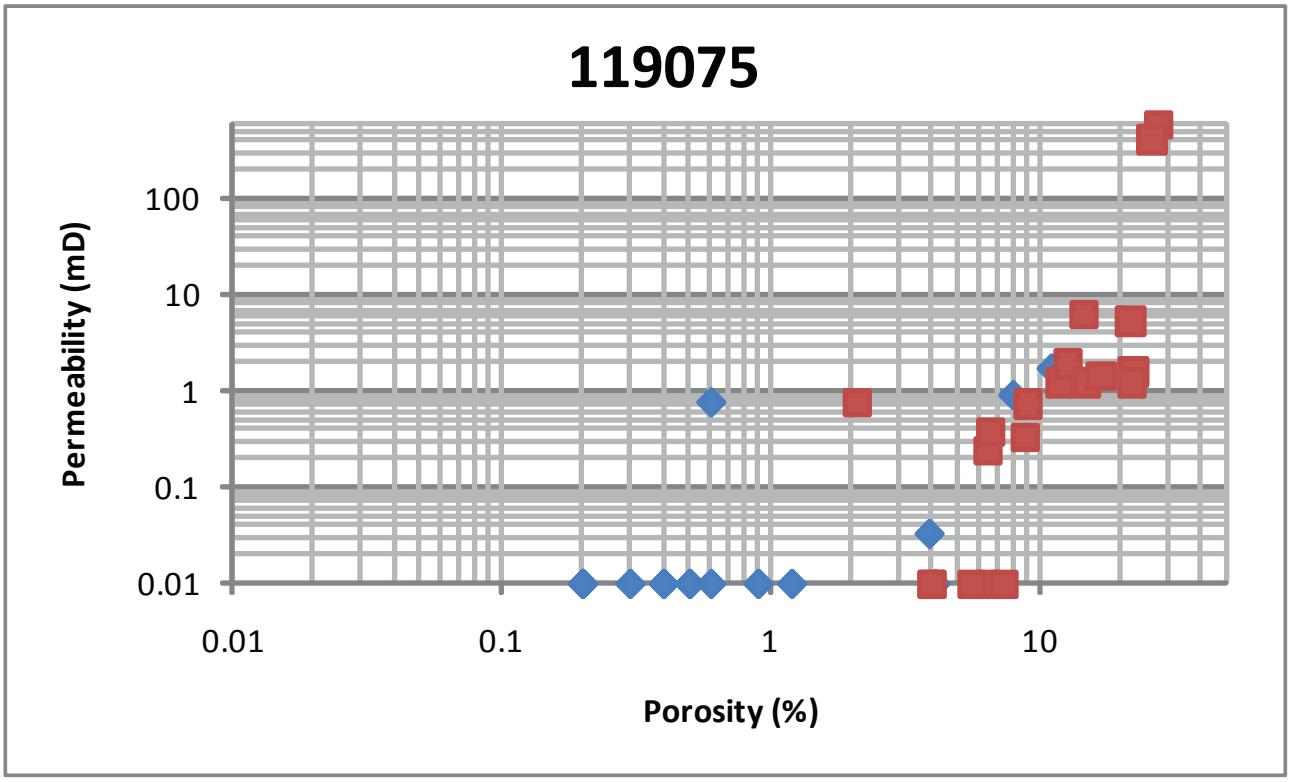

Figure 8: Porosity and permeability plot fromcore analysis of the Muscatatuck at Howesville GSP Field, Greene County. For the well locations see Figure 1. The blue points are the data from North Vernon and the red and green points are from the Jeffersonville. The chart titles list the IGS Well ID.

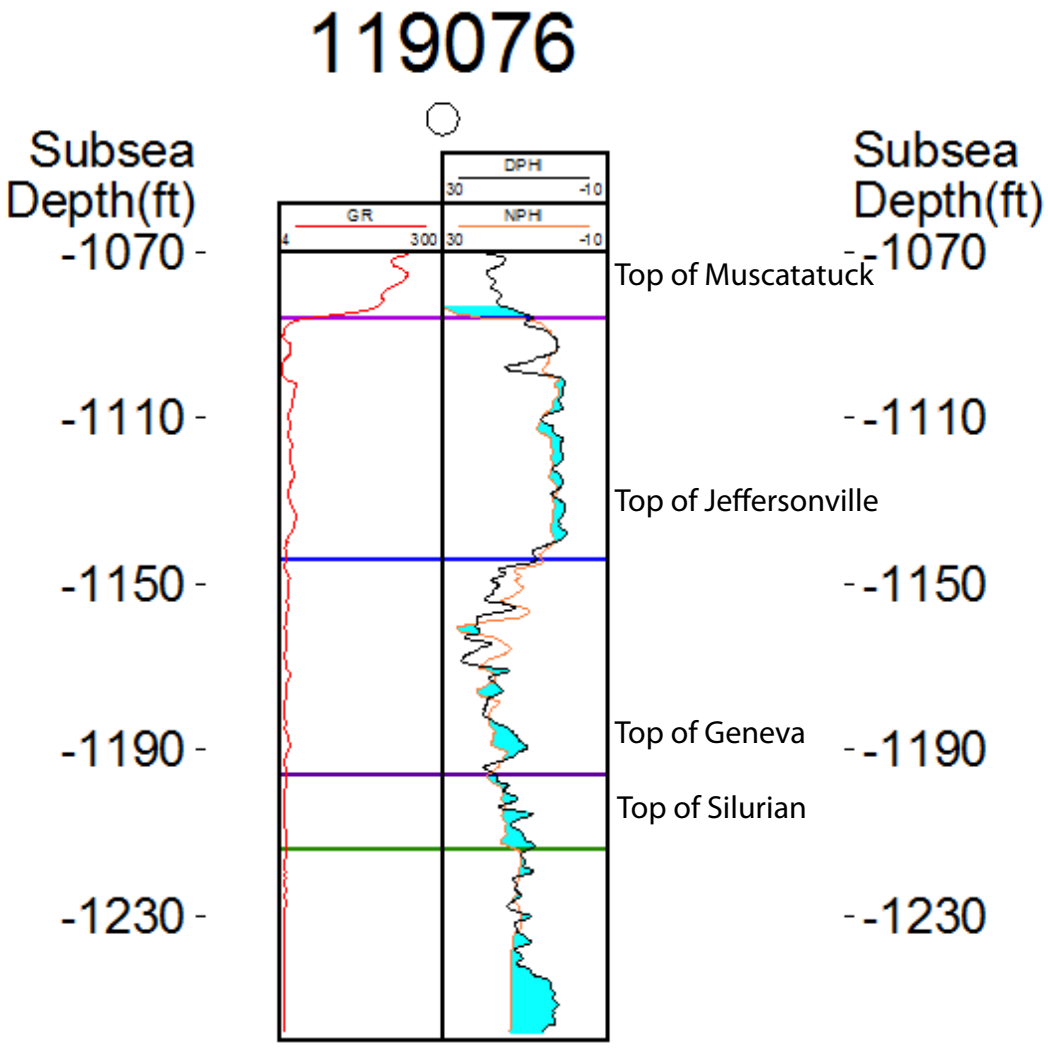

Figure 9: Type log section showing the Devonian formations from Howesville GS Field, Greene County.

HS=1

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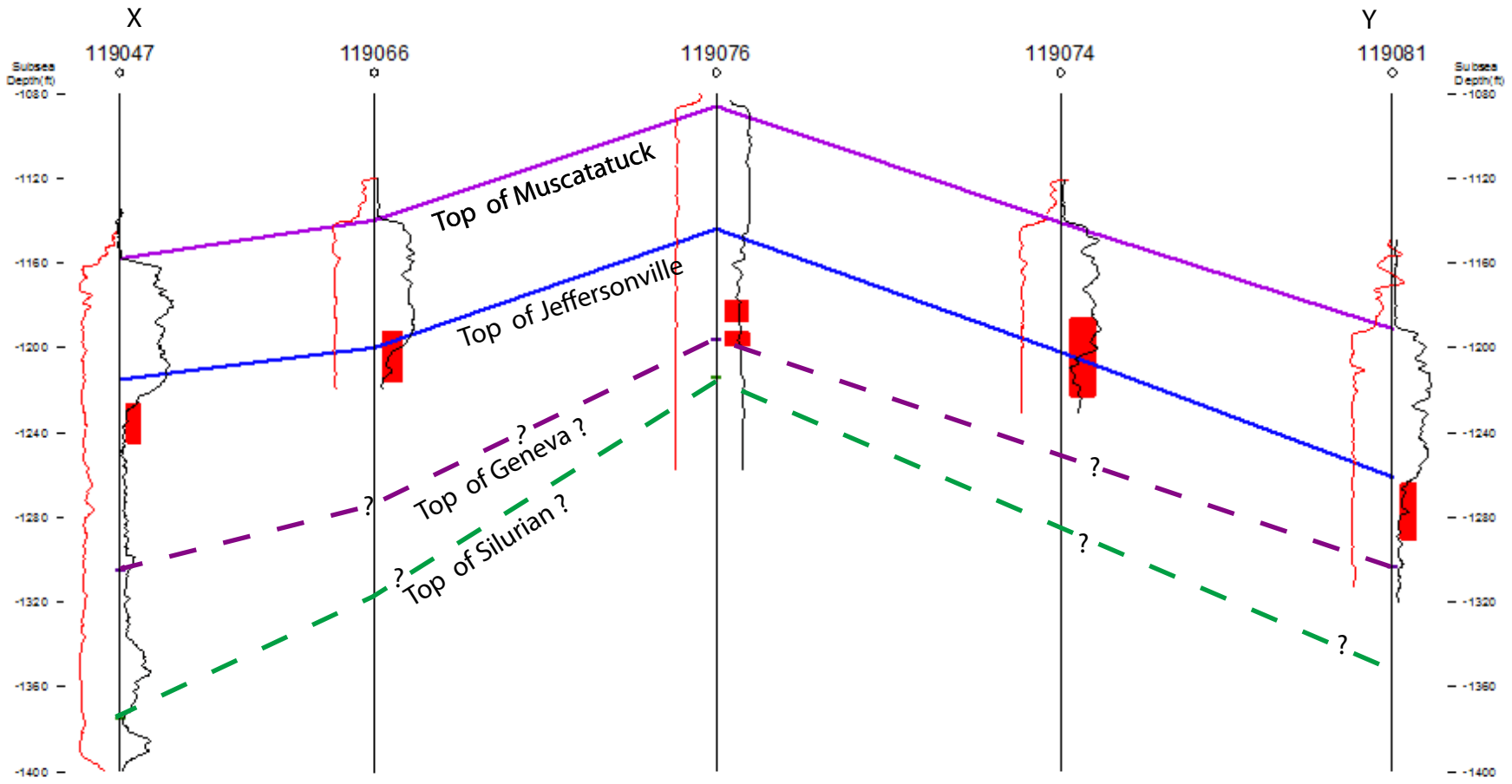


Figure 10: X-Y Cross section showing the Devonian subsurface structure across Howesville GSP Field, Greene County. The red color box shows the completion intervals for the gas storage, production or observation. For location of the cross section refer to Figure 1.

PETRA 4/15/2005 1:09:12 PM (xy-CSP)

Table-1: List of the wells used for subsurface structure mapping in Howesville GSP Field, Greene County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Gas_P (mcf)	Core	Core Analysis
119045	8	N	7	W	1	525	1699	1756					
119047	8	N	7	W	1	545	1703	1760	1850	1920			
119048	8	N	7	W	1	561	1733			1874			
119088	8	N	7	W	2	540	1735	1800	1849	1890			
119091	8	N	7	W	2	572	1775						
119053	8	N	7	W	11	540	1664	1730					
119054	8	N	7	W	11	535	1650	1706					
119055	8	N	7	W	11	544	1653						
119056	8	N	7	W	11	545	1662						
119057	8	N	7	W	11	539	1637	1680		1766	1000		
119058	8	N	7	W	11	548	1682				1000		
119060	8	N	7	W	11	540	1675	1736			250		
119062	8	N	7	W	12	538	1665	1725					
119064	8	N	7	W	12	533	1650	1704					
119065	8	N	7	W	12	536	1671	1730					
119066	8	N	7	W	12	530	1670	1730					
119069	8	N	7	W	12	537	1646	1696					Present
119070	8	N	7	W	12	540	1650	1708			300		
119071	8	N	7	W	12	534	1658	1718					
119072	8	N	7	W	12	537	1670	1726					
119073	8	N	7	W	12	541	1712	1776					
119074	8	N	7	W	12	529	1670	1731					
119075	8	N	7	W	12	541	1638	1692				Present	Present
119076	8	N	7	W	12	542	1628	1686	1729	1748			
119078	8	N	7	W	12	527	1660						
119079	8	N	7	W	12	533	1718	1778					
119080	8	N	7	W	12	562	1760	1823					
119081	8	N	7	W	13	551	1742	1812	1853				
157932	8	N	7	W	14	586	1823	1894	1940	1980			
158011	8	N	7	W	14	597	1848						
160263	8	N	7	W	14	628	1880	1950	2027	2068			
160275	8	N	7	W	14	579	1791	1857	1940	1995			
160276	8	N	7	W	14	593	1827	1900	1980	2016			
160283	8	N	7	W	14	594	1862	1928	2014	2079			

Field name: Leesville

IGS ID: 10373 (natural gas) 10810 (gas storage)

DOE ID: na

Location: Lawrence County, 5N-1&2E

Discovery date: 1918 (natural gas), 1956 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, na, (850 ft.)

Field type: natural gas & gas storage

Total number production wells: 2 (gas), 48 (storage), 19 (observation)

Area: 6,080 acres

Total capacity: 4,775,000 mcf

Other reservoir units: na

Deepest unit penetrated (depth): Precambrian (6,806 ft.)

Field characteristic: Anticline adjacent to Mt. Carmel Fault with structural closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 12%

Average permeability – na

Approximate thickness – 30 ft.

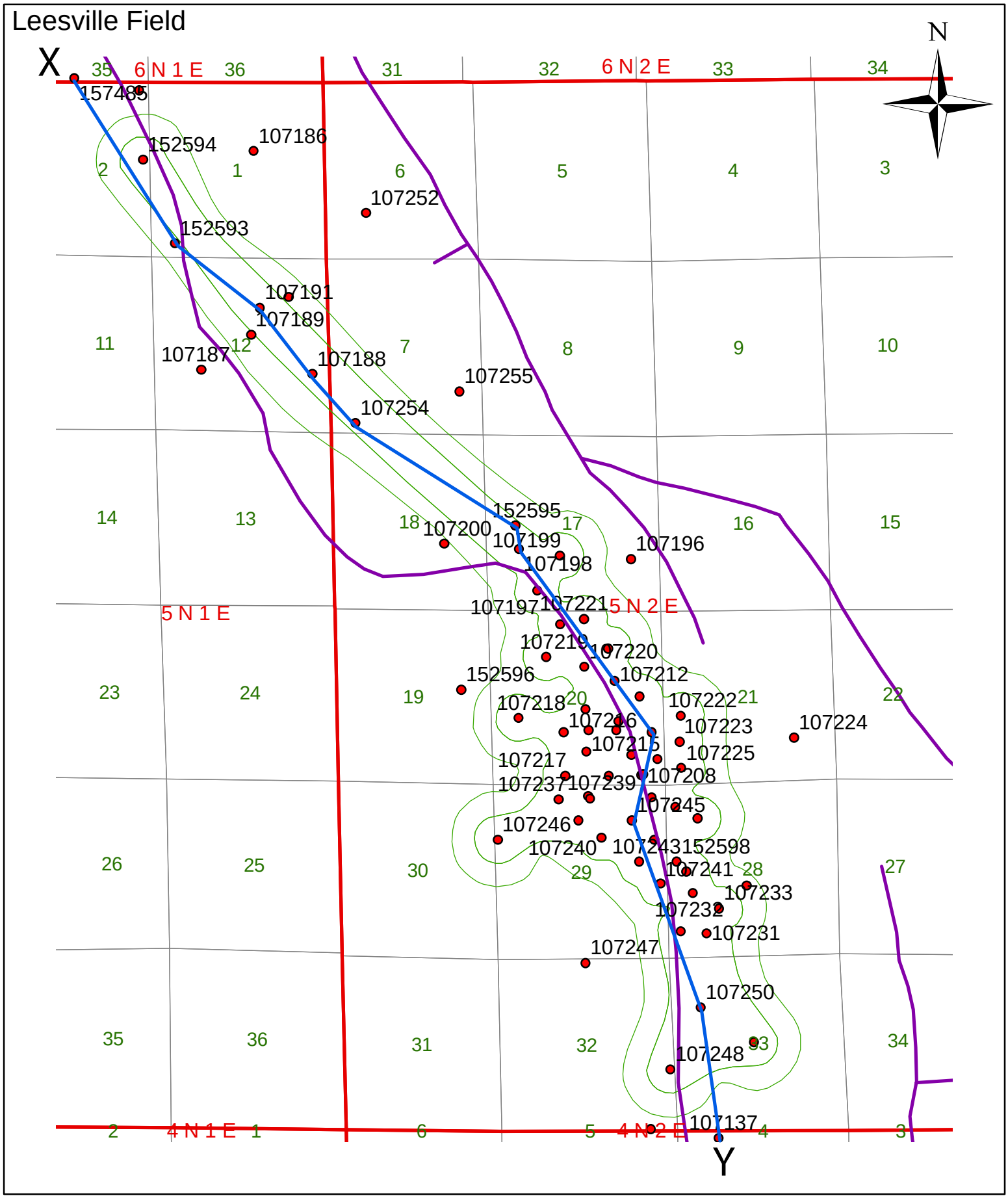


Figure 1: Map showing location and wells at Leesville Field, Lawrence County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 10. Traces of the Mt. Carmel fault are also shown.

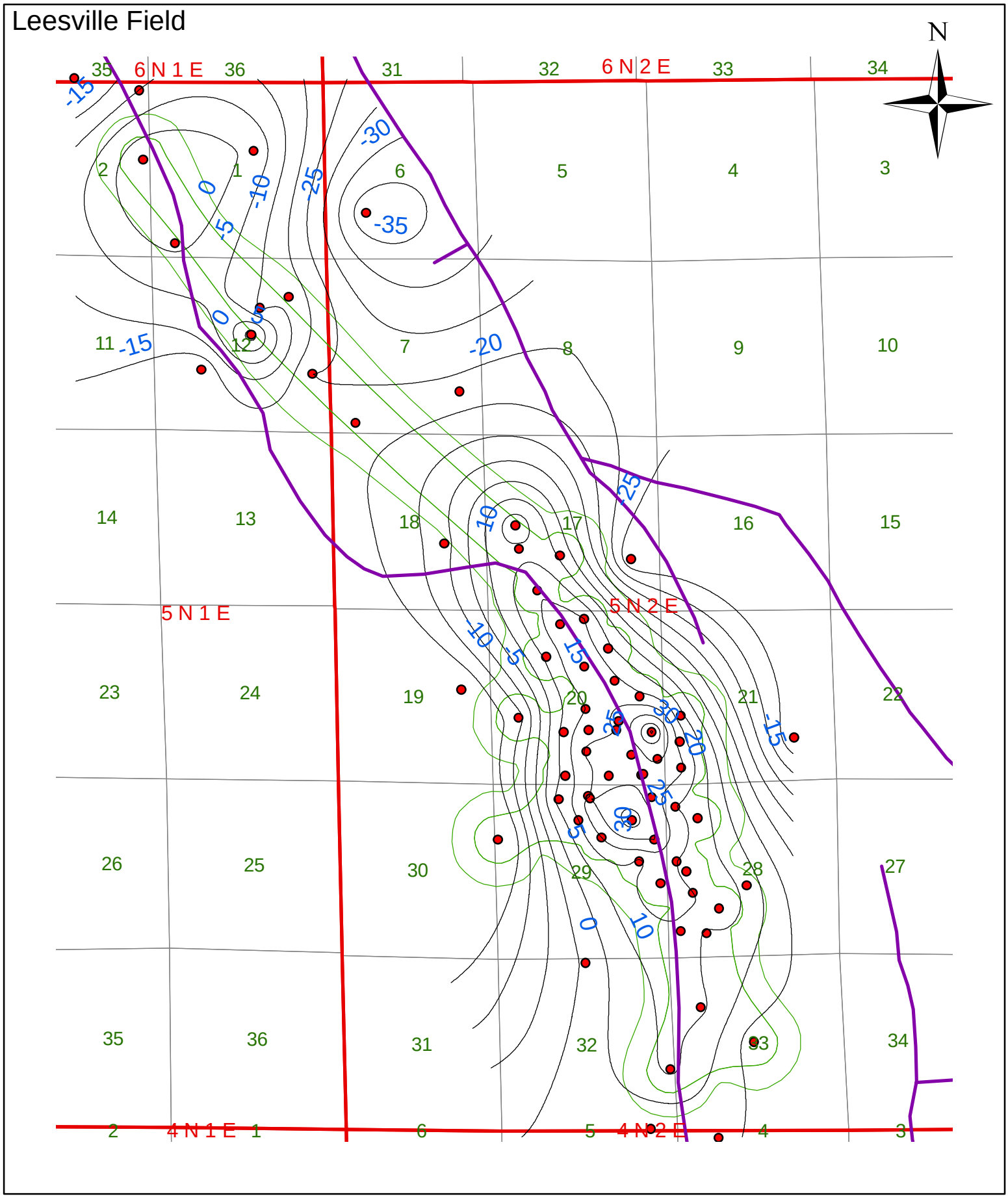


Figure 2: Structure map showing the top of the Muscatatuck Limestone in the Leesville Field, Lawrence County. Contours show values below sea level, contour interval is 5 ft .

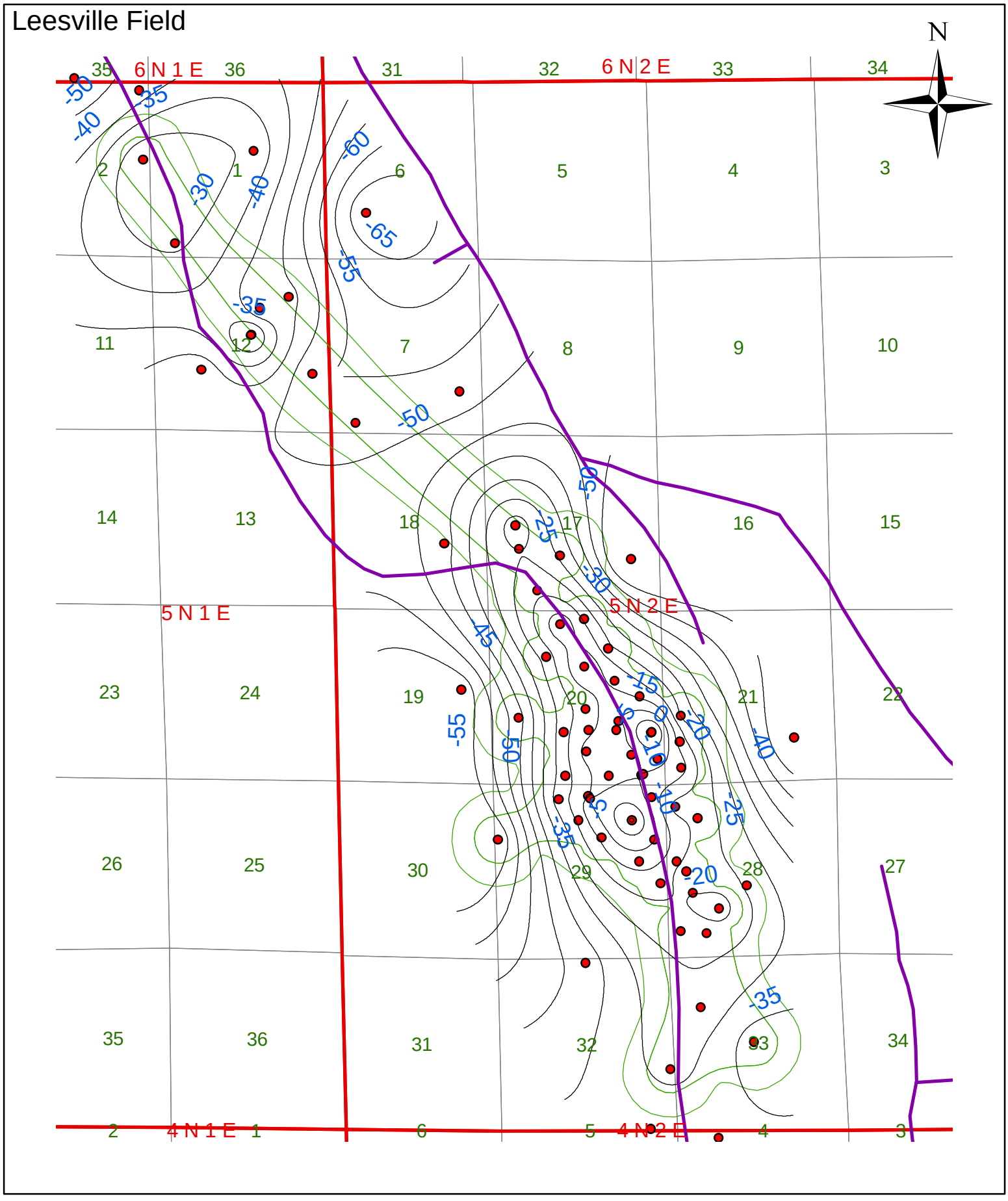


Figure 3: Structure map showing the top of the Jeffersonville Limestone in the Leesville Field, Lawrence County. Contours show values below sea level, contour interval is 5 ft .

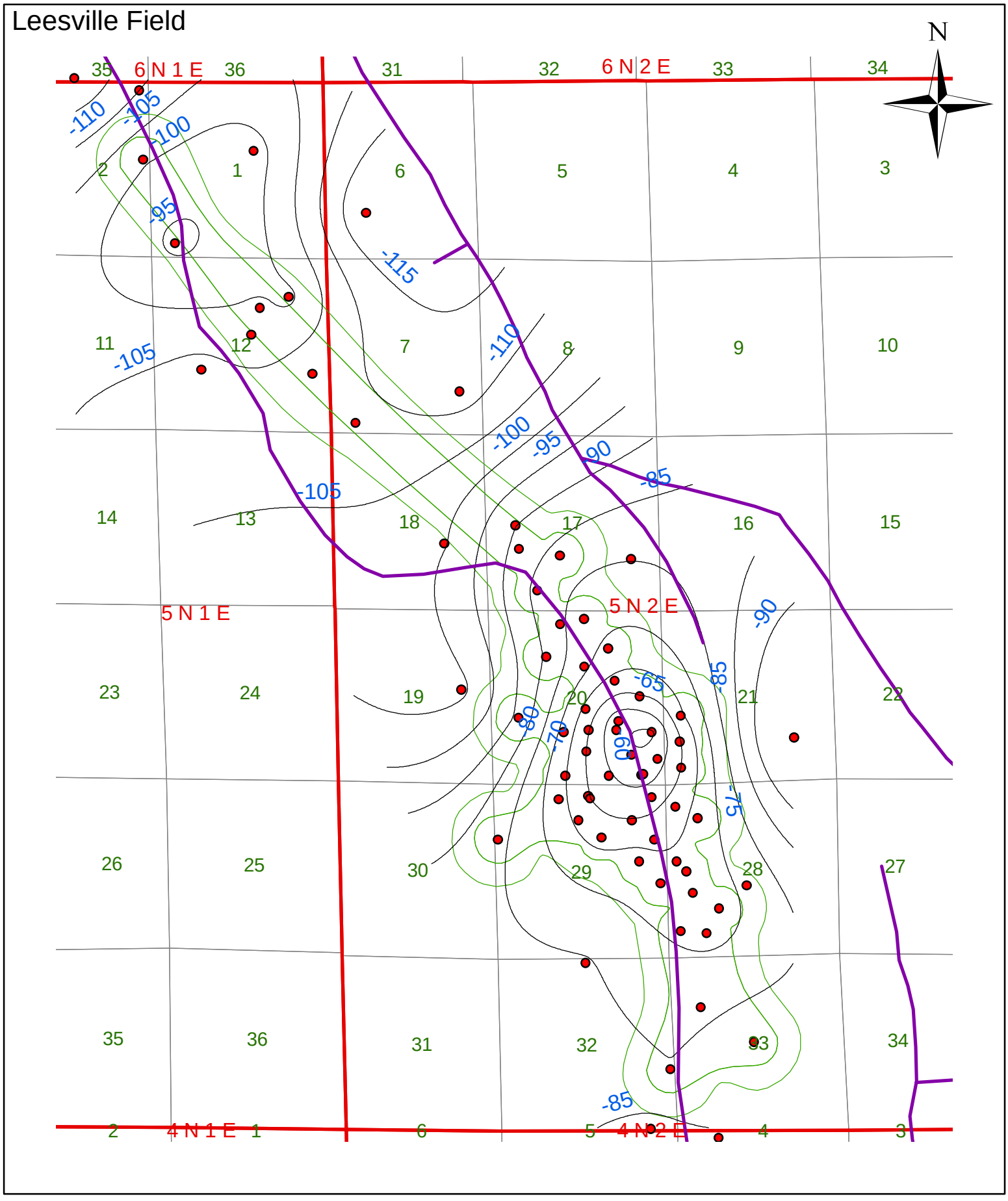


Figure 4: Structure map showing the top of the Geneva Dolomite Member in the Leesville Field, Lawrence County. Contours show values below sea level, contour interval is 5 ft .

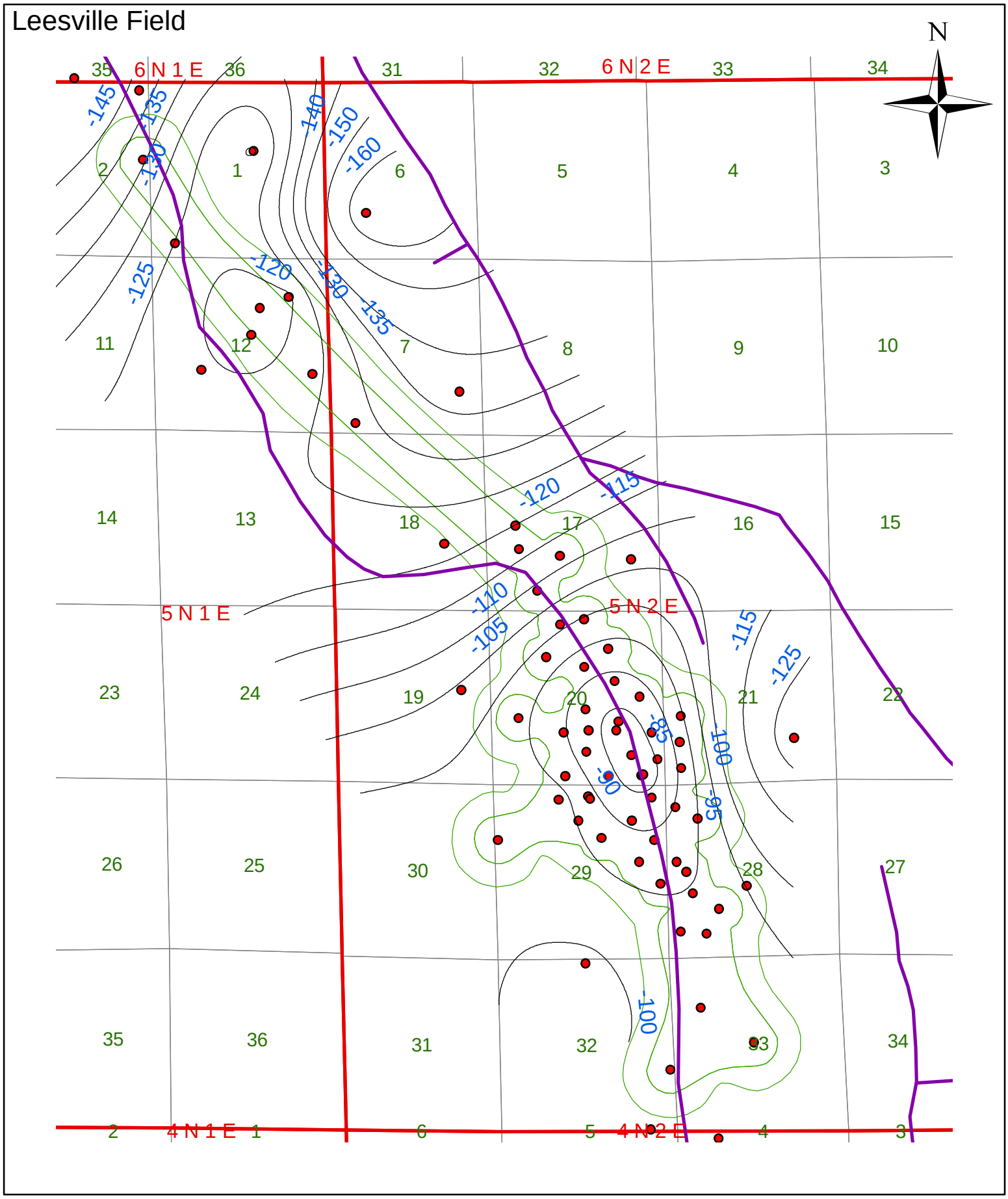


Figure 5: Structure map showing the top of the Silurian in the Leesville Field, Lawrence County. Contours show values below sea level, contour interval is 5 ft .

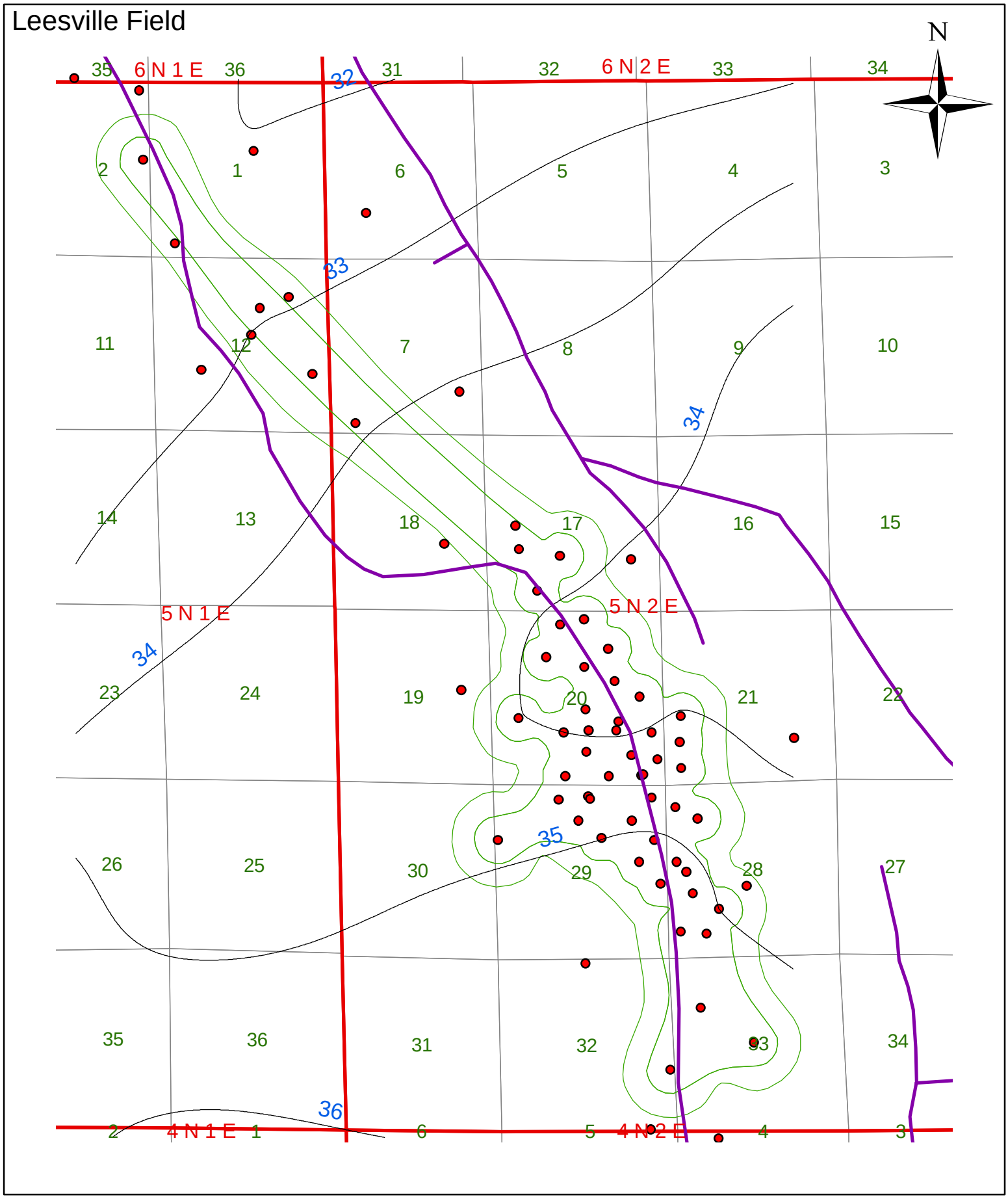


Figure 6: Isopach map showing the thickness of the North Vernon Member in the Leesville Field, Lawrence County. Contour interval is 10 ft .

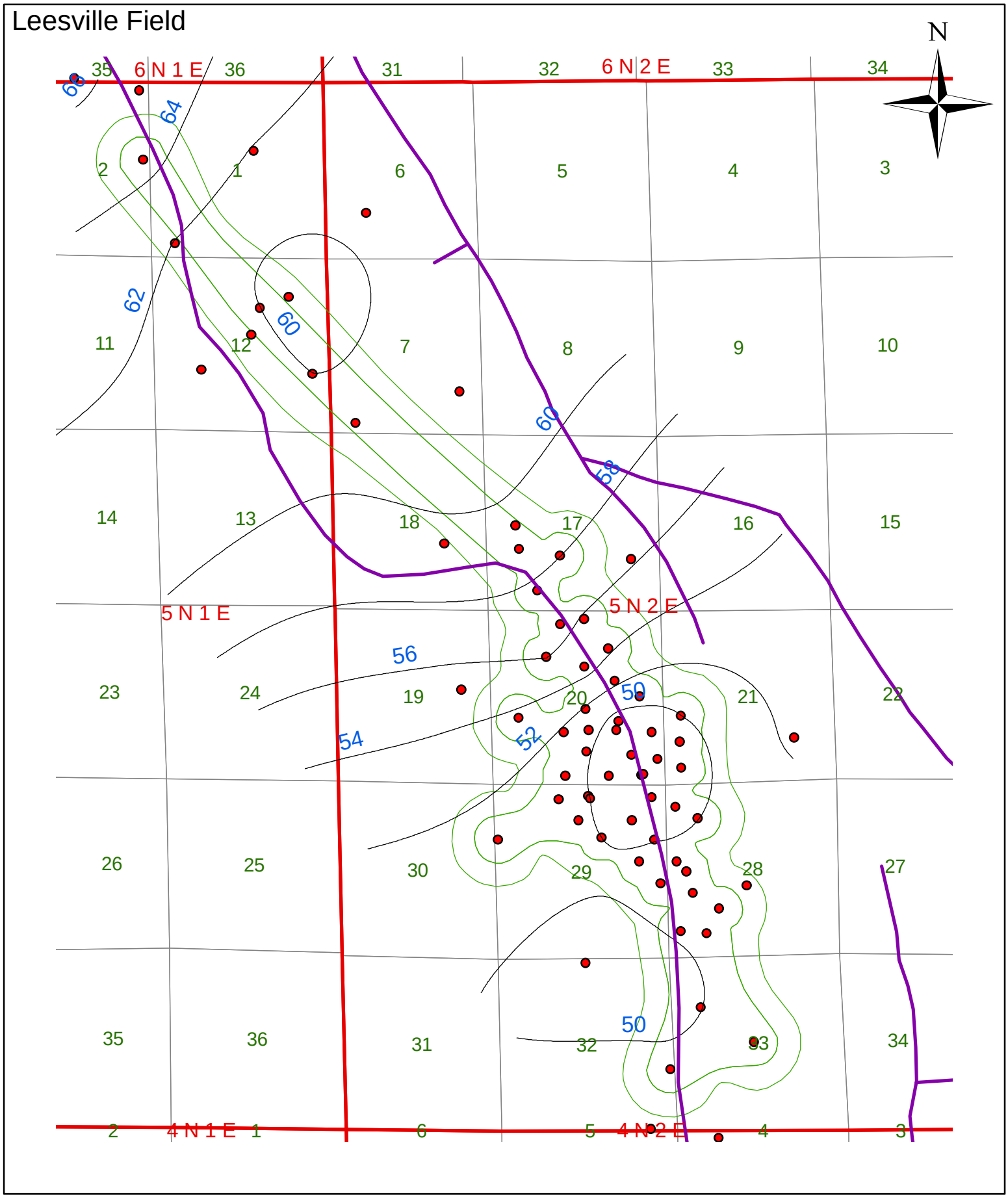


Figure 7: Isopach map showing the thickness of the Vernon Fork Member in the Leesville Field, Lawrence County. Contours interval is 20 ft .

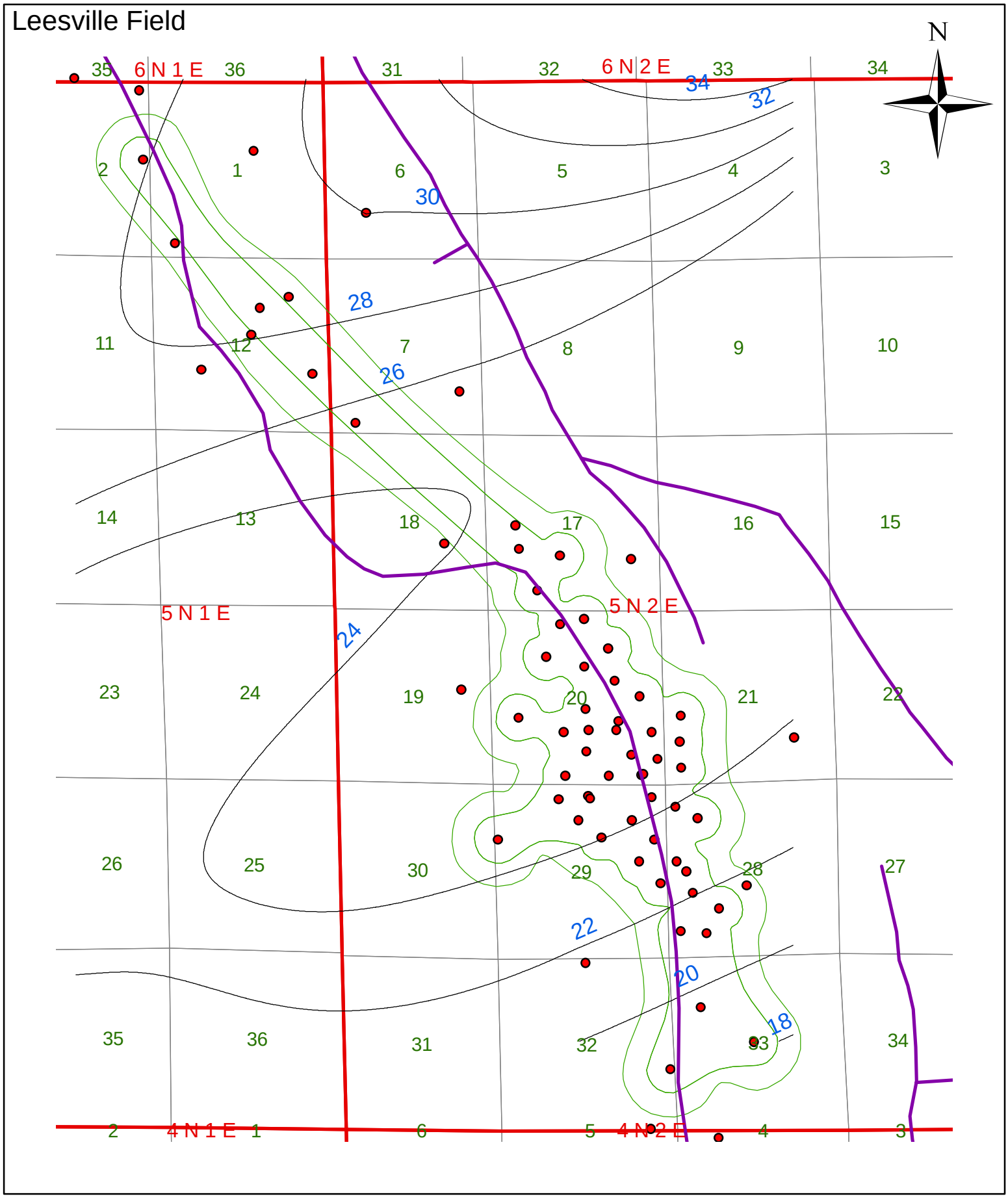


Figure 8: Isopach map showing the thickness of the Geneva Dolomite Member in the Leesville Field, Lawrence County. Contours interval is 20 ft .

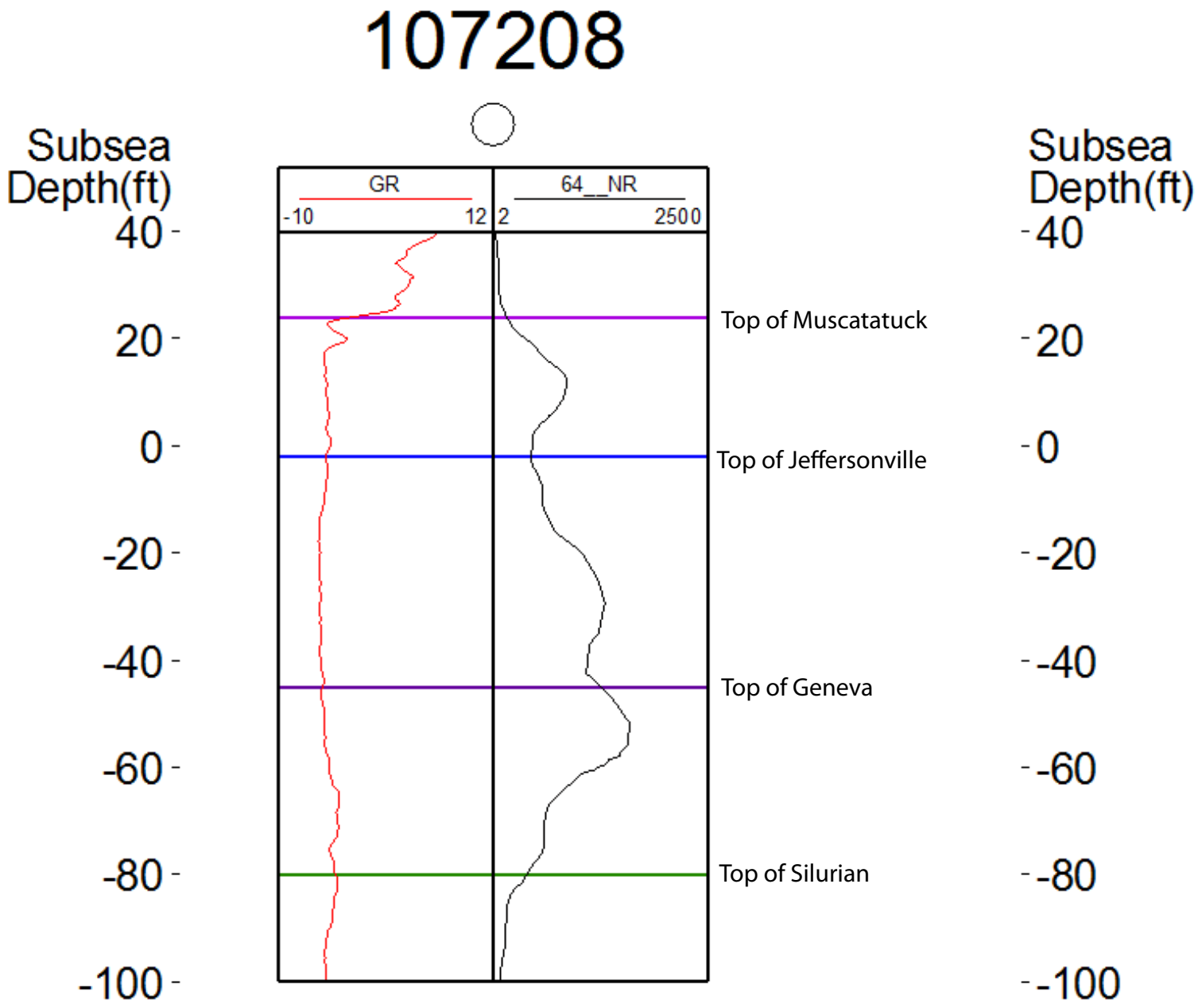


Figure 9: Type log section showing the Devonian formations at the Leesville field, Lawrence County.

HS=1

PETRA 7/3/2008 11:15:10 AM (TypeLog.CSP)

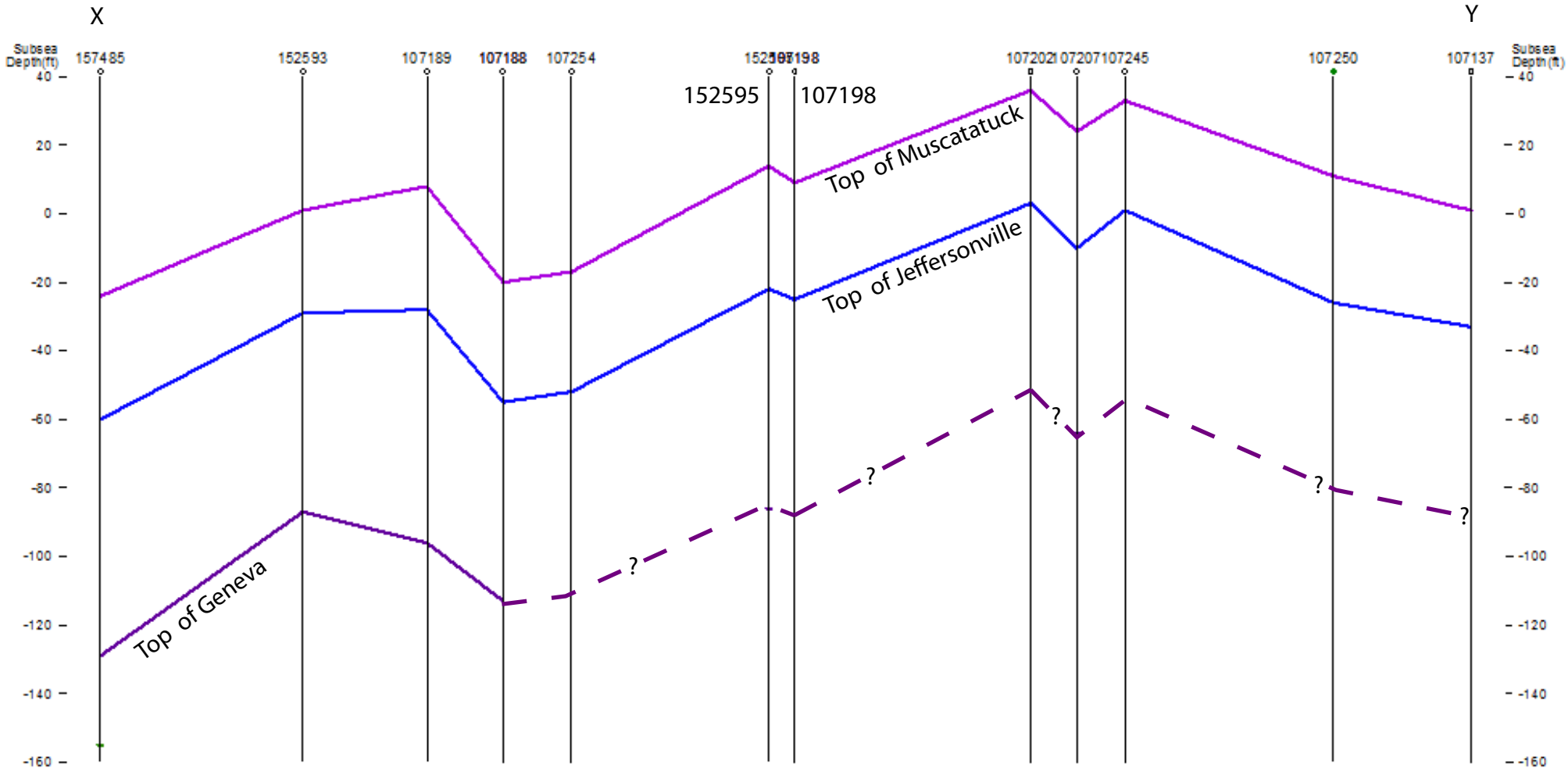
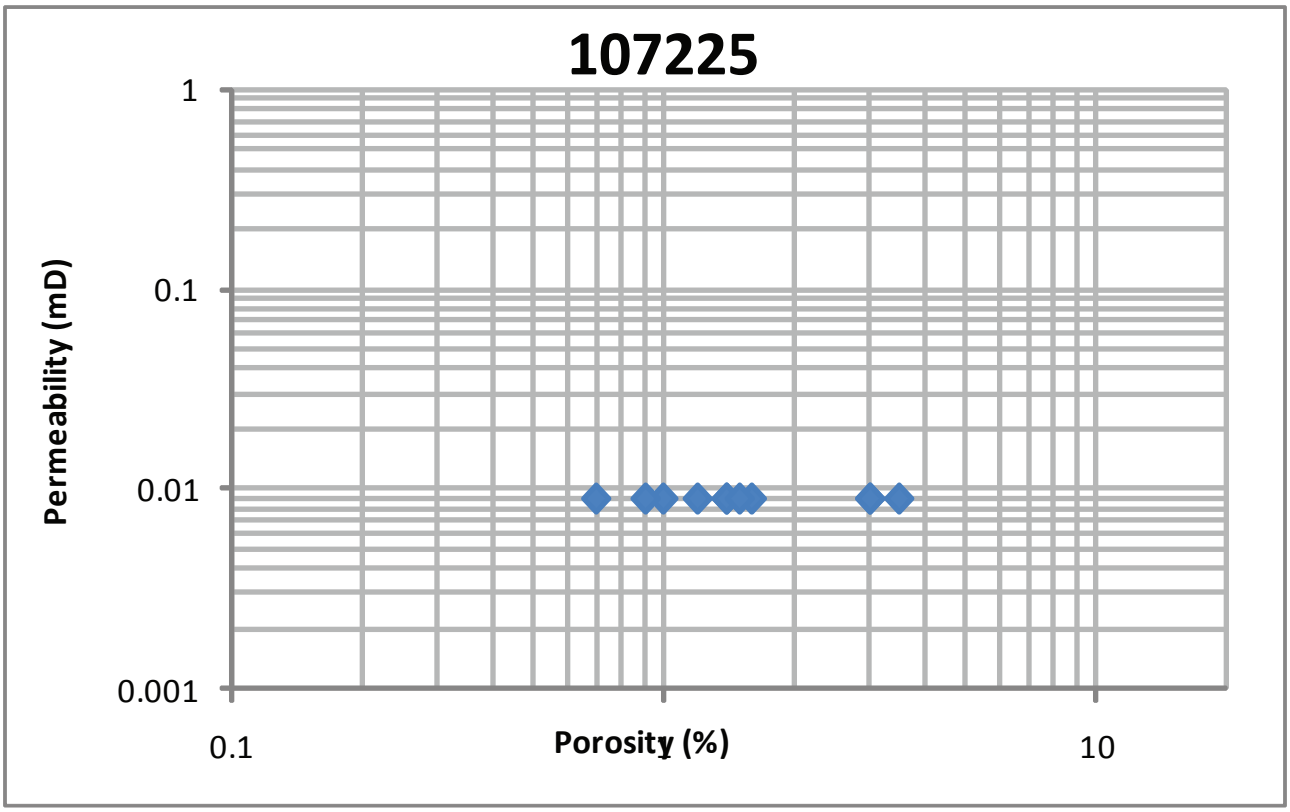


Figure 10: X-Y Cross section showing the Devonian subsurface structure across the Leesville Field, Lawrence County. For location of the cross section refer to Figure 1.

PETRA 7/3/2006 10:06:49 AM (XY.CSP)



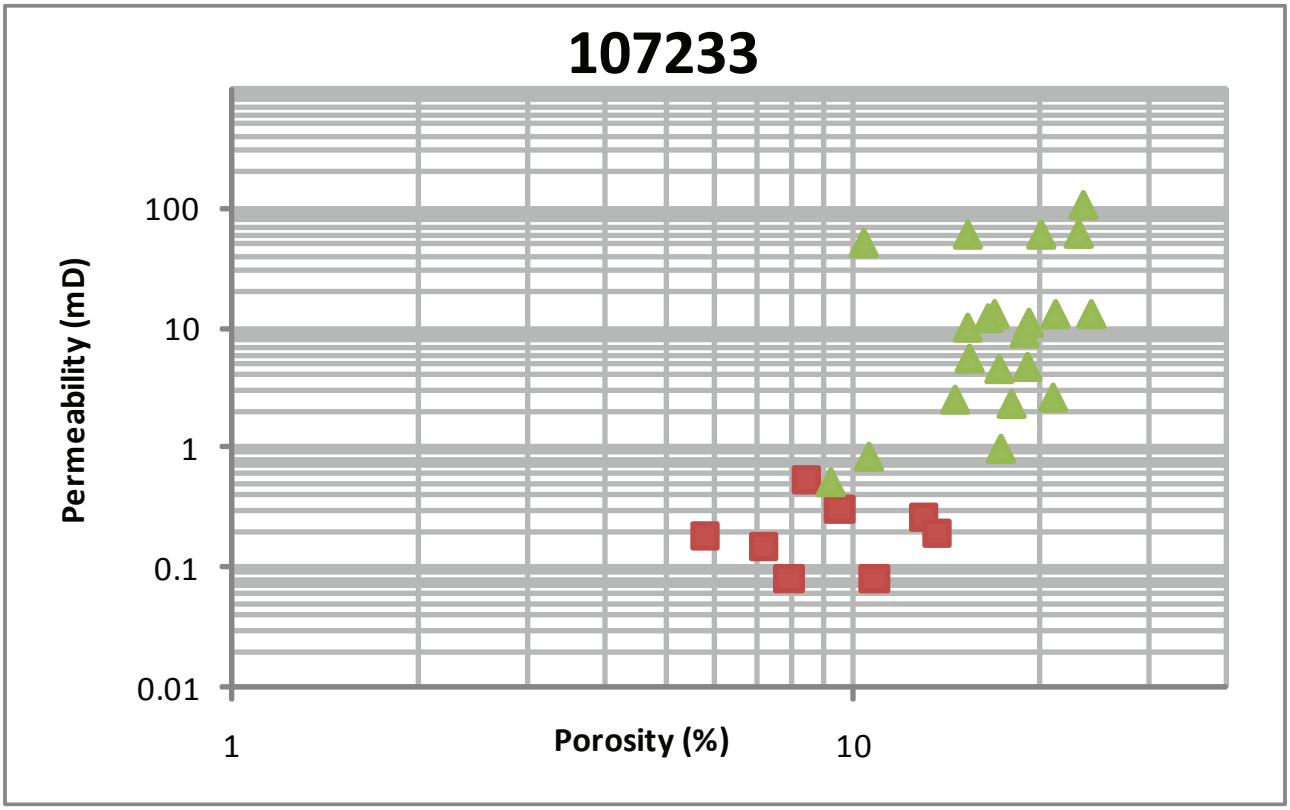


Figure 11: Porosity-permeability plots from core analysis from the Leesville Field, Lawrence County. The blue points are from North Vernon, the red points from the Vernon Fork, the green triangles from the Geneva Dolomite, and the crosses are from the Silurian. The chart title lists the IGS Well ID. For the well locations see Figure 1.

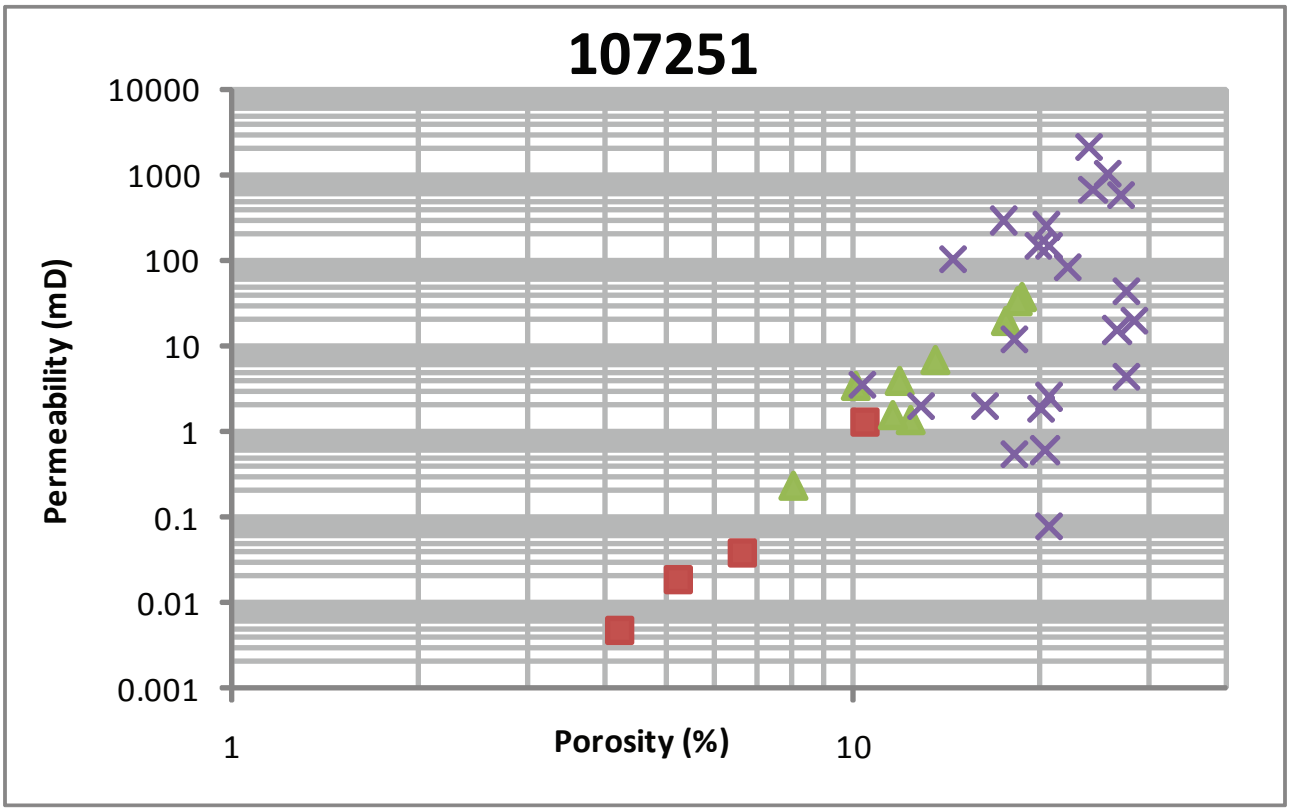


Figure 11: Continued....

Table-1: List of the wells used for subsurface structure mapping in Leesville Field, Lawrence County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
107137	4	N	2	E	4	765	764	798				
107186	5	N	1	E	1	725	726	756	816	838		
152593	5	N	1	E	1	743	742	772	830			
107192	5	N	1	E	2	737						
152594	5	N	1	E	2	747	742	772	844			
107187	5	N	1	E	12	737	757	786	850			
107188	5	N	1	E	12	759	779	814	872			
107189	5	N	1	E	12	748	740	776	844			
107190	5	N	1	E	12	755	767	798	840	868		
107191	5	N	1	E	12	746	756	792	854			
107252	5	N	2	E	6	751	790	821	884	929		
107254	5	N	2	E	7	783	800	835				
107255	5	N	2	E	7	785	803	838	904	923		
107196	5	N	2	E	17	745	775	808				
107197	5	N	2	E	17	785	770	806	864			18200
107198	5	N	2	E	17	783	774	808				955
107199	5	N	2	E	17	733	729	764				
152595	5	N	2	E	17	780	766	802	866			5000
107200	5	N	2	E	18	766	773	808	870	888		
152596	5	N	2	E	19	739	760	798	850			
107201	5	N	2	E	20	767	752	785				
107202	5	N	2	E	20	781	745	778	810			386
107203	5	N	2	E	20	778	756	788	817	858		
107204	5	N	2	E	20	789	769	803				13700
107205	5	N	2	E	20	778						650
107206	5	N	2	E	20	785	767	796				12700
107207	5	N	2	E	20	790	766	800	854	871		
107208	5	N	2	E	20	800	776	810	845	878		2571
107209	5	N	2	E	20	769	749	781				433
107210	5	N	2	E	20	778	765	800				289
107211	5	N	2	E	20	763	747	779	834			
107212	5	N	2	E	20	775	759					194
107213	5	N	2	E	20	774	763	798				715
107214	5	N	2	E	20	783	761	796				
107215	5	N	2	E	20	787	766	800				158
107216	5	N	2	E	20	776	764	798	850			336
107217	5	N	2	E	20	782	770	804				
107218	5	N	2	E	20	766	778	808	862			171
107219	5	N	2	E	20	769	758	792	857			13000
107220	5	N	2	E	20	798	778	808	878			65
107221	5	N	2	E	20	773	758	794	846			675
107222	5	N	2	E	21	774	763	800	853			129
107223	5	N	2	E	21	768	750	785				

Table-1: Continued....

107224	5	N	2	E	21	618	648	677	736	755		
107225	5	N	2	E	21	774	753	787				46
107228	5	N	2	E	28	688	673	710	760			
107229	5	N	2	E	28	608	600	634				
107230	5	N	2	E	28	776	762					65
107231	5	N	2	E	28	757	748	780	828			
107232	5	N	2	E	28	774	759	794				129
107233	5	N	2	E	28	761	746	778	830			
107234	5	N	2	E	28	765	752	790	843	858		
107235	5	N	2	E	28	763	750	784				129
152598	5	N	2	E	28	782	767	800	850	876		
107236	5	N	2	E	29	753	735	770				
107237	5	N	2	E	29	775	763	797	848	875		
107238	5	N	2	E	29	761	746	780				
107239	5	N	2	E	29	749	724	758	810			102
107240	5	N	2	E	29	774	754	788	838			177
107241	5	N	2	E	29	781	761	799	850			153
107242	5	N	2	E	29	772	747	782	834			204
107243	5	N	2	E	29	781	767	815	867			
107244	5	N	2	E	29	767	745	780	830			145
107245	5	N	2	E	29	716	683	715				
107246	5	N	2	E	29	772	797	832				
107247	5	N	2	E	32	760	760	798	844	862		
107248	5	N	2	E	32	562	551	590	636			551
107249	5	N	2	E	32	548	547	583	640			
107250	5	N	2	E	33	562	551	588				
107251	5	N	2	E	33	579	582	617	667	678		
157485	6	N	1	E	35	775	799	835	904	930		

Field name: Leesville South

IGS ID: 10374

DOE ID: na

Location: Lawrence County, 4N-2E

Discovery date: 1916

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, na (na)

Field type: natural gas

Total number production wells: 1

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Ordovician, Trenton Ls. (1,753 ft.)

Field characteristic: Anticline adjacent to Mt. Carmel Fault with structural closure in excess of 10 ft. at top of Muscatatuck.

Reservoir characteristics:

Field name: Lewis

IGS ID: 10375

DOE ID: 411940

Location: Sullivan County, 9N-8W

Discovery date: 1954

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group,

North Vernon Ls. (1,937 ft.)

Field type: oil (abandoned)

Total number production wells: 1

Area: 20 acres

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (2,241 ft.)

Field characteristic: Subtle domal anticline with closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

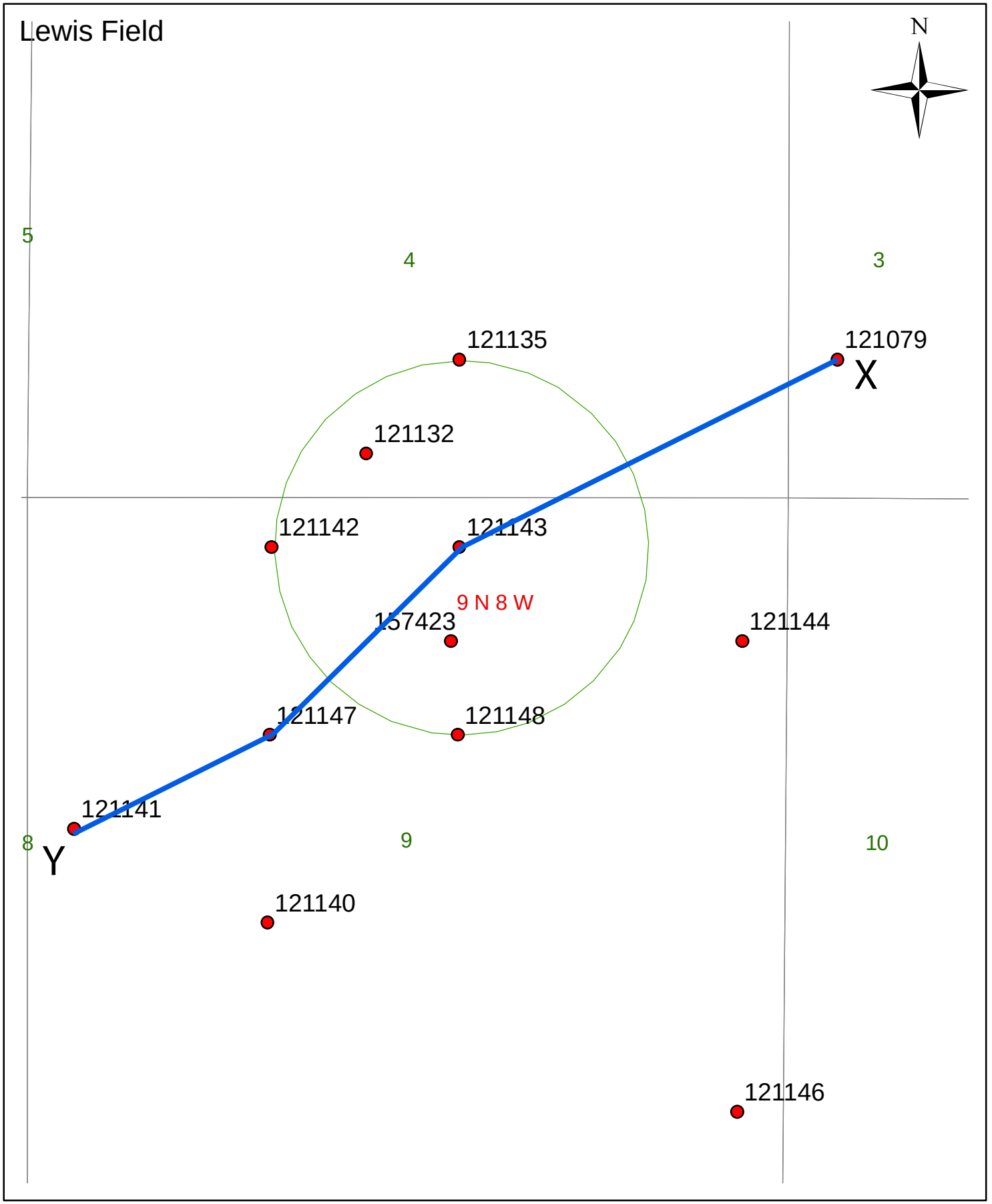


Figure 1: Map showing the location of Lewis Field, Sullivan County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

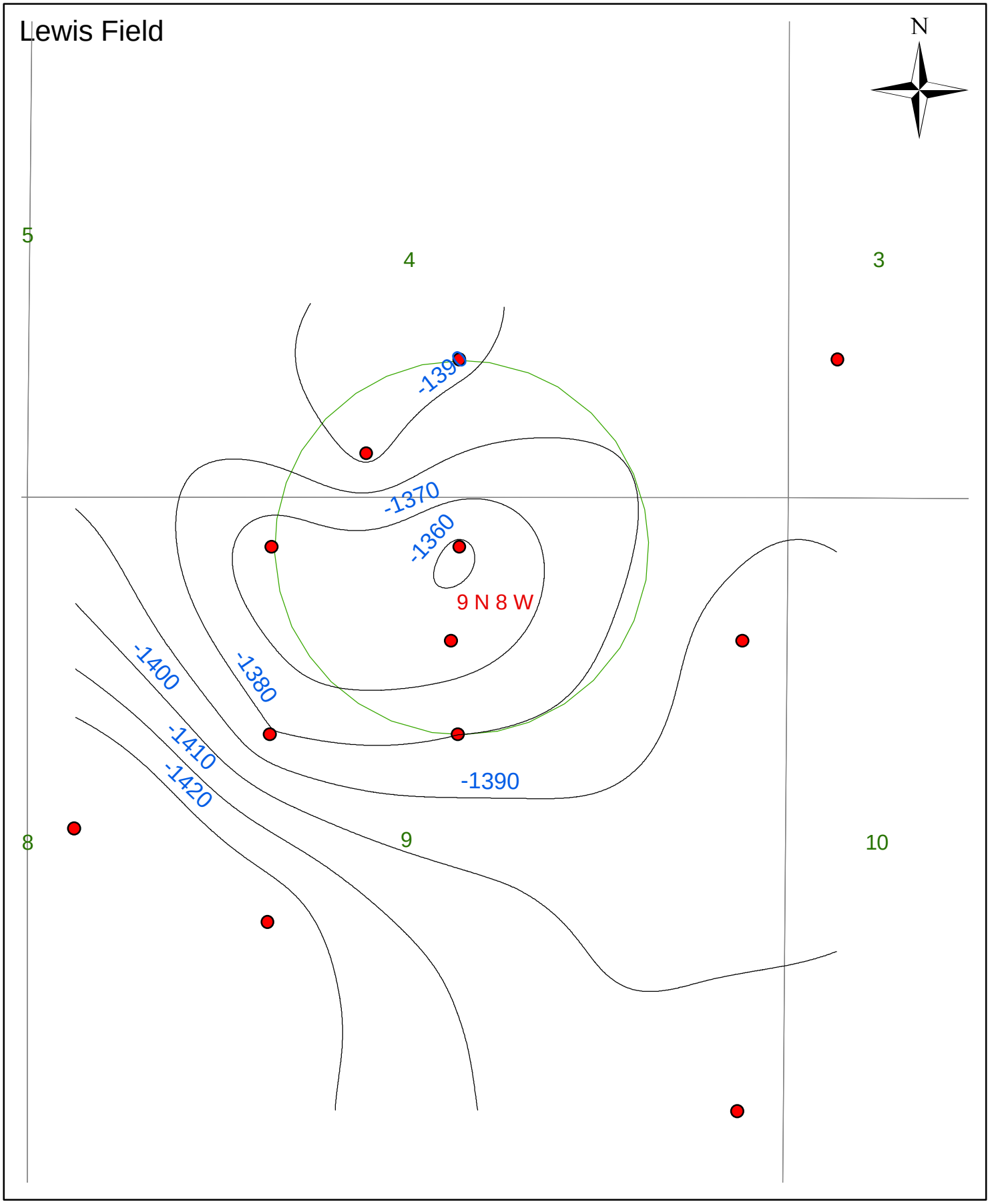


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Lewis Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

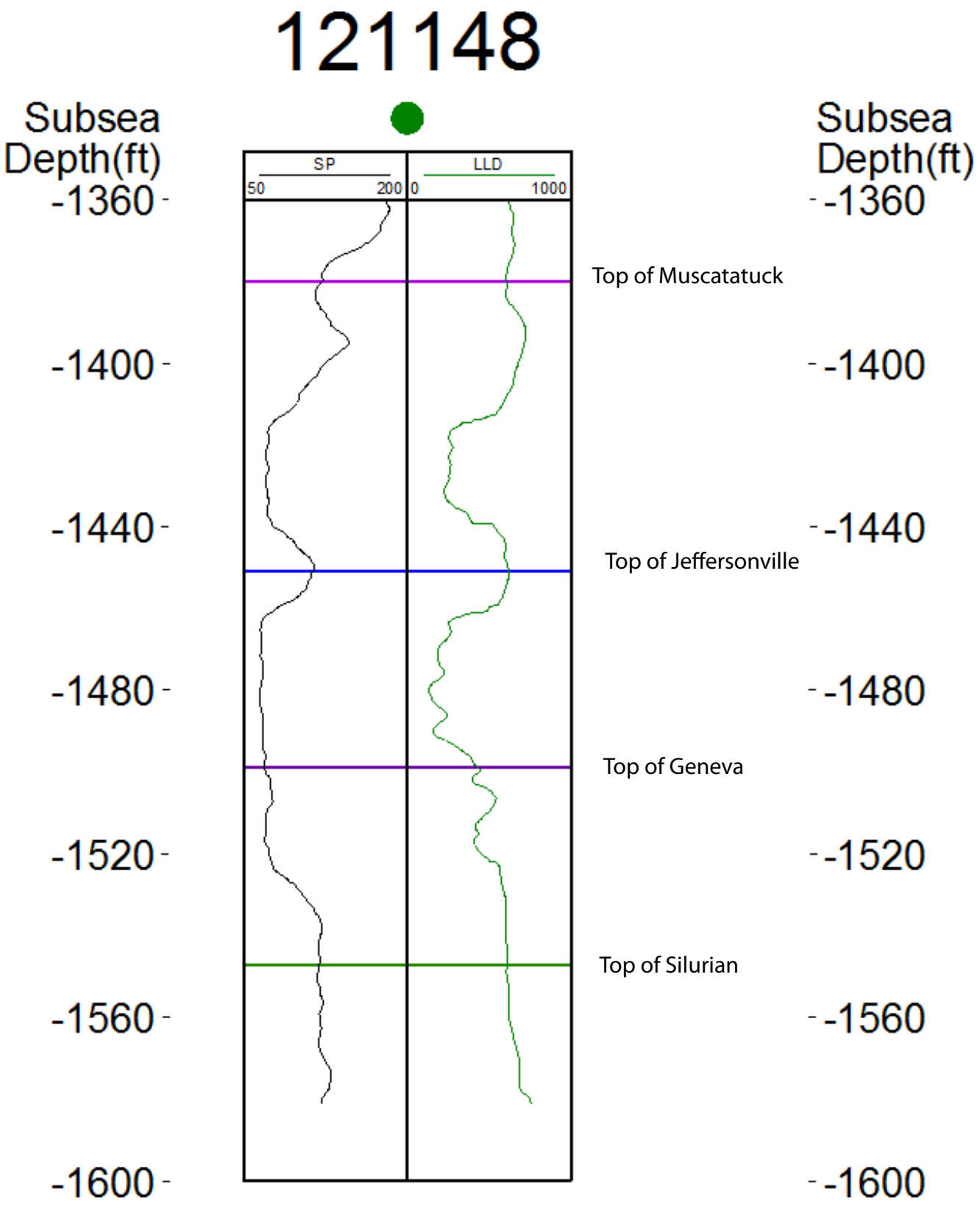


Figure 3: Type log section showing the Devonian formations from the Lewis Field, Sullivan County.

HS=1

PETRA 5/13/2008 3:26:05 PM

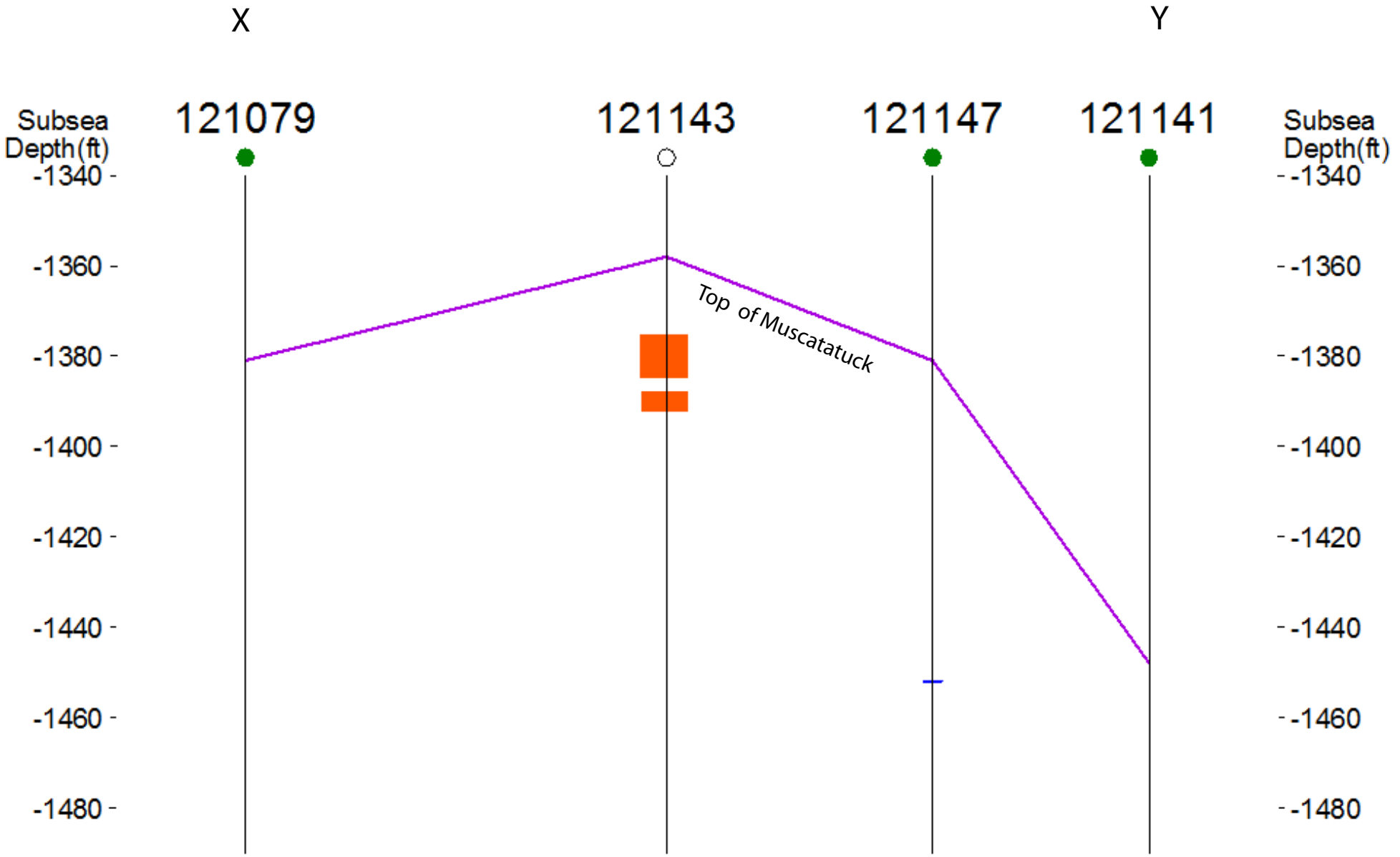


Figure 4: X-Y Cross section showing the Devonian subsurface structure across Lewis Field, Sullivan County. For location of the cross section refer to Figure 1. Red box indicates the completion intervals for oil production.

HS=1.93

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Table-1: List of the wells used for subsurface structure mapping in Lewis Field, Sullivan County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
121079	9	N	8	W	3	562	1943					
121129	9	N	8	W	4	532	1921	1996	2050	2095		
121132	9	N	8	W	4	551	1944					
121135	9	N	8	W	4	564	1956	2030				
121140	9	N	8	W	9	505	1934					
121141	9	N	8	W	9	513	1961					
121142	9	N	8	W	9	549	1912	1980	2033	2096		
121143	9	N	8	W	9	562	1920				6	
121144	9	N	8	W	9	565	1961					
121146	9	N	8	W	9	575	1979	2050	2110	2180		
121147	9	N	8	W	9	533	1914	1985	2026	2086		
121148	9	N	8	W	9	559	1939	2010	2058	2106		
157423	9	N	8	W	9	561	1925	2000				

Field name: Linton

IGS ID: 10382 (natural gas) 10812 (gas storage)

DOE ID: na

Location: Greene County, 7N-7W

Discovery date: 1952 natural gas, 1960 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,950 ft.)

Field type: natural gas (abandoned), gas storage (abandoned), & New Albany Shale gas

Total number production wells: 8 (gas), 10 (storage)

Area: 340 acres

Total capacity: 3,460,000 mcf

Other reservoir units: na

Deepest unit penetrated (depth): Ordovician, Trenton Ls. (3,267 ft.)

Field characteristic: Anticlinal nose with no structural closure at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 11.6%

Average permeability – 12.5 md.

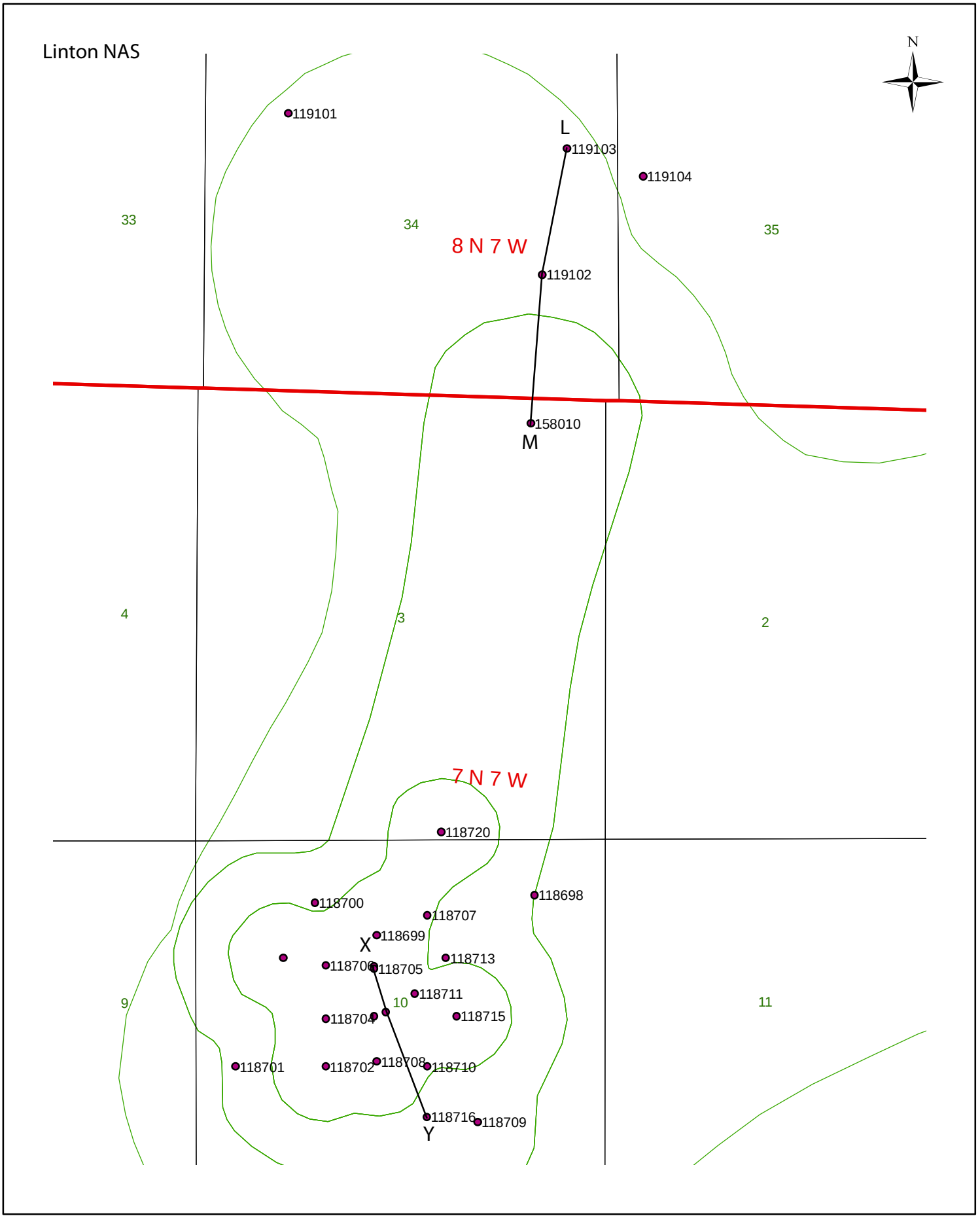


Figure 1: The map showing location amd wells at Linton NAS field, Greene County. X-Y, and L-M are the location of the cross sections that shows the subsurface Devonian structure. The wells depicted are wells that have a total depth (TD) in the Devonian.

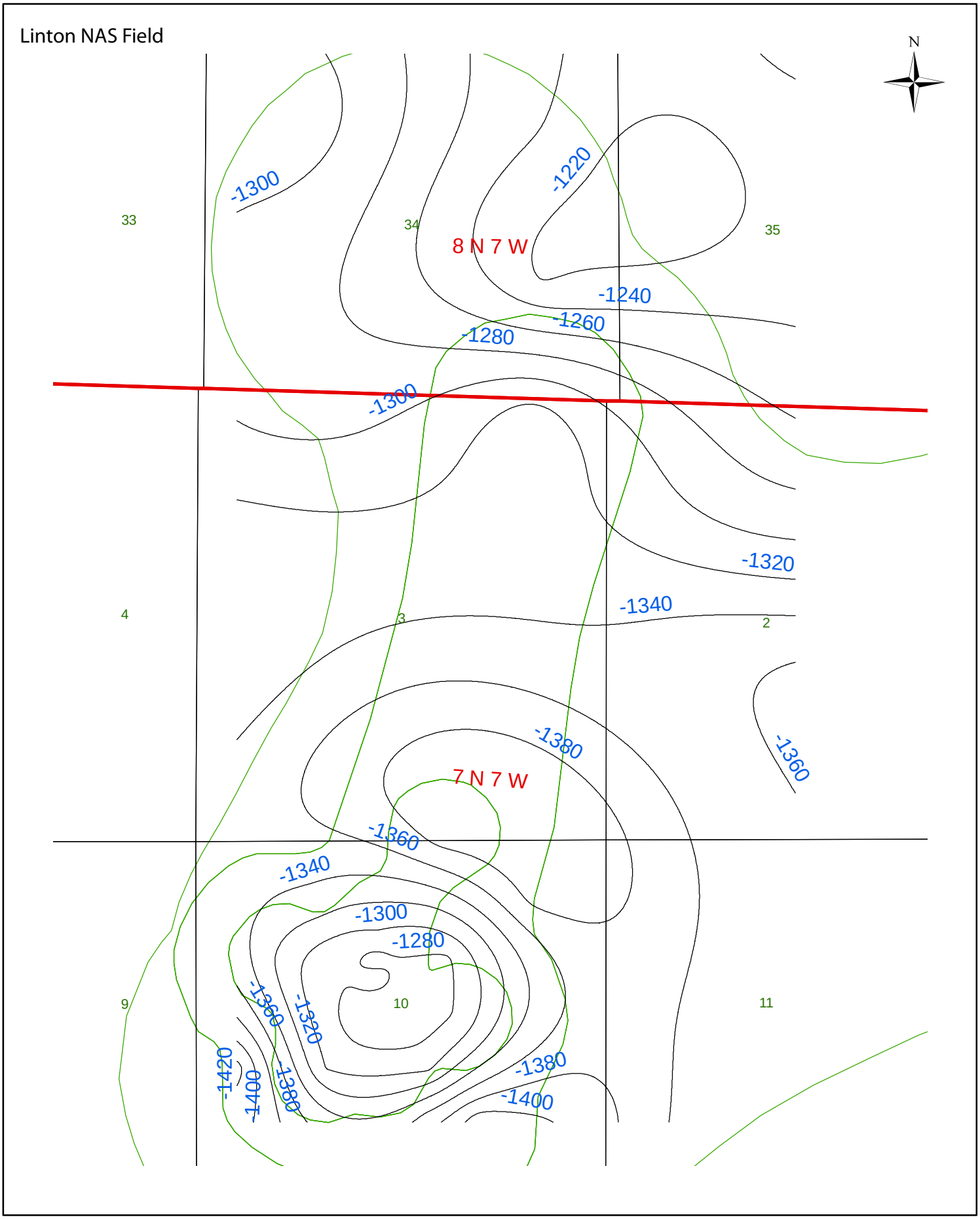


Figure 2: Structure map showing the top of the subsurface Muscatatuck Limestone in the Linton NAS field, Greene County. Countours show values below sea level, contour interval is 20 ft .

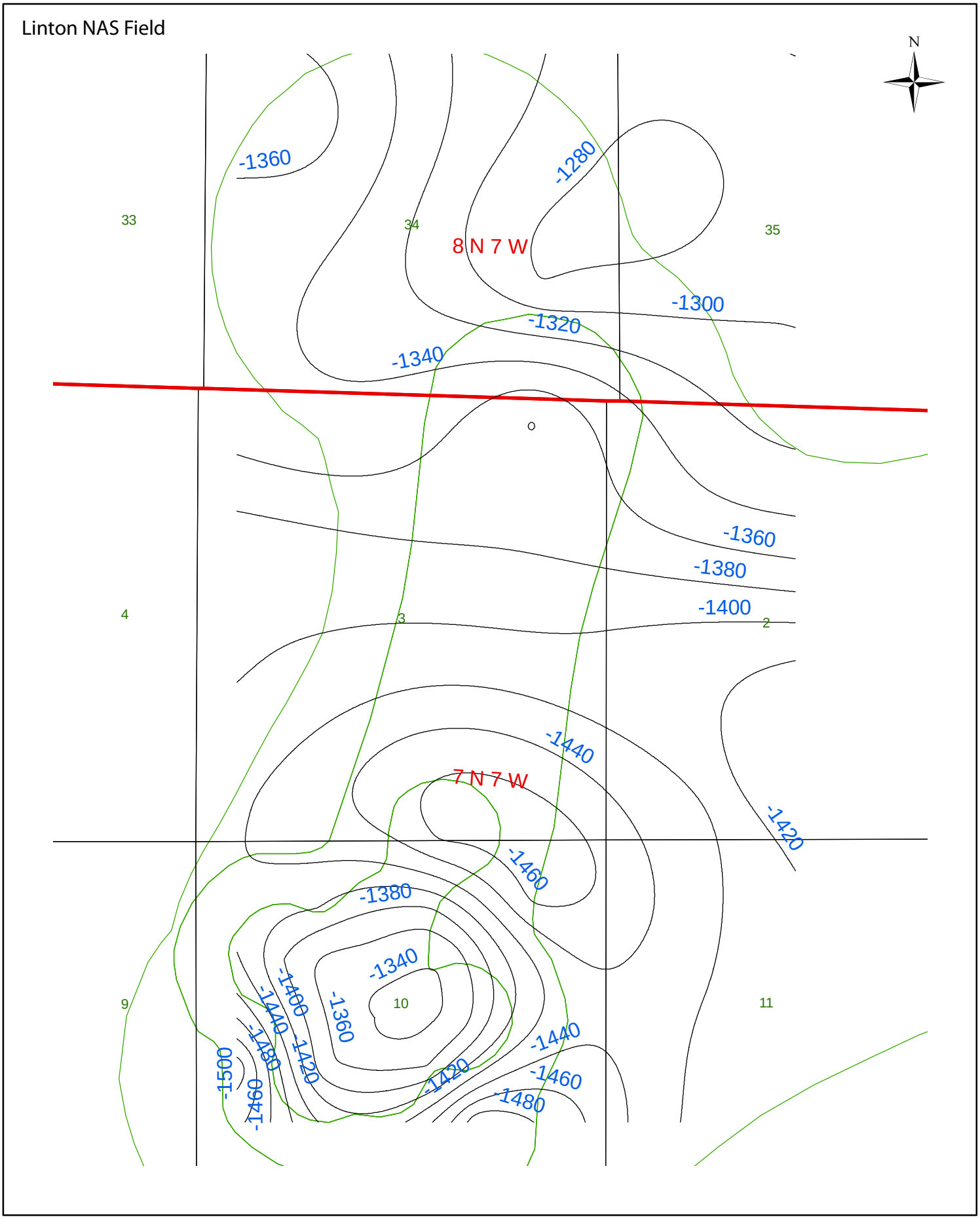


Figure 3: Structure map showing the top of the Jeffersonville Limestone in Linton NAS field, Greene County. Contours show values below sea level, contour interval is 20 ft .

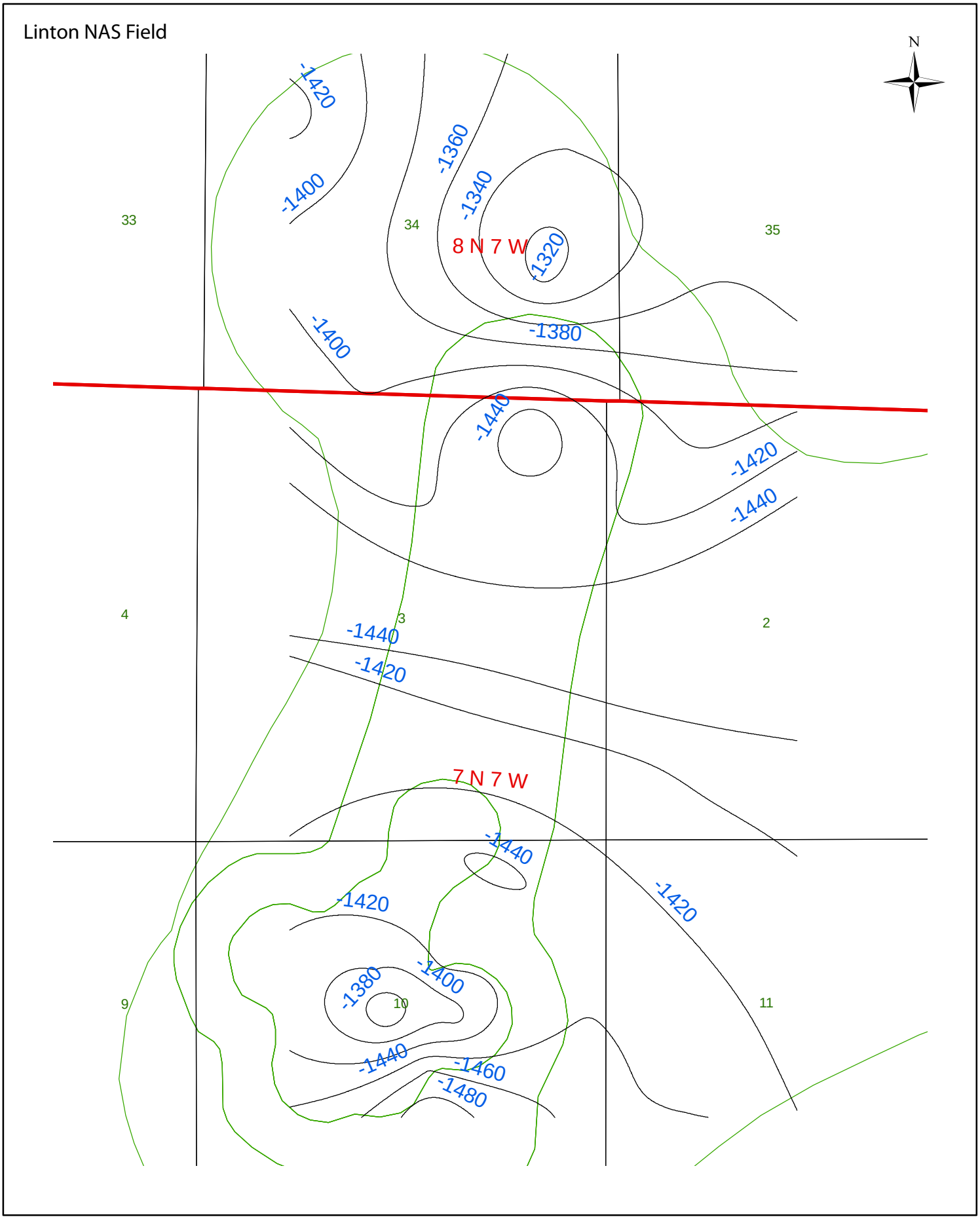


Figure 4: Structure map showing the top of Geneva Dolomite Member in Linton NAS Field, Greene County. Contours show values below sea level, contour interval is 20 ft .

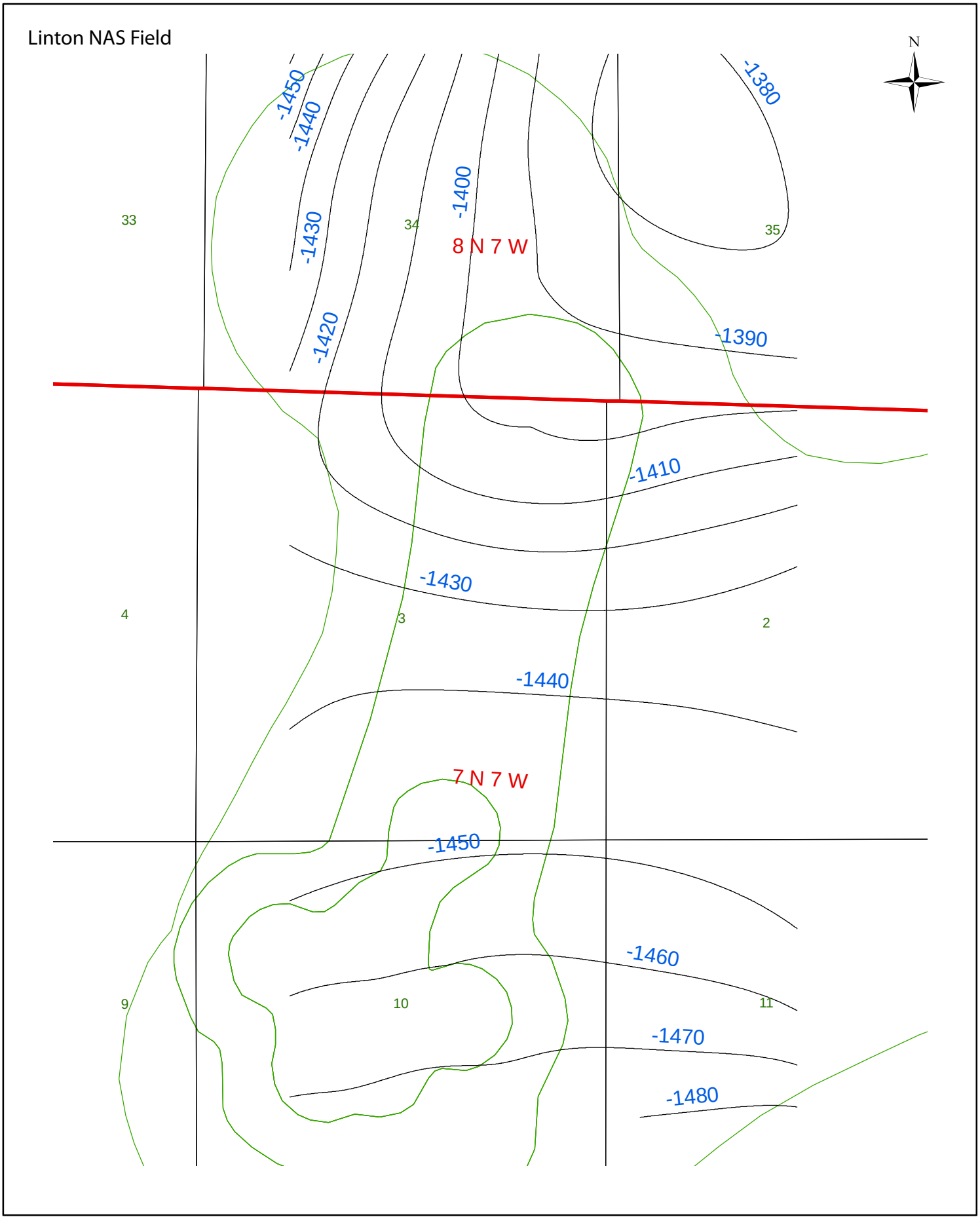
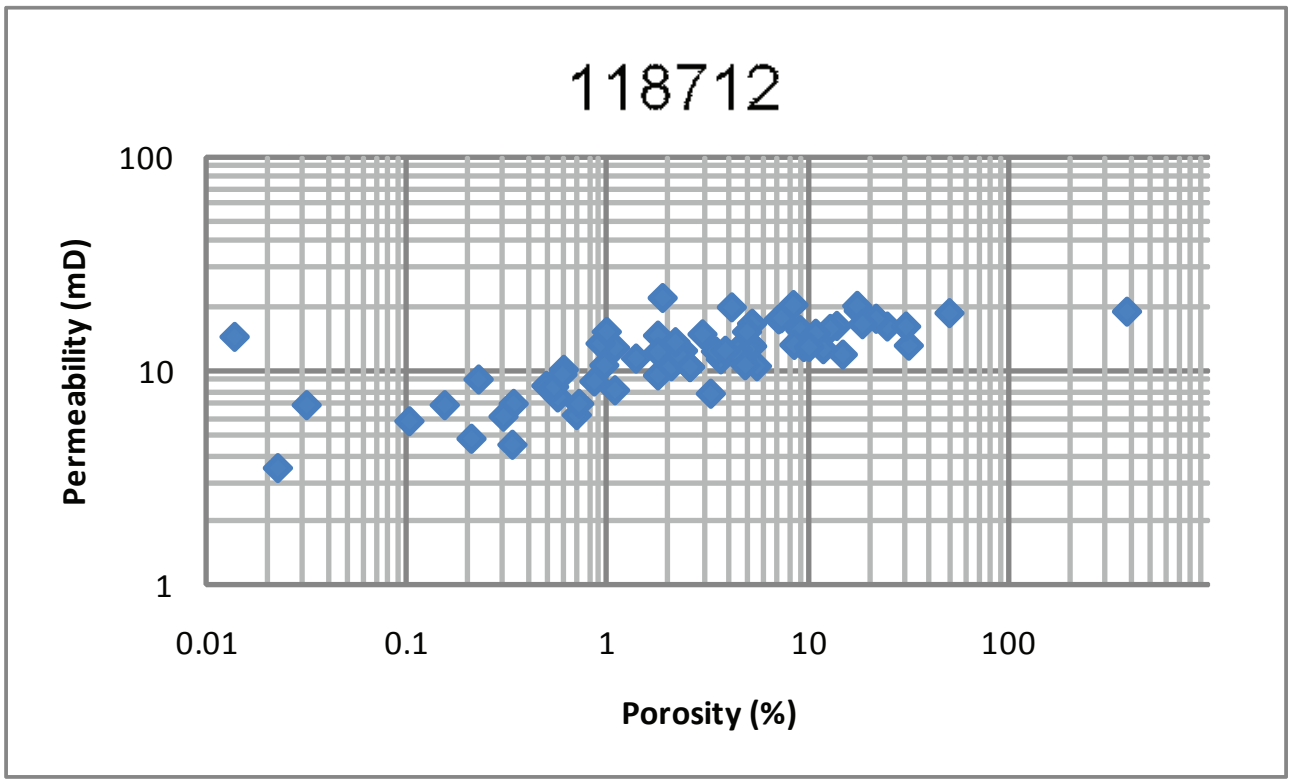


Figure 5: Structure map showing the top of Silurian in Linton NAS field, Greene County. Contours show values below sea level, contour interval is 10 ft .

A



B

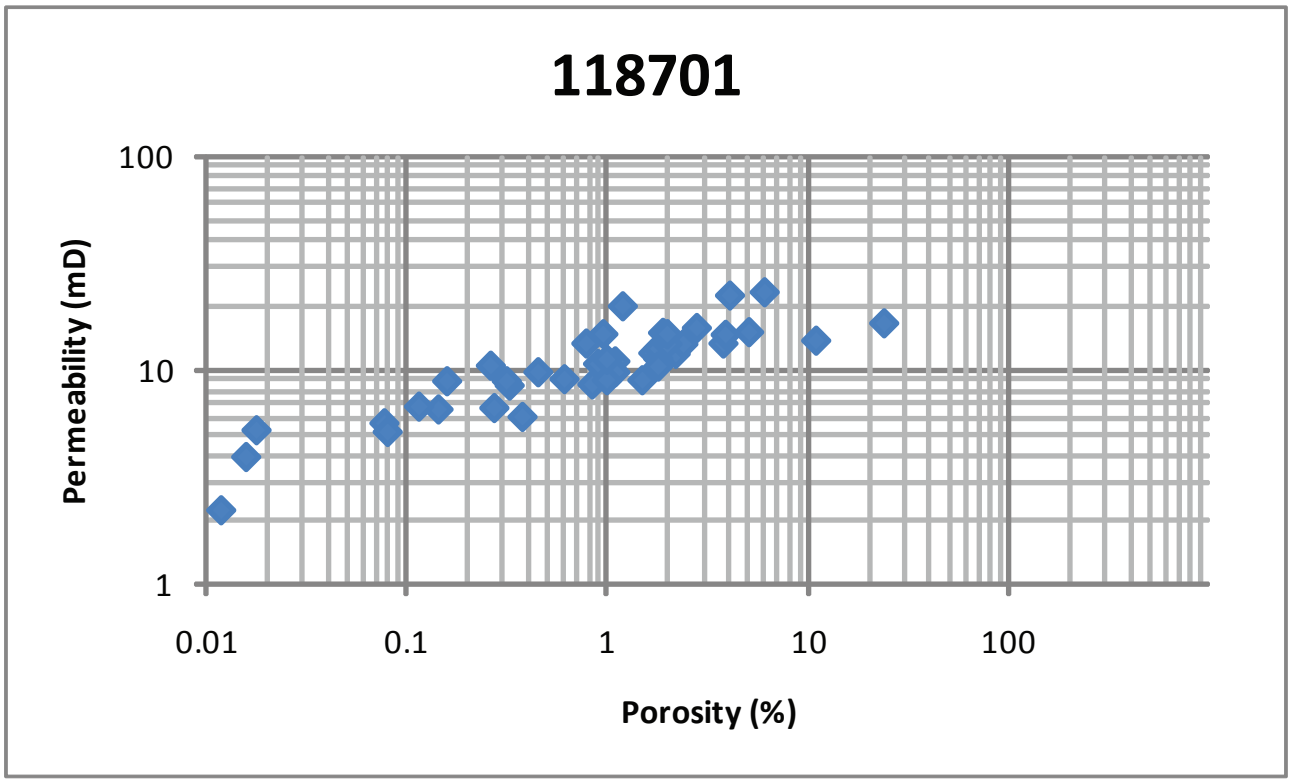


Figure 6: Porosity-permeability plot of the Geneva Dolomite Member in Linton NAS field, Greene County. (A) shows data from well at the top of the structural high, whereas (B) is from the flank of the same structural high. For the well locations see Figure 1.

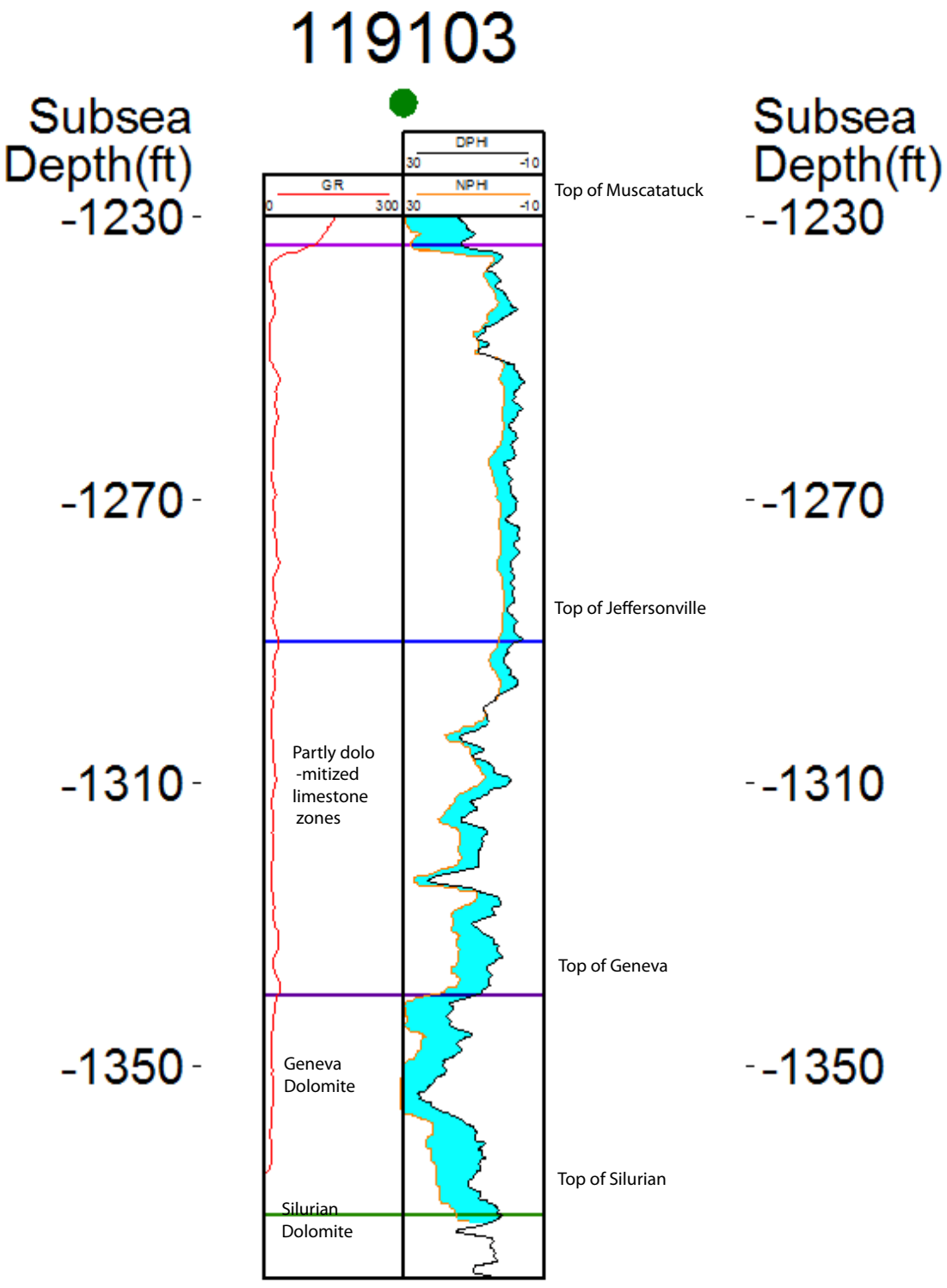


Figure 7: Type log section showing the formations at Linton NAS field, Greene County.

HS=1

PETRA 3/24/2005 9:13:35 AM

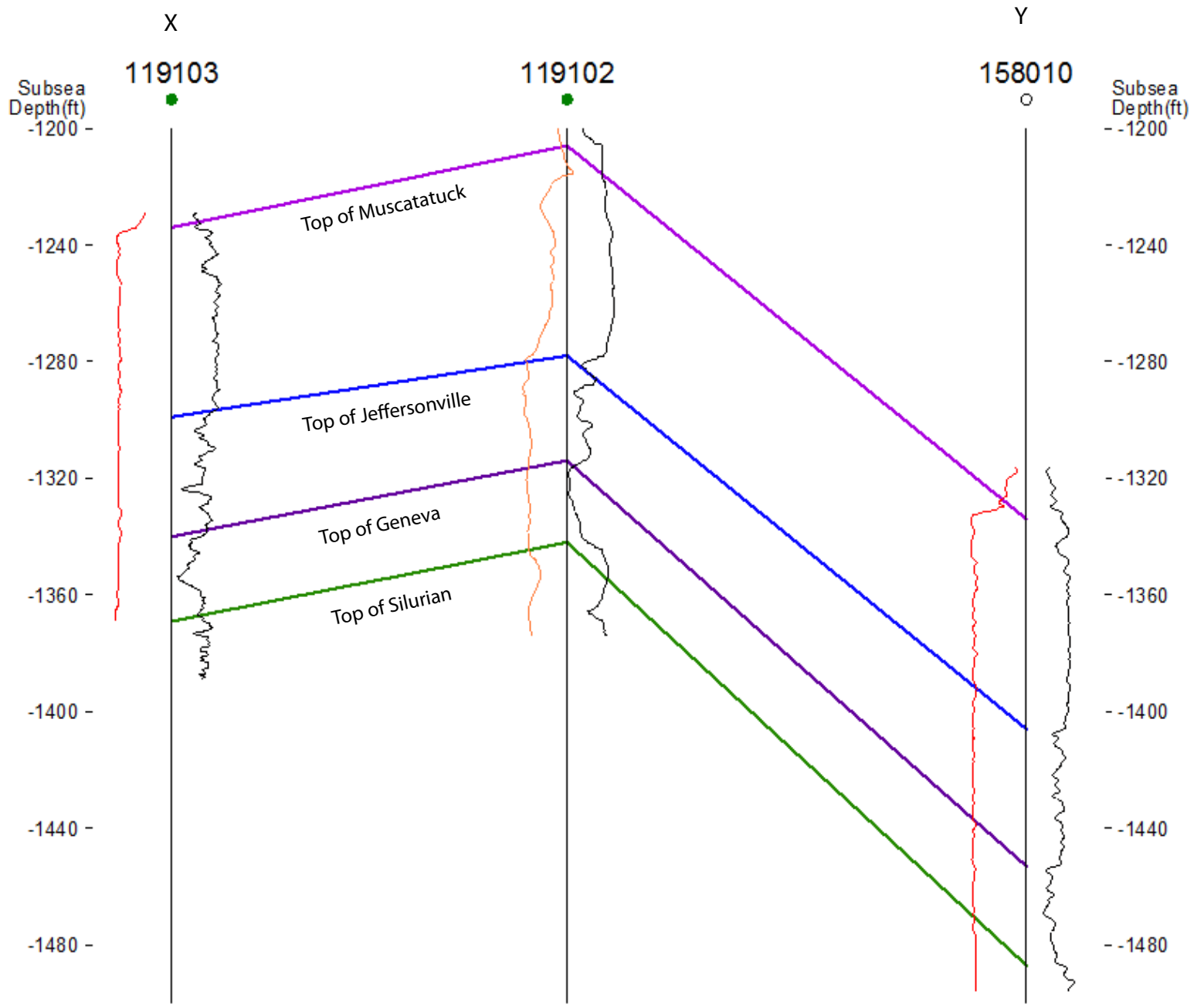


Figure 8: X-Y Cross section showing the Devonian subsurface structure across Linton NAS field, Greene County. For location of the cross section refer to Figure 1.

PETRA 3/24/2008 2:55:26 PM (XY.CSP)

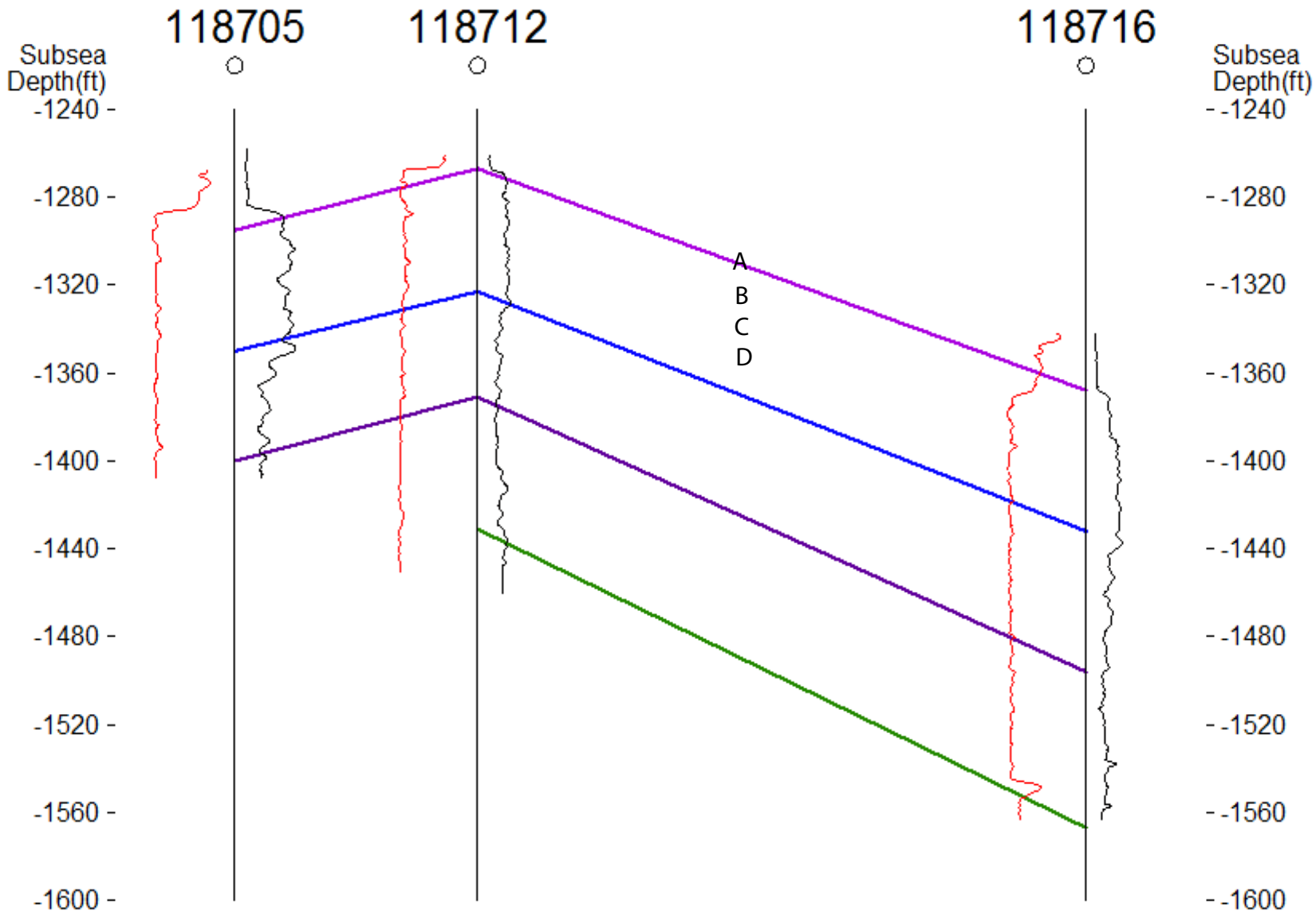


Figure 9: L-M Corss section showing the Devonian subsurface structure acorss the Linton NAS field, Greene county. For location of the cross section refer figure 1.

PETRA 3/25/2008 5:27:45 PM (JM.CSP)

Table-1: List of wells with a TD in Devonian (Linton NAS Field, Green County).

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Gas_P (mcf)	Core Analysis
118720	7	N	7	W	3	576	1968	2042				
158010	7	N	7	W	3	564	1898	1945	2017	2051	1\2	
118697	7	N	7	W	10	606	1918	1986				
118698	7	N	7	W	10	548	1936	2014				
118699	7	N	7	W	10	592	1888					
118700	7	N	7	W	10	594	1925	1998				
118701	7	N	7	W	10	597	2025	2110				Present
118702	7	N	7	W	10	595	1894	1961			2000	
118703	7	N	7	W	10	594	1860				1000	
118704	7	N	7	W	10	600	1886					
118705	7	N	7	W	10	592	1887	1942	1992		100	
118706	7	N	7	W	10	595	1879	1948				
118707	7	N	7	W	10	576	1886	1946			195	
118708	7	N	7	W	10	592	1881	1946				
118709	7	N	7	W	10	566	1980	2062				
118710	7	N	7	W	10	584	1880	1946	2042		75	
118711	7	N	7	W	10	583	1856	1920			88	
118712	7	N	7	W	10	589	1856	1920	1952	2020		Present
118713	7	N	7	W	10	584	1861	1928	2012	2028		
118714	7	N	7	W	10	580	1849	1920	1956	2016		
118715	7	N	7	W	10	553	1836	1900	1948	2001		
118716	7	N	7	W	10	588	1956	2020	2084	2156		
119099	8	N	7	W	27	585						
119101	8	N	7	W	34	634	1946	2006	2060	2120		
119102	8	N	7	W	34	628	1845	1906	1942	1983		
119103	8	N	7	W	34	571	1805	1861	1911	1942		
119104	8	N	7	W	35	594	1796	1860				
119105	8	N	7	W	35	651	1898	1954	2009	2042		

Field name: Lonetree

IGS ID: 10384 (natural gas) 10813 (gas storage)

DOE ID: na

Location: Greene County, 8N-6&7W

Discovery date: 1959 (natural gas & gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon & Jeffersonville Ls. (1,732 ft.)

Field type: natural gas (abandoned) & gas storage (abandoned)

Total number production wells: 1 (gas),

Area: 550 acres

Total capacity:

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,893 ft.)

Field characteristic: Irregular domal anticline with closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

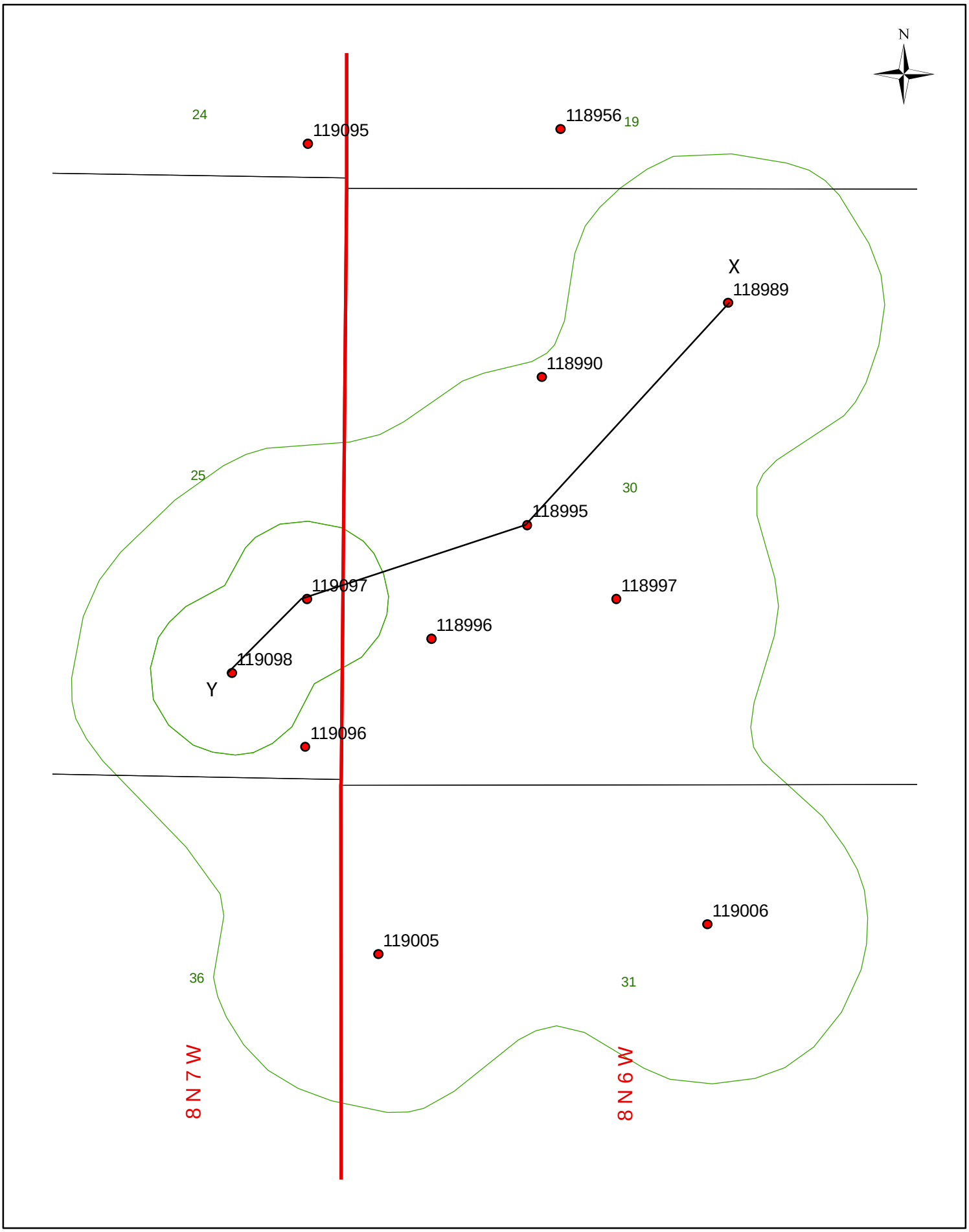


Figure 1: Map showing the location and wells at Lonetree field, Greene County. X-Y is the location of the cross section shown in Figure 4. The wells depicted have a total depth (TD) in Devonian.

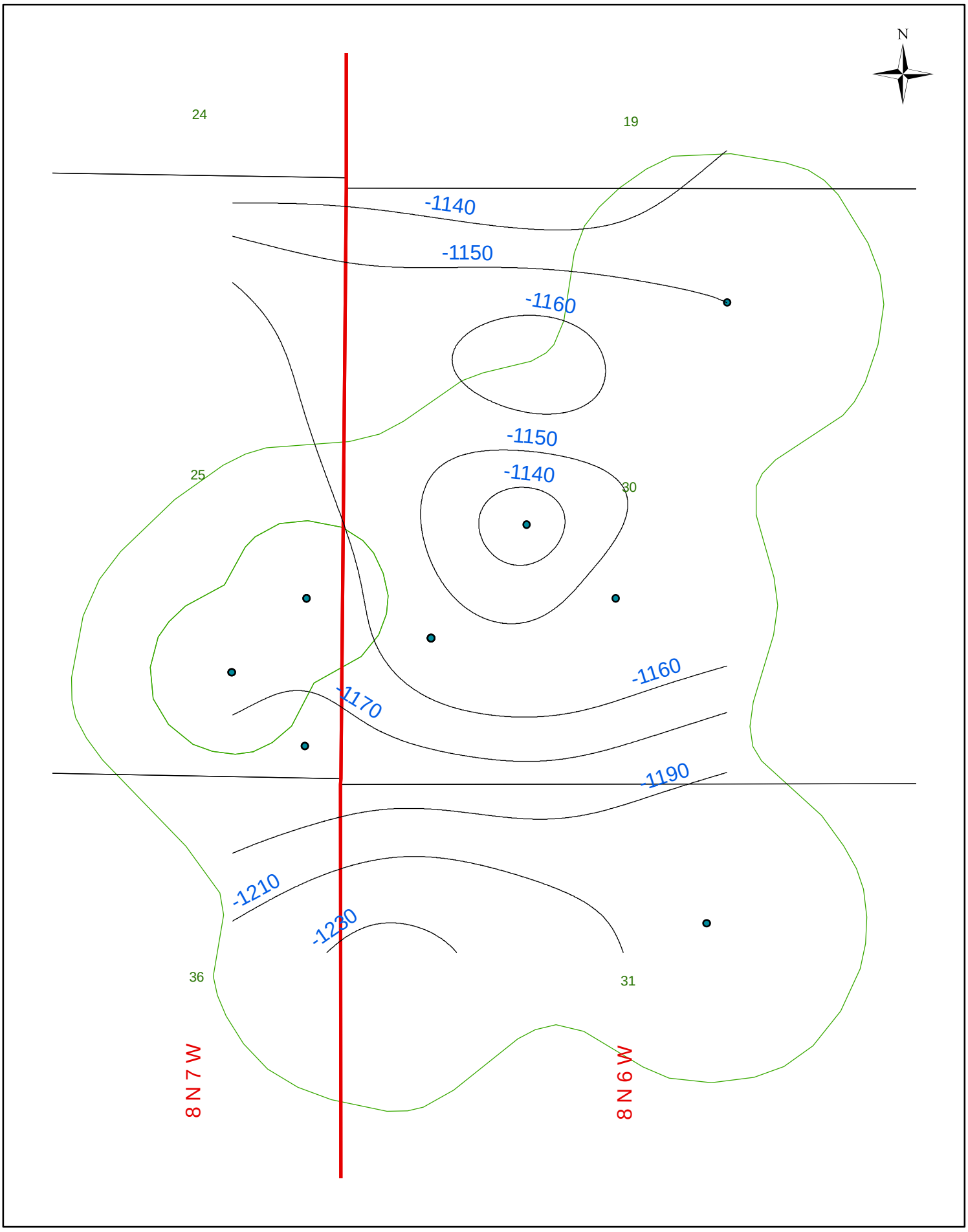


Figure 2: Structure map showing top of Muscatatuck Limestone in Lonetree Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

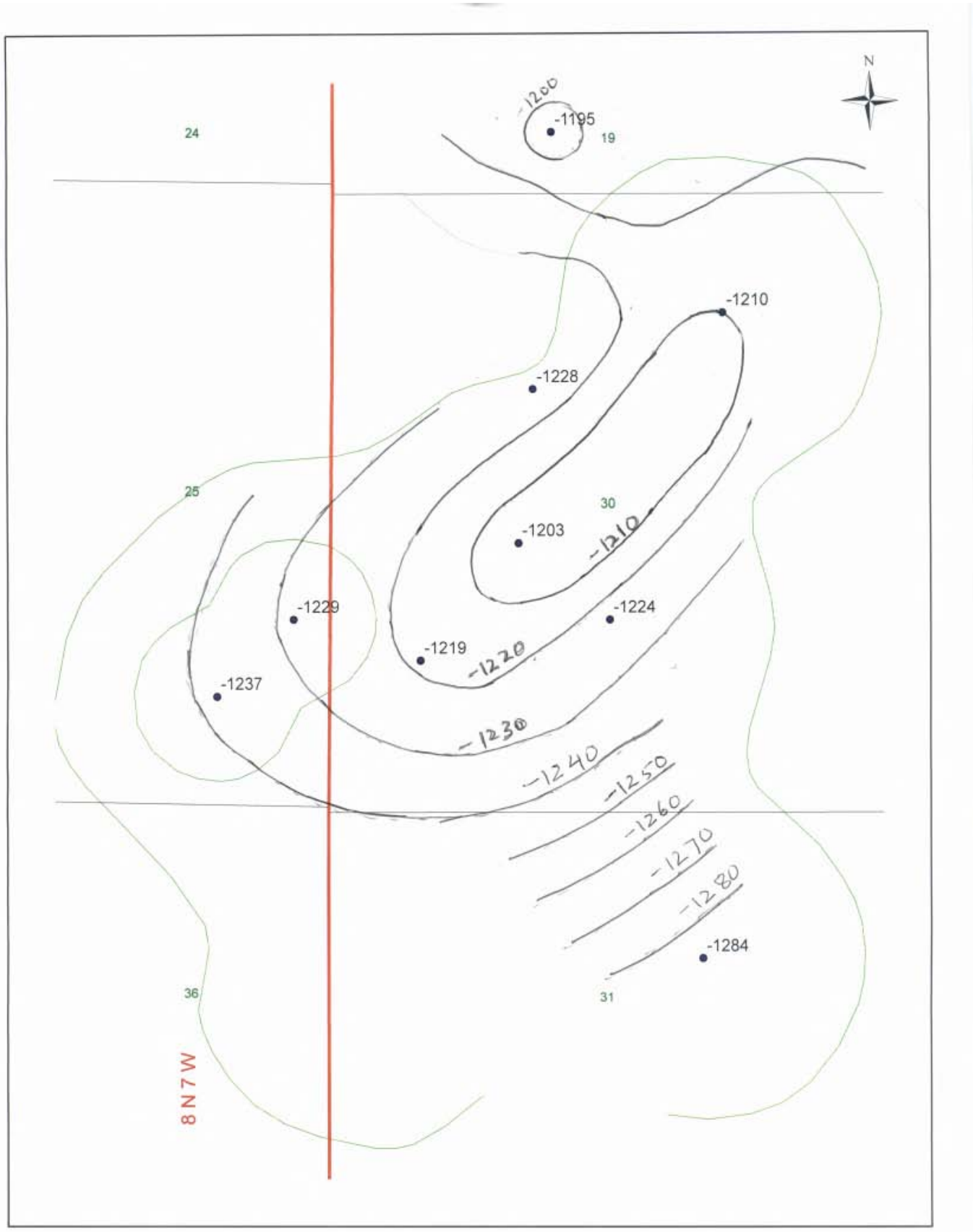


Figure 3: Structure map showing the top of Jeffersonville Limestone in Lonetree Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

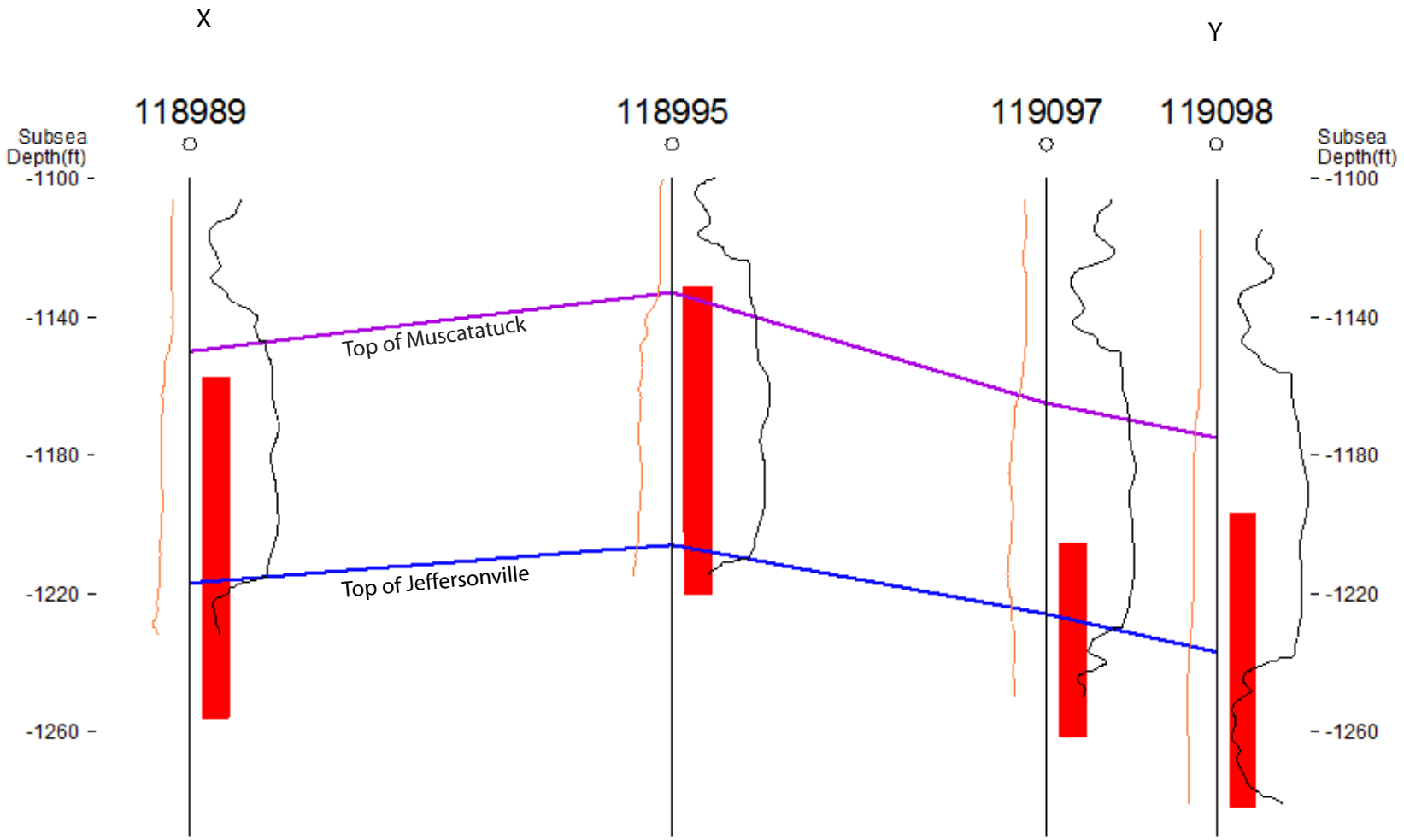


Figure 4: X-Y Cross section showing Devonian subsurface structure acorss Lonetree Field, Greene County. The red color box shows the completion intervals for the gas storage/production. For location of the cross section refer figure 1.

Table-1: List of the wells from Lonetree Field, Green County, which have TD in the Devonian.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Gas_P (mcf)
118956	8	N	6	W	19	542	1668	1737		
118989	8	N	6	W	30	544	1694	1754		
118990	8	N	6	W	30	520	1686	1748		
118995	8	N	6	W	30	519	1652	1722		138
118996	8	N	6	W	30	538	1692	1757		
118997	8	N	6	W	30	526	1682	1750		
119005	8	N	6	W	31	530	1764			
119006	8	N	6	W	31	520	1728	1804	1873	
119096	8	N	7	W	25	526	1702			40
119097	8	N	7	W	25	544	1709	1773		
119098	8	N	7	W	25	535	1702	1772		

Field name: Lyons

IGS ID: 10393

DOE ID: 436364

Location: Greene County, 6N-6W

Discovery date: 1905

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,740 ft.)

Field type: oil & natural gas

Total number production wells: 13 (oil), 3 (natural gas)

Area: 170 acres

Cumulative production: 52,689 bbls. (2002)

Other reservoir units: Devonian/Mississippian, New Albany Shale

Deepest unit penetrated (depth): Silurian (2,193 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 100 ft. at top of Muscatatuck.

Reservoir characteristics:

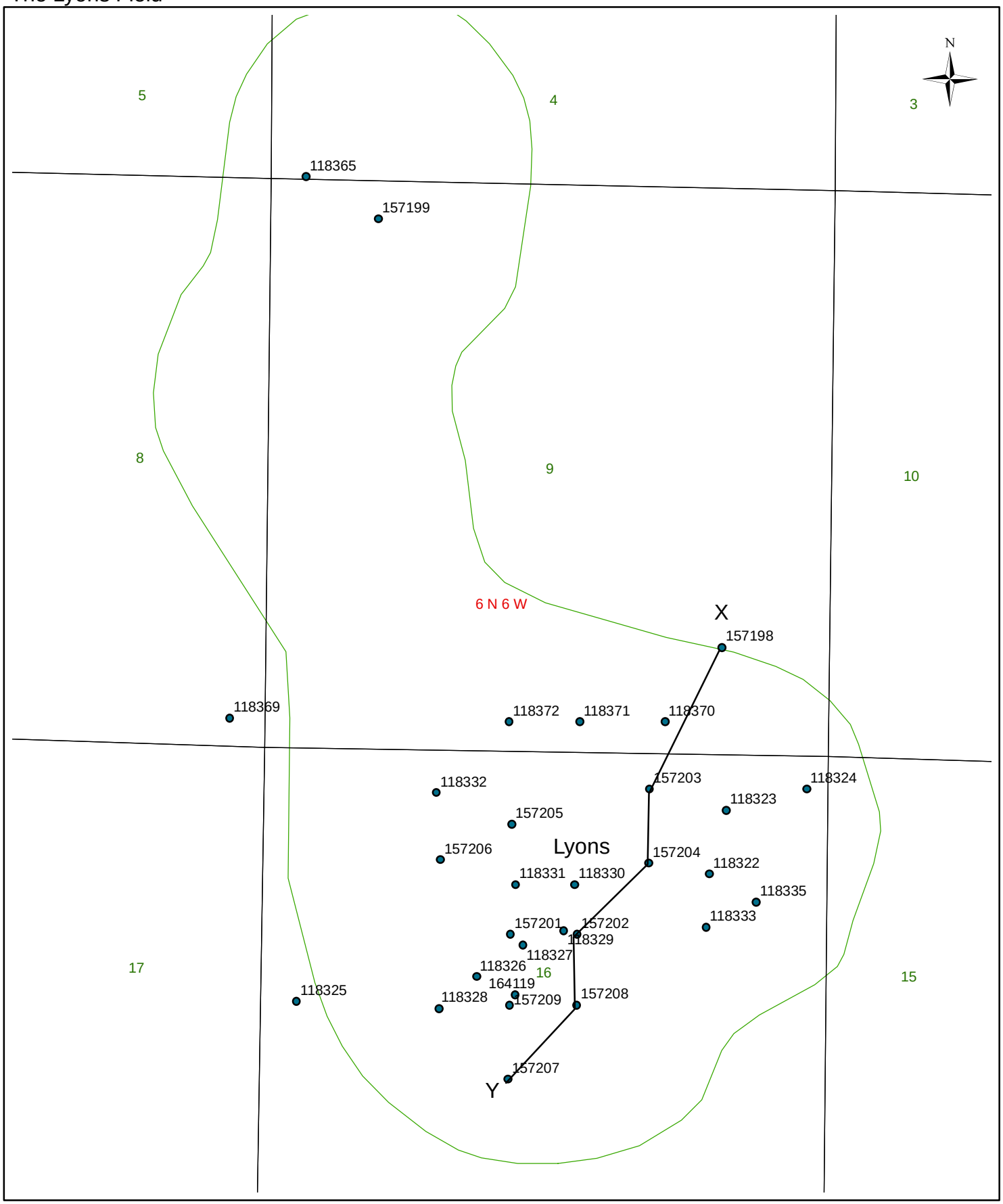


Figure 1: Map showing location and wells at Lyons Field, Greene County and wells with a total depth (TD) in Devonian units. X-Y is the location of the cross section used to show Devonian structure .

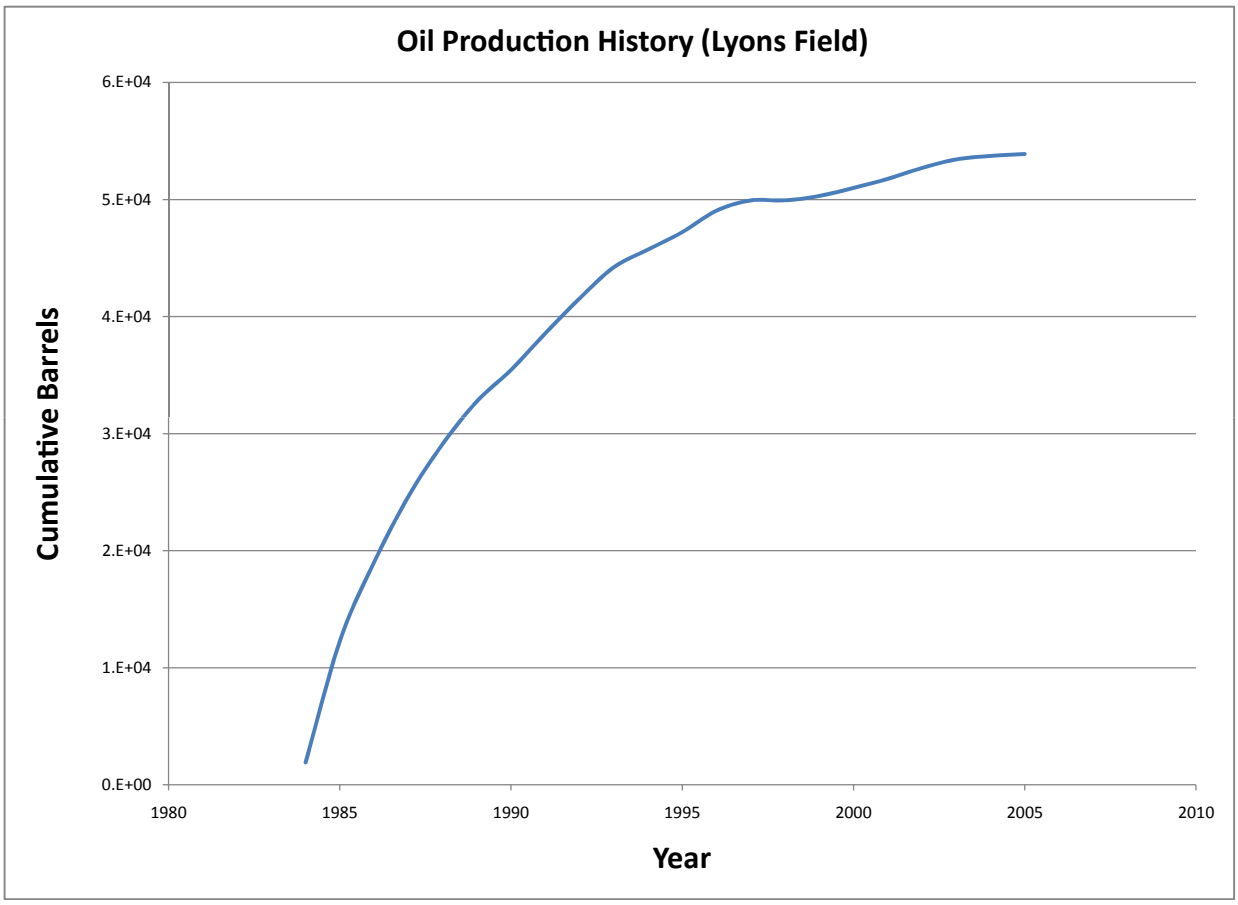


Figure 2: Cumulative oil production from Lyons field since 1982.

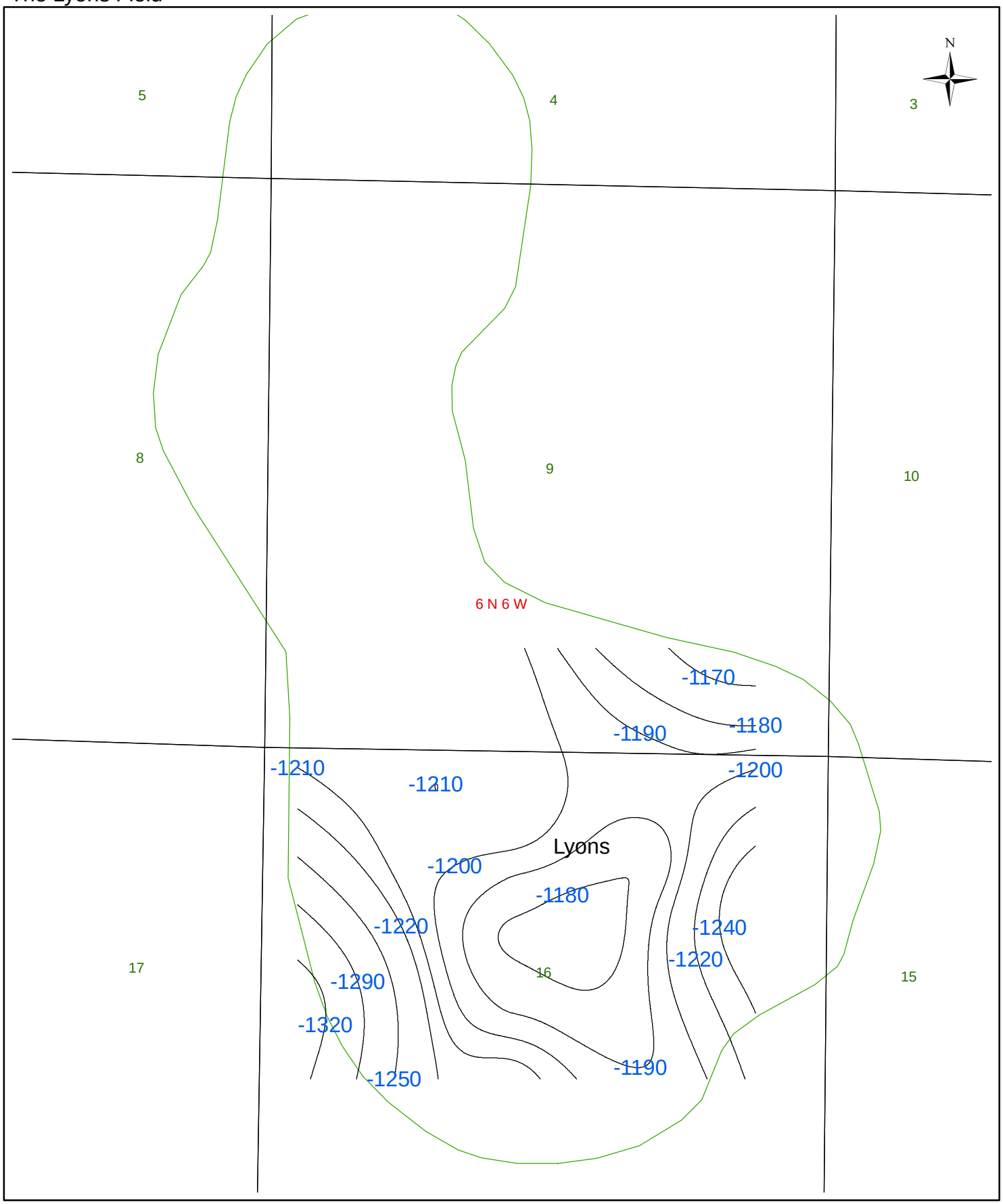


Figure 3: Structure map of the top of the Muscatatuck Limestone in Lyons Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

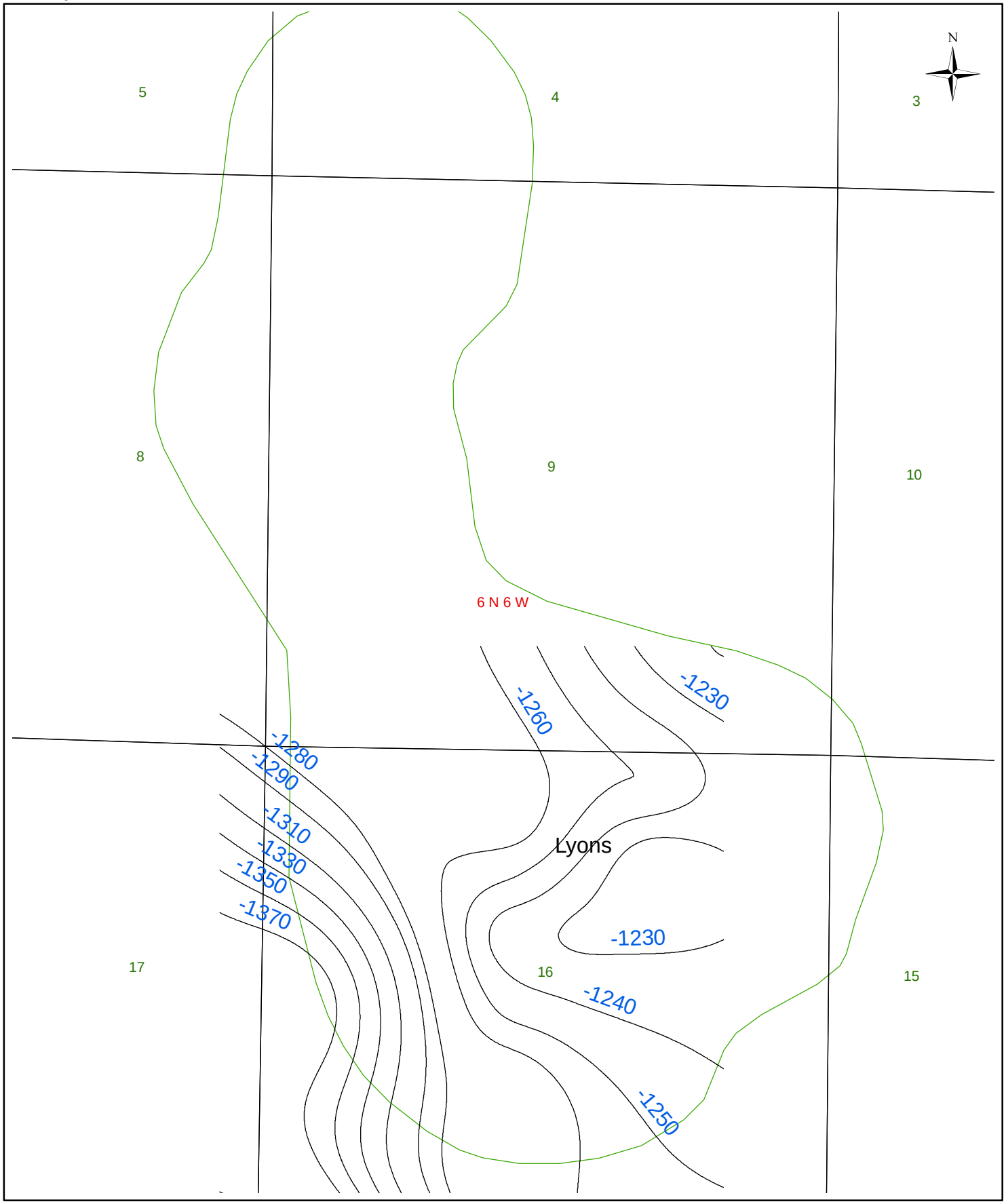


Figure 4: Structure map showing the top of the Jeffersonville Limestone in Lyons field, Greene County. Contours show values below sea level, contour interval is 10 feet.

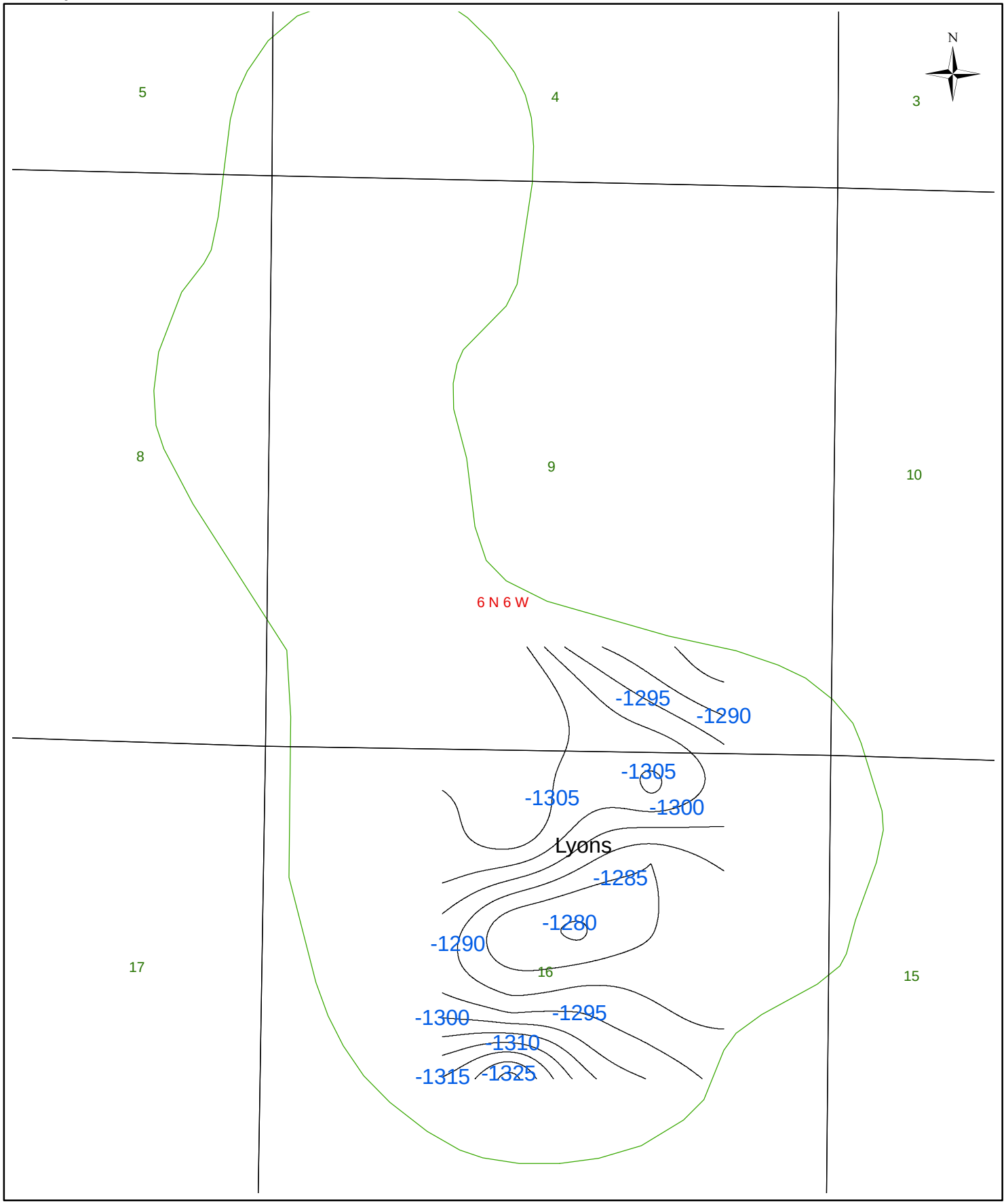


Figure 5: Structure map showing top of the Geneva Dolomite Member in Lyons Field, Greene County. Countour shows values below sea level, contour interval is 5 ft .

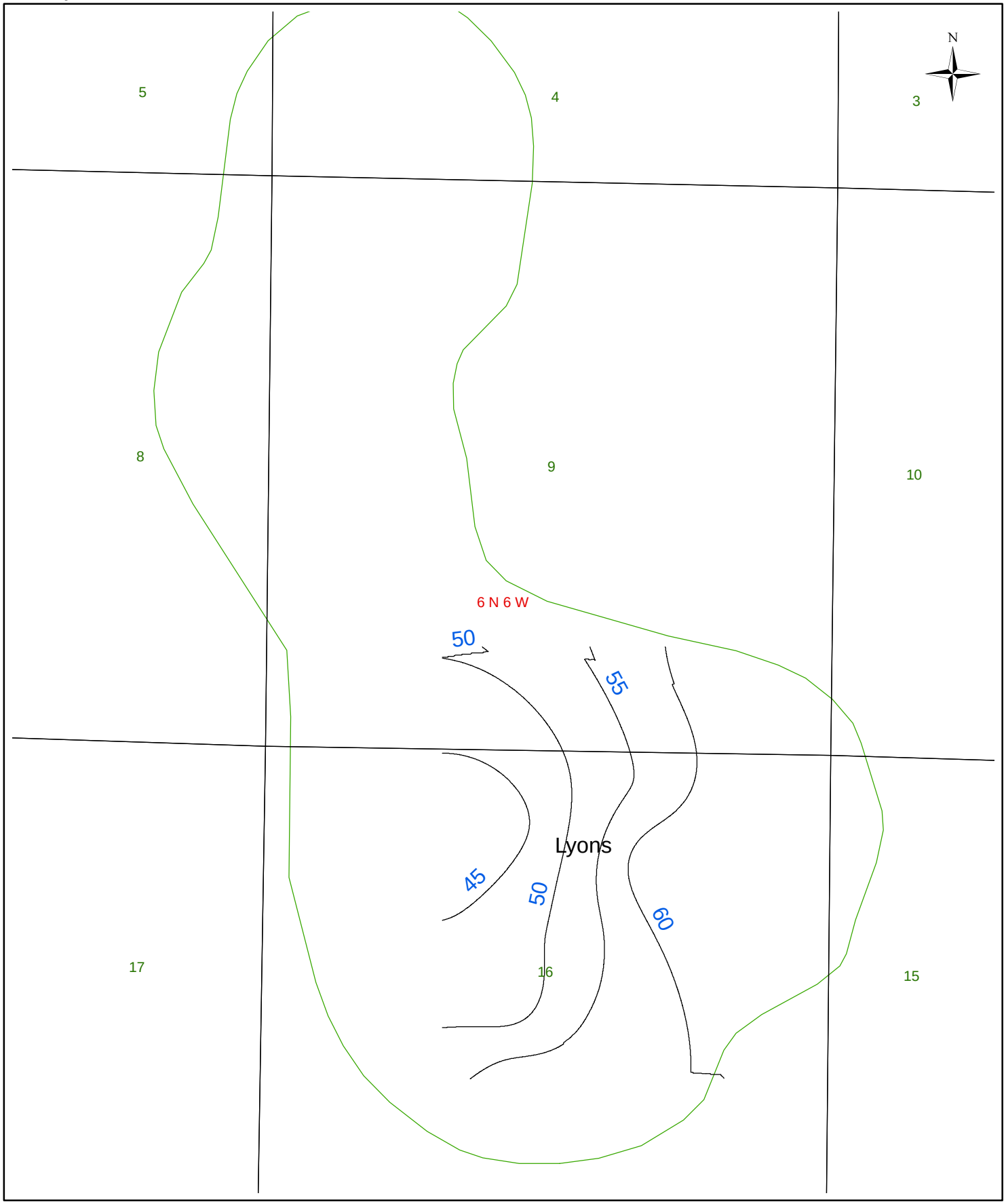


Figure 6: Isopach map showing thickness of the Vernon Fork Member of the Jeffersonville Limestone in Lyons Field, Greene County. Countour interval is 5 ft .

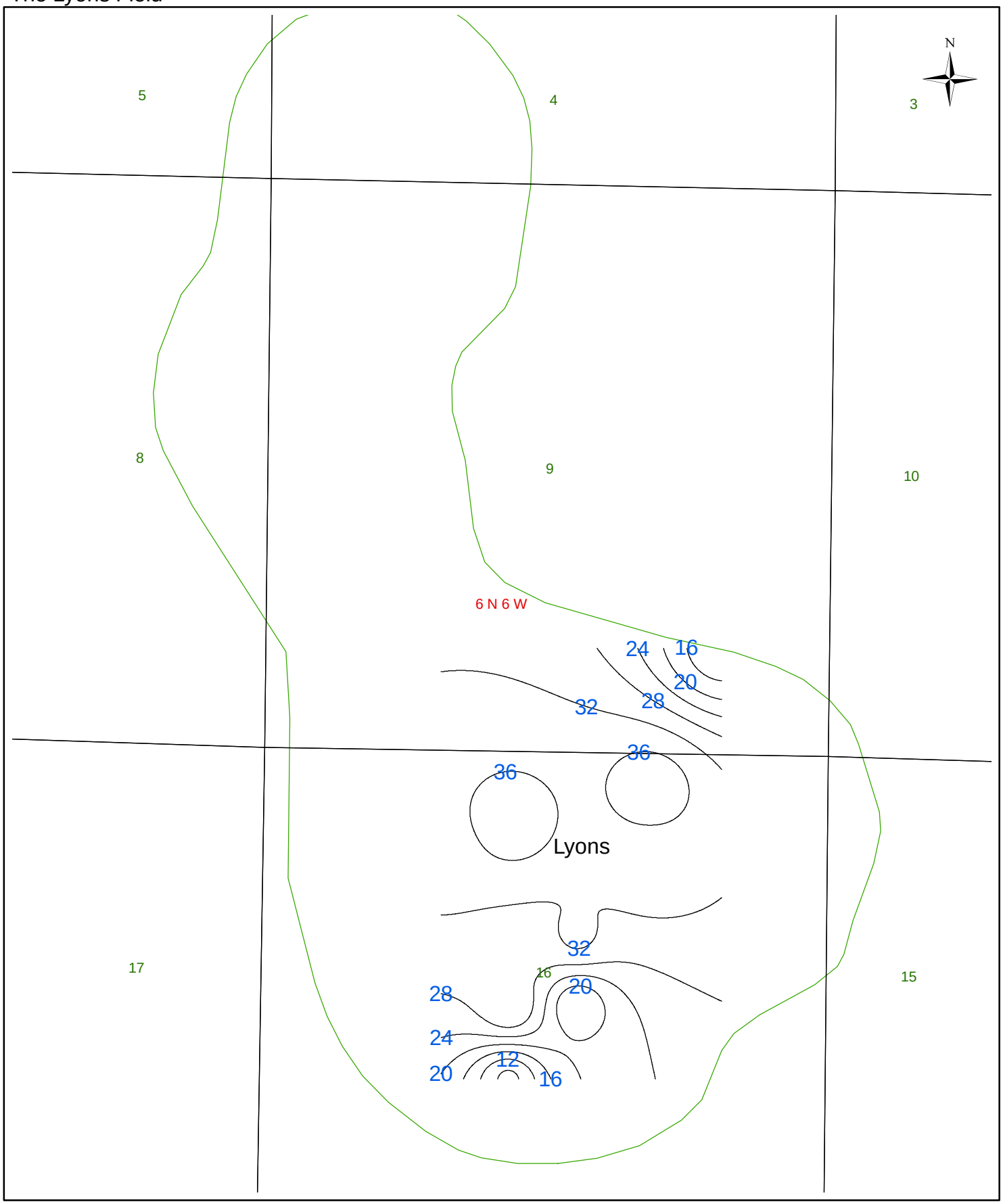


Figure 7: Map showing net porosity feet from neutron log greater than 10% porosity within the Vernon Fork Member in Lyons Field, Greene County. Contour interval is 2 feet.

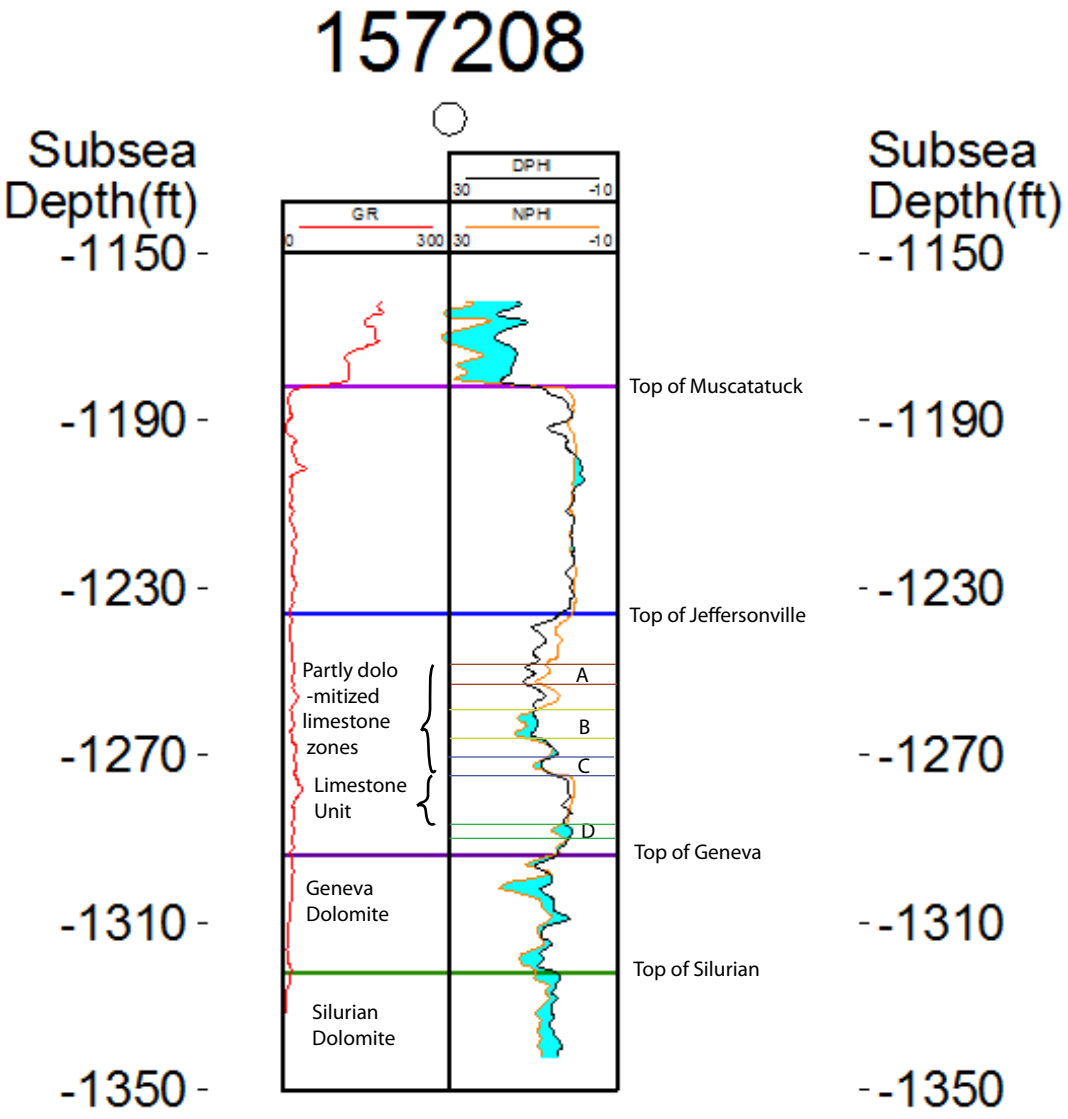


Figure 8: Type log section showing Devonian formations at Lyons Field, Greene County. A, B, C, and D are partly dolomitized Vernon Fork Member units and are generaly the prospective pay horizons.

HS=1

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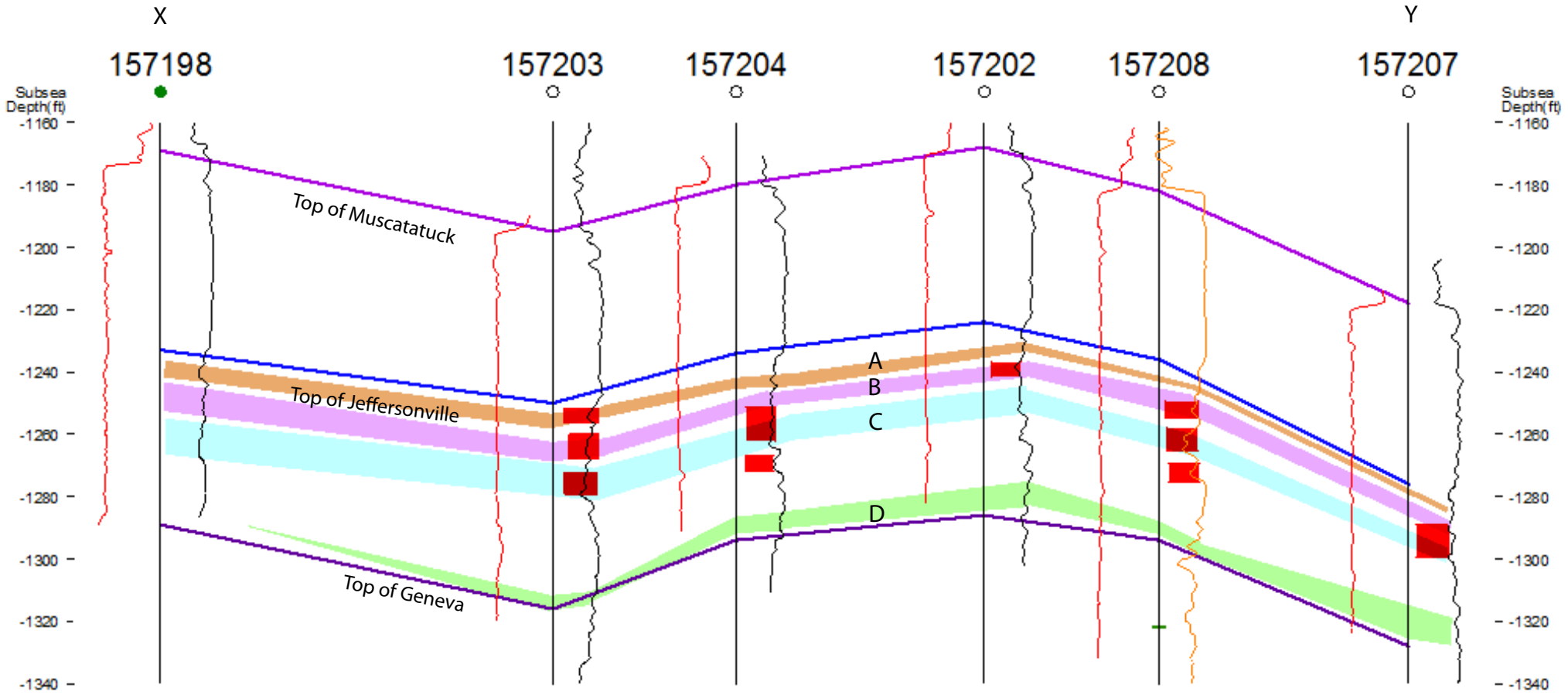

Figure 9: X-Y Cross section showing the Devonian subsurface structure across Lyons Field, Greene County. A, B, C, and D are the prospective pay horizons in the Vernon Fork Member. The red color box shows the completion interval for oil production or gas storage. For location of the cross section refer to Figure 1.

Table-1: List of Devonian Wells in Lyons Field, Greene County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil Production (BOPD/MCF)	Core P/A
118365	6	N	6	W	4	533	1848					
118369	6	N	6	W	8	523						
118370	6	N	6	W	9	487						
118371	6	N	6	W	9	485						
118372	6	N	6	W	9	494						
157198	6	N	6	W	9	591	1758	1810	1874			
157199	6	N	6	W	9	512	1826	1884				
118321	6	N	6	W	15	484						
118322	6	N	6	W	16	483					3	
118323	6	N	6	W	16	483					3	
118324	6	N	6	W	16	483						
118325	6	N	6	W	16	497	1824	1890				
118326	6	N	6	W	16	487					4	
118327	6	N	6	W	16	487					4	
118328	6	N	6	W	16	485						
118329	6	N	6	W	16	484					4	
118330	6	N	6	W	16	485						
118331	6	N	6	W	16	496	1683	1744		1841		
118332	6	N	6	W	16	531	1741	1802				
118333	6	N	6	W	16	483						
118335	6	N	6	W	16	481	1742					
157201	6	N	6	W	16	493	1670	1724	1773		21	
157202	6	N	6	W	16	488	1658	1715	1767		3	
157203	6	N	6	W	16	490	1685	1740	1796			
157204	6	N	6	W	16	489	1669	1710	1774		35	
157205	6	N	6	W	16	505	1714	1772	1815	oil well,IP not RPTD		
157206	6	N	6	W	16	531	1733	1792	1834	oil well,IP not RPTD		
157207	6	N	6	W	16	496	1714	1766	1824		show of oil	
157208	6	N	6	W	16	488	1670	1728	1782	1810	100	
157209	6	N	6	W	16	489	1677	1734	1781		28/30	
164119	6	N	6	W	16	484						
118337	6	N	6	W	20	502	1885	1970				
118338	6	N	6	W	21	478						

Field name: Lyons West

IGS ID: 10394

DOE ID: na

Location: Greene County, 7N-6W

Discovery date: 1975

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,728 ft.)

Field type: natural gas

Total number production wells: 2

Area: 170 acres

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (1,920 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 100 ft. at top of Muscatatuck.

Reservoir characteristics:

Field name: Marts

IGS ID: 10409

DOE ID: 450292

Location: Sullivan County, 9N-9W

Discovery date: 1932 (natural gas), 1949 (oil)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,133 ft.)

Field type: oil & natural gas (abandoned)

Total number production wells: 37 (oil) & 20 (natural gas)

Area: 170 acres

Cumulative production: 2,775,757 bbls. (2002)

Other reservoir units: Pennsylvanian

Deepest unit penetrated (depth): Ordovician, Black River Group (3,600 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

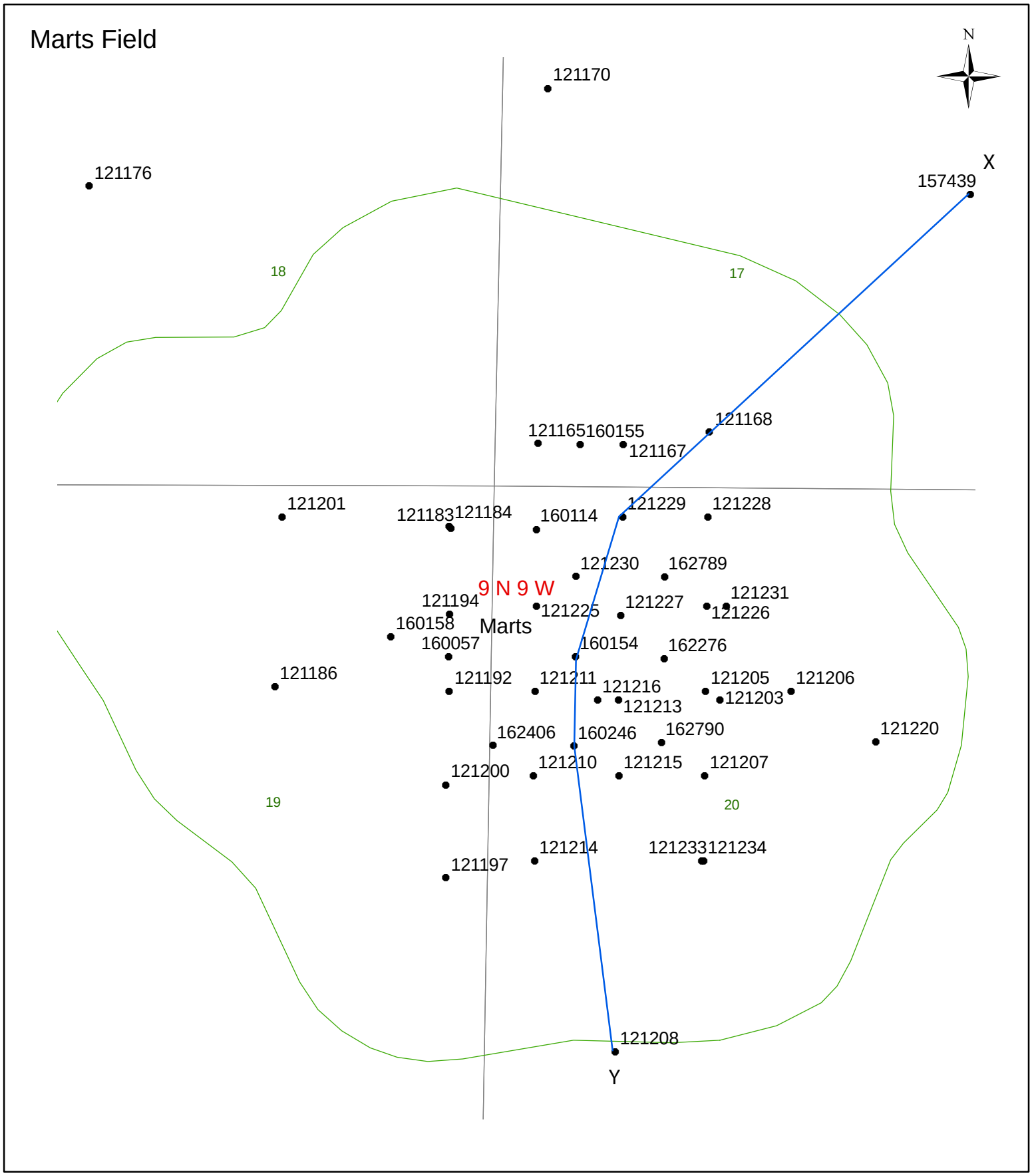

Figure 1: Map showing the location and wells at Marts Field, Sullivan County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 6). The wells depicted were used for subsurface maping and have a total depth (TD) of Devonian or deeper.

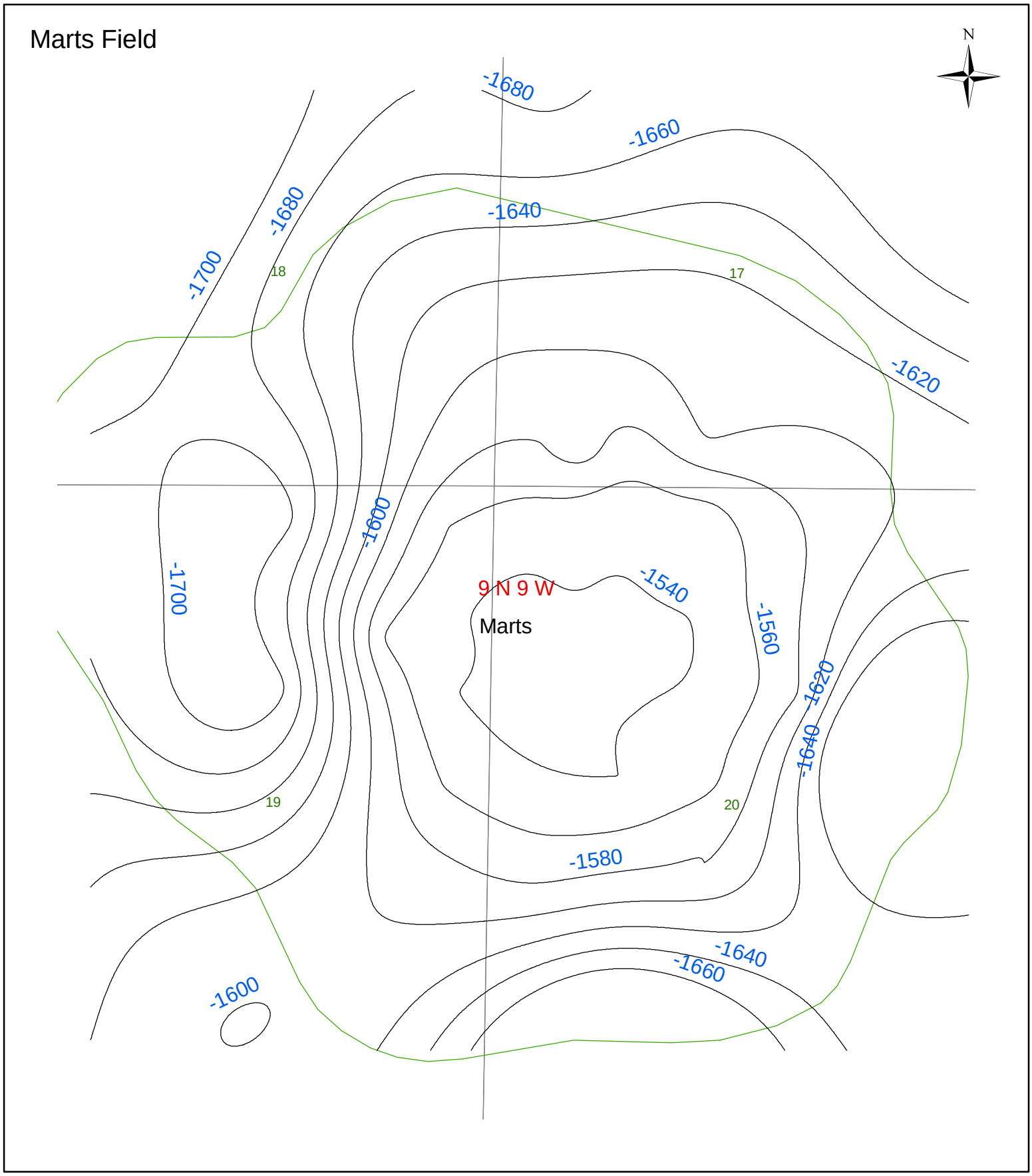

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Marts Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

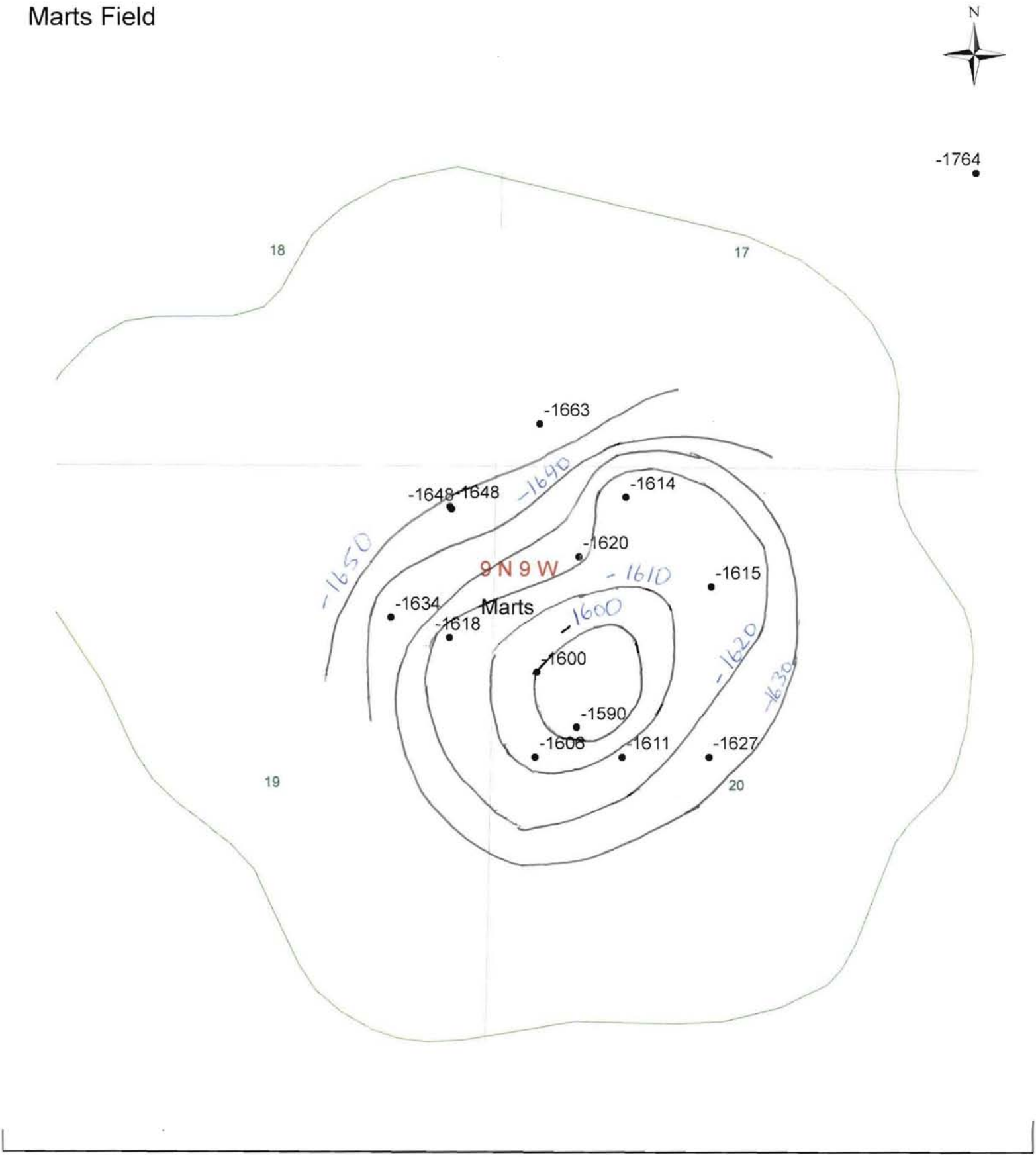

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Marts Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

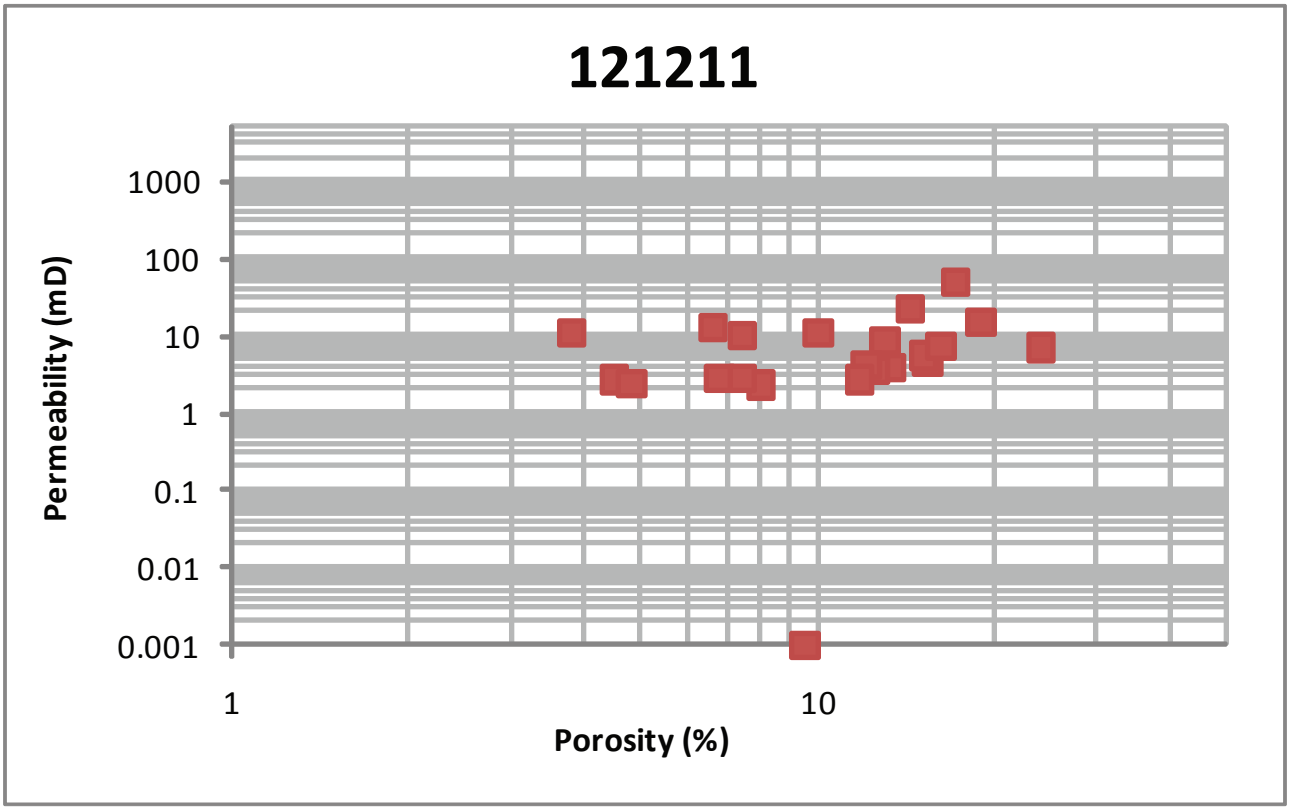

Figure 4: Porosity-permeability plot from core analysis from Marts Field, Sullivan County. The red points are data from the Vernon Fork. The chart title lists the IGS Well ID. For the well location see Figure 1.

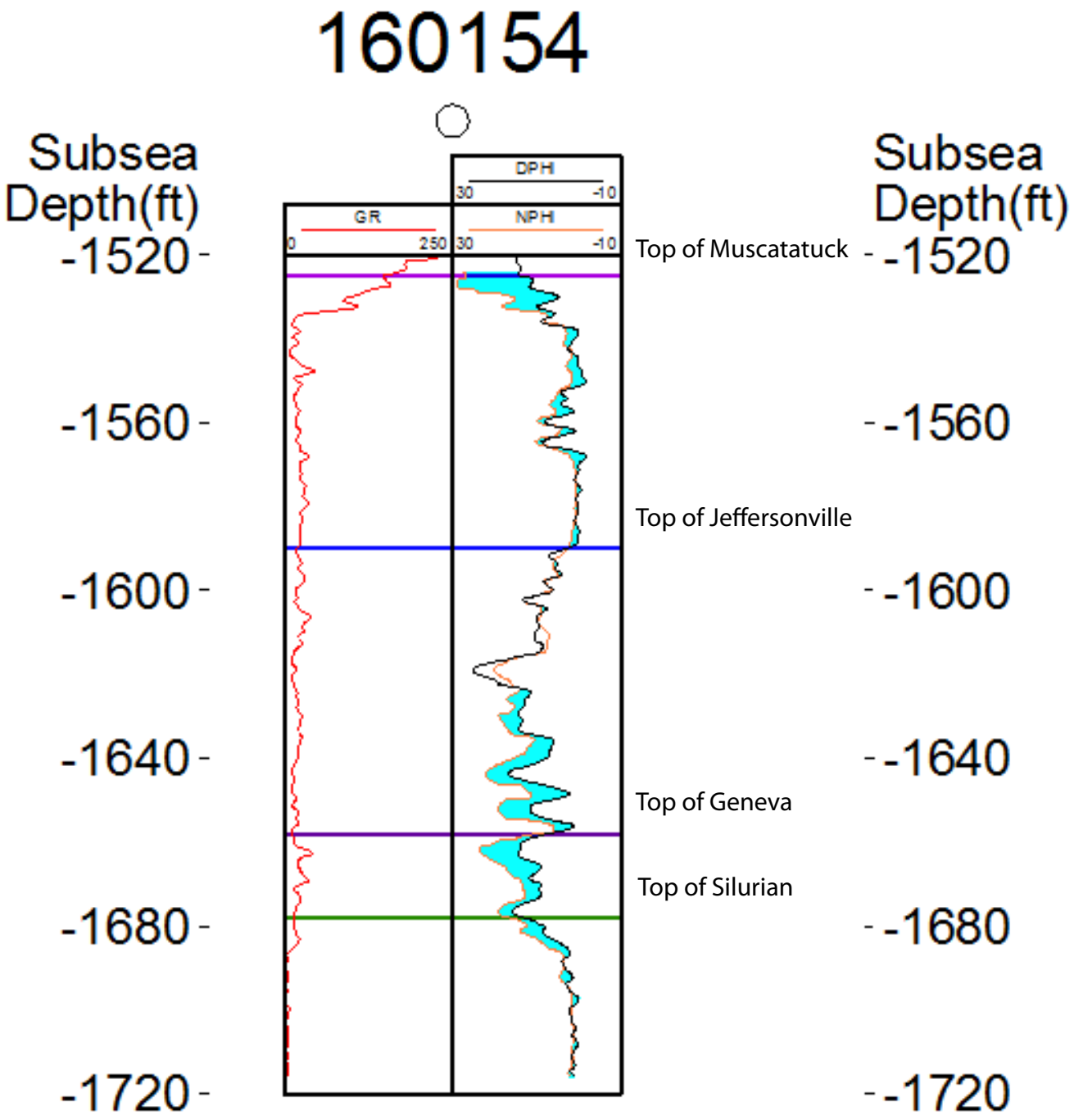

Figure 5: Type log section showing the Devonian formations at Marts Field, Sullivan County.

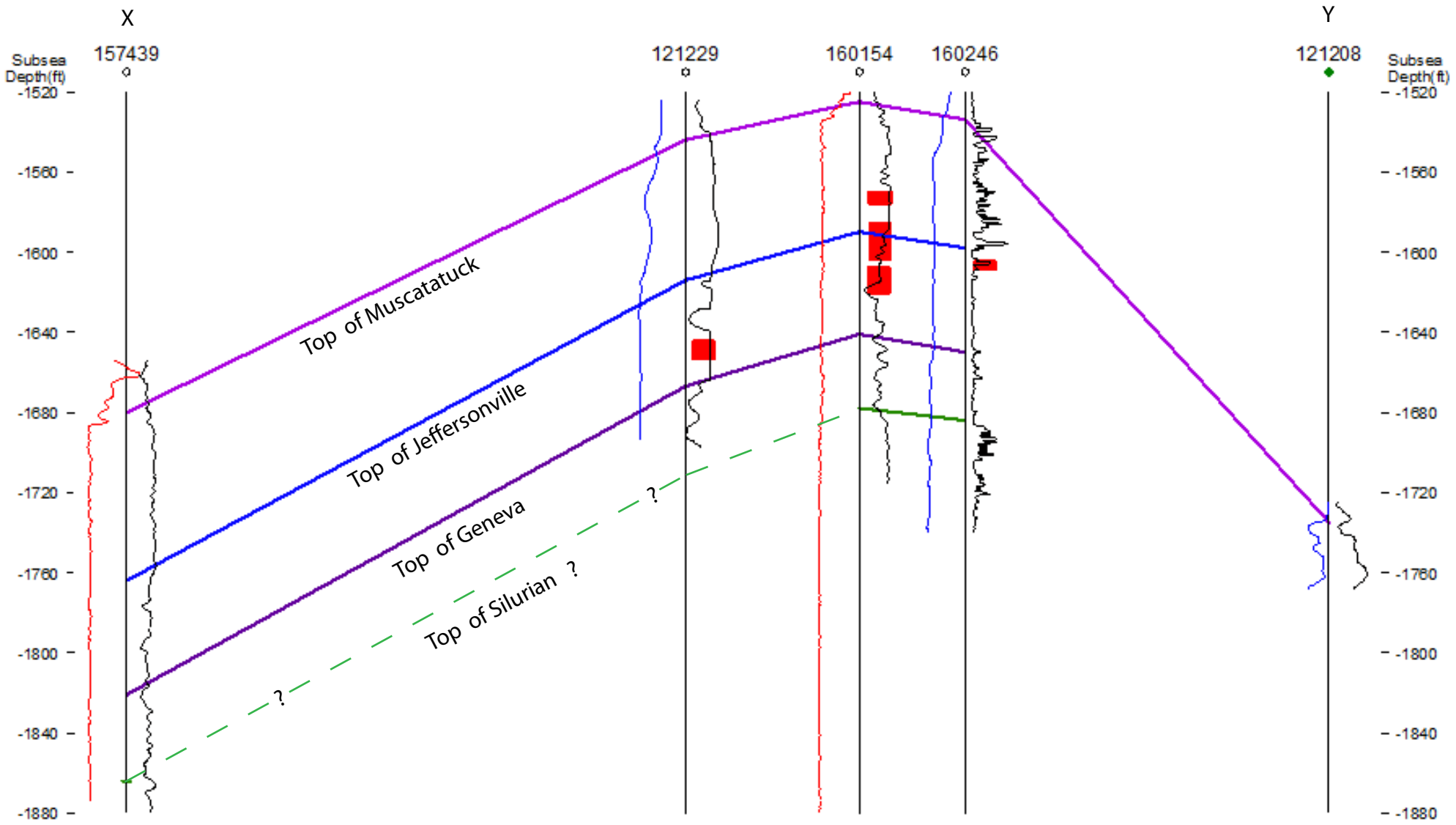

Figure 6: X-Y Cross section showing the Devonian subsurface structure across Marts Field, Sullivan County. The red color box shows the completion intervals for the oil and gas production. For location of the cross section refer to Figure 1.

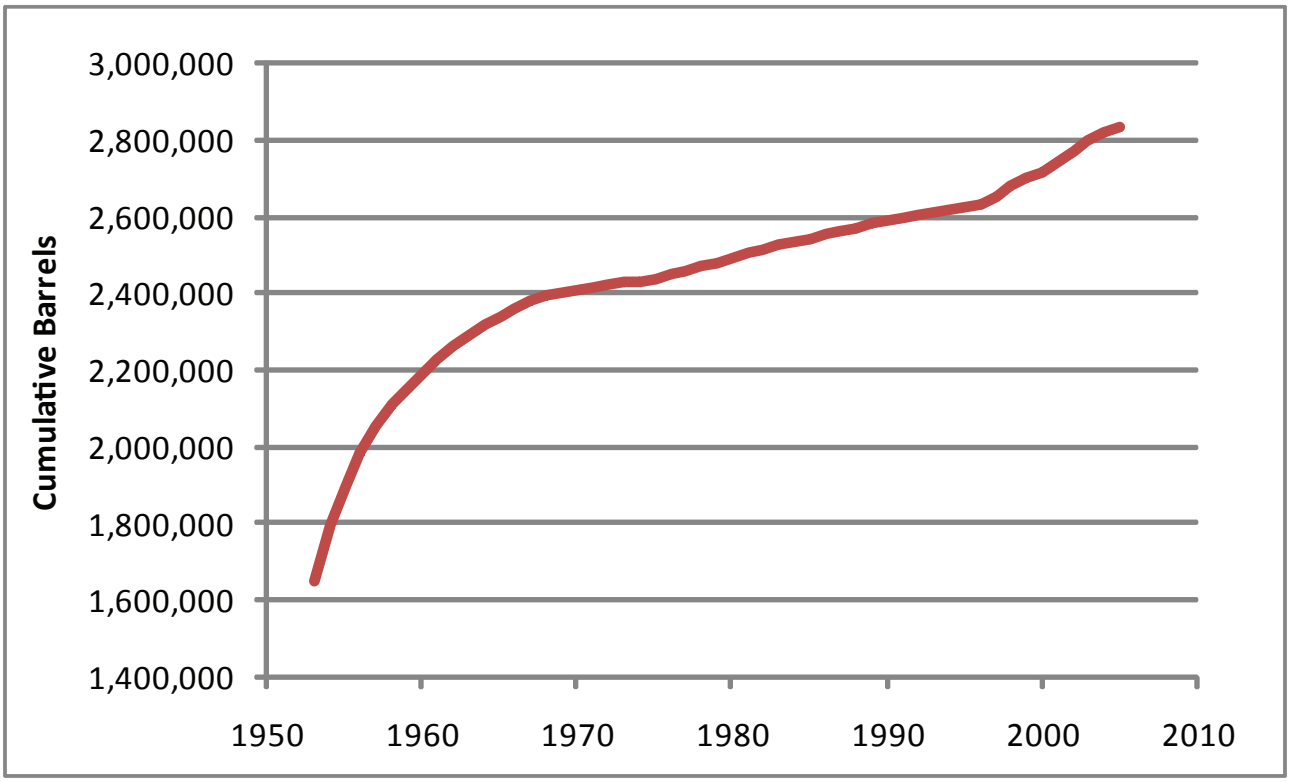

Figure - 7: Cumulative oil production history for Marts Field, Sullivan County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Marts Field, Sullivan County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
121165	9	N	9	W	17	537	2116	2200			35	
121167	9	N	9	W	17	509	2079				100	
121168	9	N	9	W	17	520	2123				25	
121170	9	N	9	W	17	543	2227					
157439	9	N	9	W	17	526	2206	2290	2344	2390		
160155	9	N	9	W	17	510	2103					
121176	9	N	9	W	18	531	2268					
121183	9	N	9	W	19	520	2079	2168			40	
121184	9	N	9	W	19	522	2082	2170			72	210
121186	9	N	9	W	19	525	2235					
121192	9	N	9	W	19	538	2079				169	
121194	9	N	9	W	19	515	2058				184	
121197	9	N	9	W	19	538	2125				60	
121200	9	N	9	W	19	533	2092				110	
121201	9	N	9	W	19	529	2238					
160057	9	N	9	W	19	532	2081	2150	2178		89	
160158	9	N	9	W	19	528	2082	2162	2192		20	
121203	9	N	9	W	20	528	2075					
121205	9	N	9	W	20	533	2079				360	
121206	9	N	9	W	20	532	2105				100	
121207	9	N	9	W	20	531	2084	2158			150	
121208	9	N	9	W	20	505	2240					
121210	9	N	9	W	20	538	2081	2144			110	
121211	9	N	9	W	20	538	2070	2138			448	
121213	9	N	9	W	20	541	2075				1500	
121214	9	N	9	W	20	535	2104				200	
121215	9	N	9	W	20	539	2079	2150			250	
121216	9	N	9	W	20	537	2076				14	
121220	9	N	9	W	20	508	2212					
121225	9	N	9	W	20	524	2056				400	
121226	9	N	9	W	20	529	2072	2144			600	
121227	9	N	9	W	20	536	2062				1300	
121228	9	N	9	W	20	529	2081				70/168	
121229	9	N	9	W	20	536	2080	2150			80	
121230	9	N	9	W	20	526	2072	2146			14	50
121231	9	N	9	W	20	528	2082				25	
121233	9	N	9	W	20	508	2090				5	
121234	9	N	9	W	20	508	2087				28/100	
160114	9	N	9	W	20	510	2057				80	
160154	9	N	9	W	20	534	2059			2220		
160246	9	N	9	W	20	540	2074	2130	2154	2220	15	
162276	9	N	9	W	20	535	2068					
162406	9	N	9	W	20	535	2077					
162789	9	N	9	W	20	530	2080					
162790	9	N	9	W	20	532	2090					

Field name: Mineral City

IGS ID: 10429 (oil), 10816 (gas storage)

DOE ID: 476691

Location: Greene County, 6N-5W

Discovery date: 1971 (including gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,500 ft.)

Field type: oil & gas storage

Total number production wells: 9 (oil), 15 (storage), 6 (observation)

Area: 400 acres

Cumulative production: 22,987 bbls. (2002)

Total capacity: 2,107,500 mcf

Other reservoir units: Mississippian, Blue River Group, Ste. Genevieve Ls. (oil)

Deepest unit penetrated (depth): Silurian (1,685 ft.)

Field characteristic: Domal anticline over probable Silurian reef with structural closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 13%

Average permeability – 30 md.

Approximate thickness – 25 ft.

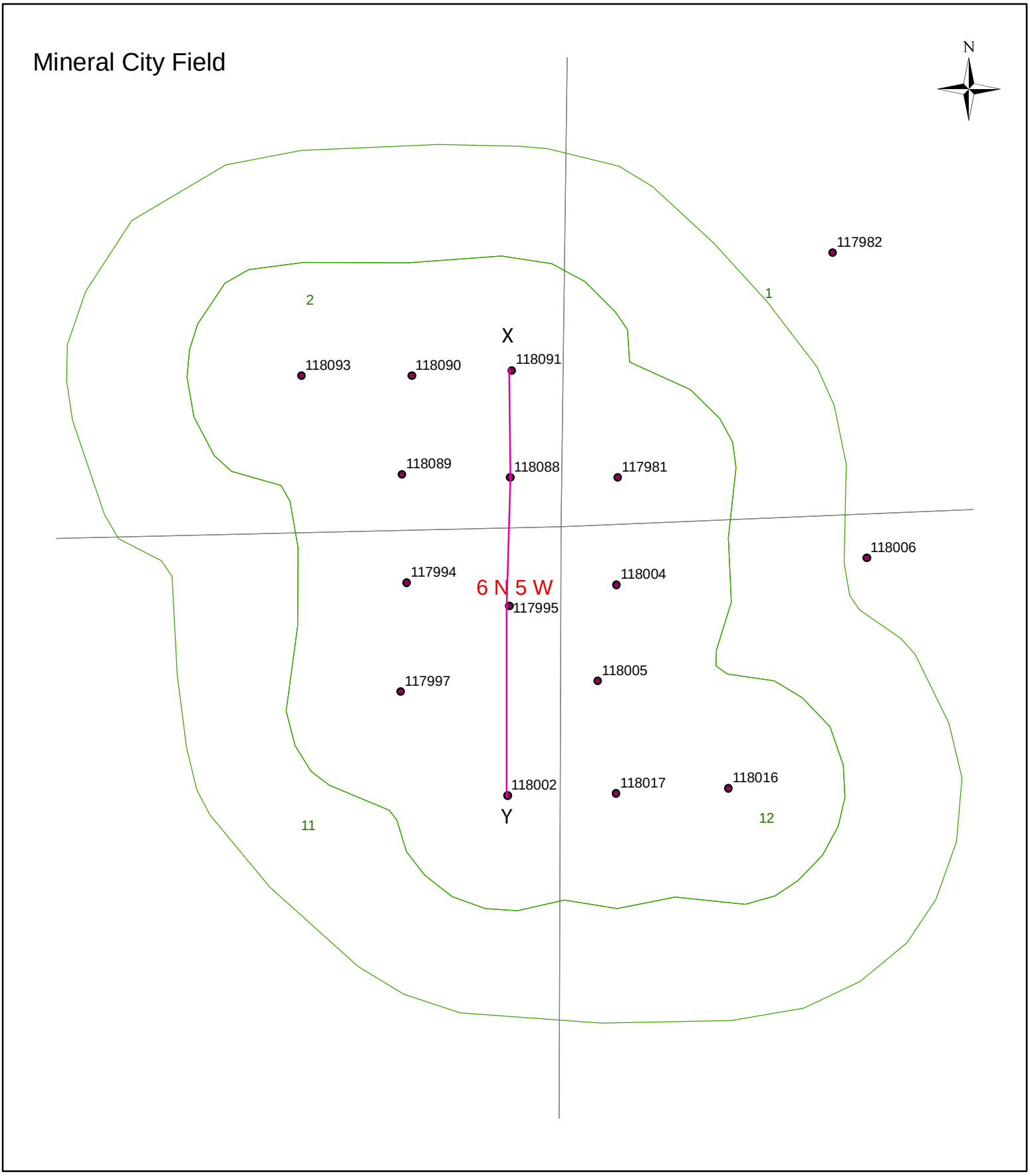

Figure 1: Map showing the location and wells at Mineral City Field, Greene County. X-Y is the location of the cross sections that show the subsurface Devonian structure (Fig. 11). The wells depicted are the wells used for subsurface maping and which have a total depth (TD) of Devonian or deeper.

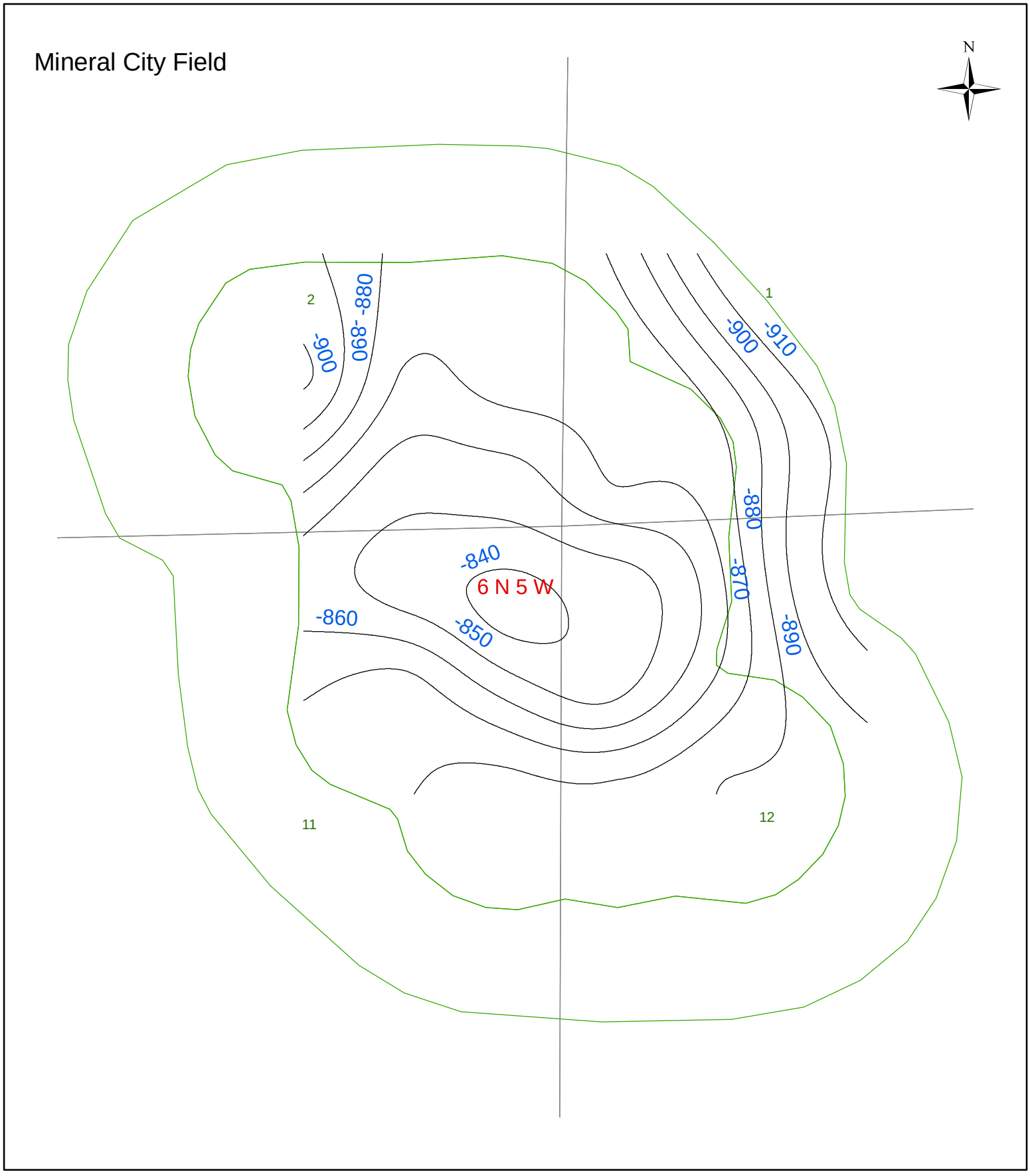

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Mineral City Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

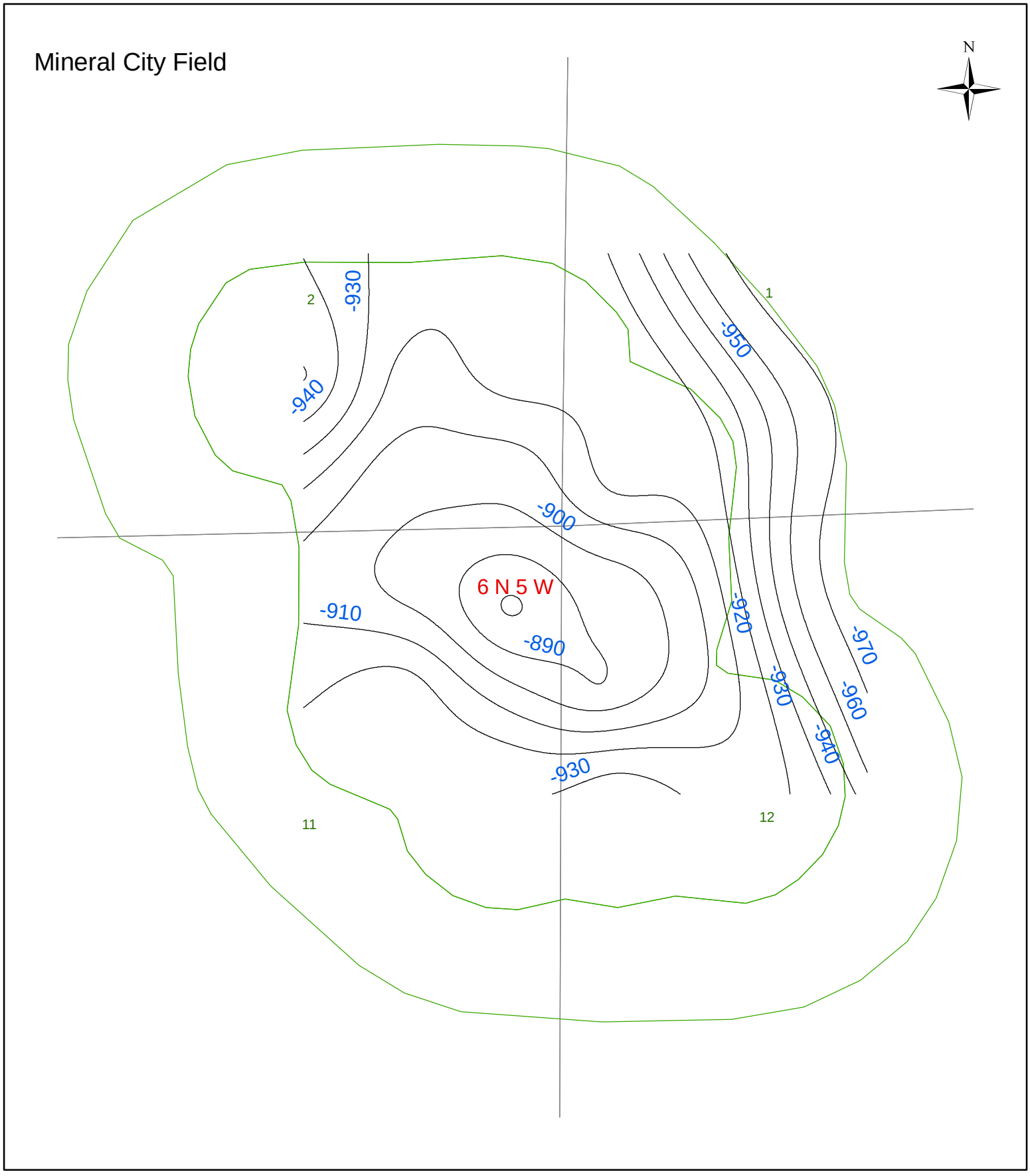

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Mineral City Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

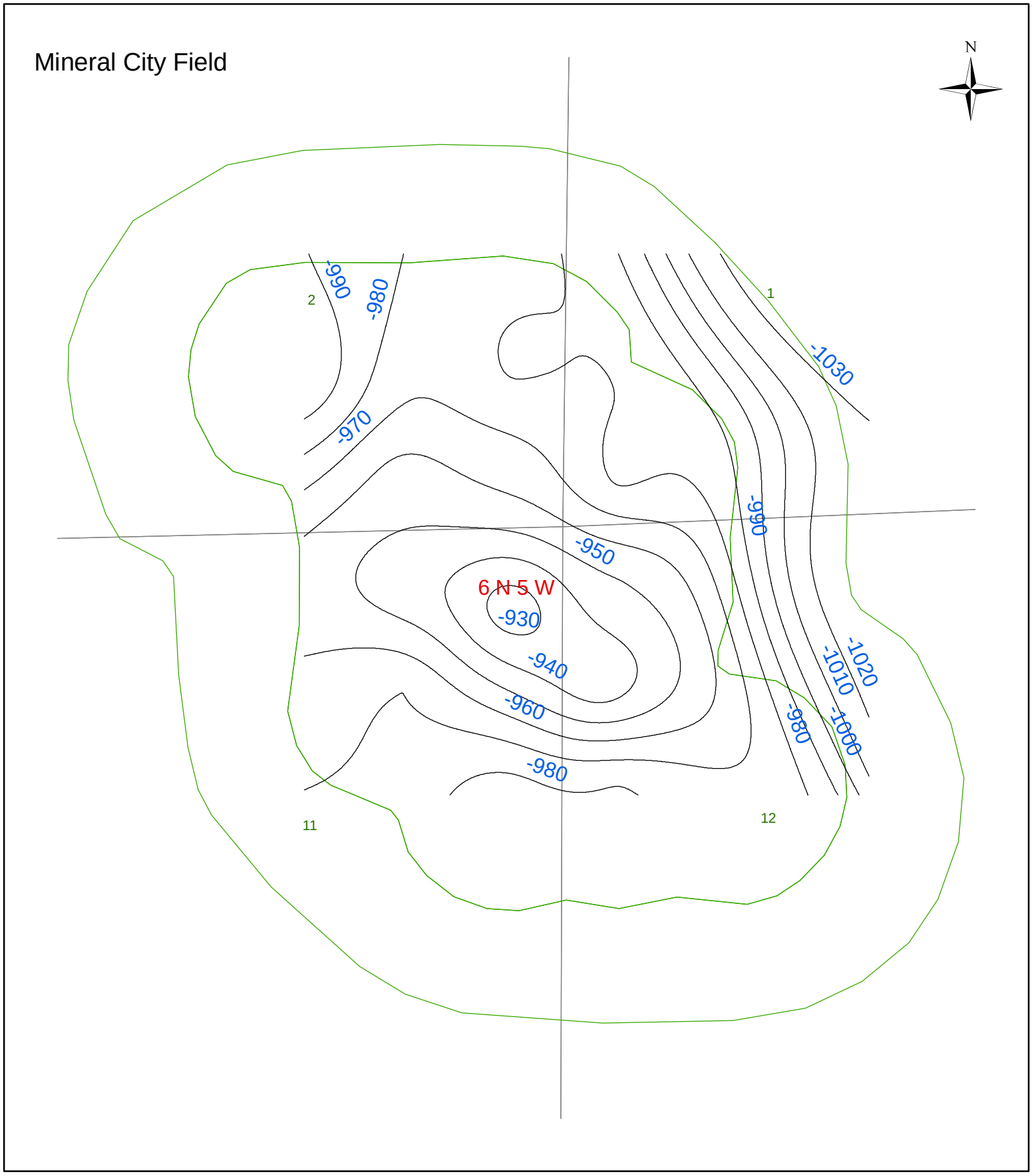

Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Member in Mineral City Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

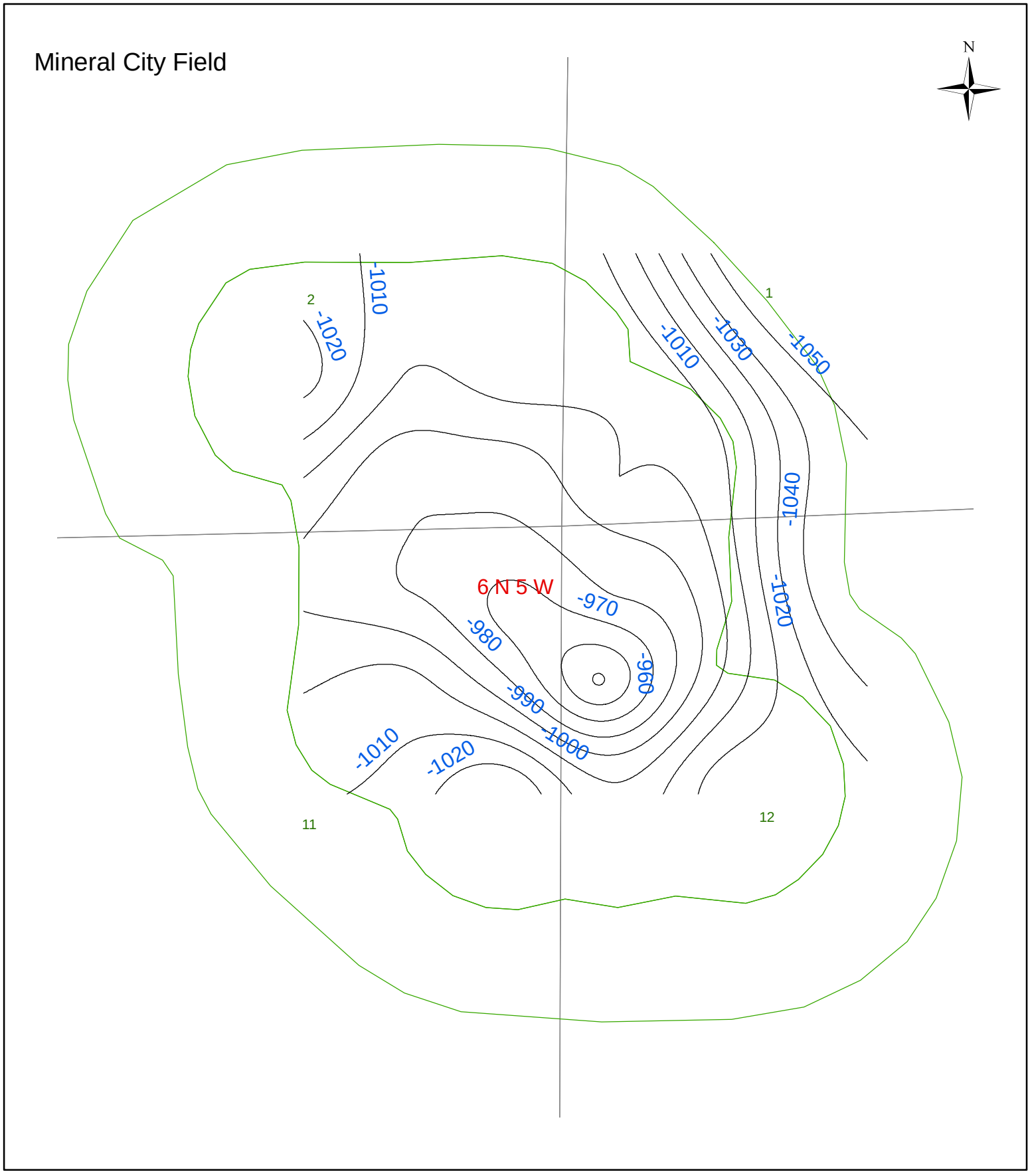

Figure 5: Structure map showing the top of the subsurface Silurian in the Mineral City Field, Greene County. Countours show values below sea level, contour interval is 10 ft .

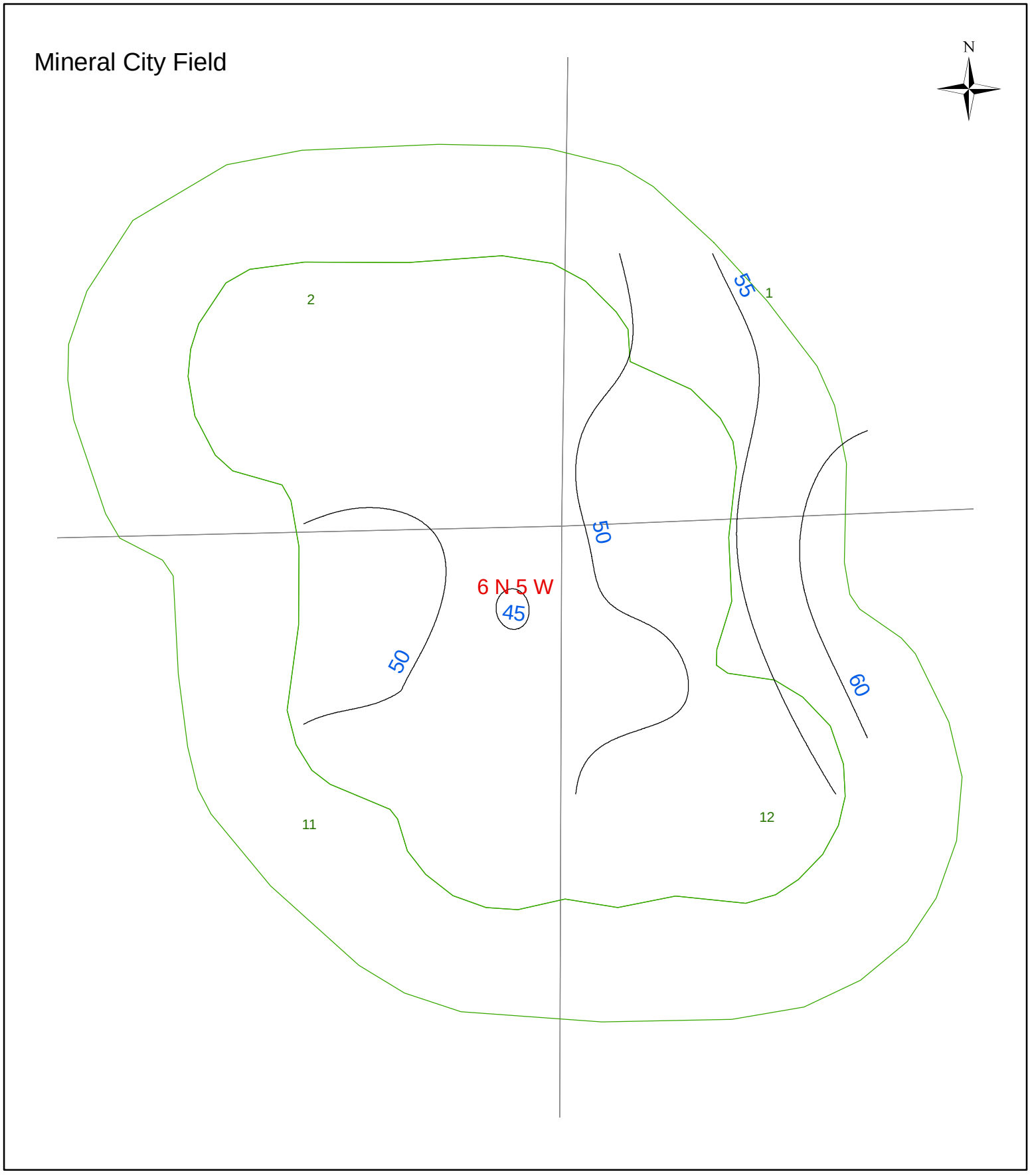

Figure 6: Isopach map showing the thickness of the Vernon Fork Member from the Mineral City Field, Greene County. Contour interval is 5 ft.

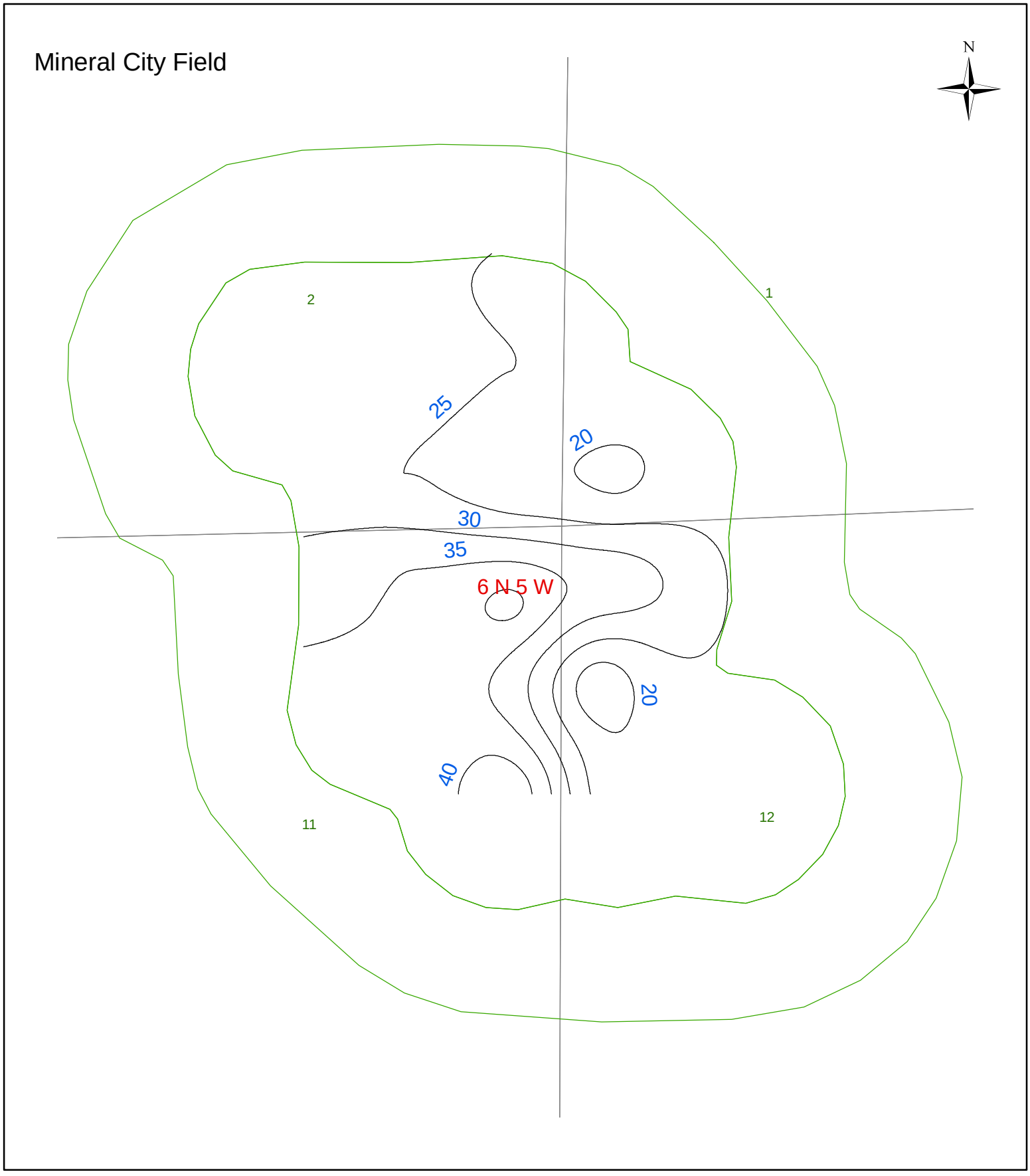

Figure 7: Isopach map showing the thickness of the Geneva Dolomite Member in the Mineral City Field, Greene County. Contour interval is 5 ft.

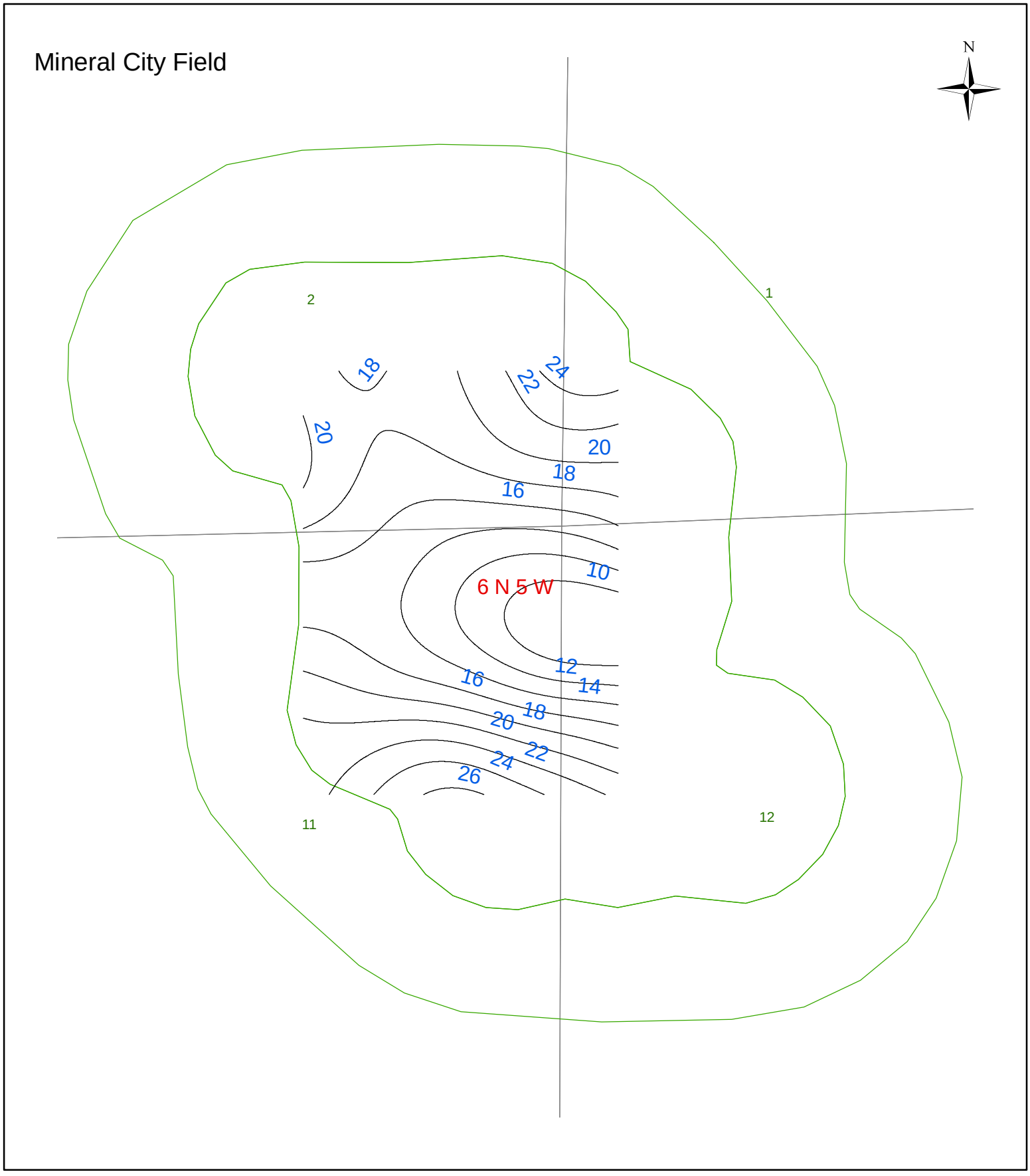

Figure 8: Map showing net porosity feet greater than 10 % from the neutron log for the Vernon Fork Member in the Mineral City field, Green County. Contour interval is 2 ft.

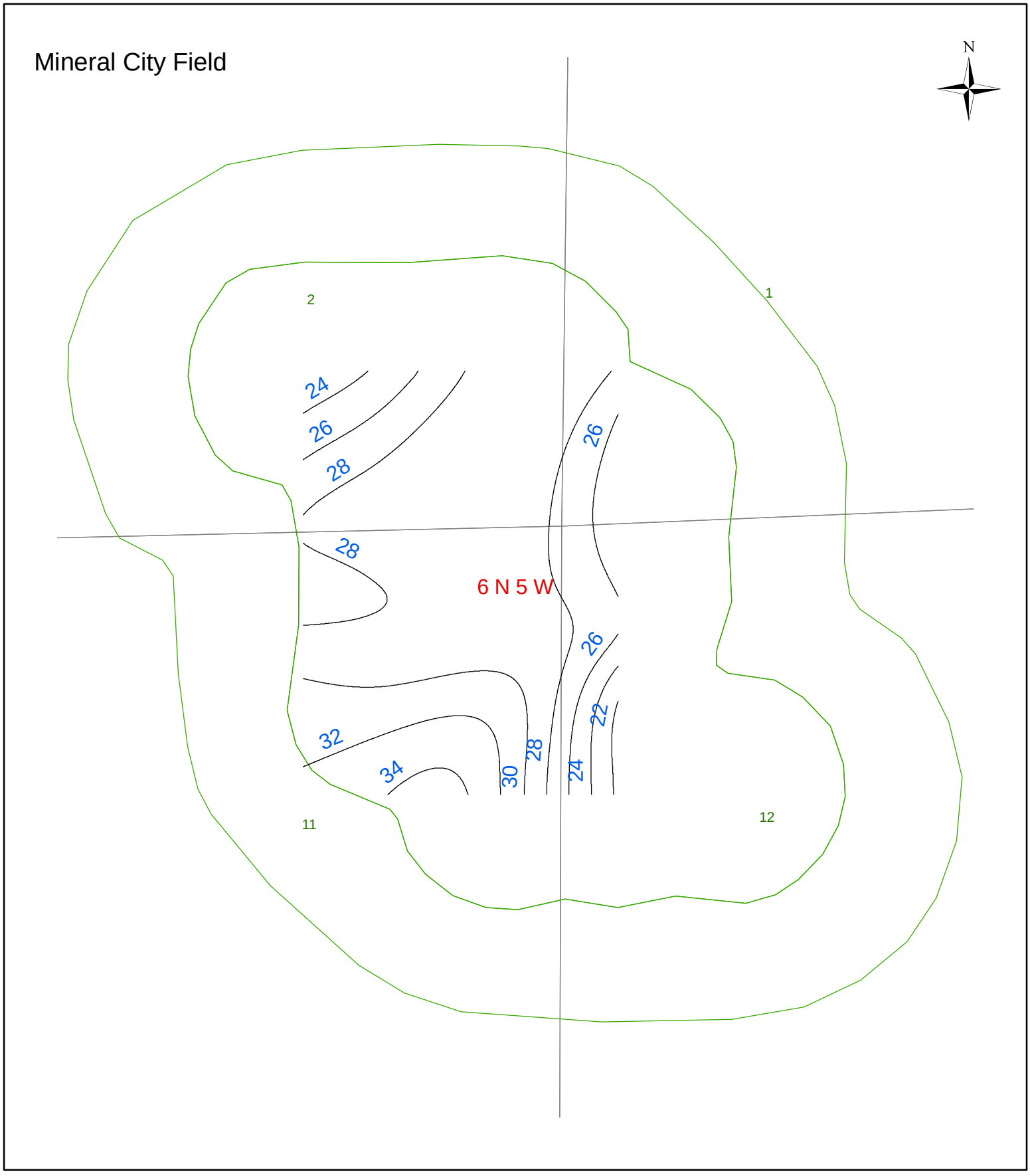

Figure 9: Map showing net porosity feet greater than 10% from the neutron log for the Geneva Dolomite Member in Mineral City Field, Green County. Contour interval is 2 ft.

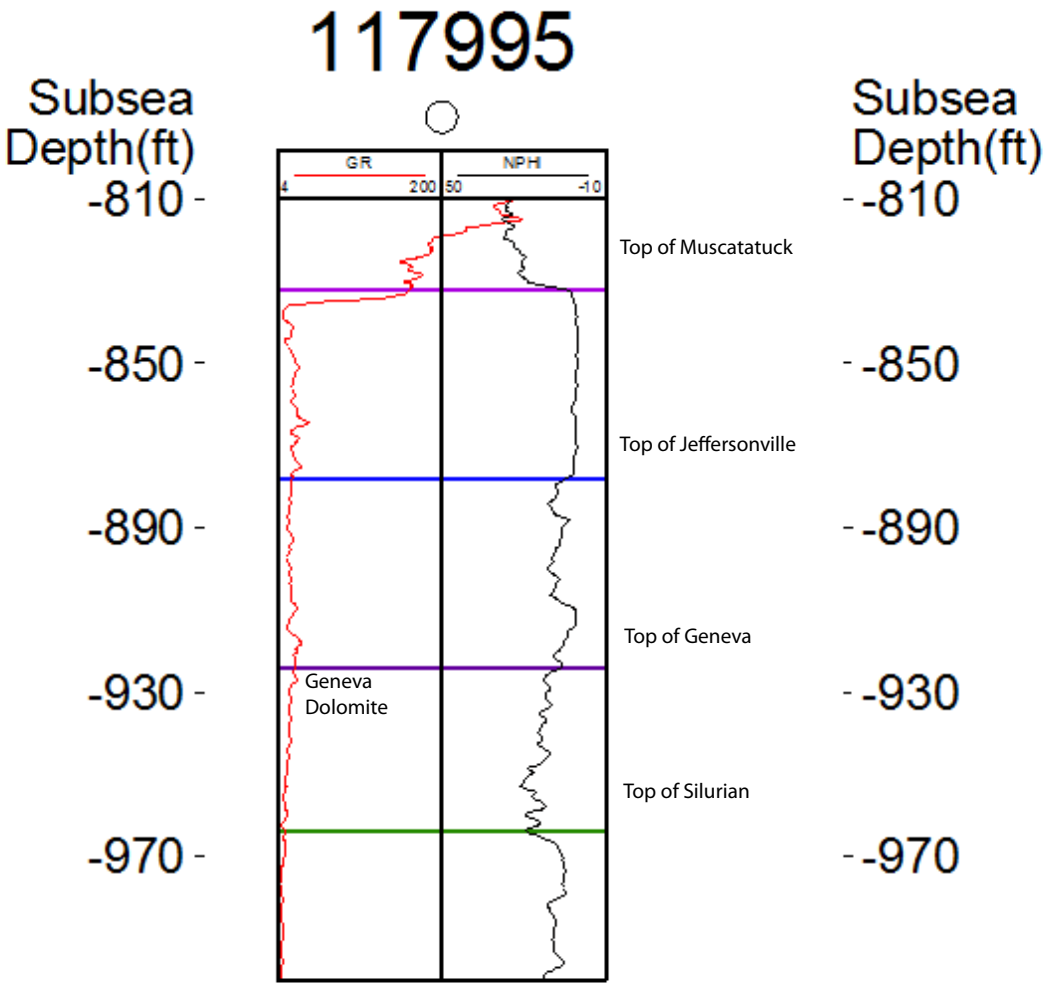

Figure 10: Type log section showing the Devonian formations from Mineral City Field, Greene County.

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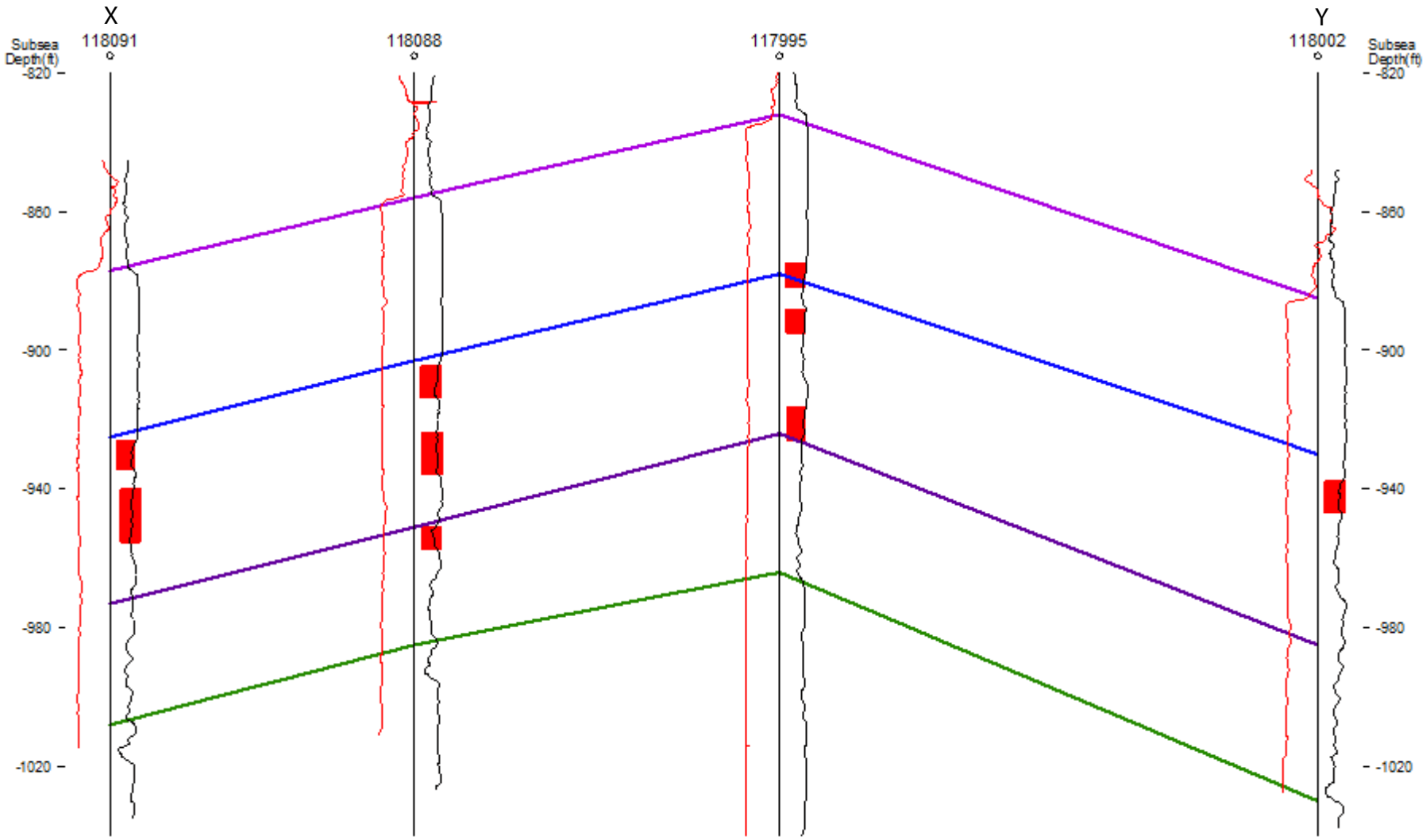

Figure 11: X-Y Cross section showing the Devonian subsurface structure across Mineral City Field, Greene County. The red color box shows the completion intervals for gas storage, production or observation. For location of the cross section refer to Figure 1.

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IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Net por-osity Ft. Vernon Fork (ft.)	Net por-osity Ft. Geneva(ft.)
IGS_ID	Twp	wp_	Rng	ng_	and_	Kb	Muskat	JeffGeneva	Sil		20	21
117981	6	N	5	W	1	564	1436	1488	1546	1564		
117982	6	N	5	W	1	531	1450	1506	1568	1590	15	32
118088	6	N	5	W	2	639	1495	1542	1602	1622	23	34
118089	6	N	5	W	2	635	1489	1538	1591	1616	7	20
118090	6	N	5	W	2	605	1472	1520	1577	1604	34	33
118091	6	N	5	W	2	615	1492	1540	1596	1621	24	22
118093	6	N	5	W	2	555	1458	1506	1554	1579		
117994	6	N	5	W	11	654	1497	1550	1597	1633	11	24
117995	6	N	5	W	11	604	1438	1482	1528	1570	5	29
117997	6	N	5	W	11	642	1518	1568	1612	1648	21	32
118002	6	N	5	W	11	612	1497	1542	1597	1642	30	37
118004	6	N	5	W	12	549	1394	1445	1498	1532		
118005	6	N	5	W	12	592	1434	1481	1524	1540	6	
118006	6	N	5	W	12	540	1454	1516	1569	1590		
118016	6	N	5	W	12	589	1480			1616		
118017	6	N	5	W	12	584	1467	1520	1566	1586	24	16

Table-1: List of the wells used for subsurface structure mapping in Mineral City Field, Greene County. The wells selected have a TD of Devonian or deeper.

Field name: Montgomery North

IGS ID: 10447

DOE ID: na

Location: Daviess County, 3N-6W

Discovery date: 1997

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,948 ft.)

Field type: non-commercial natural gas

Total number production wells: 1

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,948 ft.)

Field characteristic: Subtle anticlinal nose with no observable closure at Mississippian.

Reservoir characteristics:

Field name: Newberry

IGS ID: 10479

DOE ID: 505455

Location: Daviess County, 5N-5&6W

Discovery date: 1952

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,794 ft.)

Field type: oil, natural gas

Total number production wells: 4 (1 Devonian)

Area: na

Cumulative production: 9,109 (2002) (Paoli only)

Other reservoir units: Mississippian, Blue River Group, Paoli Limestone

Deepest unit penetrated (depth): Ordovician, Maquoketa Group (2,745 ft.)

Field characteristic: Subtle anticlinal nose with structural closure in excess of 20 ft. at Mississippian.

Reservoir characteristics:

Field name: Oakland City Consolidated

IGS ID: 10488

DOE ID: 517530

Location: Pike County, 2S-8W

Discovery date: 1907

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,926 ft.)

Field type: oil & natural gas

Total number production wells: 358

Area: 2320 acres

Cumulative production: 757,589 bbls. (2002)

Other reservoir units:

Mississippian, Stephensport Group, Big Clifty Fm.

Mississippian, West Baden Group, Elwren (Cypress) Fm.

Deepest unit penetrated (depth): Silurian (3,320 ft.)

Field characteristic: Subtle broad anticline with closure in excess of 20 ft. at Mississippian.

Reservoir characteristics:

Field name: Odon East

IGS ID: 10495, 10820 (gas storage)

DOE ID: na

Location: Daviess County, 5N-5W

Discovery date: 1952 (oil), 1964 (natural gas), 1978 (gas storage)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,133 ft.) (gas storage)

Field type: oil, natural gas & gas storage

Total number production wells: 40 (oil), 2 (natural gas), 4 (storage)

Area: 160 acres

Cumulative production: 647,027 bbls. (2002)

Total capacity: 500,000 mcf

Other reservoir units: Mississippian, Sanders Group, Salem Ls. (oil)

Deepest unit penetrated (depth): Devonian, New Harmony Group (1,830 ft.)

Field characteristic: Anticline with structural closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 11.6%

Average permeability – 10.7 md.

Approximate thickness – 33 ft.

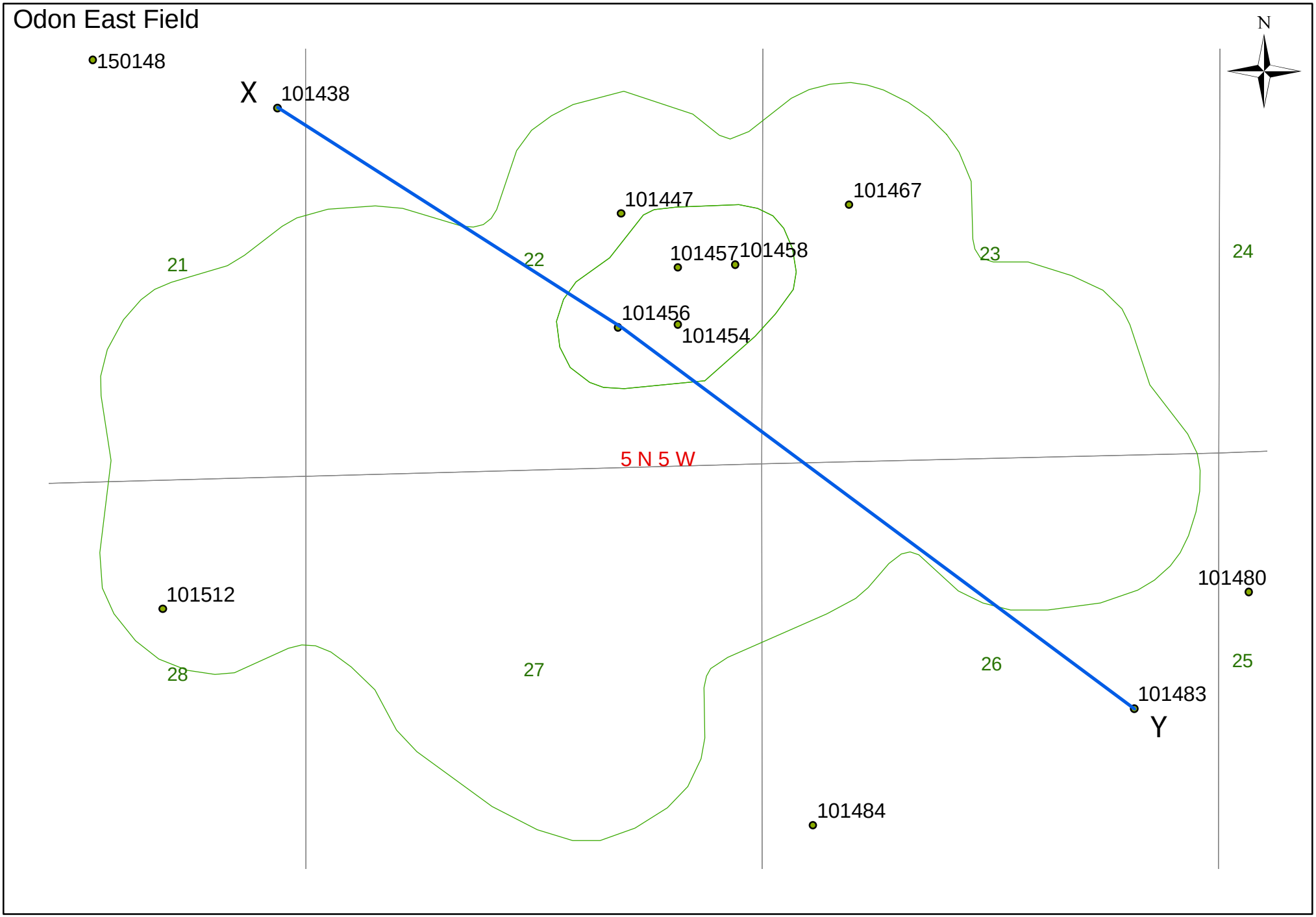

Figure 1: Map showing the location and wells at Odon East Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 5.

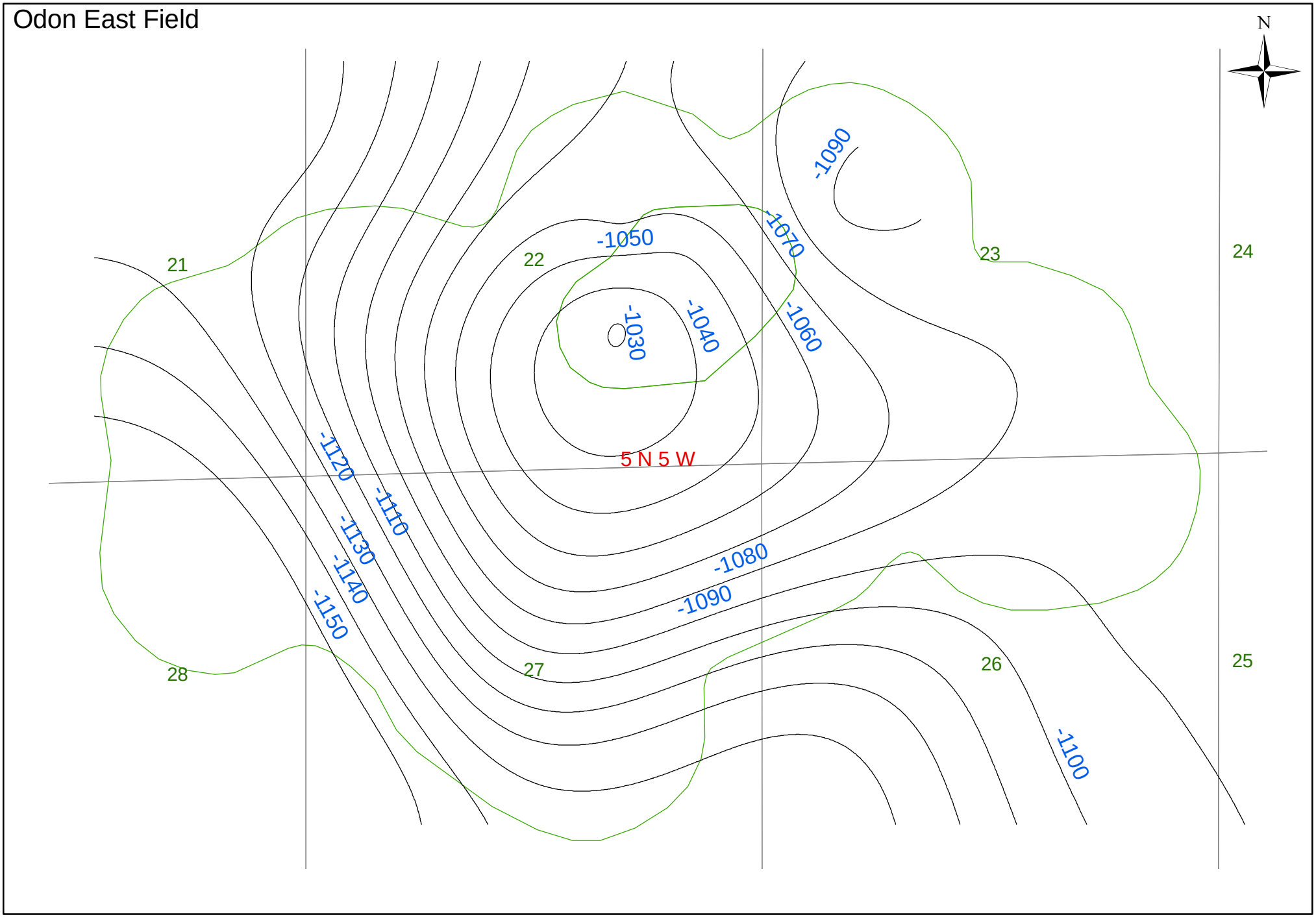

Figure 2: Structure map showing the top of the Muscatatuck Limestone in Odon East Field, Daviess County. Contours show values below sea level; contour interval is 10 ft .

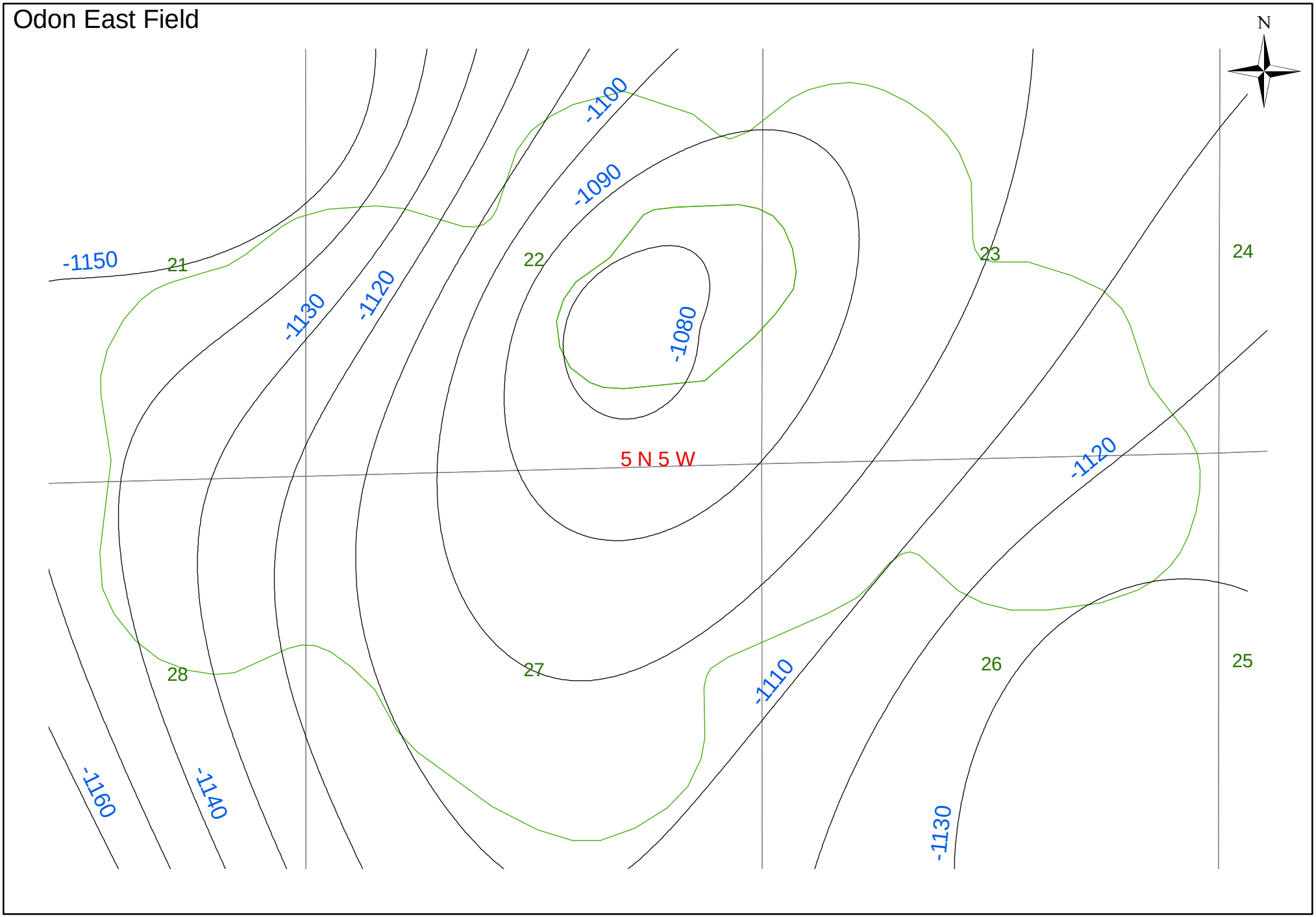

Figure 3: Structure map showing the top of the Jeffersonville Limestone in Odon East Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

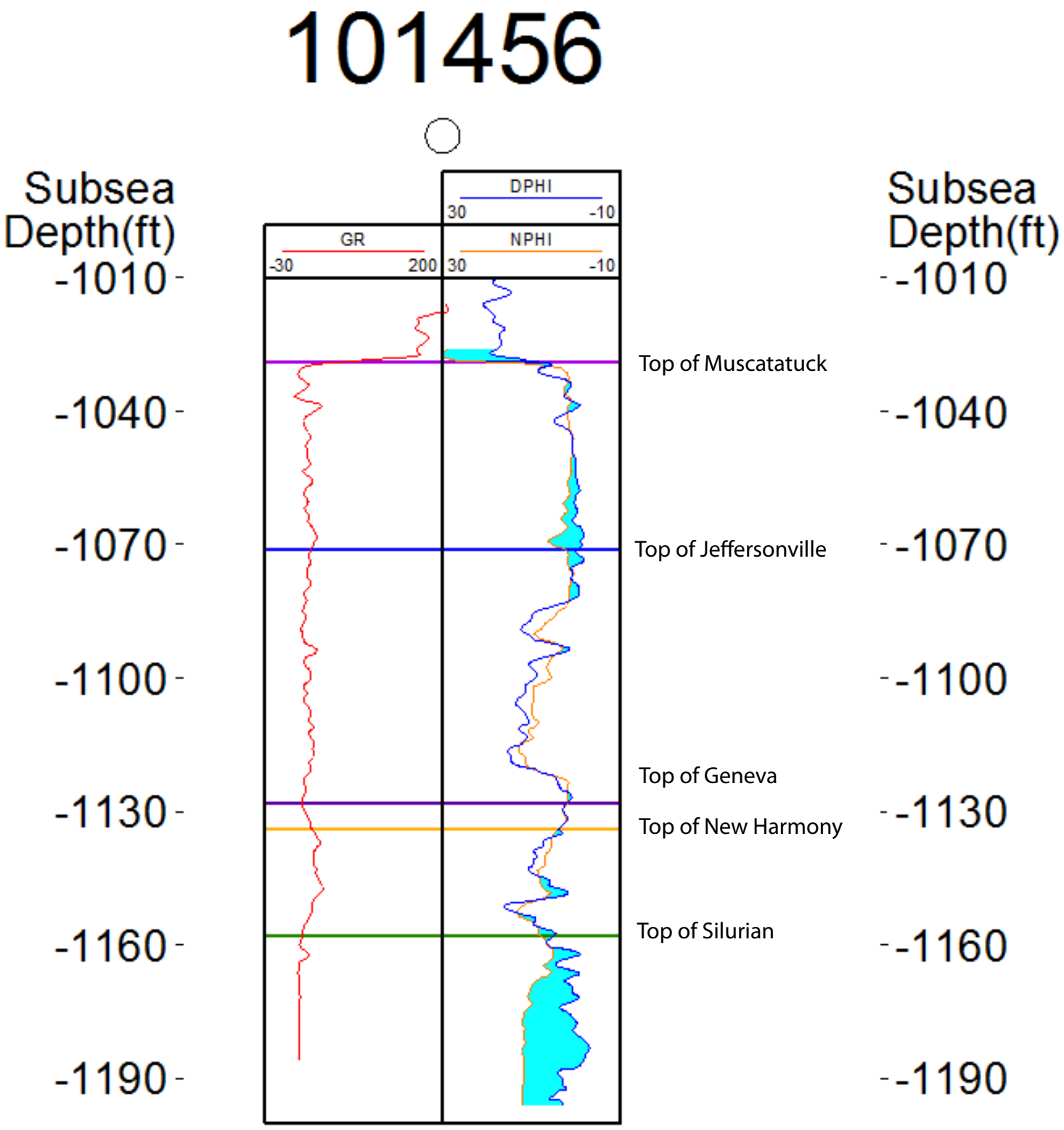

Figure 4: Type log section showing the Devonian formations at Odon East Field, Daviess County.

HS=1

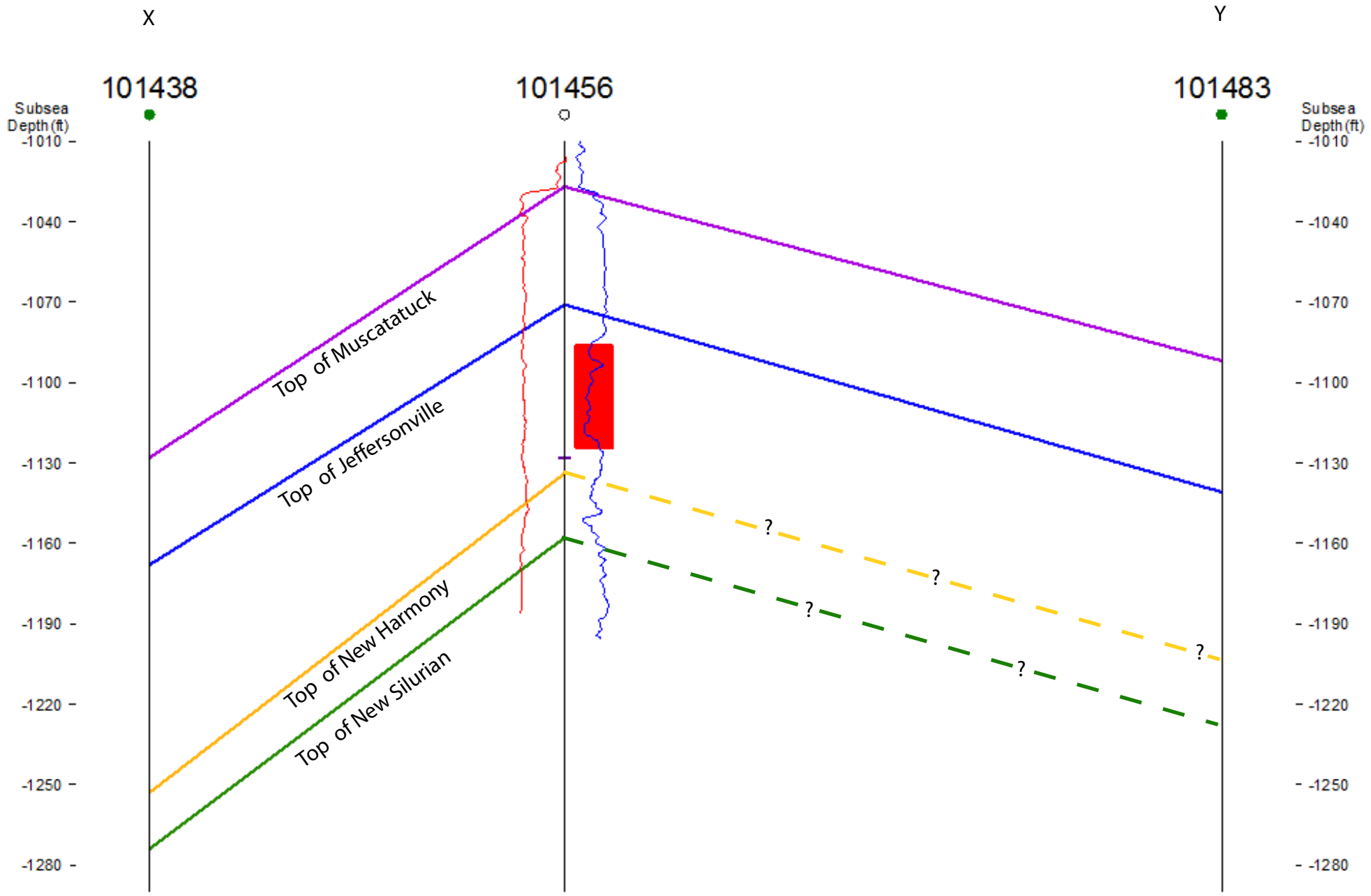

Figure 5: X-Y Cross section showing the Devonian subsurface structure across Odon East field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the gas storage zone.

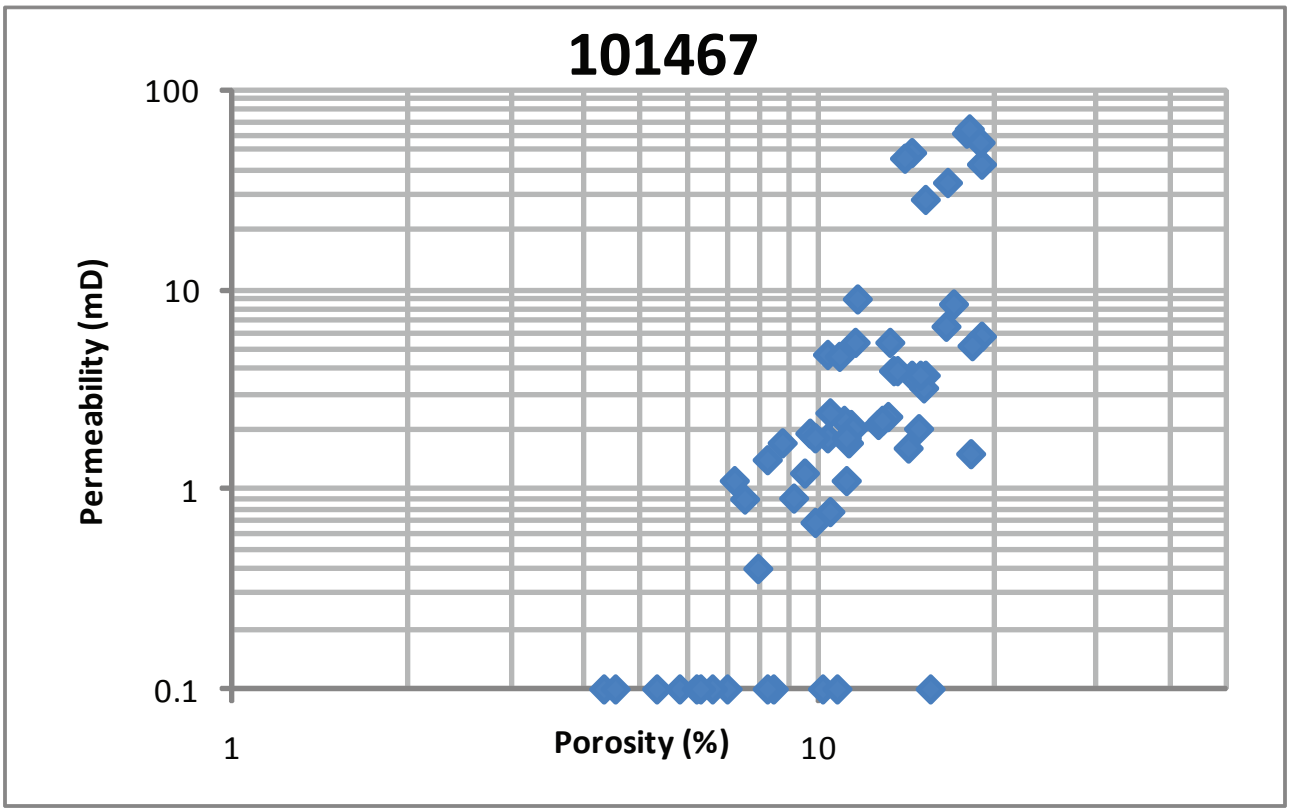

Figure 6: Porosity and permeability plot from core analysis from Odon East Field, Daviess County. The chart title lists the IGS Well ID. For the well locations see Figure 1.

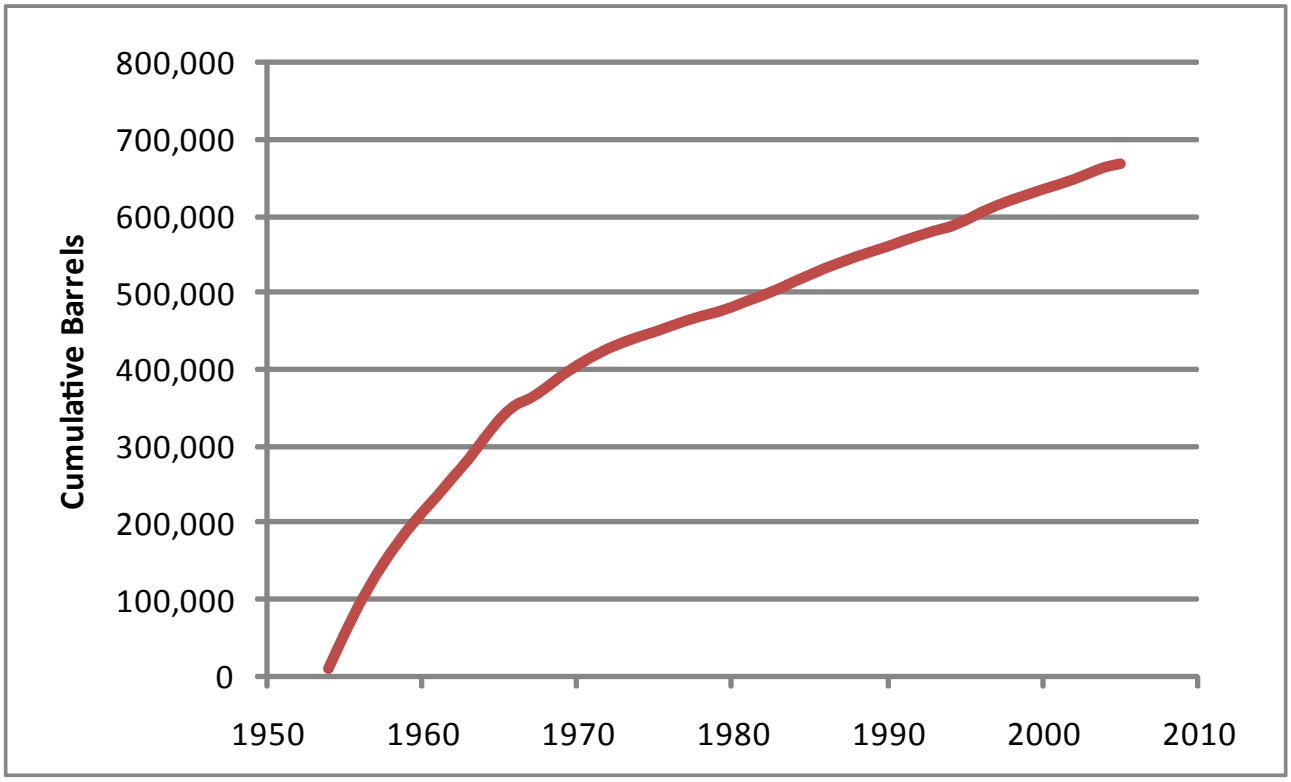

Figure - 7: Cumulative oil production history from Odon East Field, Daviess County since 1954.

Table-1: List of the wells used for subsurface structure mapping in Odon East Field, Daviess County.

IGS_ID	Twp	Twp _D	Rng	Rng_ D	Land _N	Elevatio n/Kb	Top of Musca- tatcuk	Top of Jeffer- sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
101438	5	N	5	W	21	564	1692	1732		1817	1838		
150148	5	N	5	W	21	599	1724						
101447	5	N	5	W	22	563	1626						10
101467	5	N	5	W	23	596	1689					4.5	
101480	5	N	5	W	25	614	1694	1744					
101483	5	N	5	W	26	561	1653	1702					
101484	5	N	5	W	26	549	1686						
101512	5	N	5	W	28	558	1718						
101454	5	N	5	W	22	577	1616	1656		1747			3
101456	5	N	5	W	22	564	1593	1635	1690	1714			2.7
101457	5	N	5	W	22	580	1626	1658		1744			
101458	5	N	5	W	22	591	1678	1720					

Field name: Odon North

IGS ID: 10496

DOE ID: na

Location: Daviess County, 5N-5W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,760 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units:

Deepest unit penetrated (depth): Silurian (1,907 ft.)

Field characteristic: Subtle broad anticline with closure in excess of 30 ft. at top of Muscatatuck.

Reservoir characteristics:

Approximate thickness 15 ft.

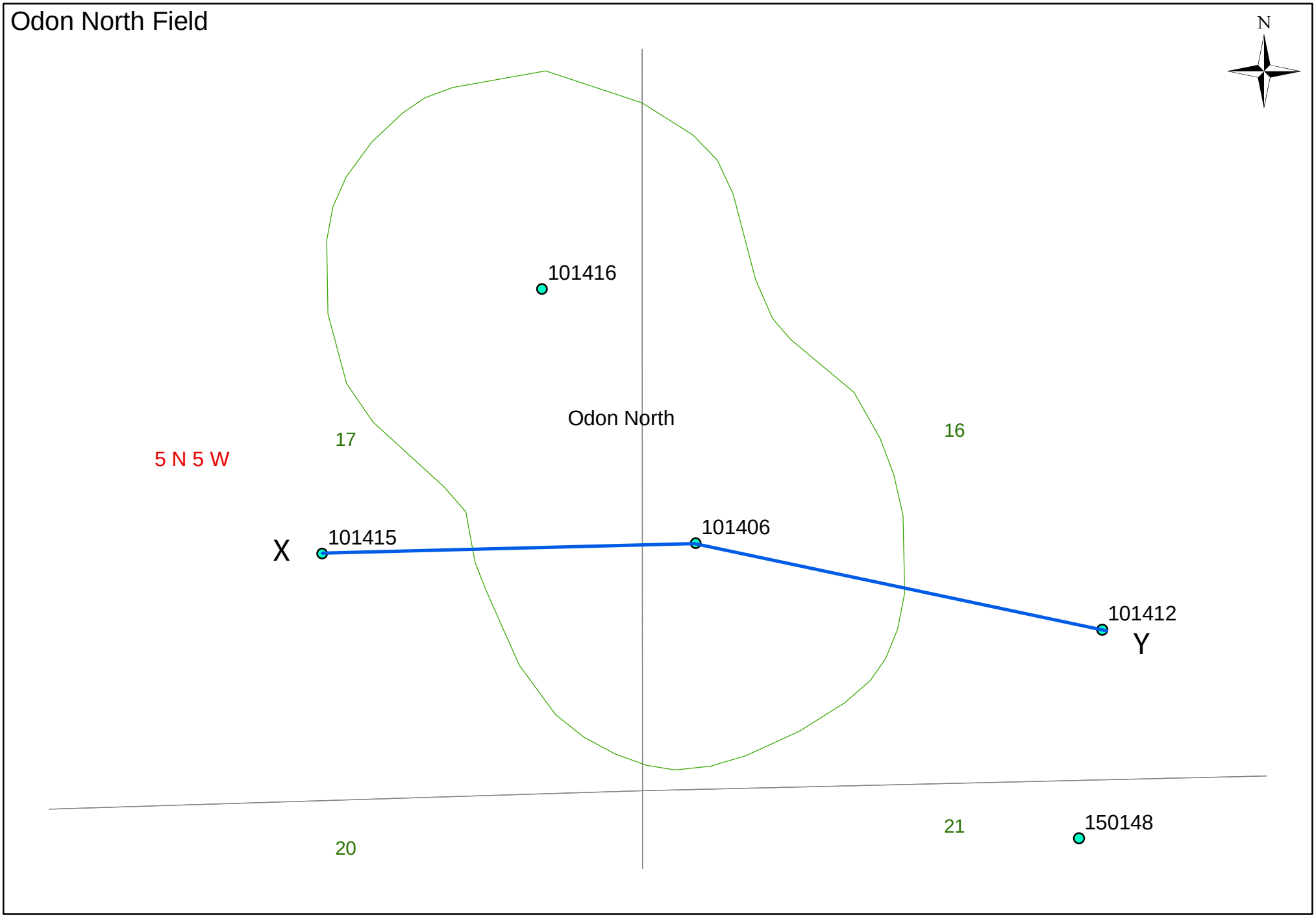

Figure 1: Map showing the location and wells at Odon North Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

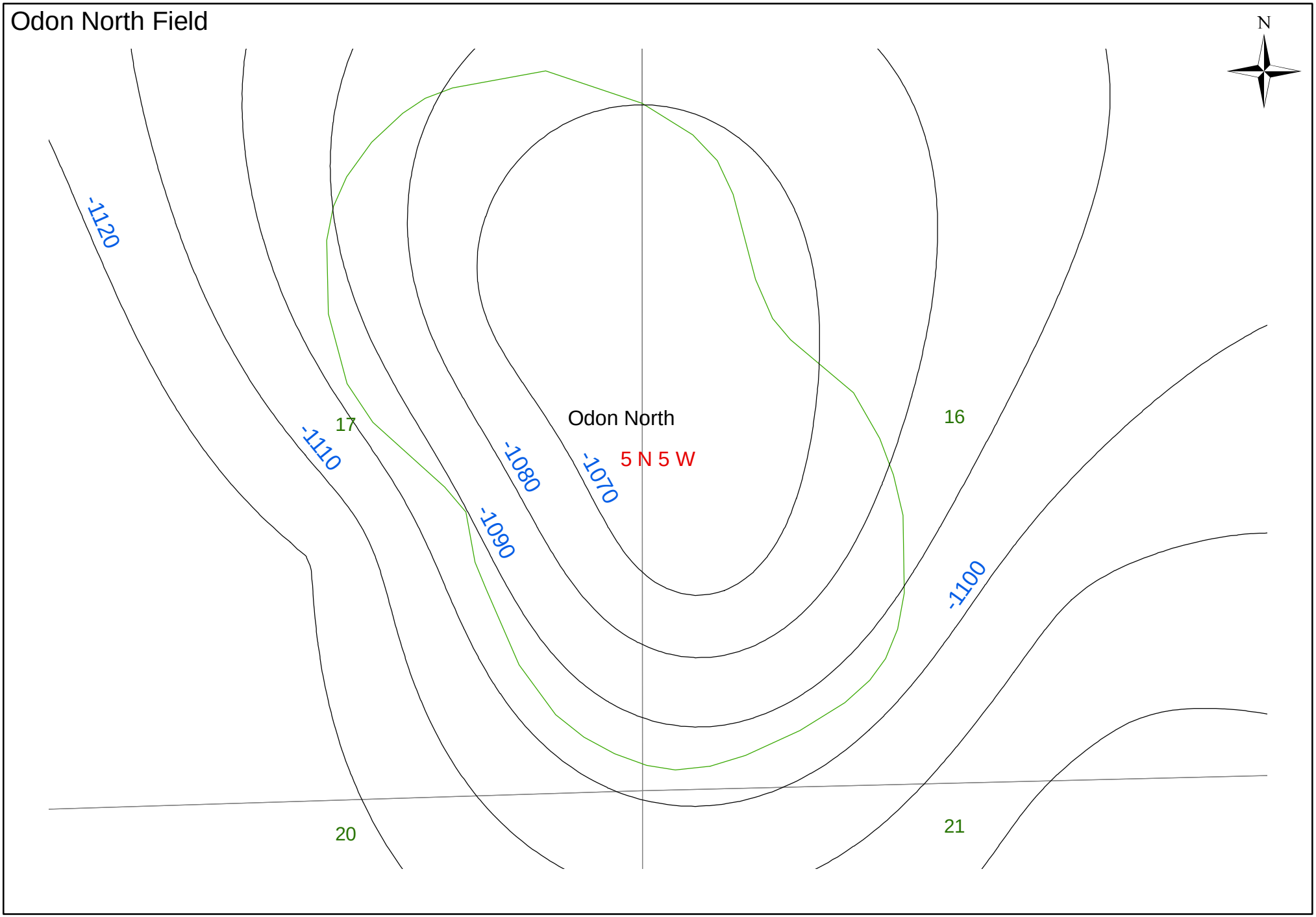

Figure 2: Structure map showing top of the Muscatatuck Limestone in Odon North Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

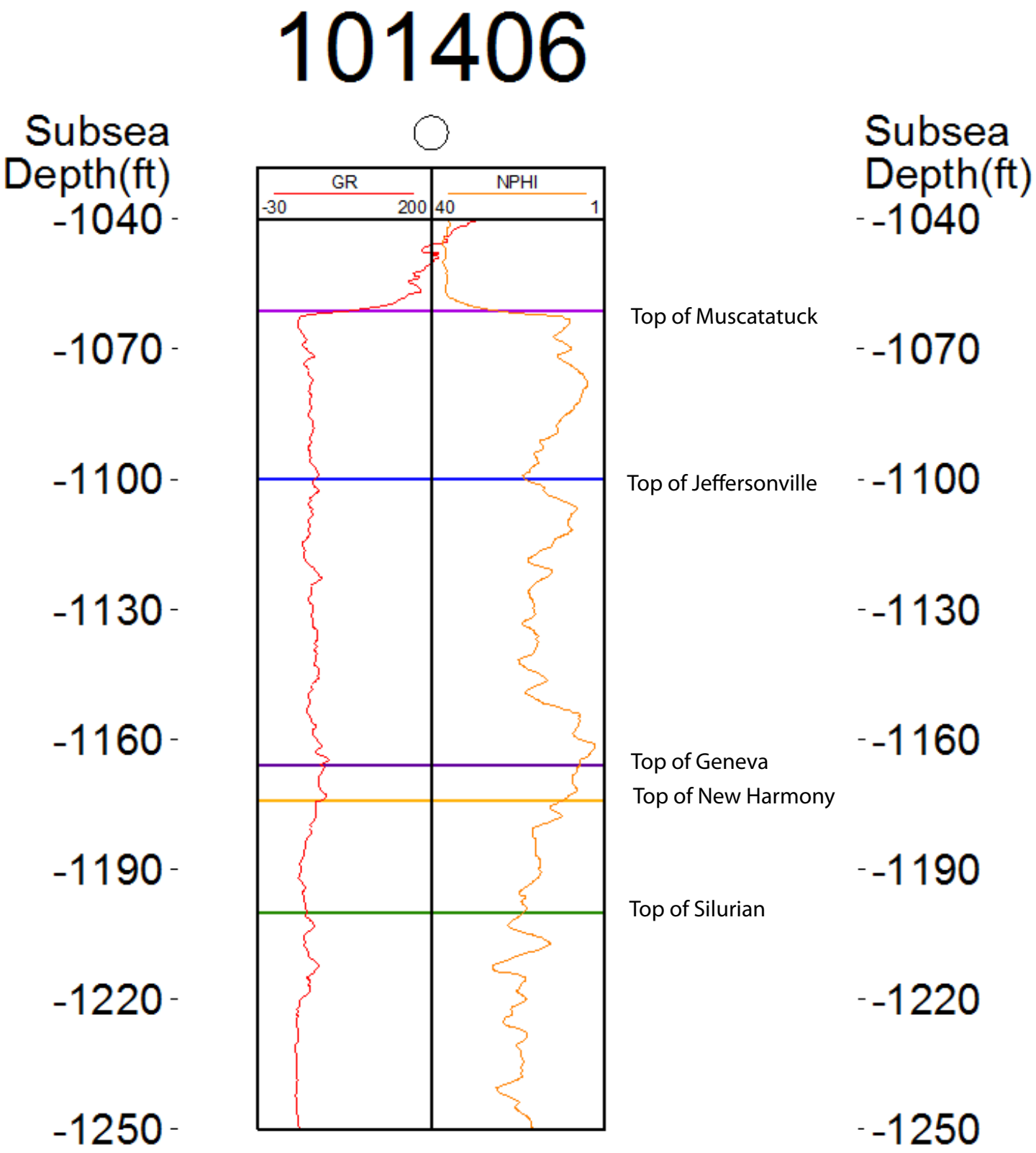

Figure 3: Type log section showing the Devonian formations at Odon North Field, Daviess County.

HS=1

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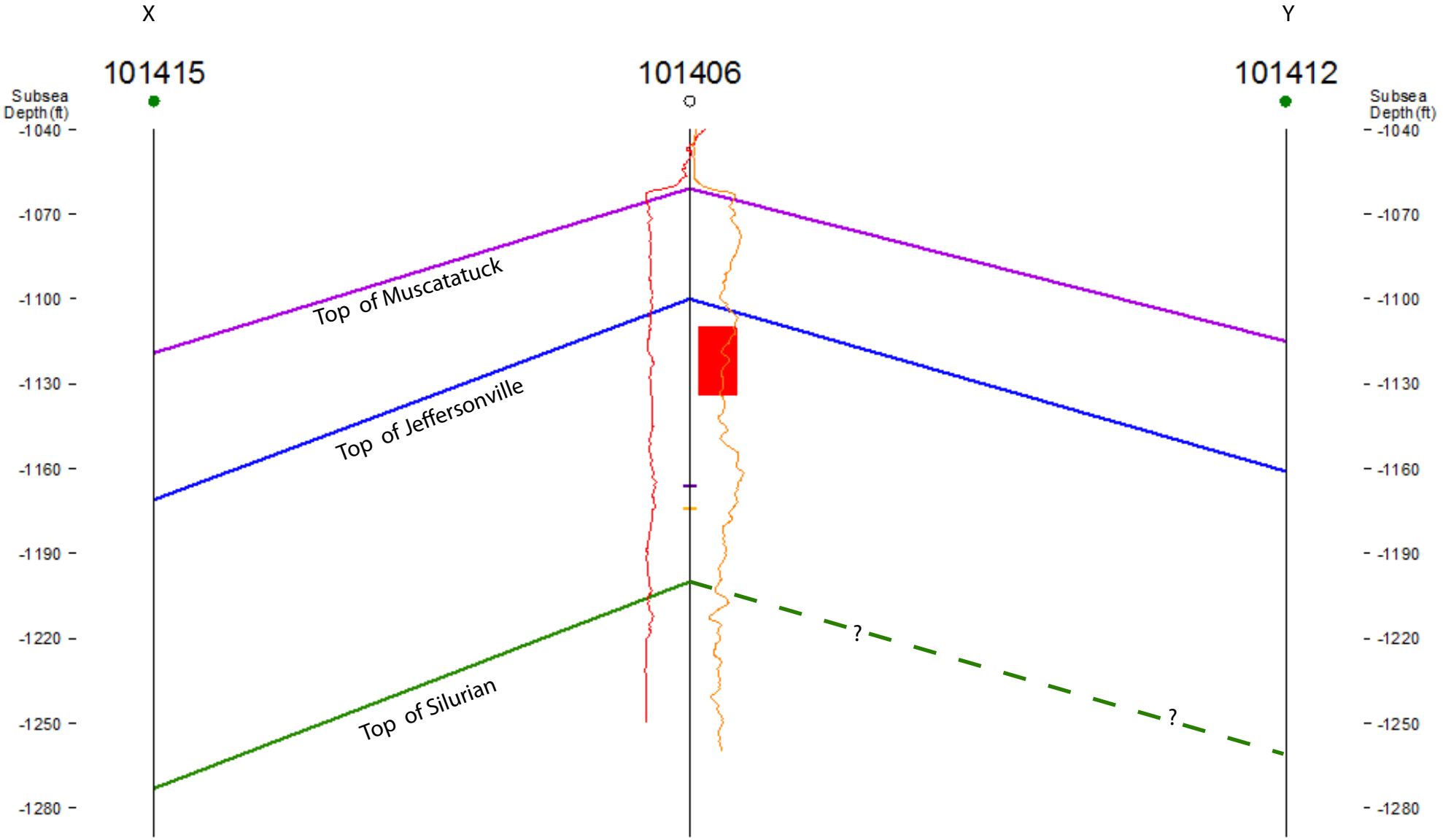

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Odon North Field, Daviess County. The red color box shows the completion intervals for the gas production. For location of the cross section refer to Figure 1.

Table-1: List of the wells used for subsurface structure mapping in Odon North Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
101406	5	N	5	W	16	650	1711	1750	1816	1824	1850		22
101412	5	N	5	W	16	649	1764	1810					40
101415	5	N	5	W	17	637	1756	1808			1910		15
101416	5	N	5	W	17	653	1713	1752					85

Field name: Odon South

IGS ID: 10497

DOE ID: 519914

Location: Daviess County, 5N-5&6W

Discovery date: 1975

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,763 ft.)

Field type: oil, natural gas

Total number production wells: 16 (1 Devonian)

Area: na

Cumulative production: 321,077 (2002) (Mississippian only)

Other reservoir units:

Mississippian, Blue River Group, Ste. Genevieve Limestone

Mississippian, Sanders Group, Salem Limestone

Deepest unit penetrated (depth): Silurian (1,950 ft.)

Field characteristic: Subtle broad anticline with no observable closure at Mississippian.

Reservoir characteristics:

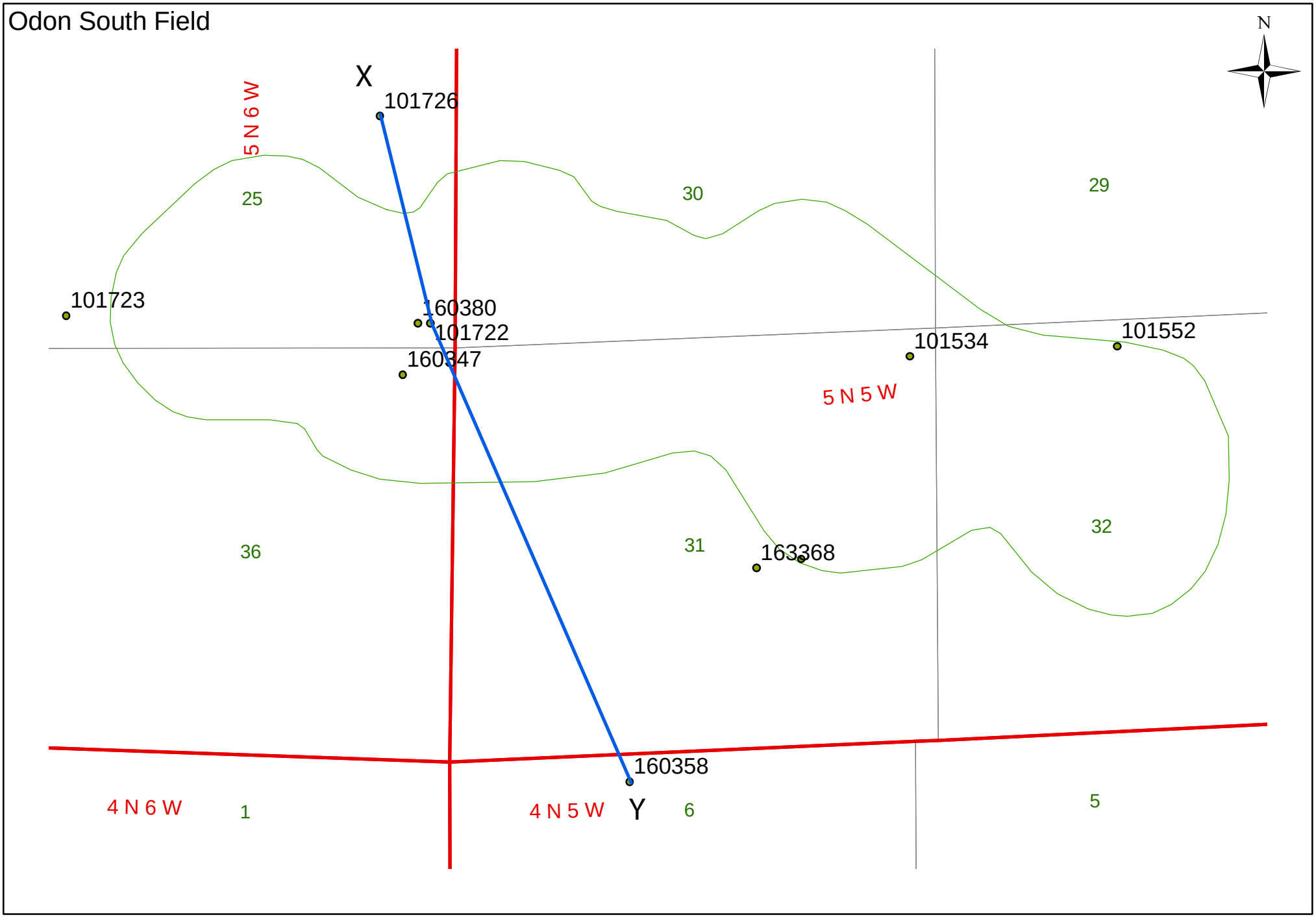

Figure 1: Map showing the location and wells at Odon South Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

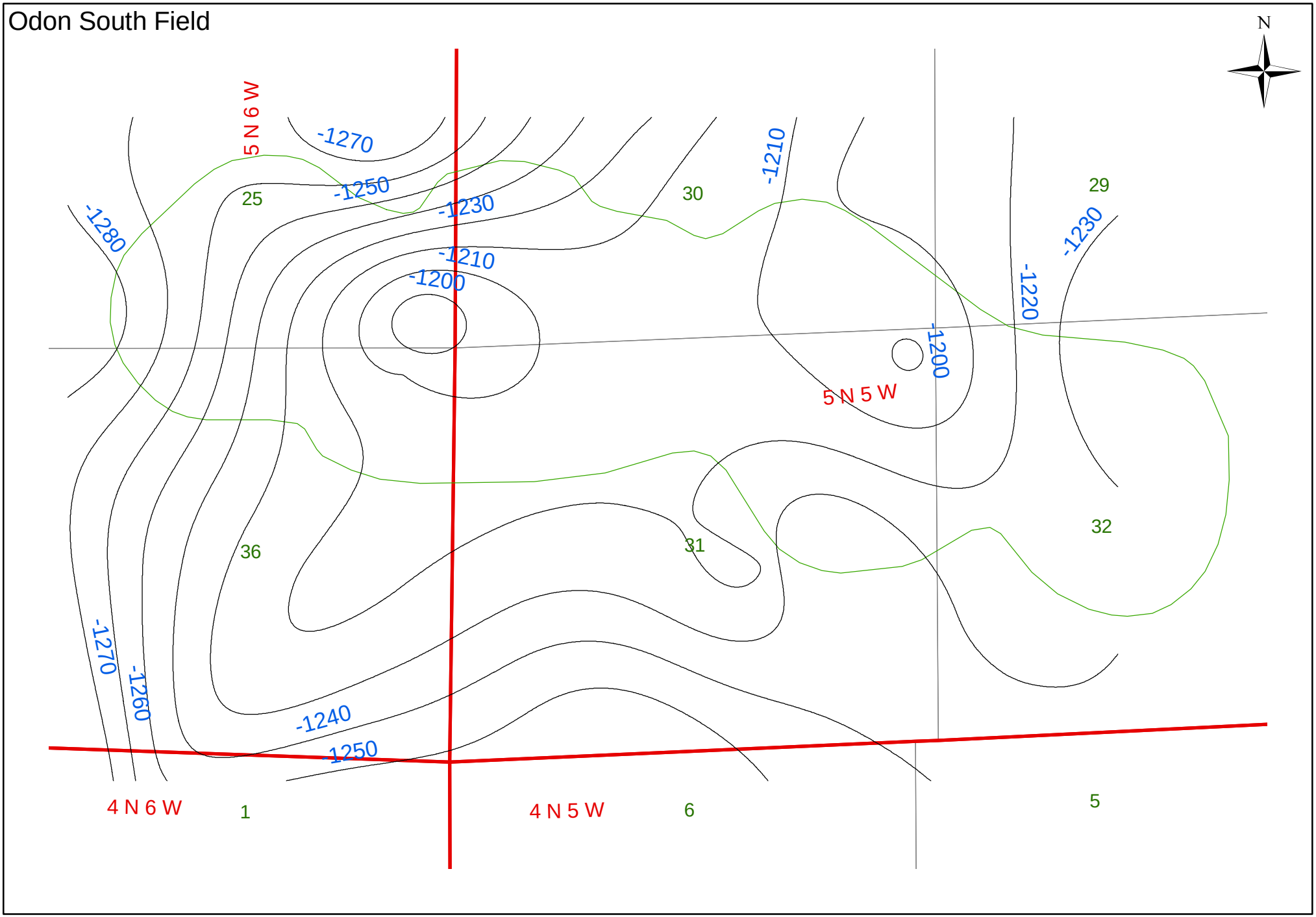

Figure 2: Structure map showing top of the Muscatatuck Limestone in Odon South Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

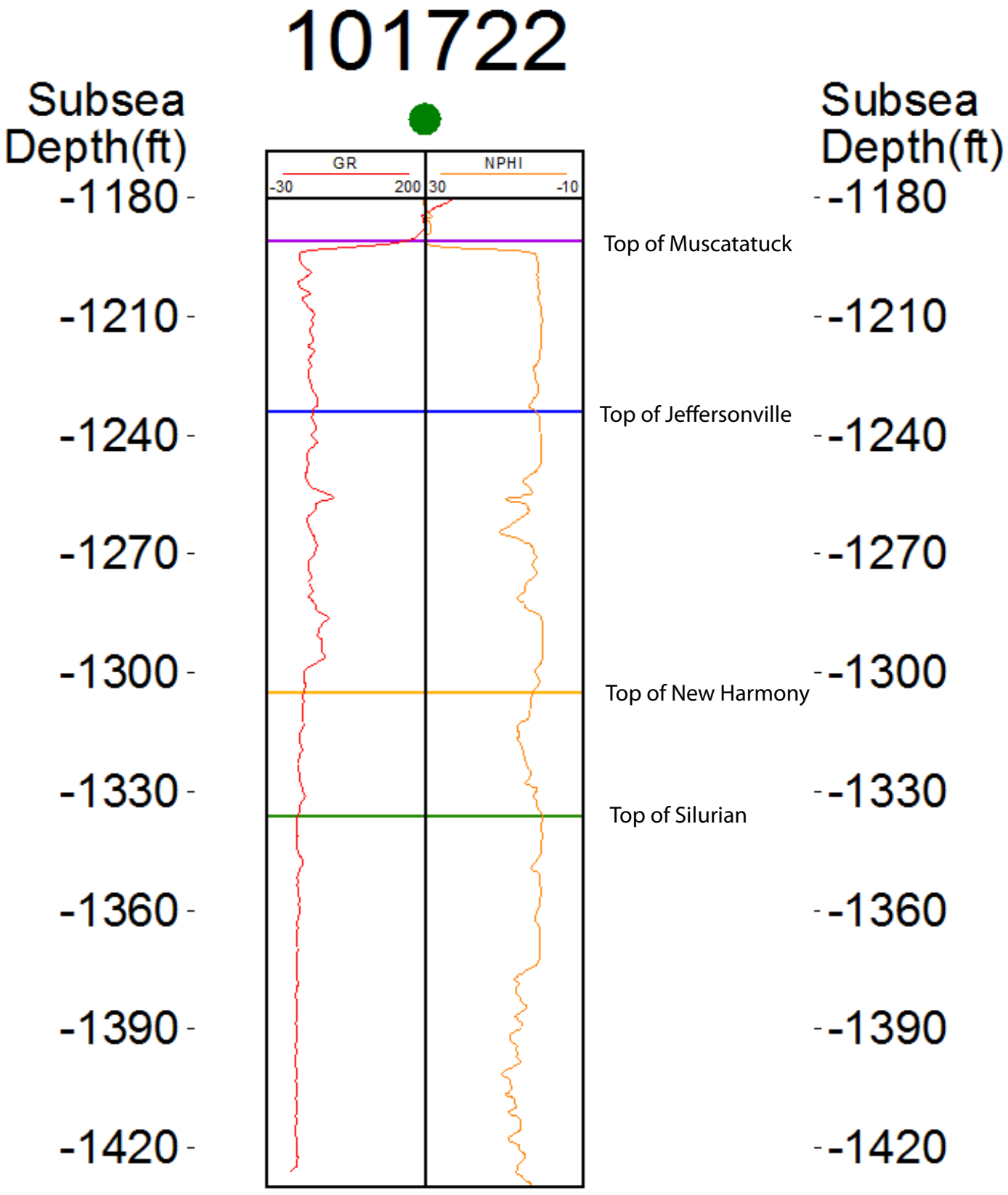

Figure 3: Type log section showing the Devonian formations at Odon South Field, Daviess County.

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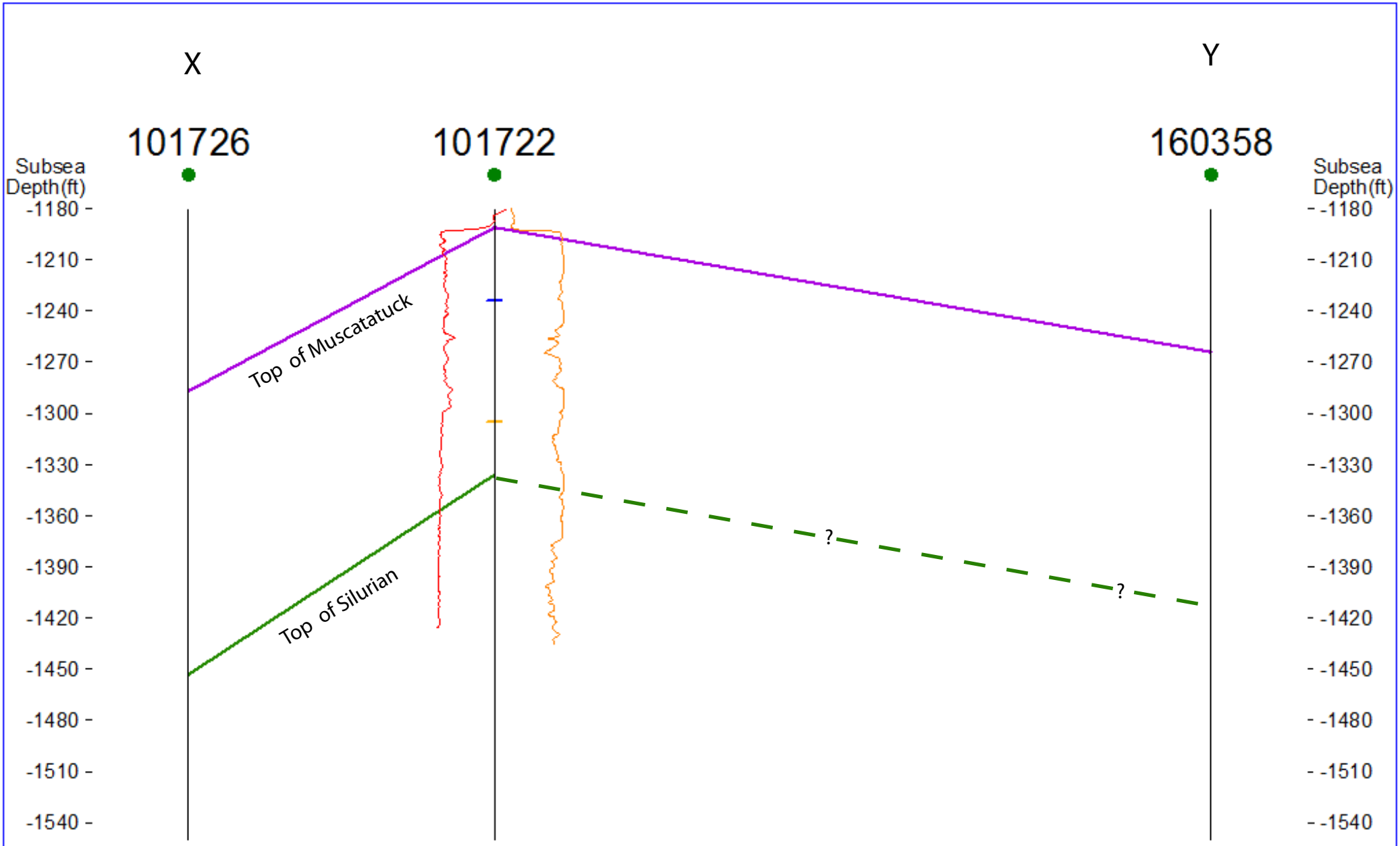

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Odon South Field, Daviess County. For location of the cross section refer figure 1.

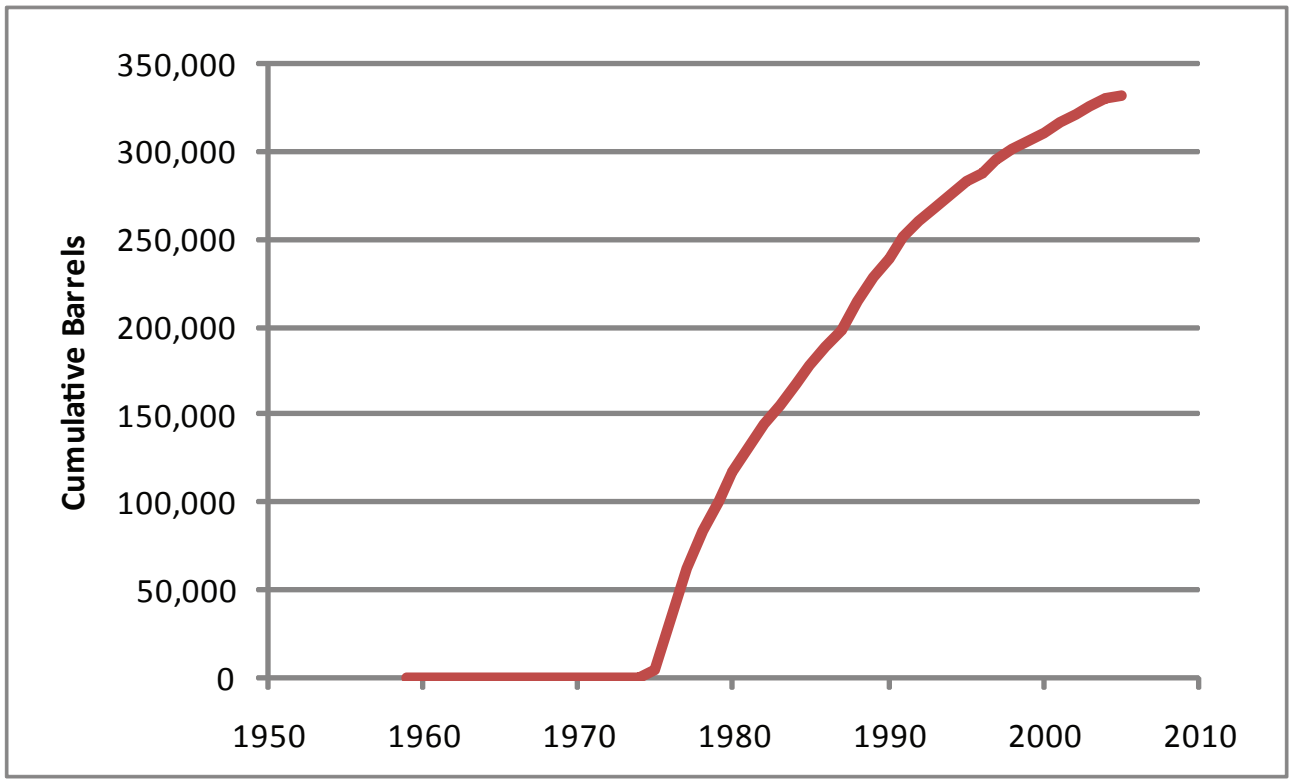

Figure - 5: Cumulative oil production history from Odon South Field, Daviess County since 1959.

Table-1: List of the wells used for subsurface structure mapping in Odon South Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_ N	Elevation/ Kb	Top of Musca- tatcuk	Top of Jeffer- sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
160358	4	N	5	W	6	506	1770						
101534	5	N	5	W	31	536	1734	1778		1850	1890		
162767	5	N	5	W	31	505	1747	1794					
163368	5	N	5	W	31	505	1723	1770					
101552	5	N	5	W	32	523	1763				1917		
101722	5	N	6	W	25	504	1696	1738	1810	1832	1880		
101723	5	N	6	W	25	487	1778	1828	1901	1932	1998		
101726	5	N	6	W	25	491	1778						
160380	5	N	6	W	25	500	1691	1736				12	
160347	5	N	6	W	36	494	1704	1747					

Field name: Pennyville

IGS ID: 10532

DOE ID: na

Location: Daviess County, 2N-5W

Discovery date: 1980

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,900 ft.)

Field type: natural gas

Total number production wells: 5

Area: na

Cumulative production: na

Other reservoir units:

Mississippian, Blue River Group, Ste. Genevieve Ls.

Mississippian, Blue River Group, St. Louis Ls.

Mississippian, Sanders Group, Salem Ls.

Deepest unit penetrated (depth): Silurian (2,222 ft.)

Field characteristic: Subtle broad anticline with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

Approximate thickness 21 ft.

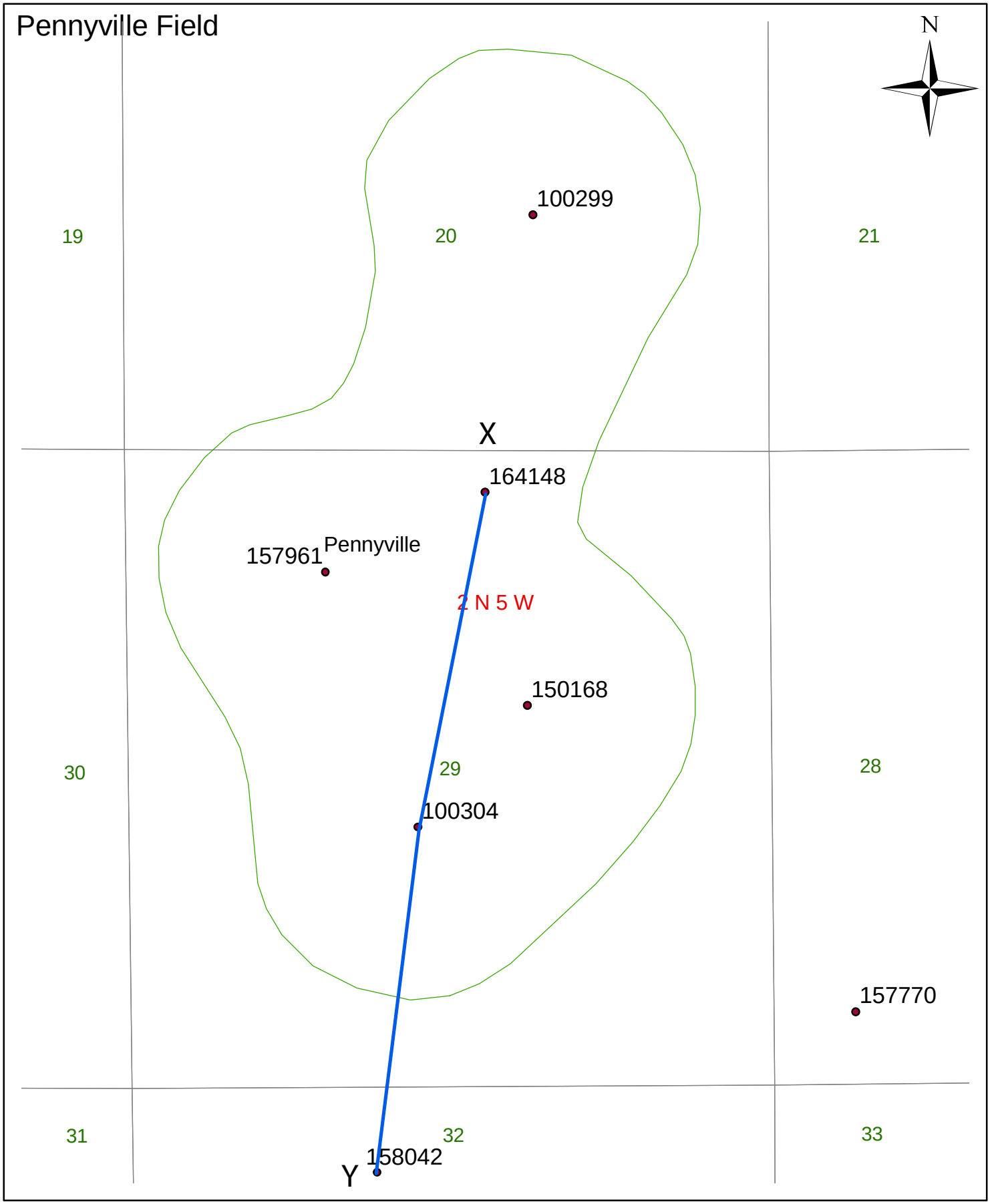

Figure 1: Map showing the location and wells at Pennyville Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

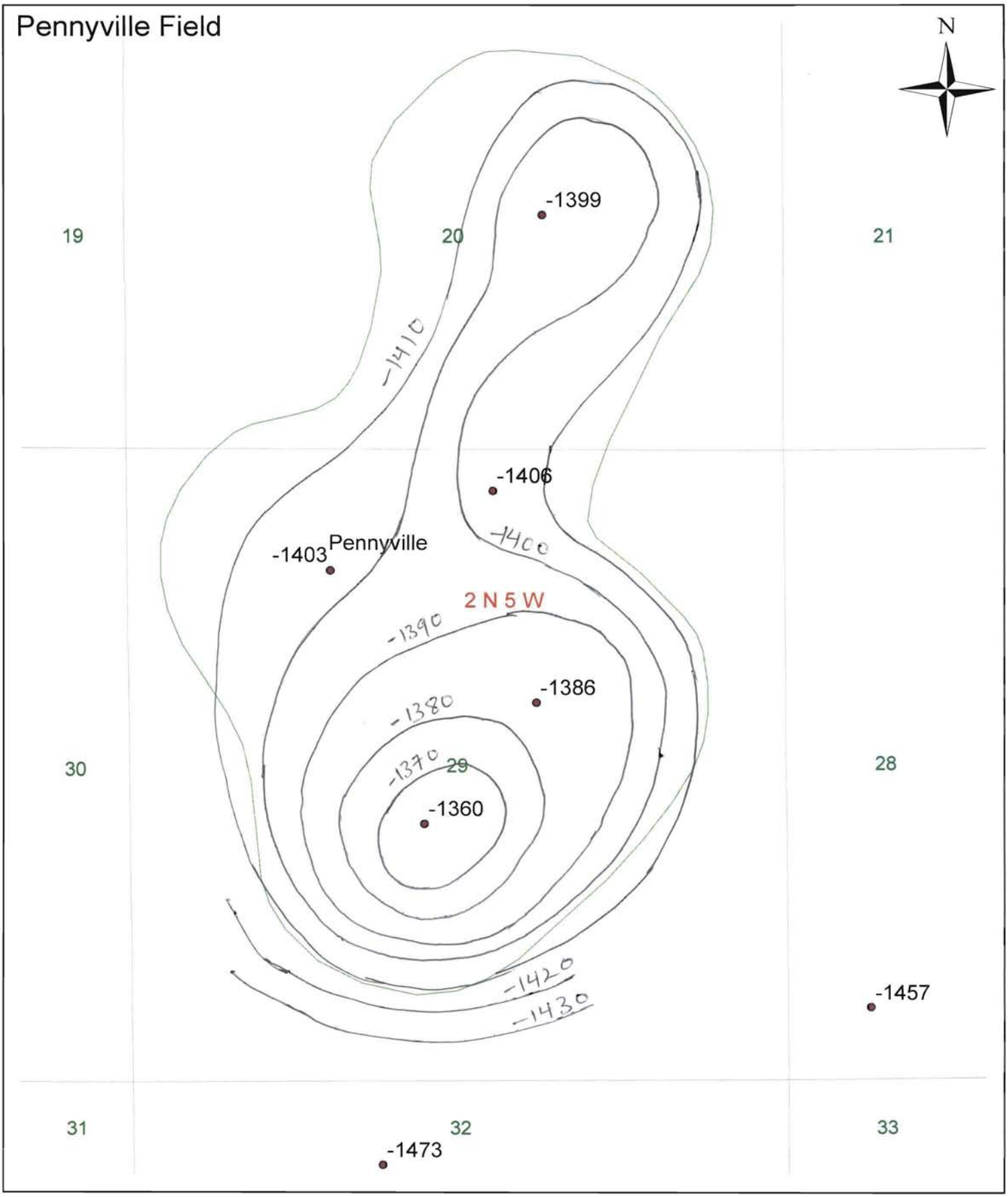

Figure 2: Structure map showing top of the Muscatatuck Limestone in Pennyville Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

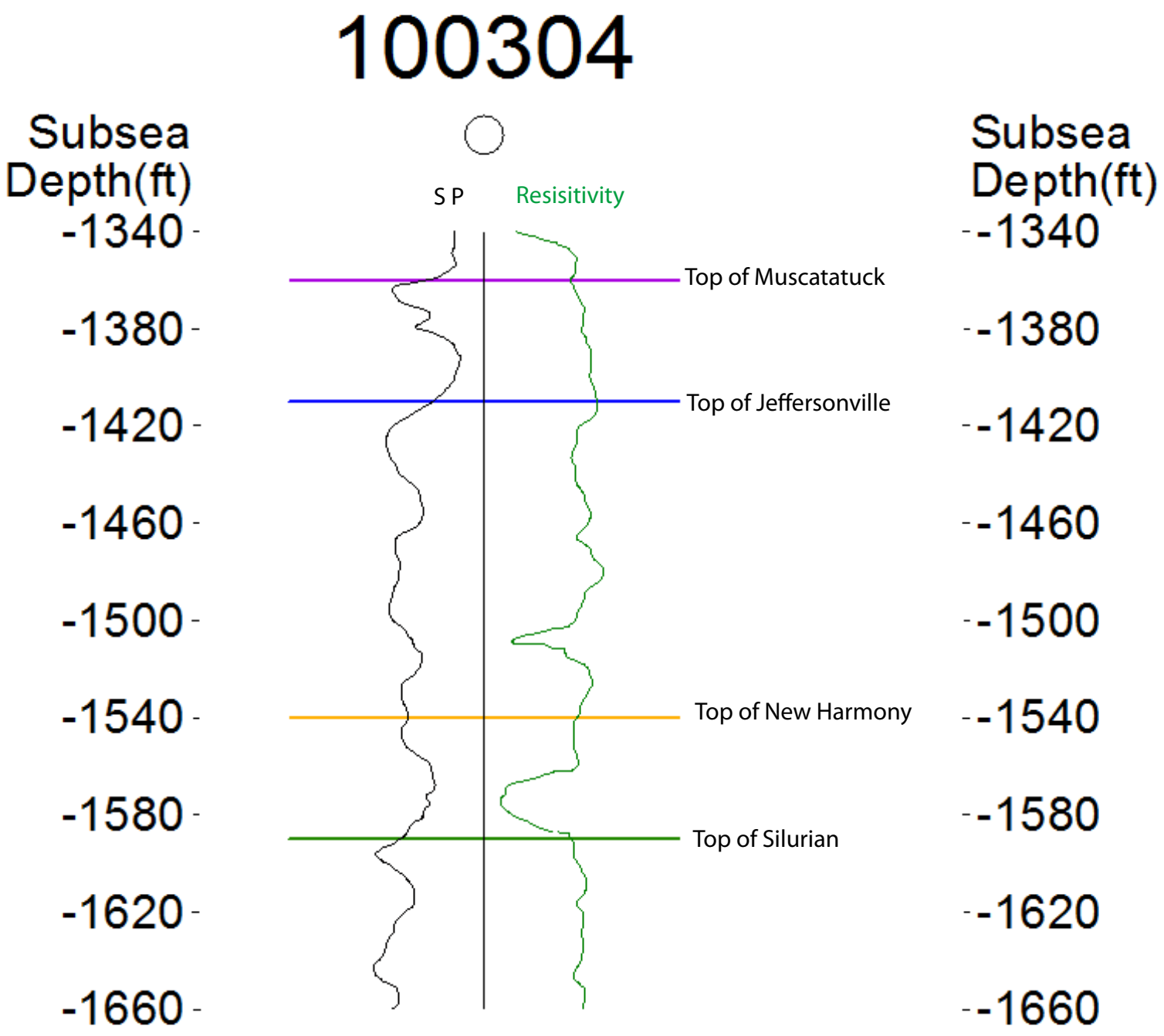

Figure 3: Type log section showing the Devonian formations at Pennyville Field, Daviess County.

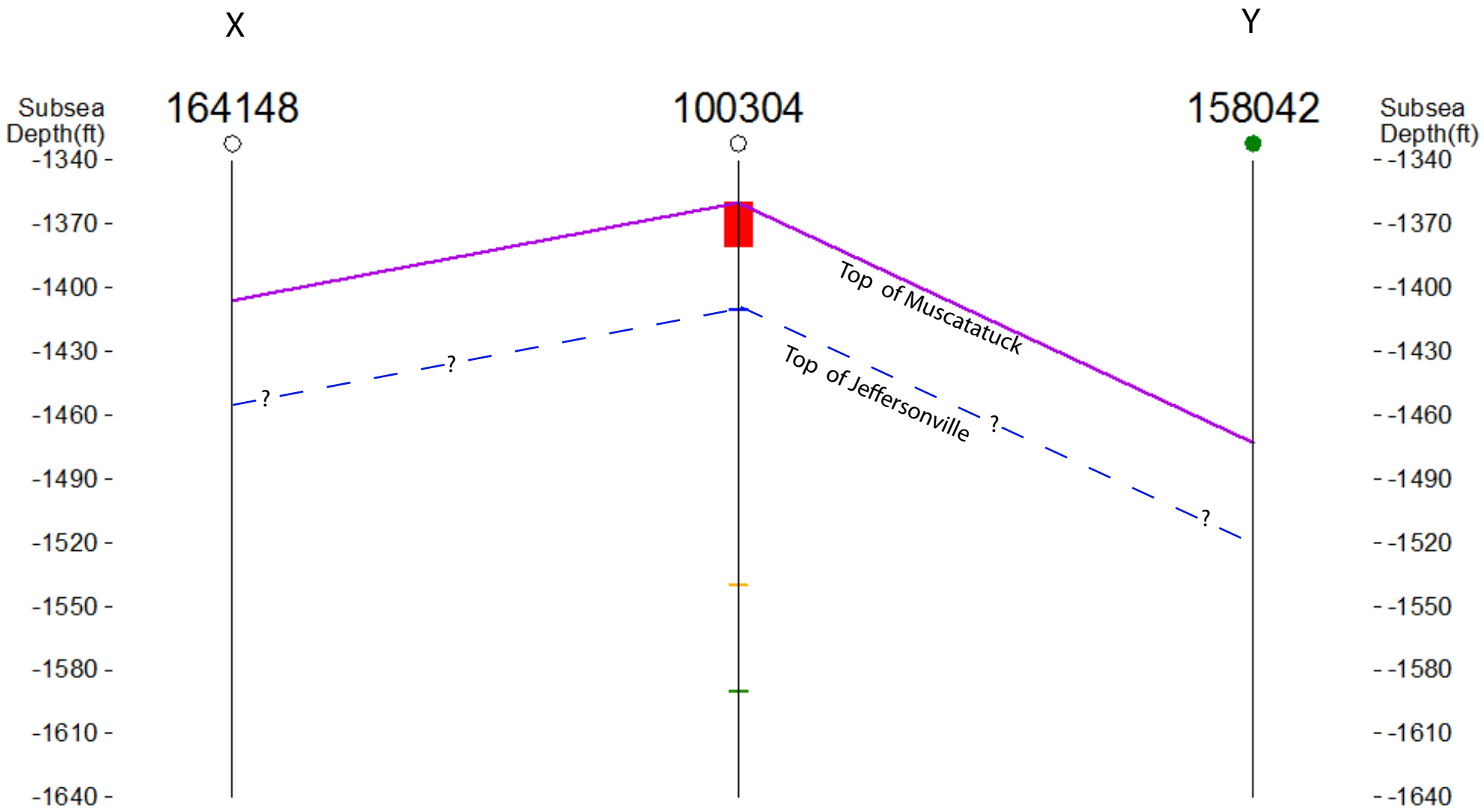

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Pennyville Field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for gas production.

HS=146

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Table-1: List of the wells used for subsurface structure mapping in Pennyville Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
100299	2	N	5	W	20	605	2004						
157770	2	N	5	W	28	507	1964	2026		2148			
100304	2	N	5	W	29	540	1900	1950		2080	2130		
150168	2	N	5	W	29	568	1954	2000					240
157961	2	N	5	W	29	530	1933	1980					22
164148	2	N	5	W	29	539	1945						
158042	2	N	5	W	32	521	1994						

Field name: Plainville

IGS ID: 10543

DOE ID: 559566

Location: Daviess County, 4N-7W

Discovery date: 1950

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,930 ft.)

Field type: oil

Total number production wells: 66

Area: 380 acres

Cumulative production: 5,128,425 bbls. (2002)

Other reservoir units:

Mississippian, Blue River Group, Paoli Ls., Aux Vases Mbr.

Mississippian, Blue River Group, Ste. Genevieve Ls.

Mississippian, Sanders Group, Salem Ls.

Devonian/Mississippian, New Albany Sh.

Deepest unit penetrated (depth): Cambrian/Ordovician, Knox Supergroup (4,969 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 80 ft. at Mississippian, limited well control at top of Muscatatuck.

Reservoir characteristics:

Approximate thickness 21 ft.

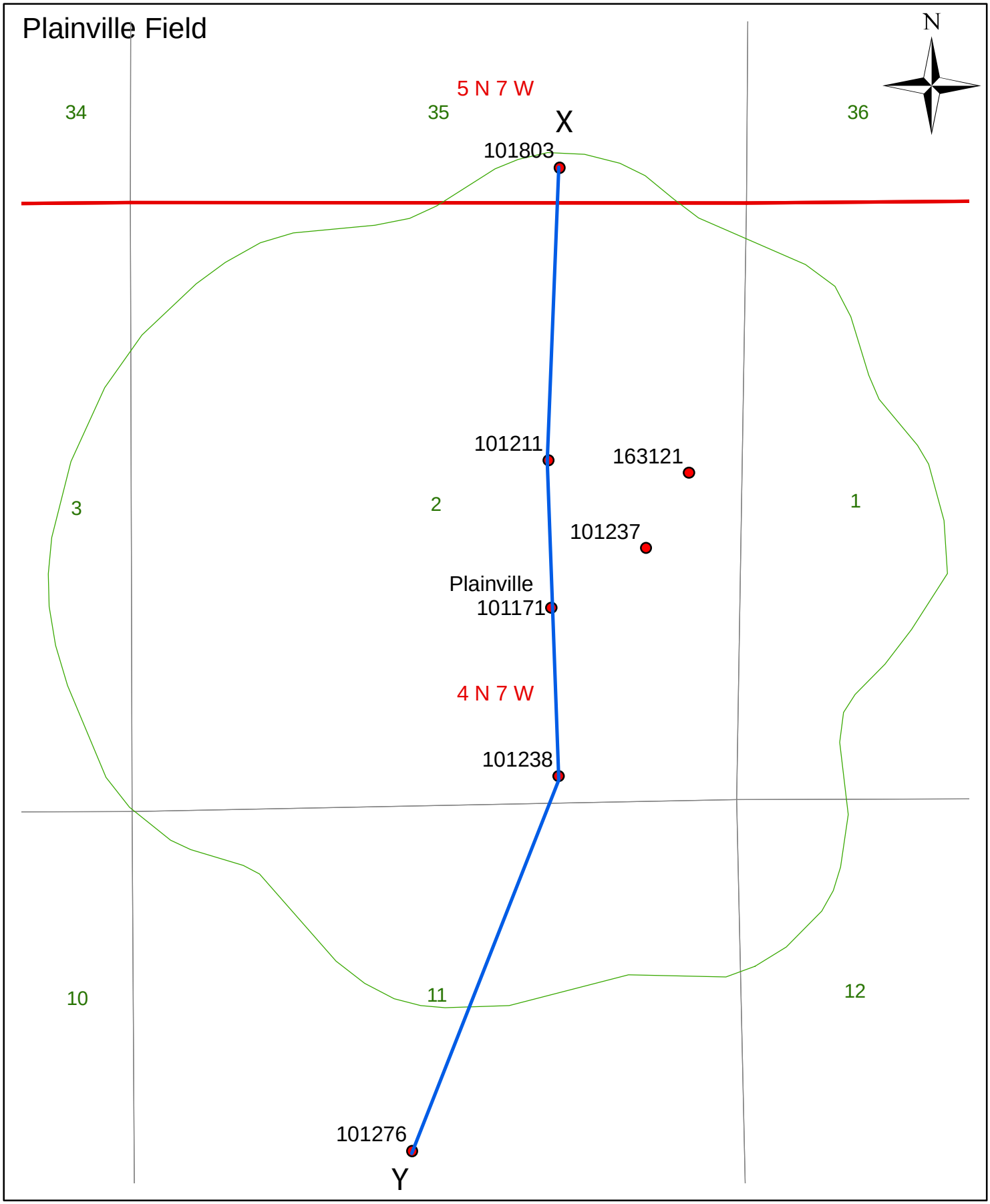

Figure 1: Map showing the location and wells at Plainville Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

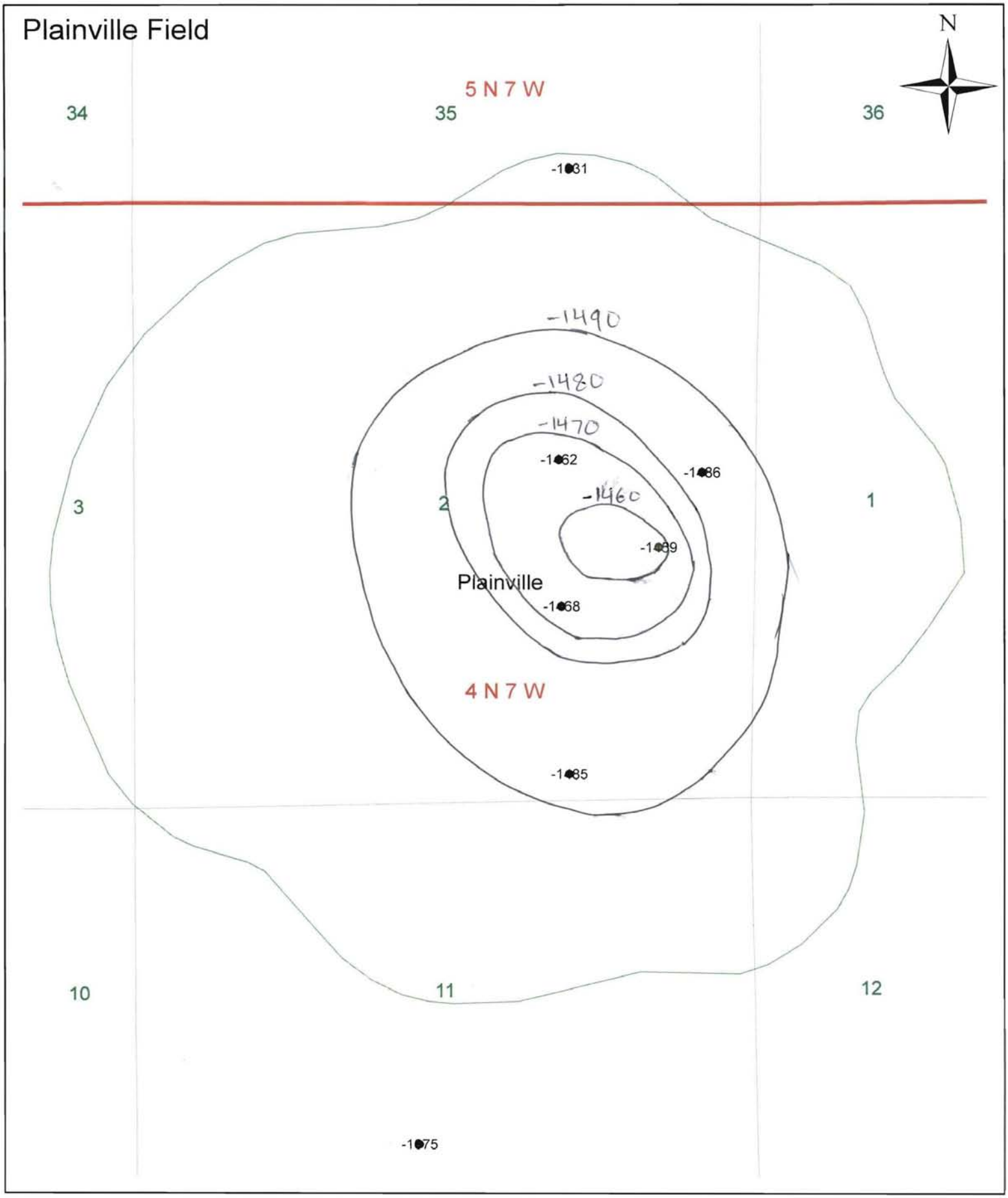

Figure 2: Structure map showing top of the Muscatatuck Limestone in Plainville Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

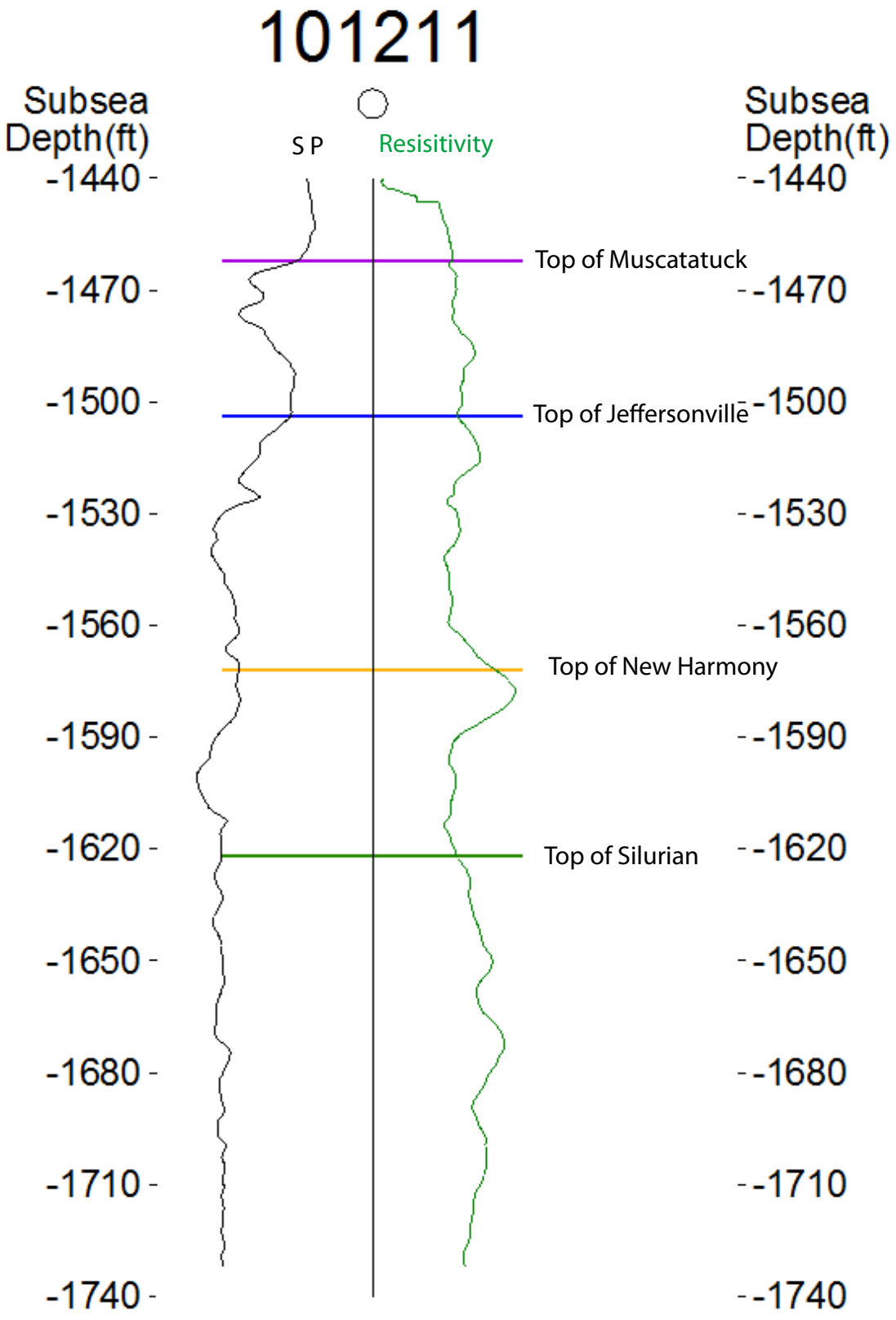

Figure 3: Type log section showing the Devonian formations at Plainville Field, Daviess County.

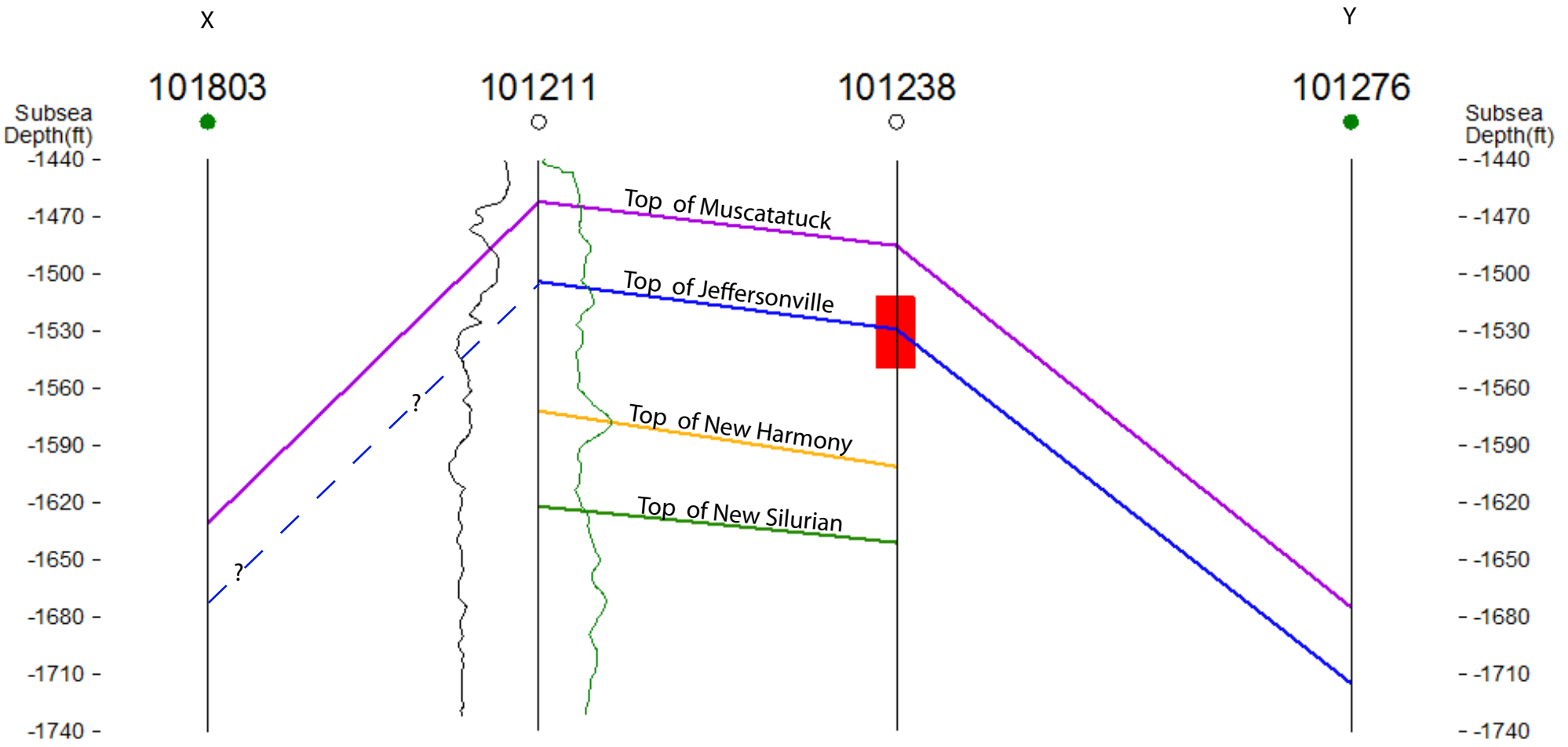

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Plainville Field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for oil production.

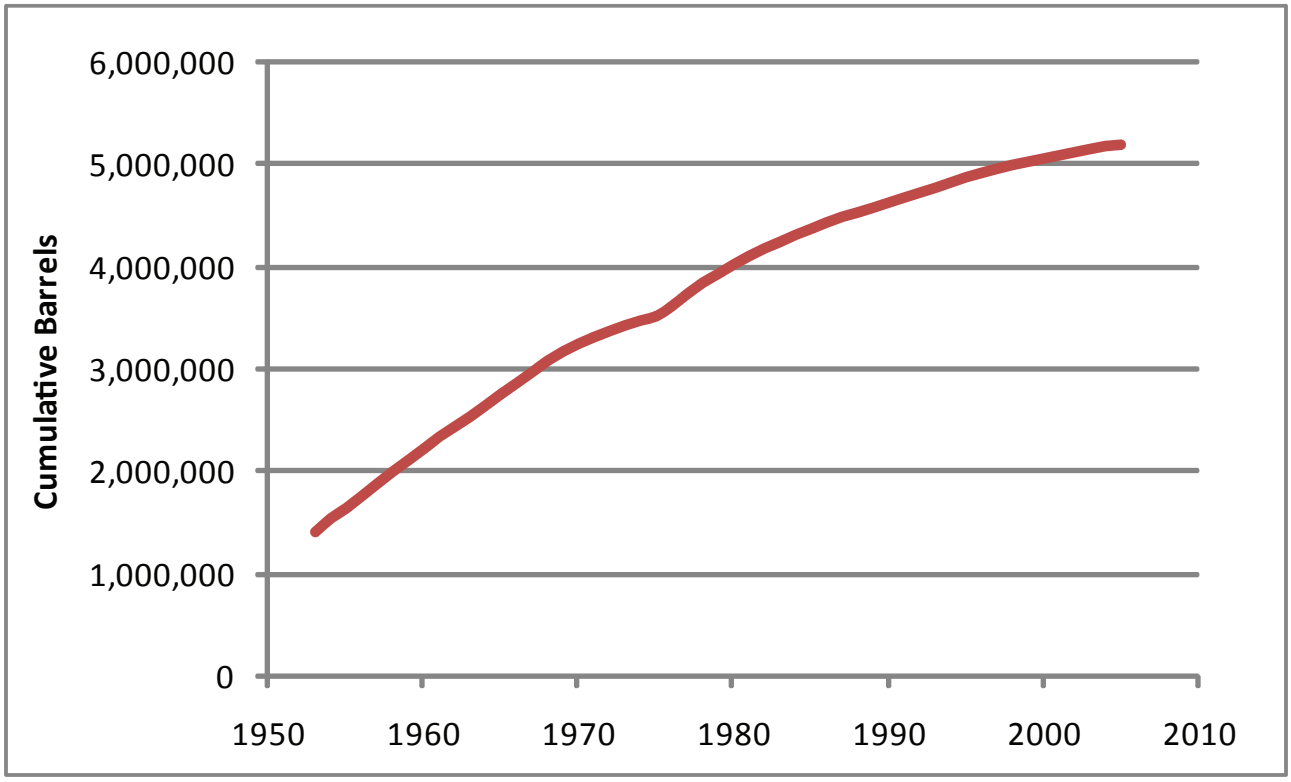

Figure - 5: Cumulative oil production history from Plainville Field, Daviess County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Plainville Field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
101565	5	N	6	W	4	473	1910				2095		
101600	5	N	6	W	15	542	1916						
101630	5	N	6	W	16	484	1792	1834	1910	1915	1945	21	
160368	5	N	6	W	16	495	1792	1834				32	
101658	5	N	6	W	17	510	1806	1850	1905	1916	1950	14	
101659	5	N	6	W	17	491	1806					120	
160341	5	N	6	W	17	514	1802					96	
160352	5	N	6	W	17	503							
160310	5	N	6	W	20	523	1788	1834				30	
160354	5	N	6	W	20	510	1819	1868				70	
160353	5	N	6	W	21	495	1790						35
133495	5	N	6	W	27	482	1931	1984	2052	2060	2090		

Field name: Plummer

IGS ID: 10546

DOE ID: 561643

Location: Greene County, 6N-5W

Discovery date: 1969

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,529 ft.)

Field type: oil & natural gas

Total number production wells: 130 (oil), 15 (natural gas)

Area: 1480 acres

Cumulative production: 6,069,055 bbls. (2002)

Other reservoir units:

Mississippian, Blue River Group, Ste. Genevieve Ls.

Mississippian, Sanders Group, Salem Ls.

Deepest unit penetrated (depth): Cambrian, Mt. Simon Ss. (6,785 ft.)

Field characteristic: Irregular domal anticline over probable Silurian reef with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

The Plummer field

History and Production

The Plummer Field in Greene County, Ind. (fig. 1), was discovered in 1969 by Citizens Gas and Coke Utility. The field largely produces oil from the Salem Formation and some from Devonian limestone (Jeffersonville Limestone Fm). The first well drilled (Fred & Lucille Rollison) had an initial production of 120 barrels of oil per day through perforations in the Salem Limestone at 688 to 698 feet and 705 to 710 feet. The well also tested 20 barrels of oil and 120 barrels of water per day from perforations at 1606 to 1611 feet and 1616 to 1621 feet in Jeffersonville Limestone.

A total of 215 wells have been drilled since then. A list of wells which are drilled up to Devonian limestone is shown in table. 1. Initial production from Devonian limestone ranged from 5 to 100 BOPD and from 5 to 750 thousand cubic feet of gas per day and averaged 33 BOPD and 163 MCFPD (Table-1). The Plummer field has produced a cumulative total of 6.39×10^6 barrels of oil till date (2005; Fig.14).

Stratigraphy

In the Illinois Basin the Muscatatuck group limestone rocks are overlain by the New Albany shale. The top of the Devonian Limestone is therefore easy to pick on any radioactivity log (Gamma ray, Neutron). The Muscatatuck group comprises of North Vernon Ls and Jeffersonville Ls. In the Plummer field upper Jeffersonville Ls is categorized as Vernon Fork Member and the lower Jeffersonville Ls is replaced by Geneva dolomite Member. The Geneva dolomite Member is unconformably underlain by the Wabash formation of the Silurian age.

STRUCTURE

The Plummer field is arcuate in shape with the arc trending NW-SE to S. Structure contour maps on top of Muscatatuck group, top of Jeffersonville Limestone, and top of Geneva dolomite Mbr all depict this arcuate form (Figs. 2-4). The structure is believed to be formed due to differential compaction of overlying rocks over a Silurian reef (Fig.5).

An Isopach map of the Vernon Fork Mbr (Fig.6) and the Geneva dolomite Mbr (Fig. 7) shows the thickness and extent of Devonian reservoirs in the Plummer field. Although not as precise as the structure maps, these Isopach maps conform to the shape and trend of the arcuate structure of the Plummer field.

Porosity-Permeability analysis

The Net porosity feet maps show relatively higher porosity range in the Geneva dolomite Mbr (Fig.9) than the Vernon Fork Mbr (Fig.8). However, the core analysis reports from the 26 different wells don't show any marked difference in porosity range between the Vernon Fork Mbr and the Geneva dolomite Mbr. The porosity-permeability plots for the Vernon Fork Mbr shows high variability reflecting the heterogeneity in the facies (Fig. 15). The higher permeability values with low porosity values are perhaps due to the presence of fractures. However, the permeability values in the Vernon Fork Mbr tend to be relatively lower than in the Geneva dolomite Mbr. The porosity-permeability plots in the Geneva dolomite Mbr show almost a linear correlation, which indicates to a better connected pore system (Fig. 15).

Cross Sections

In addition to the structure maps, correlation cross sections were made to capture the sub surface structure of the Devonian reservoirs. The cross section 'X-Y' (Fig.11) is a N-S section cutting across the main structural highs of the Plummer field. Gamma ray, Sidewall Neutron Porosity, and Bulk Density logs were used to correlate the variation in porosities or the Density.

The oil producing horizons in the Vernon Fork Mbr are commonly named as A, B, C, and D. These porous horizons show marked variations in their thickness as they are mapped and correlated for three different cross sections across the Plummer field. Horizon D is one of the main oil producing zones and its thickness varies the most ranging between 4-30 ft. Horizon B and C are other main oil producing zones. Although the Geneva dolomite Member shows good porosity and permeability, it largely contains salt water. Therefore, the upper Jeffersonville Limestone namely Vernon Fork Member is the main Devonian reservoir in the Plummer field.

In order to show the structure in other directions/dimensions cross section 'P-O' and 'X-Z' (Figs.12 and 13) were made in the SE-NW and NE-SW directions, respectively. The gamma ray, neutron porosity well logs were correlated to map productive horizons namely A, B, C, and D. The red colored box indicates the completion interval or the oil producing zone. The cross sections show a vertical exaggeration of 16X.

THE PLUMMER FIELD

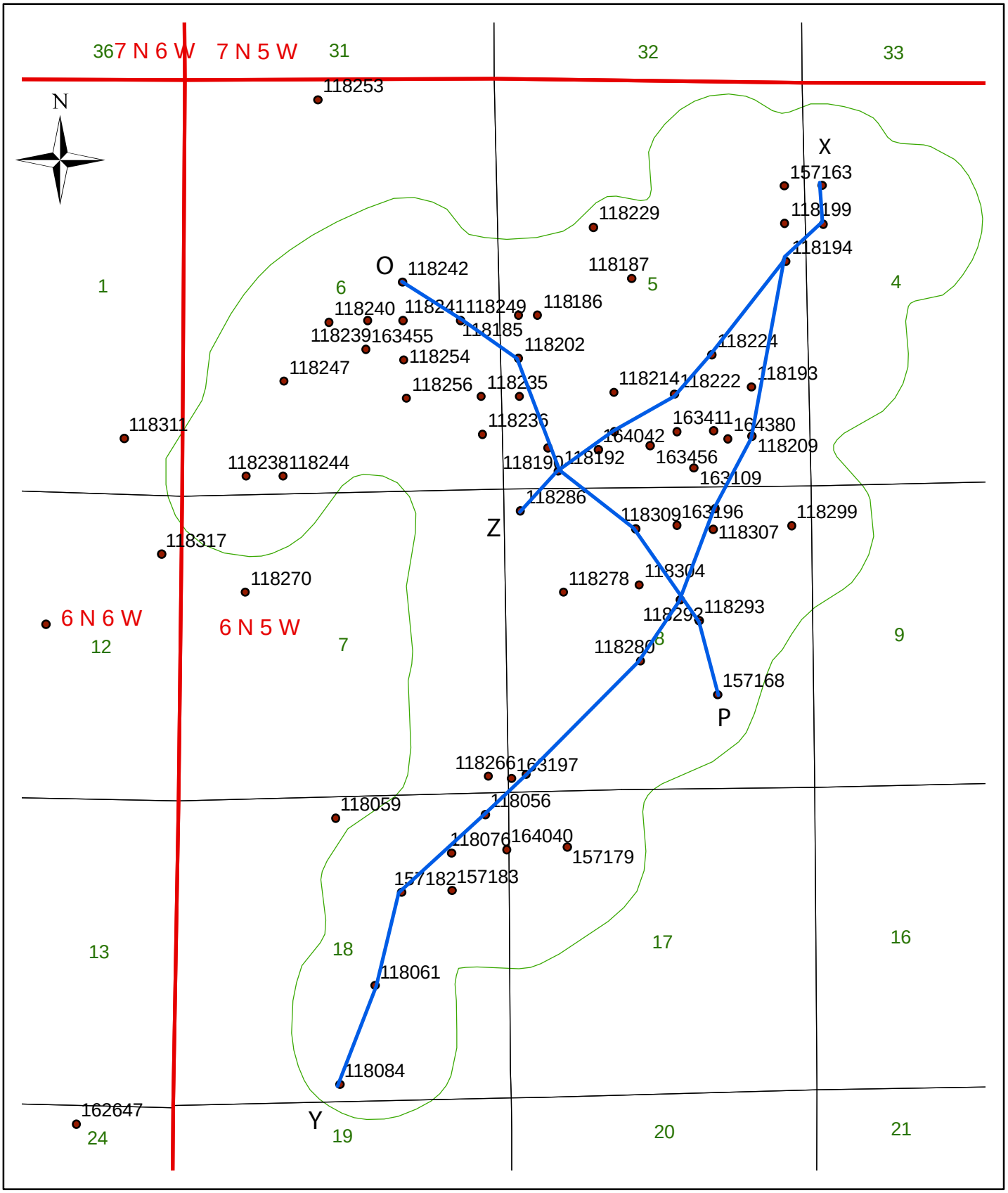

Figure 1: Map showing the location and wells at Plummer field, Greene County. X-Y, P-O, and X-Z are the locations of the cross sections showing Devonian structure in Figures. 11, 12, and 13. The wells shown have a total depth (TD) of Devonian or deeper.

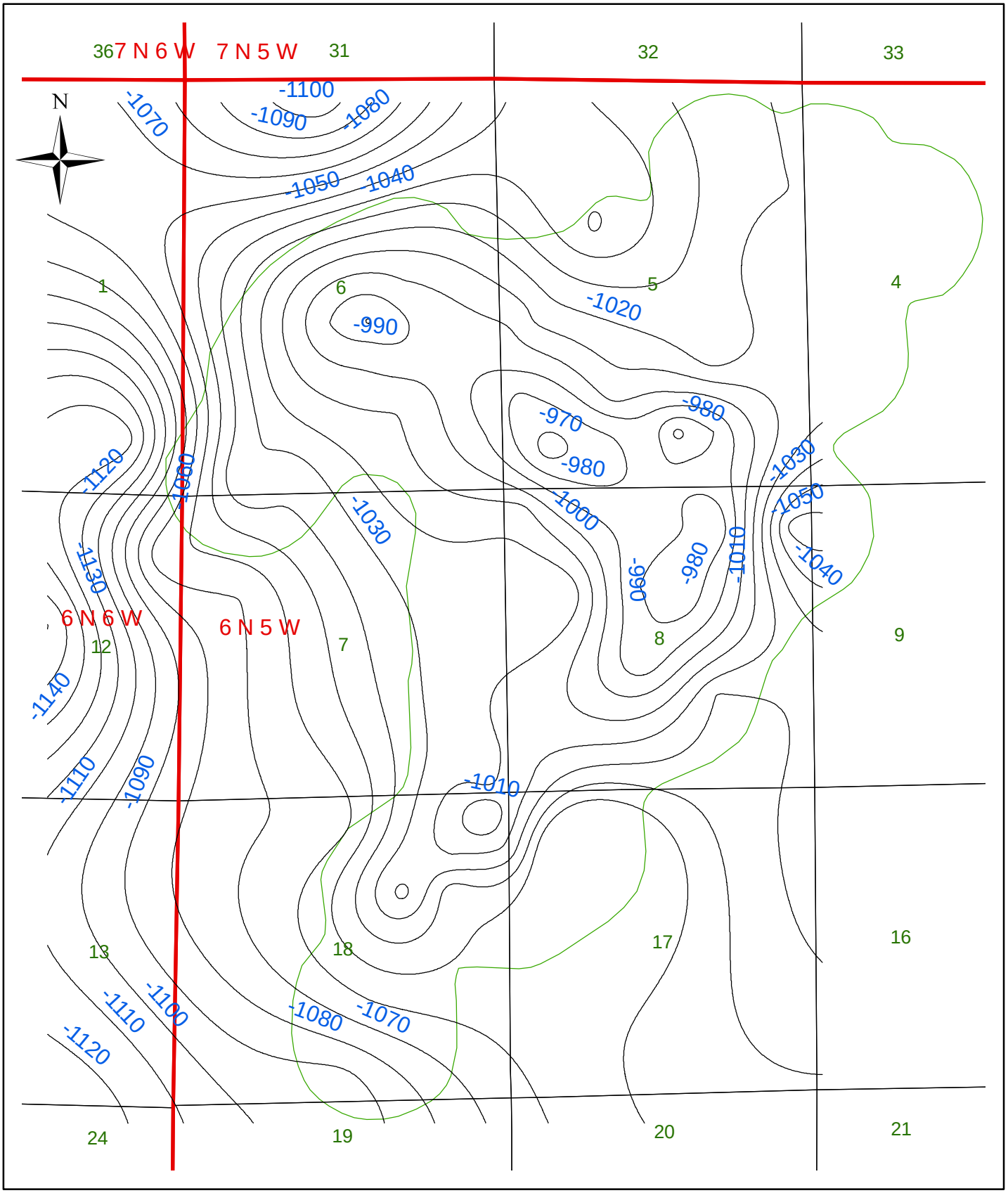

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Plummer Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

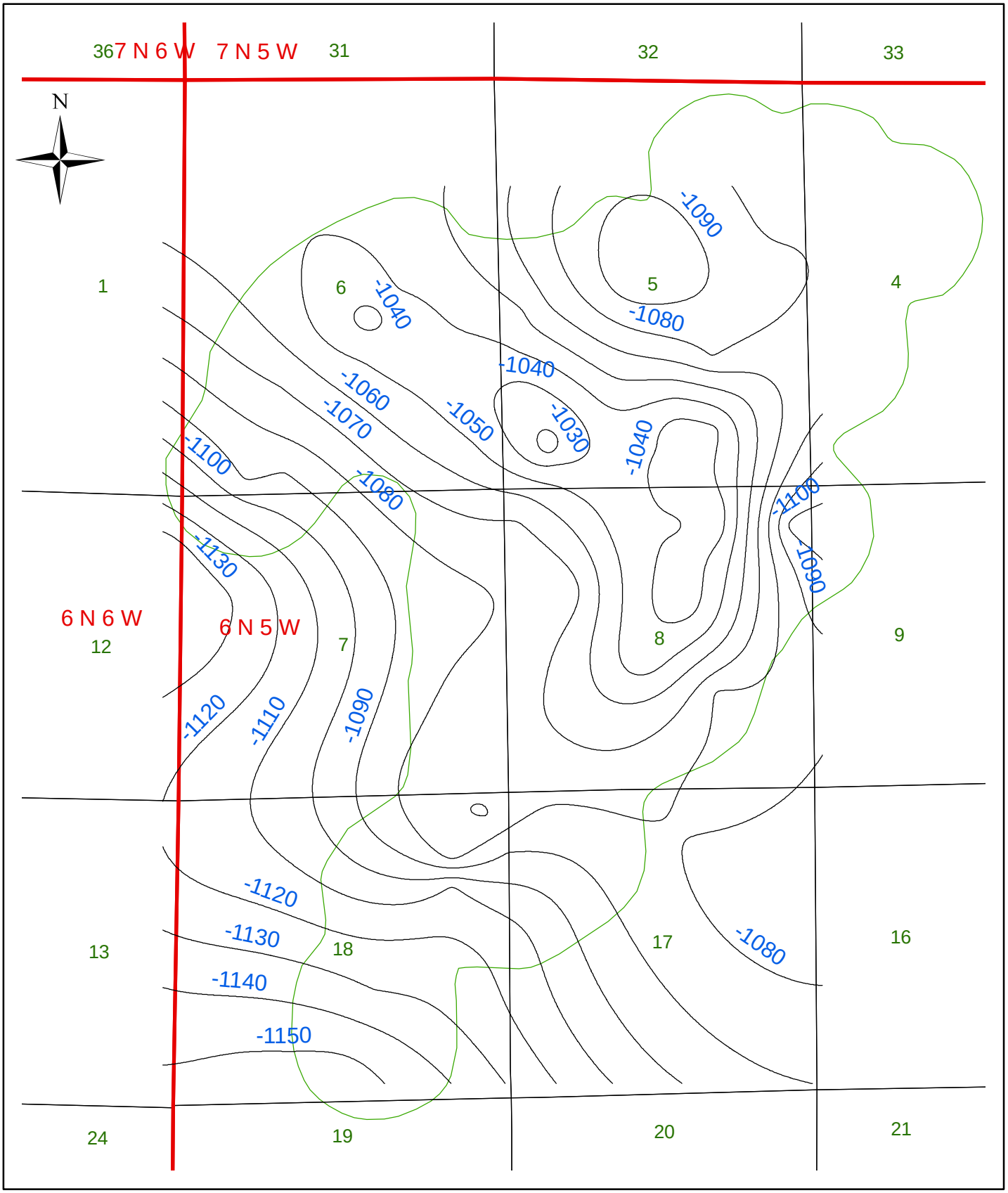

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Plummer Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

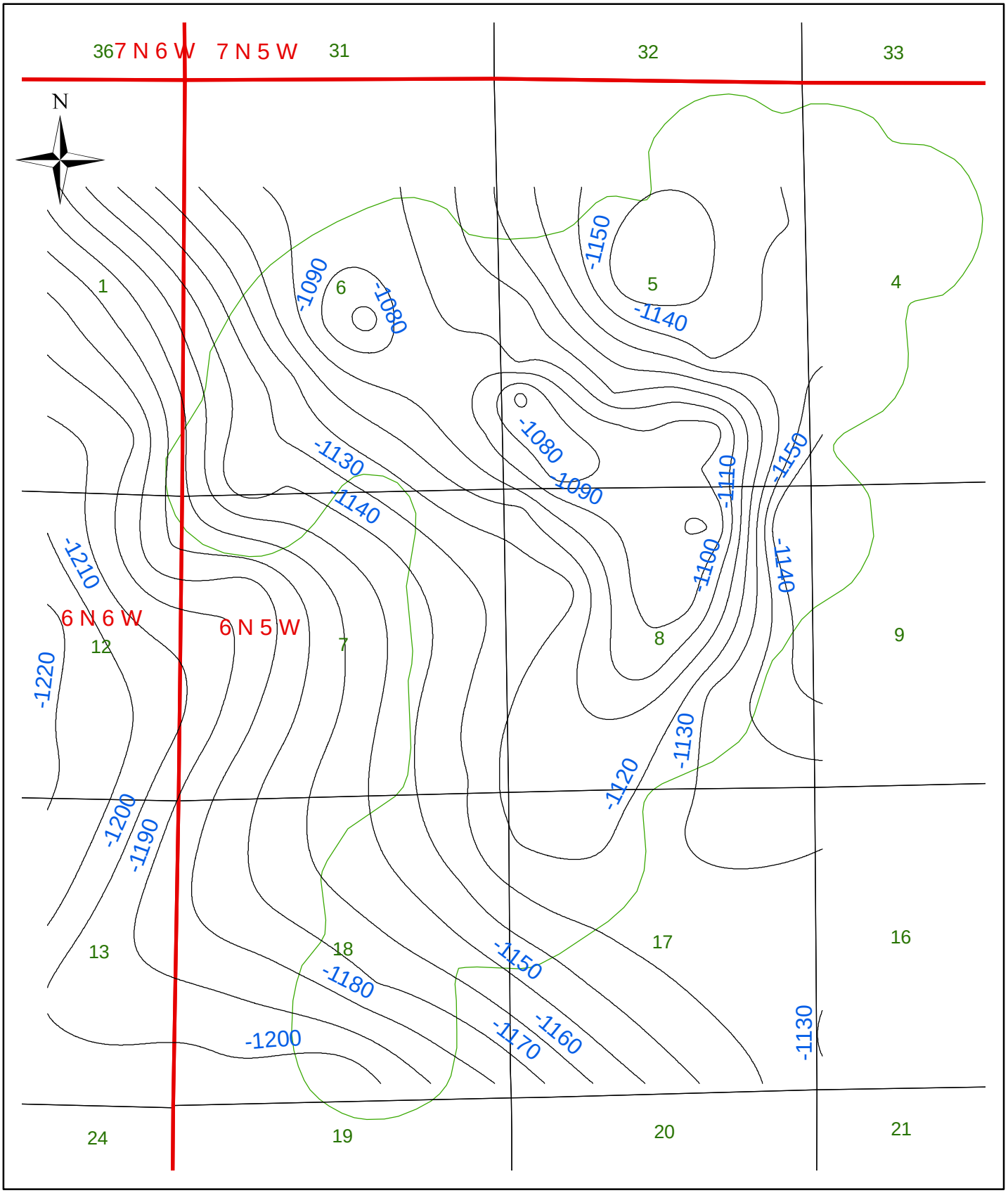

Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Member in Plummer Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

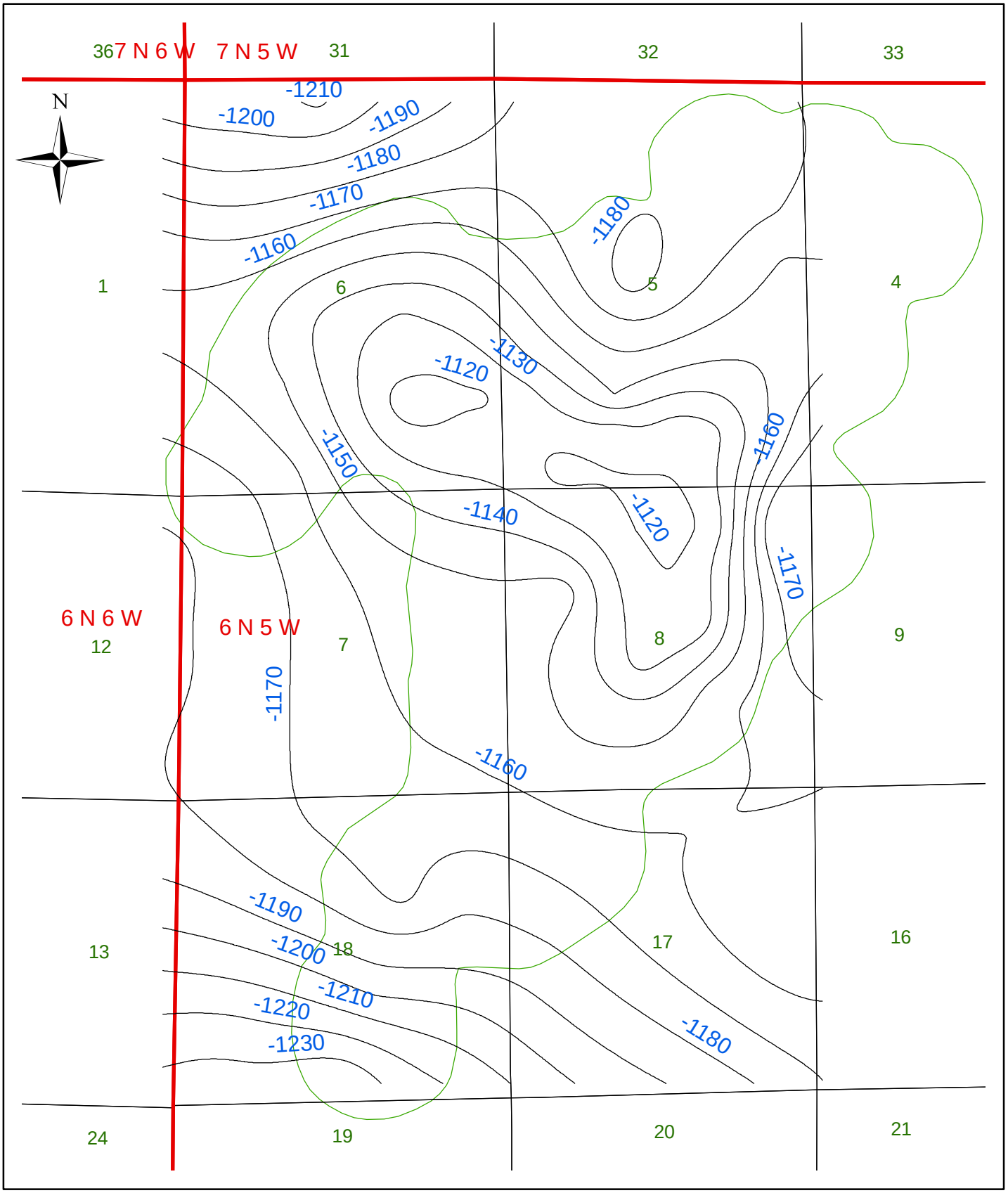

Figure 5: Structure map showing the top of the subsurface Silurian in Plummer Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

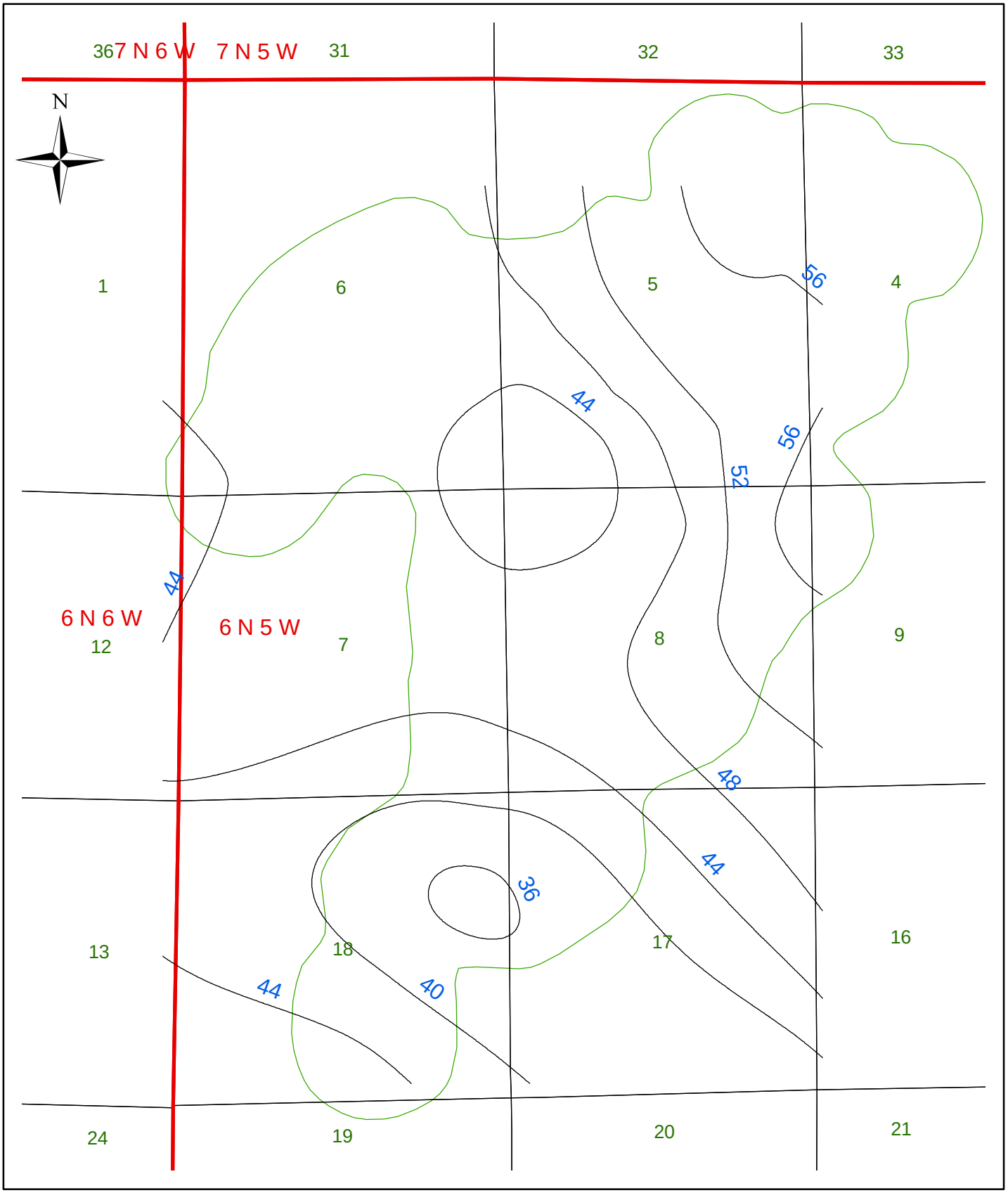

Figure 6: Isopach map of the Vernon Fork Member from Plummer Field, Greene County. Contour interval is 4 ft.

THE PLUMMER FIELD

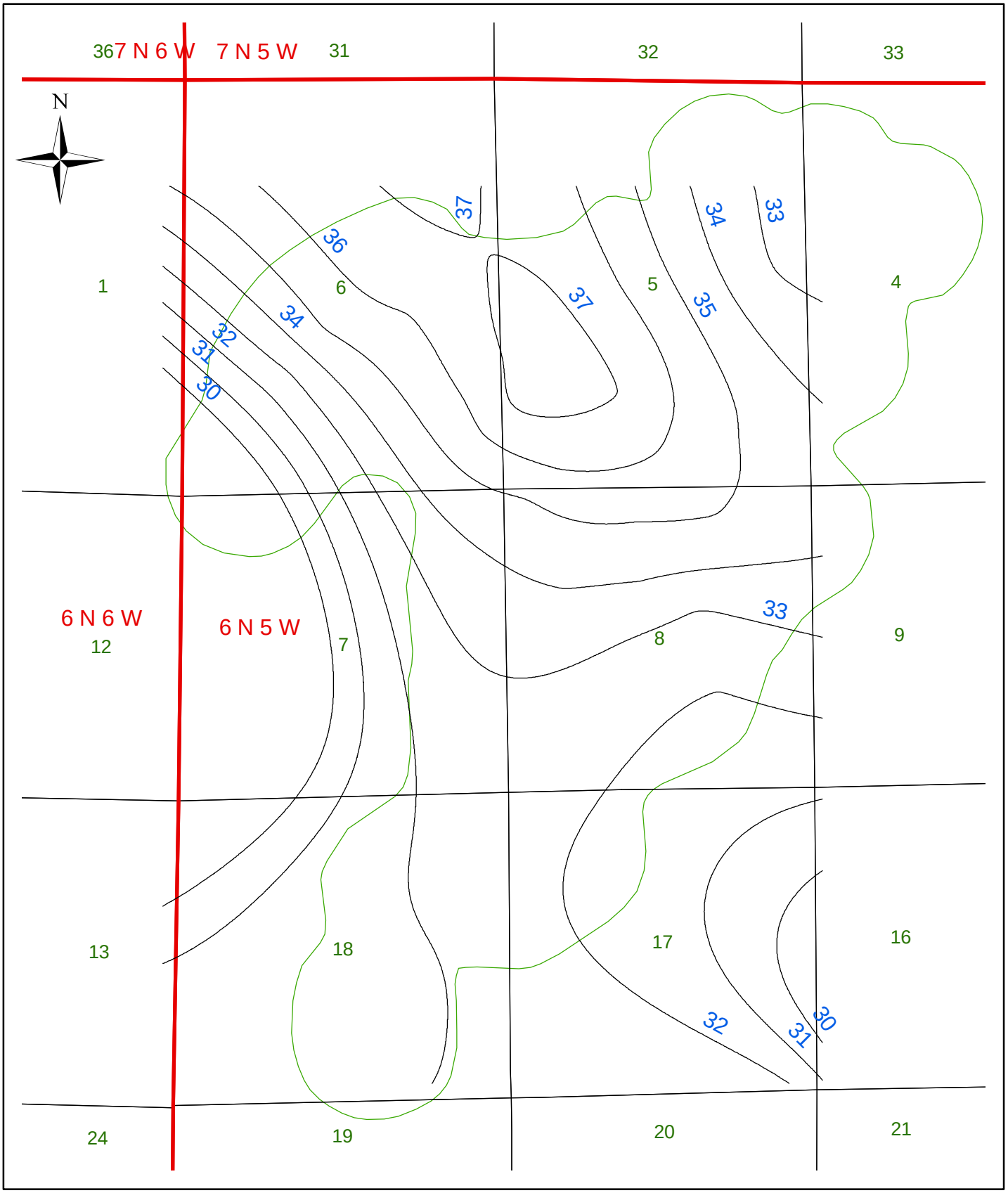

Figure 7: Isopach map of the Geneva Dolomite Member from Plummer Field, Greene County. Contour interval is 1 ft.

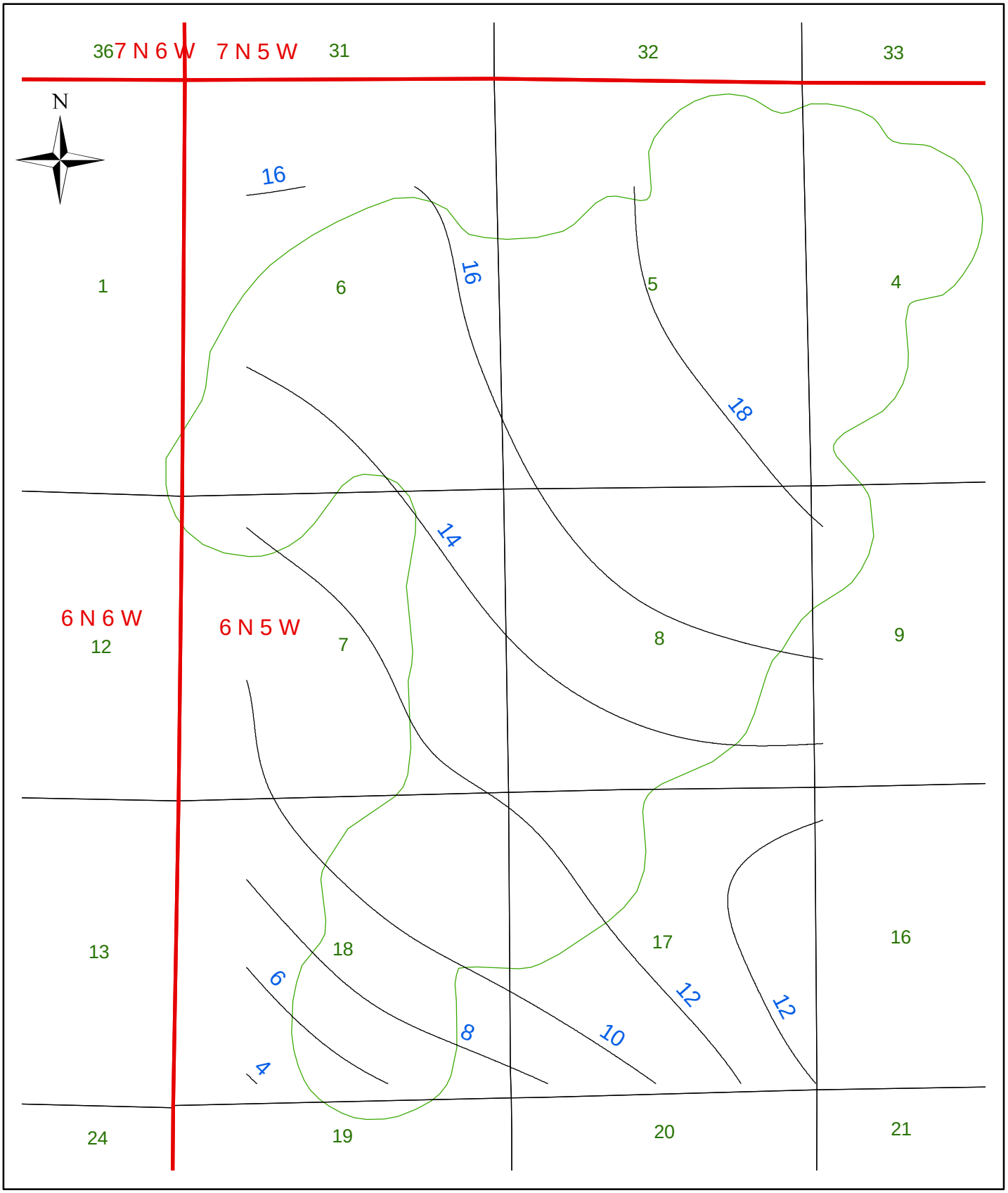

Figure 8: Map showing net porosity feet greater than 10% from neutron logs for the Vernon Fork Member in Plummer Field. Contour interval is 2 ft.

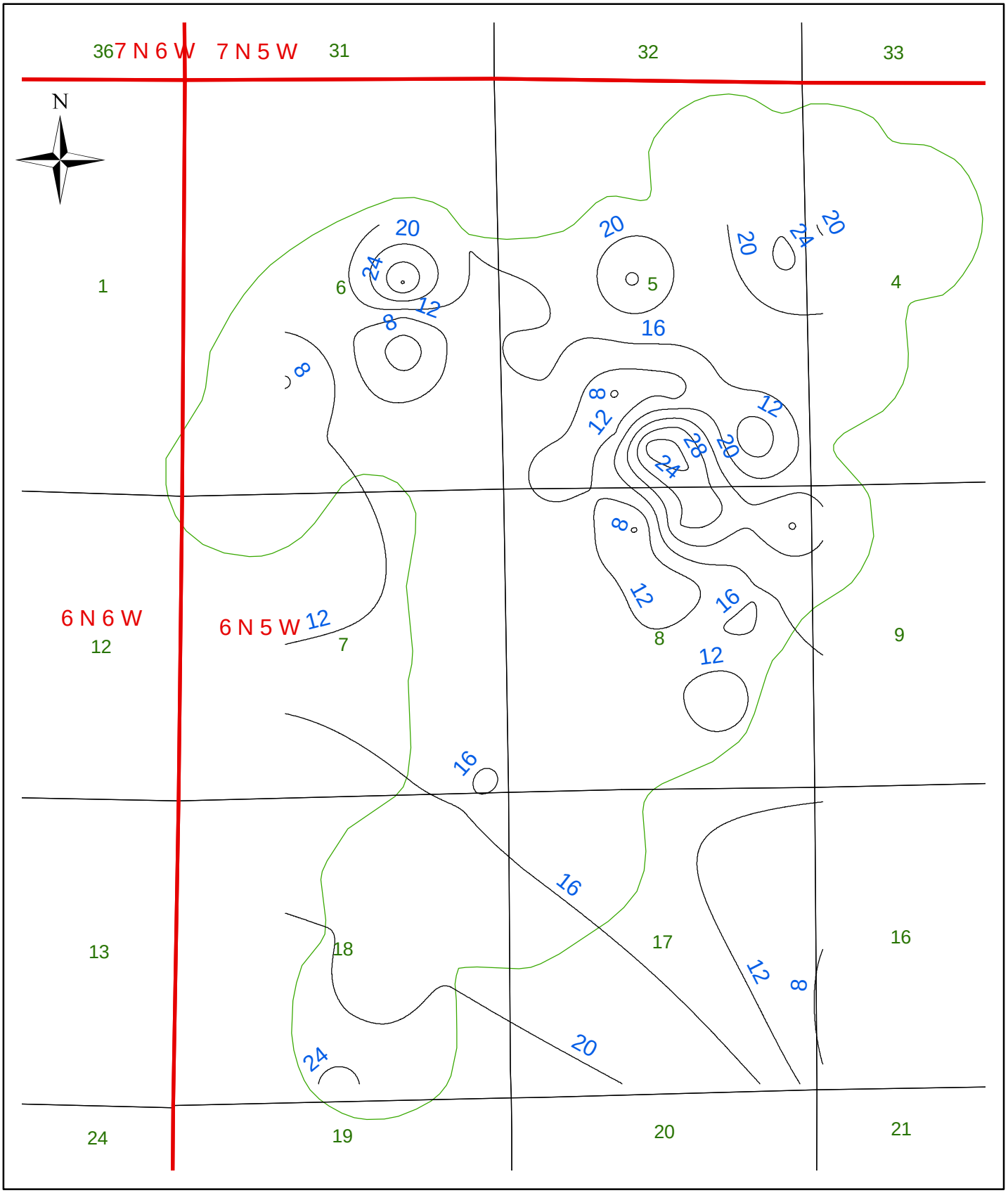

Figure 9: Map showing net porosity feet greater than 10% from neutron logs for the Geneva Dolomite Member at Plummer Field. Contour interval is 4 ft.

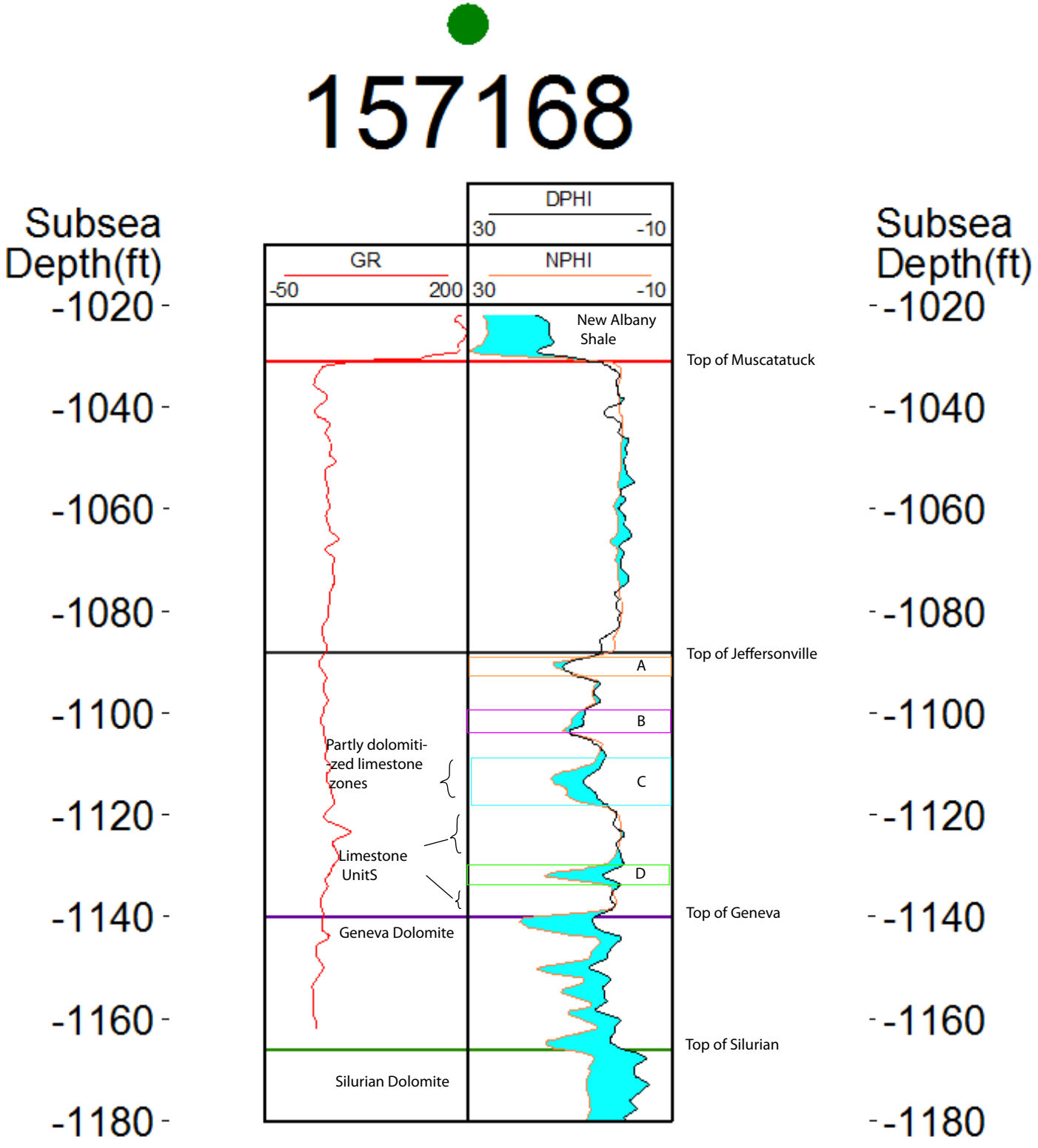

Figure 10: Type log section showing the Devonian formations at Plummer Field, Greene County. A, B, C, and D are partly dolomitized zones in the Vernon Fork Member.

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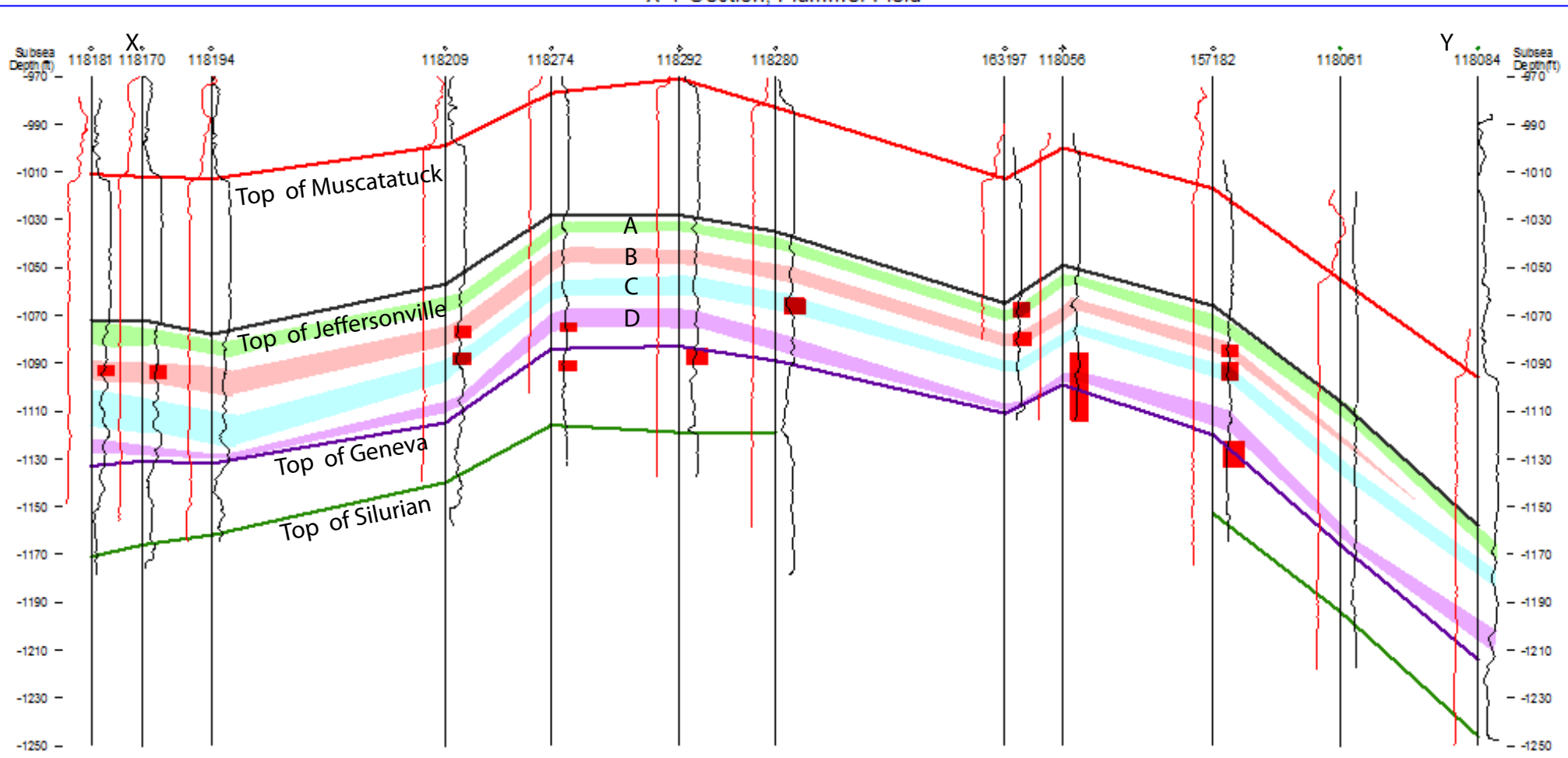

Figure 11: Cross section X-Y showing the Devonian subsurface structure across Plummer Field, Greene County. The red color box shows the completion intervals for the oil and gas production. A, B, C, and D are commonly named porosity zones. For location of the cross section refer to Figure 1.

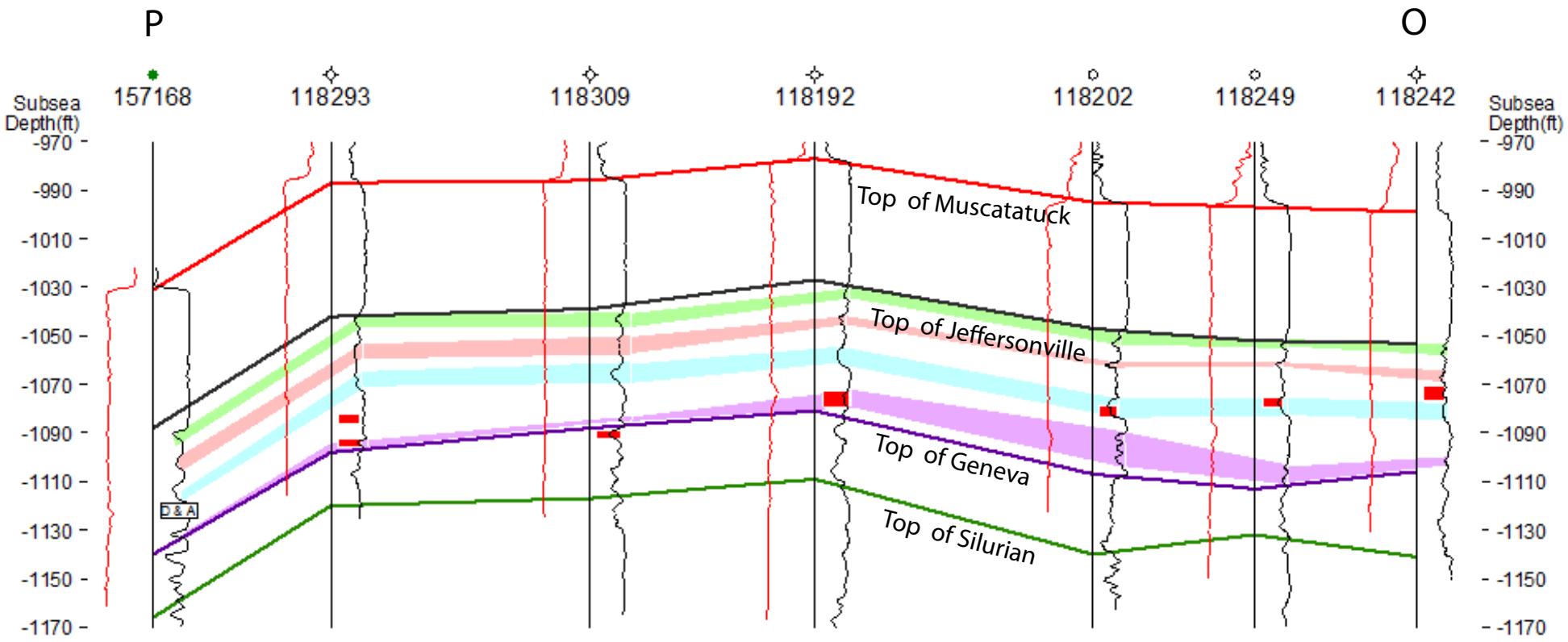

Figure 12: Cross section P-O showing the Devonian subsurface structure across Plummer Field, Greene County. The red color box shows the completion intervals for the oil and gas production. For location of the cross section see Figure 1.

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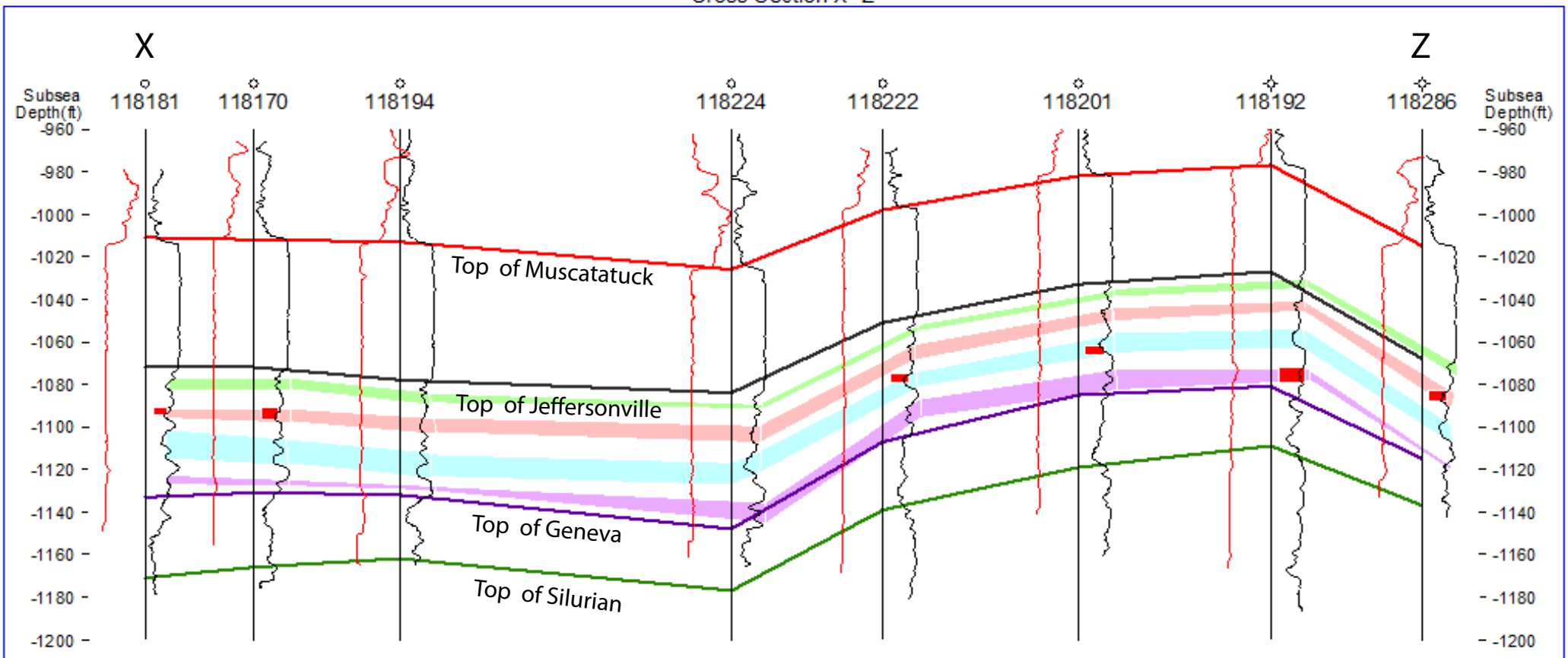

Figure 13: Cross section X-Z showing the Devonian subsurface structure across Plummer Field, Greene County. The red color box shows the completion intervals for the oil and gas production. For location of the cross section see Figure 1.

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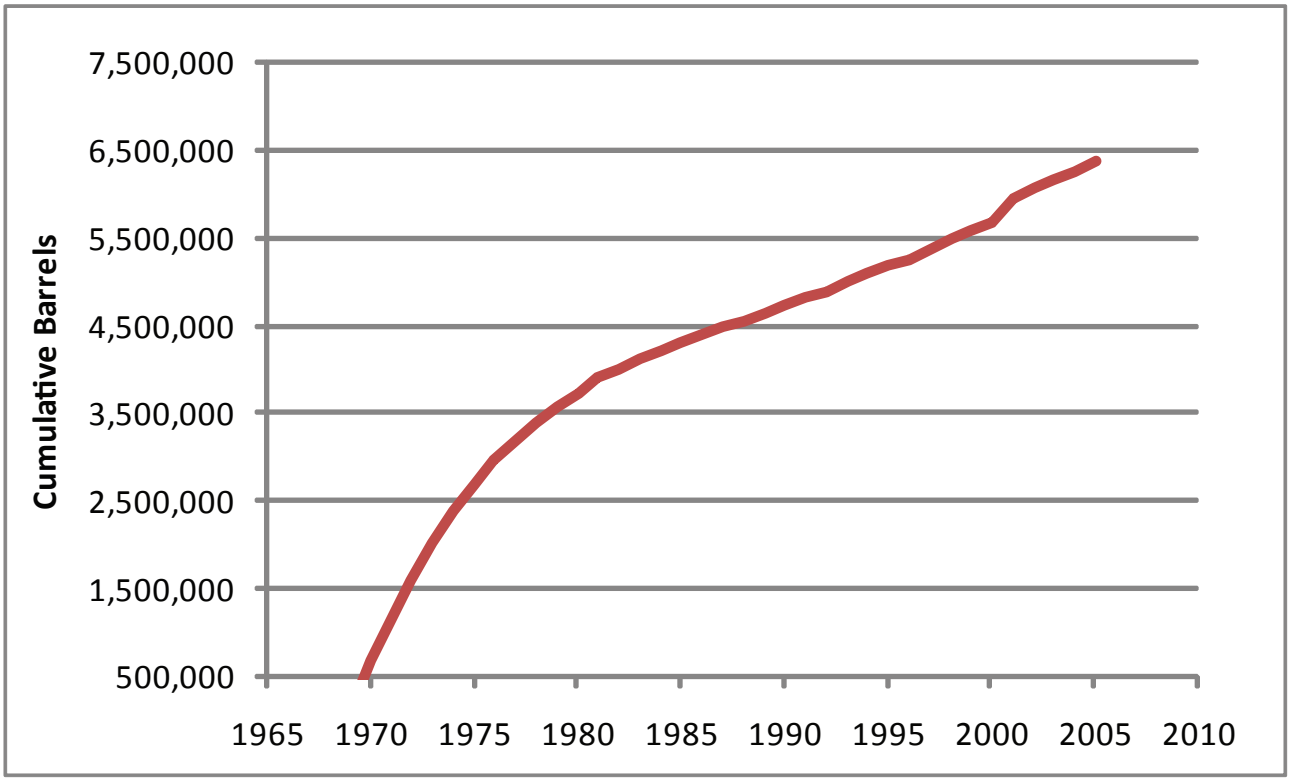
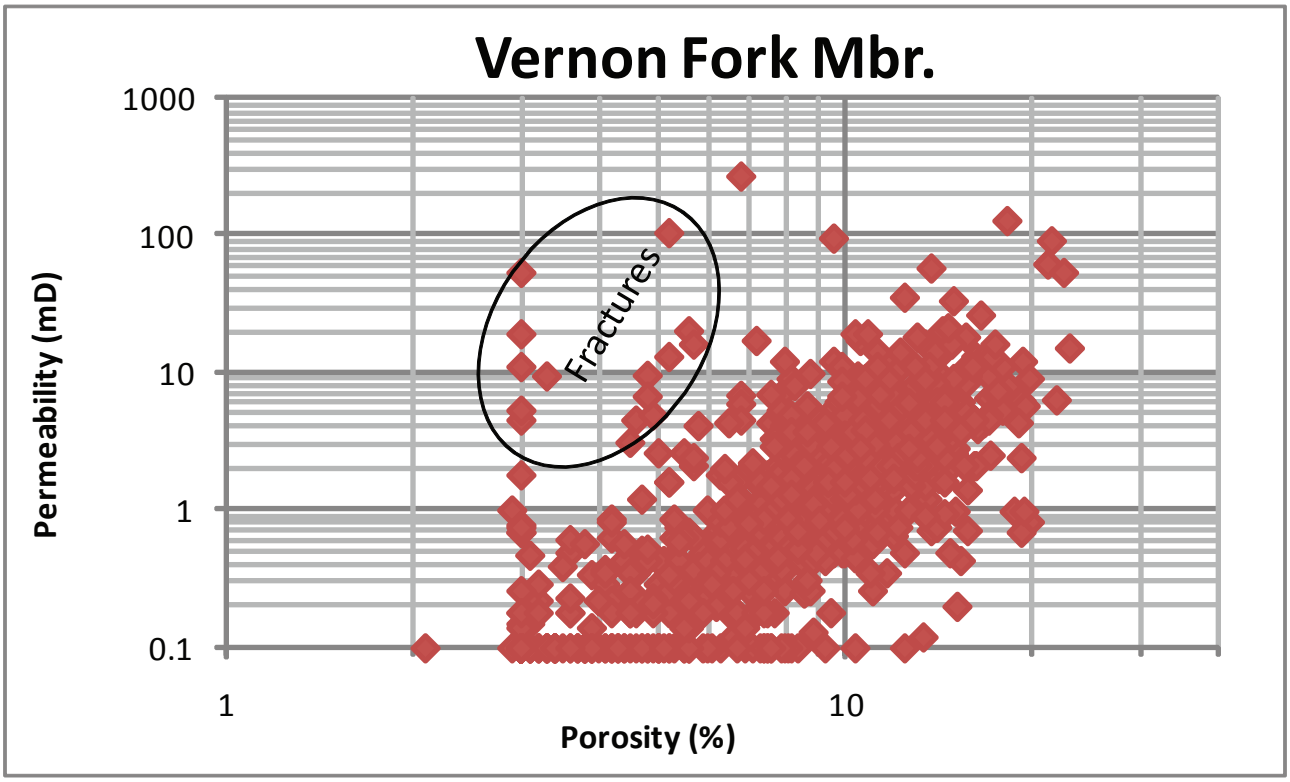


Figure - 14: Cumulative oil production history from Plummer Field, Greene County since 1969.



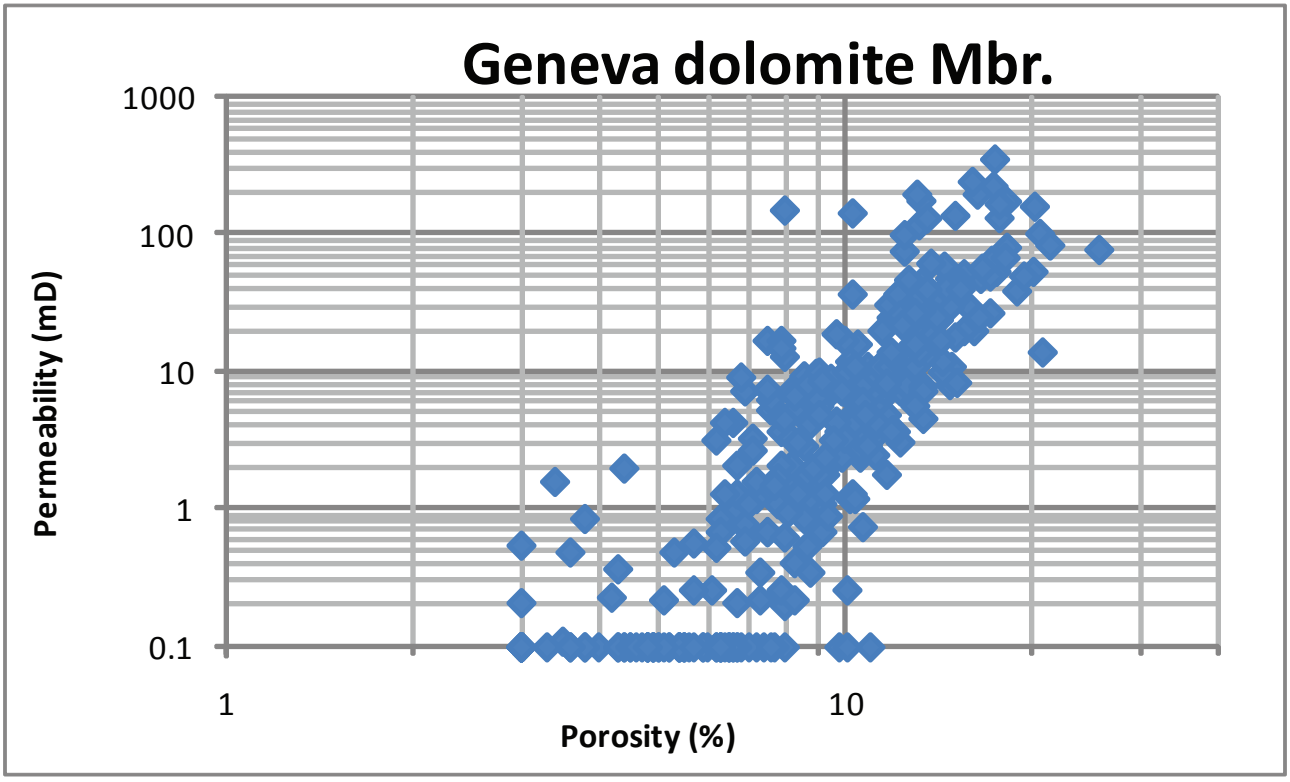


Figure 15: Porosity-permeability cross plots for Vernon Fork and Geneva zones at Plummer Field, Greene County.

Table-1: List of wells used for subsurface structure mapping in Plummer field, Greene County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil_P	Gas_P	Core P/A
118170	6	N	5	W	4	534	1546	1610	1665	1698	12		p
118181	6	N	5	W	4	521	1532	1592	1654	1690	15/150		p
118185	6	N	5	W	5	523	1526	1578	1622	1670	18/150	50	p
118186	6	N	5	W	5	520	1534	1588	1632		25	50	A
118187	6	N	5	W	5	543	1575	1645	1704	1736		500	
118190	6	N	5	W	5	543	1508	1560					p
118192	6	N	5	W	5	543	1520	1590	1614	1652	4\5	250	p
118193	6	N	5	W	5	550	1560	1614			2\38		
118194	6	N	5	W	5	555	1568	1640	1688	1710			p
118199	6	N	5	W	5	556	1572	1630	1698	1728	24\78		p
118201	6	N	5	W	5	549	1531	1595	1634	1668	30\10		p
118202	6	N	5	W	5	527	1522	1576	1634	1667	34\100	100	p
118205	6	N	5	W	5	530	1508	1562	1590	1650			
118209	6	N	5	W	5	560	1559	1618	1673	1700	30\100	50	
118213	6	N	5	W	5	548	1528	1582	1628	1671	100\20	50	
118214	6	N	5	W	5	547	1552	1605	1660	1708	30\50	150	p
118222	6	N	5	W	5	531	1529	1582	1634	1670	25\50	150	p
118224	6	N	5	W	5	538	1564	1623	1684		60\6		
118229	6	N	5	W	5	534	1585						
157163	6	N	5	W	5	521	1542						
163109	6	N	5	W	5	538	1522	1576	1630	1662	15\11		
163411	6	N	5	W	5	537	1504	1568	1621	1654	20\24		
163456	6	N	5	W	5	530	1516	1573	1618	1658	42\60		
164380	6	N	5	W	5	547							
118235	6	N	5	W	6	512	1499	1554	1600	1625			p
118236	6	N	5	W	6	508	1499	1556	1600	1640	25\50		p
118238	6	N	5	W	6	555	1582	1640	1678		2\100	750	
118239	6	N	5	W	6	504	1483	1535	1574			200	
118240	6	N	5	W	6	514	1504	1558	1600	1647	49	350	p
118241	6	N	5	W	6	507	1496	1550	1604	1630	15	100	p
118242	6	N	5	W	6	499	1498	1554	1596	1640	50		
118244	6	N	5	W	6	535	1574	1628	1676	1704			p
118247	6	N	5	W	6	507	1522	1576	1634	1658	70		p
118249	6	N	5	W	6	510	1507	1562	1612	1642	30	125	p
118253	6	N	5	W	6	542	1649			1760			
118254	6	N	5	W	6	506	1499	1552	1601	1636	44	180	p
118256	6	N	5	W	6	503	1512			1606			
163455	6	N	5	W	6	491	1486	1540	1580		72		
118266	6	N	5	W	7	497	1522	1574	1626	1657	10		p
118270	6	N	5	W	7	536	1605	1665	1726				

Table-1: Continued....

118274	6	N	5	W	8	567	1544	1598	1651	1690	40\300	100	
118278	6	N	5	W	8	504	1534	1586	1633	1670	8\80		
118280	6	N	5	W	8	501	1484	1540	1590	1620	50\20	175	p
118286	6	N	5	W	8	507	1522	1578	1622	1644	10\60	100	p
118290	6	N	5	W	8	494	1512	1574			250		
118292	6	N	5	W	8	532	1505	1562	1614	1651	5\100	100	
118293	6	N	5	W	8	534	1521	1576	1632	1650	14	200	
118299	6	N	5	W	8	556	1610	1668	1738	1775			
118304	6	N	5	W	8	516	1496	1560	1602	1639	6\20	200	p
118307	6	N	5	W	8	568	1538	1596	1645	1685			
118309	6	N	5	W	8	525	1511	1566	1612	1644	8	75	p
157168	6	N	5	W	8	498	1529	1584	1636	1664			
163196	6	N	5	W	8	535	1517	1580	1616	1652	2		
163197	6	N	5	W	8	490	1503	1558	1600				
157179	6	N	5	W	17	488	1570						
118056	6	N	5	W	18	546	1546	1612			20	650	
118059	6	N	5	W	18	528	1595						
118061	6	N	5	W	18	532	1587	1660	1702	1726			
118076	6	N	5	W	18	544	1564	1610			9		
118084	6	N	5	W	18	564	1660	1724	1776	1812			
157182	6	N	5	W	18	545	1562			1705			
157183	6	N	5	W	18	538	1584	1658	1682	1720	8		
164040	6	N	5	W	18	547	1570	1638	1668		6		
118311	6	N	6	W	1	500	1636		1698				
118317	6	N	6	W	12	497	1560	1638	1667	1682			
118318	6	N	6	W	12	499	1660		1726				
162647	6	N	6	W	24	532	1658						
164042	8	N	5	W	5	536	1509						

Field name: Portersville

IGS ID: 10549

DOE ID: 566906

Location: Daviess County, 1N-5W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth):

Devonian, Muscatatuck Group, North Vernon Ls. 1,855 ft.)

Devonian, Muscatatuck Group, Jeffersonville Ls. (1,926 ft.)

Devonian, New Harmony Group ((2,031 ft.)

Field type: natural gas & oil (abandoned)

Total number production wells: 1 (natural gas), 2 (oil)

Area: na

Cumulative production: na

Other reservoir units: Mississippian, West Baden Group, Elwren (Cypress) Fm.

Deepest unit penetrated (depth): Silurian (2,225 ft.)

Field characteristic: No observable structure.

Reservoir characteristics:

Field name: Portersville West

IGS ID: 10551

DOE ID: na

Location: Daviess County, 1N-5W

Discovery date: 1973

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,888 ft.)

Field type: natural gas

Total number production wells: 3

Area: na

Cumulative production: na

Other reservoir units:

Deepest unit penetrated (depth): Silurian (2,385 ft.)

Field characteristic: Subtle anticline with closure in excess of 20 ft. at top of Muscatatuck.

Reservoir characteristics:

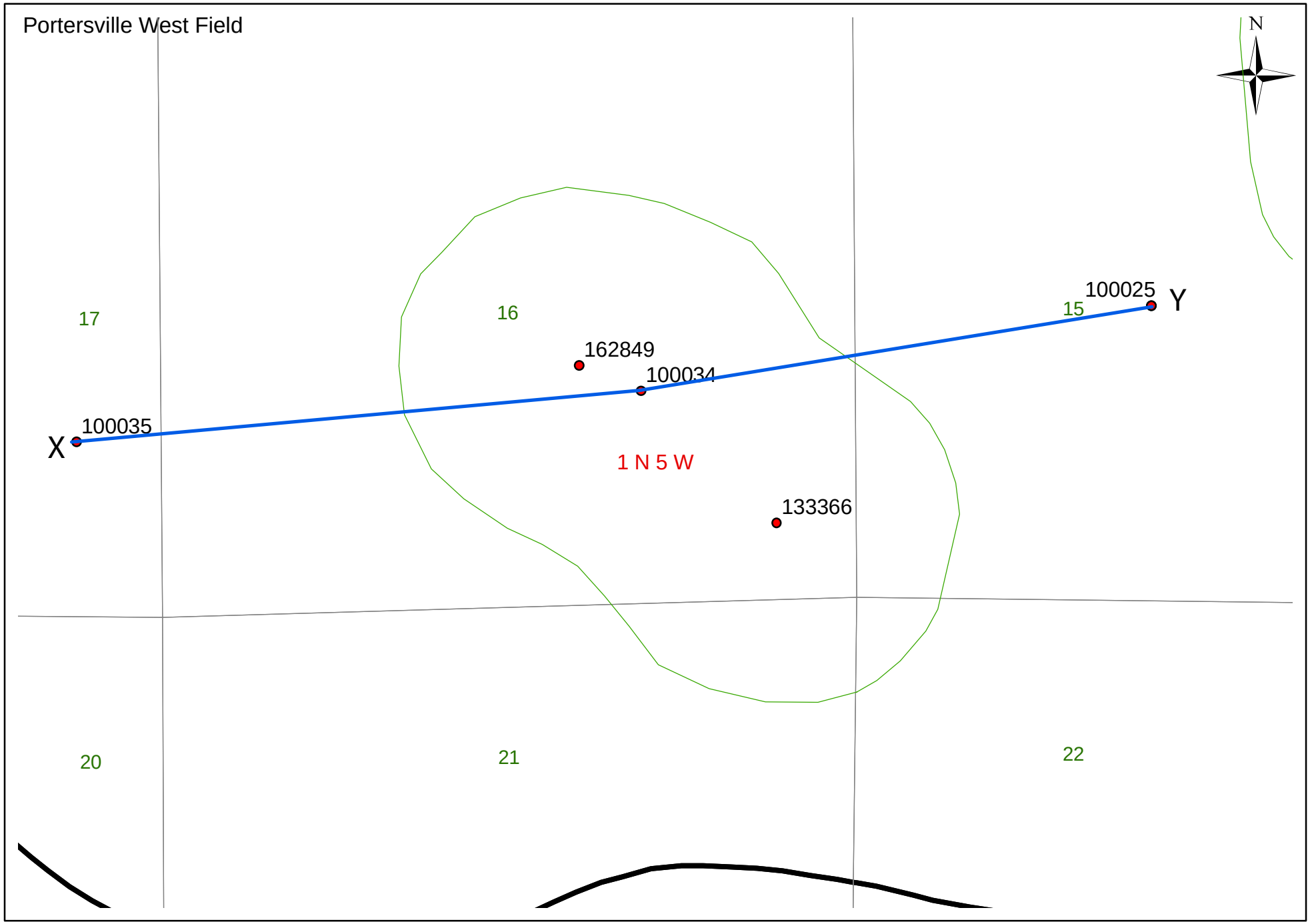


Figure 1: Map showing the location and wells at Portersville West Field, Daviess County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figures 4.

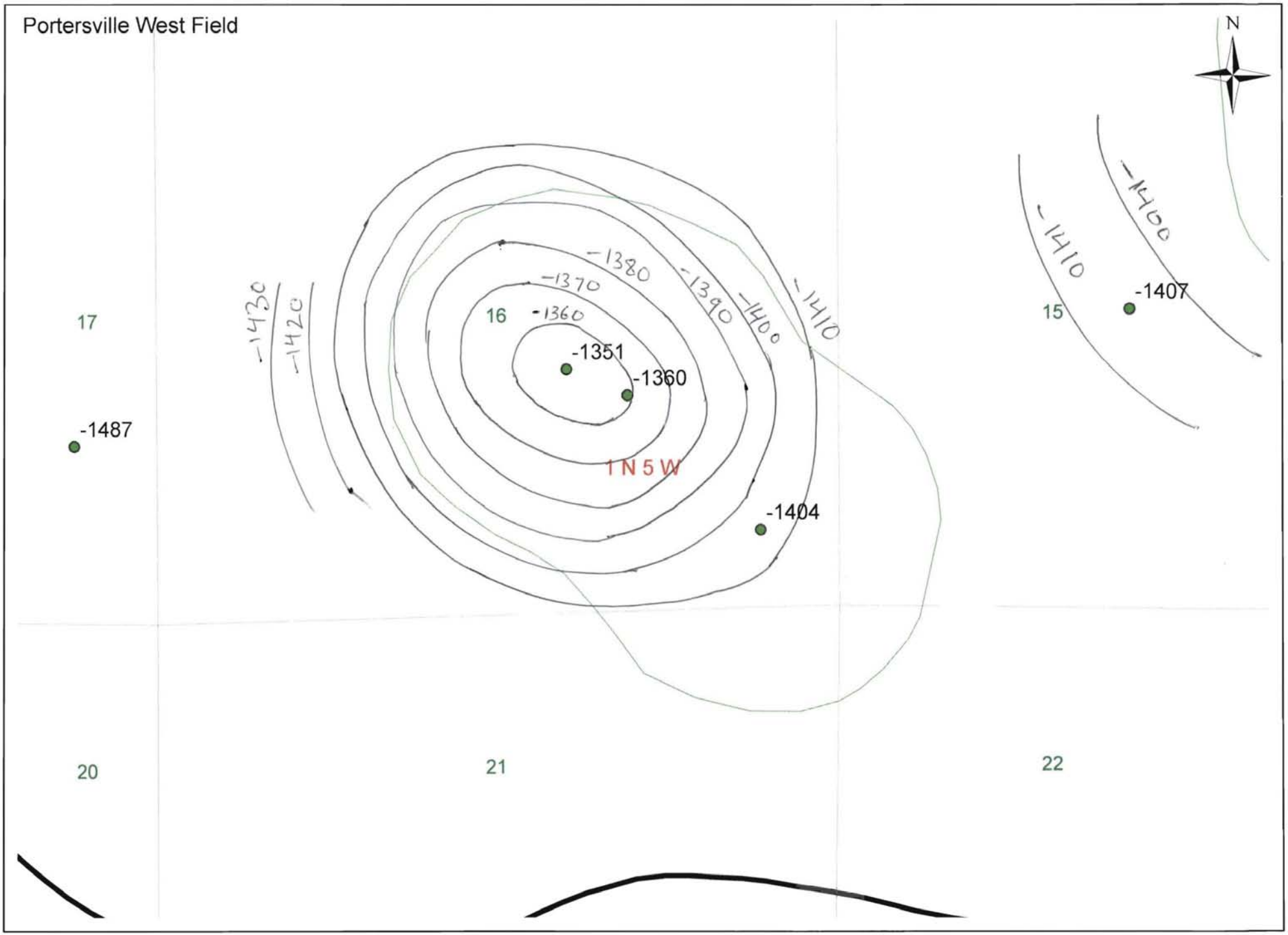


Figure 2: Structure map showing the top of the Muscatatuck Limestone in Portersville West Field, Daviess County. Contours show values below sea level, contour interval is 10 ft .

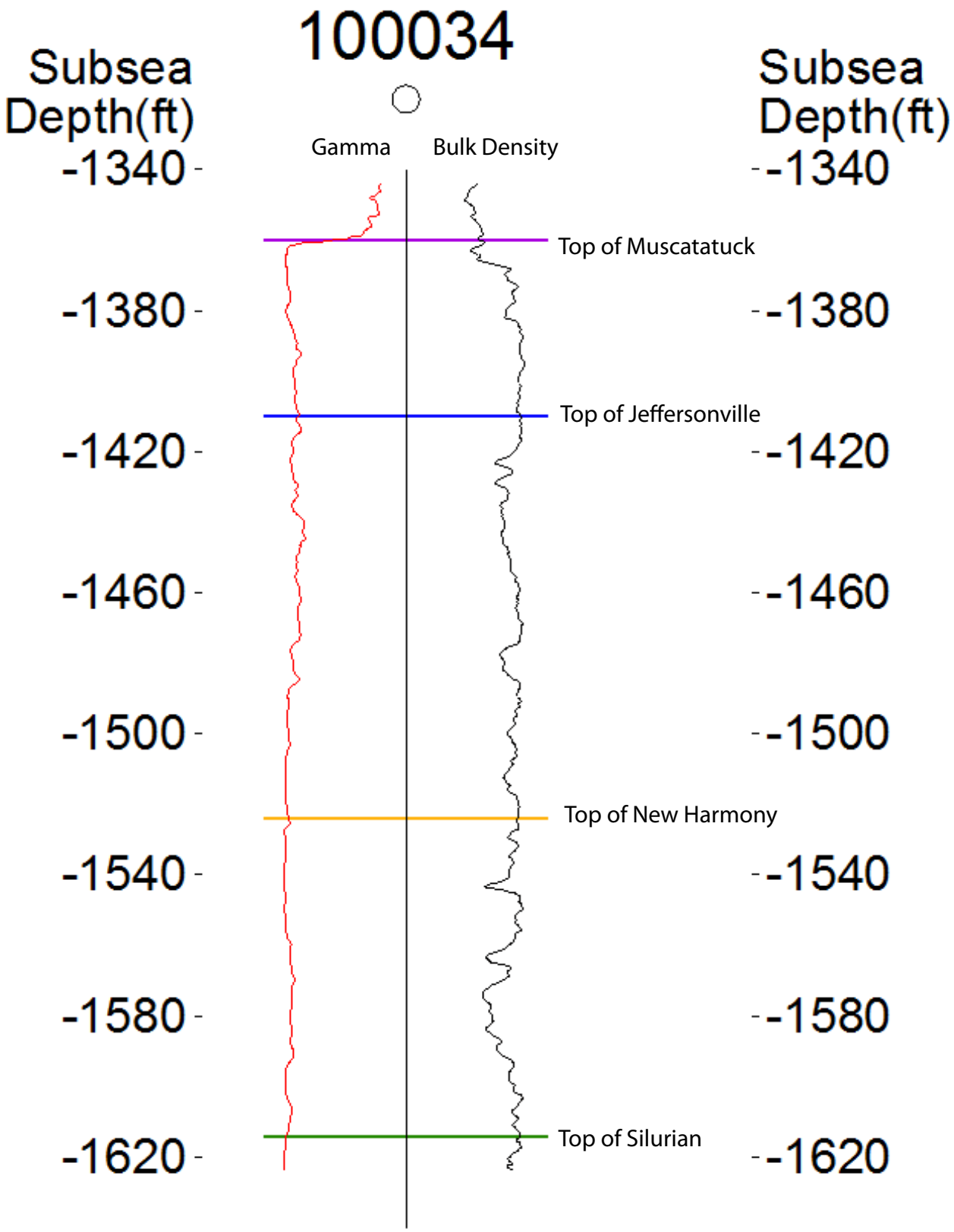


Figure 3: Type log section showing the Devonian formations from Portersville West Field, Daviess County.

HS=1

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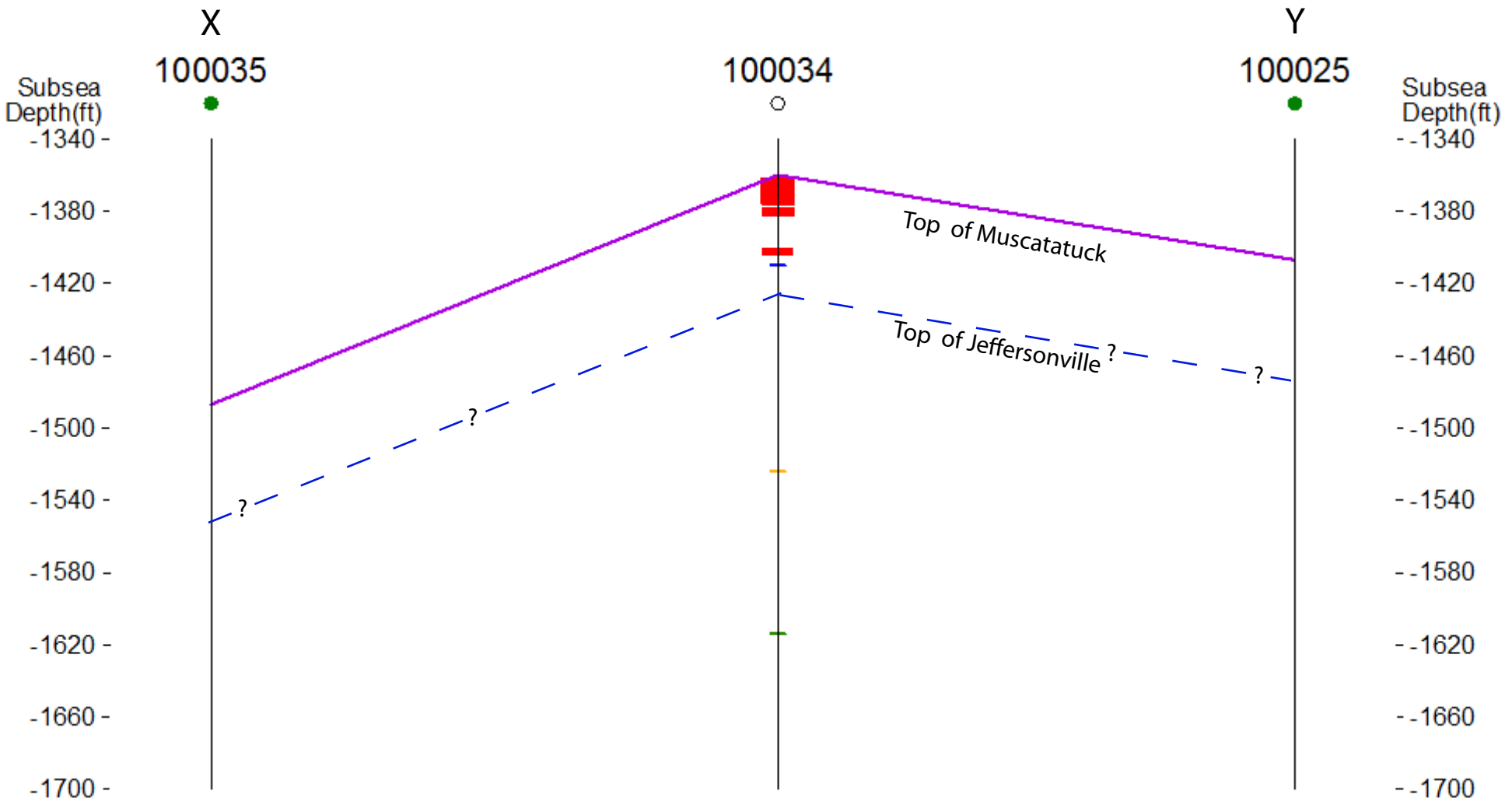

Figure 4: X-Y Cross section showing the Devonian subsurface structure acrorss Portersville West Field, Daviess County. For location of the cross section refer to Figure 1. Red box indicates the completion interval for gas production.

Table-1: List of the wells used for subsurface structure mapping in Portersville West field, Daviess County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
100025	1	N	5	W	15	505	1912				2230		
100033	1	N	5	W	16	507	1933	1986					
100034	1	N	5	W	16	526	1886	1934		2050	2140		35
133366	1	N	5	W	16	562	1966						1500
162849	1	N	5	W	16	510	1861						
100035	1	N	5	W	17	492	1979						
107344	1	N	5	W	28	499							

Field name: Prairie Creek

IGS ID: 10556

DOE ID: 570448

Location: Vigo County, 10N-10W

Discovery date: 1933 (natural gas), 1937 (oil)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon & Jeffersonville Ls. (2,132 ft.)

Field type: natural gas & oil

Total number production wells: 3 (natural gas), 80 (oil)

Area: 700 acres

Cumulative production: 2,363,156 bbls. (2002)

Other reservoir units:

Pennsylvanian

Mississippian, Blue River Group, Ste. Genevieve Ls.

Mississippian, Sanders Group, Salem Ls.

Deepest unit penetrated (depth): Silurian (2,329 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

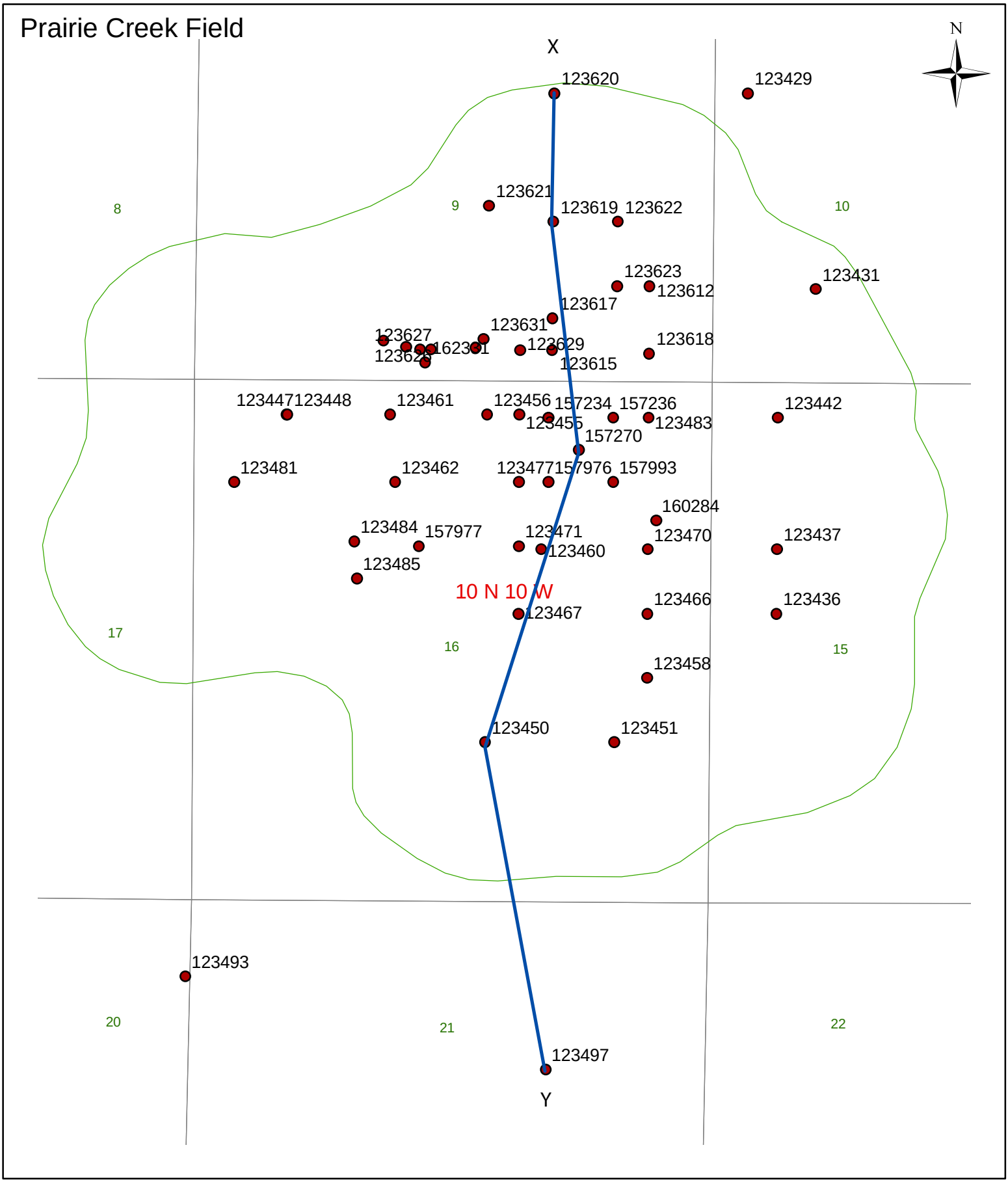

Figure 1: Map showing the location and wells at Prairie Creek Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 4).

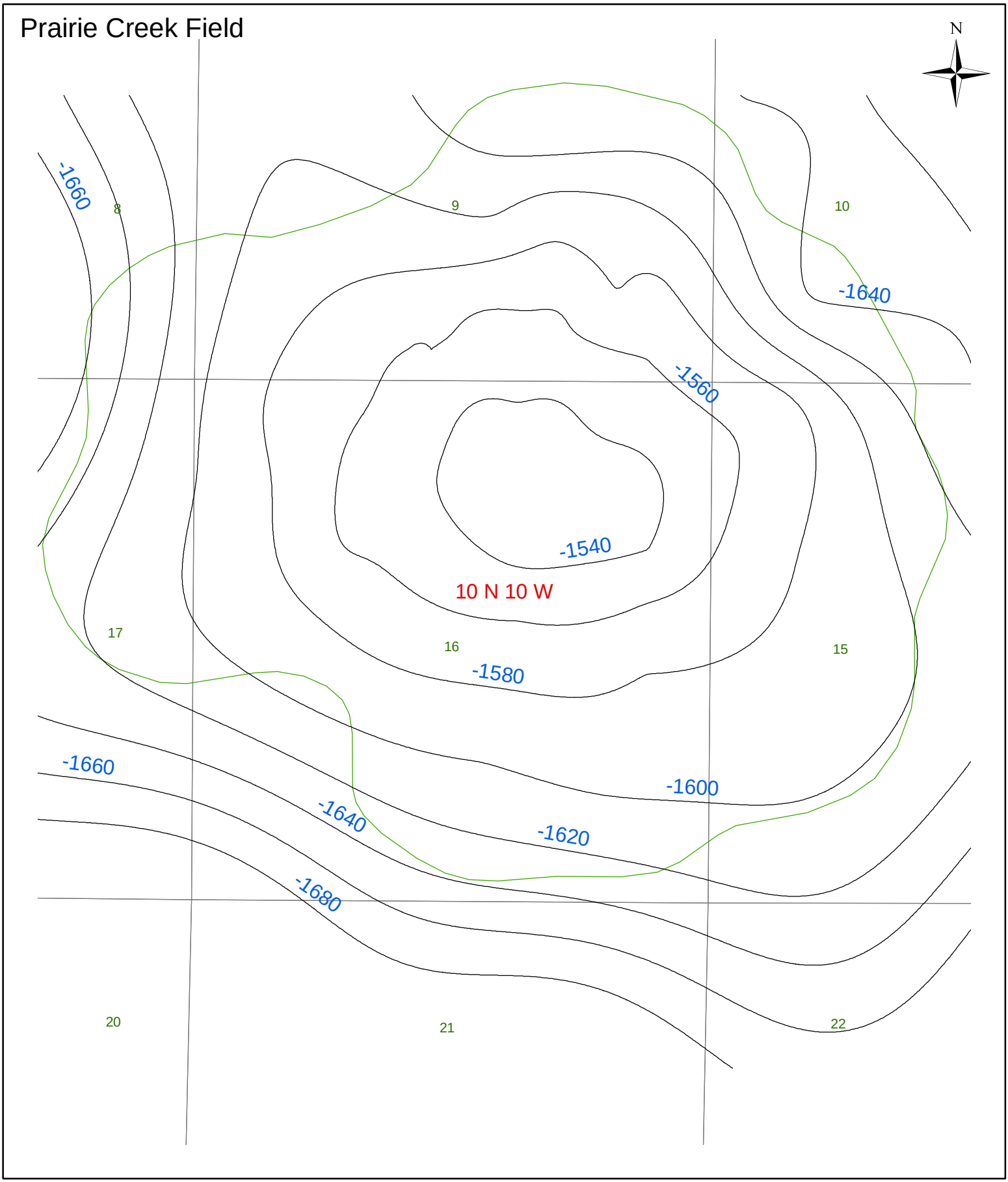

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Prairie Creek Field, Vigo County. Contours show values below sea level, contour interval is 20 ft .

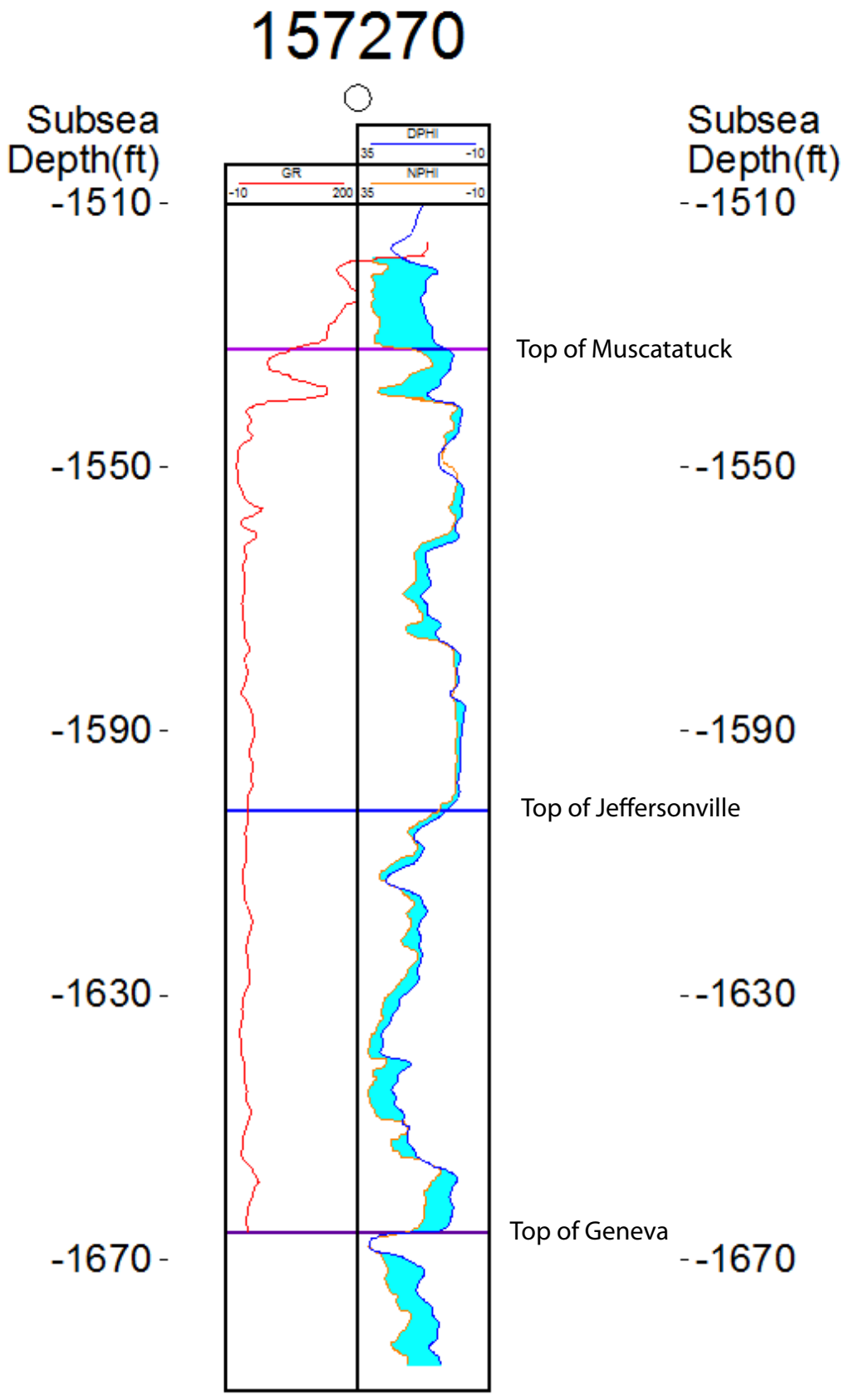

Figure 3: Type log section showing the Devonian formations at Prairie Creek Field, Vigo County.

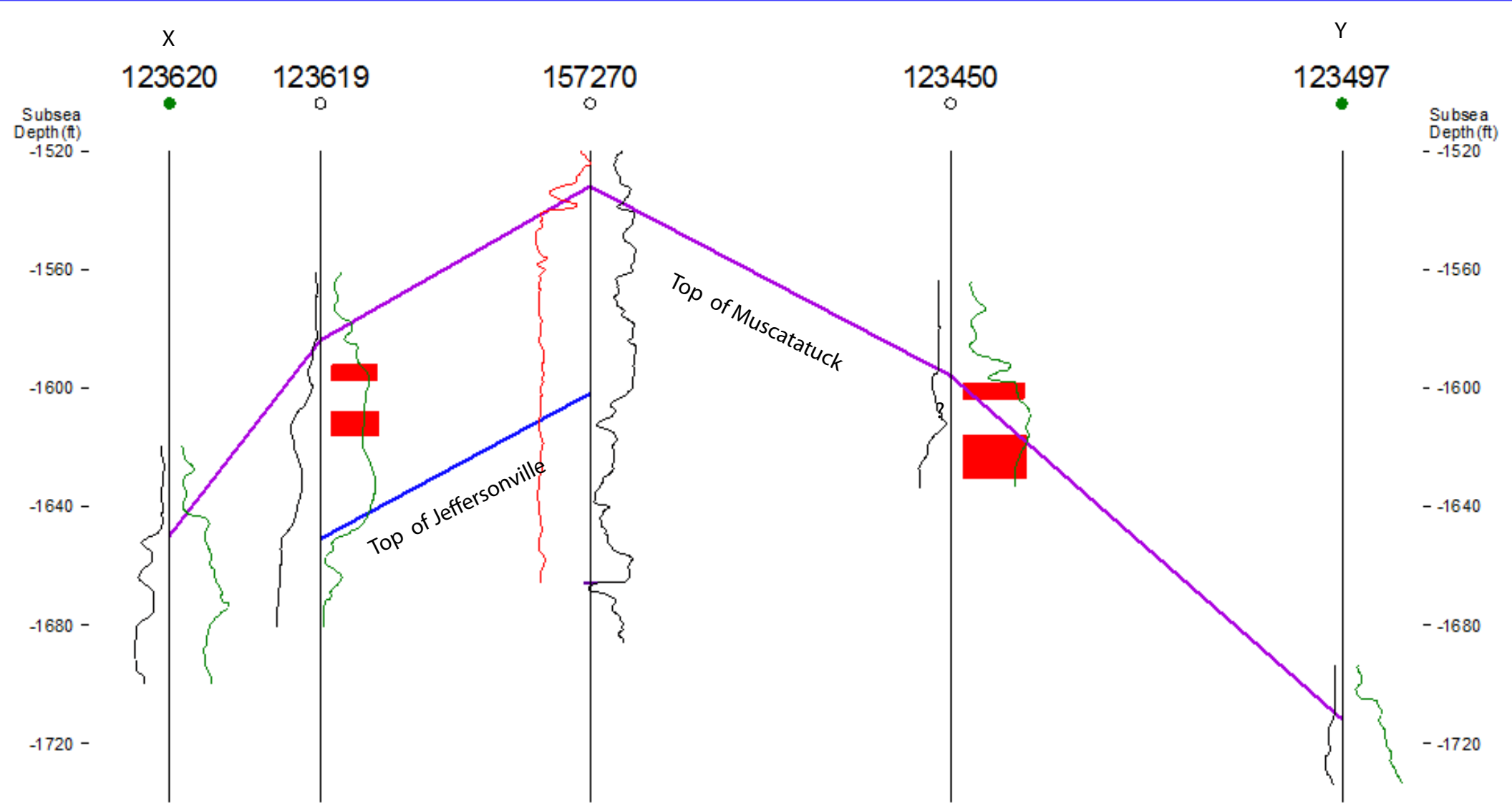

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Prairie Creek Field, Vigo County. The red color box shows the completion intervals for oil or gas production. For location of the cross section refer to Figure 1.

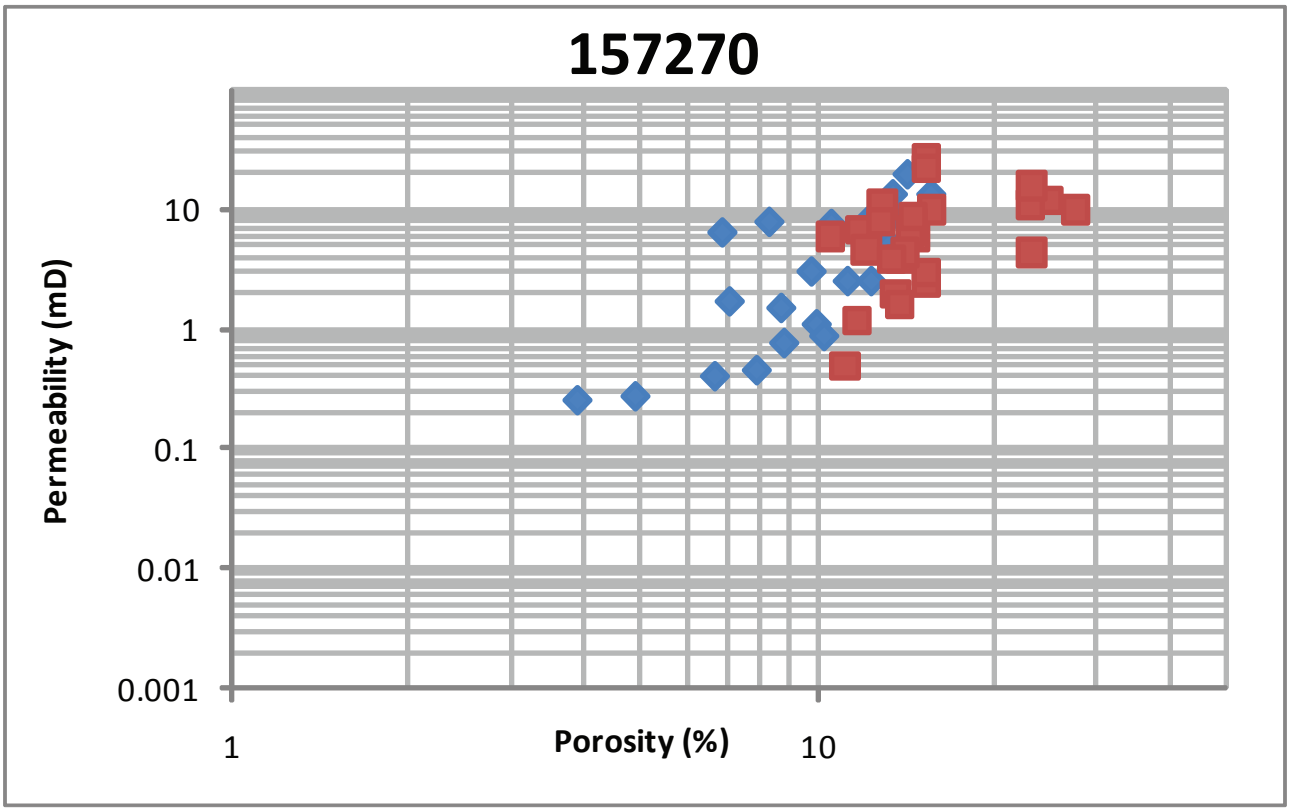

Figure 5: Porosity-permeability plot from core analysis from Prairie Creek Field, Vigo County. The blue points are from North Vernon and the red points from the Vernon Fork. The chart title lists the IGS Well ID. For the well locations see Figure 1.

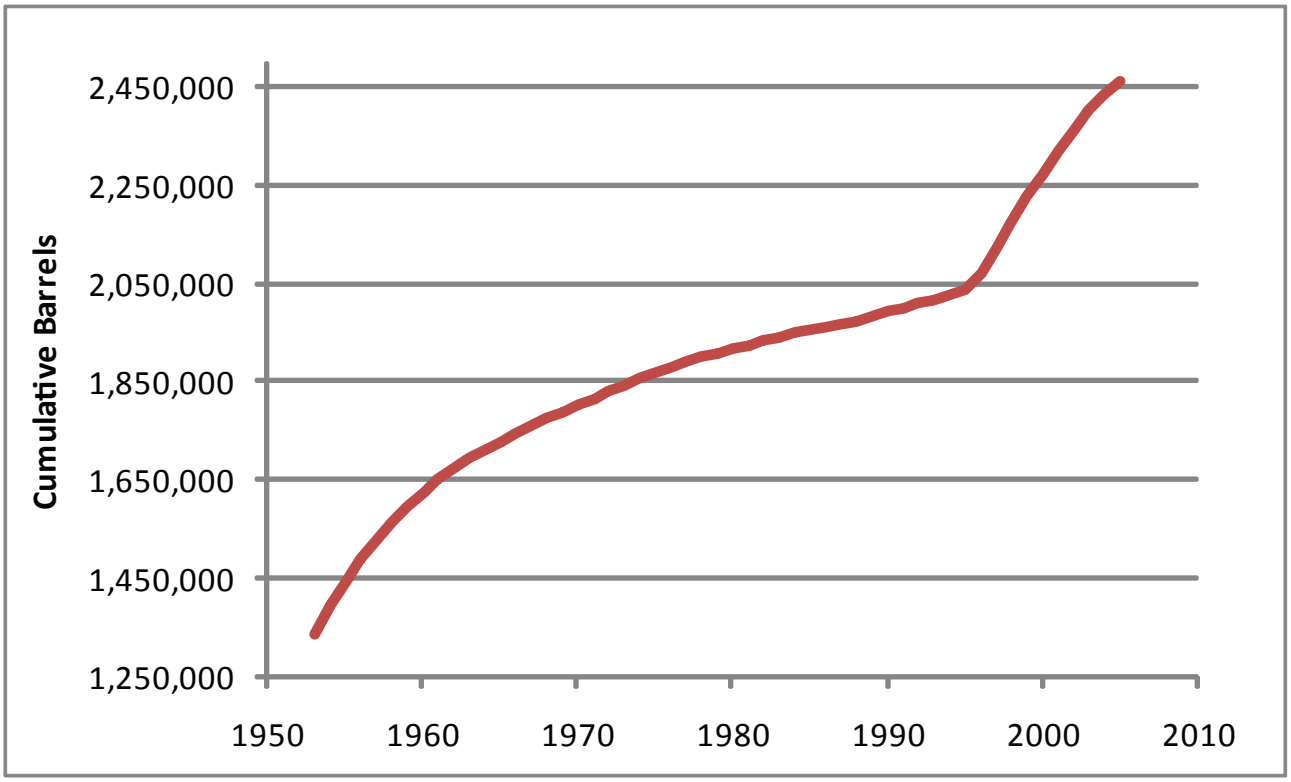

Figure - 6: Cumulative oil production history for Prairie Creek Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Prairie Creek Field, Vigo County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)	Core (P/A)
123611	10	N	10	W	8	448	2162						
123612	10	N	10	W	9	530	2105						
123615	10	N	10	W	9	536	2094						
123616	10	N	10	W	9	532							
123617	10	N	10	W	9	534	2091						
123618	10	N	10	W	9	529	2090				200		
123619	10	N	10	W	9	539	2123	2190			40		
123620	10	N	10	W	9	510	2160						
123621	10	N	10	W	9	528	2133						
123622	10	N	10	W	9	532	2122				26		
123623	10	N	10	W	9	529	2110				25		
123624	10	N	10	W	9	539	2096				35		
123625	10	N	10	W	9	534	2095						
123626	10	N	10	W	9	495	2060				30		
123627	10	N	10	W	9	533	2093				40		
123629	10	N	10	W	9	533	2088				44		
123630	10	N	10	W	9	528	2085				43		
123631	10	N	10	W	9	525	2073				60		
160289	10	N	10	W	9	544	2149				65		
162331	10	N	10	W	9	535	2087						
123429	10	N	10	W	10	506	2147						Present
123430	10	N	10	W	10	531	2086				12		
123431	10	N	10	W	10	530	2175						
123434	10	N	10	W	14	531							
123436	10	N	10	W	15	539	2119				87		
123437	10	N	10	W	15	540	2116				57		
123438	10	N	10	W	15	534					82		
123439	10	N	10	W	15	546					30		
123442	10	N	10	W	15	530	2097				60		
123443	10	N	10	W	15	530	2175						Present
123447	10	N	10	W	16	533	2106						
123448	10	N	10	W	16	536	2108	2172					
123450	10	N	10	W	16	536	2132				20		
123451	10	N	10	W	16	552	2140						
123455	10	N	10	W	16	532	2070	2148			220		
123456	10	N	10	W	16	535	2070	2140			678		
123458	10	N	10	W	16	547	2128				202		
123460	10	N	10	W	16	547	2081	2150			15		
123461	10	N	10	W	16	510	2066				26		
123462	10	N	10	W	16	533	2078				25		
123465	10	N	10	W	16	531					35		

Table-1: Continued....

123466	10	N	10	W	16	539	2103				85		
123467	10	N	10	W	16	545	2103				205		
123470	10	N	10	W	16	538	2078				38		
123471	10	N	10	W	16	545	2078	2150			317		
123476	10	N	10	W	16	533					65		
123477	10	N	10	W	16	537	2068				310		
123478	10	N	10	W	16	539					50		
123479	10	N	10	W	16	539					200		
123480	10	N	10	W	16	549					50		
123481	10	N	10	W	16	557	2149						
123483	10	N	10	W	16	530	2081	2150			71		
123484	10	N	10	W	16	558	2113				11		
123485	10	N	10	W	16	549	2119						
157234	10	N	10	W	16	538	2070	2140	2200	2245	13		
157235	10	N	10	W	16	538							
157236	10	N	10	W	16	532	2084				12		
157270	10	N	10	W	16	544	2076	2146	2210		16		Present
157976	10	N	10	W	16	547	2078				30		
157977	10	N	10	W	16	546	2094				10		
157993	10	N	10	W	16	540	2063				15		
160098	10	N	10	W	16	535	2080				76		
160284	10	N	10	W	16	536	2075						
160288	10	N	10	W	16	532	2084				93		
123493	10	N	10	W	20	465	2194						
123497	10	N	10	W	21	526	2238						
123502	10	N	10	W	22	527	2220						

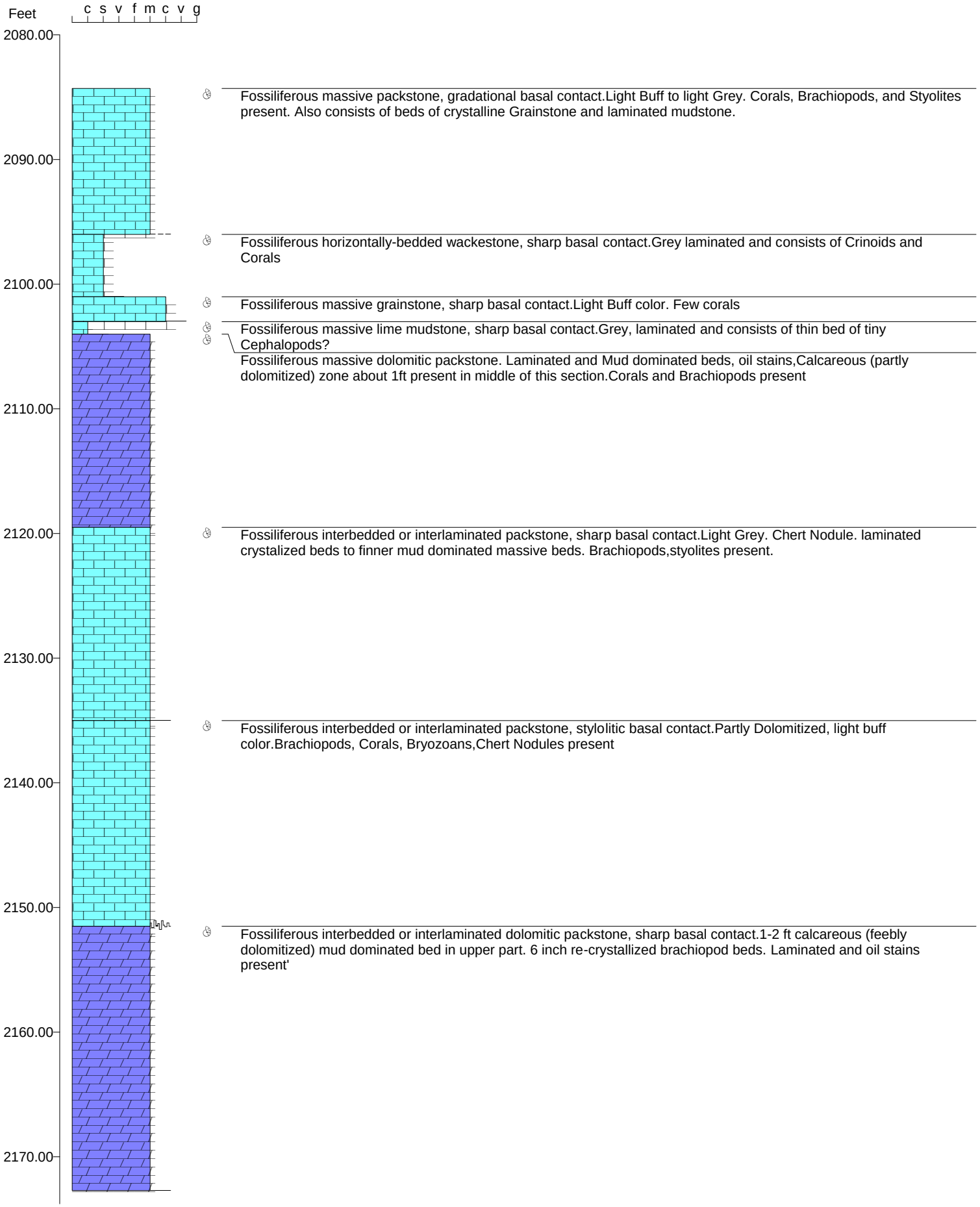

Figure 7: Core description of IGS well ID 157270, Prairie Creek Field, Vigo County.

Figure 8: Photo of the core ID 879, IGS ID # 157270 from Prairie Creek Field, Greene County.

Figure 8: Continues....

Bottom

Top

Figure 8: Continues....

Figure 8: Continues....

Figure 8: Continues....

Figure 8: Continues....

Figure 8: Continues....

Figure 8: Continues....

Figure 8: Continues....

Field name: Riley

IGS ID: 10581

DOE ID: 601450

Location: Vigo County, 11N-8W

Discovery date: 1906

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,609 ft.)

Field type: oil

Total number production wells: 49

Area: 230 acres

Cumulative production: 64,565 bbls. (2002)

Other reservoir units:

Deepest unit penetrated (depth): Ordovician Black River Group (3,000 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

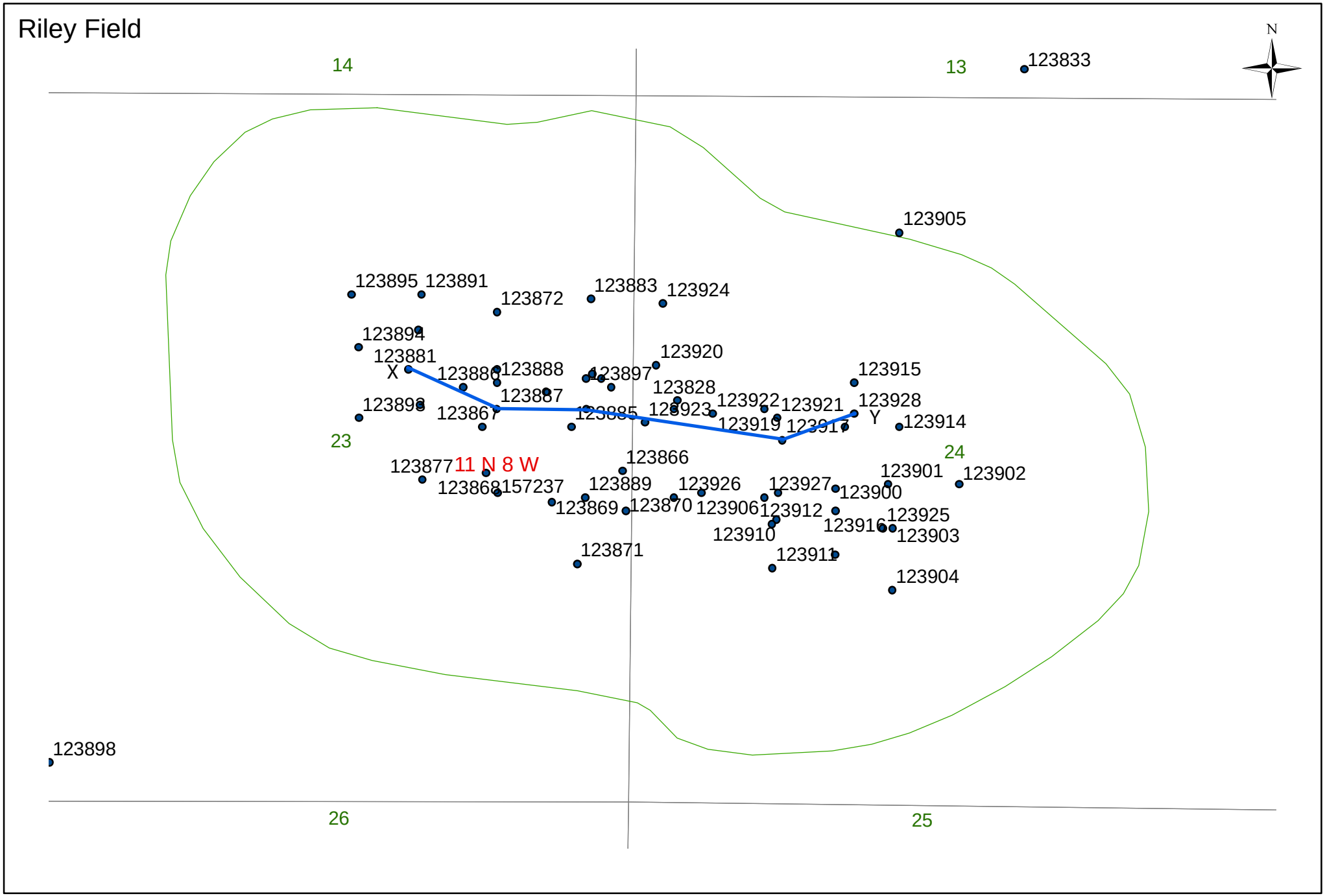

Figure 1: Map showing the location and wells at Riley Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 4).

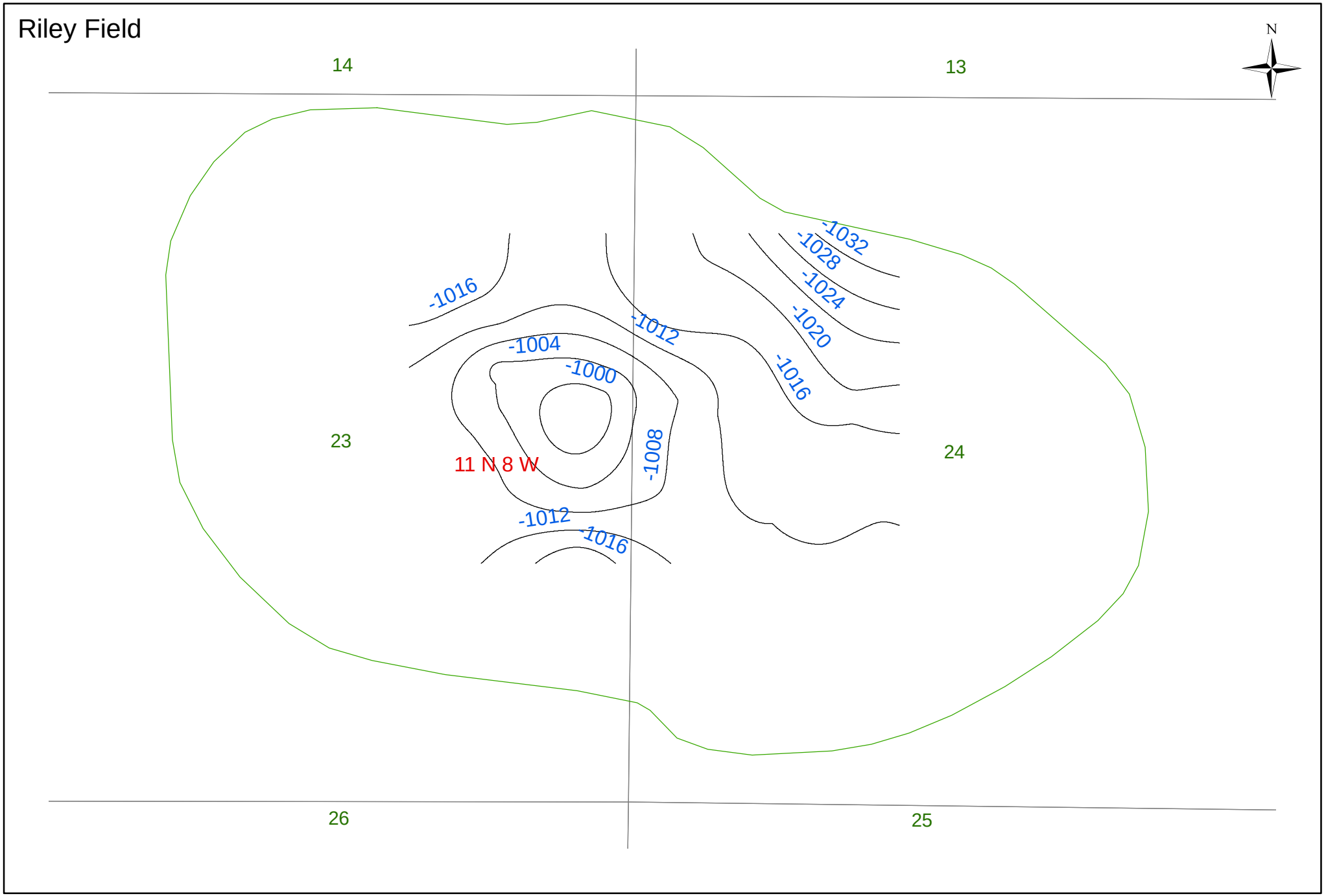

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Riley Field, Vigo County. Contours show values below sea level, contour interval is 4 ft .

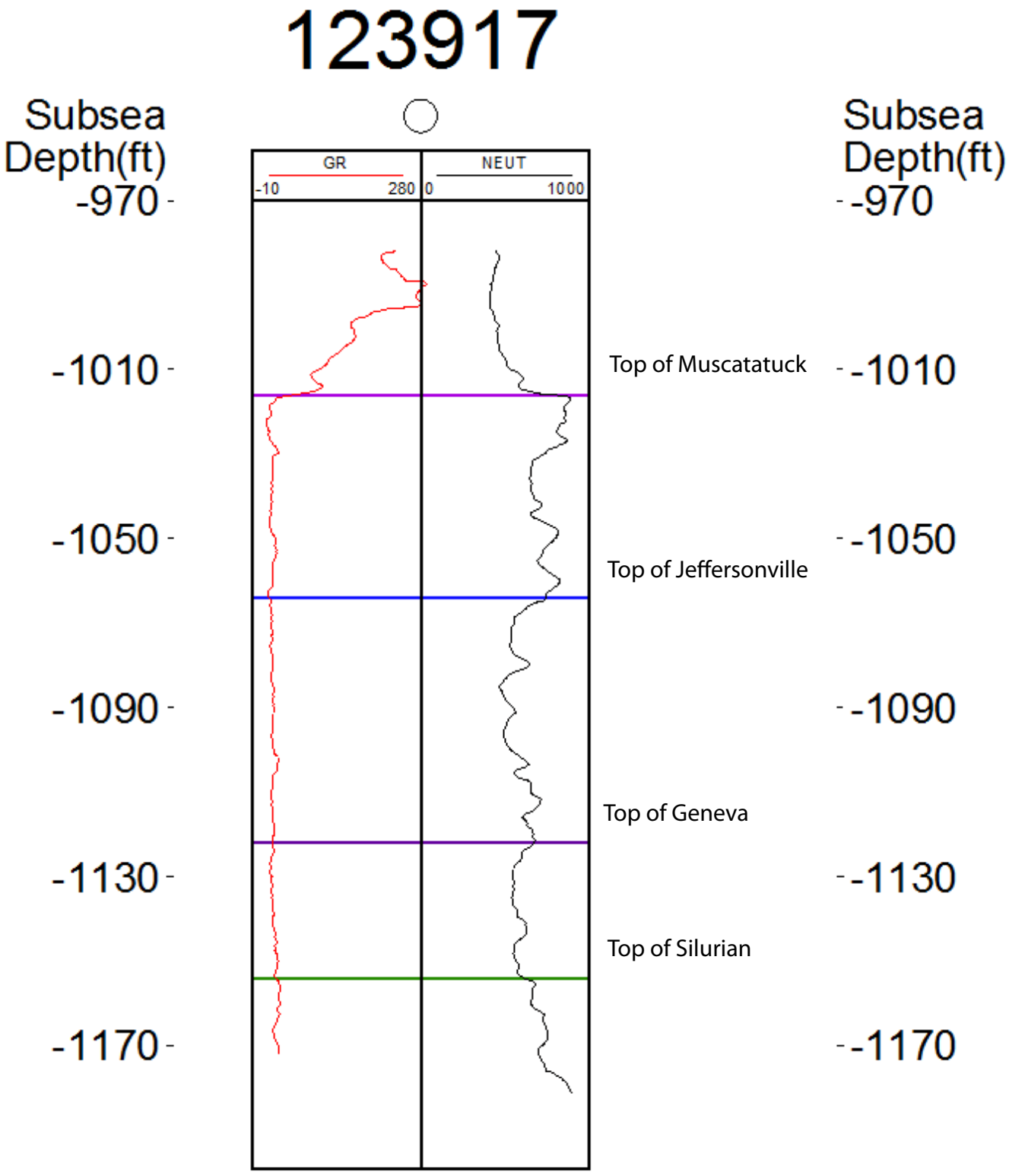

Figure 3: Type log section showing the Devonian formations at Riley Field, Vigo County.

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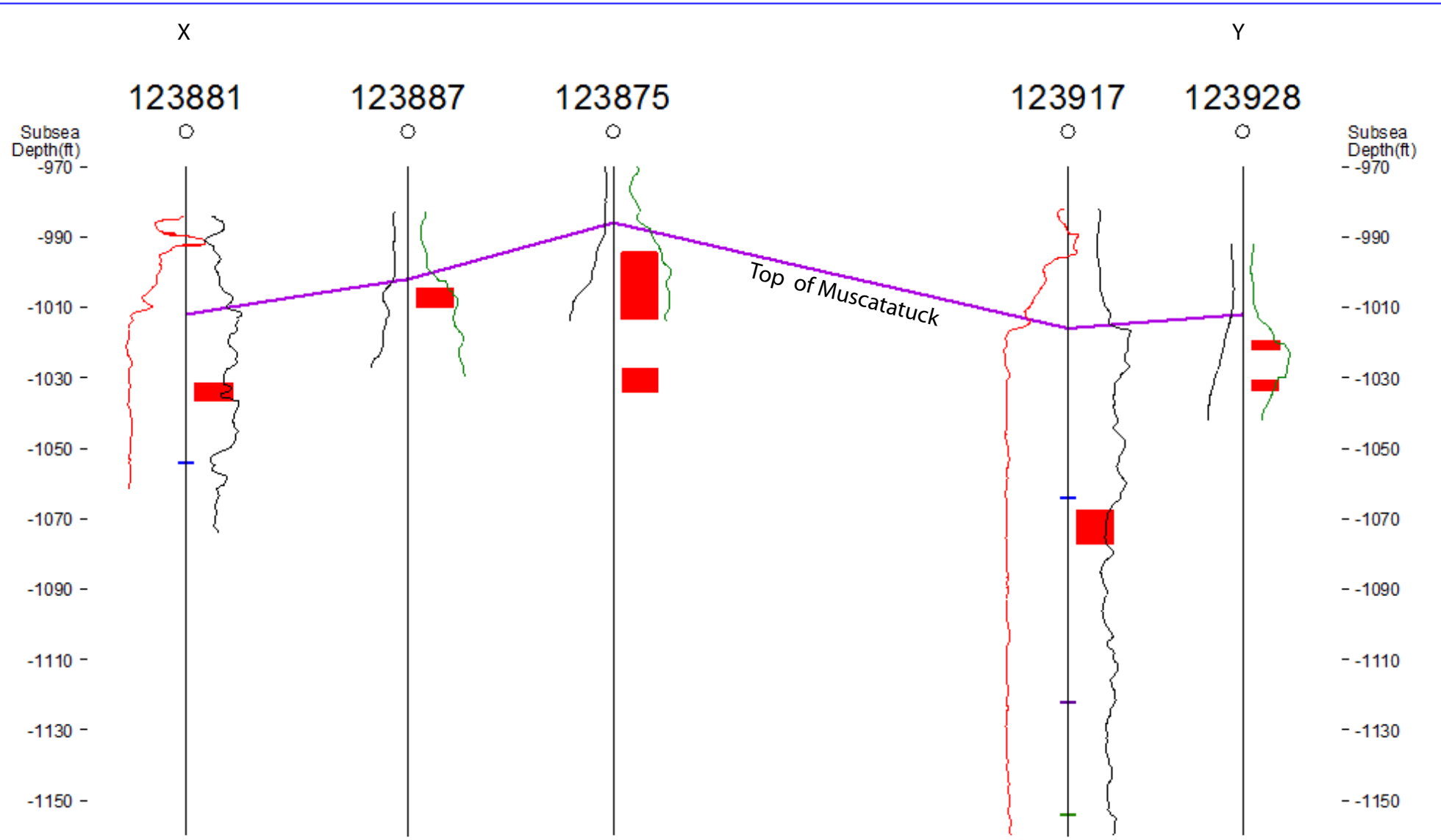
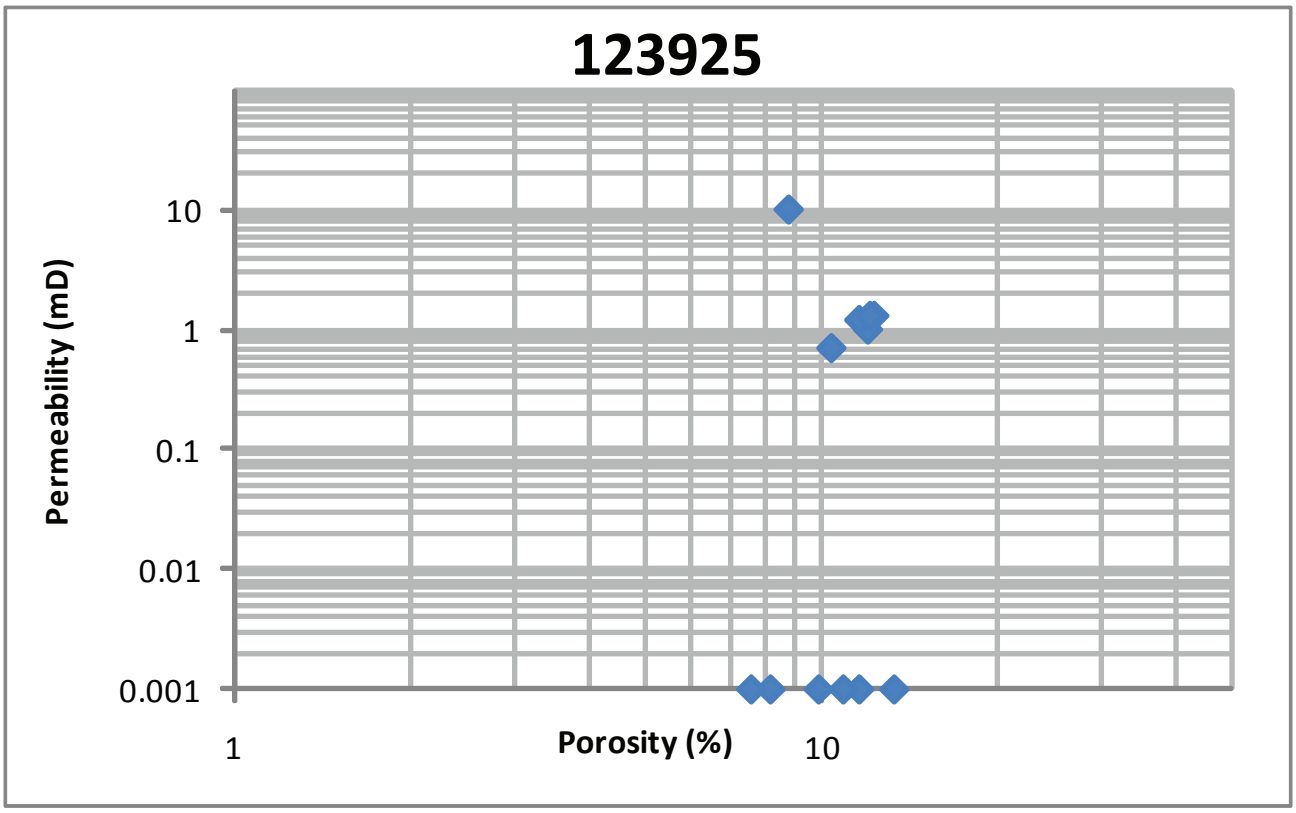


Figure 4: X-Y Cross section showing the Devonian subsurface structure across Riley Field, Vigo County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.



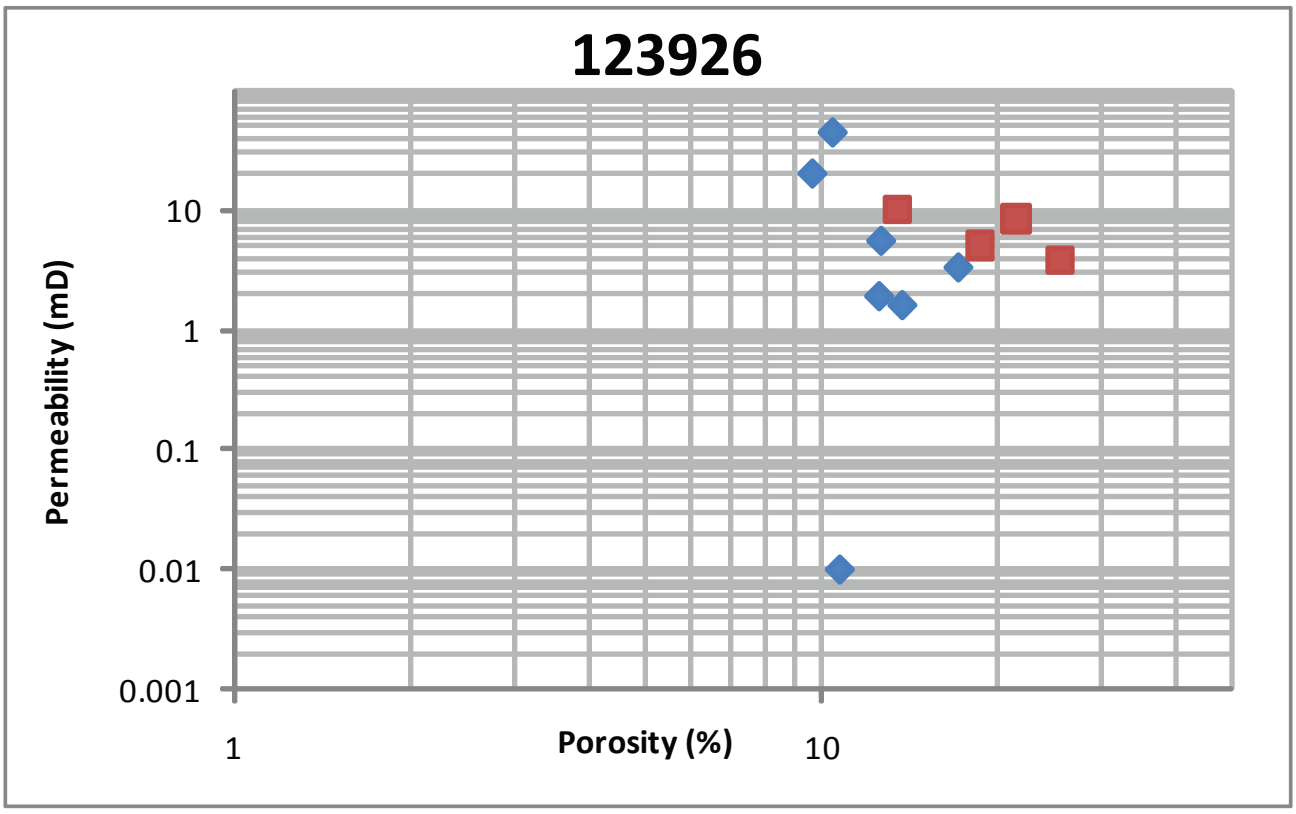


Figure 5: Porosity-permeability plots from core analysis from Riley Field, Vigo County. The blue points are from North Vernon and the red points from the Vernon Fork. The chart title lists the IGS Well ID. For the well locations see Figure 1.

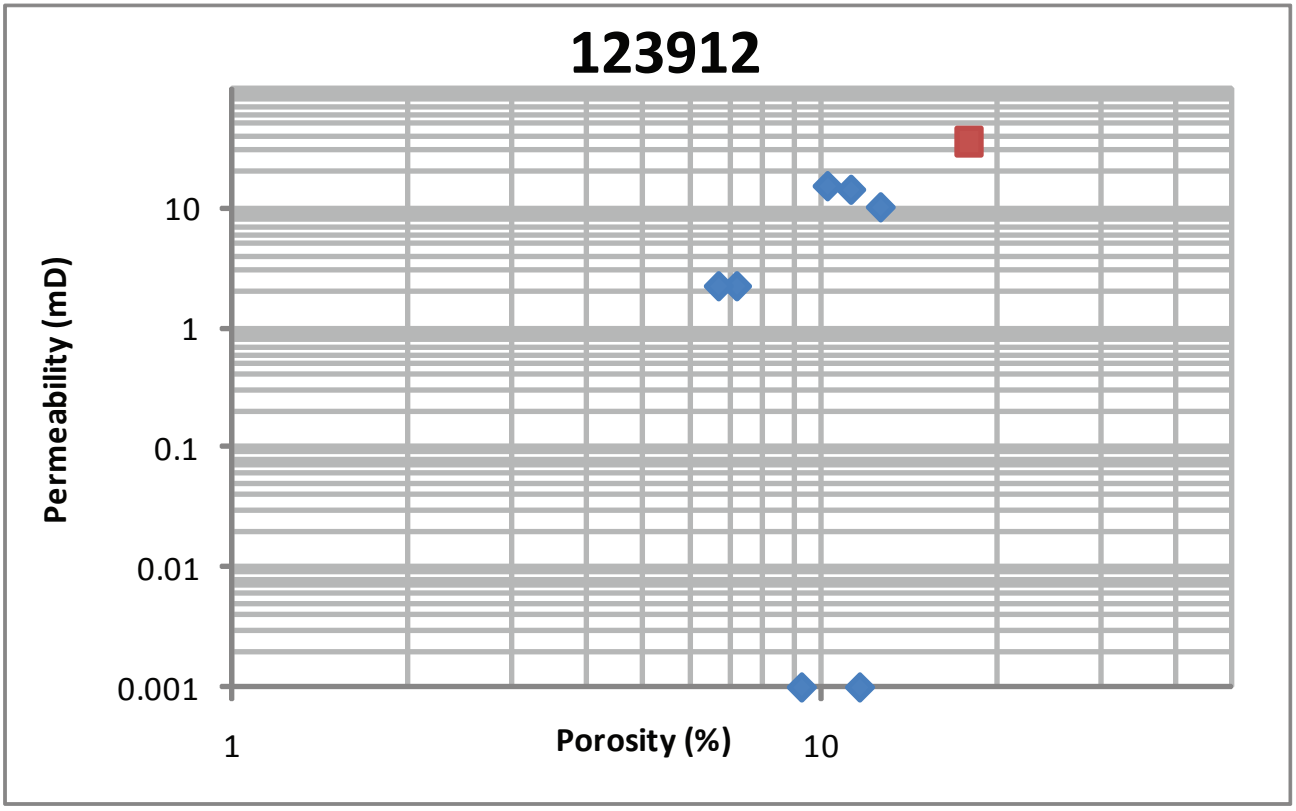


Figure 5: Continued....

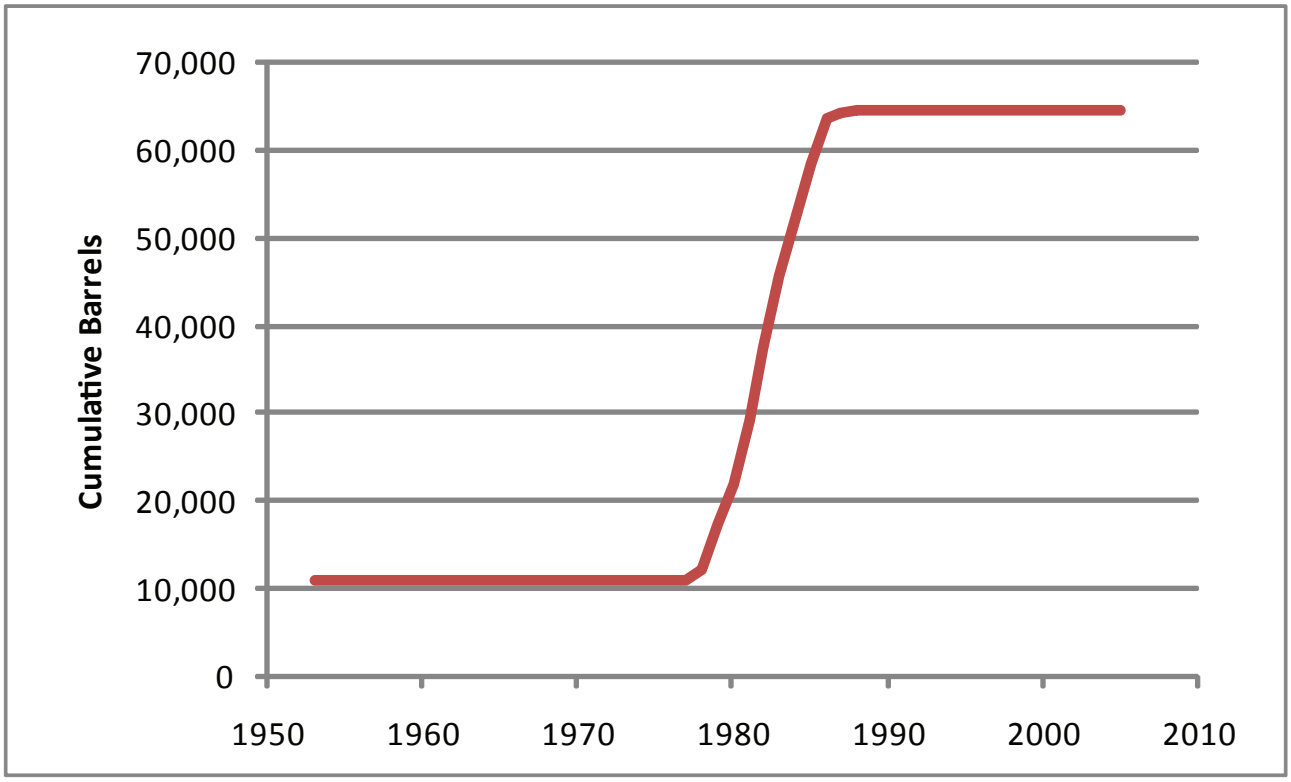


Figure - 6: Cumulative oil production history for Riley Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Riley Field, Vigo County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)
117565	11	N	7	W	19	602					
123833	11	N	8	W	13	604					
123834	11	N	8	W	13	626	1662				
123839	11	N	8	W	14	581	1626	1673	1753		
123848	11	N	8	W	15	577	1638	1694	1760	1800	
123865	11	N	8	W	23	607	1598				
123866	11	N	8	W	23	602	1607				
123867	11	N	8	W	23	616	1626				
123868	11	N	8	W	23	618	1630				
123869	11	N	8	W	23	612	1617				
123870	11	N	8	W	23	605	1614				
123871	11	N	8	W	23	609	1638				
123872	11	N	8	W	23	602	1622				
123873	11	N	8	W	23	602					18
123875	11	N	8	W	23	606	1595				20
123876	11	N	8	W	23	598	1598				7
123877	11	N	8	W	23	625					
123881	11	N	8	W	23	626	1638	1680			18
123882	11	N	8	W	23	595	1598				
123883	11	N	8	W	23	600	1615				
123884	11	N	8	W	23	595	1602				
123885	11	N	8	W	23	603	1594				
123886	11	N	8	W	23	619					3
123887	11	N	8	W	23	617	1619				40
123888	11	N	8	W	23	607	1616				12
123889	11	N	8	W	23	608	1609				20
123890	11	N	8	W	23	621					
123891	11	N	8	W	23	621	1644				
123892	11	N	8	W	23	625					
123893	11	N	8	W	23	619					
123894	11	N	8	W	23	620					
123895	11	N	8	W	23	618					
123897	11	N	8	W	23	599	1593				10
123898	11	N	8	W	23	597	1695				
157237	11	N	8	W	23	614	1622				15
123828	11	N	8	W	24	599	1604				20
123899	11	N	8	W	24	608					
123900	11	N	8	W	24	602					
123901	11	N	8	W	24	600					
123902	11	N	8	W	24	604					
123903	11	N	8	W	24	608					
123904	11	N	8	W	24	607					

Table-1: Continued....

123905	11	N	8	W	24	618	1654			1824	
123906	11	N	8	W	24	603	1616				
123909	11	N	8	W	24	602	1619				
123910	11	N	8	W	24	607					
123911	11	N	8	W	24	606					
123912	11	N	8	W	24	613	1623	1660			12
123913	11	N	8	W	24	606	1622				
123914	11	N	8	W	24	604					
123915	11	N	8	W	24	613	1640				
123916	11	N	8	W	24	606	1618				
123917	11	N	8	W	24	608	1623	1662			
123918	11	N	8	W	24	599					2
123919	11	N	8	W	24	608					5
123920	11	N	8	W	24	607					
123921	11	N	8	W	24	606					
123922	11	N	8	W	24	602	1616				
123923	11	N	8	W	24	600	1610				
123924	11	N	8	W	24	609	1635				
123925	11	N	8	W	24	612	1623	1669			19
123926	11	N	8	W	24	610	1616	1660			21
123927	11	N	8	W	24	609					5
123928	11	N	8	W	24	608	1620				60

Field name: Riley South

IGS ID: 10582

DOE ID: 601512

Location: Vigo County, 11N-8W

Discovery date: 1952

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,683 ft.)

Field type: oil

Total number production wells: 16

Area: 270 acres

Cumulative production: 788,809 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1,913 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

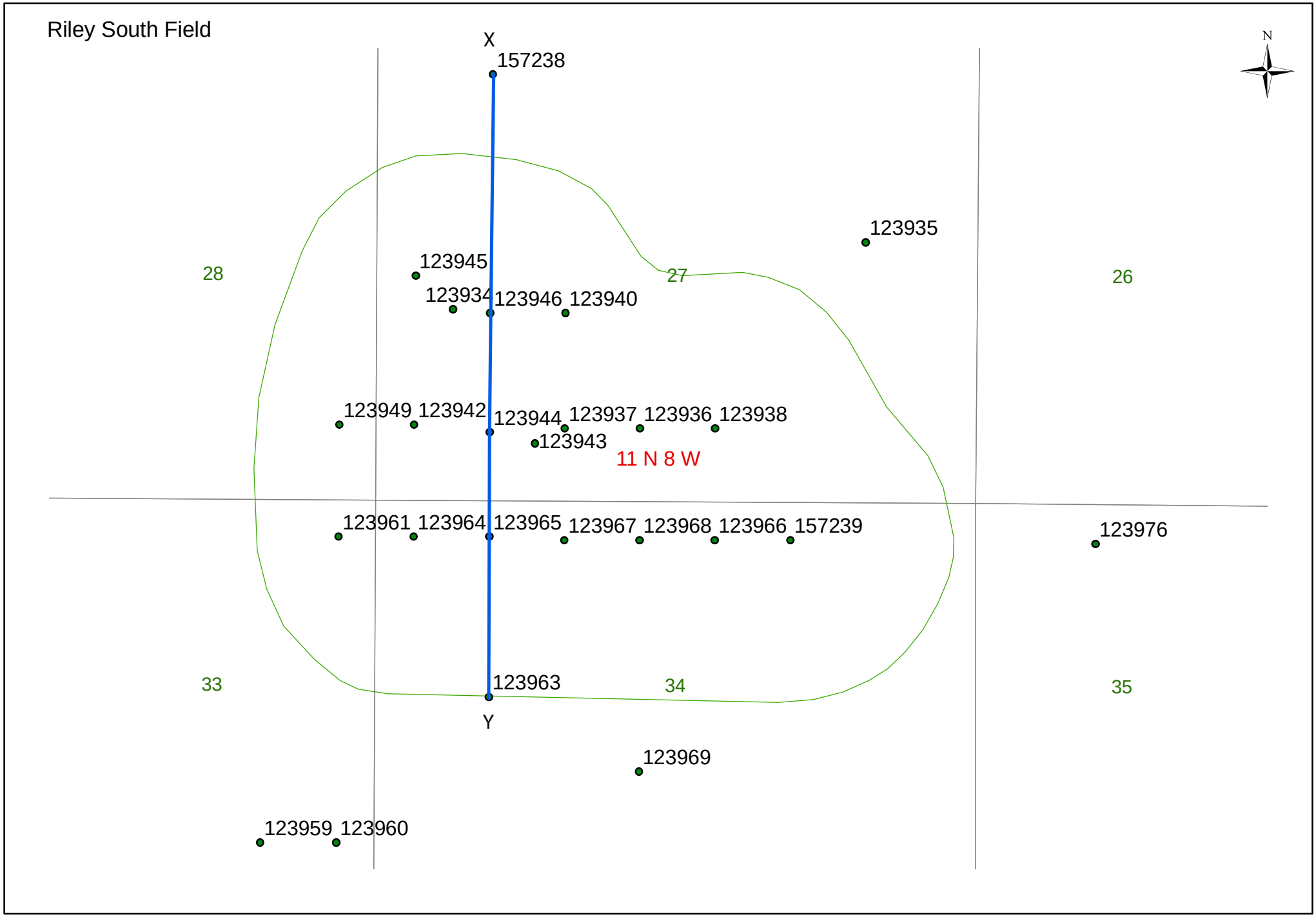


Figure 1: Map showing the location and wells at Riley South Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 5).

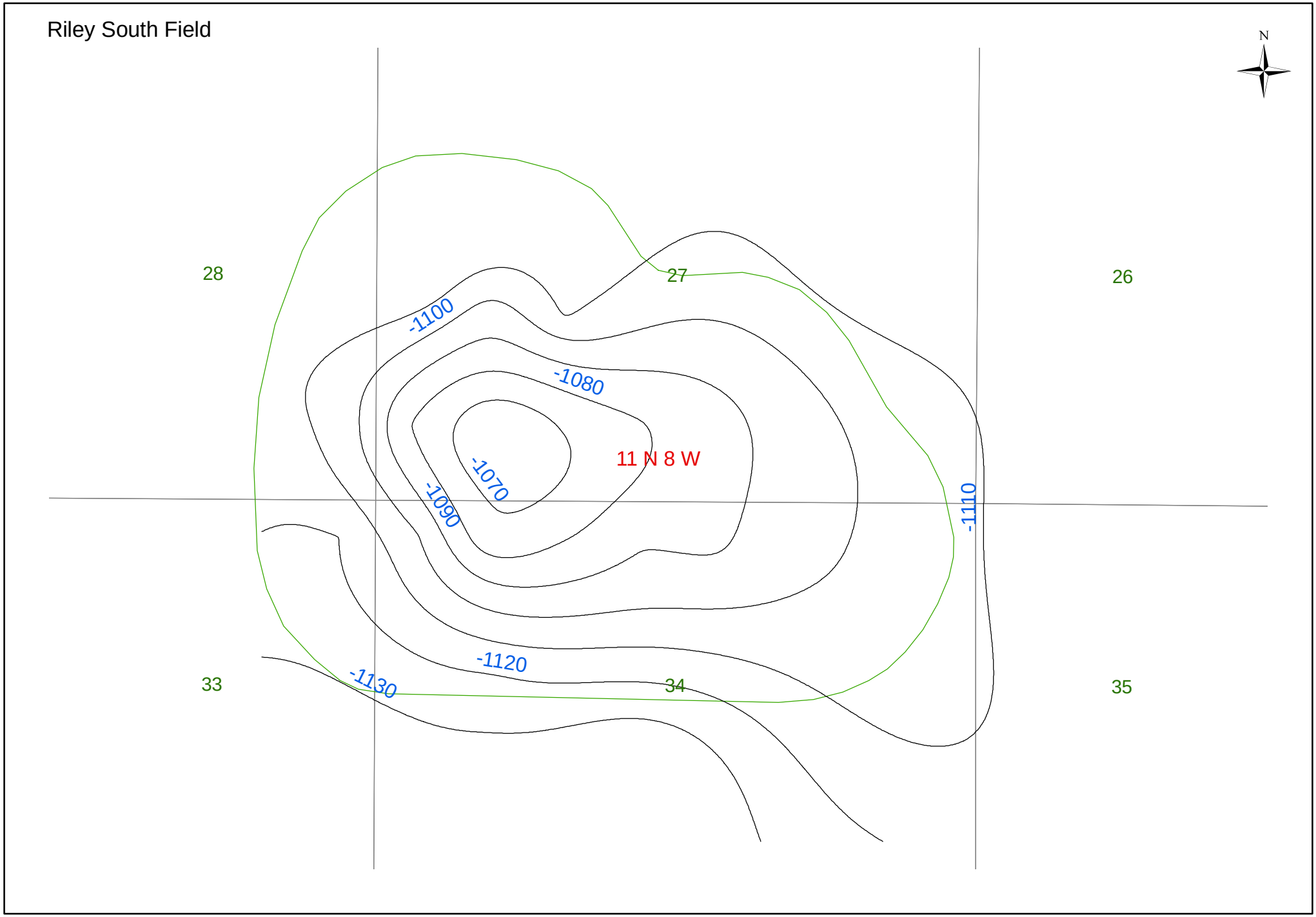


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Riley South Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

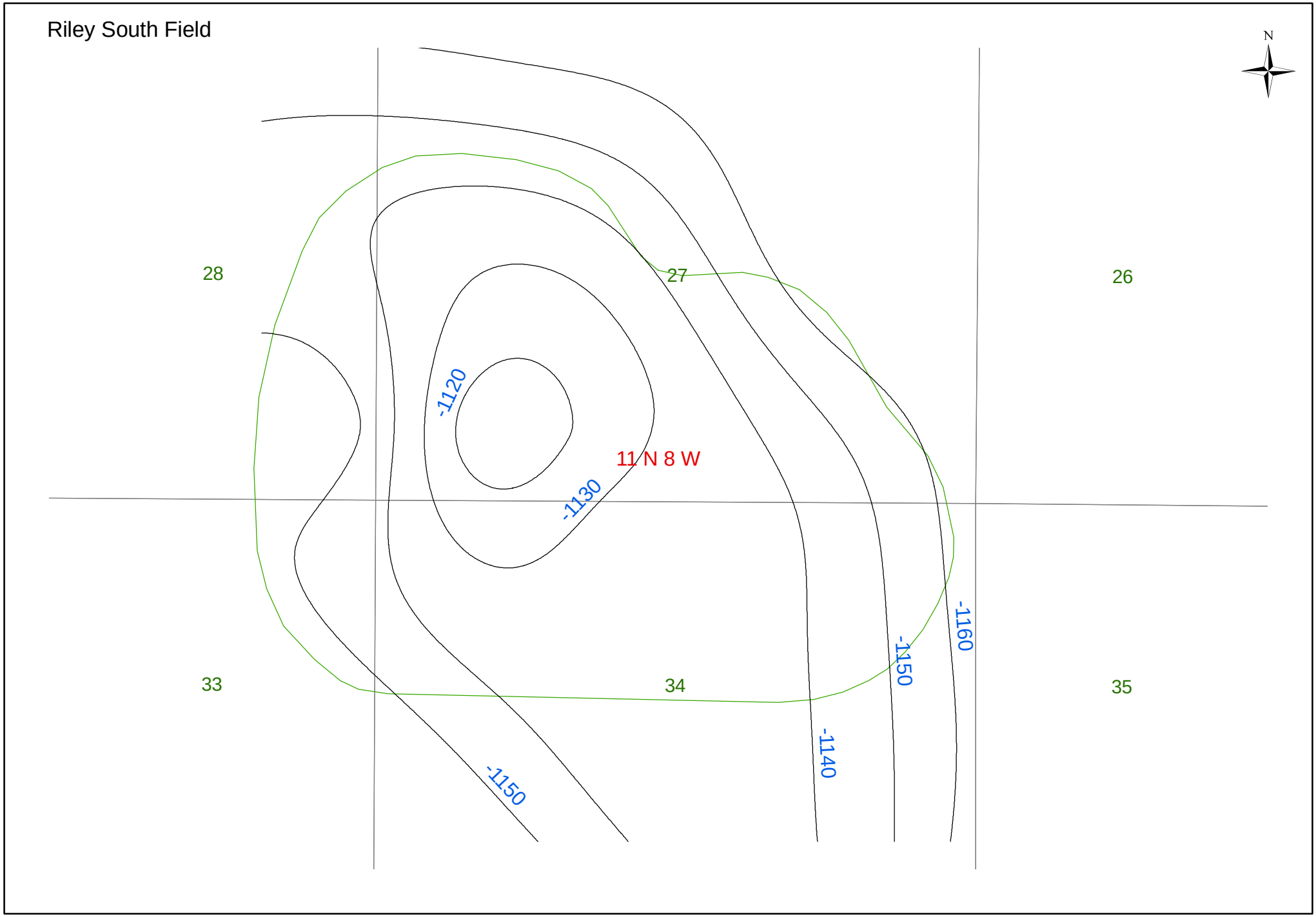


Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Riley South Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

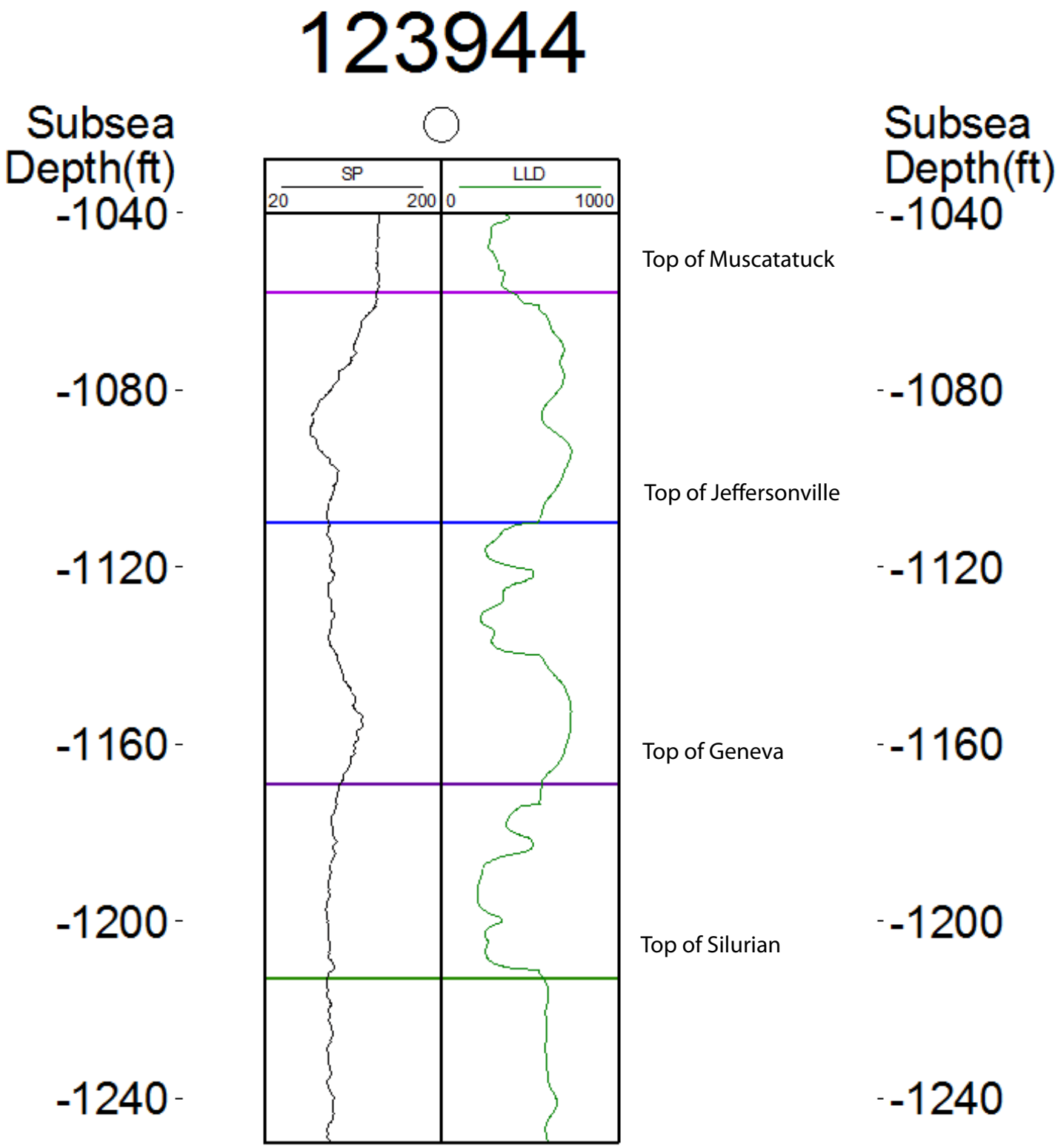


Figure 4: Type log section showing the Devonian formations at Riley South Field, Vigo County.

HS=1

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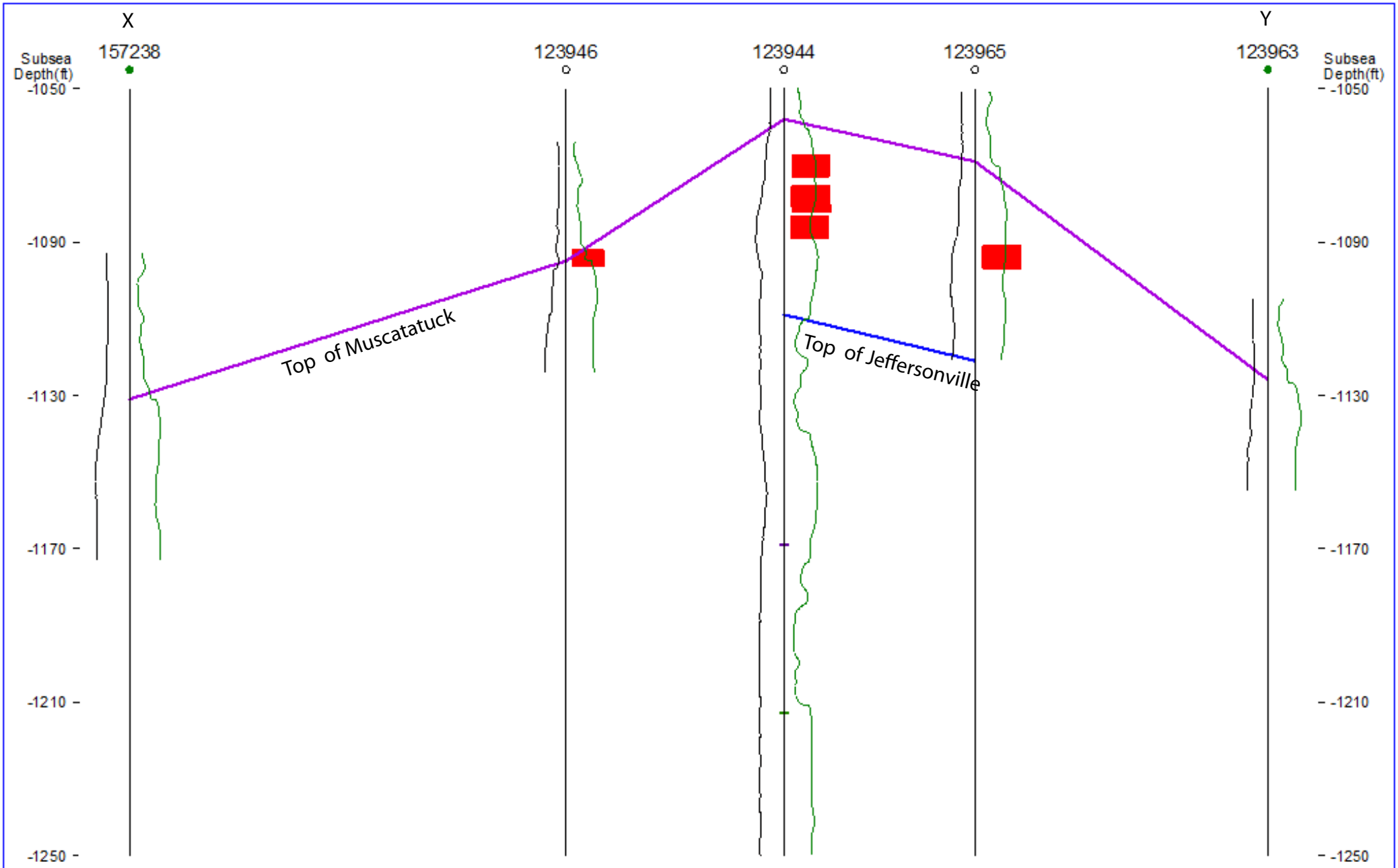

Figure 5: X-Y Cross section showing the Devonian subsurface structure across Riley South Field, Vigo County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

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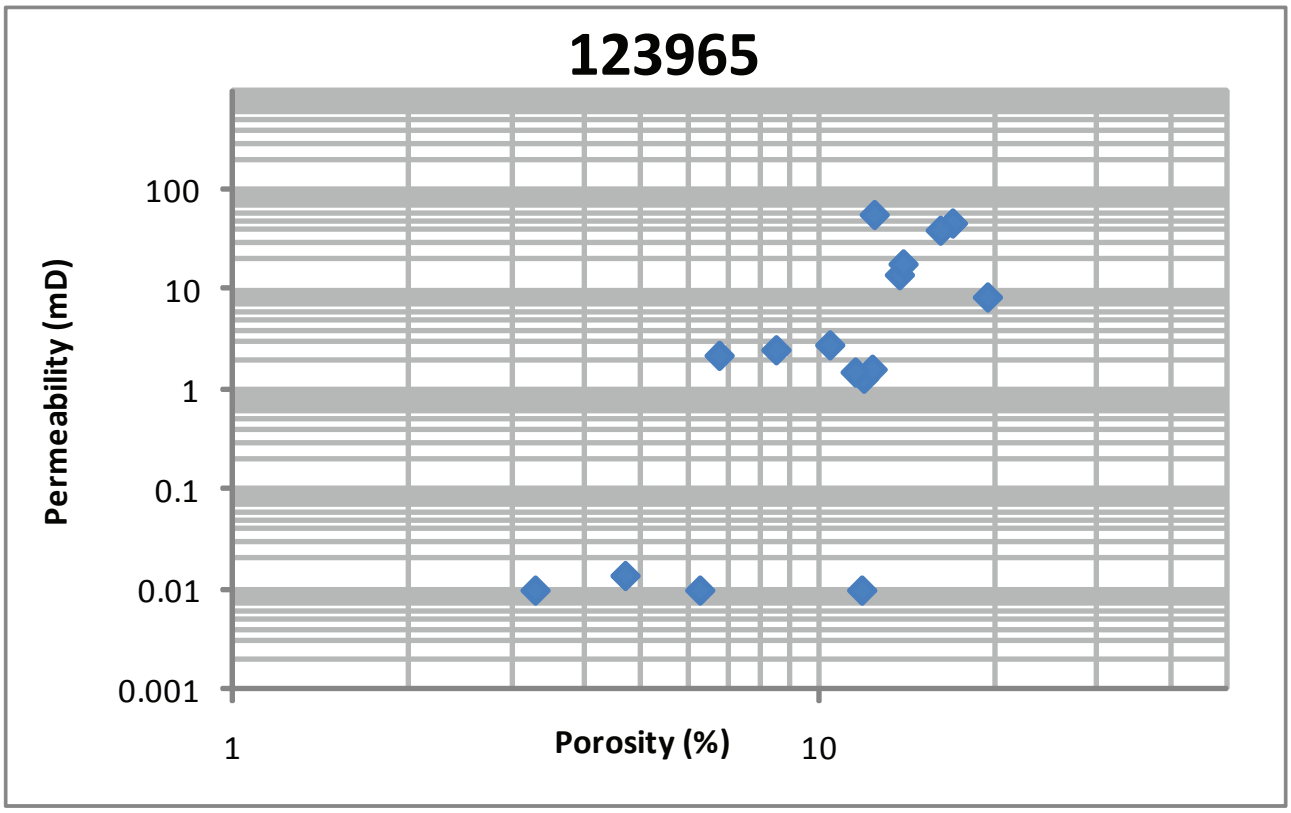

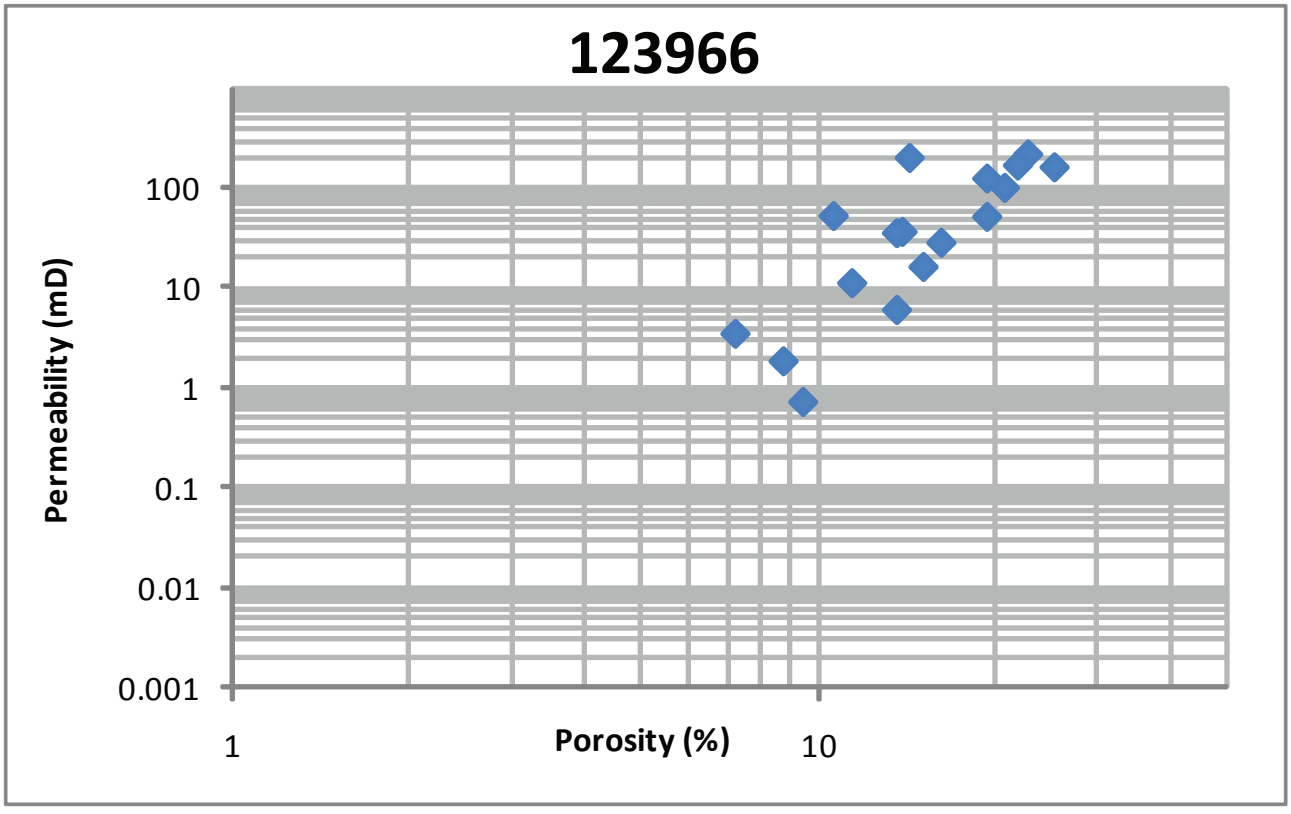

Figure 6: Porosity-permeability plots from core analysis from Riley South Field, Vigo County. The blue points are from North Vernon. The chart title lists the IGS Well ID. For the well locations see Figure 1.

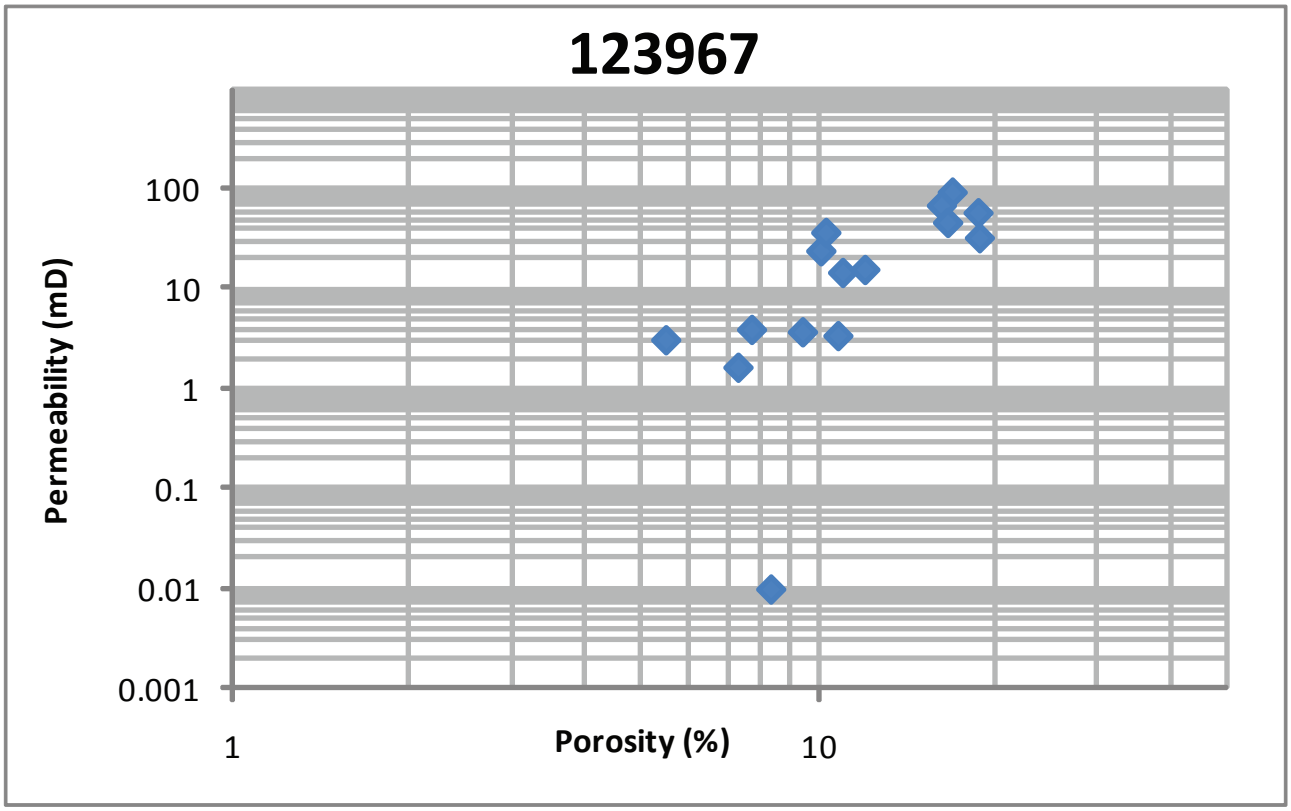

Figure 6: Continues....

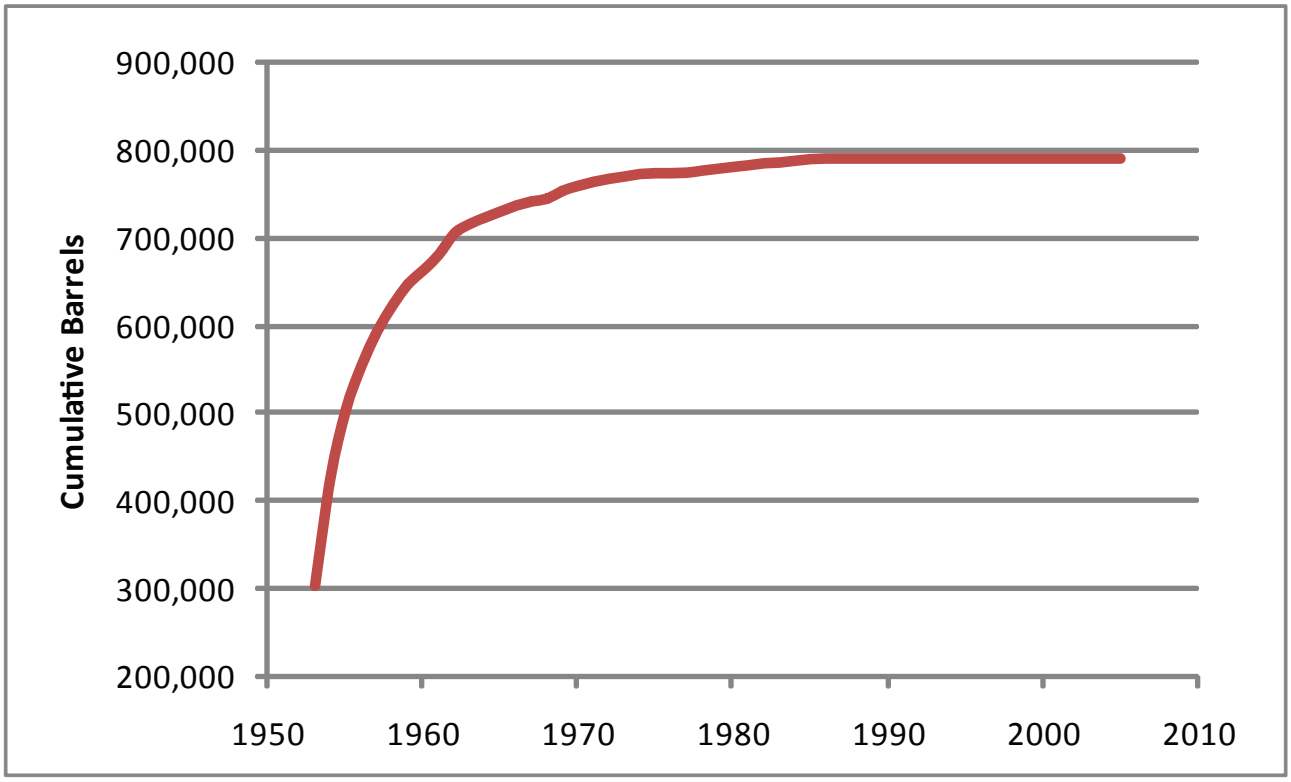

Figure - 7: Cumulative oil production history from Riley South Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Riley South Field, Vigo County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
123934	11	N	8	W	27	604					1	
123935	11	N	8	W	27	577	1695	1750	1830			
123936	11	N	8	W	27	591	1670	1720			442	
123937	11	N	8	W	27	603	1674	1722			312	
123938	11	N	8	W	27	574	1660				480	
123939	11	N	8	W	27	619	1731	1784	1848			
123940	11	N	8	W	27	604	1715					
123942	11	N	8	W	27	606	1685				190	
123943	11	N	8	W	27	597	1660				8	
123944	11	N	8	W	27	607	1667	1718	1776	1820	215	
123945	11	N	8	W	27	600	1722		1871			
123946	11	N	8	W	27	606	1701				100	
157238	11	N	8	W	27	607	1738					
123949	11	N	8	W	28	606	1712	1761	1830			
123959	11	N	8	W	33	585	1739	1752	1820	1870		
123960	11	N	8	W	33	574						
123961	11	N	8	W	33	597	1717					
123963	11	N	8	W	34	595	1721					
123964	11	N	8	W	34	599	1701			1888	108	
123965	11	N	8	W	34	609	1682				385	
123966	11	N	8	W	34	575	1663	1710			200	
123967	11	N	8	W	34	597	1677				187	
123968	11	N	8	W	34	582	1671	1720			150	
123969	11	N	8	W	34	587	1729				3	
157239	11	N	8	W	34	568	1665					
123976	11	N	8	W	35	573	1690	1746	1830	1880		

Field name: Saline City

IGS ID: 10605

DOE ID: 625557

Location: Clay County, 11N-7W

Discovery date: 1951

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,453 ft.)

Field type: oil

Total number production wells: 13

Area: 180 acres

Cumulative production: 70,126 bbls. (2002)

Other reservoir units:

Deepest unit penetrated (depth): Silurian (1,720 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 60 ft. at top of Muscatatuck.

Reservoir characteristics:

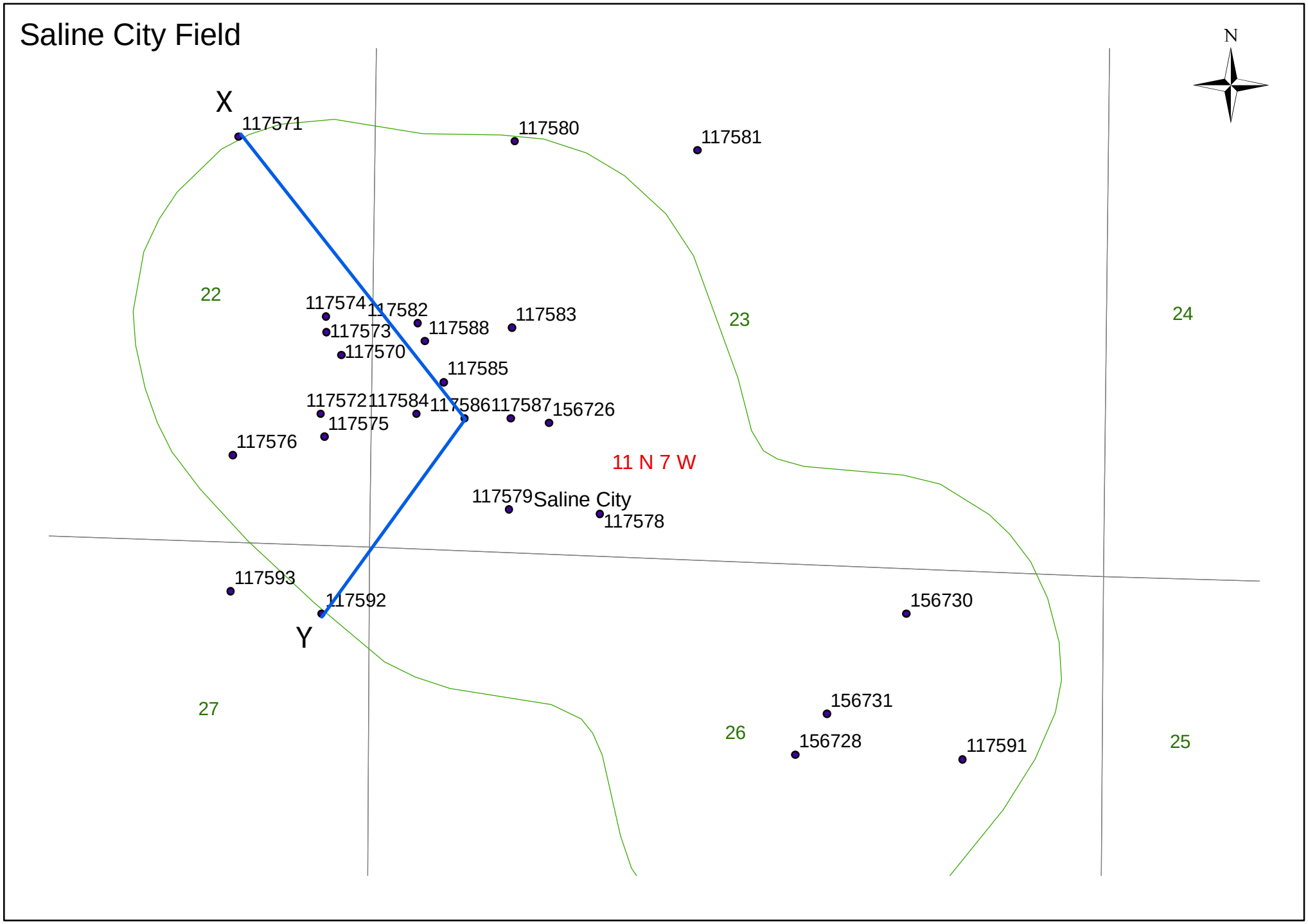

Figure 1: Map showing the location and wells at Saline City Field, Clay County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 3.

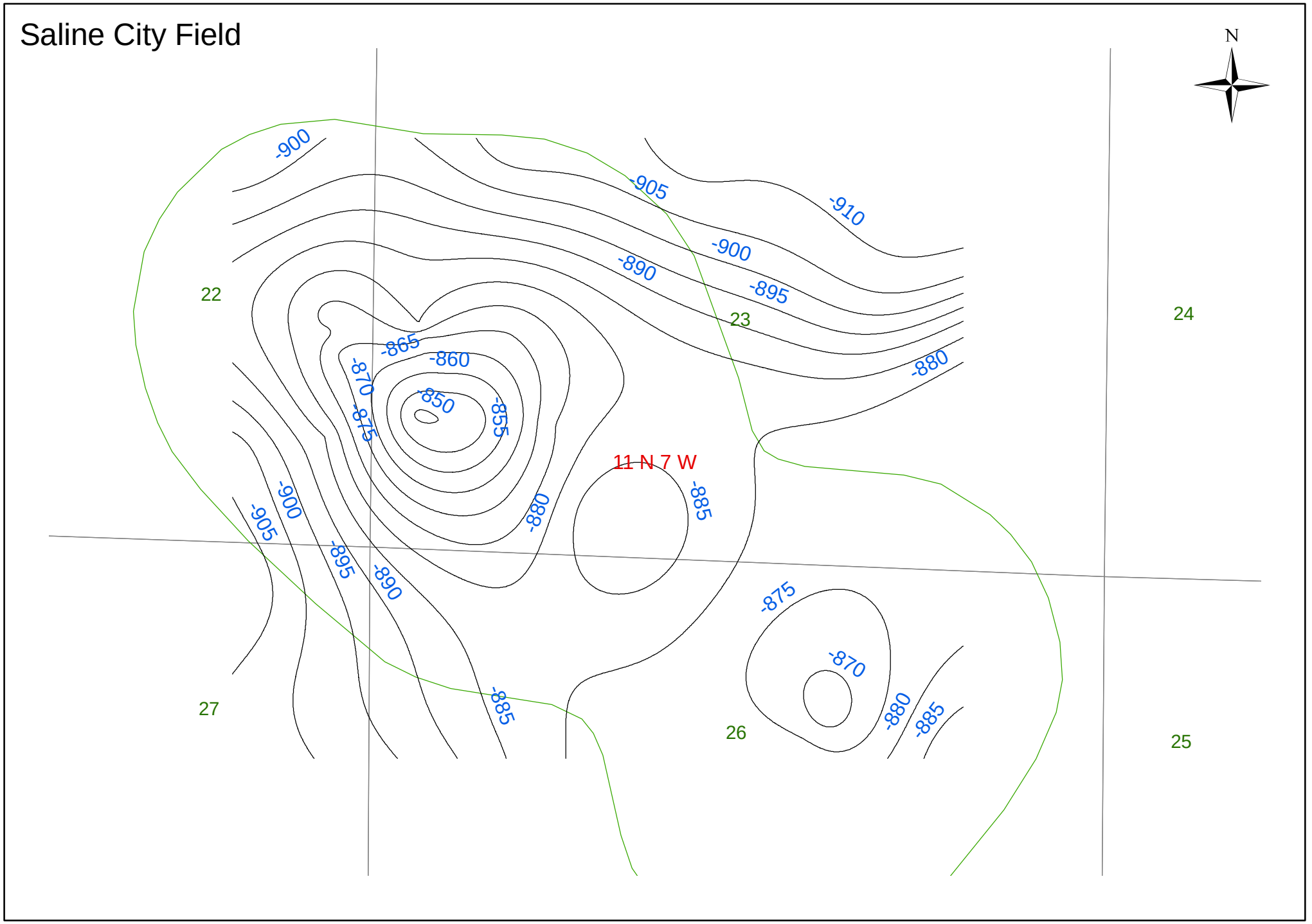

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in the Saline City Field, Clay County. Contours show values below sea level, contour interval is 5 ft .

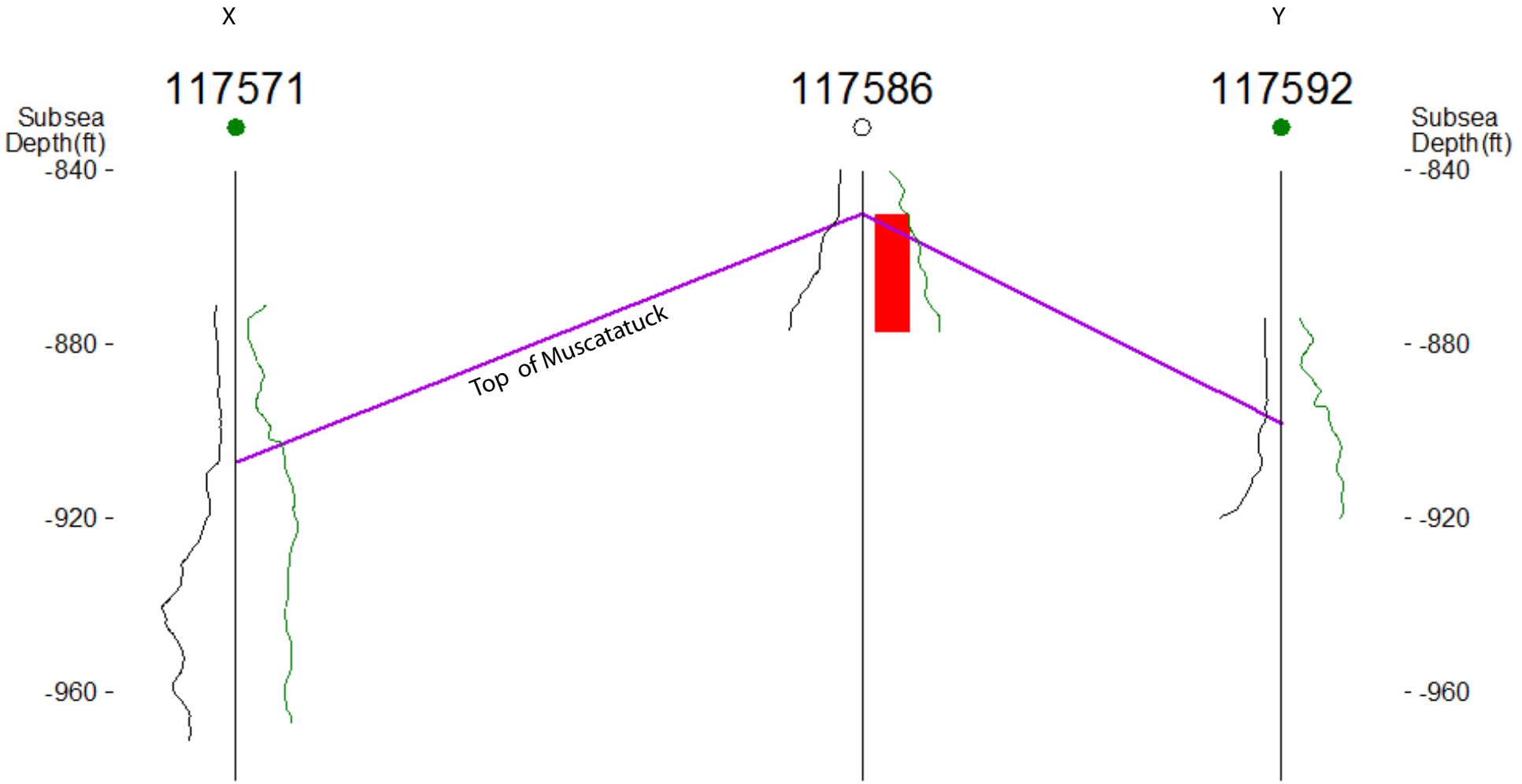

Figure 3: X-Y Cross section showing the Devonian subsurface structure across Saline City field, Clay County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

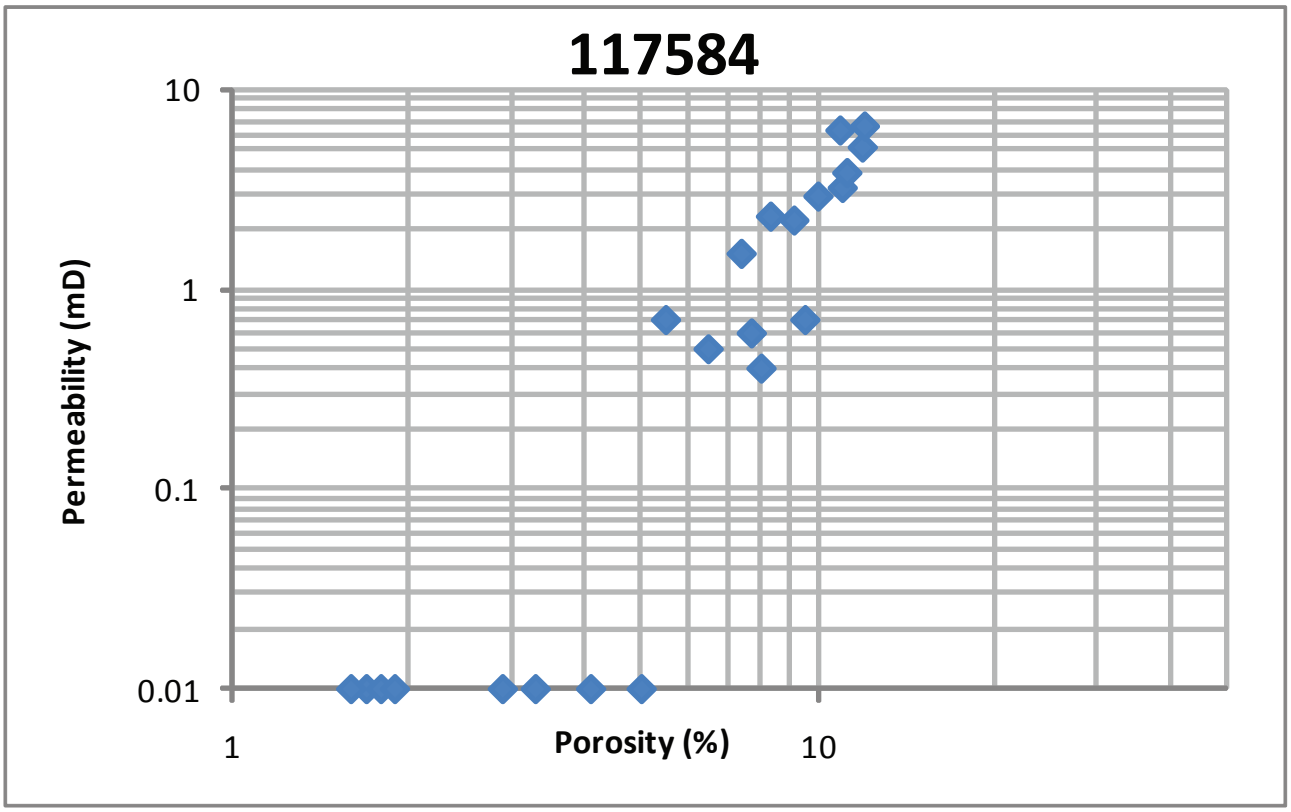

Figure 4: Porosity and permeability plot from core analysis from Saline City Field, Clay County. The blue points are from North Vernon. The chart title lists the IGS Well ID. For the well locations see Figure 1.

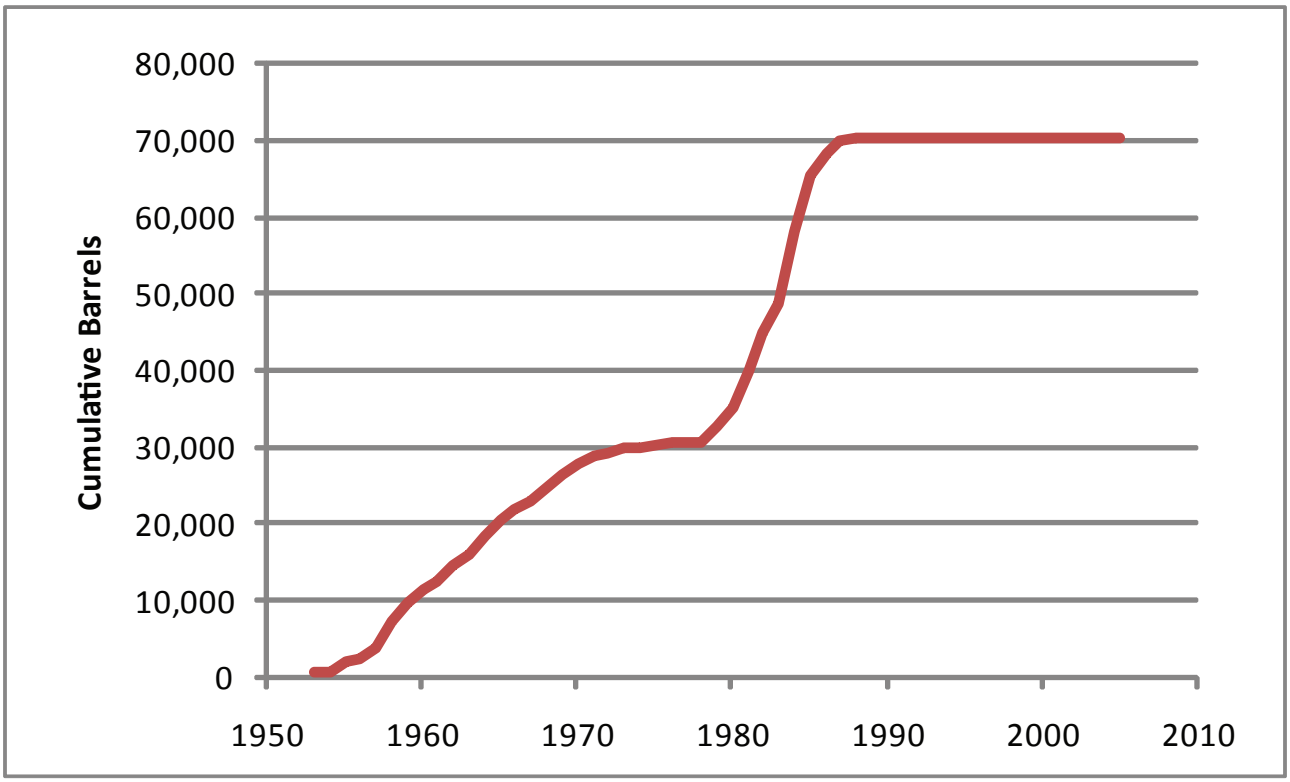

Figure - 5: Cumulative oil production history from Saline City Field, Clay County since 1953.

Table-1: List of the wells used for subsurface structure maping in Saline City Field, Clay County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117570	11	N	7	W	22	631	1500				10	
117571	11	N	7	W	22	629	1536	1570				
117572	11	N	7	W	22	634	1515					
117573	11	N	7	W	22	637	1513					
117574	11	N	7	W	22	639	1512	1560			31	
117575	11	N	7	W	22	637	1522	1562		1670		
117576	11	N	7	W	22	639	1543					
117577	11	N	7	W	22	622	1504					
117578	11	N	7	W	23	589	1479					
117579	11	N	7	W	23	606	1478				15	
117580	11	N	7	W	23	577	1486					
117581	11	N	7	W	23	594	1506					
117582	11	N	7	W	23	608	1488				12	
117583	11	N	7	W	23	596	1467				25	
117584	11	N	7	W	23	624	1473				100	
117585	11	N	7	W	23	617	1475				5	
117586	11	N	7	W	23	613	1463				12	
117587	11	N	7	W	23	613	1474				67	
117588	11	N	7	W	23	620	1488				5	
156726	11	N	7	W	23	591	1465				14	
117589	11	N	7	W	26	613						
117590	11	N	7	W	26	567	1505	1546				
117591	11	N	7	W	26	570	1460	1498	1556	1630		
156727	11	N	7	W	26	568						
156728	11	N	7	W	26	579	1458				10	
156729	11	N	7	W	26	574	1460				10	
156730	11	N	7	W	26	571	1447					
156731	11	N	7	W	26	578	1445				10	
117592	11	N	7	W	27	636	1534					
117593	11	N	7	W	27	650	1561					
117597	11	N	7	W	28	633	1607					

Field name: Sandborn North

IGS ID: 10608

DOE ID: na

Location: Greene County, 6N-7W

Discovery date: 1970

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,987 ft.)

Field type: natural gas

Total number production wells: 8

Area: na

Cumulative production: na

Other reservoir units:

Pennsylvanian

Mississippian, Sanders Group, Salem Ls.

Deepest unit penetrated (depth): Silurian (2,840 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 160 ft. at top of Muscatatuck.

Reservoir characteristics:

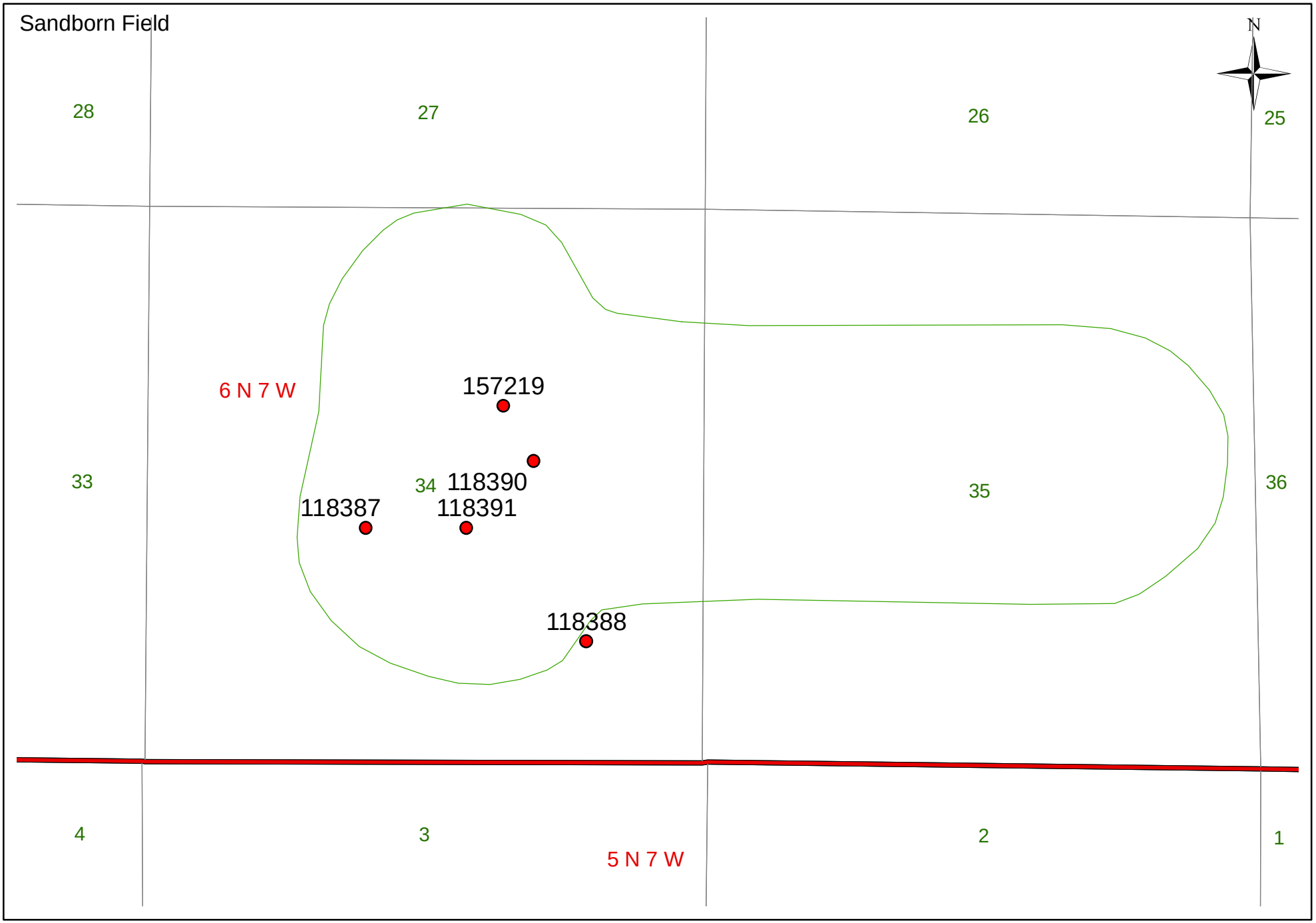

Figure 1: Map showing the location and wells at Sandborn Field, Greene County.

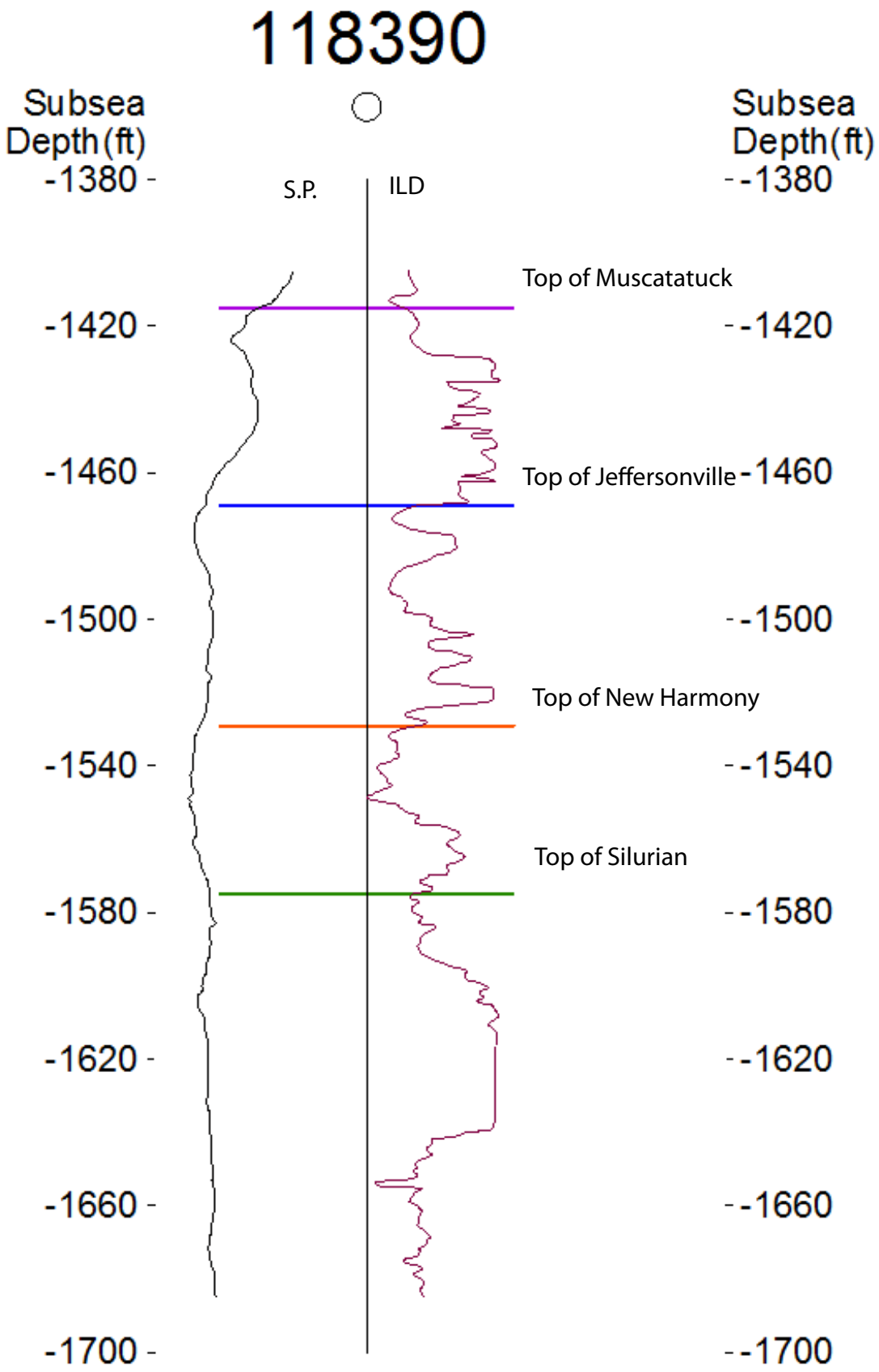

Figure 2: Type log section showing the Devonian formations at Sandborn North Field, Greene County.

HS=1

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Field name: Shelburne Consolidated

IGS ID: 10624

DOE ID: 13300

Location: Sullivan County, 8&9N-9&10W

Discovery date: 1913 (oil), 1916 (natural gas)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group,

(2,290 ft.) oil, (2,183 ft.) natural gas

Field type: oil & natural gas

Total number production wells: 389

Area: 1590 acres

Cumulative production: 424,119 bbls. (2002)

Other reservoir units:

Pennsylvanian

Deepest unit penetrated (depth): Ordovician, Black River Group (4,013 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

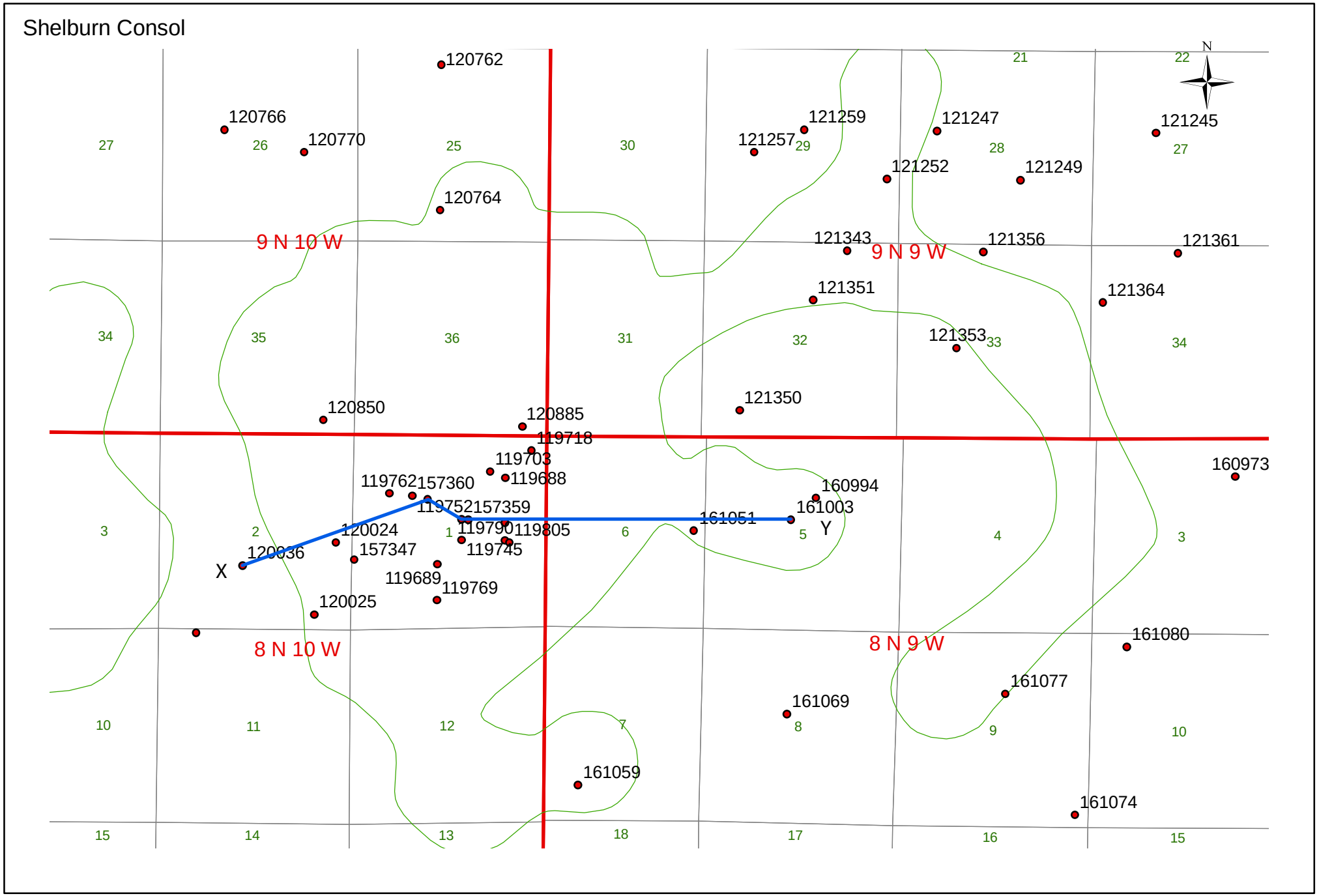

Figure 1: Map showing the location and wells at Shelburn Consolidated Field, Sullivan County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 9).

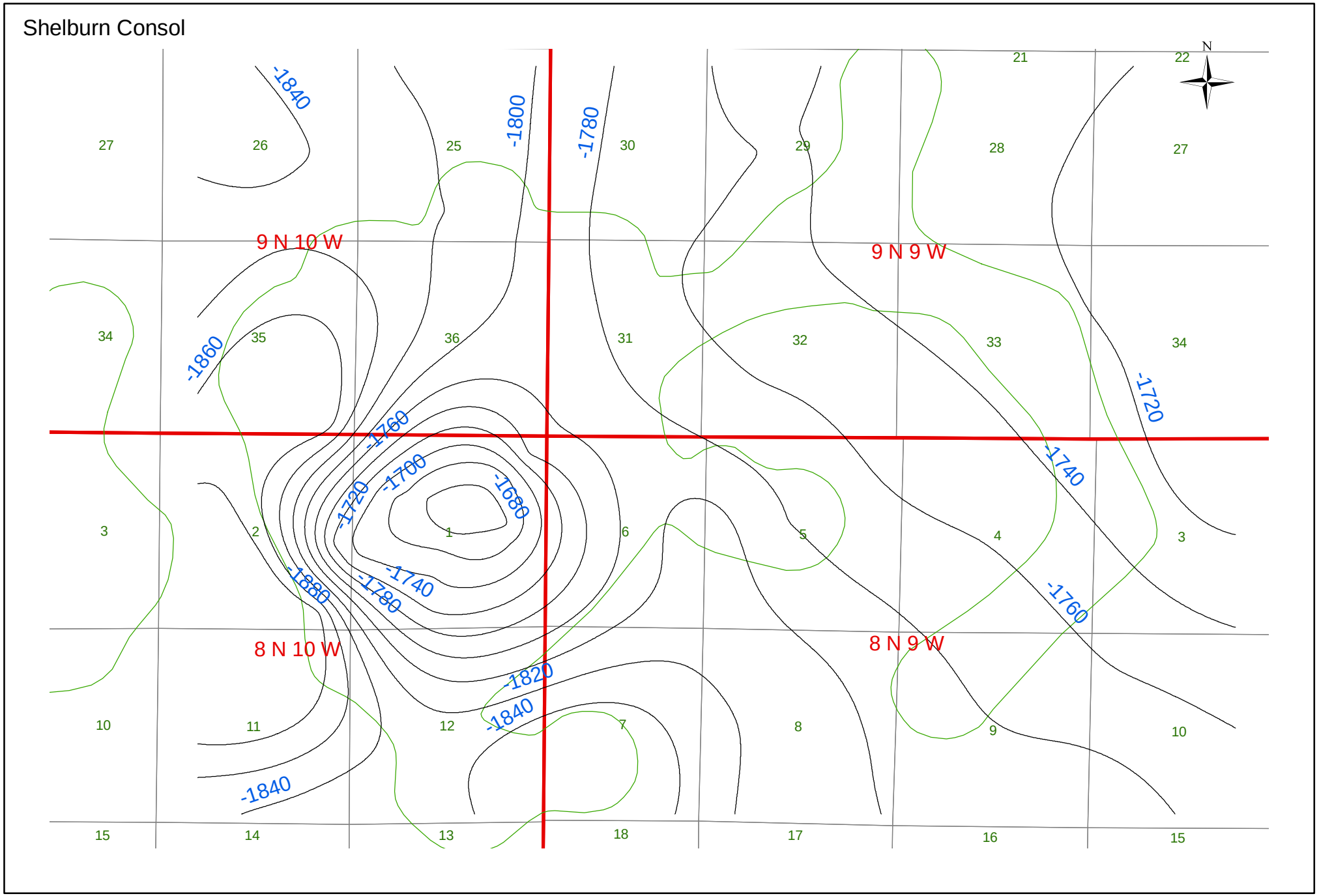

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Shelburn Consol. Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

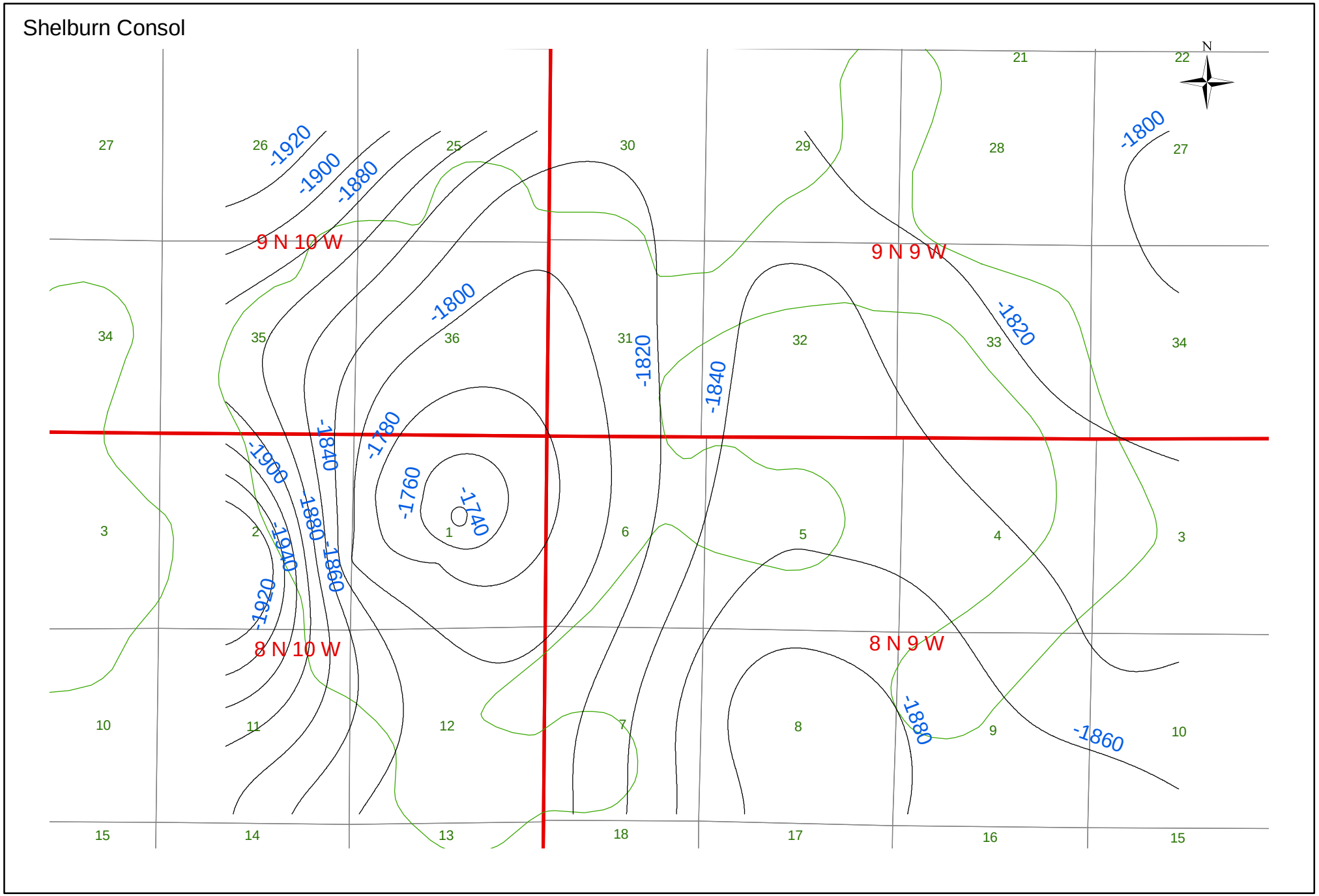

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Shelburn Consol. Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

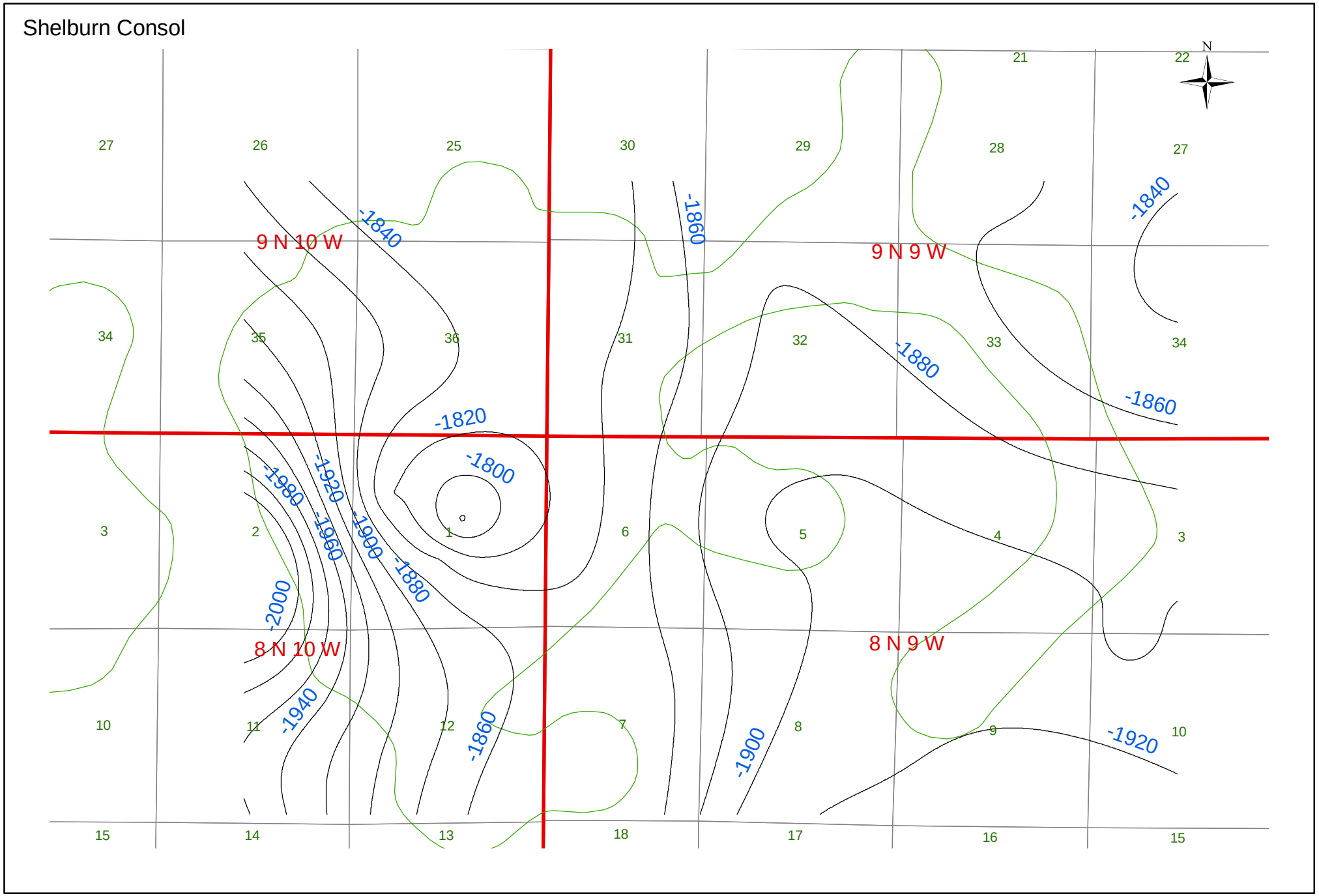

Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Mbr. in Shelburn Consol. Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

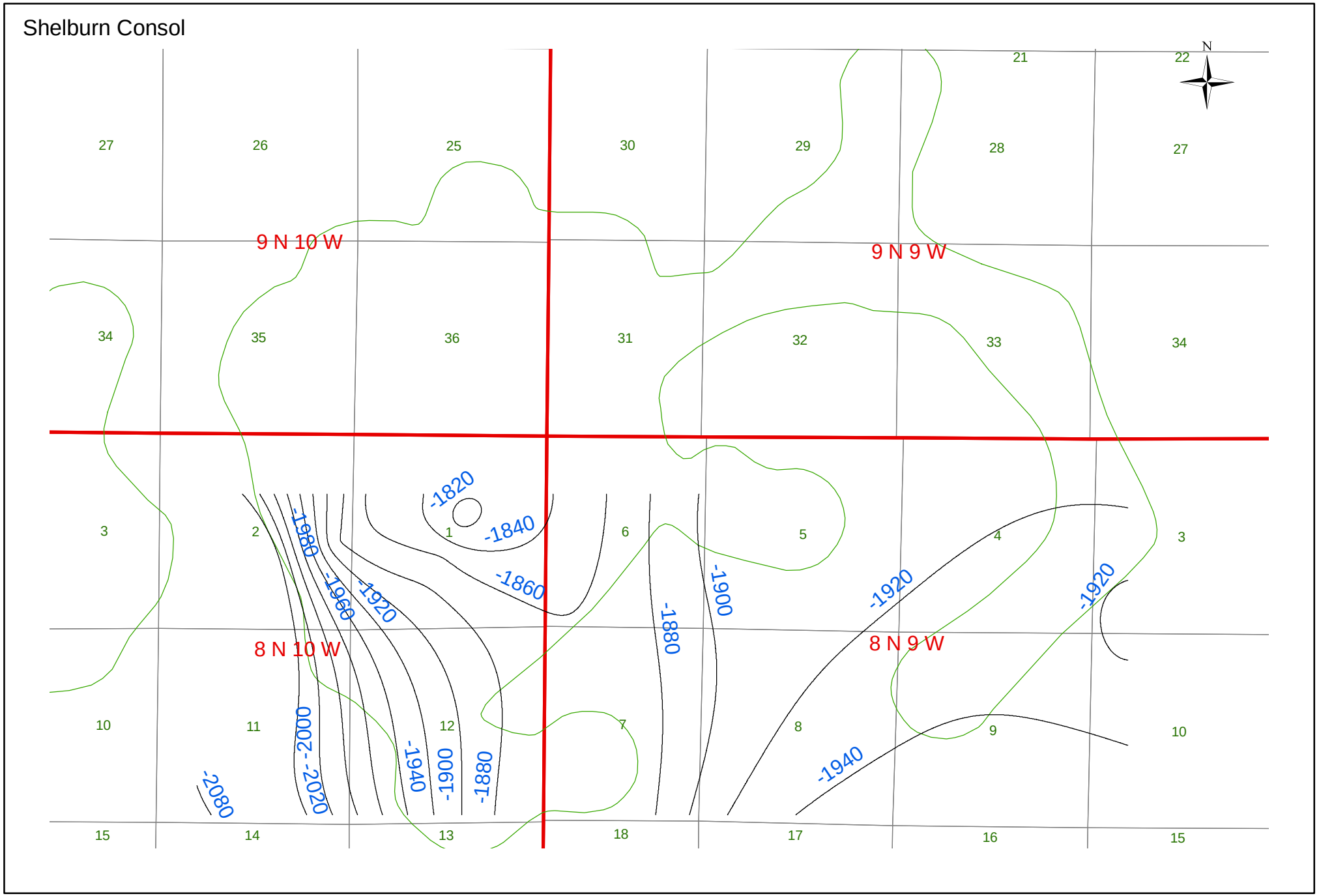

Figure 5: Structure map showing the top of the subsurface Silurian in Shelburn Consol. Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

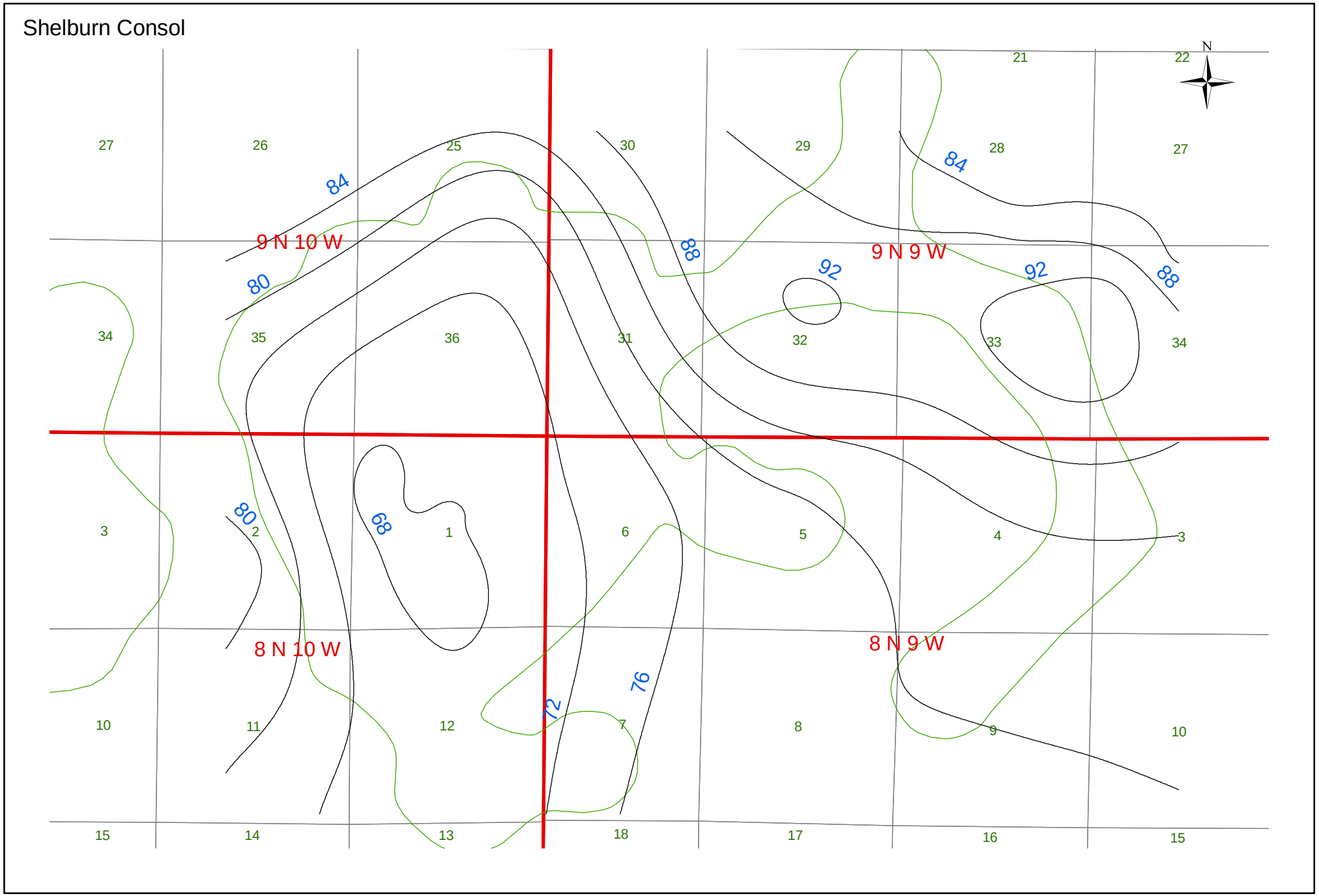

Figure 6: Isopach map showing the thickness of the North Vernon Ls. from Shelburn Consol. Field, Sullivan County. Contour interval is 4 ft.

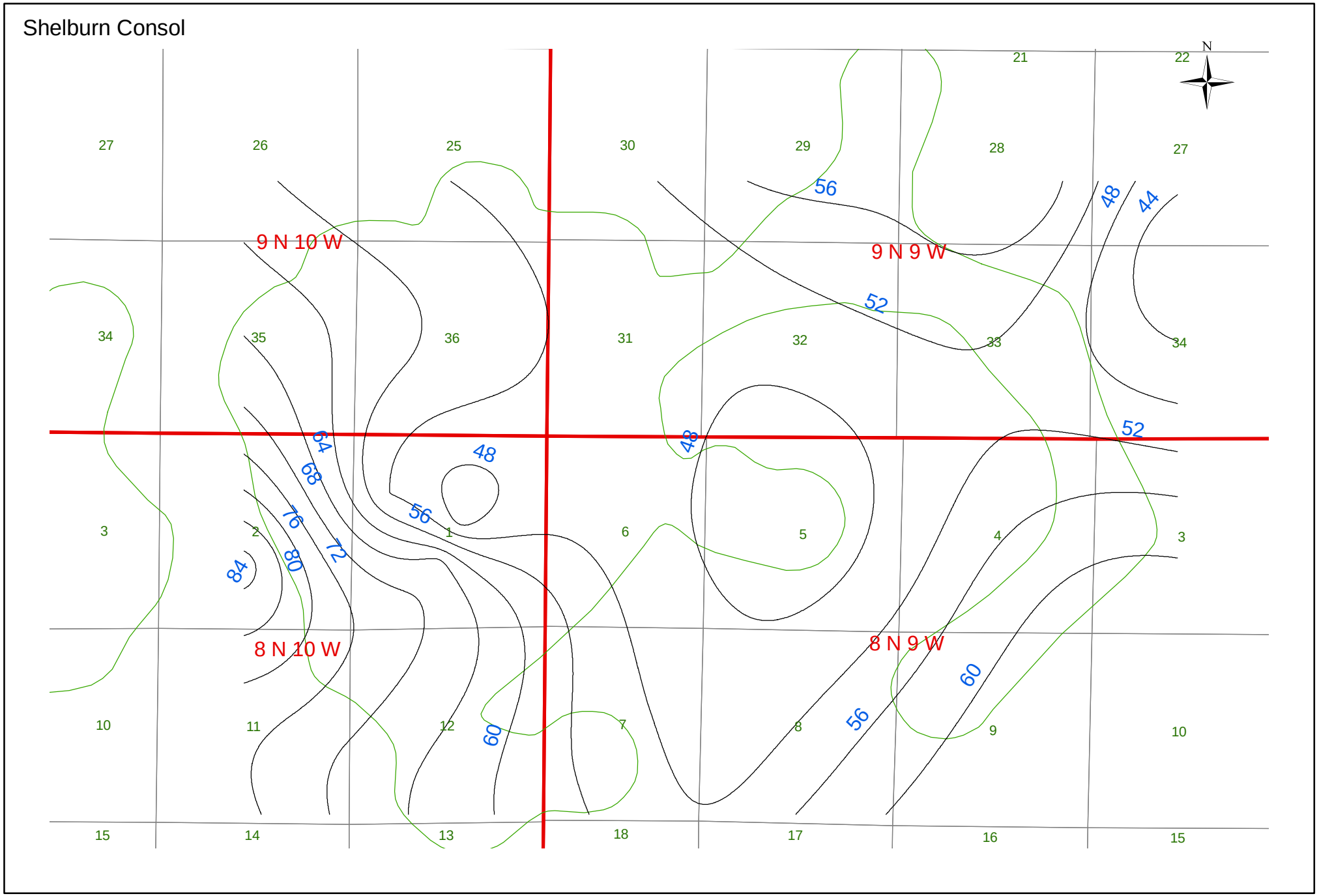

Figure 7: Isopach map showing the thickness of the Vernon Fork Member from Shelburn Consol. Field, Sullivan County. Contour interval is 4 ft.

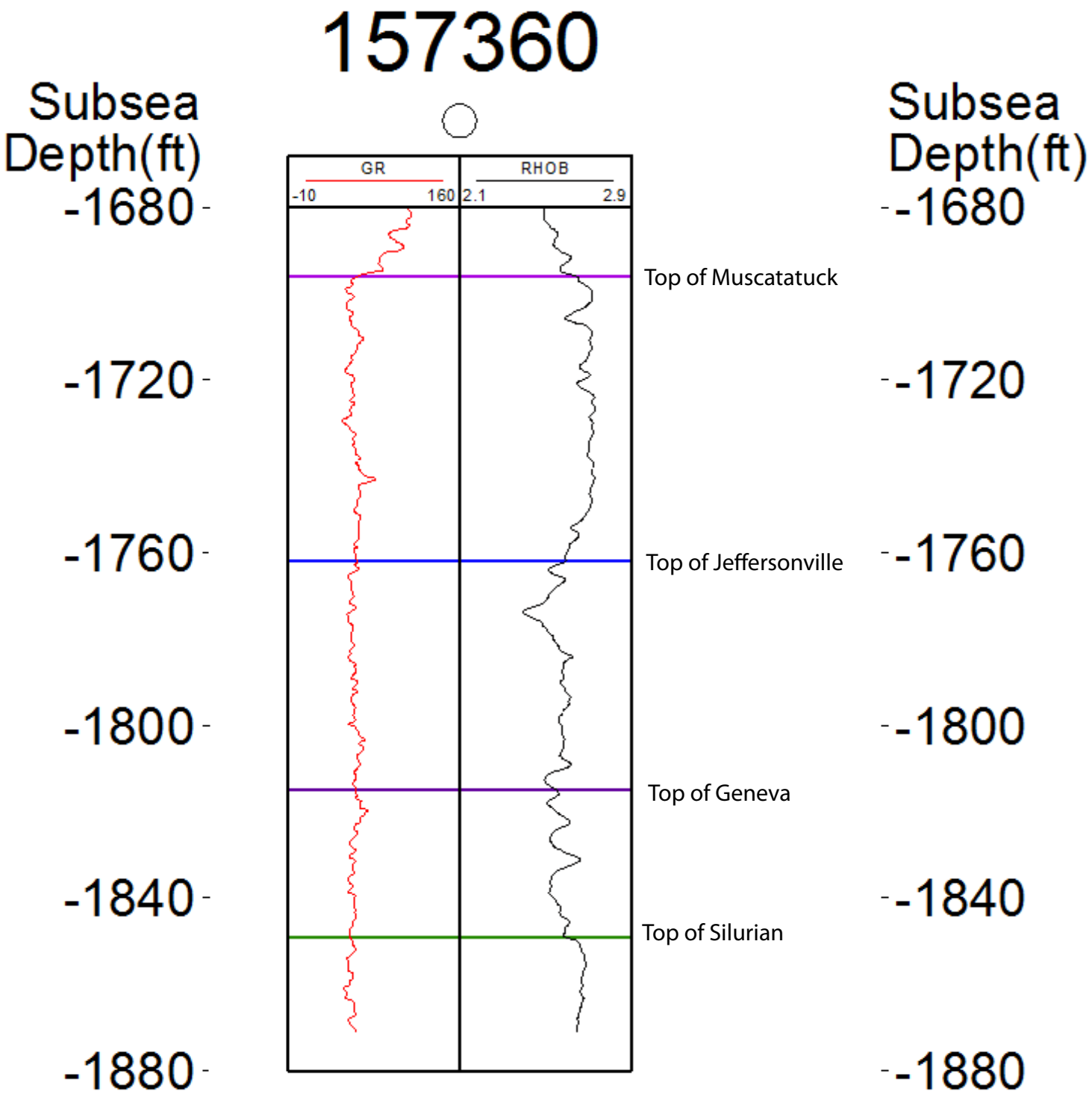

Figure 8: Type log section showing the Devonian formations at Shelburn Consol. Field, Sullivan County.

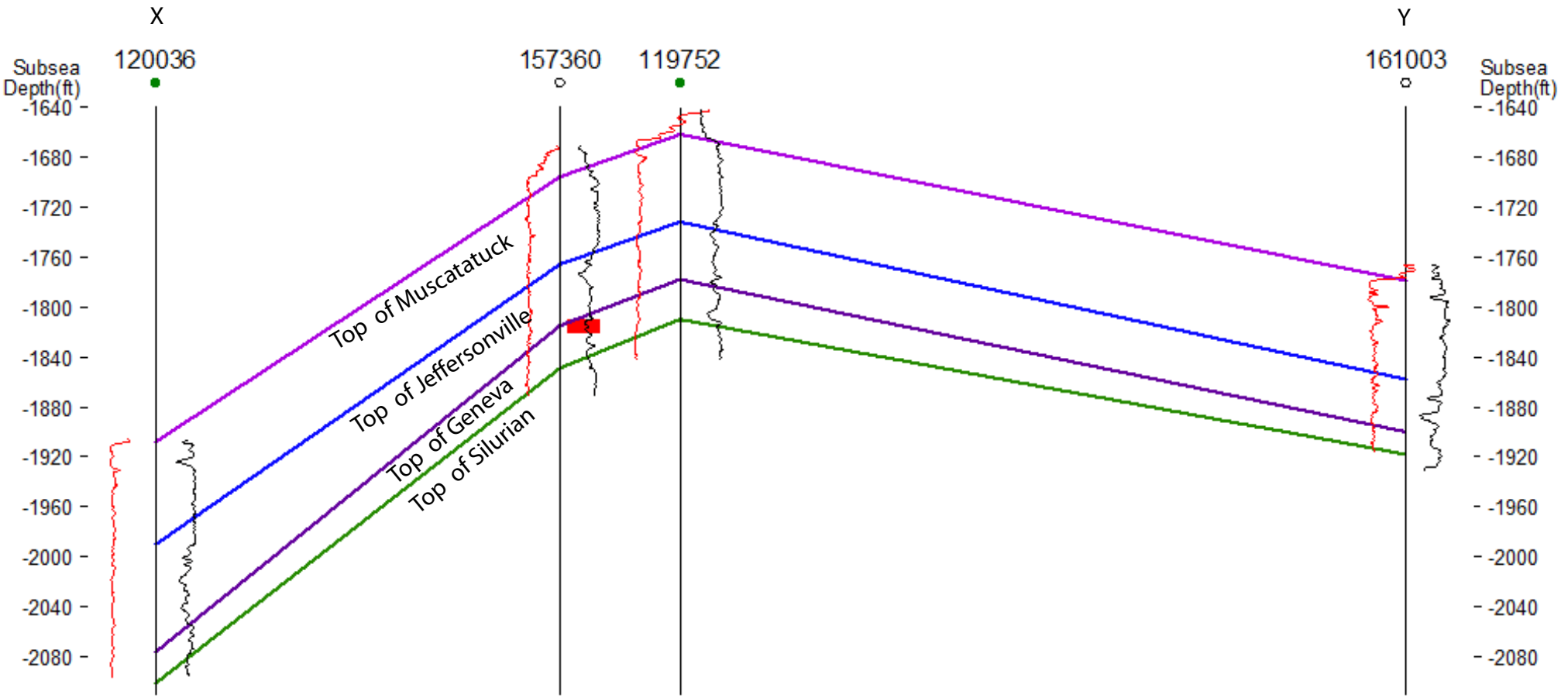

Figure 9: X-Y Cross section showing the Devonian subsurface structure across Shelburn Consol. Field, Sullivan County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

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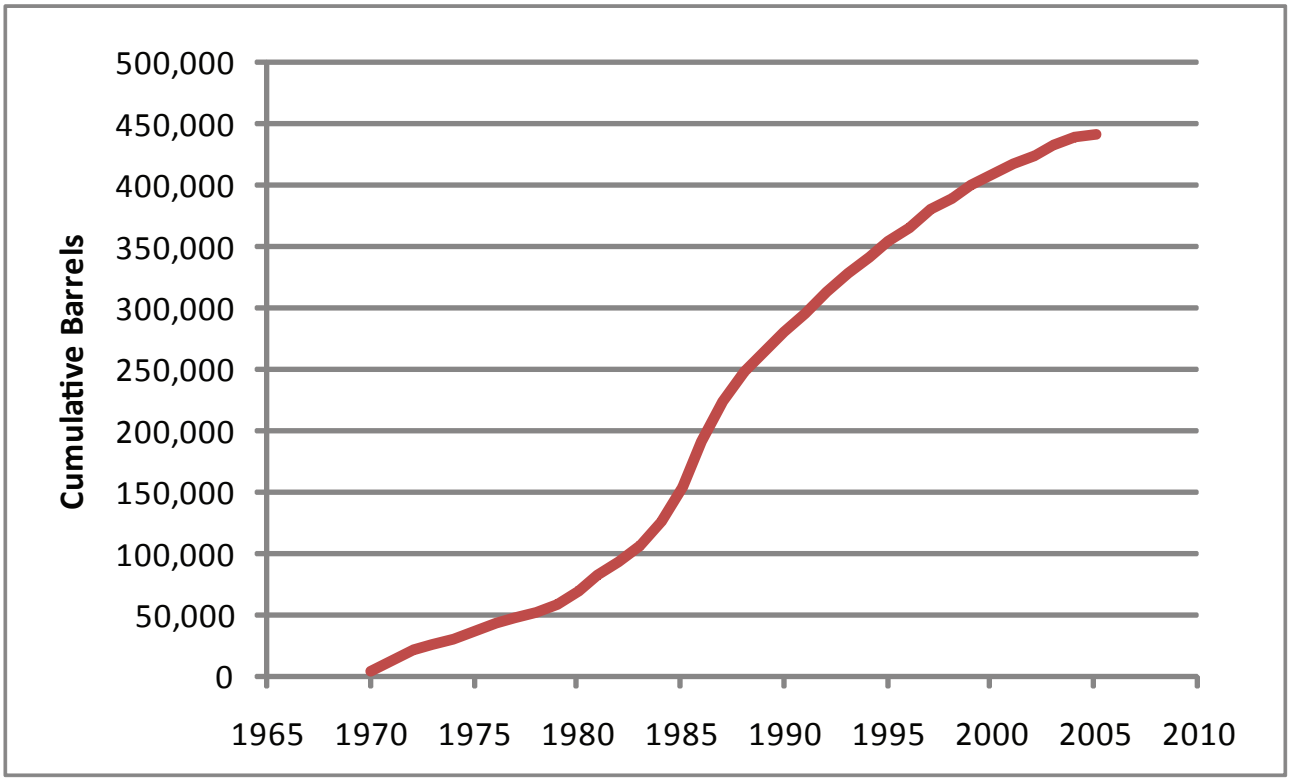

Figure - 10: Cumulative oil production history from Shelburn Consol. Field, Sullivan County since 1970.

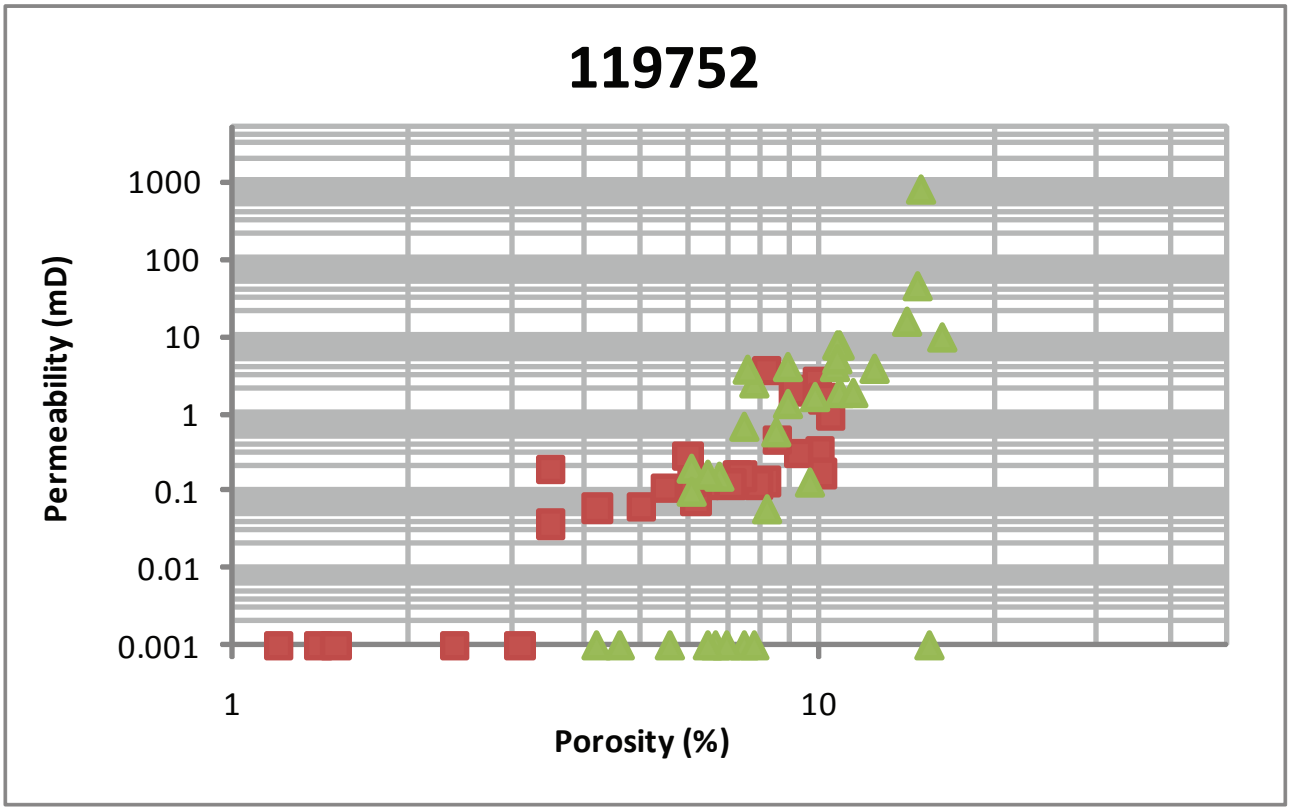

Figure 11: Porosity-permeability plot from core analysis for Shelburn Consol. Field, Sullivan County. The red points are data from the Vernon Fork Mbr. and green from the Geneva Dolomite Mbr. The chart title lists the IGS Well ID. For the well location see Figure 1.

Table-1: List of the wells used for subsurface structure mapping in Shelburn Consol. Field, Sullivan County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
160973	8	N	9	W	3	536	2245					
160994	8	N	9	W	5	535	2308					
161003	8	N	9	W	5	534	2313	2392	2438	2450		
161051	8	N	9	W	6	507	2319					
161059	8	N	9	W	7	536	2423					
161069	8	N	9	W	8	525	2340	2420				
161074	8	N	9	W	9	497	2291	2370	2433	2456		
161077	8	N	9	W	9	516	2292					
161080	8	N	9	W	10	504	2258	2340	2402	2422		
119680	8	N	10	W	1	476	2155					
119683	8	N	10	W	1	501	2179					
119688	8	N	10	W	1	479	2176					
119689	8	N	10	W	1	509	2225	2290	2356	2378		300
119703	8	N	10	W	1	491	2183					
119718	8	N	10	W	1	501	2267					
119745	8	N	10	W	1	505	2191	2258			28	
119752	8	N	10	W	1	508	2174	2240	2286	2321		
119762	8	N	10	W	1	489	2193	2258	2310	2332		
119769	8	N	10	W	1	501	2229					
119790	8	N	10	W	1	498						
119805	8	N	10	W	1	495	2194	2264				
157347	8	N	10	W	1	508	2234	2304				
157359	8	N	10	W	1	506	2180	2250				
157360	8	N	10	W	1	479	2175	2245	2296	2325	24	
120024	8	N	10	W	2	472	2206			2355		
120025	8	N	10	W	2	497	2388				3	
120036	8	N	10	W	2	504	2412	2494	2580	2605		
119853b	8	N	10	W	11	504	2453			2624		
121245	9	N	9	W	27	545	2261					
121247	9	N	9	W	28	538	2268					
121249	9	N	9	W	28	547	2269	2350	2410			
121252	9	N	9	W	29	551	2279	2364				
121257	9	N	9	W	29	533	2294					
121259	9	N	9	W	29	531	2269					
121343	9	N	9	W	32	548	2276					
121350	9	N	9	W	32	531	2296					
121351	9	N	9	W	32	533	2287	2380				
121353	9	N	9	W	33	545	2282					
121356	9	N	9	W	33	548	2274	2364				
121361	9	N	9	W	34	546	2257	2340	2380			
121364	9	N	9	W	34	545	2263	2358				
120762	9	N	10	W	25	483	2298					
120764	9	N	10	W	25	509	2330					
120766	9	N	10	W	26	484	2332	2420				
120770	9	N	10	W	26	494	2335					
120850	9	N	10	W	35	494	2370					
120885	9	N	10	W	36	493						

Field name: Simpson Chapel

IGS ID: 10631 (oil & natural gas), 10825 (gas storage)

DOE ID: 657104

Location: Greene County, 6N-4&5W

Discovery date: 1972

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,987 ft.)

Field type: oil, natural gas, & gas storage

Total number production wells: 18 (storage), 8 (observation)

Area: 400 acres

Total capacity: 2.205,000 mcf

Other reservoir units:

Mississippian, Blue River Group, Ste. Genevieve Ls.

Mississippian/Devonian, New Albany Sh.

Deepest unit penetrated (depth): Knox Supergroup (4,467 ft.)

Field characteristic: Irregular domal anticline over probable Silurian reef with closure in excess of 60 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 12%

Average permeability – 11 md.

Approximate thickness – 22 ft.

The Simpson Chapel field

History and Production

The Simpson Chapel field in the Greene County, Ind. (fig. 1), was founded in 1974 and has been operated by Manihal oil Ltd and Citizens Gas and Coke Utility. The field largely produces oil from the St. Genevieve formation and used to store gas in the New Albany Shale. It consists of a total of 40 wells, which are mainly used for gas storage. A list of wells that has completion interval in Devonian units is shown in table 1. The Simpson Chapel field has produced a cumulative total of 3.9×10^4 barrels of oil till date (2005; Fig.2).

Structure

The Simpson Chapel field is elongate in shape with its shape trending NW-SE. Structure contour maps on top of Muscatatuck group, top of Jeffersonville Limestone, and top of Geneva dolomite Mbr all depict the major structure in the west and a minor structure in the east of the field (Figs. 3-5).

An Isopach map of the Vernon Fork Mbr (Fig. 7) shows its thickness and extent. The thickness of the Vernon Fork Mbr ranges from 55-95 ft with the thickest structure congruent with the main western and eastern structures of the field (Fig. 3). Another Isopach map shows the thickness and extent of the Geneva dolomite Mbr (Fig. 8) Geneva Dolomite Mbr is the thickest under the western structure of the field and ranges in thickness from 23-35 ft.

Stratigraphy

In the Illinois Basin the Muscatatuck group limestone rocks are overlain by the New Albany shale (Devonian age; Fig. 9). The Muscatatuck group comprises of North Vernon Ls and Jeffersonville Ls. in the Simpson Chapel field. The upper Jeffersonville Ls is categorized as Vernon Fork Member and the lower Jeffersonville Ls is replaced by Geneva dolomite Member (Fig. 9). The Geneva dolomite Member is unconformably underlain by the Wabash formation of the Silurian age. The Jeffersonville Ls. is sub classified into so called productive horizons namely A, B, C, and D. These horizons are partly dolomitized and separated by thin un-dolomitized limestone units (Fig. 9). A type log section describes the carbonate lithology in the Devonian subsurface section of the Simpson Chapel field (Fig.9). The overlap of the Sidewall Neutron Porosity and Compensated Density Porosity logs describes the extent of dolomitization of the Devonian Limestone.

Cross Sections

In addition to the structure maps, three correlation cross sections were made to capture the sub surface structure of the prospective Devonian reservoirs. The cross section 'X-Y' is a W-E section cutting across the main western structural high of the Simpson Chapel field. 'P-O' is a NE-SW cross section also across the western structural high, and 'L-M' is a W-E cross section across the eastern structural high (Fig. 1).

Gamma ray, Sidewall Neutron Porosity, and Bulk Density logs were used to correlate the variation in porosities or the Density to correlate and map the prospective producing horizons namely A, B, C, and D (Fig. 10, 11, and 12). These prospective oil and gas producing and/or gas storing horizons in the Vernon Fork Mbr are partially dolomitized limestone units and which being a reason for the development of porosity in the Vernon Fork Mbr . These porous horizons show marked variations in their thickness as they are mapped and correlated for three different cross sections across the Simpson Chapel field.

Cross section 'X-Y' shows a good structural trap in the west part of the field. Similarly a structural trap is observed in 'P-O' cross section. The 'L-M' cross section shows a small structural trap in the east part of the field. The red colored box along the well log indicates the completion interval or the prospective gas storage zone. The cross sections shown have a vertical exaggeration of 8X.

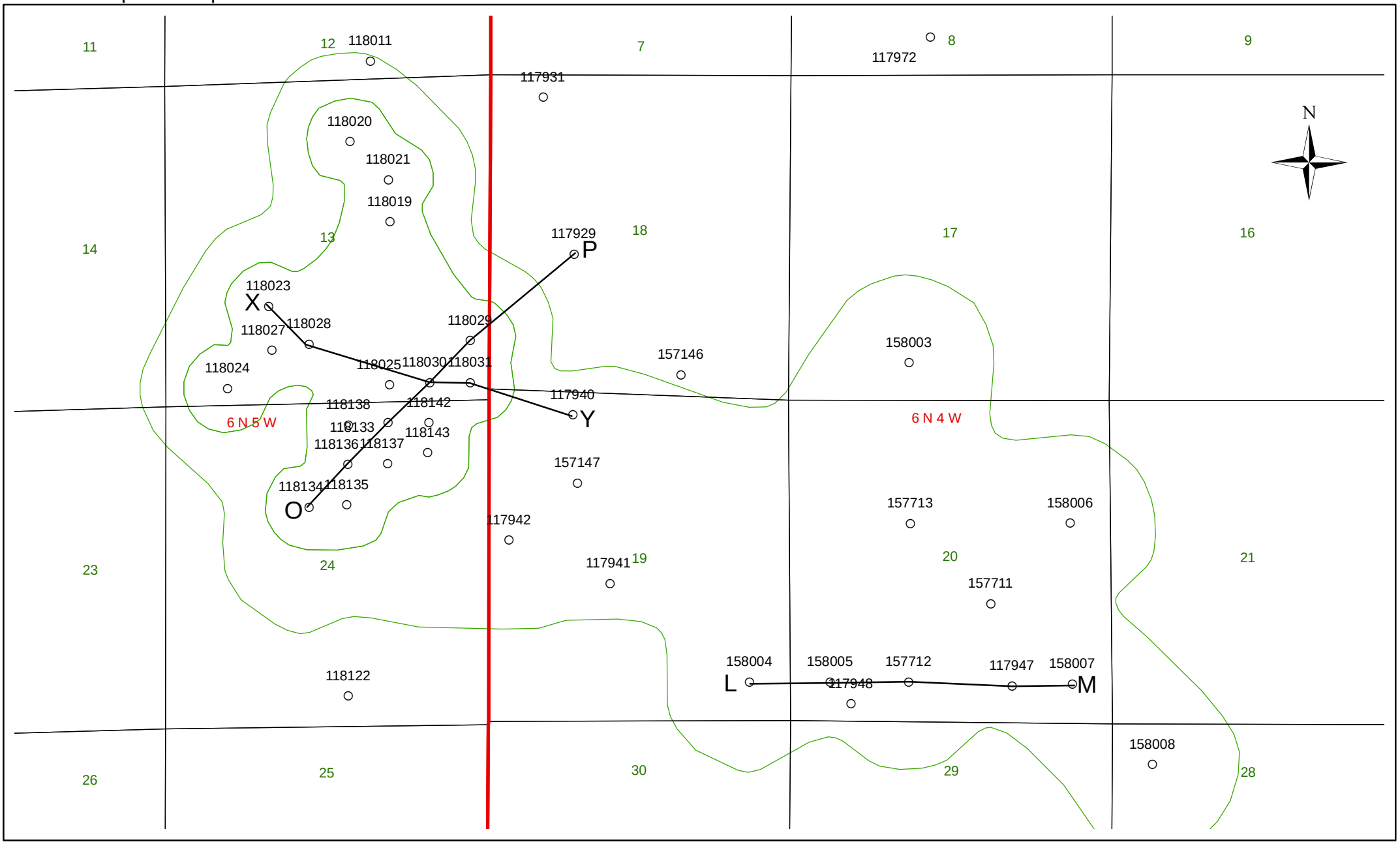

Figure 1: Map showing location and wells at Simpson Chapel Field, Greene County. X-Y, O-P, and L-M are the location of the cross sections used to show the subsurface Devonian structure in the field.

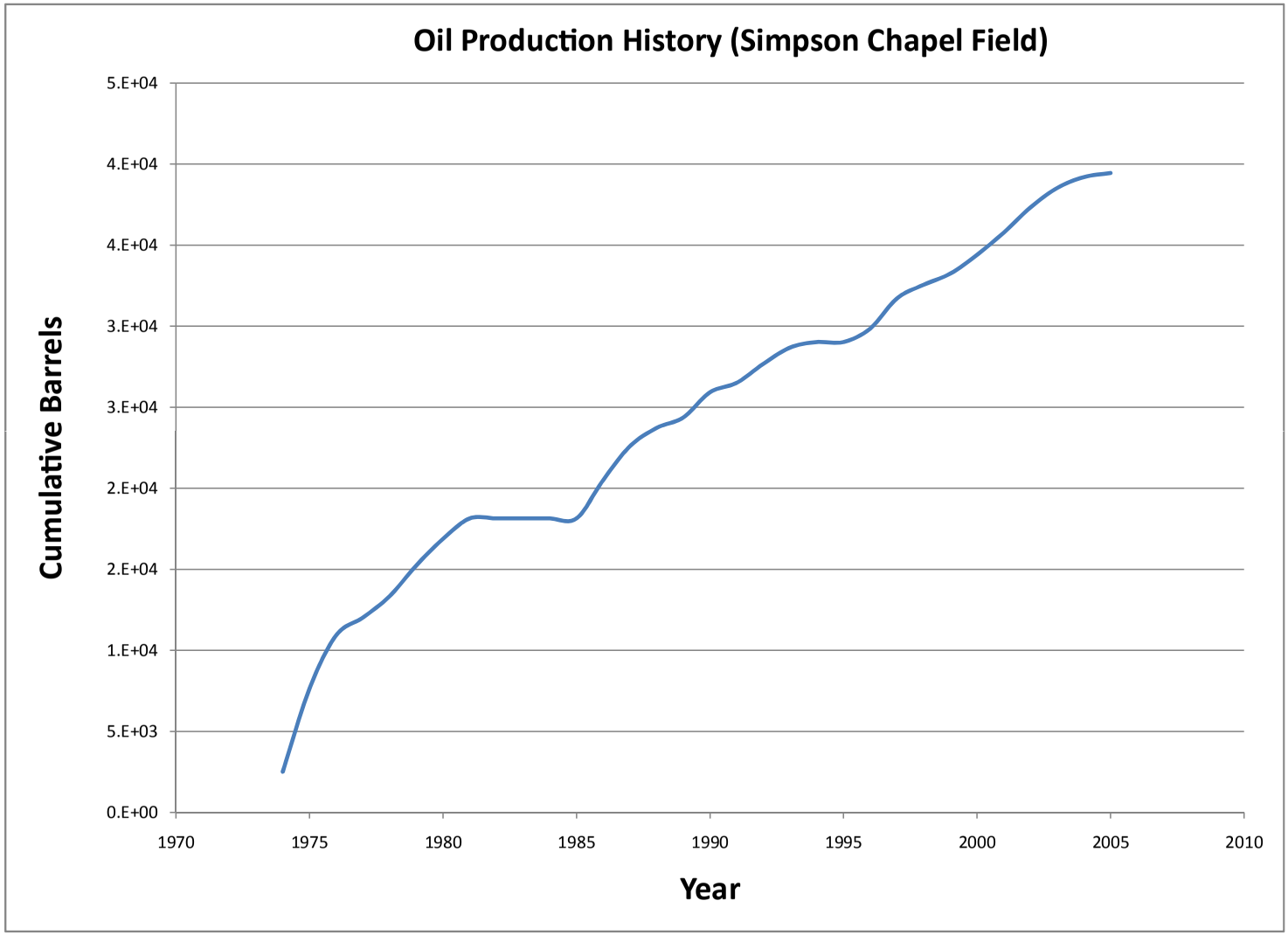

Figure 2: Cumulative oil production from Simpson Chapel Field since 1974.

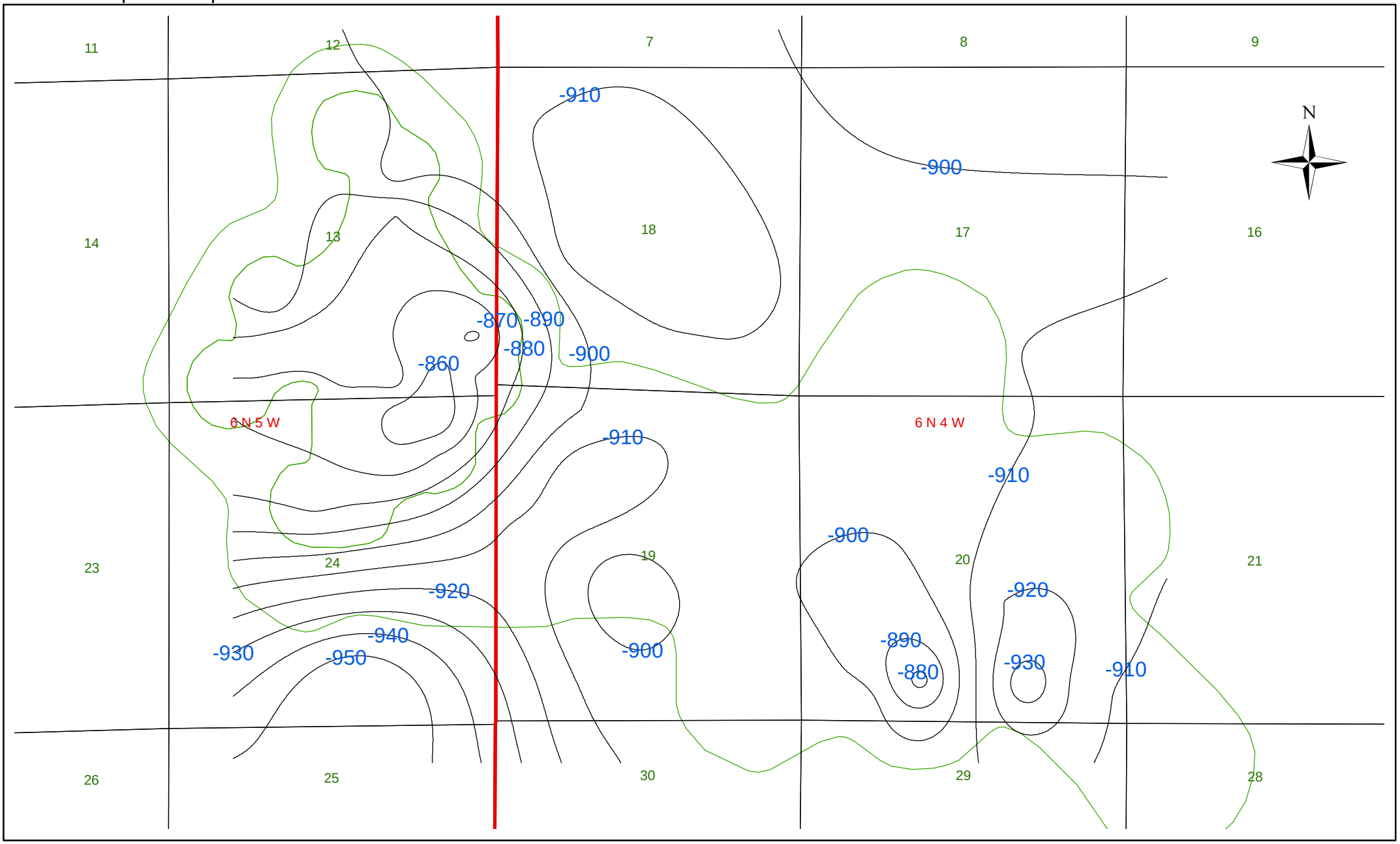

Figure 3: Structure map showing top of the Muscatatuck Limestone in Simpson Chapel Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

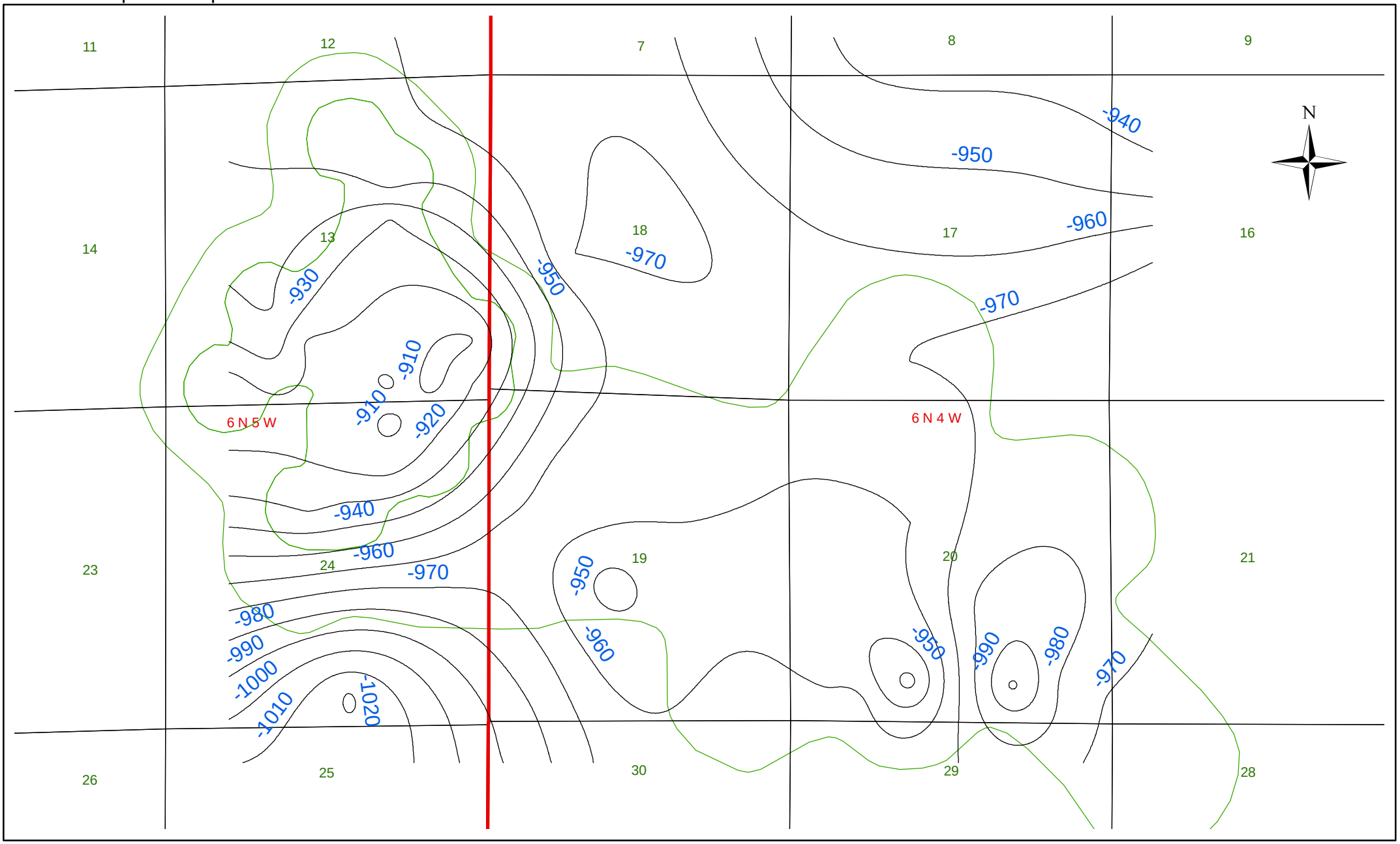

Figure 4: Structure map showing top of the Jeffersonville Limestone in Simpson Chapel Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

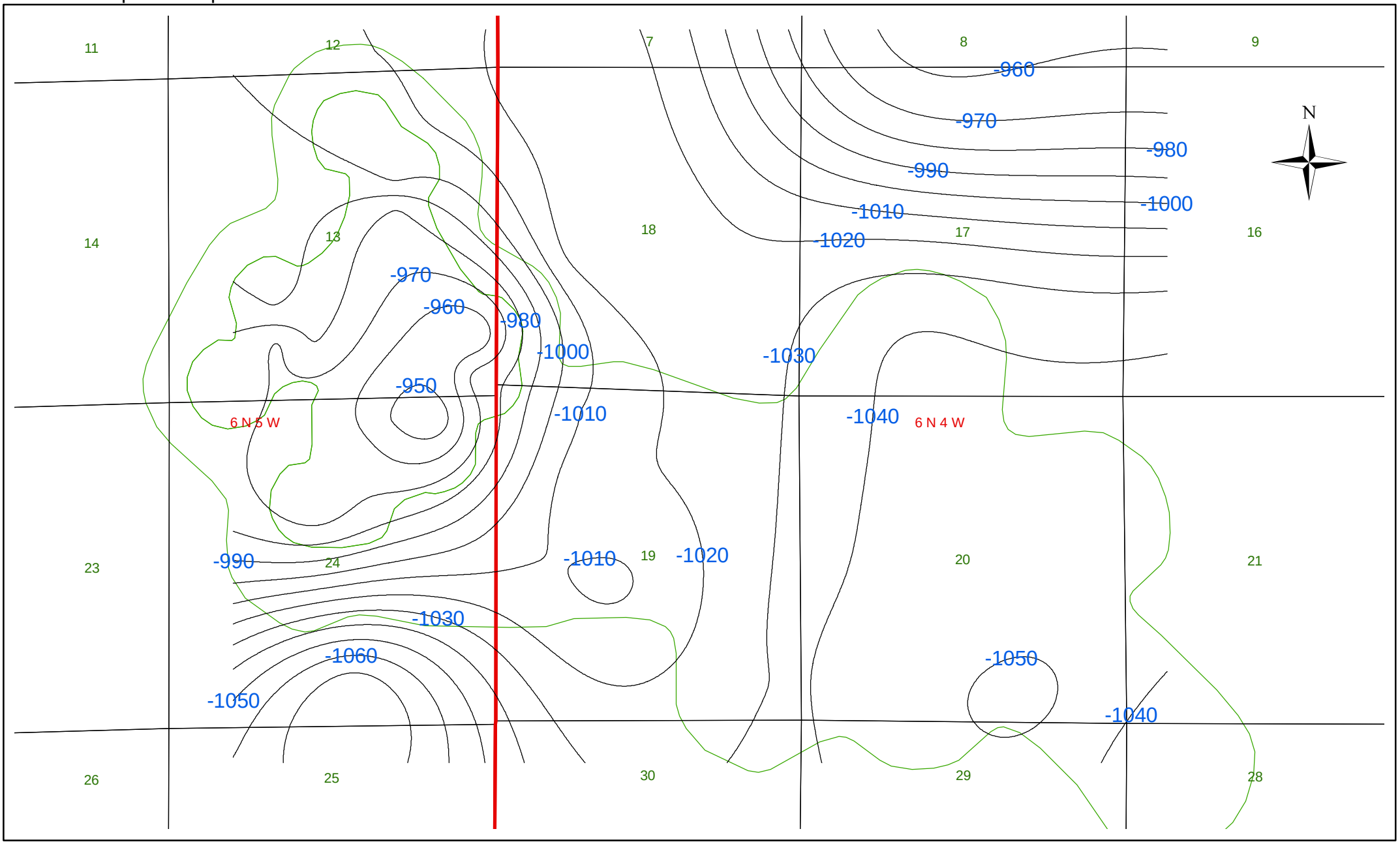

Figure 5: Structure map showing top of the Geneva Dolomite Member in Simpson Chapel Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

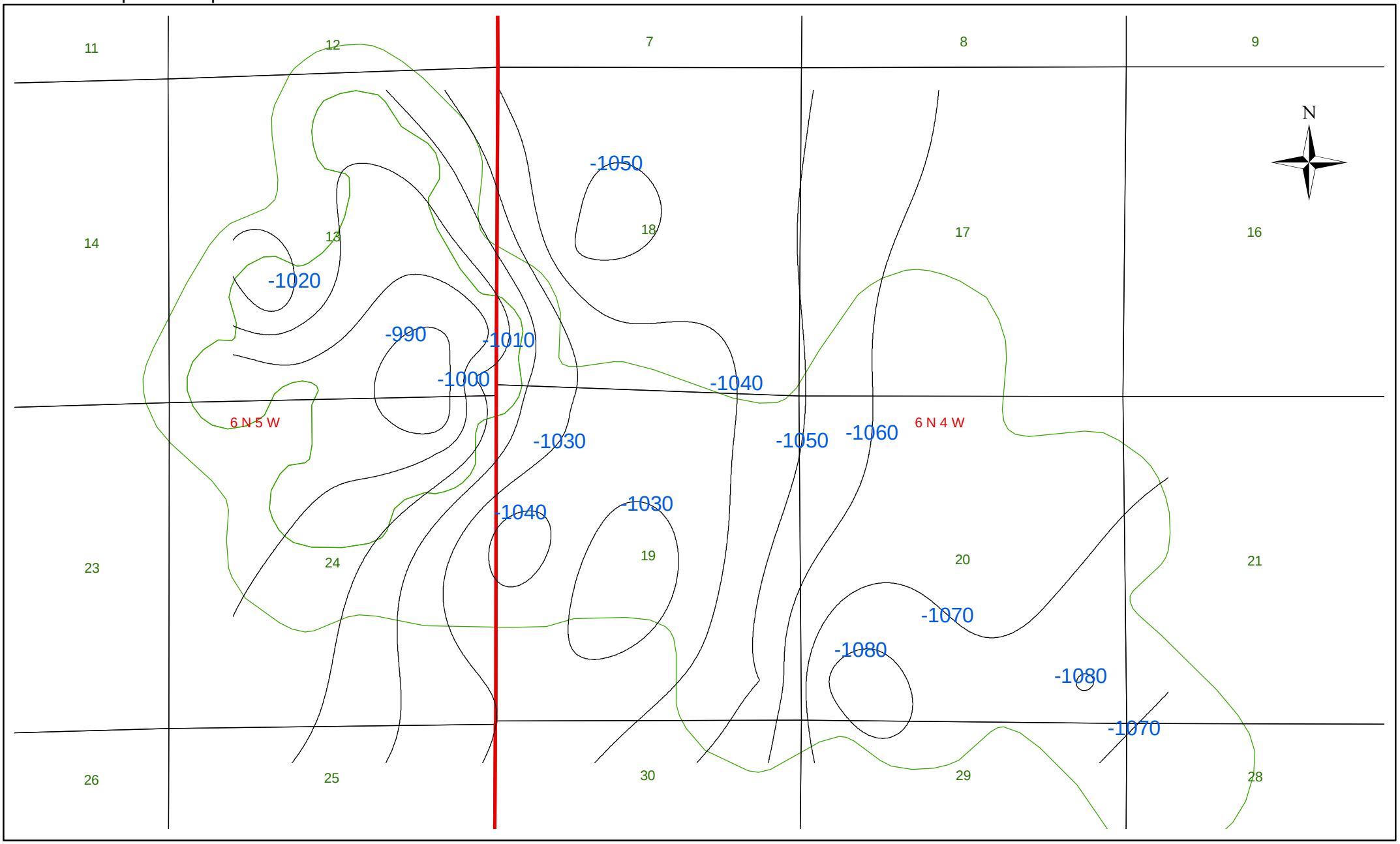

Figure 6: Structure map showing top of the Silurian in Simpson Chapel Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

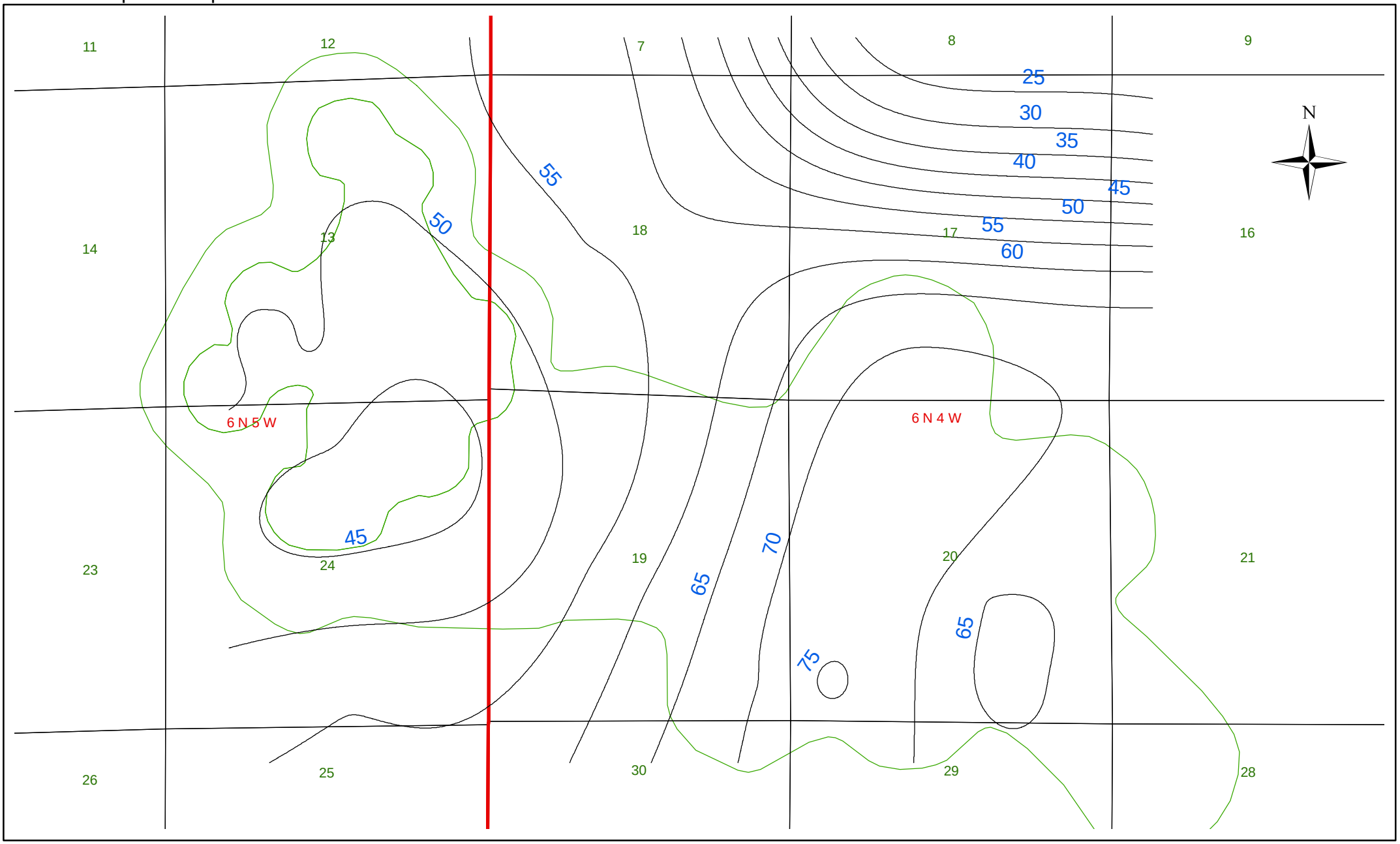

Figure 7: Isopach map showing the thickness of Vernon Fork Member of the Jeffersonville Limestone in Simpson Chapel Field, Greene County. Countour interval is 5 ft .

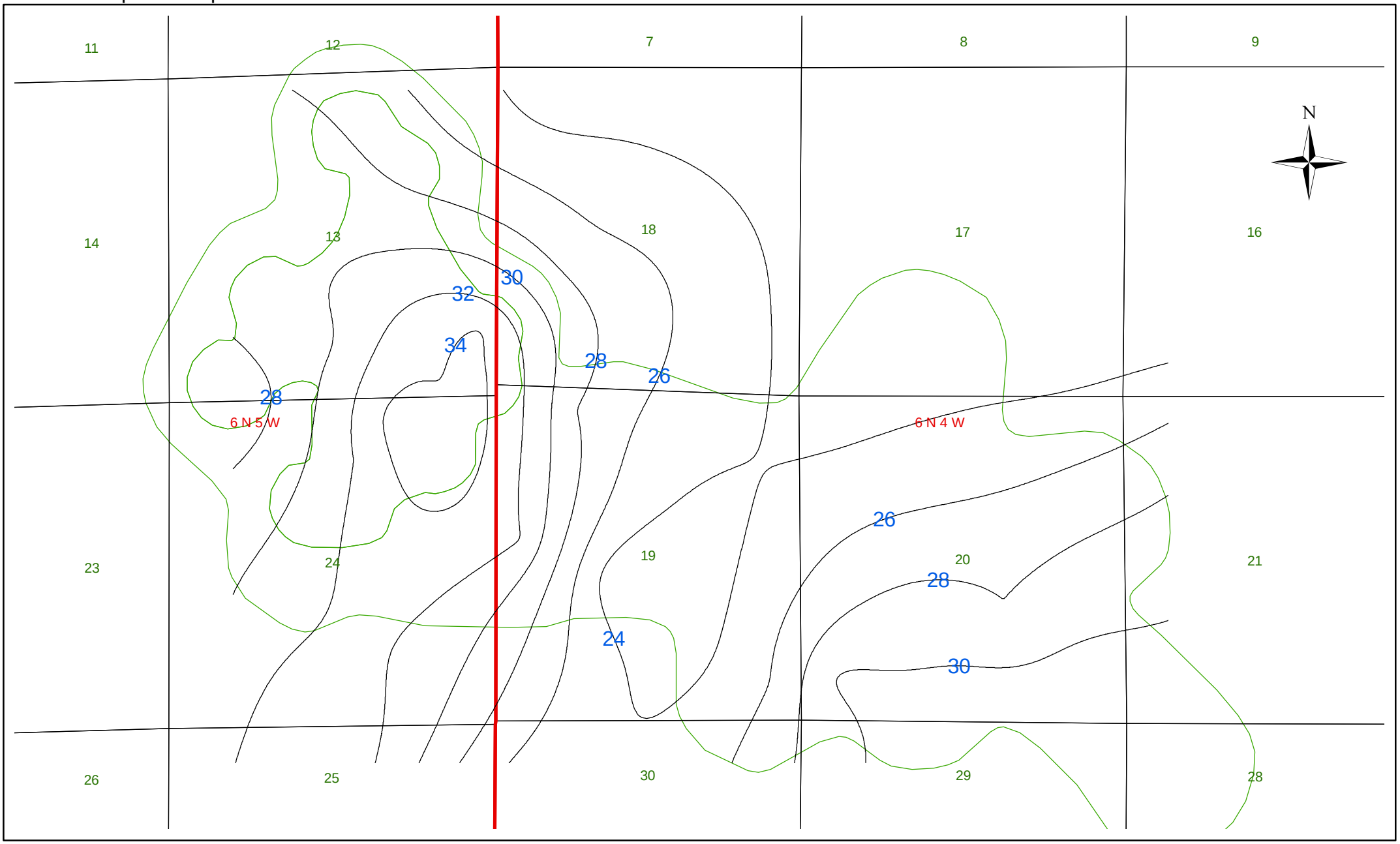

Figure 8: Isopach map showing the thickness of the Geneva Dolomite Member of the Jeffersonville Limestone in Simpson Chapel Field, Greene County. Contour interval is 2 ft .

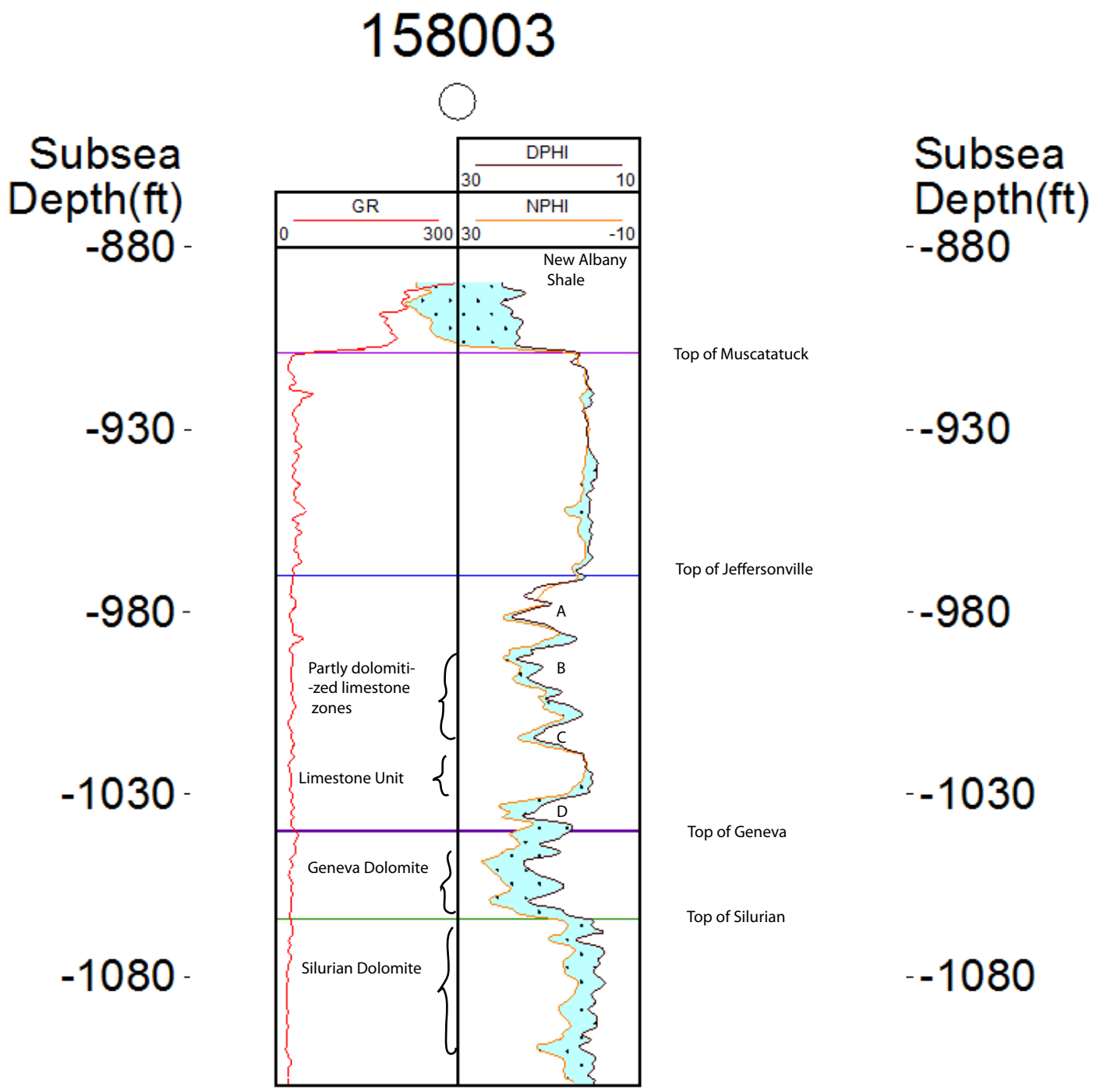

Figure 9: Type log section showing the Devonian formations at Simpson Chapel Field, Greene County. A, B, C, and D are partly dolomitized Vernon Fork Member Units and are generally the prospective pay horizons.

HS=1

PETRA 5/7/2008 5:19:05 PM (Type-Log CSP)

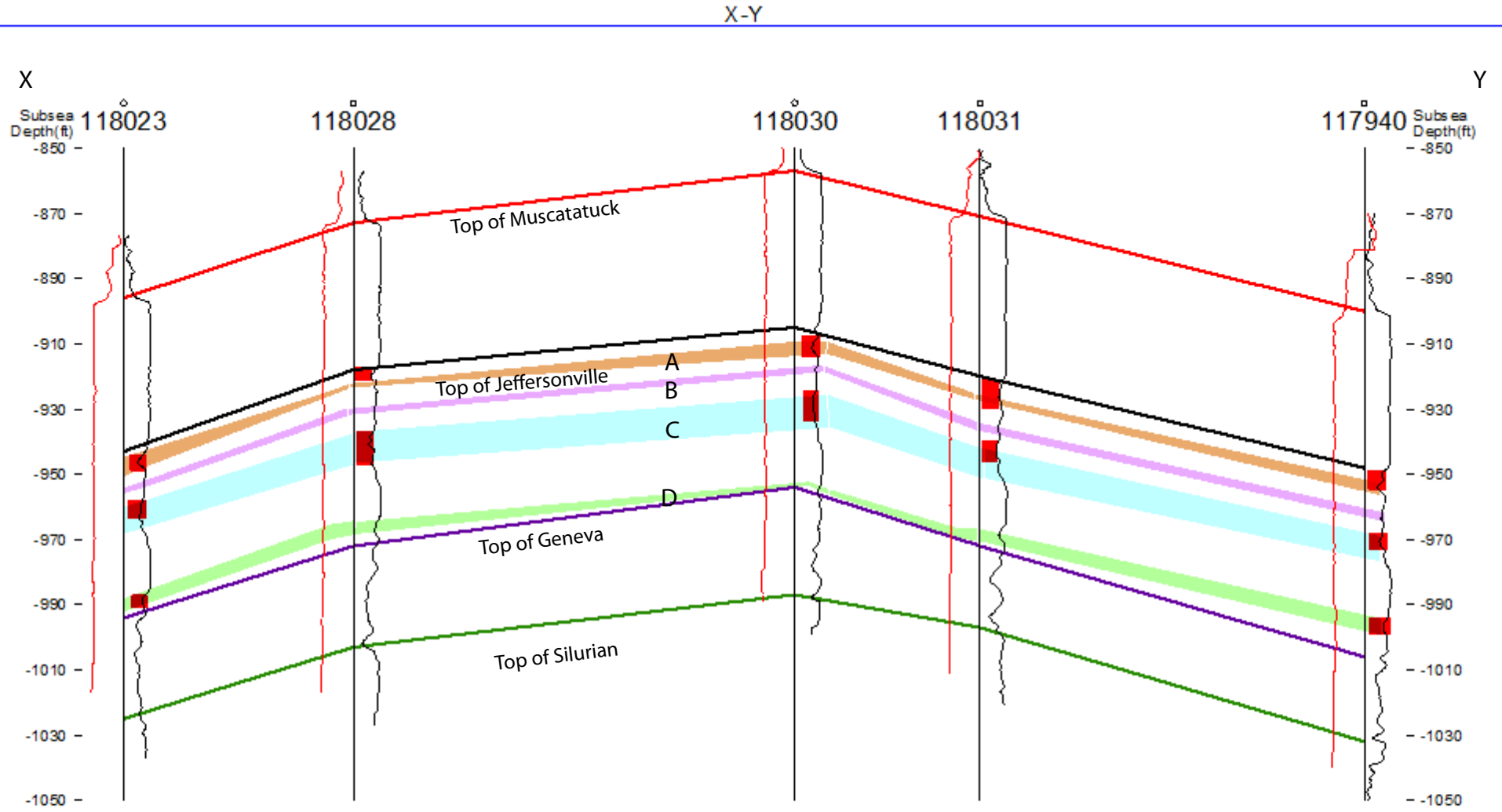

Figure 10: X-Y Cross section showing the Devonian subsurface structure across Simpson Chapel Field, Greene County. A, B, C, and D are the prospective pay horizons in the Vernon Fork Member. The red color box shows the gas storage zone. For location of the cross section refer to Figure 1.

PETRA 5/7/2008 3:35:06 PM (SimpsonXY.CSP)

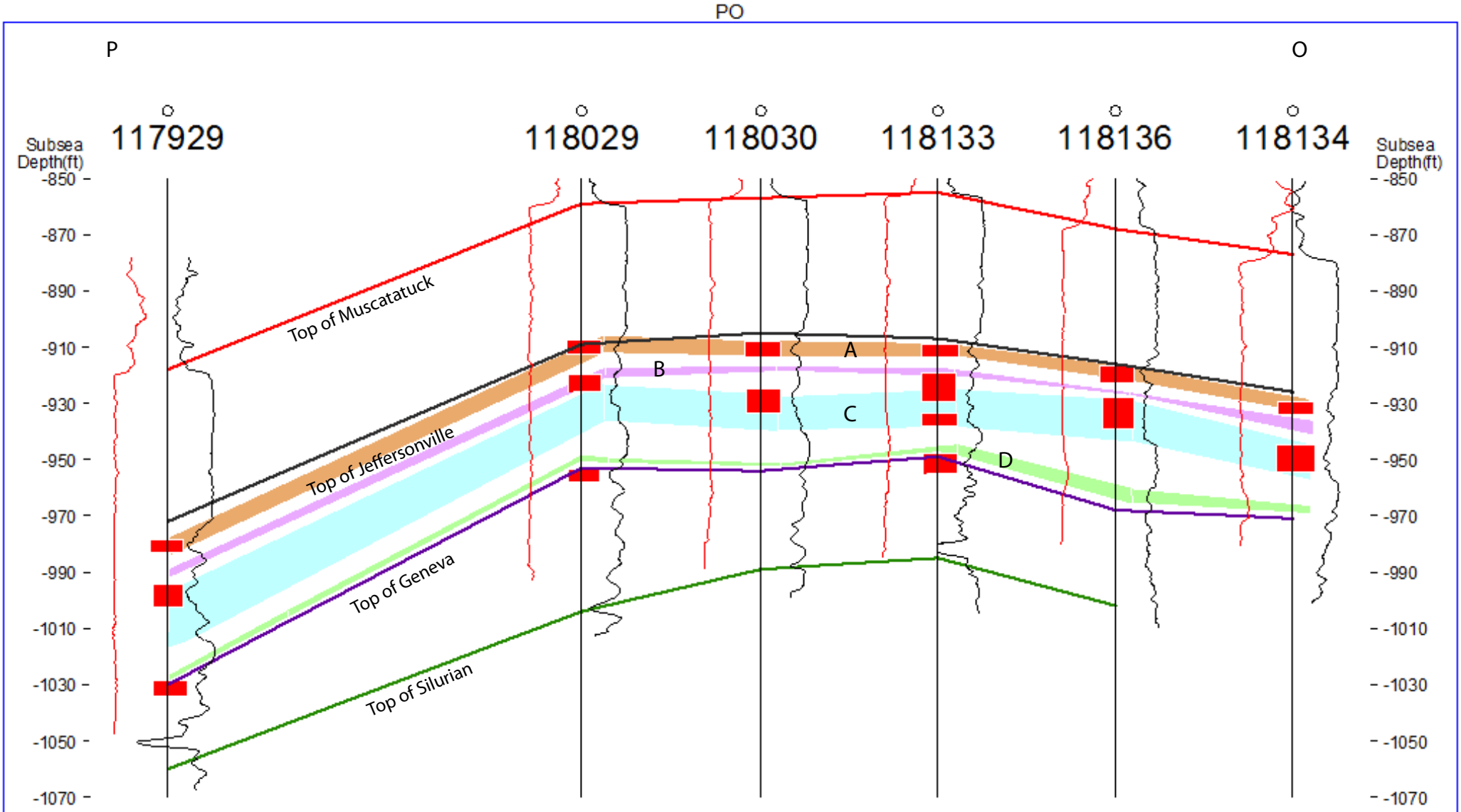

Figure 11: P-O Cross section showing the Devonian subsurface structure across Simpson Chapel Field, Greene County. A, B, C, and D are the prospective pay horizons in the Vernon Fork Member. The red color box shows the gas storage zone. For location of the cross section refer to Figure 1.

PETRA 5/7/2008 4:53:03 PM (Simpson PO.CSP)

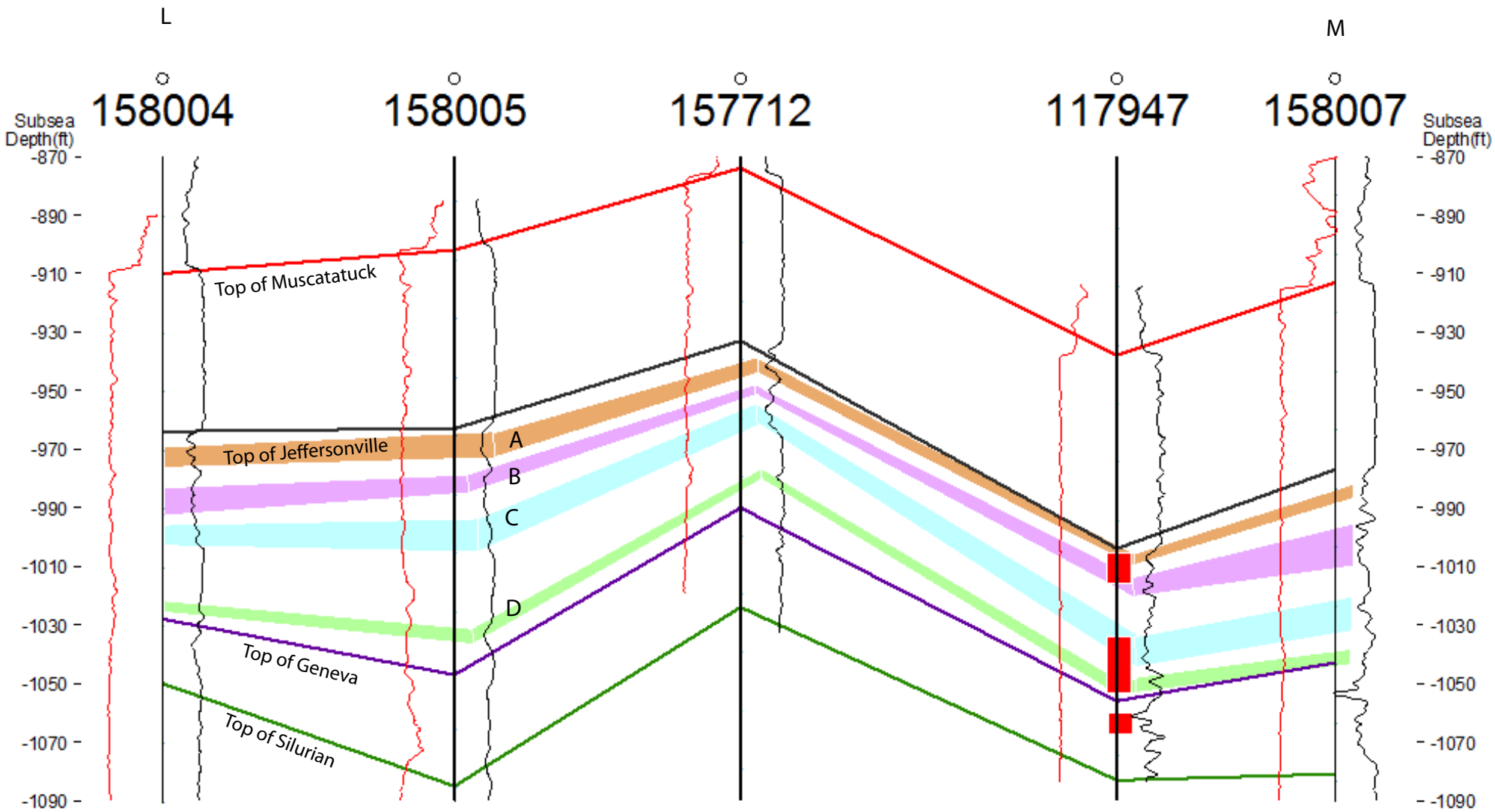

Figure 12: L-M Cross section showing the Devonian subsurface structure across Simpson Chapel Field, Greene County. A, B, C, and D are the prospective pay horizons in the Vernon Fork Member. The red color box shows the gas storage zone. For location of the cross section refer to Figure 1.

PETRA 5/7/2008 5:15:00 PM (SimpsonLM.CSP)

Table-1: List of the wells used for subsurface structure mapping in Simpson Chapel Field, Greene County. The wells selected have a TD in the Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation /Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Core P/A	Oil_P	Gas_P
117972	6	N	4	W	8	699	1593	1636	1654				
158003	6	N	4	W	17	630	1539	1600	1672	1694			
117929	6	N	4	W	18	722	1640	1692	1750	1774			
117931	6	N	4	W	18	691	1600	1658	1719	1738	Present		
157146	6	N	4	W	18	672	1580	1636		1708			
117940	6	N	4	W	19	680	1580	1638	1690	1712			
117941	6	N	4	W	19	698	1590	1644	1706	1718			
117942	6	N	4	W	19	556	1470			1598			
157147	6	N	4	W	19	670	1590	1638	1688				
158004	6	N	4	W	19	690	1600	1654	1718	1740			
117947	6	N	4	W	20	666	1604	1668	1720				
117948	6	N	4	W	20	691	1598	1658					
157711	6	N	4	W	20	732	1652	1718	1774	1798			
157712	6	N	4	W	20	661	1537	1597					
157713	6	N	4	W	20	658	1560	1618	1702				
158005	6	N	4	W	20	715	1617	1673	1762	1800			
158006	6	N	4	W	20	728	1642	1706			Present		
158007	6	N	4	W	20	697	1610	1670	1744	1778			
158008	6	N	4	W	28	658	1558	1620	1690	1720			
118011	6	N	5	W	12	614	1517	1572	1624				
118019	6	N	5	W	13	689	1569	1618	1666	1693			
118020	6	N	5	W	13	610	1500						
118021	6	N	5	W	13	645	1550	1600	1650				
118023	6	N	5	W	13	573	1469	1514	1565	1598			
118024	6	N	5	W	13	624	1493	1538	1598	1614			
118025	6	N	5	W	13	678	1552	1600					
118027	6	N	5	W	13	614	1488	1548	1583	1620			
118028	6	N	5	W	13	673	1546	1591	1654	1676			
118029	6	N	5	W	13	727	1586	1636	1678	1721			
118030	6	N	5	W	13	711	1568	1618	1664	1692			
118031	6	N	5	W	13	699	1570	1618	1674	1710			
118122	6	N	5	W	24	659	1626	1680	1740				
118133	6	N	5	W	24	695	1550			1679			
118134	6	N	5	W	24	599							
118135	6	N	5	W	24	617							
118136	6	N	5	W	24	670							
118137	6	N	5	W	24	639	1503	1554					
118138	6	N	5	W	24	665	1534	1582					
118142	6	N	5	W	24	704	1555	1620	1646	1687			
118143	6	N	5	W	24	652	1519			1650			

Field name: Siosi

IGS ID: 10632

DOE ID: 657891

Location: Sullivan & Vigo Counties, 9&10N-10W

Discovery date: 1926

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,167 ft.)

Field type: oil

Total number production wells: 103

Area: 1,000 acres

Cumulative production: 5,298,432 bbls. (2002)

Other reservoir units:

Pennsylvanian

Deepest unit penetrated (depth): Ordovician, Trenton Ls. (3,534 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 120 ft. at top of Muscatatuck.

Reservoir characteristics:

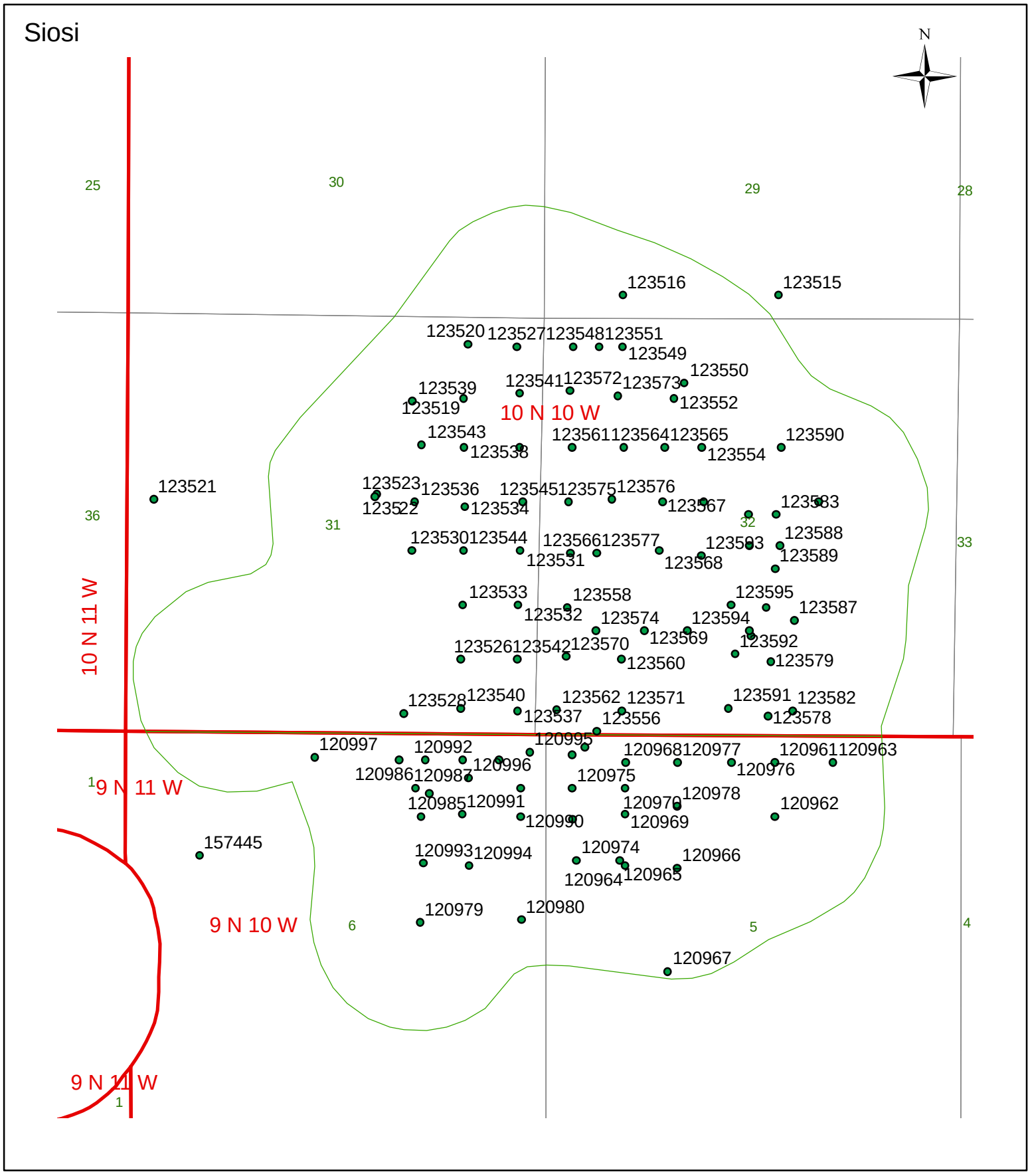

Figure 1: Map showing the location and wells at Siosi Field, Vigo and Sullivan Counties.

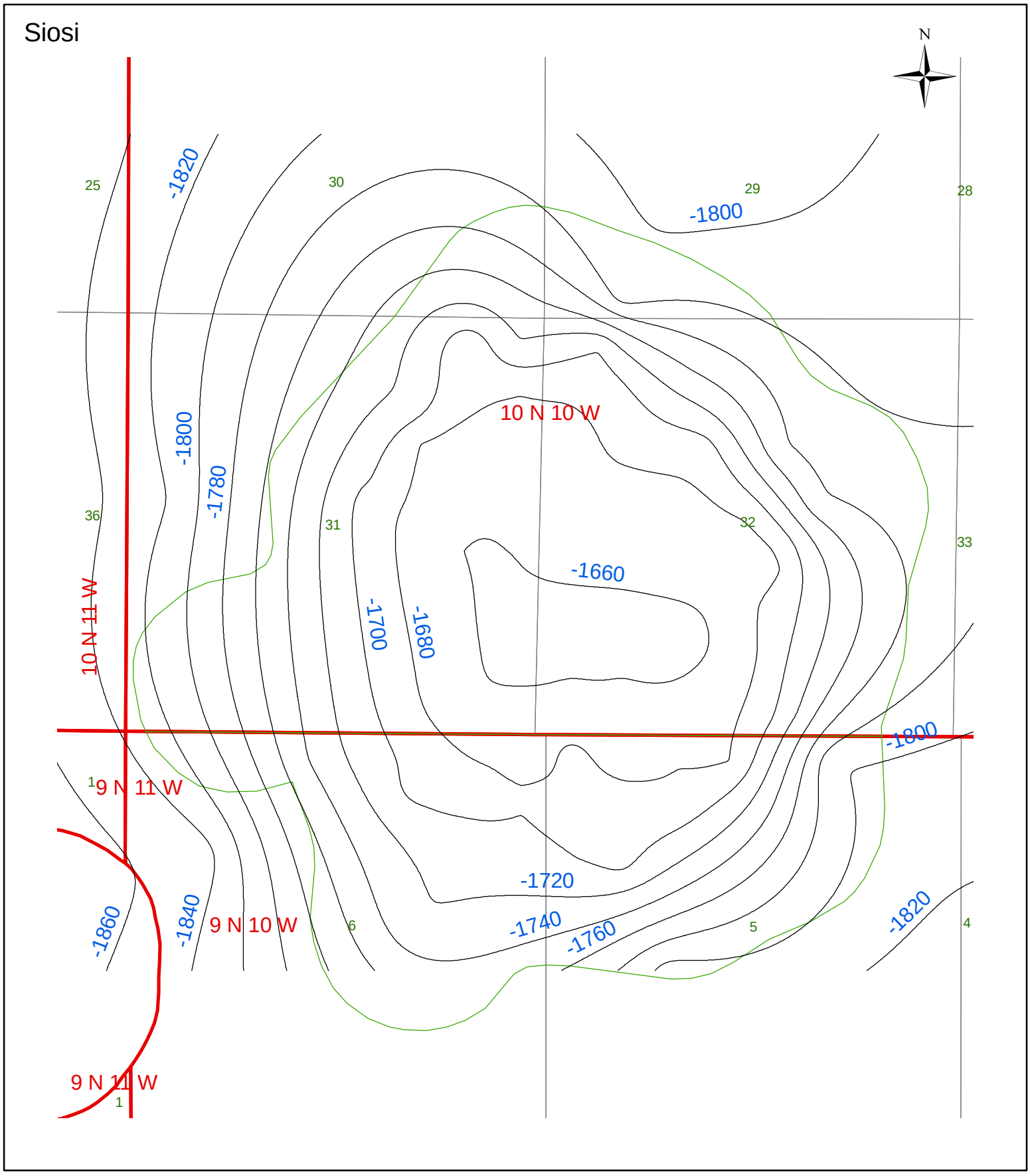

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Siosi field, Sullivan and Vigo Counties. Contours show values below sea level, contour interval is 20 ft .

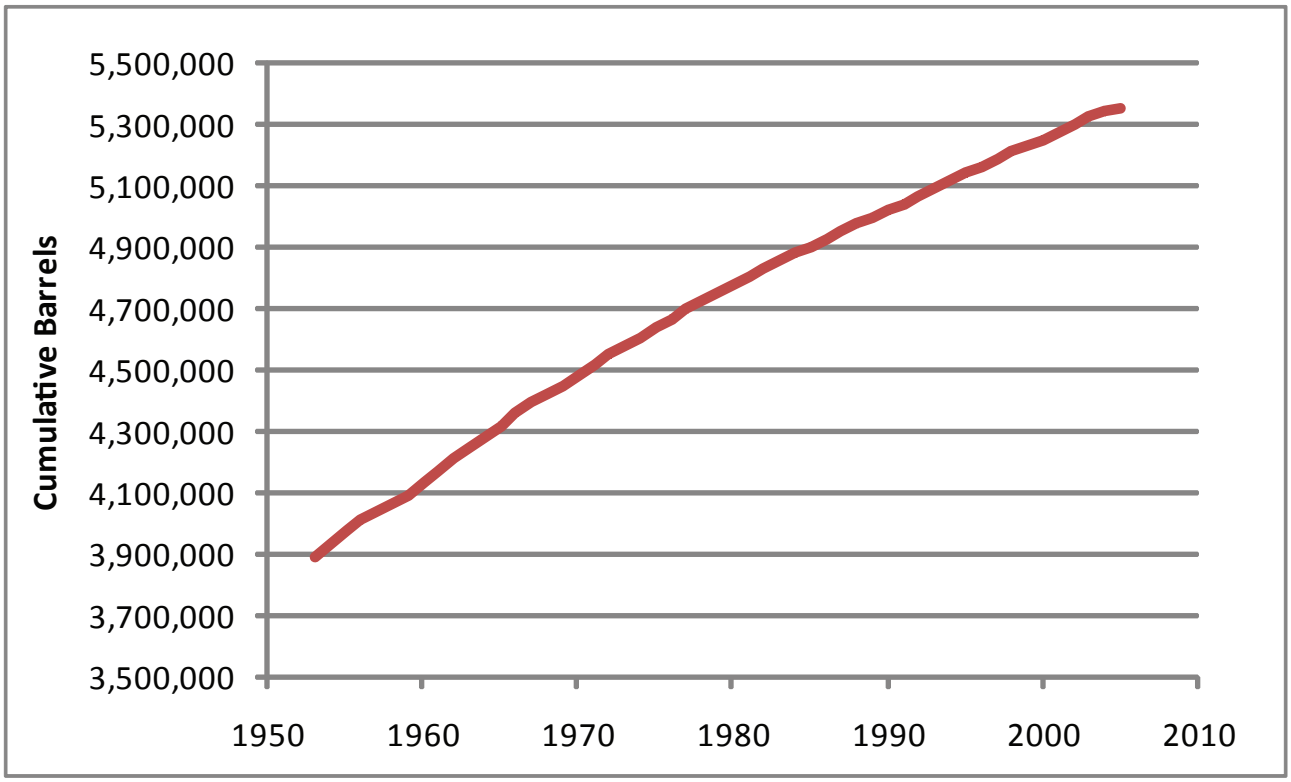

Figure - 3: Cumulative oil production history from Siosi Field, Sullivan and Vigo Counties since 1953.

Table-1: List of the wells used for subsurface structure mapping in Siosi Field, Sullivan and Vigo Counties. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
120961	9	N	10	W	5	486							
120962	9	N	10	W	5	515	2261						
120963	9	N	10	W	5	521	2318						
120964	9	N	10	W	5	475	2173					20	
120965	9	N	10	W	5	476	2169					85	
120966	9	N	10	W	5	523						40	
120967	9	N	10	W	5	530	2339						
120968	9	N	10	W	5	473	2148					80	
120969	9	N	10	W	5	470	2161						
120970	9	N	10	W	5	475	2157					85	
120971	9	N	10	W	5	460						110	
120972	9	N	10	W	5	466	2153						
120973	9	N	10	W	5	465	2157						
120974	9	N	10	W	5	469	2170						
120975	9	N	10	W	5	467	2151					125	
120976	9	N	10	W	5	479	2160					40	
120977	9	N	10	W	5	473	2152					40	
120978	9	N	10	W	5	474	2162						
120979	9	N	10	W	6	468	2190					5	
120980	9	N	10	W	6	471							
120983	9	N	10	W	6	440	2135						
120984	9	N	10	W	6	449	2140						
120985	9	N	10	W	6	456	2164						
120986	9	N	10	W	6	437	2136						
120987	9	N	10	W	6	440	2132					35	
120988	9	N	10	W	6	469	2150					86	
120989	9	N	10	W	6	458	2135						
120990	9	N	10	W	6	466	2167					60	
120991	9	N	10	W	6	461	2160					75	
120992	9	N	10	W	6	448	2130					75	
120993	9	N	10	W	6	458	2176					30	
120994	9	N	10	W	6	462	2176					30	
120995	9	N	10	W	6	460	2126					100	
120996	9	N	10	W	6	455	2141					50	
120997	9	N	10	W	6	437	2172						
120998	9	N	10	W	7	444							
123514	10	N	10	W	28	540	2313						
123515	10	N	10	W	29	458	2247						
123516	10	N	10	W	29	448	2238						
123519	10	N	10	W	31	442	2130						
123520	10	N	10	W	31	443	2130						

Table-1: Continued ....

123521	10	N	10	W	31	443	2270						
123522	10	N	10	W	31	442	2138	2220					
123523	10	N	10	W	31	437	2124						
123526	10	N	10	W	31	437	2104					90	
123527	10	N	10	W	31	442	2160					3.5	
123528	10	N	10	W	31	439	2128					75	
123529	10	N	10	W	31	445	2112					130	
123530	10	N	10	W	31	436	2110						
123531	10	N	10	W	31	439	2100						
123532	10	N	10	W	31	443	2100						
123533	10	N	10	W	31	438	2100						
123534	10	N	10	W	31	444						75	
123536	10	N	10	W	31	438	2114					90	
123537	10	N	10	W	31	447	2117					125	
123538	10	N	10	W	31	444	2114					90	
123539	10	N	10	W	31	439	2153					50	
123540	10	N	10	W	31	440	2104					90	
123541	10	N	10	W	31	445	2126					40	
123542	10	N	10	W	31	444	2094					90	
123543	10	N	10	W	31	441	2120					60	
123544	10	N	10	W	31	437	2097					90	
123545	10	N	10	W	31	444						90	
123547	10	N	10	W	32	479	2234	2304				20	
123548	10	N	10	W	32	444	2152						
123549	10	N	10	W	32	445	2168						
123550	10	N	10	W	32	450	2180					8	
123551	10	N	10	W	32	448	2150	2236				5	
123552	10	N	10	W	32	446	2161						
123553	10	N	10	W	32	460	2144					74	
123554	10	N	10	W	32	451	2141					60	
123555	10	N	10	W	32	457	2135					65	
123556	10	N	10	W	32	464	2131					90	
123558	10	N	10	W	32	446	2099					96	
123560	10	N	10	W	32	456	2115					90	
123561	10	N	10	W	32	442	2115					55	
123562	10	N	10	W	32	455						75	
123564	10	N	10	W	32	442	2128					30	
123565	10	N	10	W	32	443	2133					40	
123566	10	N	10	W	32	442	2113					120	
123567	10	N	10	W	32	450	2123					55	
123568	10	N	10	W	32	453	2122					157	
123569	10	N	10	W	32	457						70	
123570	10	N	10	W	32	449	2107					75	
123571	10	N	10	W	32	461	2125					60	

Table-1: Continued ....

123572	10	N	10	W	32	444	2128					30	
123573	10	N	10	W	32	442	2134					25	
123574	10	N	10	W	32	450	2102				2252	200	
123575	10	N	10	W	32	441	2115					75	
123576	10	N	10	W	32	445	2115					2.5	
123577	10	N	10	W	32	448	2117					60	
123578	10	N	10	W	32	481	2177						
123579	10	N	10	W	32	475	2165						
123581	10	N	10	W	32	472							
123582	10	N	10	W	32	496	2211						
123583	10	N	10	W	32	470							
123584	10	N	10	W	32	471	2147						
123585	10	N	10	W	32	461	2134					60	
123586	10	N	10	W	32	472	2157						
123587	10	N	10	W	32	476	2175						
123588	10	N	10	W	32	475	2161					25	
123589	10	N	10	W	32	482	2159	2220	2298			15	
123590	10	N	10	W	32	474	2230						
123591	10	N	10	W	32	472	2147						
123592	10	N	10	W	32	468	2135					90	
123593	10	N	10	W	32	458	2130						
123594	10	N	10	W	32	461	2117					8	
123595	10	N	10	W	32	463	2130					120	
123597	10	N	10	W	33	532	2318						
123639	10	N	11	W	25	445	2303	2390	2471				
157271	10	N	11	W	36	446	2331	2418	2488		2520		
157445	9	N	10	W	6	446	2297	2381	2418	2440	2482		

Field name: South Martin

IGS ID: 10645

DOE ID: na

Location: Martin County, 1N-4W

Discovery date: 1986

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,796 ft.)

Field type: natural gas

Total number production wells: 2

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Ordovician, Knox Supergroup (5,705 ft.)

Field characteristic: Limited well control, but no observable closure at Mississippian.

Reservoir characteristics:

Field name: Spencer Consolidated

IGS ID: 10649

DOE ID: 669059

Location: Posey County, 7&8S-14W

Discovery date: 1948

Lower Paleozoic reservoir unit (depth):

Devonian, Muscatatuck Group, Jeffersonville Ls. (4,784 ft.)

Cambrian/Ordovician, Knox Supergroup (7,750 ft.)

Field type: oil

Total number production wells: 175

Area: 1170 acres

Cumulative production: 4,233,833 bbls. (2002)

Other reservoir units:

Eight different Mississippian units

Deepest unit penetrated (depth): Cambrian/Ordovician, Knox Supergroup (8,429 ft.)

Field characteristic: Anticline on graben structure along Wabash Valley Fault System with closure in excess of 20 ft. at Mississippian against east bounding fault.

Reservoir characteristics:

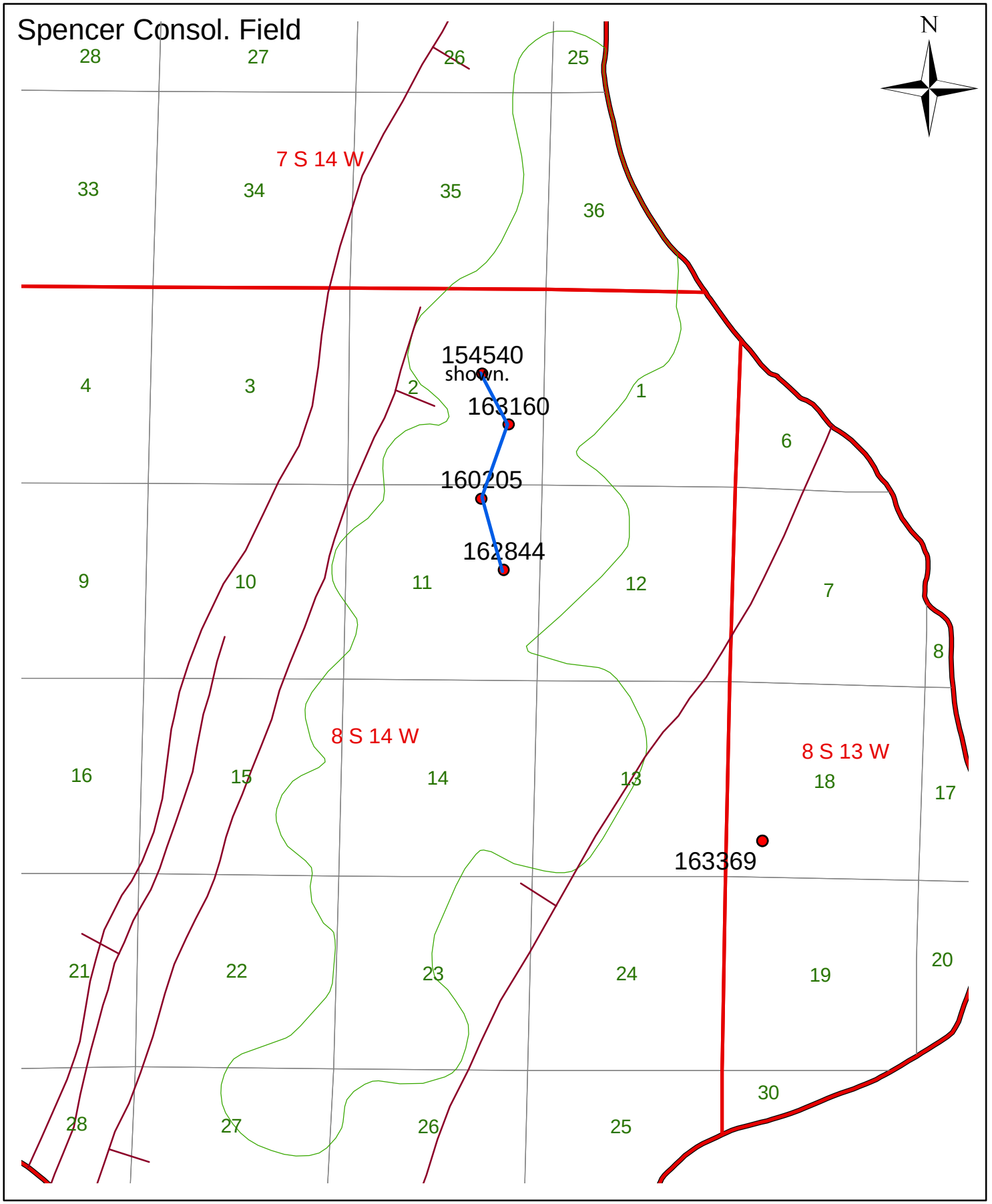

Figure 1: Map showing the location and wells at Spencer Consolidated Field, Posey County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 3. Bounding fault traces for the field are also shown.

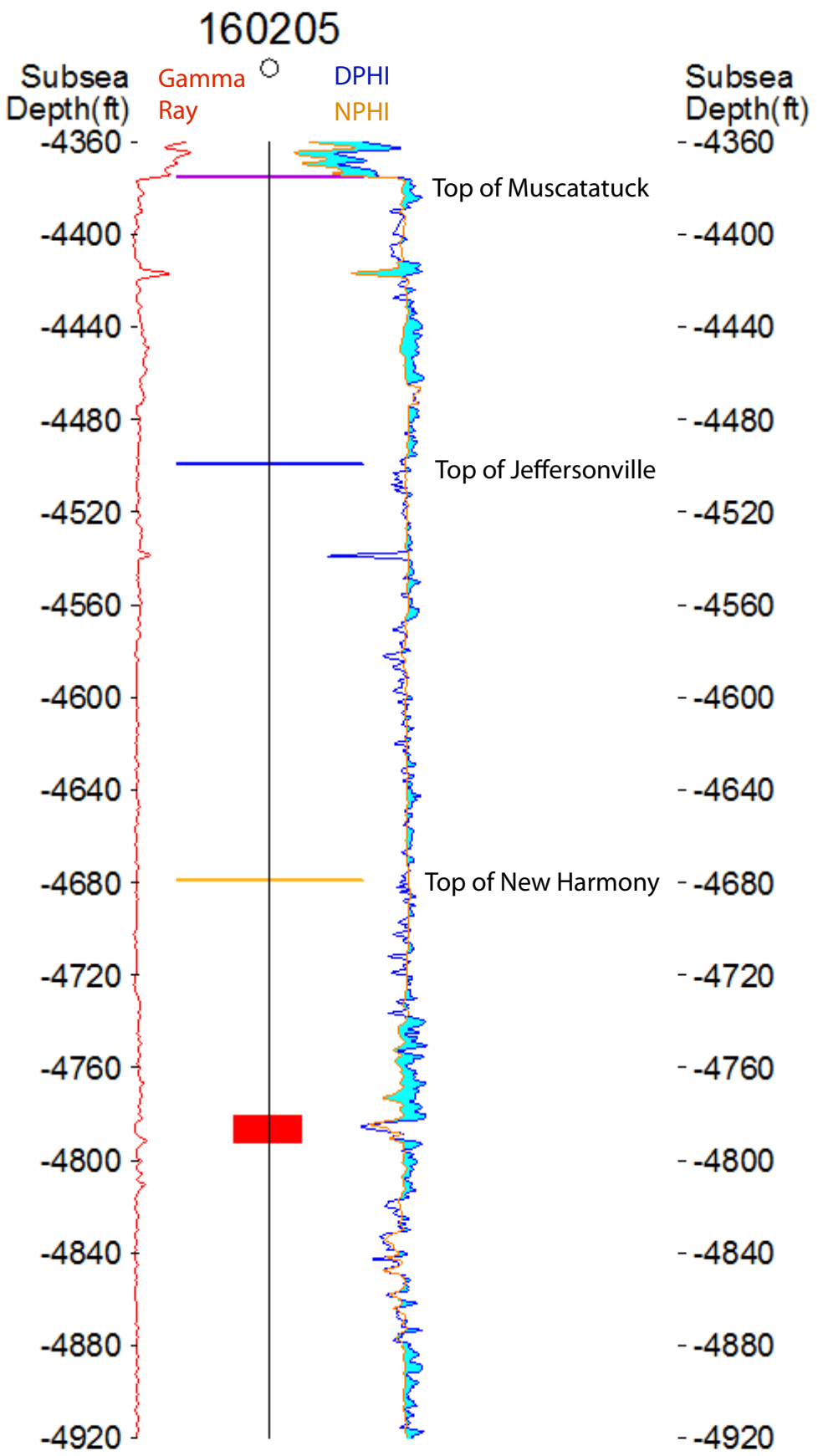

Figure 2: Type log section showing the Devonian formations at Spencer Consol. Field, Posey County. Red box shows completion interval for oil production.

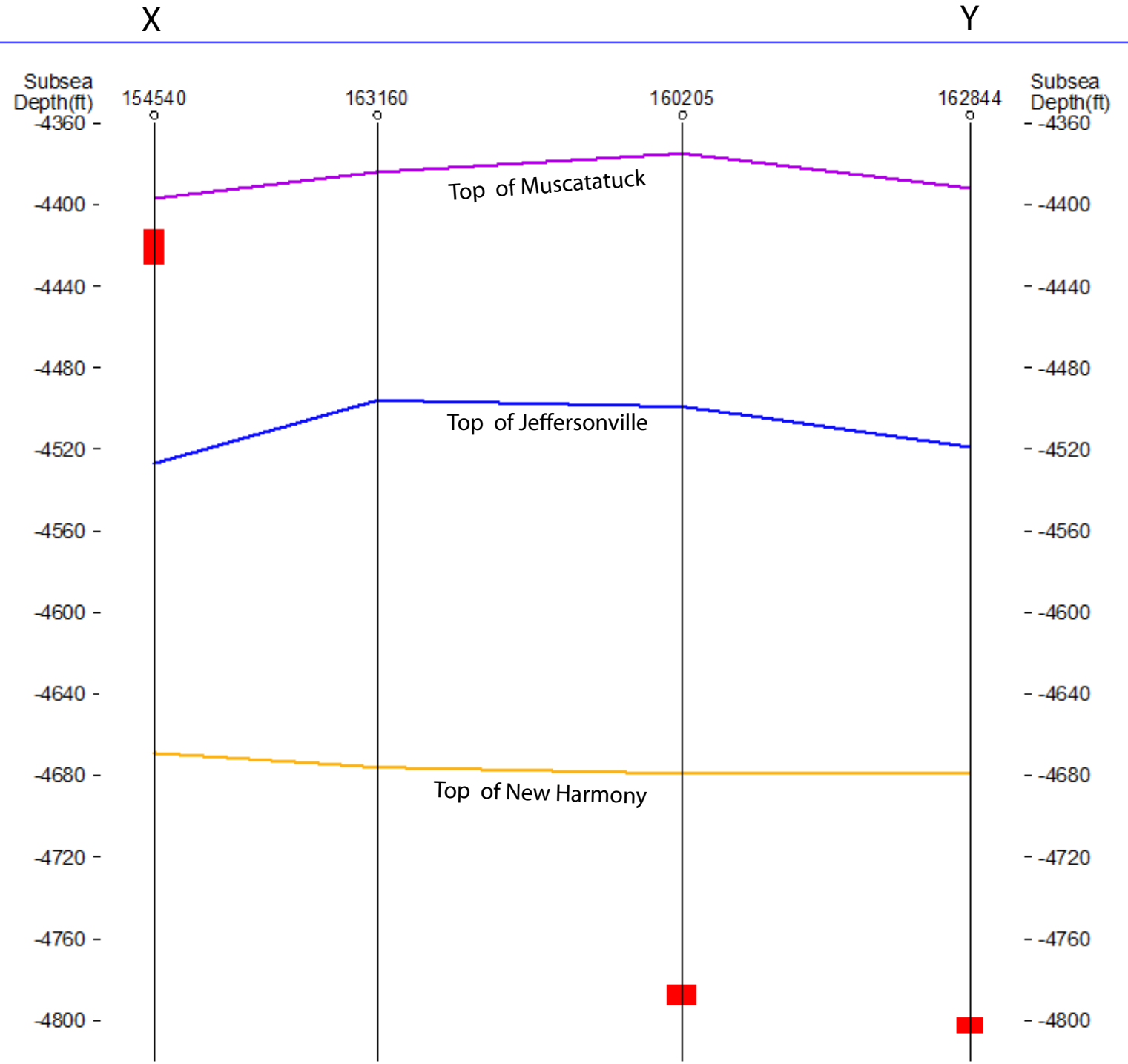

Figure 3: X-Y Cross section showing the Devonian subsurface structure across Spencer Consol. Field, Posey County. For location of the cross section refer to Figure 1. Red boxes indicate the completion intervals for oil production.

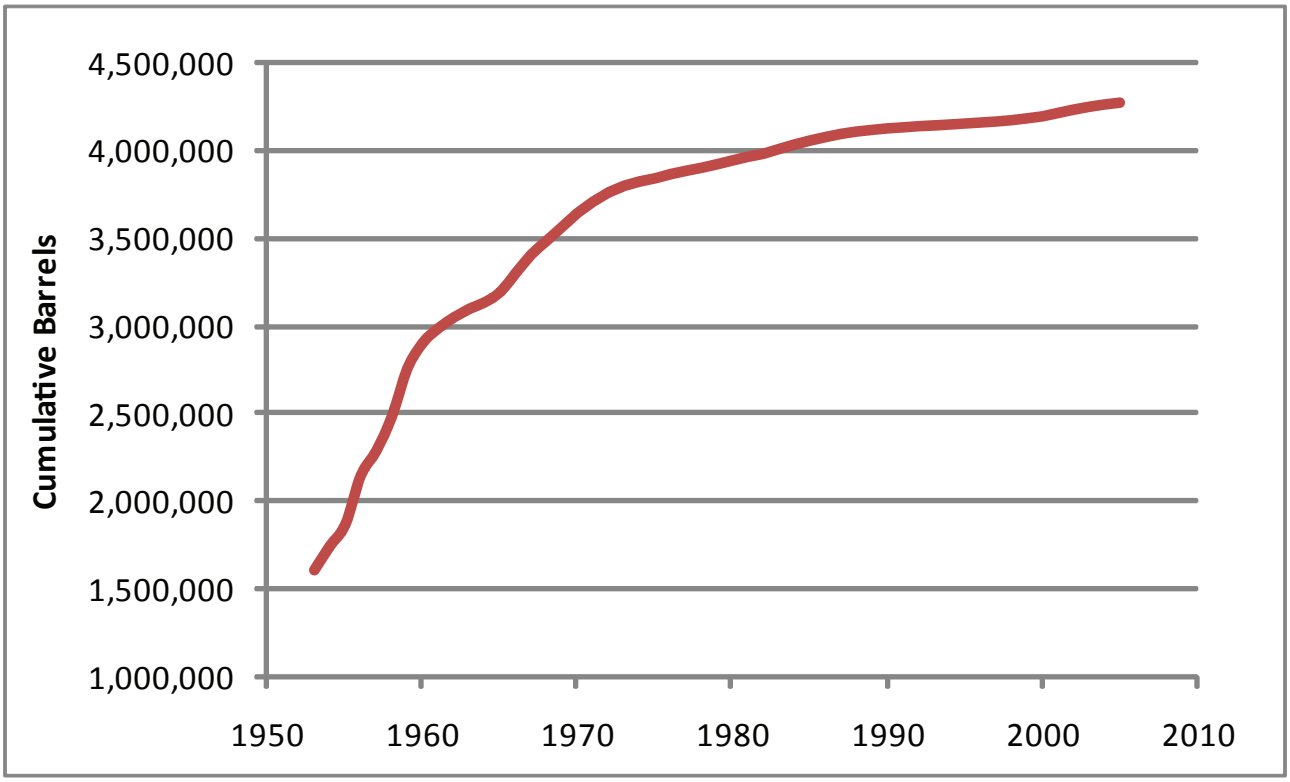

Figure - 4: Cumulative oil production history from Spencer Consol. Field, Posey County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Spencer Consol. Field, Posey County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of New Harmony	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
163369	8	S	13	W	18	350	4483	4606	4749		14	
154540	8	S	14	W	2	371	4768	4898	5040		50	
163160	8	S	14	W	2	374	4758	4870	5050		24	
160205	8	S	14	W	11	381	4756	4880	5080		32	
162844	8	S	14	W	11	361	4753	4880	5040		86	

Field name: Spring Hill

IGS ID: 10651

DOE ID: 671136

Location: Vigo County, 11N-9W

Discovery date: 1948

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,668 ft.)

Field type: oil

Total number production wells: 39

Area: 370 acres

Cumulative production: 1,105,310 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Ordovician, Trenton Ls. (2,933 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

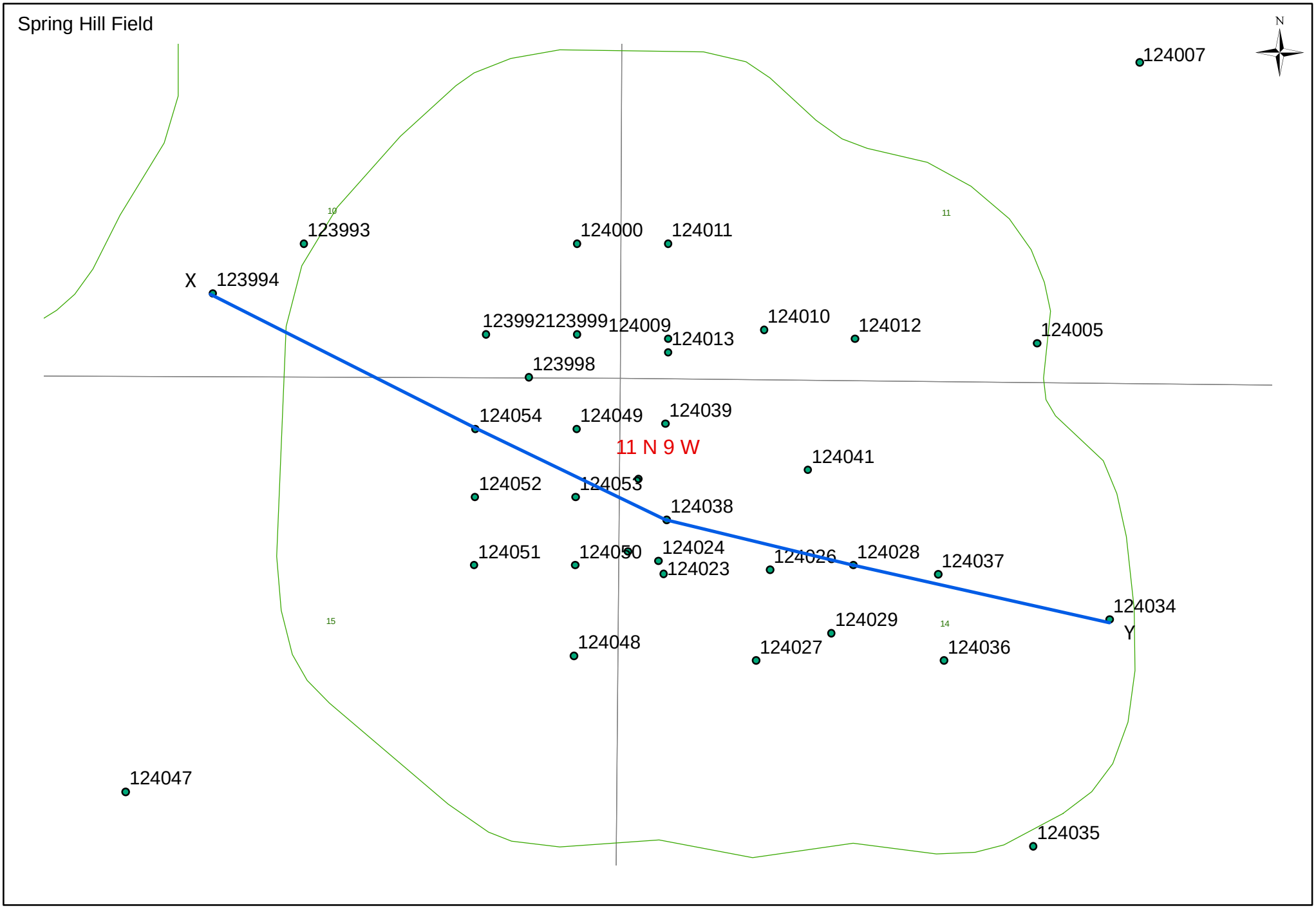

Figure 1: Map showing the location of Spring Hill Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 4).

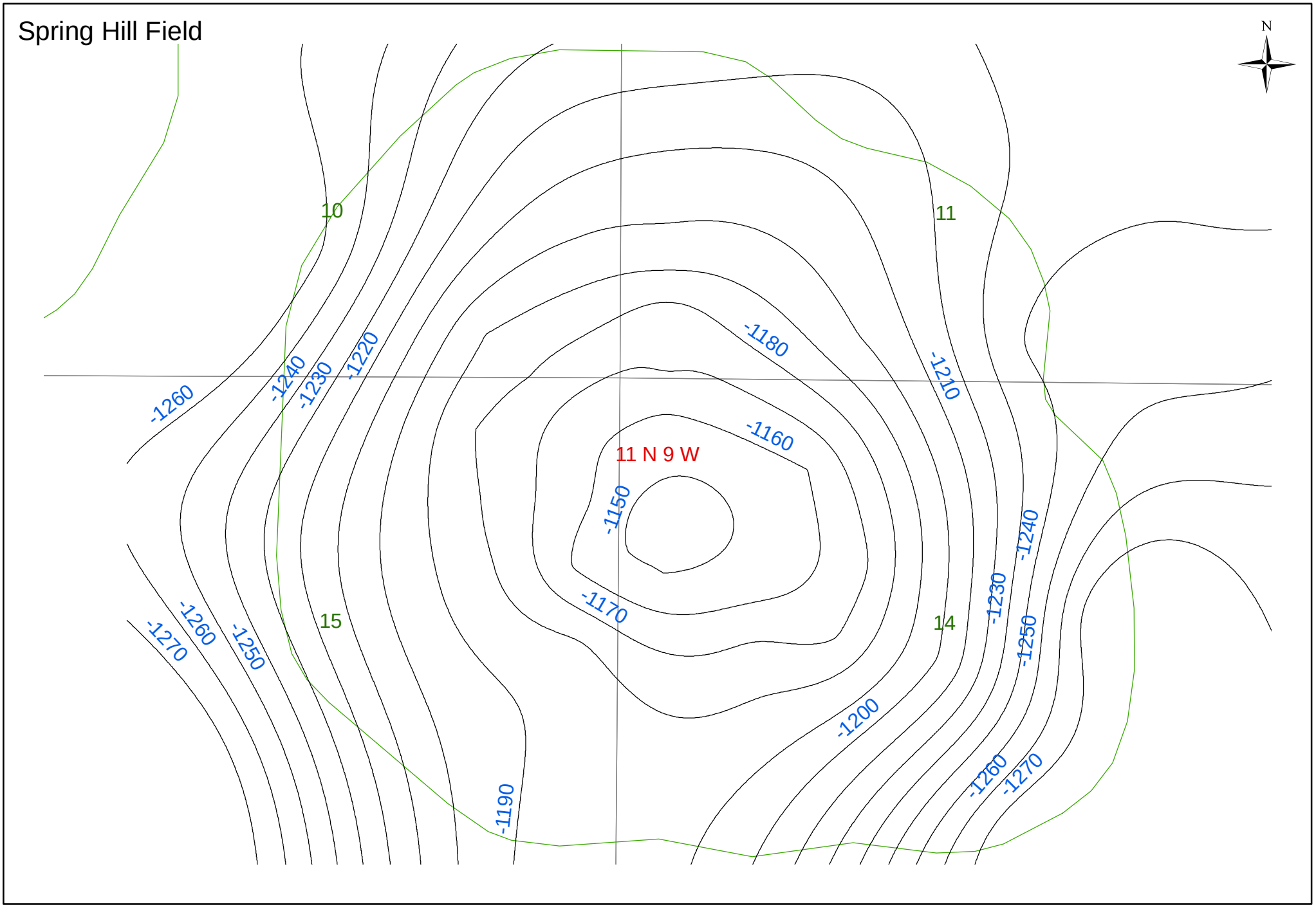

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Spring Hill Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

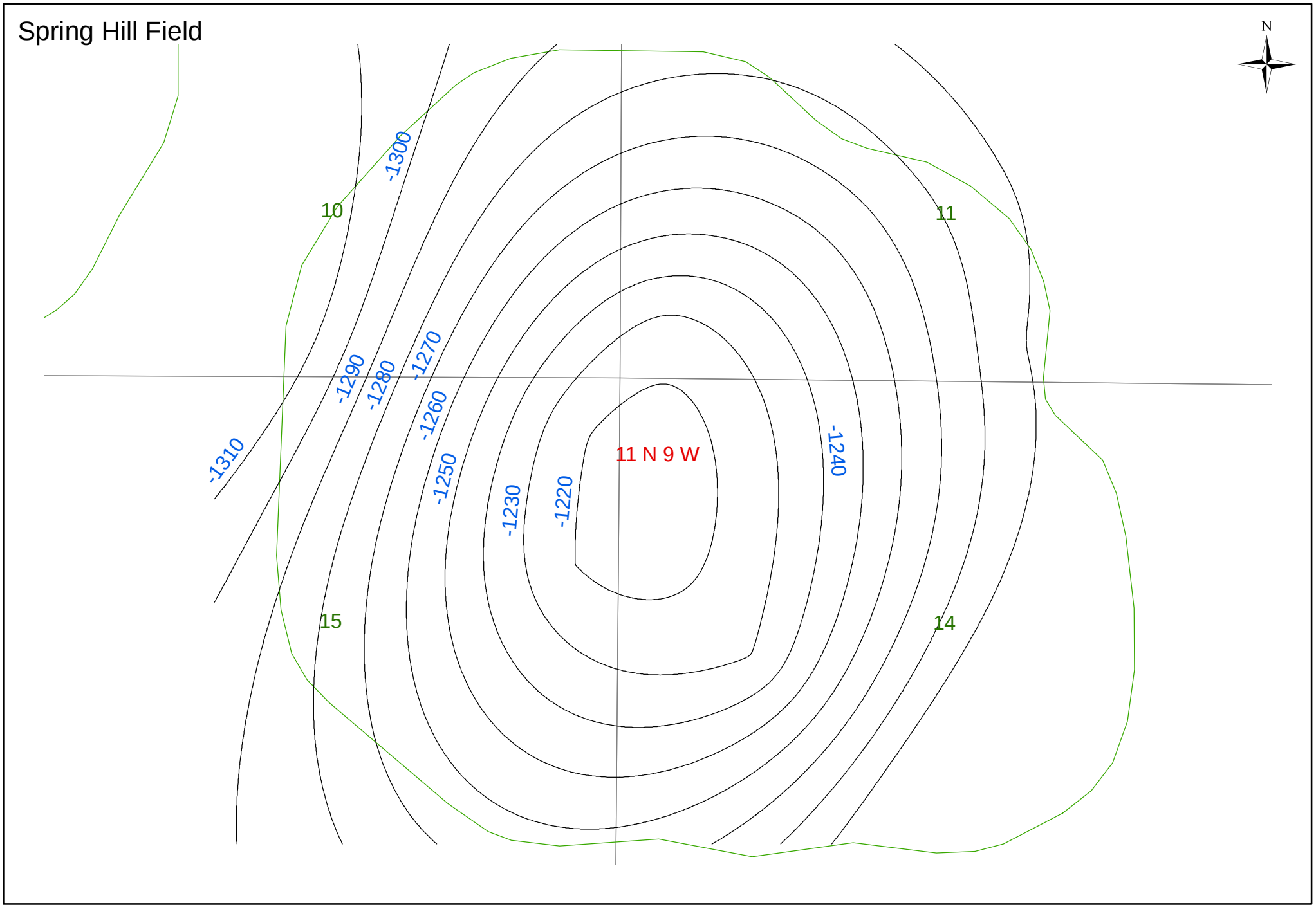

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Spring Hill Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

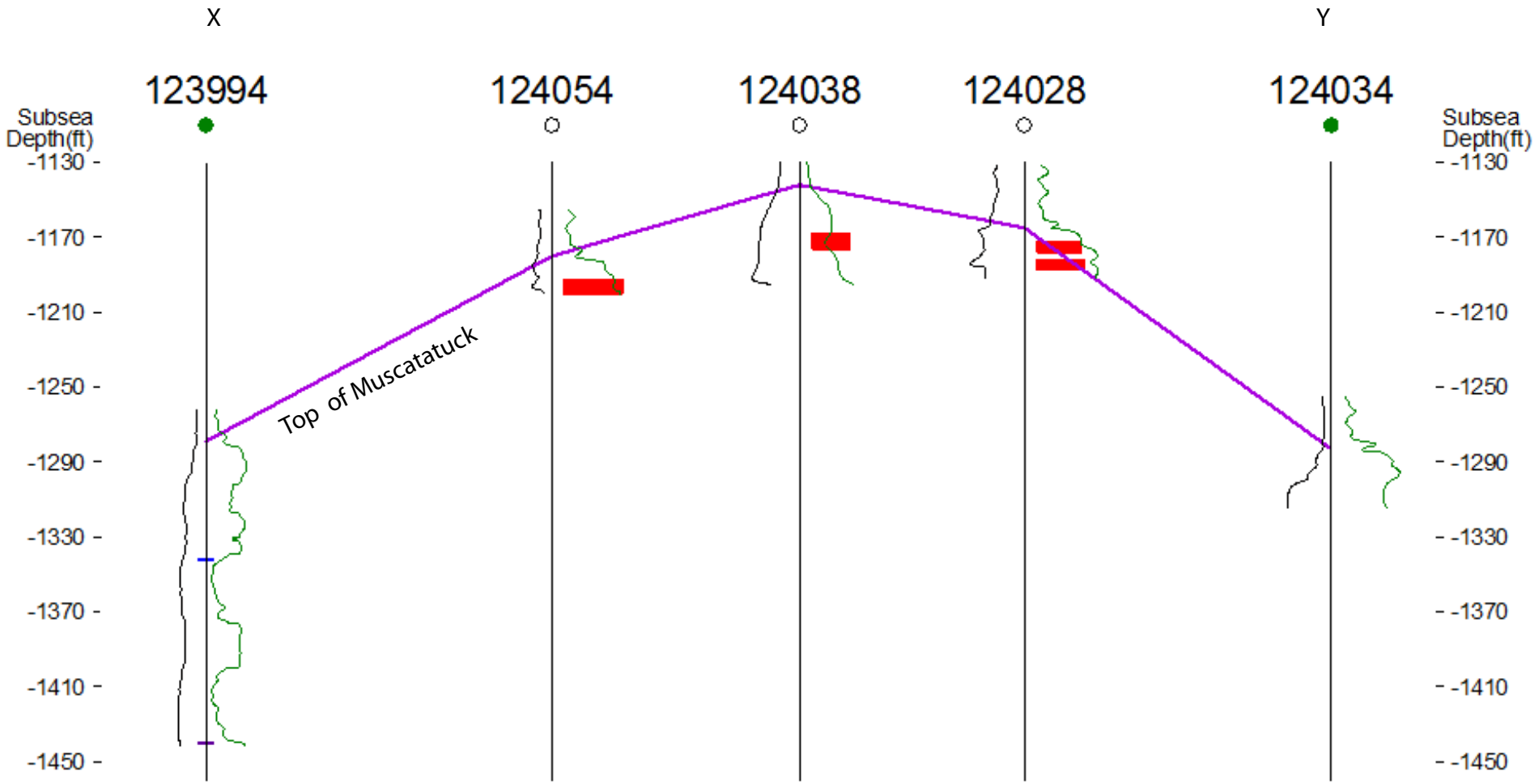

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Spring Hill Field, Vigo County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

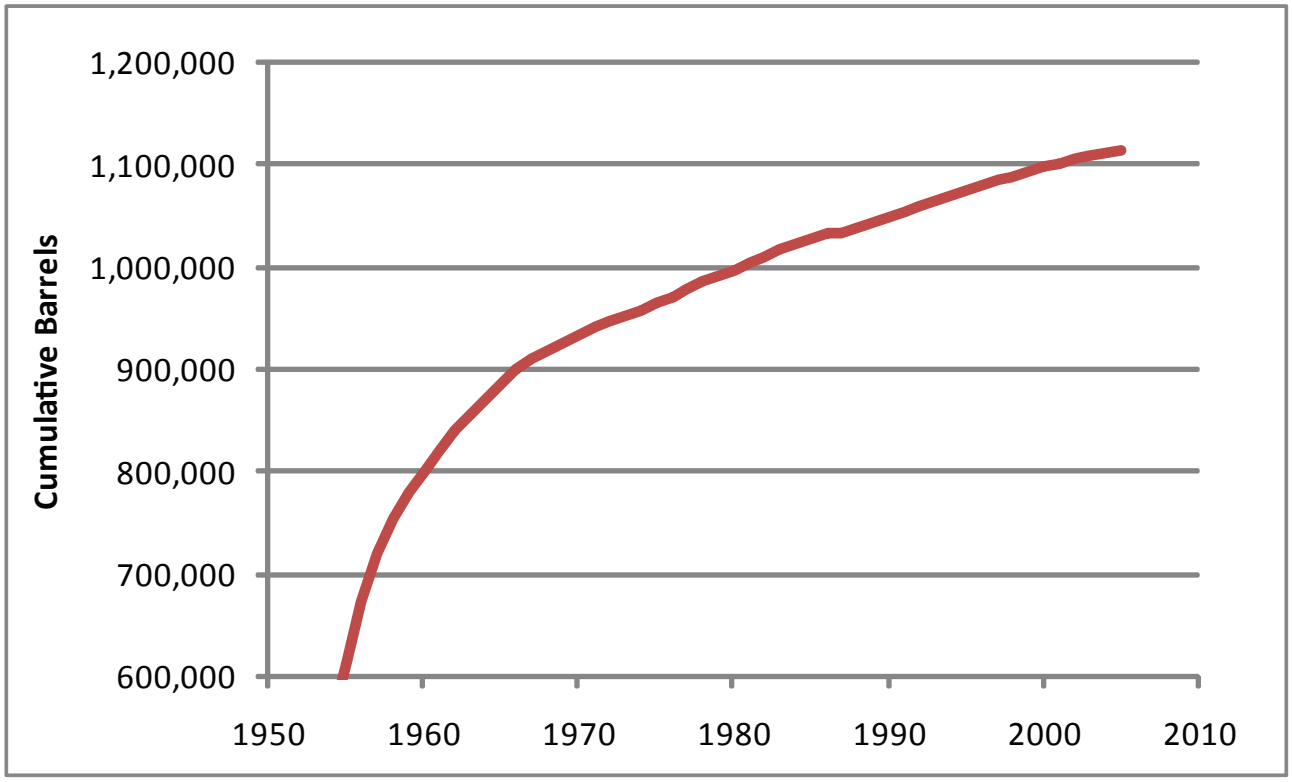

Figure - 5: Cumulative oil production history for Spring Hill Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in the Spring Hill Field, Vigo County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
123992	11	N	9	W	10	502	1692				170	
123993	11	N	9	W	10	495	1761					
123994	11	N	9	W	10	498	1777	1840	1938			
123996	11	N	9	W	10	505	1767					
123998	11	N	9	W	10	500	1680				120	
123999	11	N	9	W	10	502	1683				175	
124000	11	N	9	W	10	504	1703				52	
124005	11	N	9	W	11	528	1771	1820				
124006	11	N	9	W	11	502	1739	1794				
124007	11	N	9	W	11	556	1797					
124008	11	N	9	W	11	499					30	
124009	11	N	9	W	11	504	1672	1728			84	
124010	11	N	9	W	11	502	1687				126	
124011	11	N	9	W	11	501	1698				95	
124012	11	N	9	W	11	499	1698				45	
124013	11	N	9	W	11	499	1673				60	
124014	11	N	9	W	11	498	1689				25	
124016	11	N	9	W	12	558	1789	1846				
124021	11	N	9	W	13	511	1776					
124023	11	N	9	W	14	502	1652					
124024	11	N	9	W	14	503	1652				100	
124025	11	N	9	W	14	505					25	
124026	11	N	9	W	14	506	1661				190	
124027	11	N	9	W	14	503	1678	1734			50	
124028	11	N	9	W	14	528	1693				185	
124029	11	N	9	W	14	517	1685				30	
124032	11	N	9	W	14	501	1651				16	
124033	11	N	9	W	14	506	1659				7	
124034	11	N	9	W	14	525	1808					
124035	11	N	9	W	14	507	1793	1845				
124036	11	N	9	W	14	514	1716				20	
124037	11	N	9	W	14	515	1711				80	
124038	11	N	9	W	14	504	1646				60	
124039	11	N	9	W	14	503	1661	1720	1786		200	
124040	11	N	9	W	14	498					60	
124041	11	N	9	W	14	510	1670				30	
124042	11	N	9	W	14	498					50	
124043	11	N	9	W	14	497					120	
124044	11	N	9	W	14	497					8	
124045	11	N	9	W	14	507					30	
124046	11	N	9	W	14	512	1793					
124047	11	N	9	W	15	504	1801					
124048	11	N	9	W	15	508	1693				23	
124049	11	N	9	W	15	502	1666	1724	1784	1846	90	
124050	11	N	9	W	15	504	1663	1724			200	
124051	11	N	9	W	15	504	1688				50	
124052	11	N	9	W	15	503	1684				110	
124053	11	N	9	W	15	503	1667				30	
124054	11	N	9	W	15	505	1685				109	

Field name: State Line

IGS ID: 10685 (oil), 10826 (gas storage)

DOE ID: 677538

Location: Vigo County, 12N-10W

Discovery date: 1950 (oil), 1963 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,823 ft.)

Field type: oil (abandoned) & gas storage (not currently in use)

Total number production wells: 7 (oil), 11 (storage)

Area: 140 acres

Cumulative production: 26,767 bbls. (2002)

Other reservoir units: na

Deepest unit penetrated (depth): Silurian (2,181 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 100 ft. at top of Muscatatuck.

Reservoir characteristics:

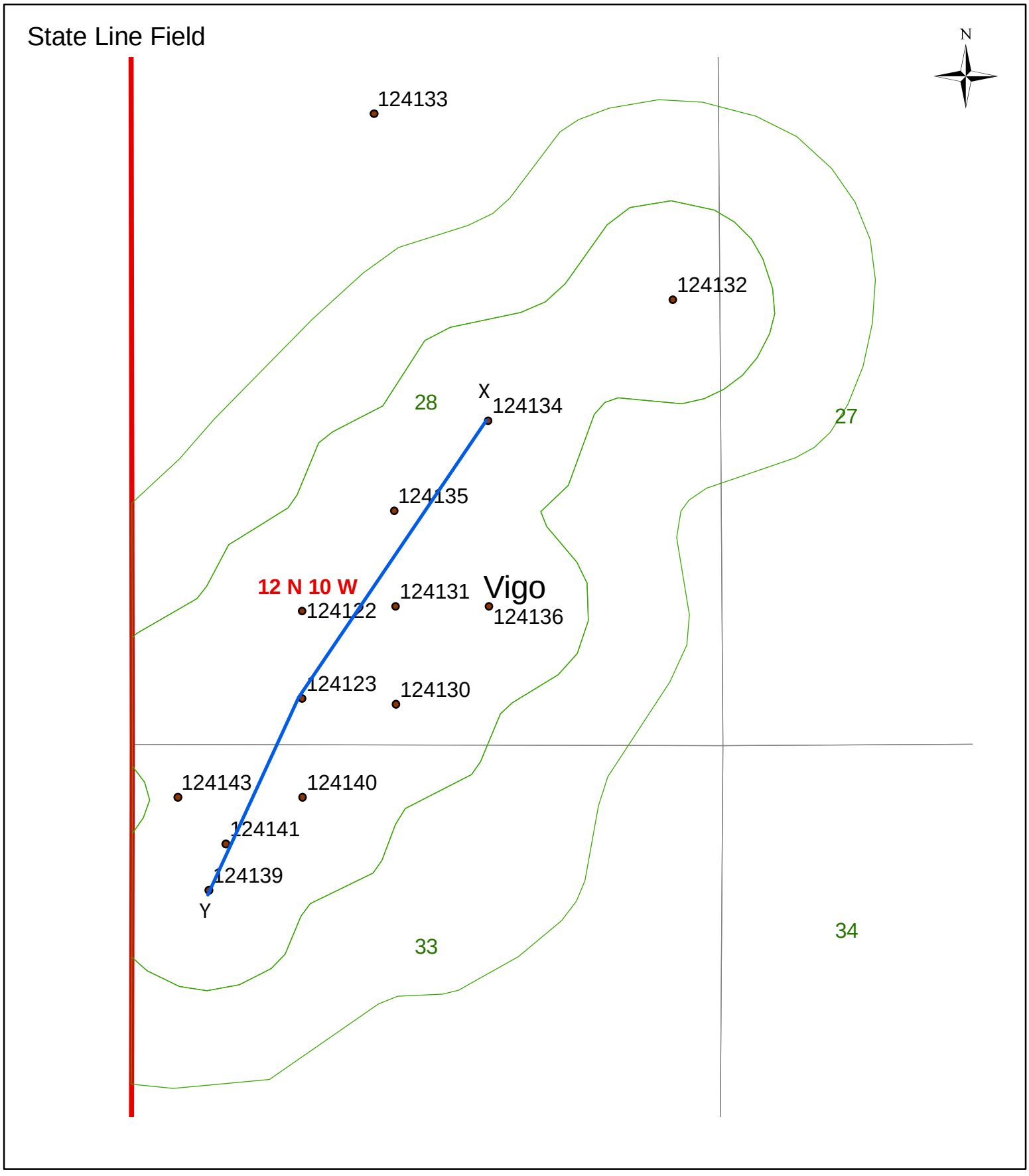

Figure 1: Map showing the location of State Line Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 5).

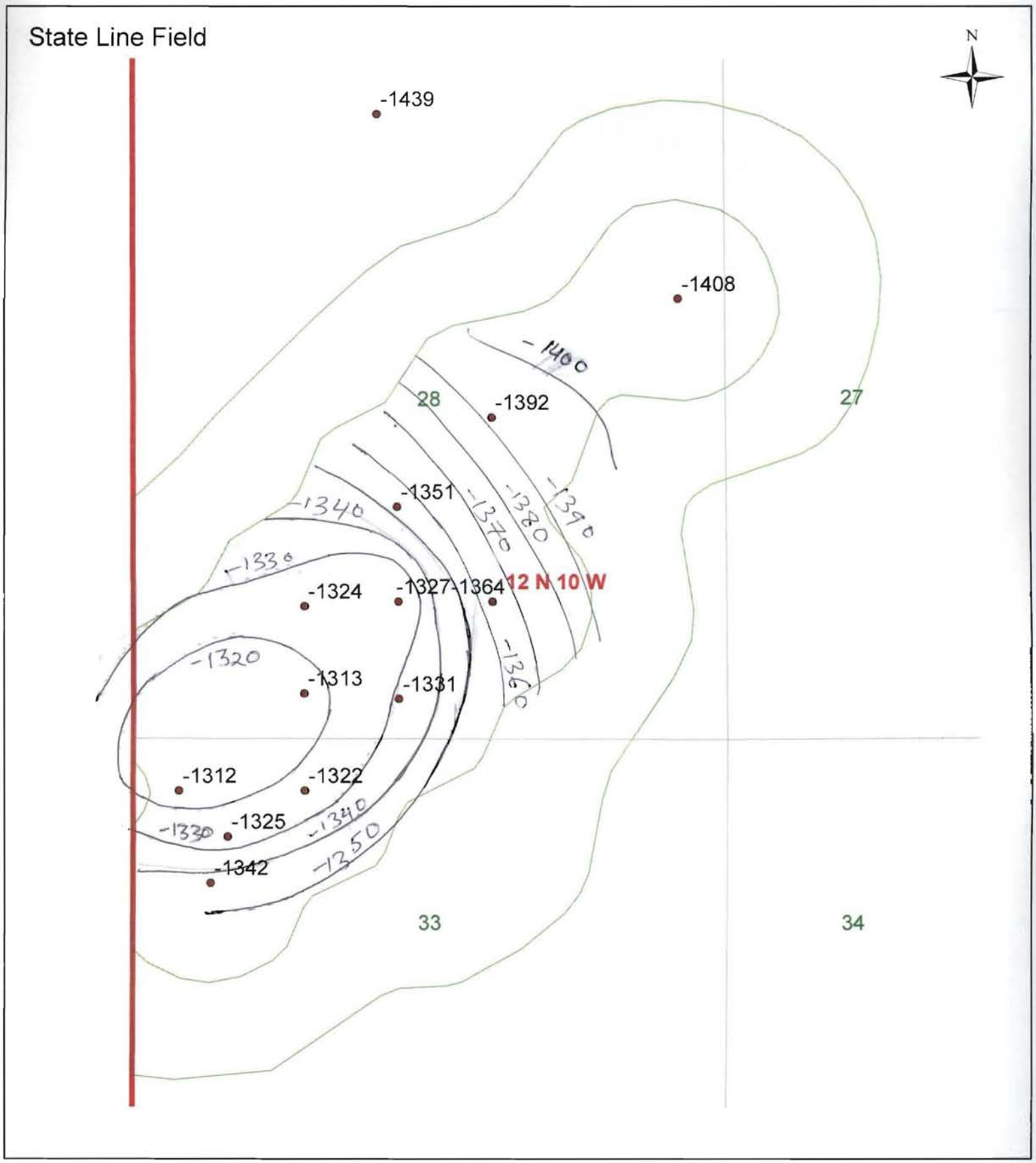

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in State Line Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

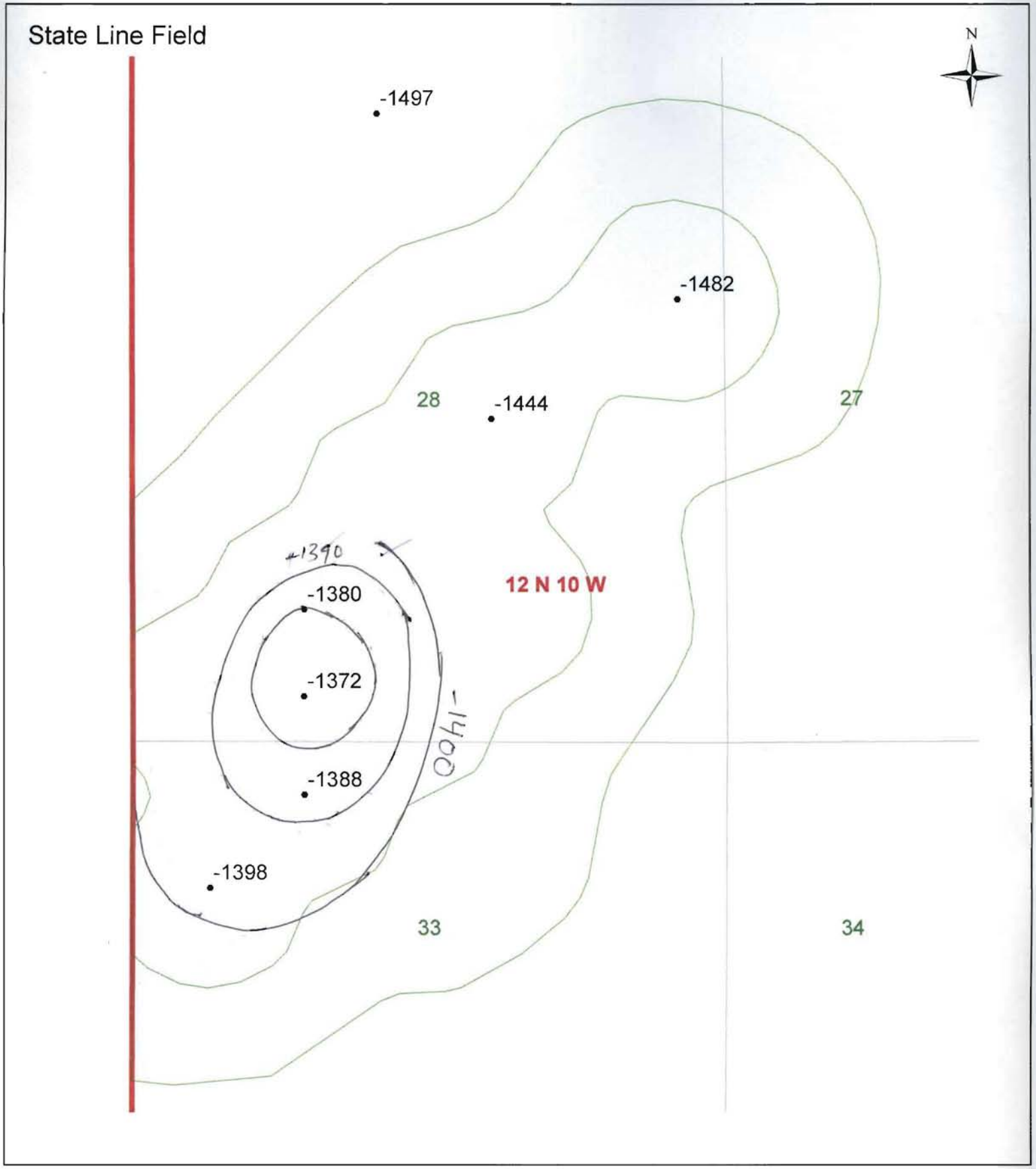

Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in State Line Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

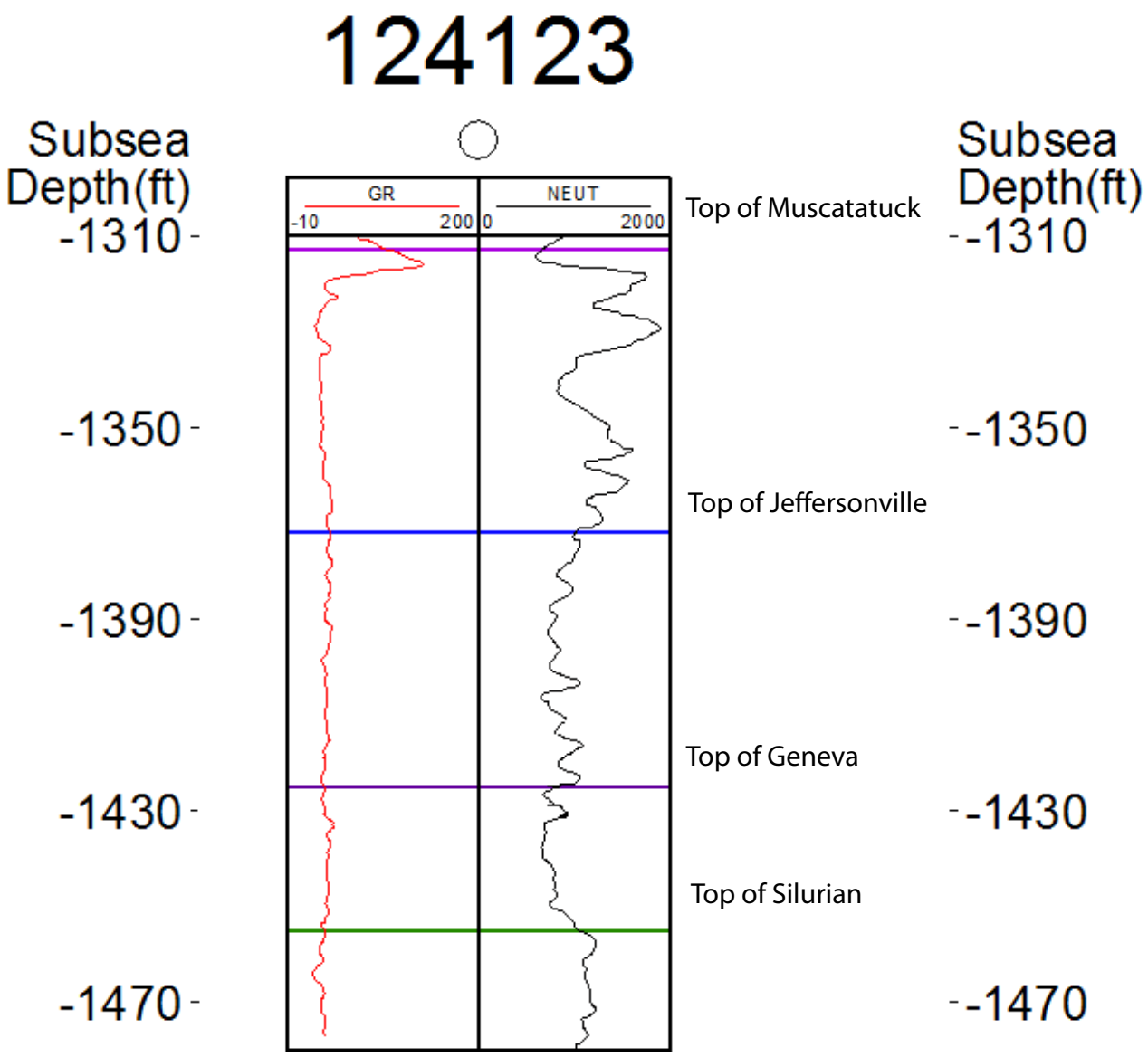

Figure 4: Type log section showing the Devonian formations at State Line Field, Vigo County.

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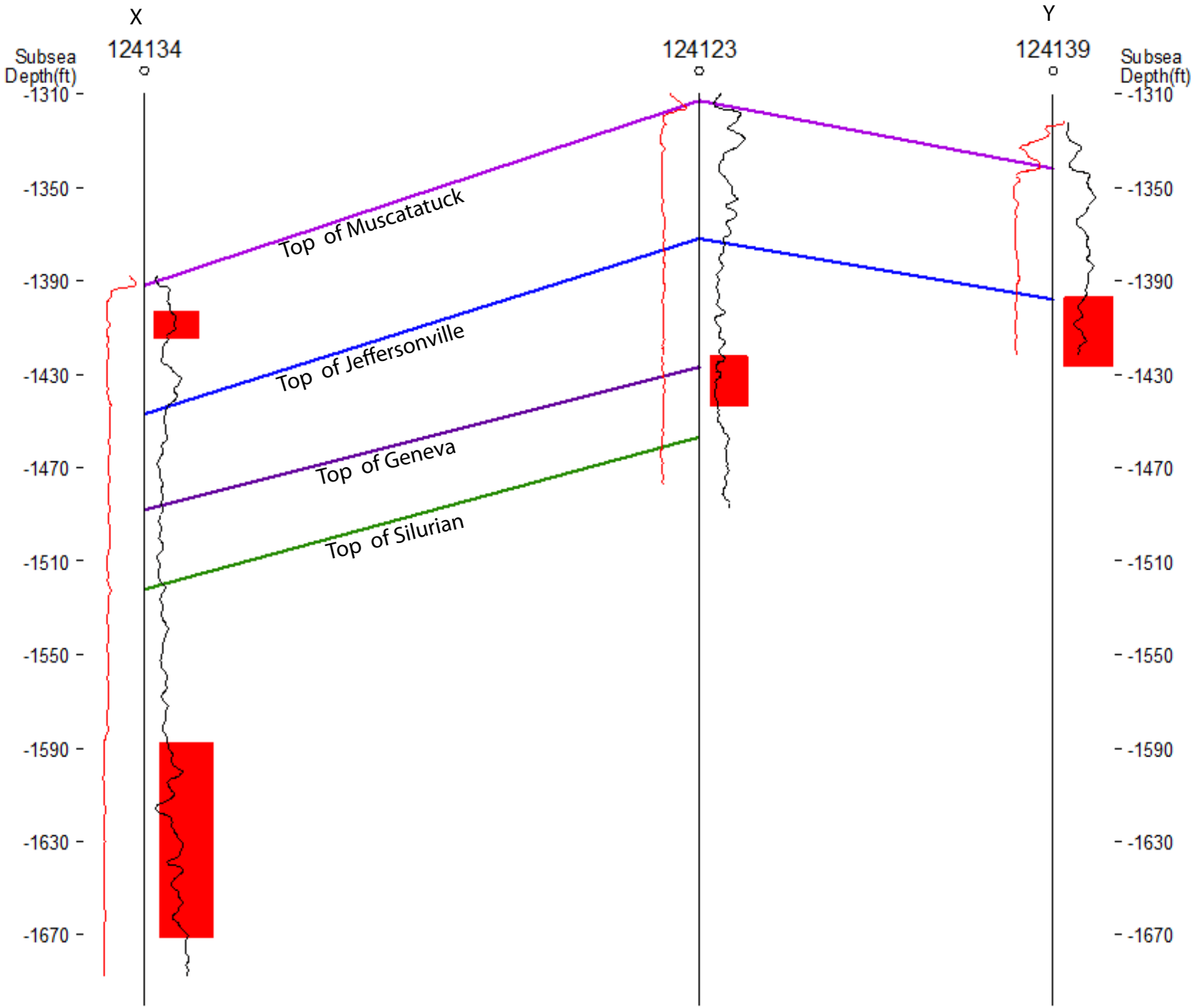

Figure 5: X-Y Cross section showing the Devonian subsurface structure acorss State Line Field, Vigo County. The red color box shows the completion intervals for the oil production or gas storage. For location of the cross section refer to Figure 1.

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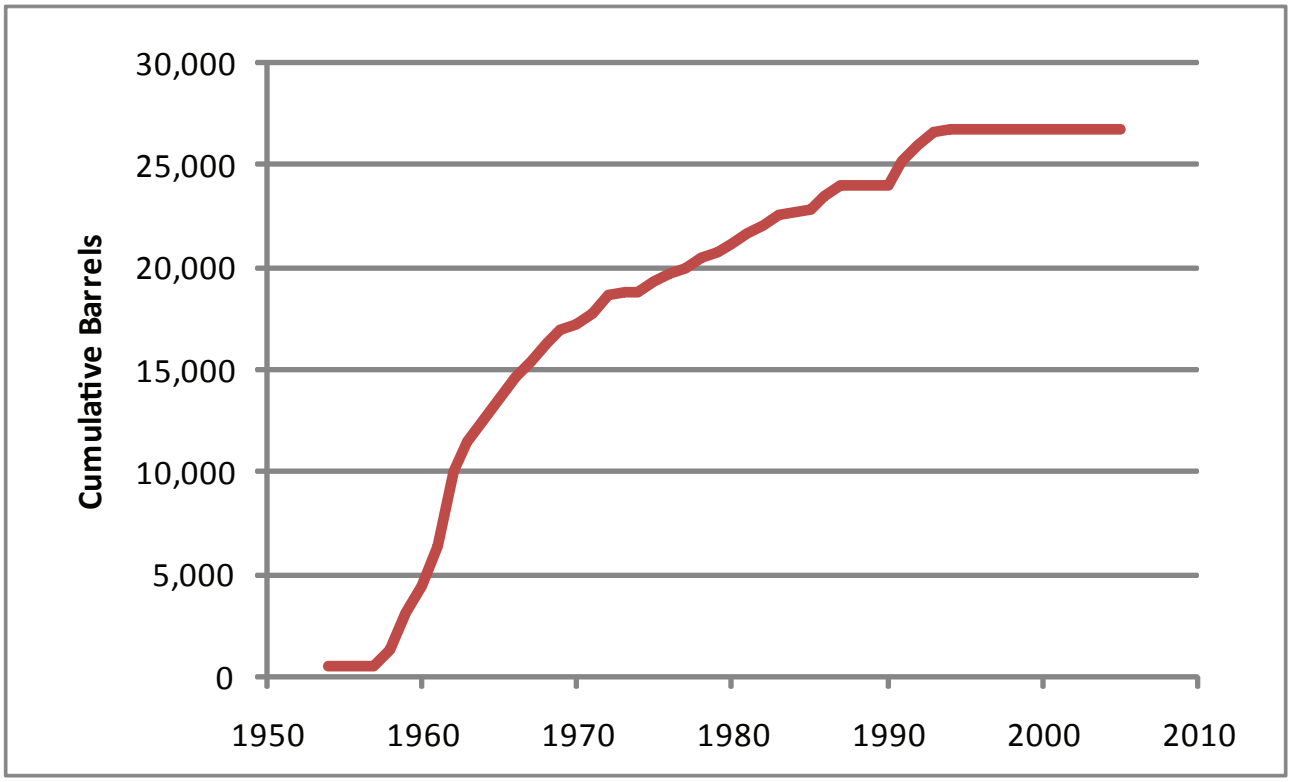

Figure - 6: Cumulative oil production history from State Line Field, Vigo County since 1954.

Table-1: List of the wells used for subsurface structure mapping in State Line Field, Vigo County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)	Core (P/A)
124122	12	N	10	W	28	494	1818	1874	1932	1970			
124123	12	N	10	W	28	493	1806	1865	1920	1948			Present
124124	12	N	10	W	28	489							
124129	12	N	10	W	28	491					5		
124130	12	N	10	W	28	487	1818				3		
124131	12	N	10	W	28	491	1818				4		
124132	12	N	10	W	28	518	1926	2000	2048	2078			
124133	12	N	10	W	28	565	2004	2062					
124134	12	N	10	W	28	512	1904	1956	2000	2050			
124135	12	N	10	W	28	507	1858						
124136	12	N	10	W	28	486	1850						
124137	12	N	10	W	28	489							
124139	12	N	10	W	33	538	1880	1936					
124140	12	N	10	W	33	488	1810	1876			3		
124141	12	N	10	W	33	500	1825				14		
124143	12	N	10	W	33	492	1804				9		
124144	12	N	10	W	33	489					20		

Field name: Staunton

IGS ID: 10686

DOE ID: na

Location: Clay County, 12N-7W

Discovery date: 1953

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1823 ft.)

Field type: oil

Total number production wells: 13

Area: 220 acres

Cumulative production: 420,134 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1711 ft.)

Field characteristic: Subtle anticlinal structure with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

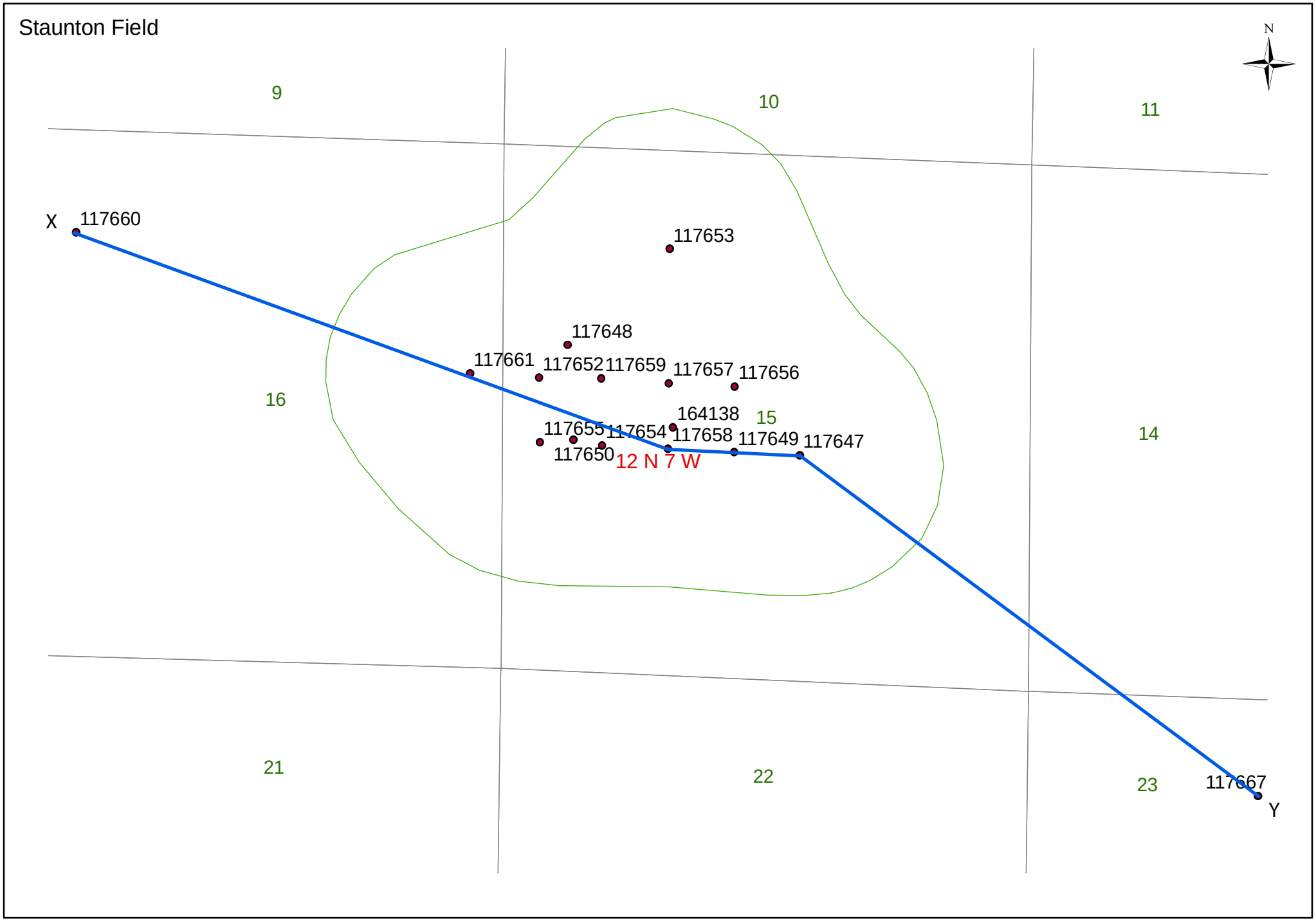

Figure 1: Map showing the location and wells at Staunton Field, Clay County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figure 4.

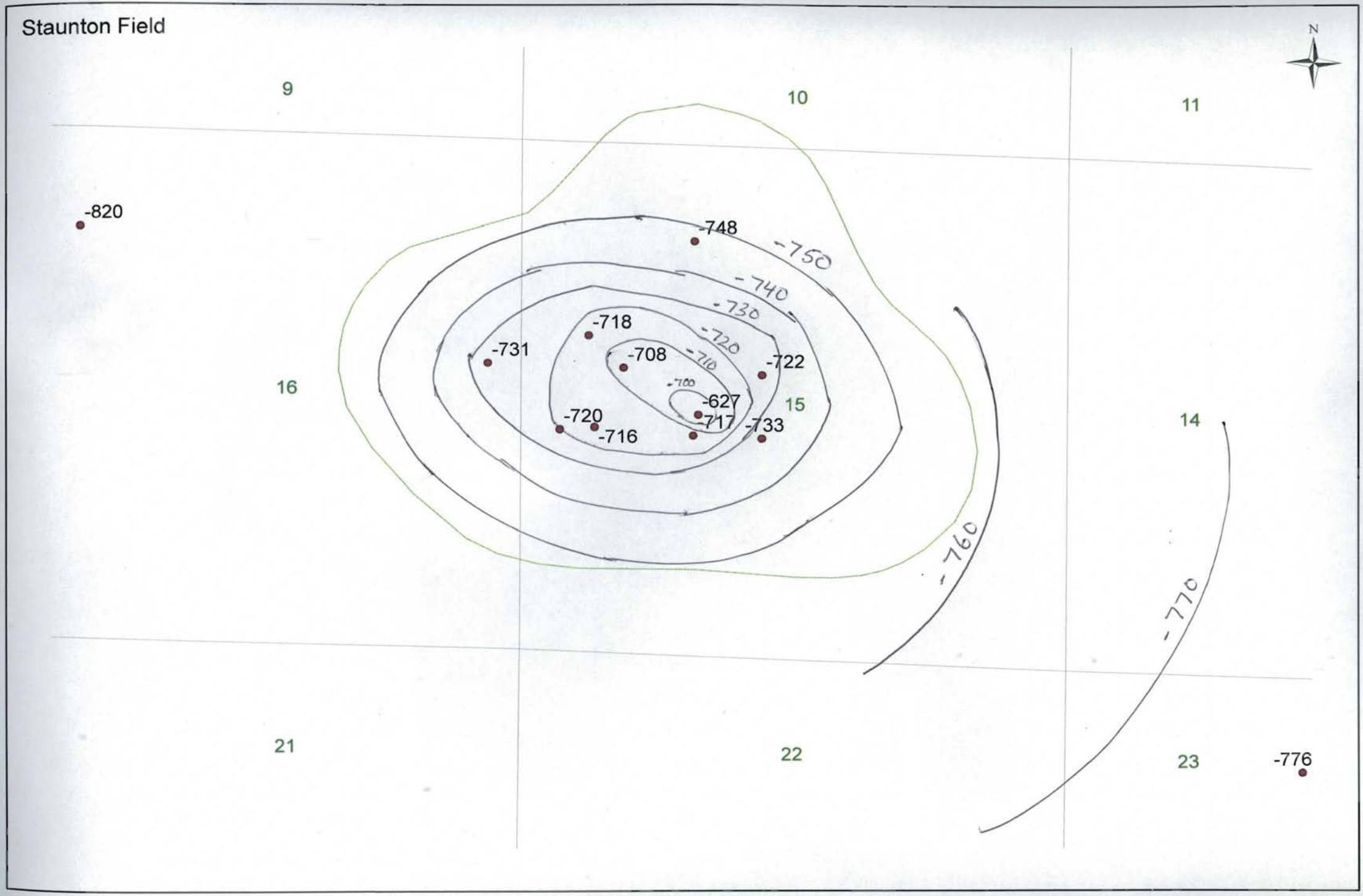

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Staunton Field, Clay County. Contours show values below sea level, contour interval is 10 ft .

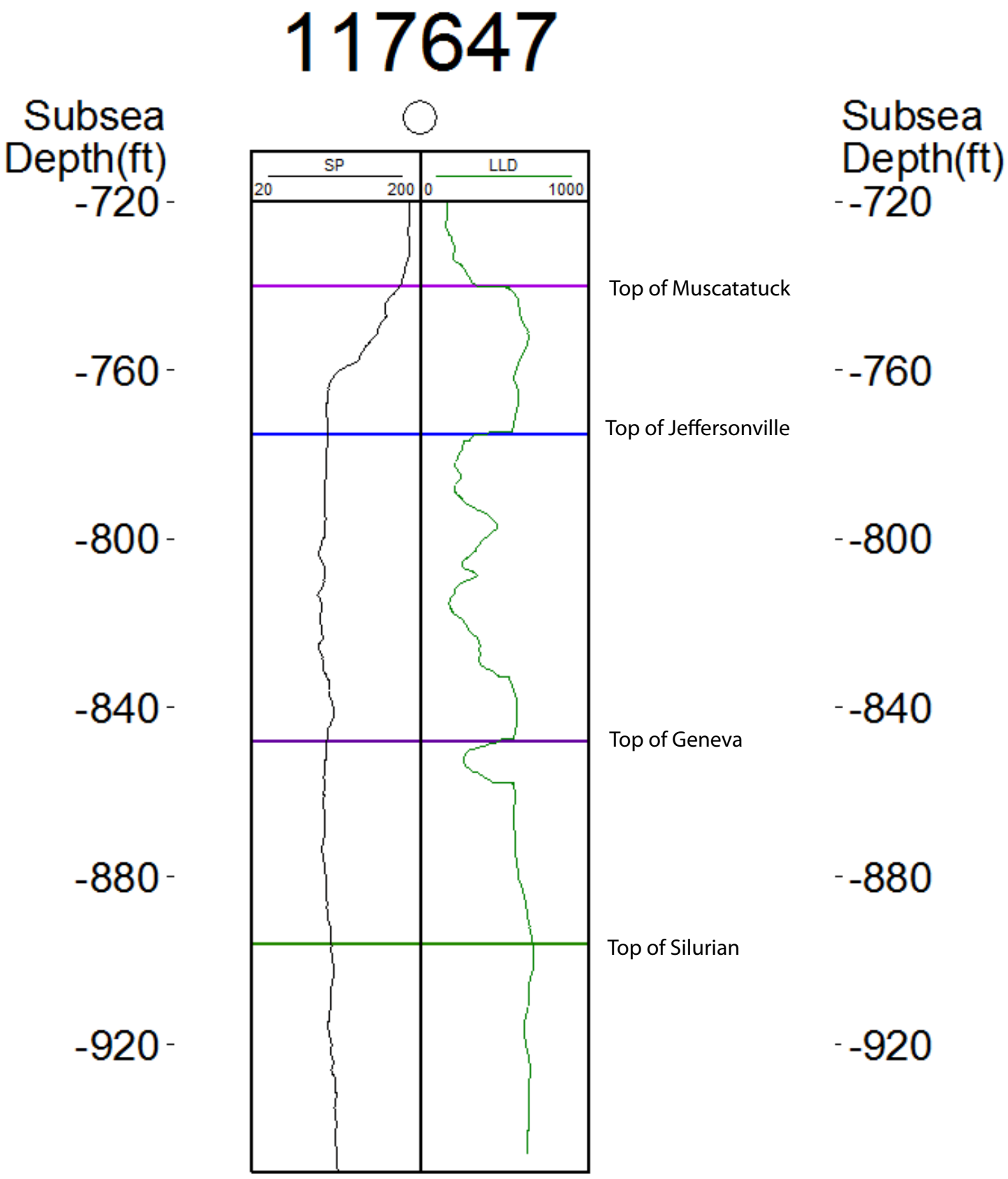

Figure 3: Type log section showing the Devonian formations at Staunton Field, Clay County.

HS=1

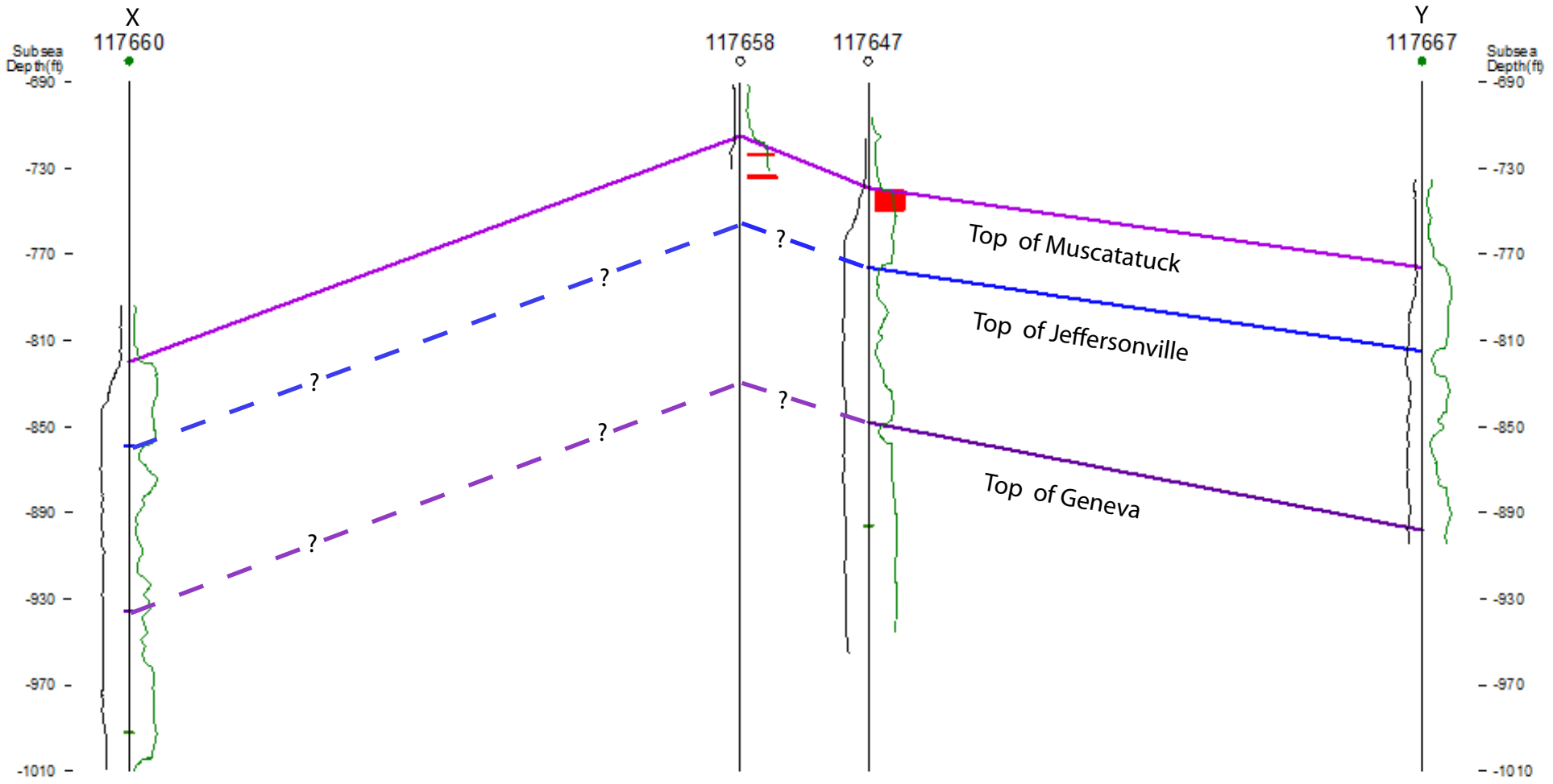

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Staunton Field, Clay County. The red color box shows the completion intervals for the oil production or observation. For location of the cross section refer to Figure 1.

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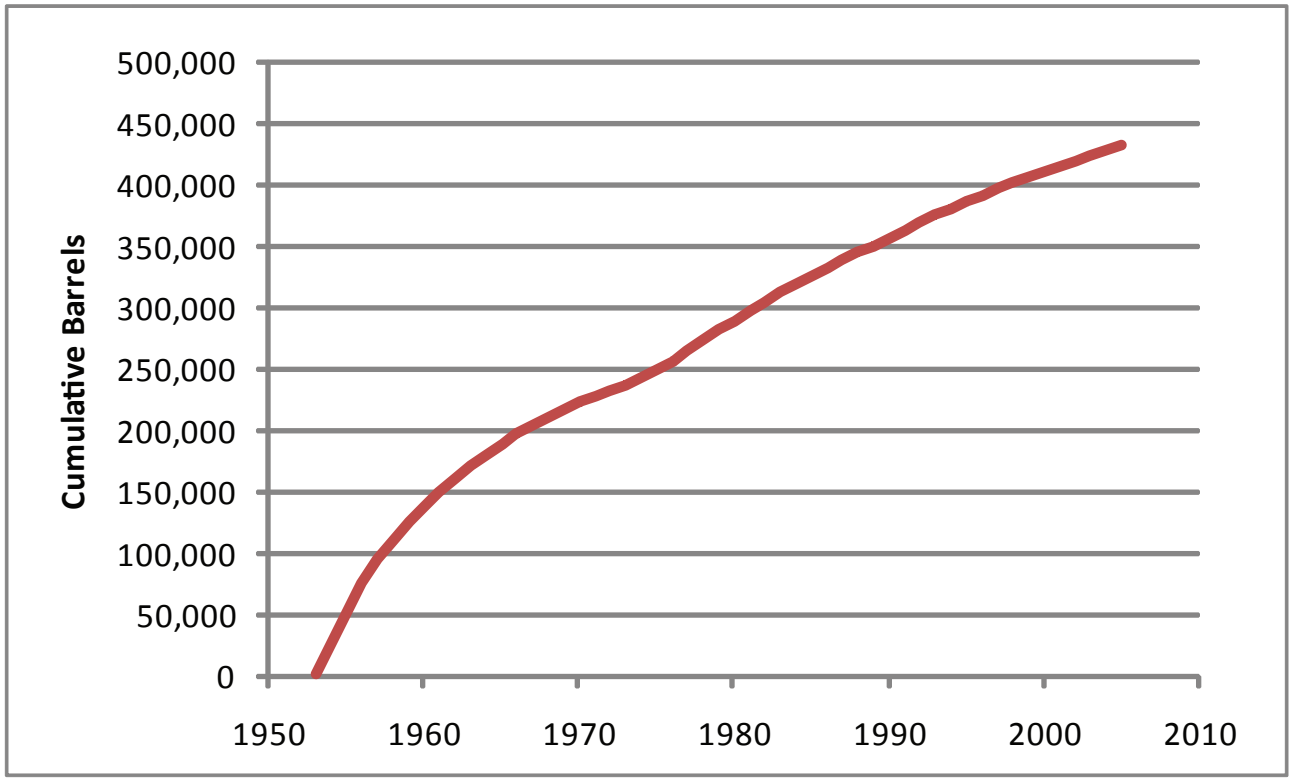

Figure - 5: Cumulative oil production history from Staunton Field, Clay County since 1953.

Table-1: List of the wells used for subsurface structure mapping in the Staunton Field, Clay County. The wells selected have a TD at least in the formation of the Devonian age.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
117647	12	N	7	W	15	664	1405	1445	1512	1560	24	
117648	12	N	7	W	15	670	1388				12	
117649	12	N	7	W	15	653	1386				15	
117650	12	N	7	W	15	660	1376				10	
117652	12	N	7	W	15	667					40	
117653	12	N	7	W	15	659	1407				16	
117654	12	N	7	W	15	658					40	
117655	12	N	7	W	15	661	1381				20	
117656	12	N	7	W	15	656	1378				20	
117657	12	N	7	W	15	650					15	
117658	12	N	7	W	15	659	1376				35	
117659	12	N	7	W	15	668	1376				20	
164138	12	N	7	W	15	653	1280					
117660	12	N	7	W	16	636	1456	1495	1572	1628		
117661	12	N	7	W	16	664	1395				18	
117665	12	N	7	W	21	690	1518	1564				
117666	12	N	7	W	22	635	1433					
117667	12	N	7	W	23	665	1441	1480	1565			

Field name: Switz City

IGS ID: 10704 (oil), 10827 (gas storage)

DOE ID: na

Location: Greene County, 7N-6W

Discovery date: 1940 (oil), 1964 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,700 ft.)

Field type: oil & gas storage

Total number production wells: 44 (storage), 9 (observation)

Area: 1,000 acres

Total capacity: 5,680,000 mcf

Other reservoir units:

Deepest unit penetrated (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,871 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 12%

Average permeability – 20 md.

Approximate thickness – 60 ft.

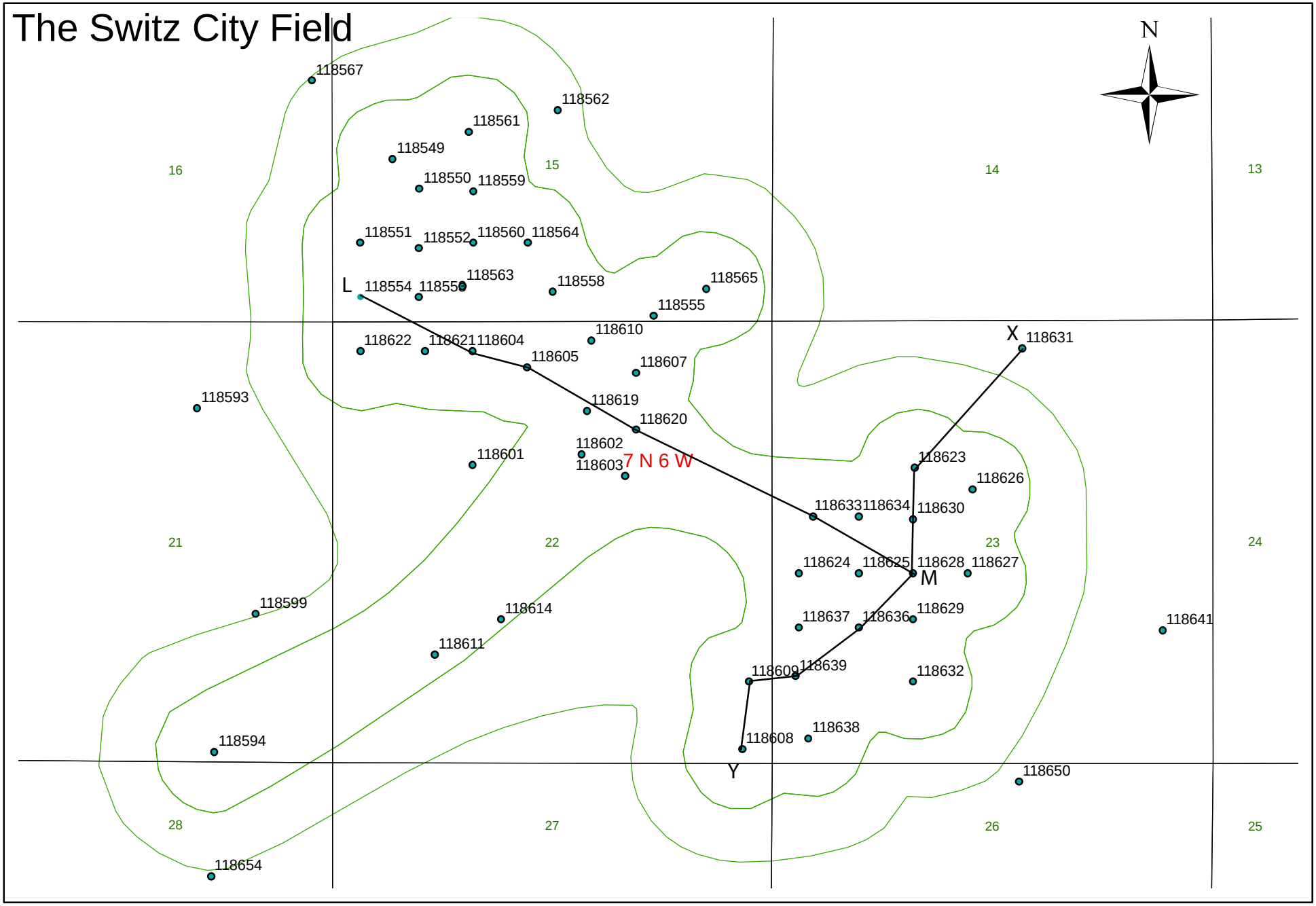

Figure 1: Map showing the location and wells at Switz City Field, Greene County. X-Y, and L-M are the location of the cross sections used to show the subsurface Devonian structure in the Figures 7 and 8.

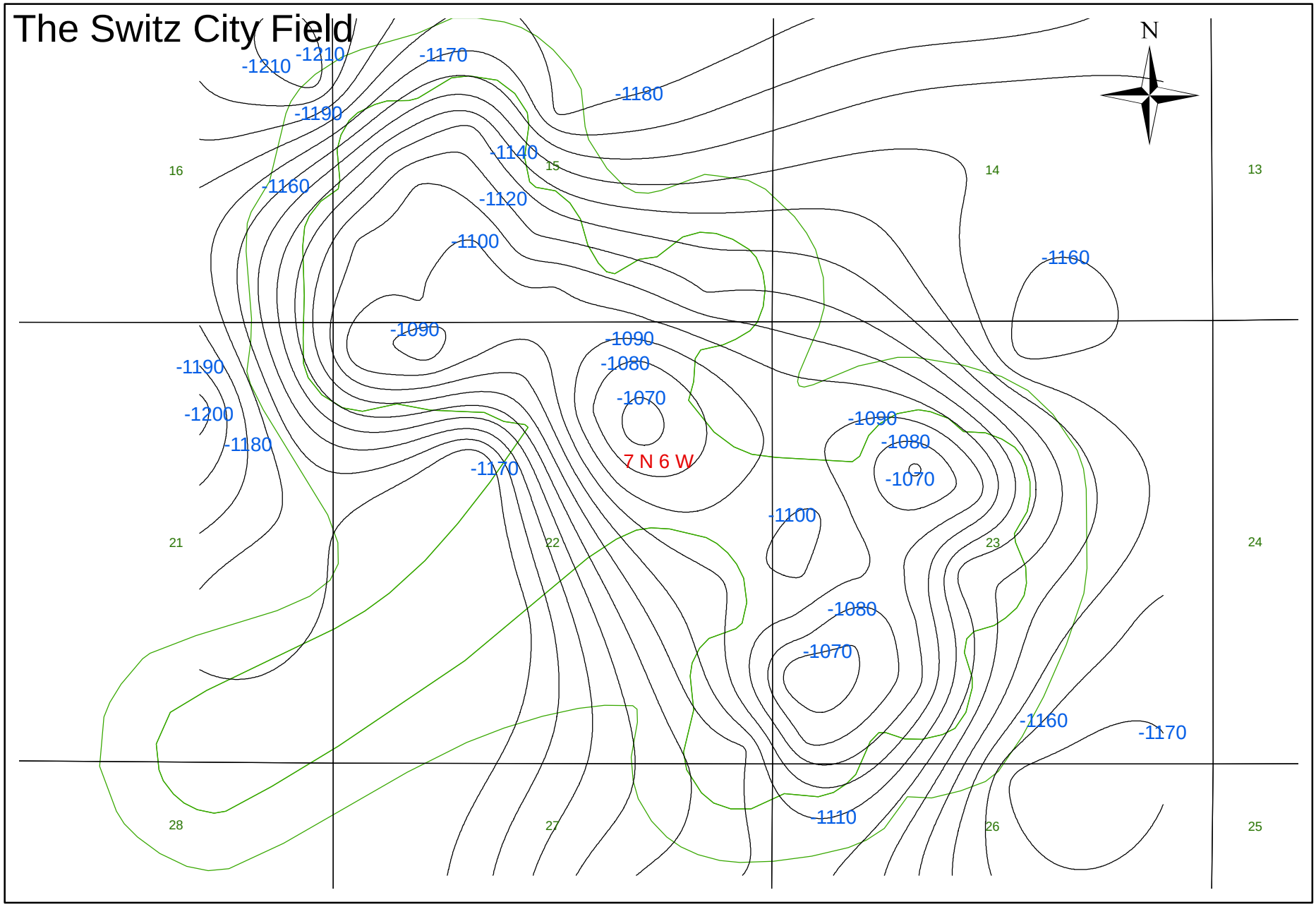

Figure 2: Structure map showing top of the Muscatatuck Limestone in the Switz City Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

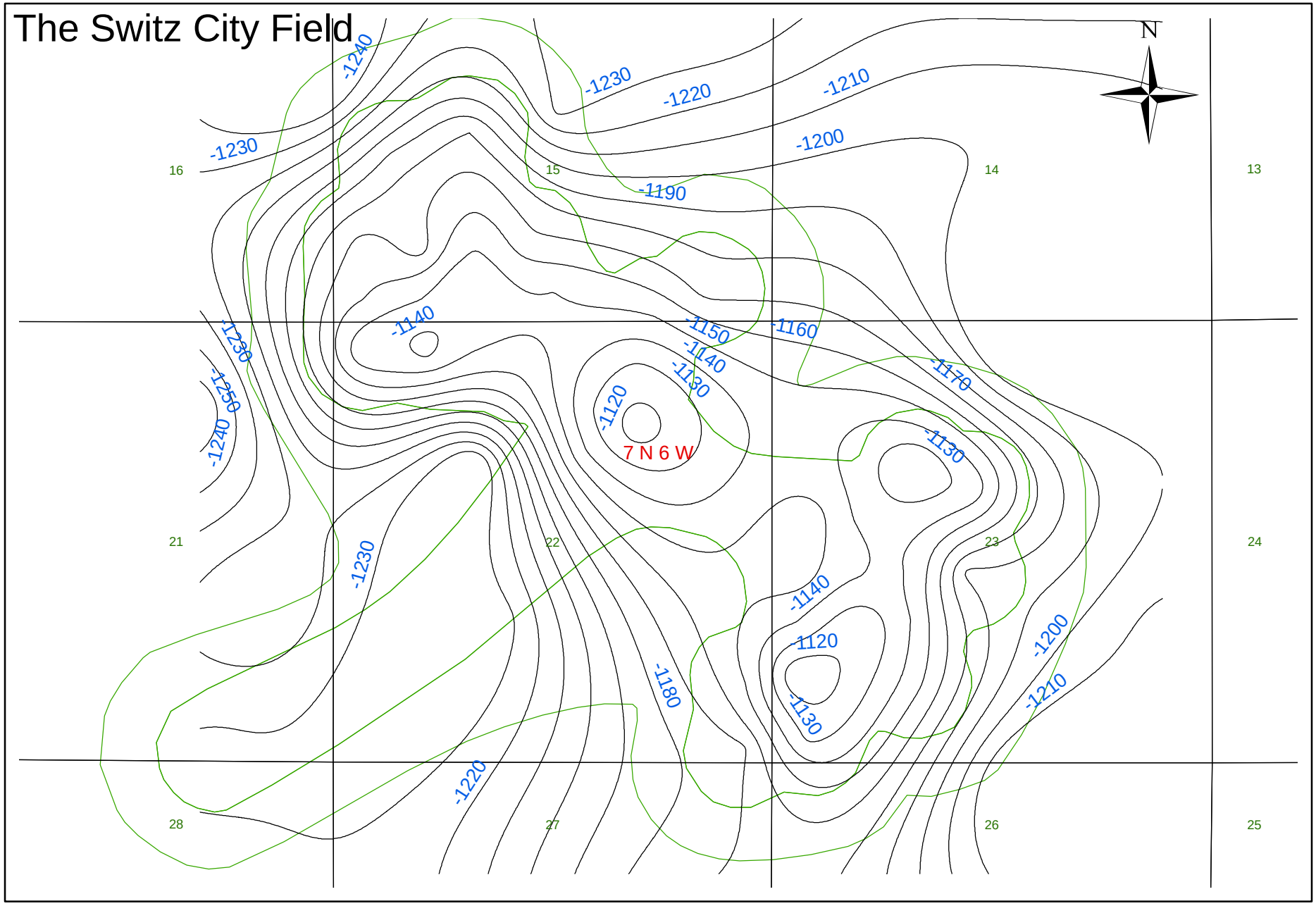

Figure 3: Structure map showing top of Jeffersonville Limestone in Switz City Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

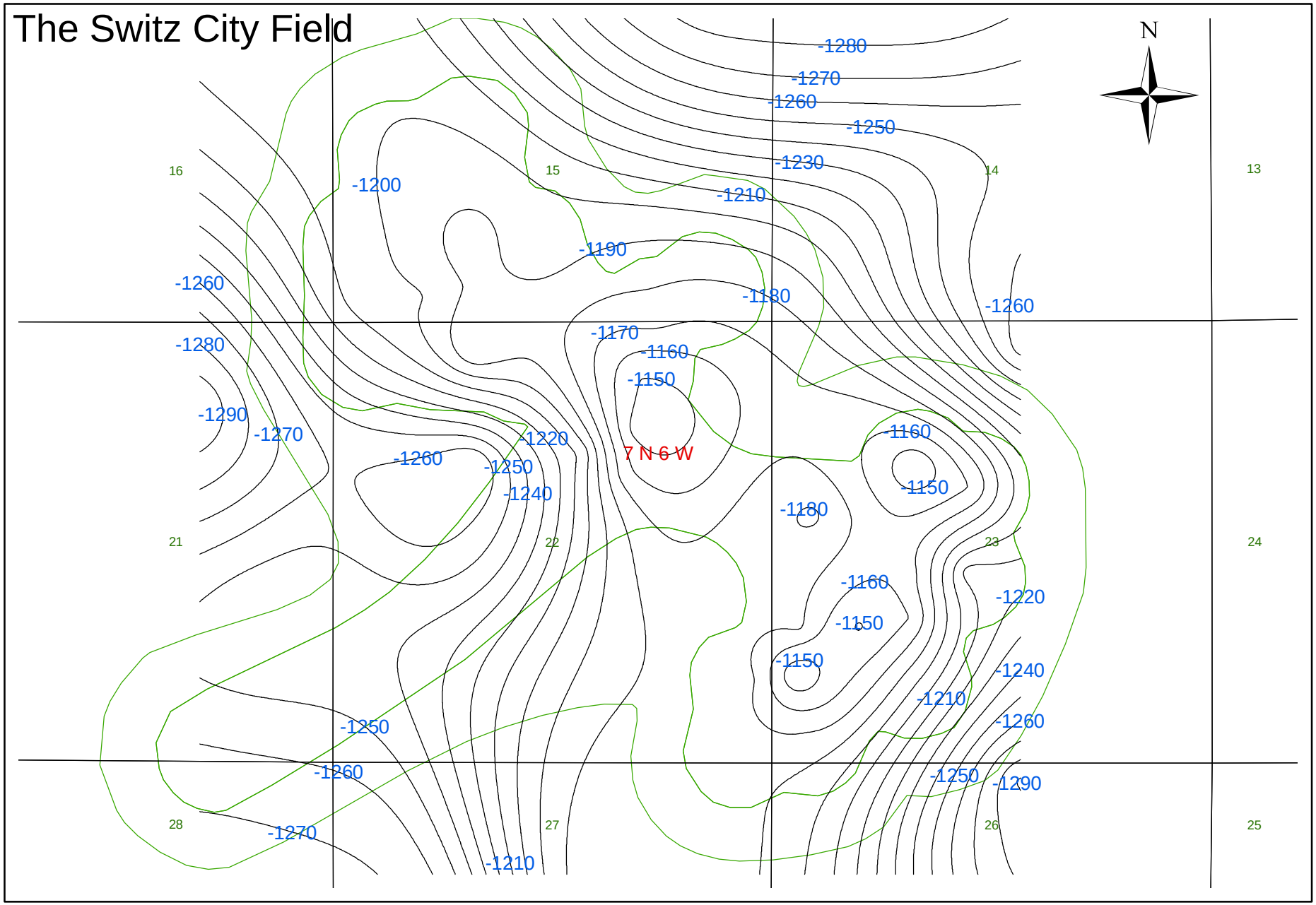

Figure 4: Structure map showing the top of the Geneva Dolomite Member in Switz City Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

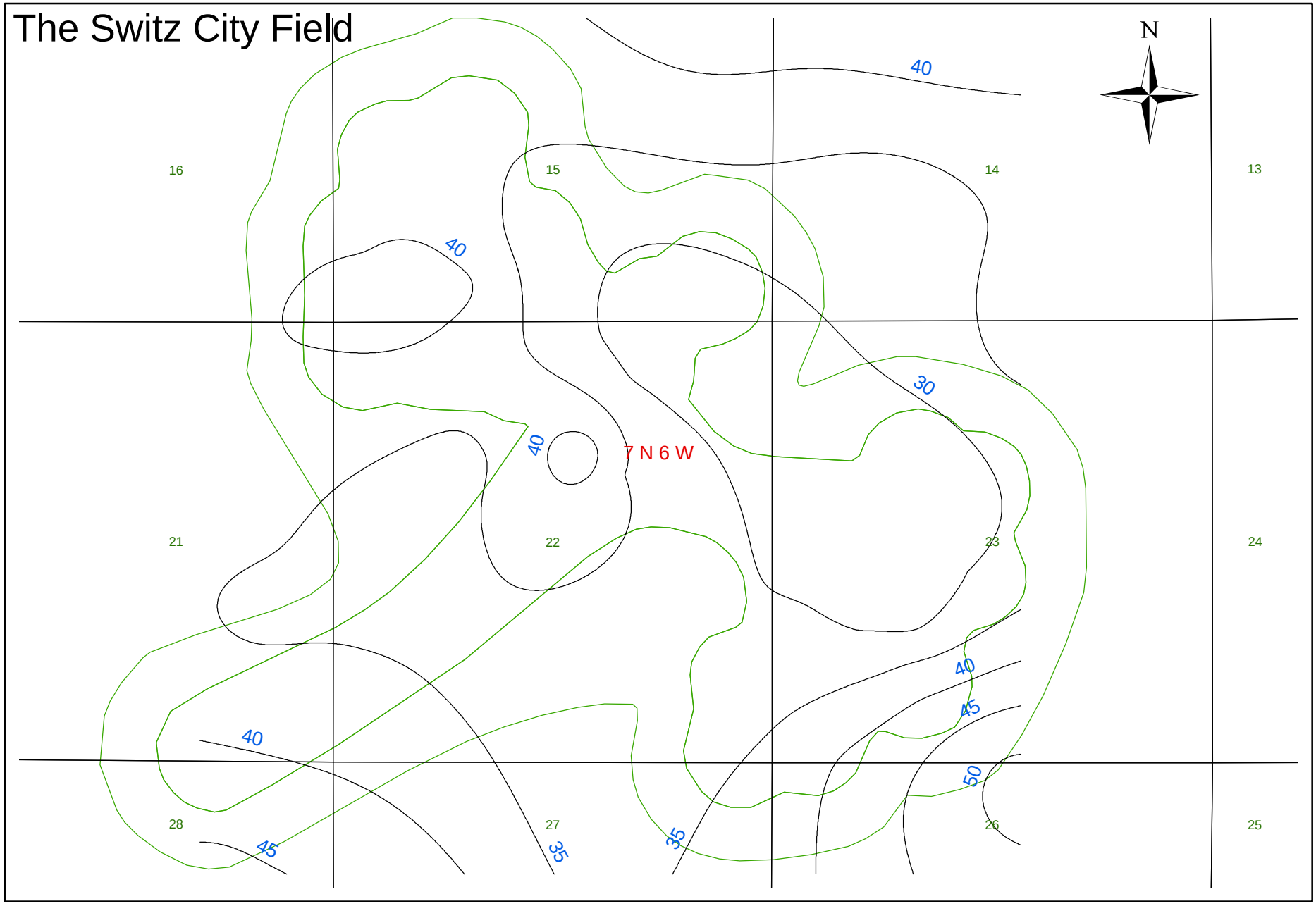

Figure 5: Isopach map showing thickness of Vernon Fork Member of Jeffersonville Limestone in Switz City Field, Greene County. Contour interval is 5 ft .

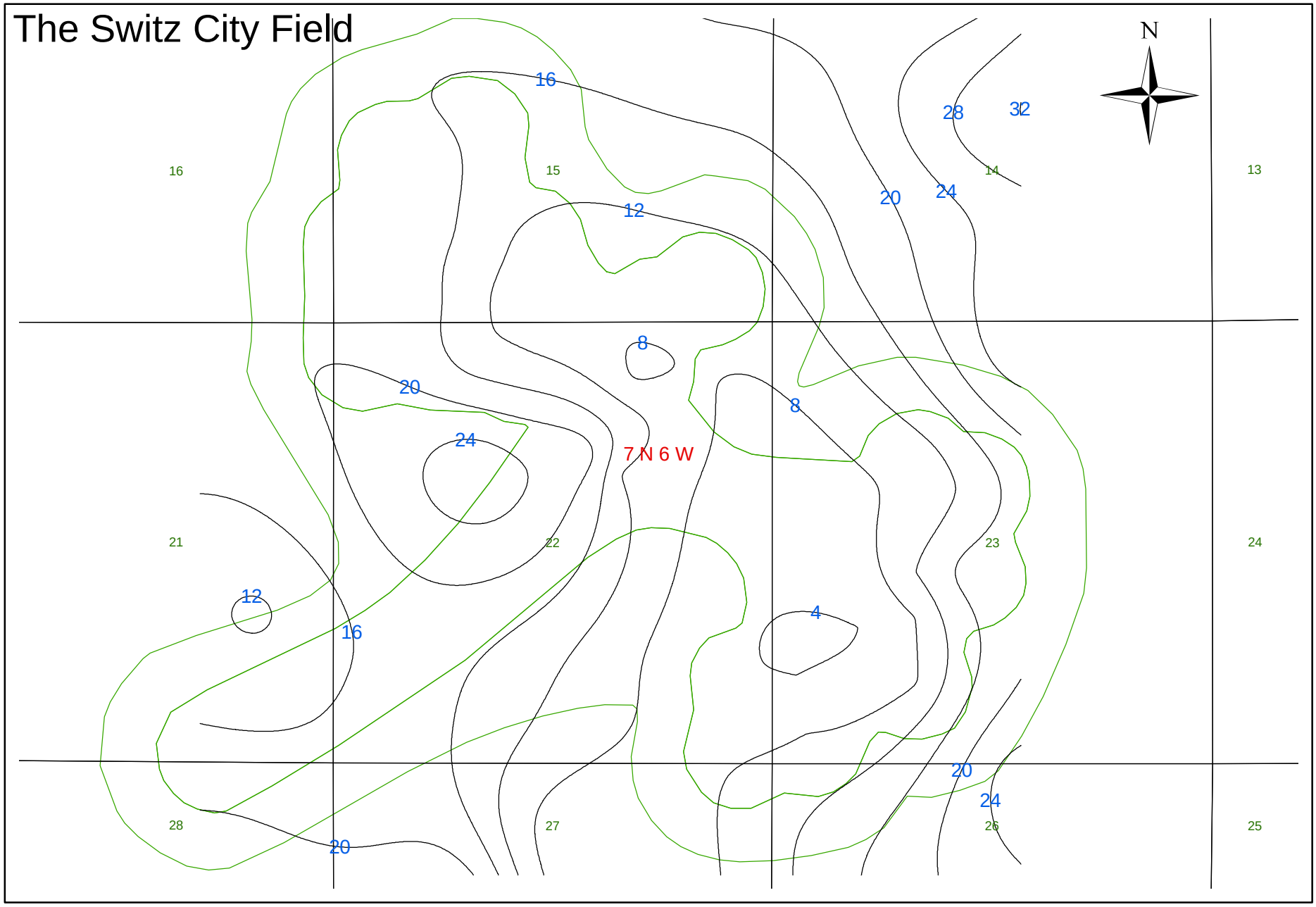

Figure 5: Map showing thickness of net porosity feet greater than 10% from neutron logs in Vernon Fork Member. Contour interval is 4 ft.

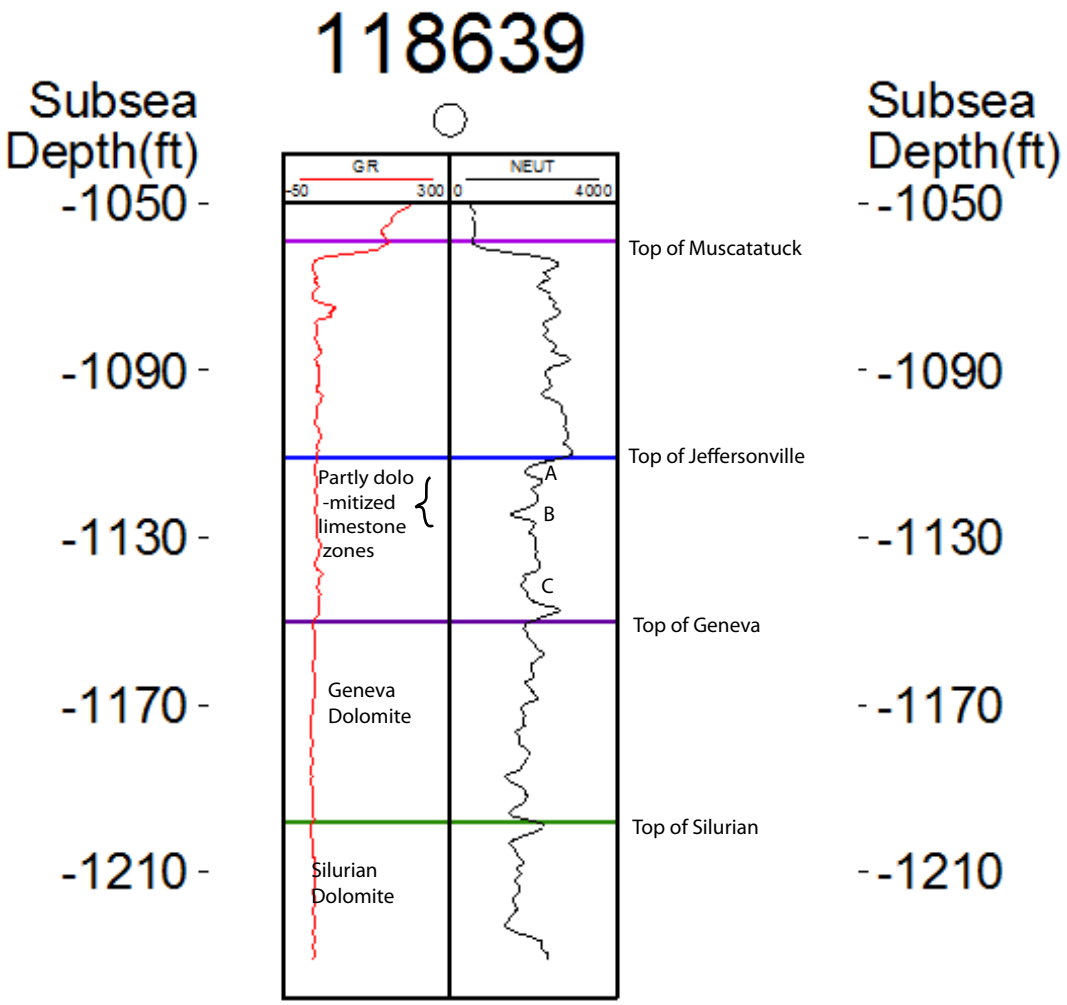

Figure 6: Type log section showing the Devonian formations at Switz City Field, Greene County. A, B, C are partly dolomitized zones in the Vernon Fork Member and are generally the prospective pay horizons.

HS=1

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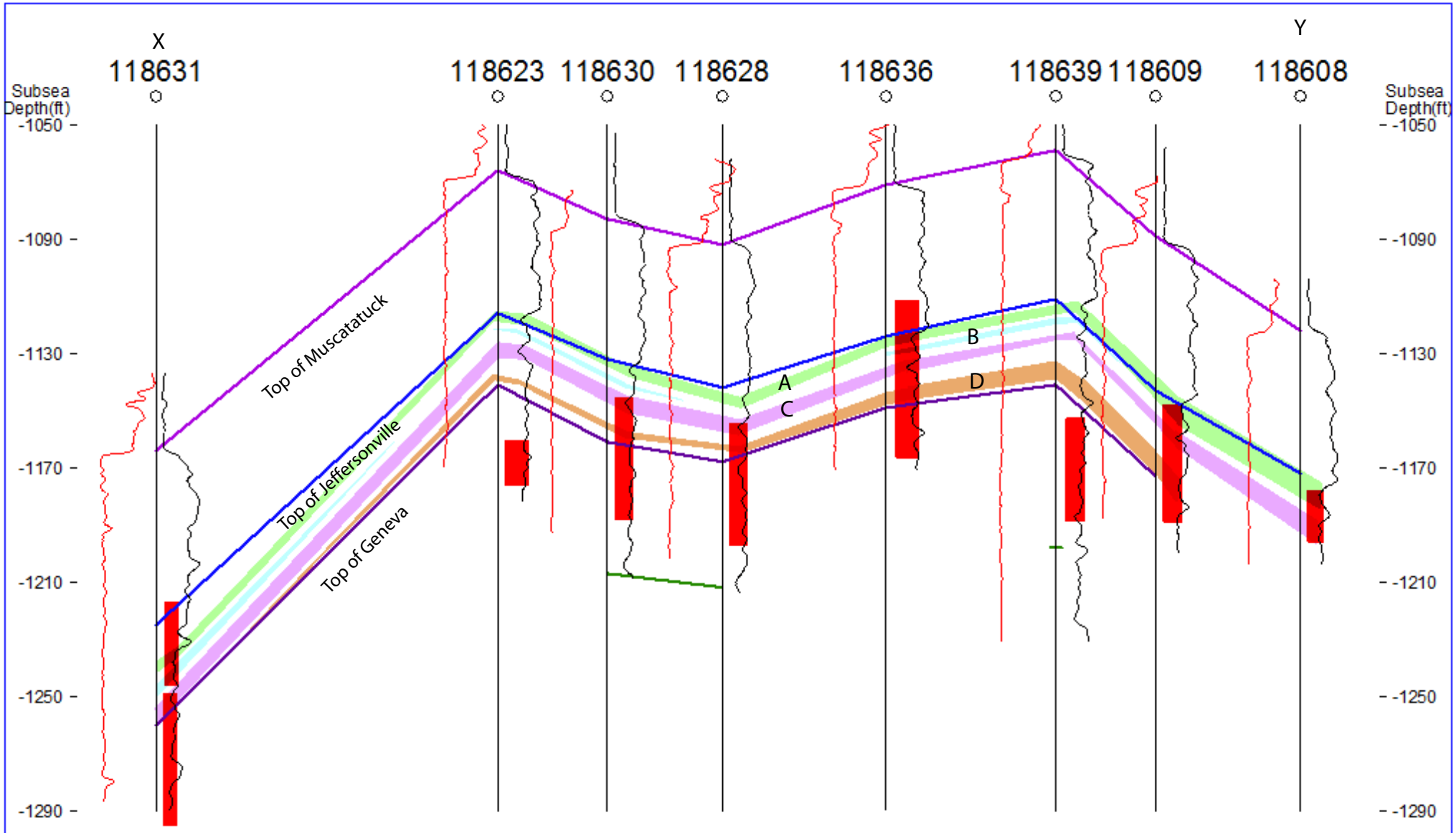

Figure 7: X-Y Cross section showing the Devonian subsurface structure across Switz City Field, Greene County. A, B, C, and D are the gas storage horizons in the Vernon Fork Member. The red color box shows the completion interval for gas storage. For location of the cross section refer to Figure 1.

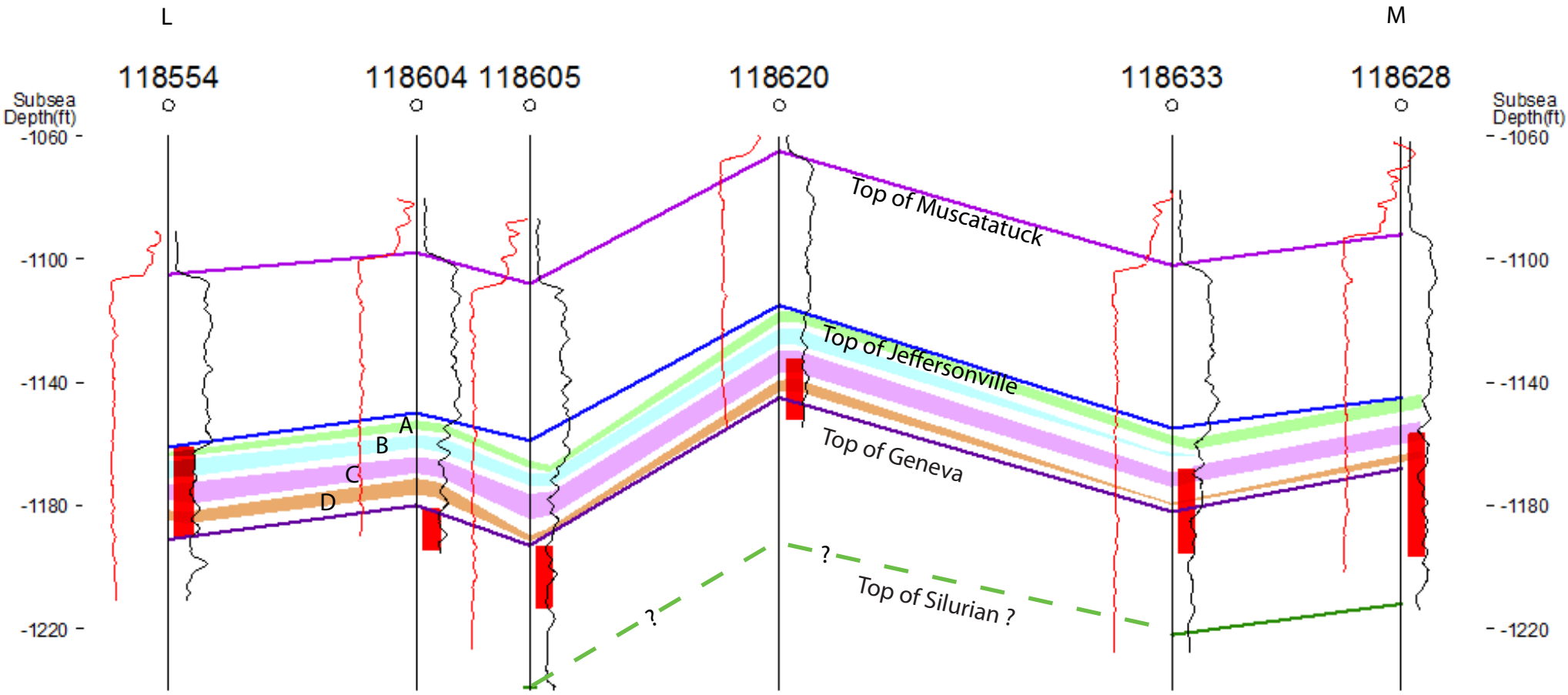

Figure 8: L-M Cross section showing the Devonian subsurface structure across Switz City Field, Greene County. A, B, C, and D are the gas storage horizons in the Vernon Fork Member. The red color box shows the completion interval for gas storage zones. For location of the cross section refer to Figure 1.

Table-1: List of the wells from Switz City Field, Green County, which have a TD in Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil_P	Gas_P
118549	7	N	6	W	15	570	1696	1736				
118550	7	N	6	W	15	566	1674	1720				351
118551	7	N	6	W	15	578	1686	1725	1782			
118552	7	N	6	W	15	566	1672	1720				
118553	7	N	6	W	15	559	1660	1690	1760			
118554	7	N	6	W	15	559	1662	1700	1763			
118555	7	N	6	W	15	534	1636	1664	1710			
118557	7	N	6	W	15	518	1710	1742	1808			
118558	7	N	6	W	15	550	1648	1680				
118559	7	N	6	W	15	561	1674	1704				
118560	7	N	6	W	15	577	1676	1708	1760			
118561	7	N	6	W	15	540	1665	1700				
118562	7	N	6	W	15	548	1730	1760				
118563	7	N	6	W	15	580	1670	1700	1770			
118564	7	N	6	W	15	583	1700	1730	1782			
118565	7	N	6	W	15	536	1657	1690				
118567	7	N	6	W	16	562	1776	1806				
118593	7	N	6	W	21	588	1794	1828	1888			
118594	7	N	6	W	21	567	1746	1780				
118599	7	N	6	W	21	520	1680	1710	1762			
118601	7	N	6	W	22	536	1722	1760	1808			
118602	7	N	6	W	22	573	1671	1696	1780	1816		
118603	7	N	6	W	22	548	1632	1664	1712			
118604	7	N	6	W	22	580	1678	1710	1760			
118605	7	N	6	W	22	573	1681	1710	1766	1812		
118607	7	N	6	W	22	540	1614	1646	1691			
118608	7	N	6	W	22	516	1638	1668				
118609	7	N	6	W	22	562	1653	1690	1735			
118610	7	N	6	W	22	544	1636	1668	1716			
118611	7	N	6	W	22	500	1688	1722				
118614	7	N	6	W	22	507	1689	1722				
118619	7	N	6	W	22	560	1642	1672				
118620	7	N	6	W	22	545	1610	1640	1690			
118621	7	N	6	W	22	557	1642	1674				
118622	7	N	6	W	22	587	1678	1710				431
118623	7	N	6	W	23	530	1598	1630	1671			
118624	7	N	6	W	23	528	1629	1664				
118625	7	N	6	W	23	521	1612	1642				
118626	7	N	6	W	23	533	1616	1646	1694			
118627	7	N	6	W	23	514	1642	1676	1728			
118628	7	N	6	W	23	518	1610	1640	1686	1718		

Table-1: Continued...

118629	7	N	6	W	23	529	1618	1650	1690			
118630	7	N	6	W	23	517	1600	1632	1678	1724		
118631	7	N	6	W	23	503	1667	1706	1768			
118632	7	N	6	W	23	551	1636	1676	1738	1780		
118633	7	N	6	W	23	522	1624	1656	1704	1744		
118634	7	N	6	W	23	518	1606	1636	1686	1731		
118636	7	N	6	W	23	529	1600	1630	1678			
118637	7	N	6	W	23	540	1626	1658	1712	1750		
118638	7	N	6	W	23	528	1605	1636	1700	1750		
118639	7	N	6	W	23	569	1630	1660	1710	1767		
118641	7	N	6	W	23	540	1706	1735				
118650	7	N	6	W	26	497	1672	1706	1788			
118654	7	N	6	W	28	563	1740	1770	1838			

Field name: Terre Haute

IGS ID: 10712

DOE ID: 701976

Location: Vigo County, 12N-9W

Discovery date: 1889

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, (na)

Field type: oil

Total number production wells: 6

Area: 80 acres

Cumulative production: na

Other reservoir units:

Deepest unit penetrated (depth): Devonian, Muscatatuck Group (1,800 ft.)

Field characteristic: Limited well information suggests domal anticline over probable Silurian reef with closure in excess of 60 ft. at top of Muscatatuck.

Reservoir characteristics:

Field name: Terre Haute East

IGS ID: 10713

DOE ID: 702007

Location: Vigo County, 12N-9W

Discovery date: 1951

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,608 ft.)

Field type: oil

Total number production wells: 21

Area: 380 acres

Cumulative production: 1,874,290 bbls. (2002)

Other reservoir units:

Deepest unit penetrated (depth): Silurian (1,860 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

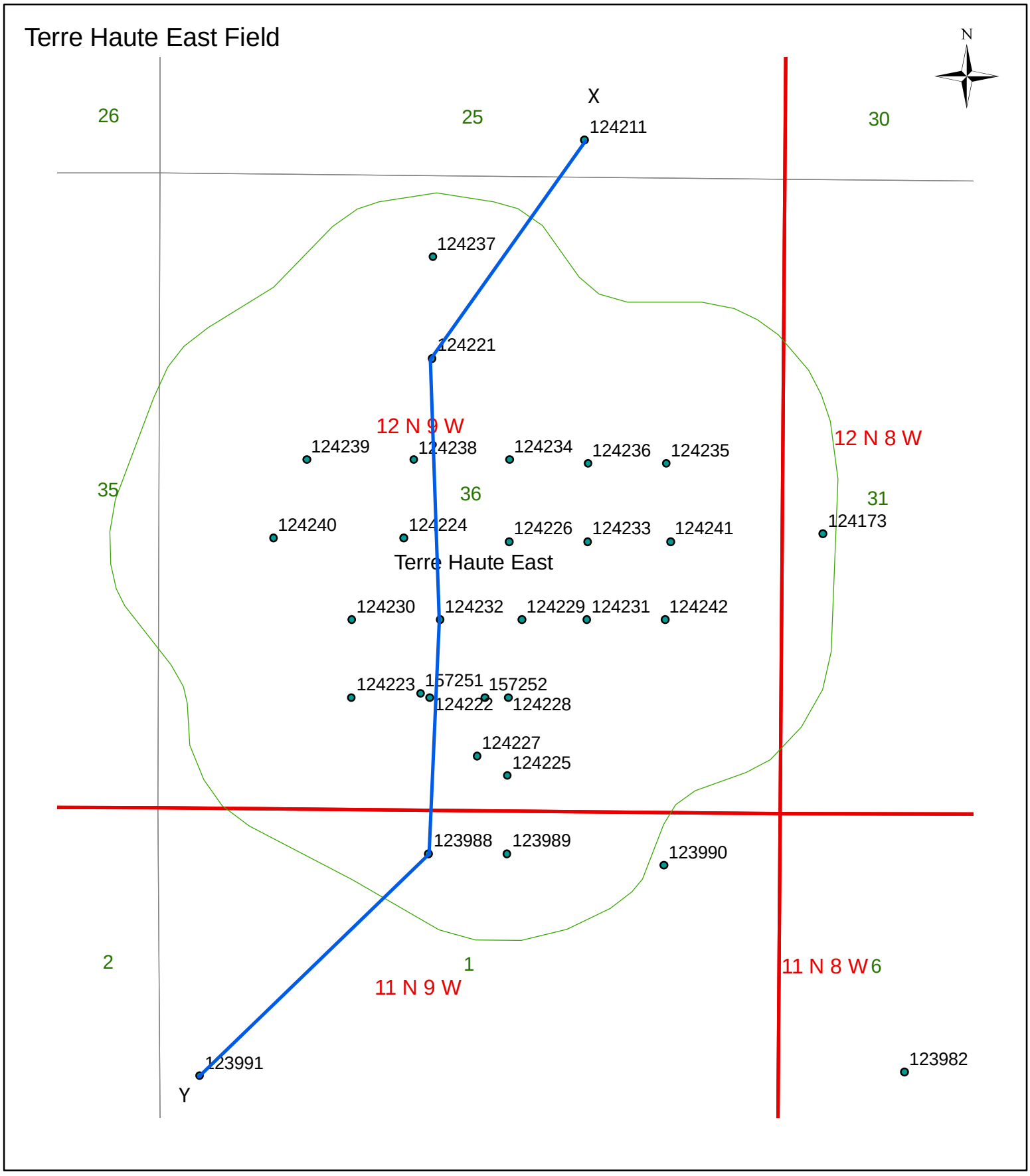

Figure 1: Map showing the location and wells at Terre Haute East Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 3).

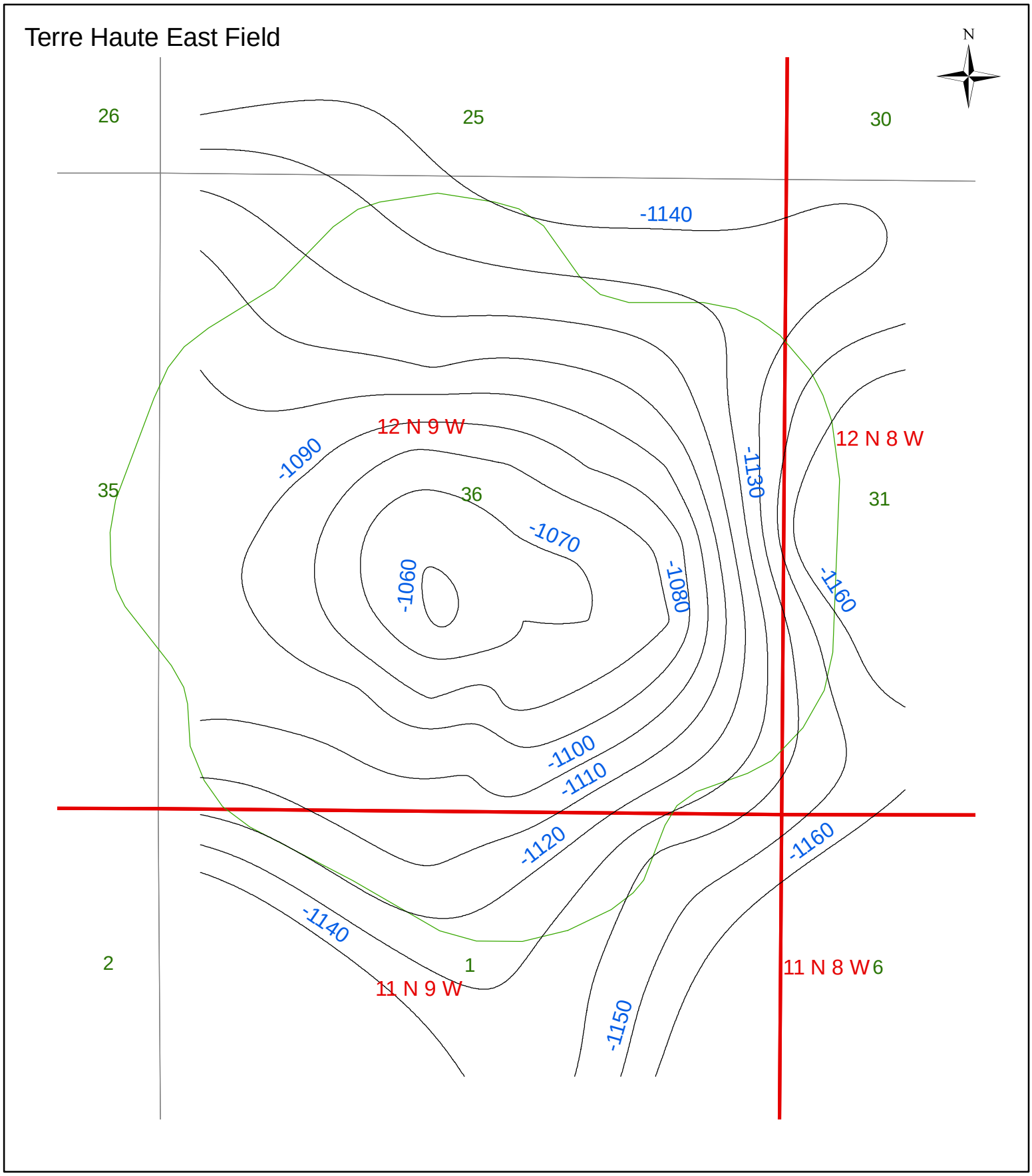

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Terre Haute East Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

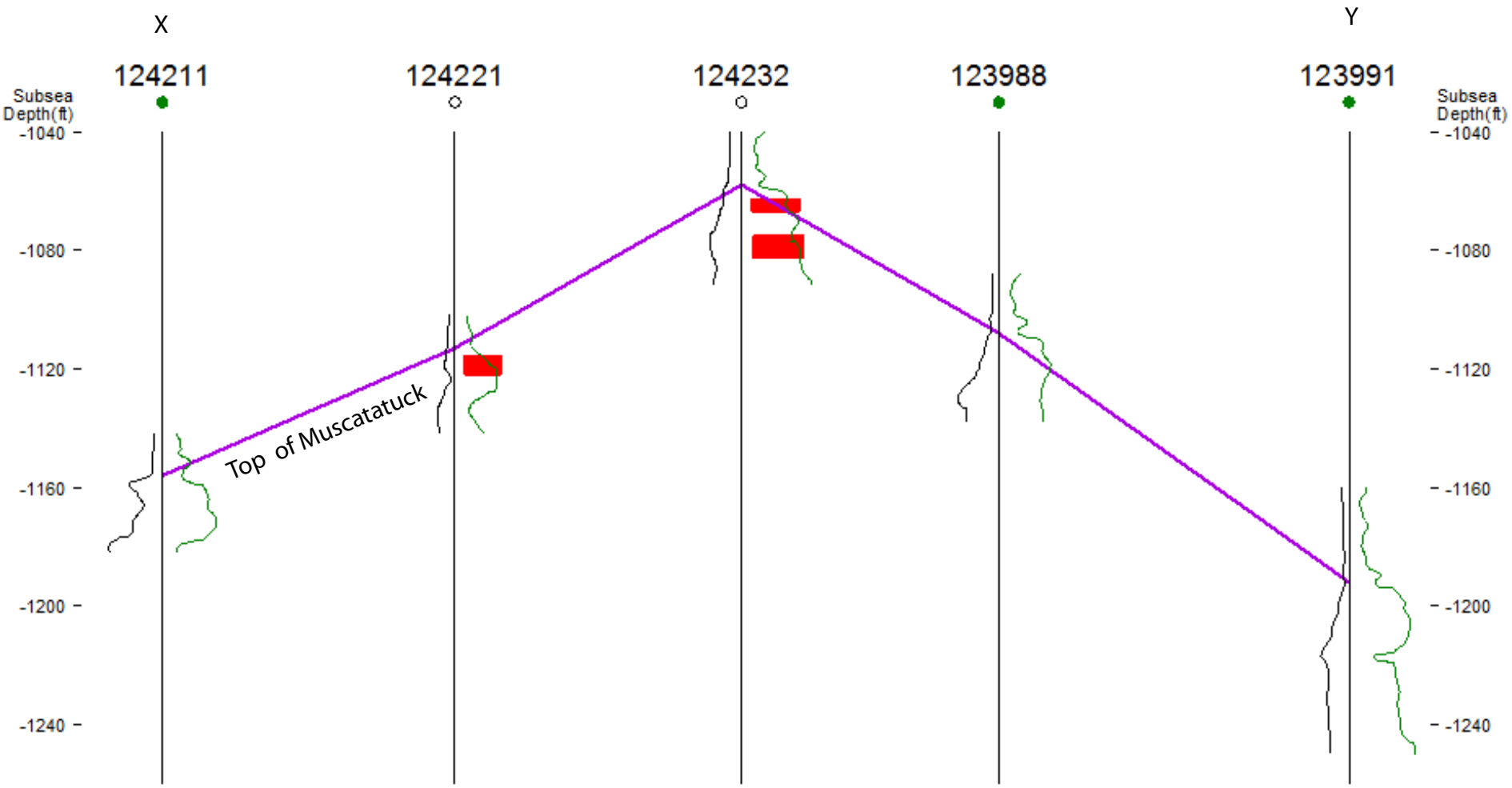

Figure 3: X-Y Cross section showing the Devonian subsurface structure across the Terre Haute East Field, Vigo County. The red color box shows the completion intervals for oil production. For location of the cross section refer to Figure 1.

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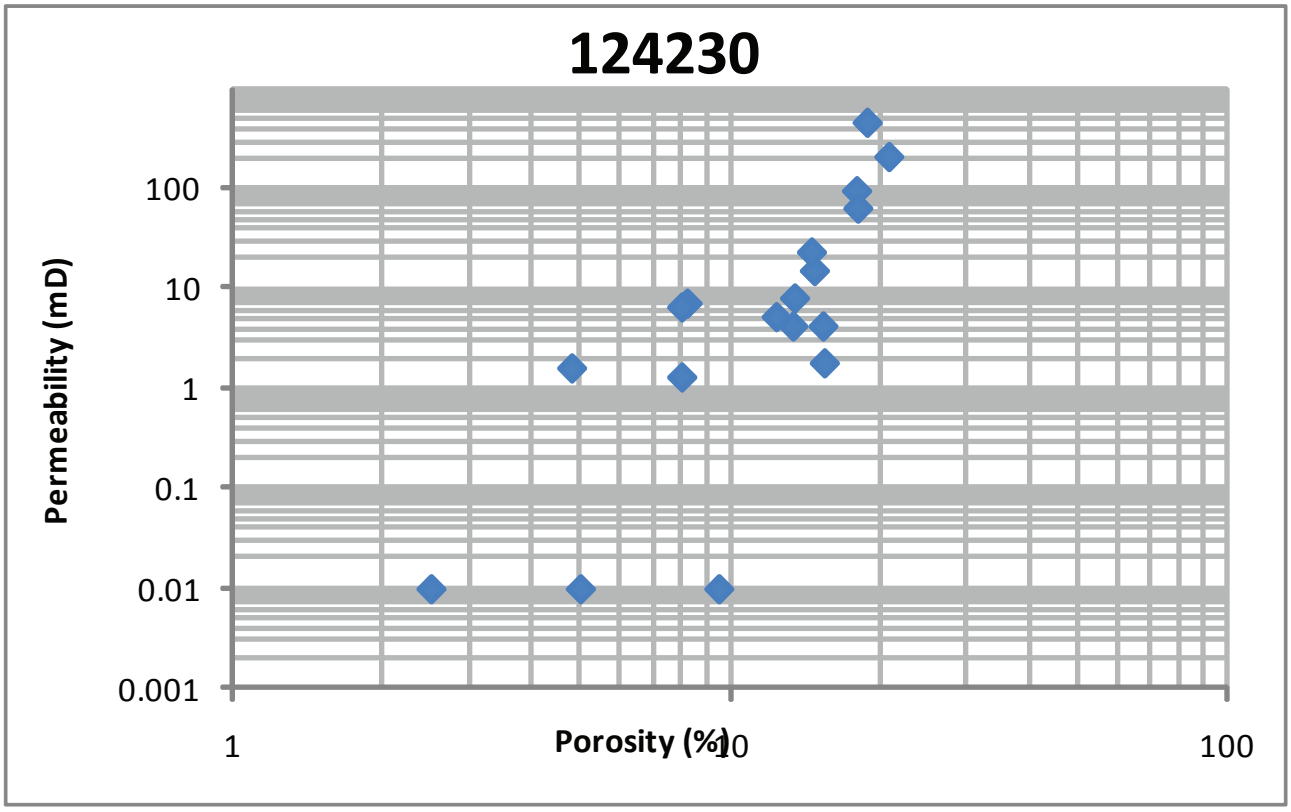

Figure 4: Porosity-permeability plot from core analysis from Terre Haute East Field, Vigo County. The blue points are from North Vernon. The graph title displays the IGS Well ID. For the well locations see Figure 1.

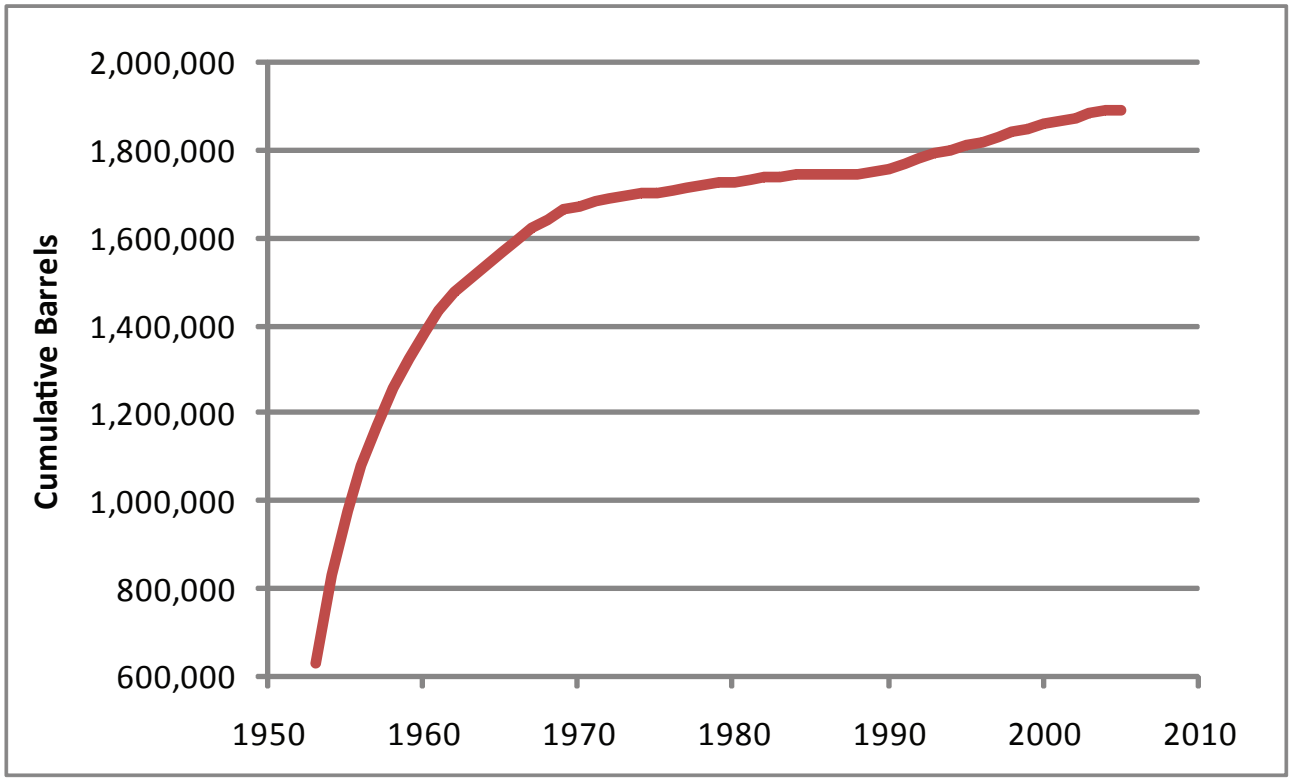

Figure - 5: Cumulative oil production history from Terre Haute East Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in the Terre Haute East Field, Vigo County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
123982	11	N	8	W	6	565	1780	1830				
123988	11	N	9	W	1	562	1670					
123989	11	N	9	W	1	565	1679					
123990	11	N	9	W	1	559	1704					
123991	11	N	9	W	1	560	1752					
124173	12	N	8	W	31	564	1744	1798				
124210	12	N	9	W	25	498	1672	1724				
124211	12	N	9	W	25	568	1724					
124221	12	N	9	W	36	518	1631				15	
124222	12	N	9	W	36	568	1648				158	
124223	12	N	9	W	36	573	1667				100	
124224	12	N	9	W	36	568	1629				168	
124225	12	N	9	W	36	561	1655				90	
124226	12	N	9	W	36	569	1638				160	
124227	12	N	9	W	36	556	1655			1837		
124228	12	N	9	W	36	566	1642				100	
124229	12	N	9	W	36	561	1631				100	
124230	12	N	9	W	36	569	1644				100	
124231	12	N	9	W	36	570	1640				50	
124232	12	N	9	W	36	562	1620				152	
124233	12	N	9	W	36	568	1640				75	
124234	12	N	9	W	36	564	1645				122	
124235	12	N	9	W	36	568	1669				50	
124236	12	N	9	W	36	558	1649				75	
124237	12	N	9	W	36	516	1645					
124238	12	N	9	W	36	567	1643				120	
124239	12	N	9	W	36	518	1610				32	
124240	12	N	9	W	36	511	1599				100	
124241	12	N	9	W	36	565	1650				120	
124242	12	N	9	W	36	565	1644				75	
157251	12	N	9	W	36	566	1646				11	
157252	12	N	9	W	36	564	1650	1696				

Field name: Terre Haute South

IGS ID: 10714

DOE ID: 702038

Location: Vigo County, 11N-9W

Discovery date: 1949

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, North Vernon Ls. (1,654 ft.)

Field type: oil

Total number production wells: 17

Area: 260 acres

Cumulative production: 345,112 bbls. (2002)

Other reservoir units: Mississippian, Borden Group, Carper Ss.

Deepest unit penetrated (depth): Silurian (1,992 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

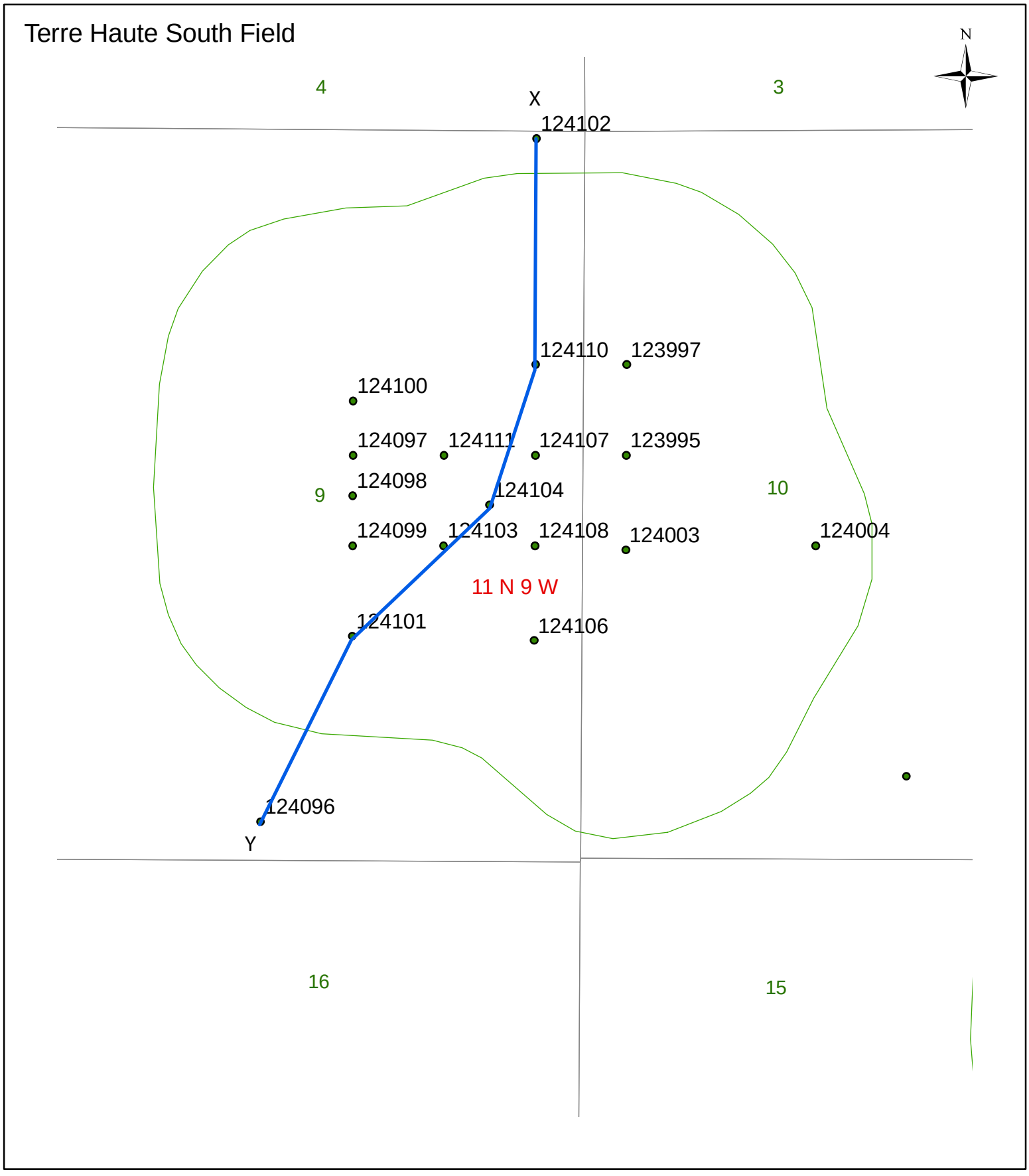

Figure 1: Map showing the location and wells at Terre Haute South Field, Vigo County. X-Y is the location of the cross section that shows the subsurface Devonian structure (Fig. 3).

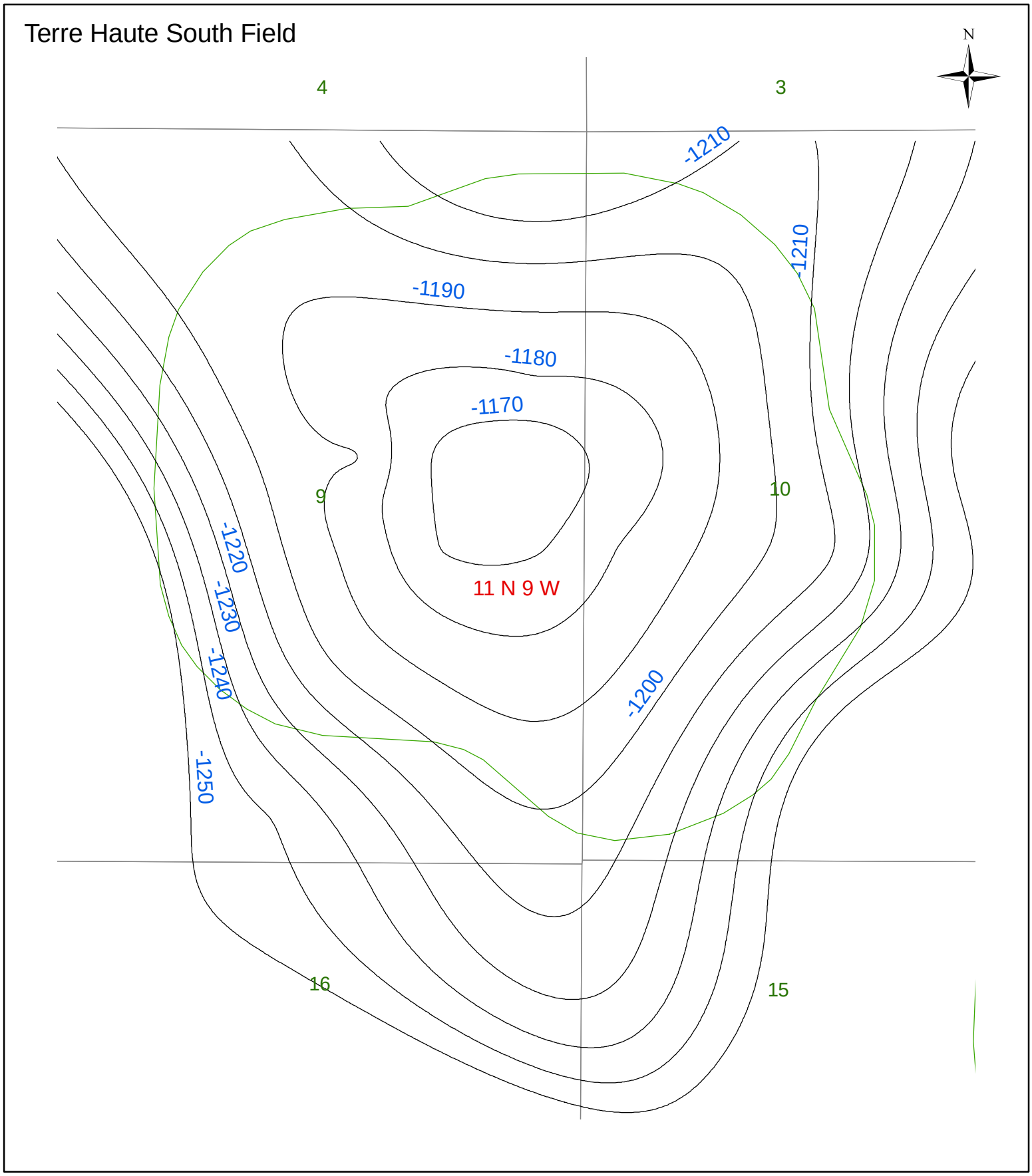

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Terre Haute South Field, Vigo County. Contours show values below sea level, contour interval is 10 ft .

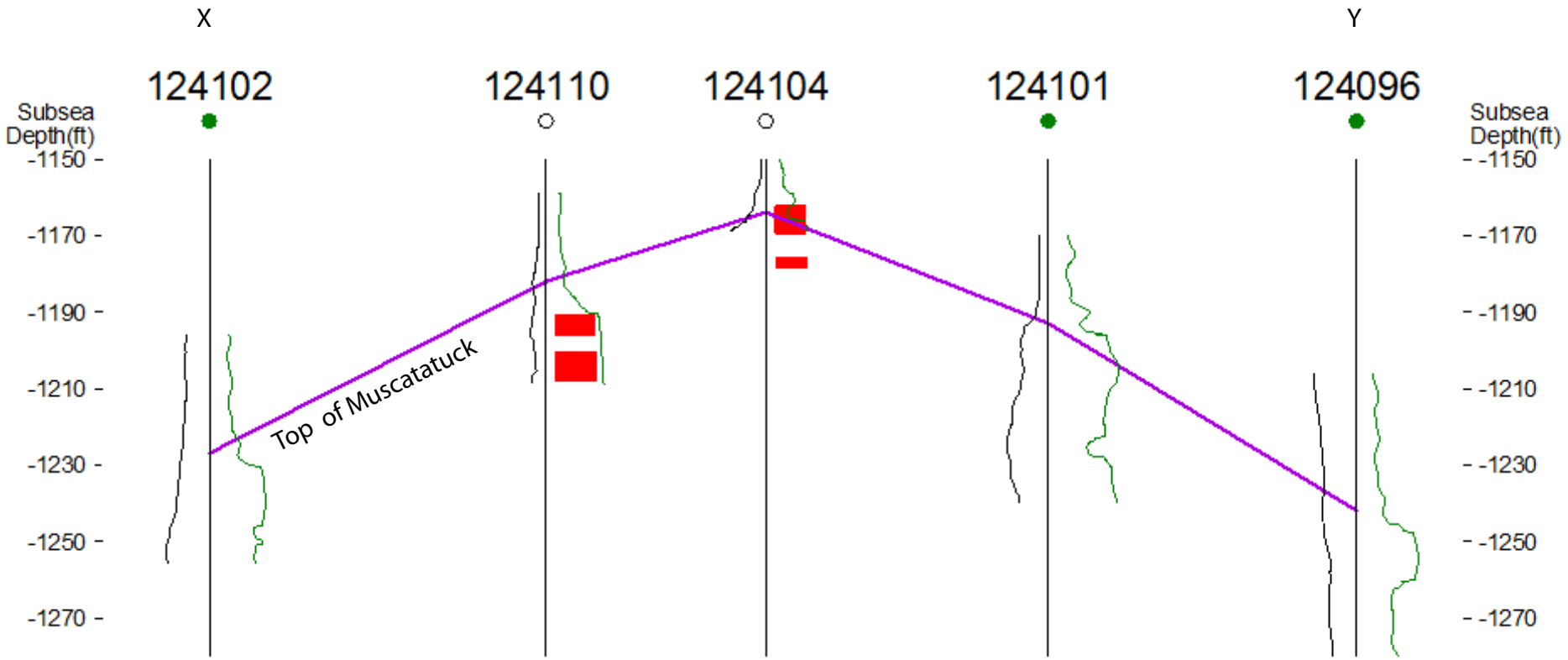

Figure 3: X-Y Cross section showing the Devonian subsurface structure across the Terre Haute South Field, Vigo County. The red color box shows the completion intervals for the oil production. For location of the cross section refer to Figure 1.

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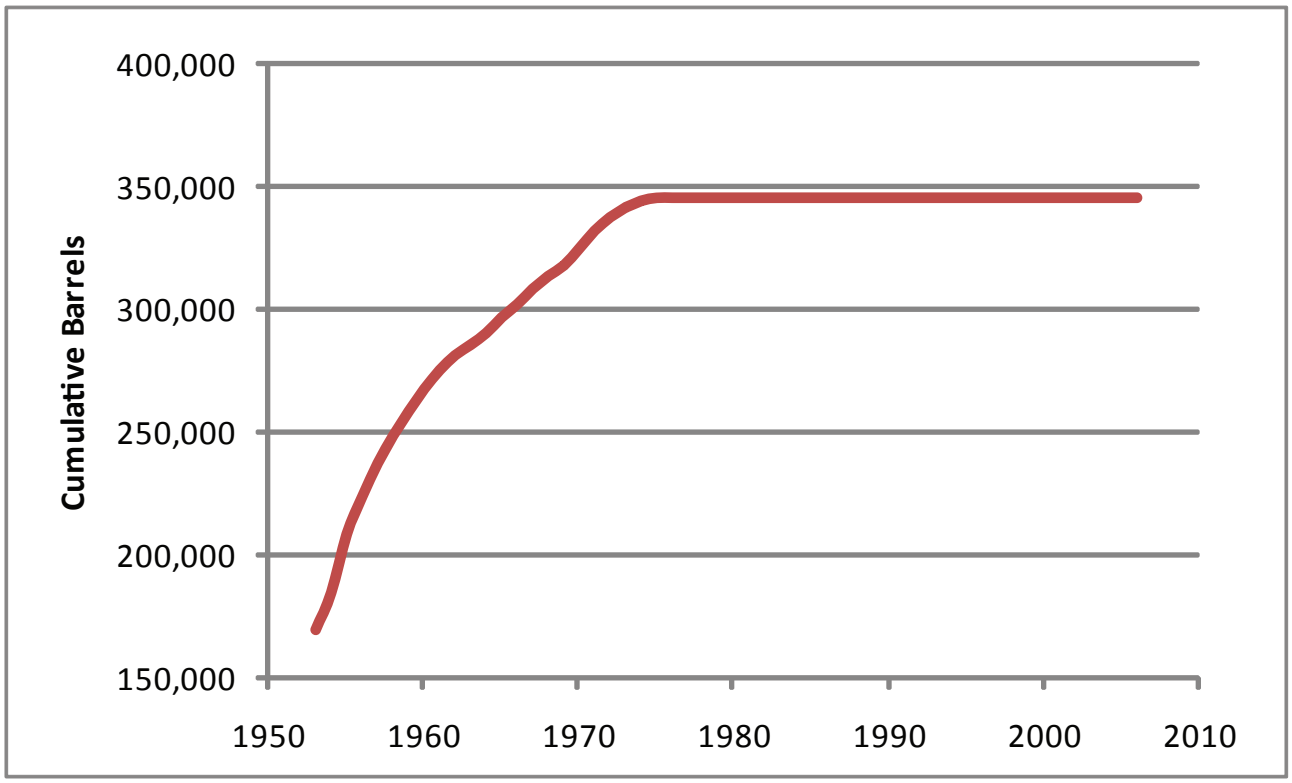

Figure - 4: Cumulative oil production history from Terre Haute South Field, Vigo County since 1953.

Table-1: List of the wells used for subsurface structure mapping in Terre Haute South Field, Vigo County. The wells selected have TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
124095	11	N	9	W	9	493	1829					
124096	11	N	9	W	9	494	1736	1794				
124097	11	N	9	W	9	489	1680				50	
124098	11	N	9	W	9	488	1672				28	
124099	11	N	9	W	9	491	1678				24	
124100	11	N	9	W	9	489	1671				35	
124101	11	N	9	W	9	500	1693					
124102	11	N	9	W	9	494	1721					
124103	11	N	9	W	9	492	1661	1720			54	
124104	11	N	9	W	9	491	1655				30	
124106	11	N	9	W	9	495	1676					
124107	11	N	9	W	9	493	1656				90	
124108	11	N	9	W	9	492	1661				94	
124110	11	N	9	W	9	491	1673				75	
124111	11	N	9	W	9	491	1658				98	
123995	11	N	9	W	10	493	1667				105	
123996	11	N	9	W	10	505	1767					
123997	11	N	9	W	10	493	1676				40	
124001	11	N	9	W	10	492					41	
124002	11	N	9	W	10	491					5	
124003	11	N	9	W	10	492	1674				16	
124004	11	N	9	W	10	497	1703					
123994	11	N	9	W	10	498	1777	1840	1938			
124055	11	N	9	W	16	501	1823	1880				

Field name: Unionville (includes Hindustan GSP)

IGS ID: 10734 (oil & natural gas), 10829 (gas storage)

DOE ID: 728572

Location: Monroe County, 9N-1E & 10N-1W

Discovery date: 1929 (natural gas), 1953 (gas storage initiated), 1978 (oil)

Lower Paleozoic reservoir unit (depth):

Devonian, Muscatatuck Group, North Vernon & Jeffersonville Ls. (810 ft.)

Ordovician, Trenton Ls. (1,760 ft.)

Field type: oil, natural gas, & gas storage

Total number production wells: 2 (oil), 2 (natural gas), 58 (storage), 20 (observation)

Area: 20,024 acres

Total capacity: 6,275,000 mcf

Other reservoir units:

Deepest unit penetrated (depth): Cambrian/Ordovician, Knox Supergroup (2,470 ft.)

Field characteristic: Anticlinal structure adjacent to Mt. Carmel Fault with closure in excess of 40 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 6.5%

Average permeability – 500 md.

Approximate thickness – 21-32 ft. (Devonian), 15 ft. (Ordovician)

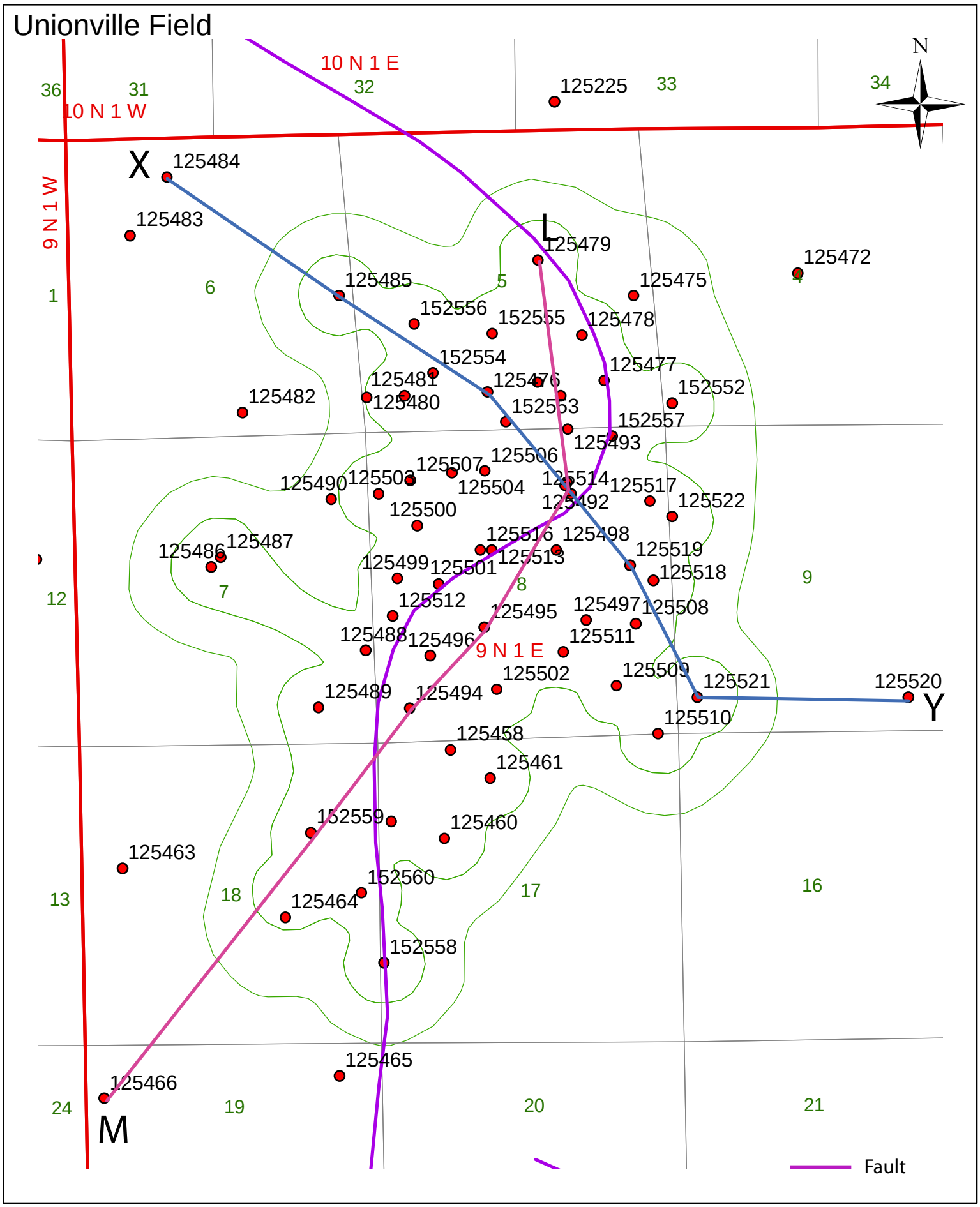

Figure 1: Map showing location and wells at Unionville Field, Monroe County. X-Y, and L-M are locations of the cross sections that shows the subsurface Devonian structure in Figures 10 and 11. Trace of the Mt. Carmel Fault is also shown.

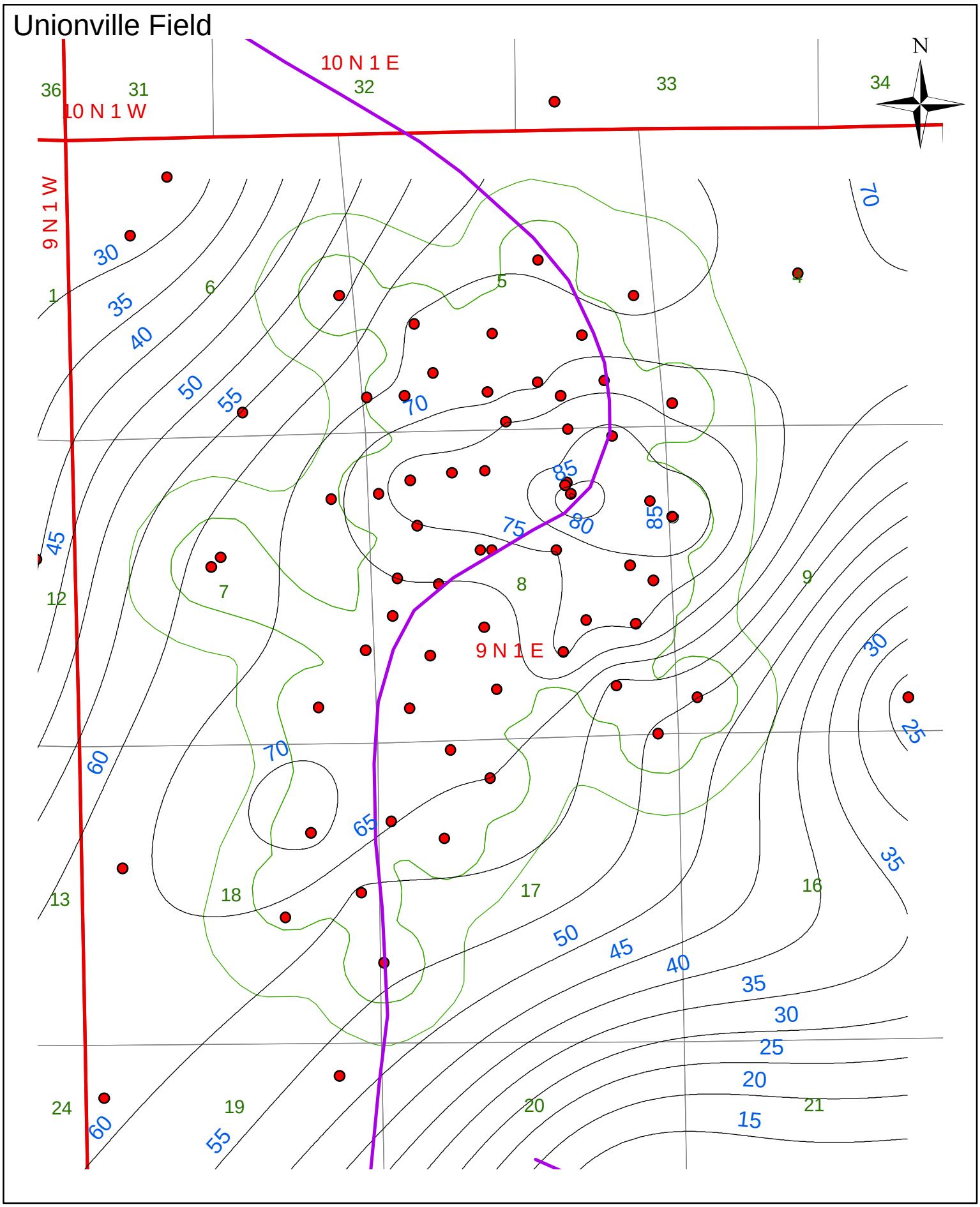

Figure 2: Structure map showing top of the Muscatatuck Limestone in Unionville Field, Monroe County. Contours show values below sea level, contour interval is 5 ft .

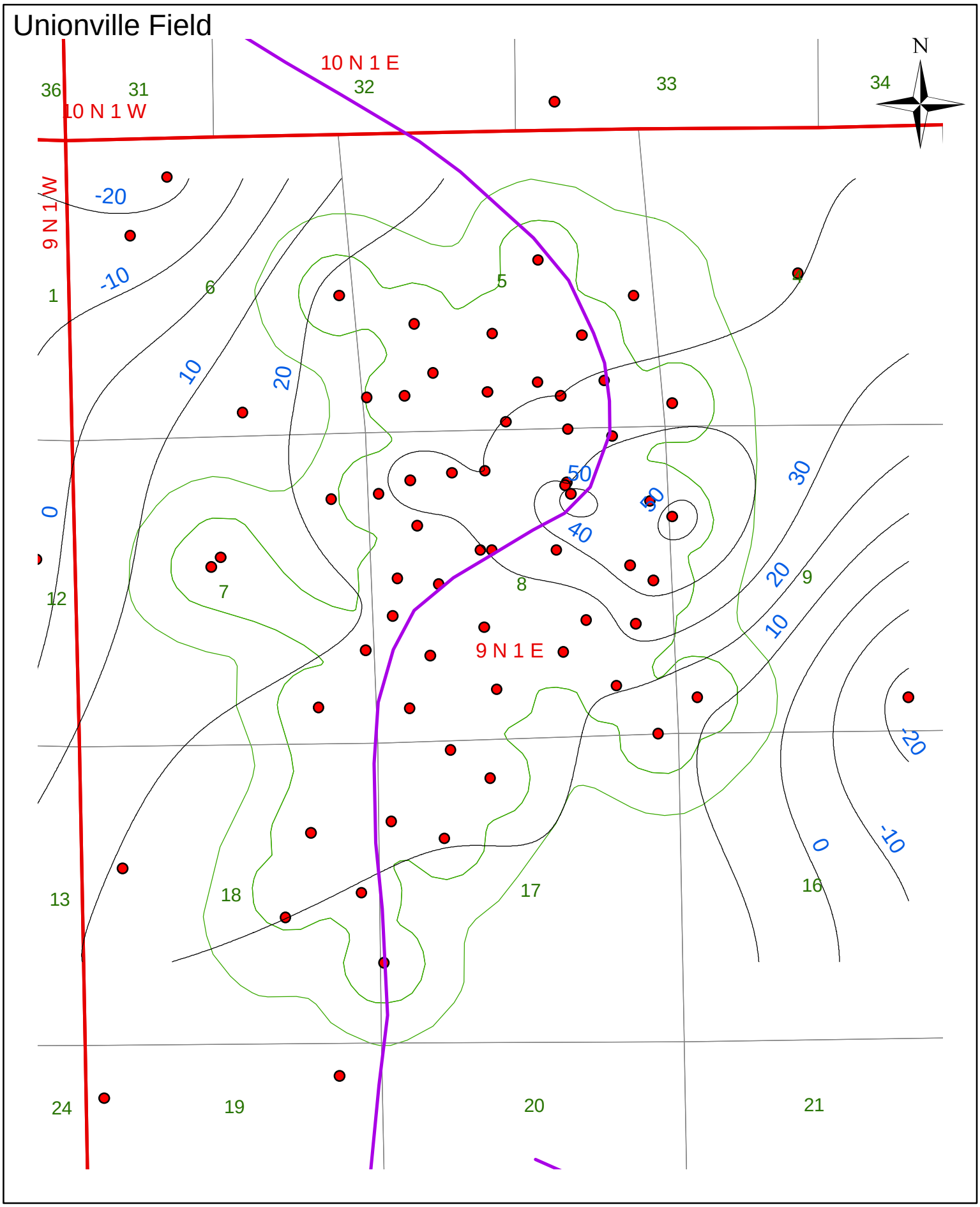

Figure 3: Structure map showing top of the Jeffersonville Limestone in the Unionville Field, Monroe County. Contours show values below sea level, contour interval is 10 ft .

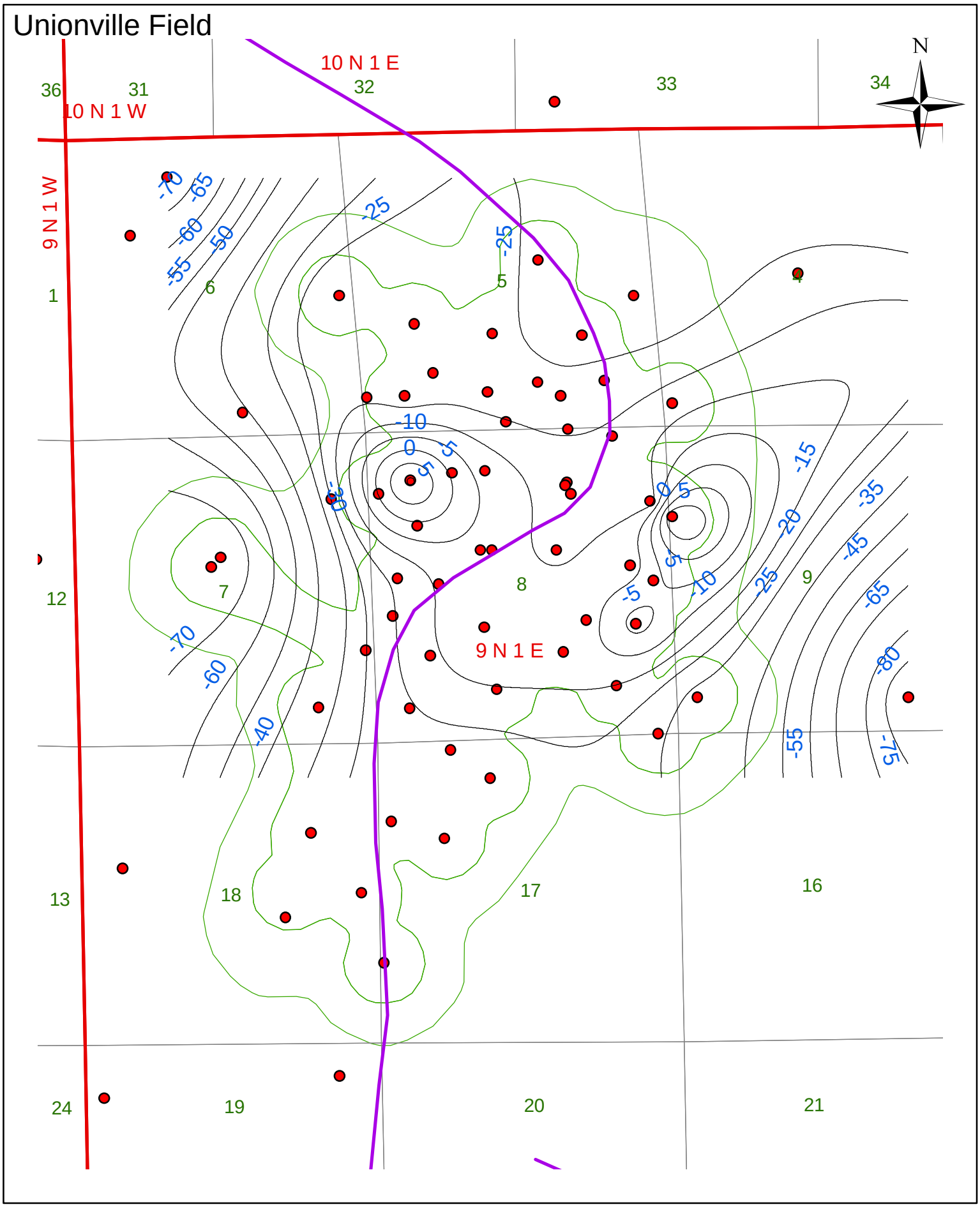

Figure 4: Structure map showing top of the Geneva Dolomite Member in Unionville Field, Monroe County. Contours show values below sea level, contour interval is 5 ft .

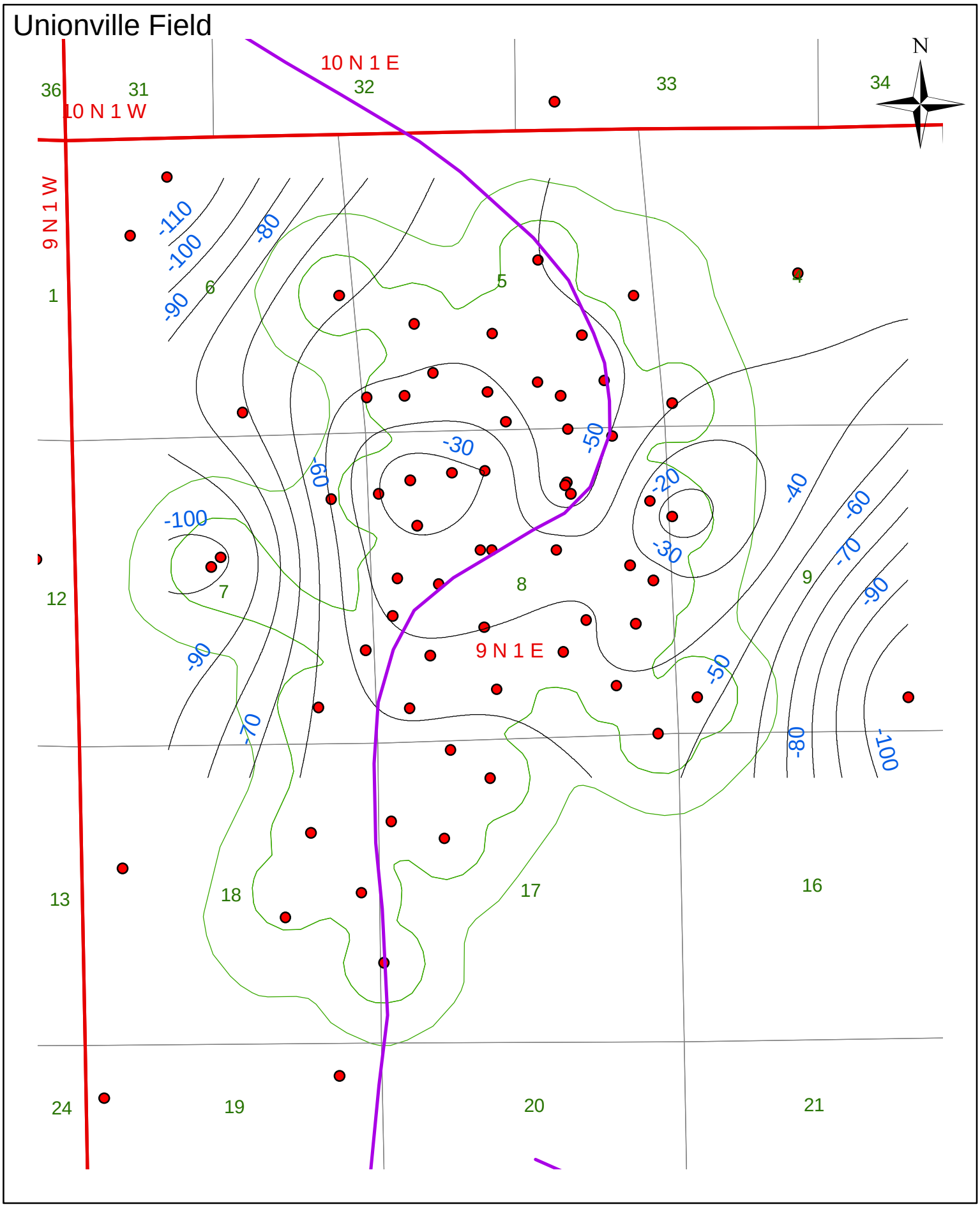

Figure 5: Structure map showing top of the Silurian in Unionville Field, Monroe County. Contours show values below sea level, contour interval is 10 ft .

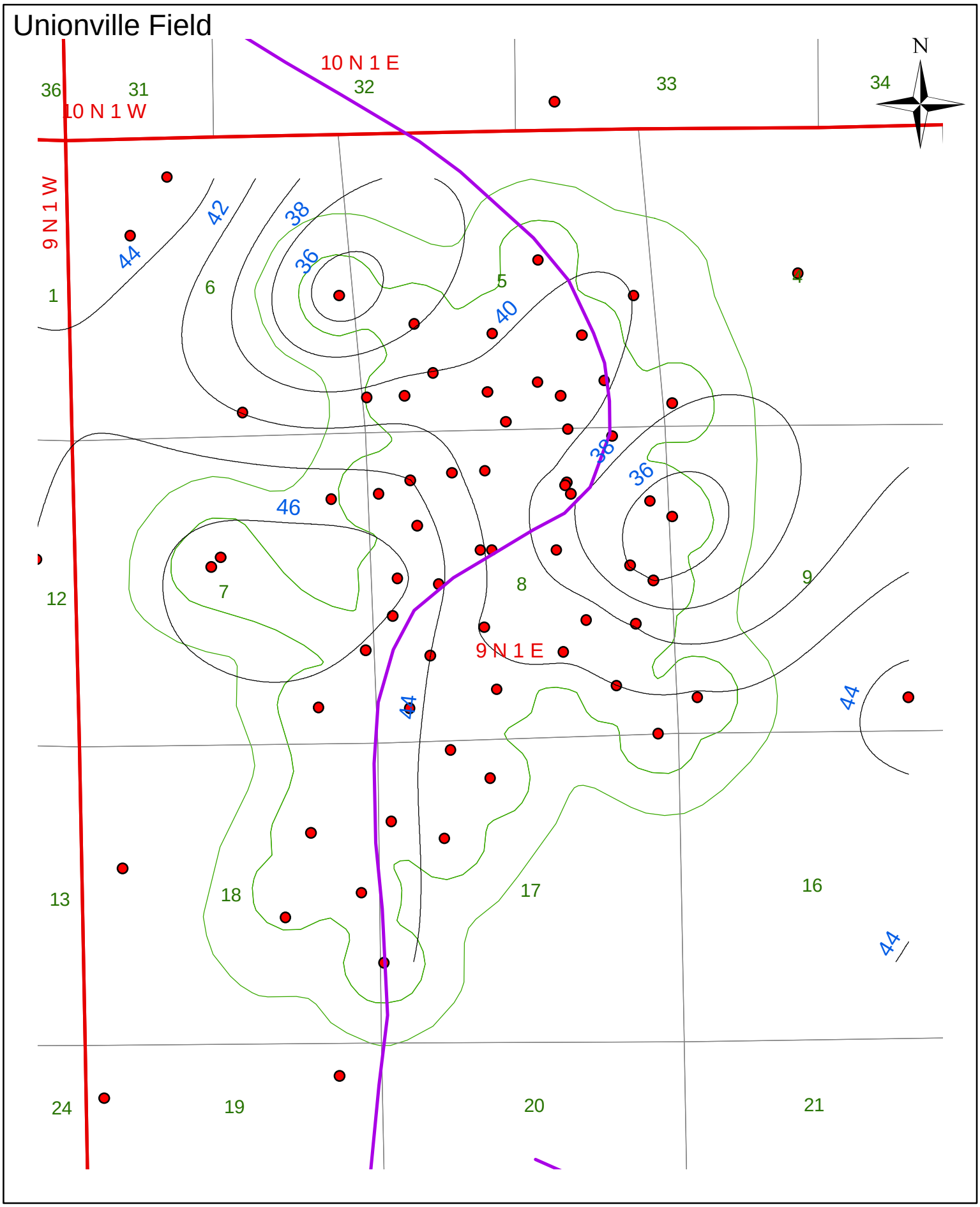

Figure 6: Isopach map showing the thickness of the North Vernon Member in Unionville field, Monroe County. Countour interval is 2 ft.

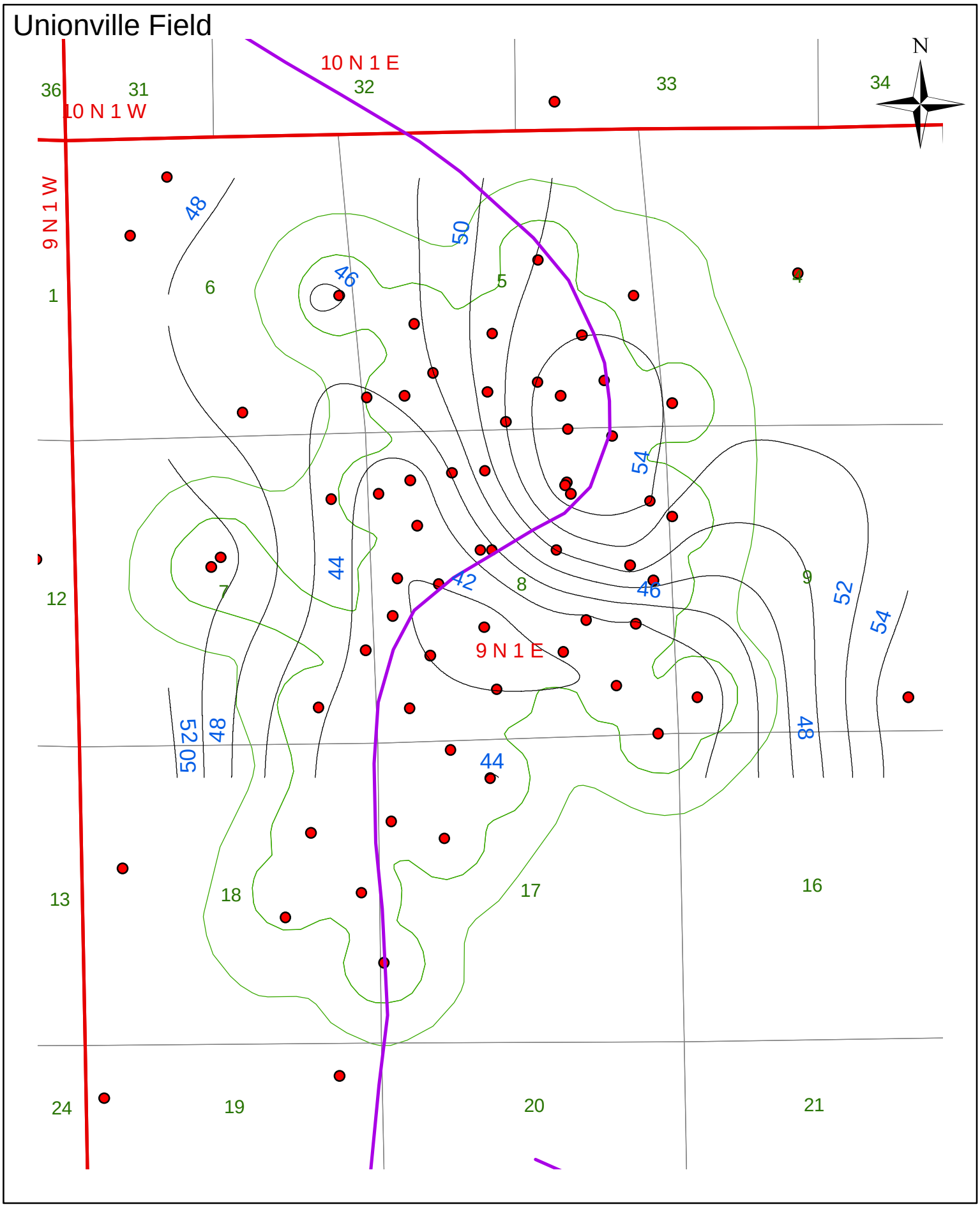

Figure 7: Isopach map showing the thickness of the Vernon Fork Member in Unionville Field, Monroe County. Contour interval is 2 ft.

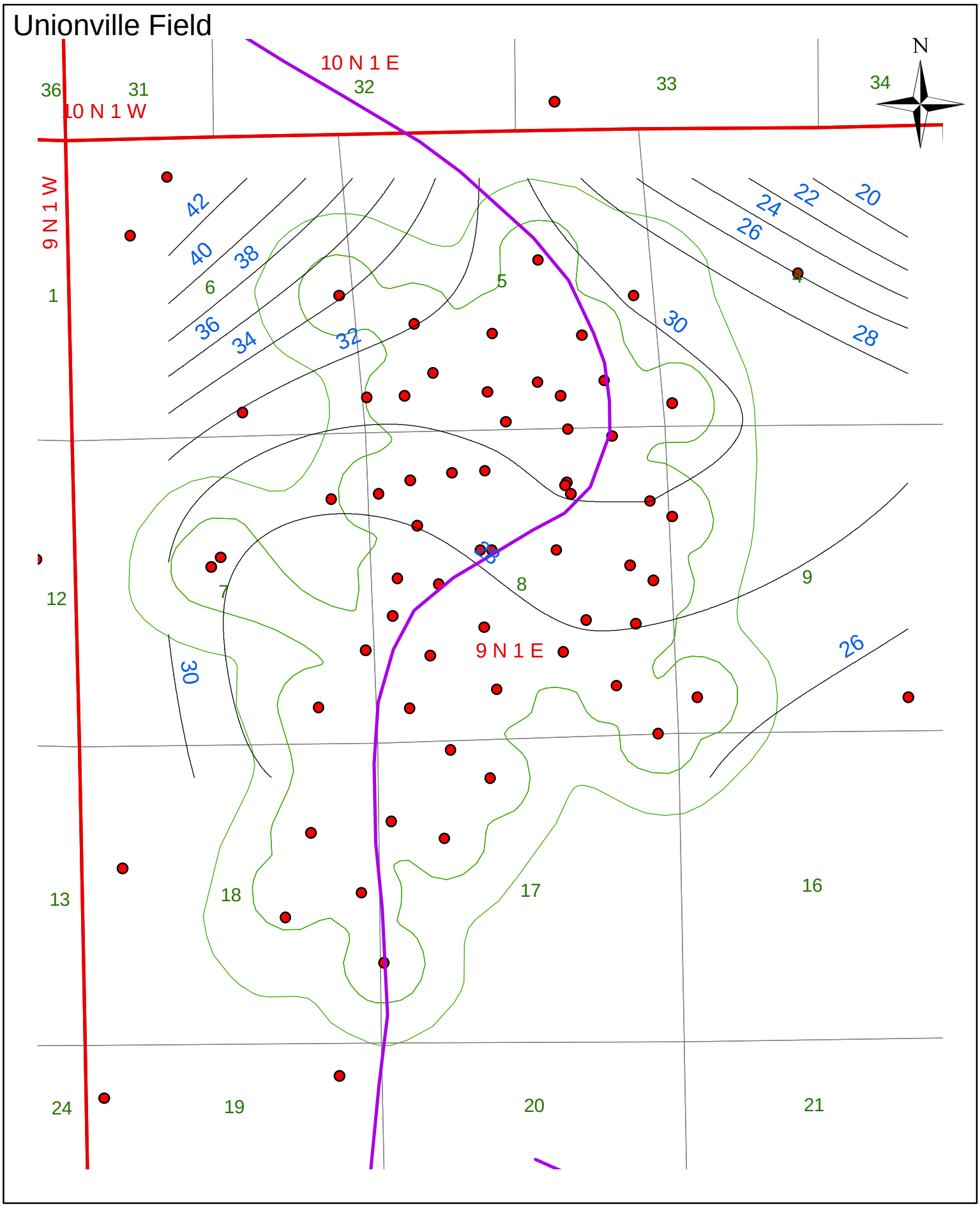

Figure 8: Isopach map showing the thickness of the Geneva Dolomite Member in Unionville field, Monroe County. Contour interval is 2 ft.

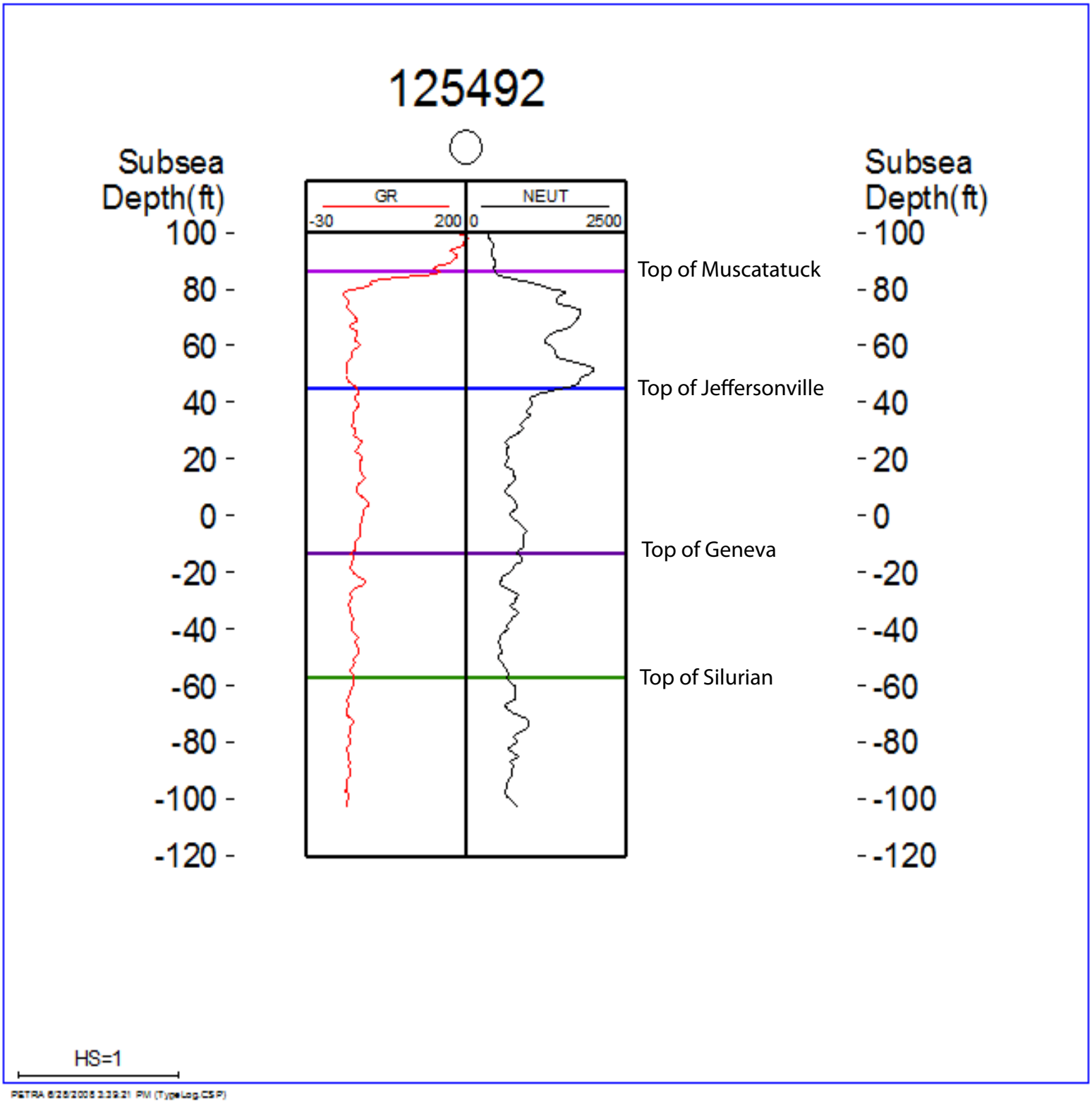

Figure 9: Type log section showing the Devonian formations at Unionville Field, Monroe County.

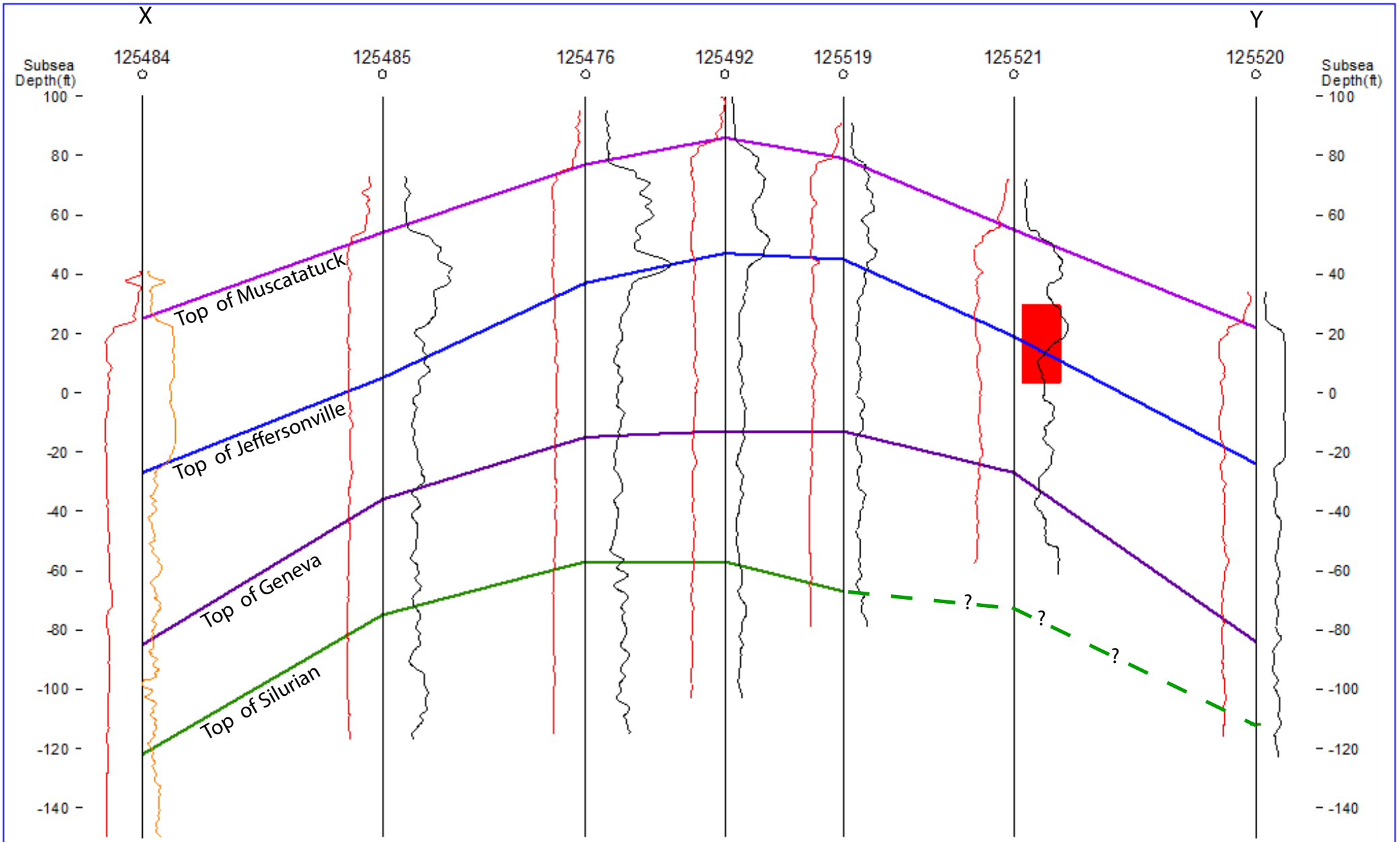

Figure 10: X-Y Cross section showing the Devonian subsurface structure across Unionville Field, Monroe County. The red color box shows the completion intervals for the gas storage. For location of the cross section refer to Figure 1.

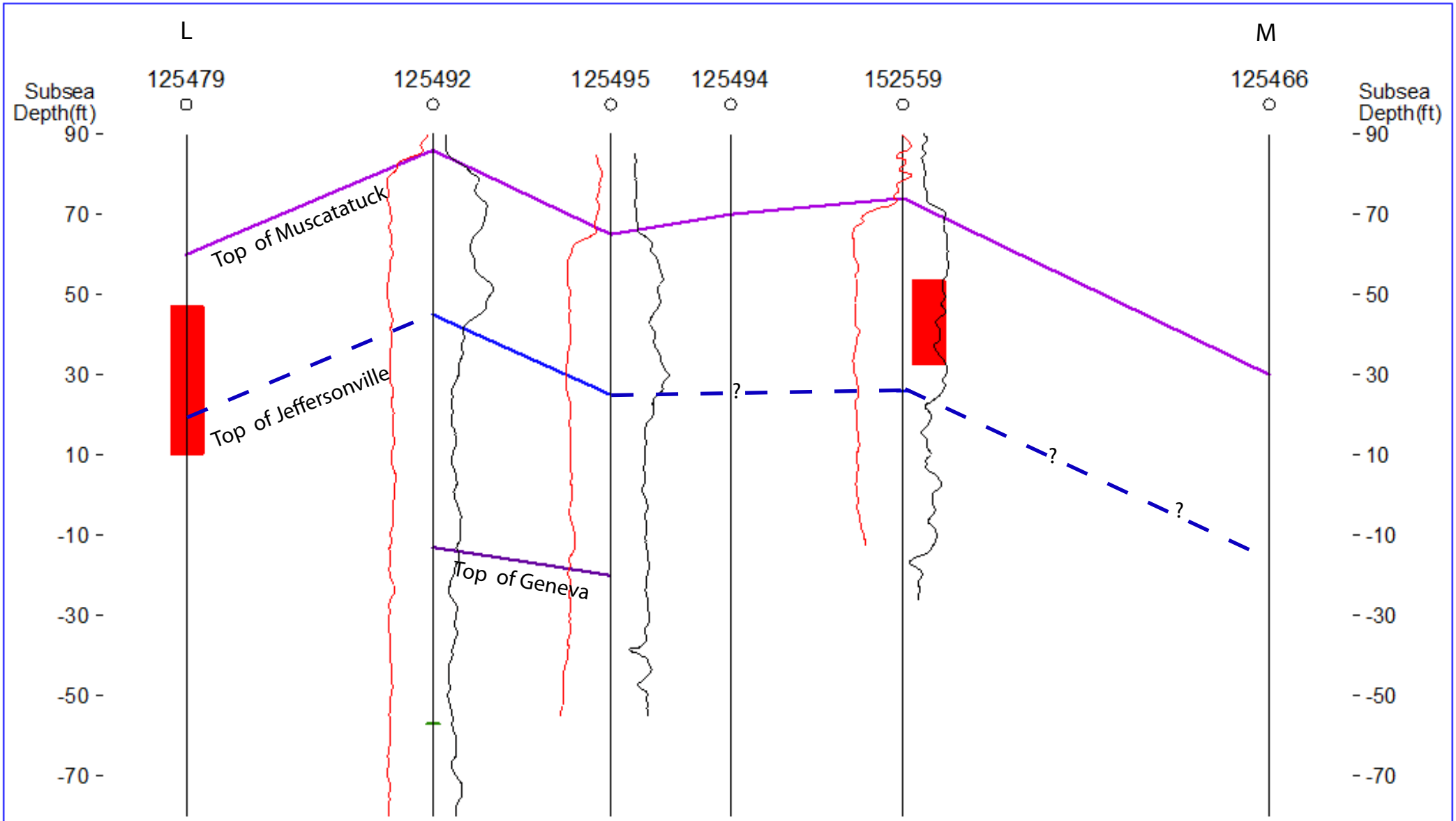

Figure 11: L-M Cross section showing the Devonian subsurface structure across Unionville Field, Monroe County. The red color box shows the completion intervals for the gas storage. For location of the cross section refer to Figure 1.

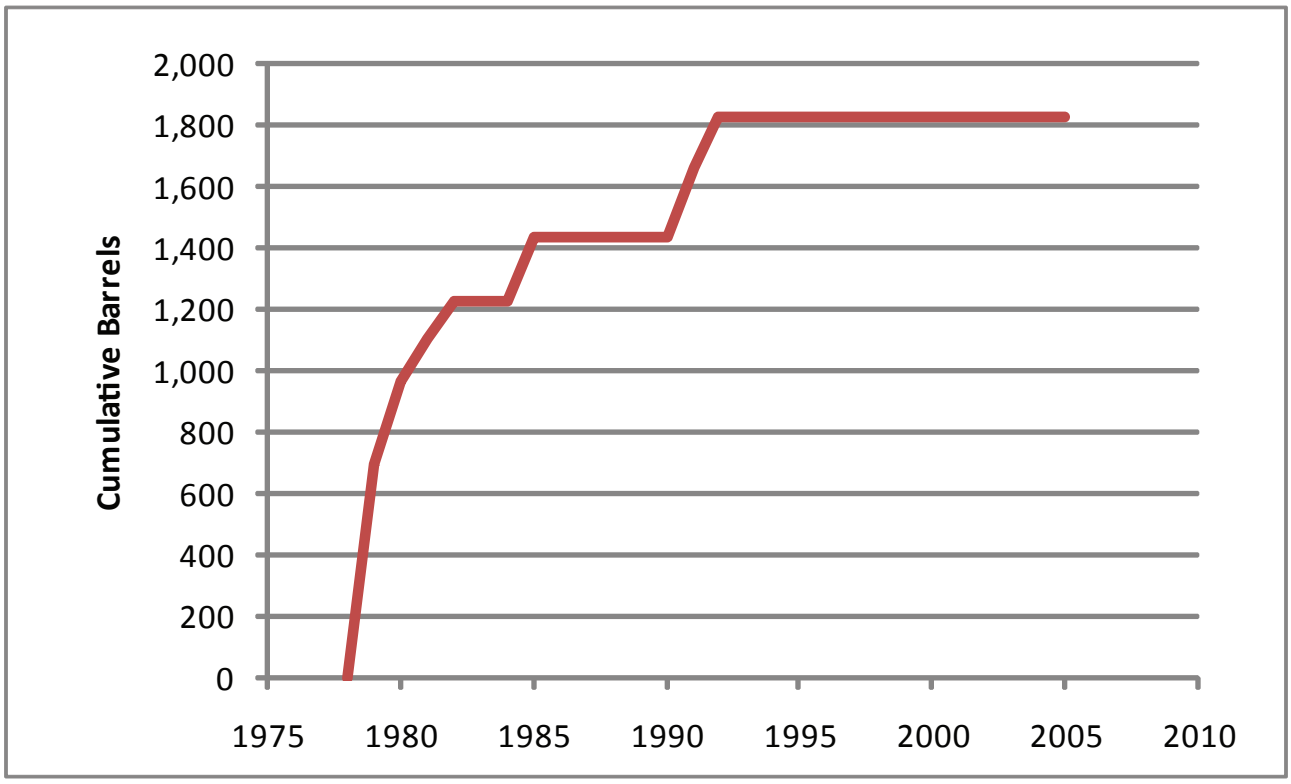

Figure - 12: Cumulative oil production history from Unionville GSP Field, Monroe County since 1978.

Table-1: List of the wells from Uniоinville Field, Monroe County.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)	Core (P/A)
125475	9	N	1	E	5	863	800	840	892	910			
125506	9	N	1	E	8	892	814	854	904	922			
125472	9	N	1	E	4	685							Present
152552	9	N	1	E	4	873	800						
125473	9	N	1	E	5	891	822	862				964	
125474	9	N	1	E	5	888	806	850	912	946			Present
125476	9	N	1	E	5	875	808	848	898	940			
125477	9	N	1	E	5	886							
125478	9	N	1	E	5	872							
125479	9	N	1	E	5	872	812					681	
125480	9	N	1	E	5	856						800	
125481	9	N	1	E	5	872	806	848	895	920			
152553	9	N	1	E	5	885	810						
152554	9	N	1	E	5	886	819						
152555	9	N	1	E	5	889	820						
152556	9	N	1	E	5	879	813						
125482	9	N	1	E	6	873						260	
125483	9	N	1	E	6	846	818			970			
125484	9	N	1	E	6	831	806	854	904	950			
125485	9	N	1	E	6	863	809	840	884	924			
125486	9	N	1	E	7	709						880	
125487	9	N	1	E	7	716	654	710	766	800			
125488	9	N	1	E	7	853							
125489	9	N	1	E	7	823						1080	
125490	9	N	1	E	7	735						922	
125491	9	N	1	E	8	883	802	846	899	940			
125492	9	N	1	E	8	897	813	852	914	956			
125493	9	N	1	E	8	884							
125494	9	N	1	E	8	870	800						
125495	9	N	1	E	8	865	800	840	875				
125496	9	N	1	E	8	883							
125497	9	N	1	E	8	873	802	846	885	915			Present
125498	9	N	1	E	8	854	779	818	870	890			
125499	9	N	1	E	8	871	801	850	890	906			
125500	9	N	1	E	8	857							
125501	9	N	1	E	8	860							
125502	9	N	1	E	8	851							
125503	9	N	1	E	8	871							
125504	9	N	1	E	8	893						1200	
125507	9	N	1	E	8	890	803	848	884	912			
125508	9	N	1	E	8	875	799	840	878	906			
125509	9	N	1	E	8	861	803						

Table-1: List of the wells continued....

125510	9	N	1	E	8	806							
125511	9	N	1	E	8	851	775						
125512	9	N	1	E	8	757						1000	
125513	9	N	1	E	8	880						900	
125514	9	N	1	E	8	891	800	834				878	
125516	9	N	1	E	8	880							
125517	9	N	1	E	8	870	790	826	888	930			
125518	9	N	1	E	8	882	804	838	888	916			
125519	9	N	1	E	8	871	792	826	884	904			
152557	9	N	1	E	8	888	806						
125520	9	N	1	E	9	834	812	858	918	944			Present
125521	9	N	1	E	9	832	777	820	859	880		700	
125522	9	N	1	E	9	876	790	822	866	891			
125457	9	N	1	E	17	865						1520	
125458	9	N	1	E	17	857							
125460	9	N	1	E	17	851							
125461	9	N	1	E	17	872	807	850	896	928			
152558	9	N	1	E	17	812	756	800					
125463	9	N	1	E	18	844							
125464	9	N	1	E	18	840						10	
152559	9	N	1	E	18	844	772	818					
152560	9	N	1	E	18	861	802						
125465	9	N	1	E	19	726							
125466	9	N	1	E	19	885	855						
125467	9	N	1	E	20	810	801			958			
125523	9	N	1	W	12	651							
152562	9	N	1	W	12	628	611	652		765			
125225	10	N	1	E	33	828							

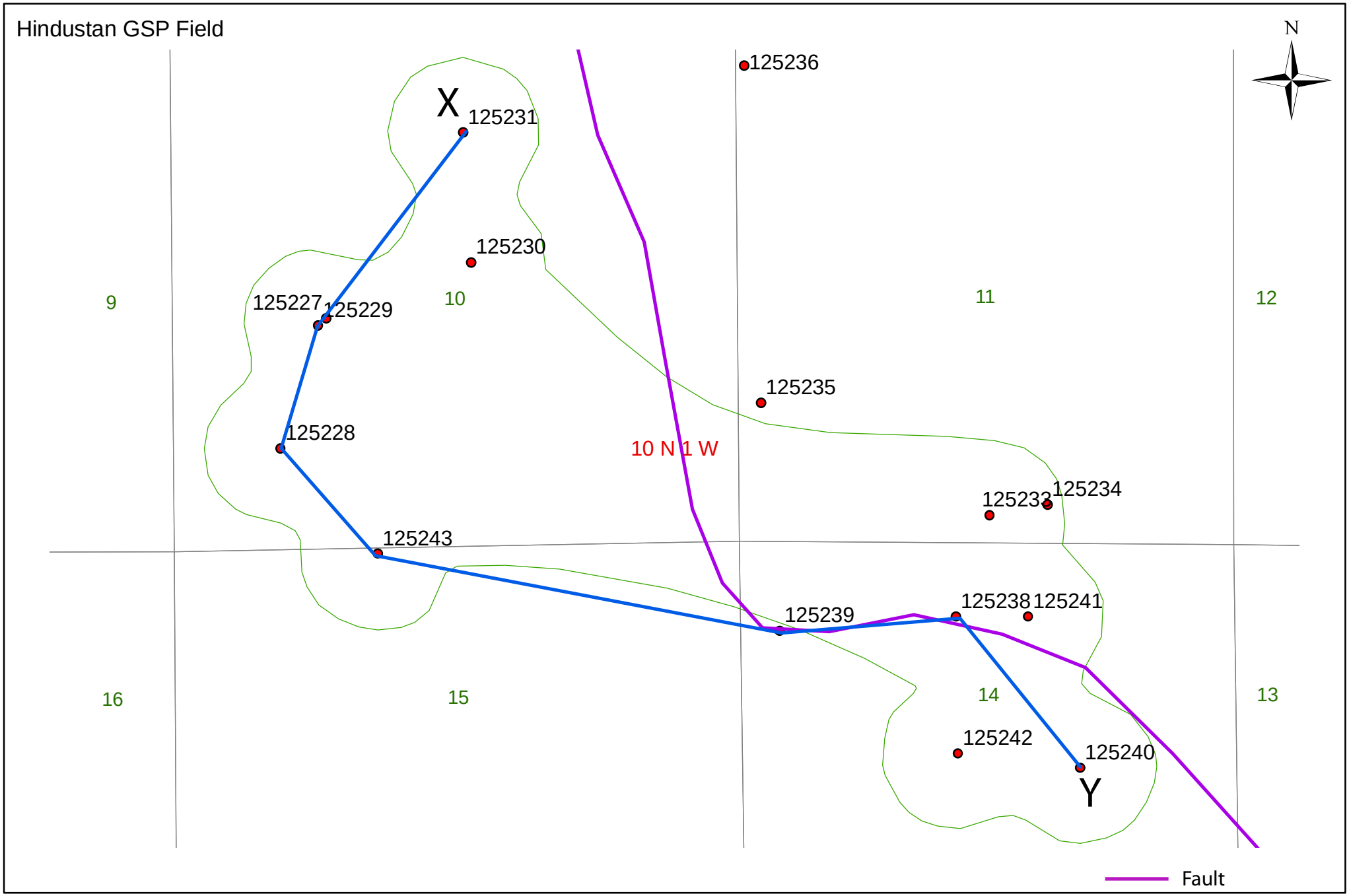

Figure 1: Map showing the location and wells at Hindustan GSP Field, Monroe County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figures 4. The trace of the Mt. Carmel Fault is also shown.

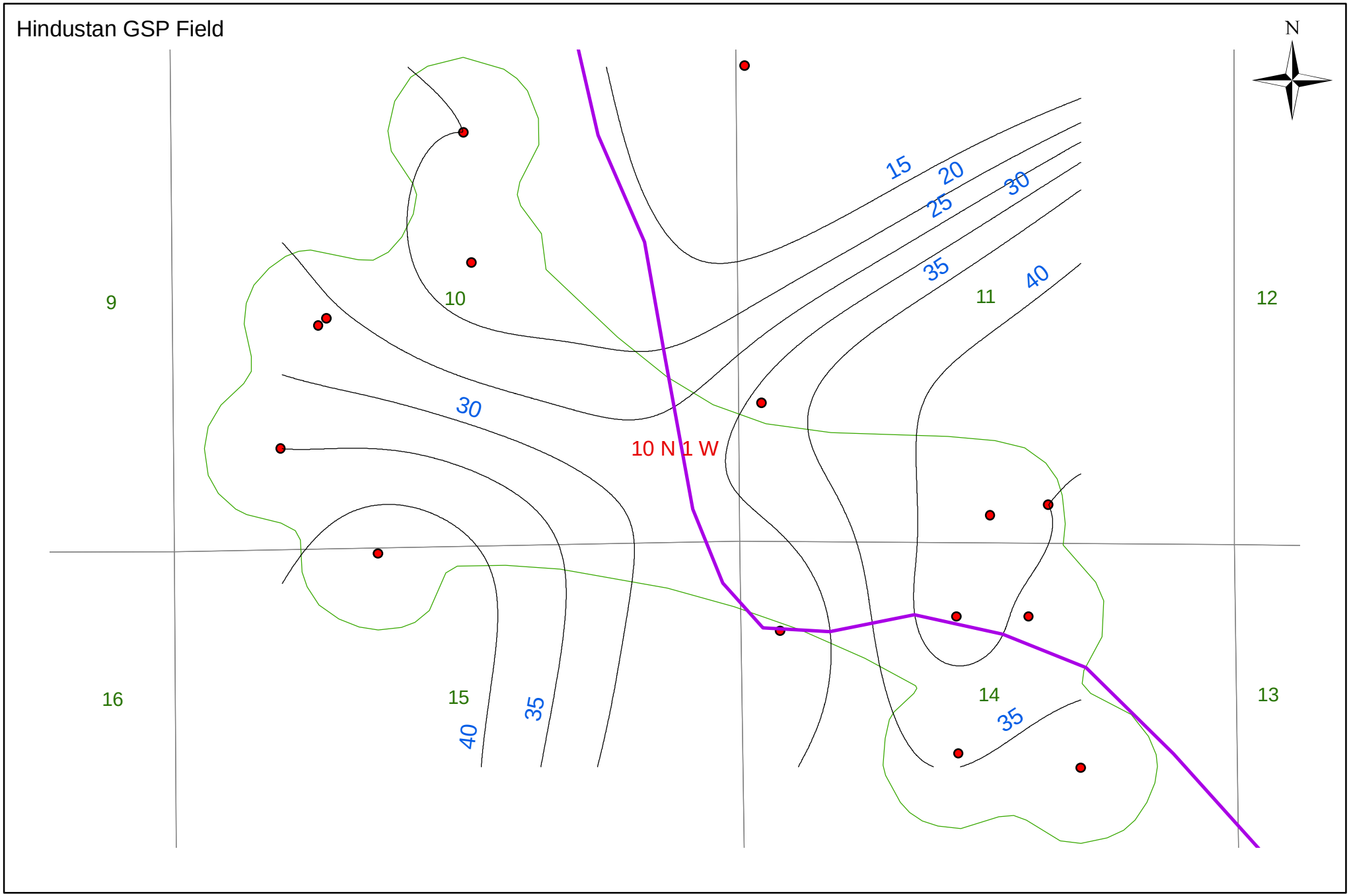

Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Hindustan GSP Field, Monroe County. Contours show values below sea level, contour interval is 5 ft .

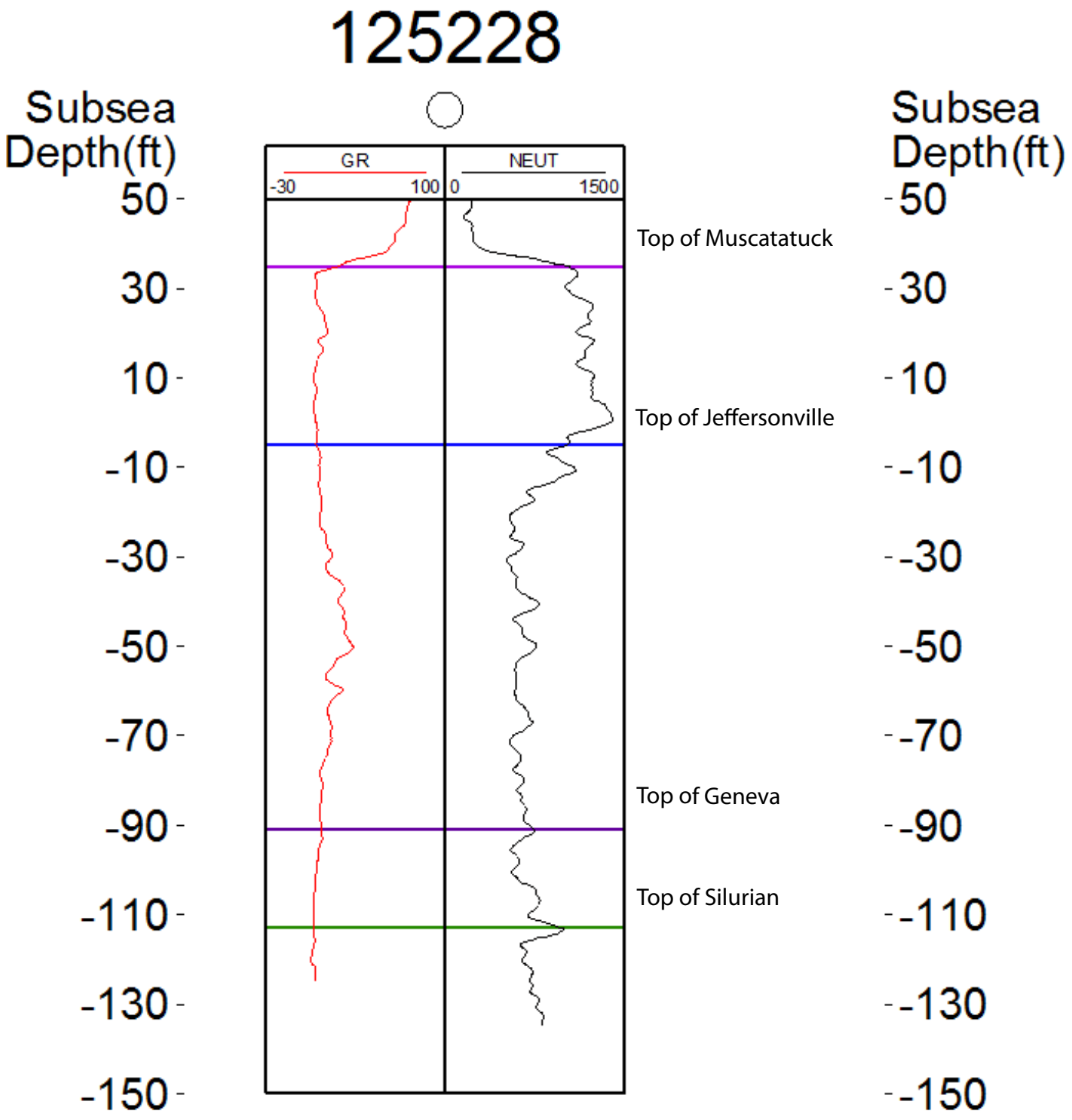

Figure 3: Type log section showing the Devonian formations at Hindustan GSP Field, Monroe County.

HS=1

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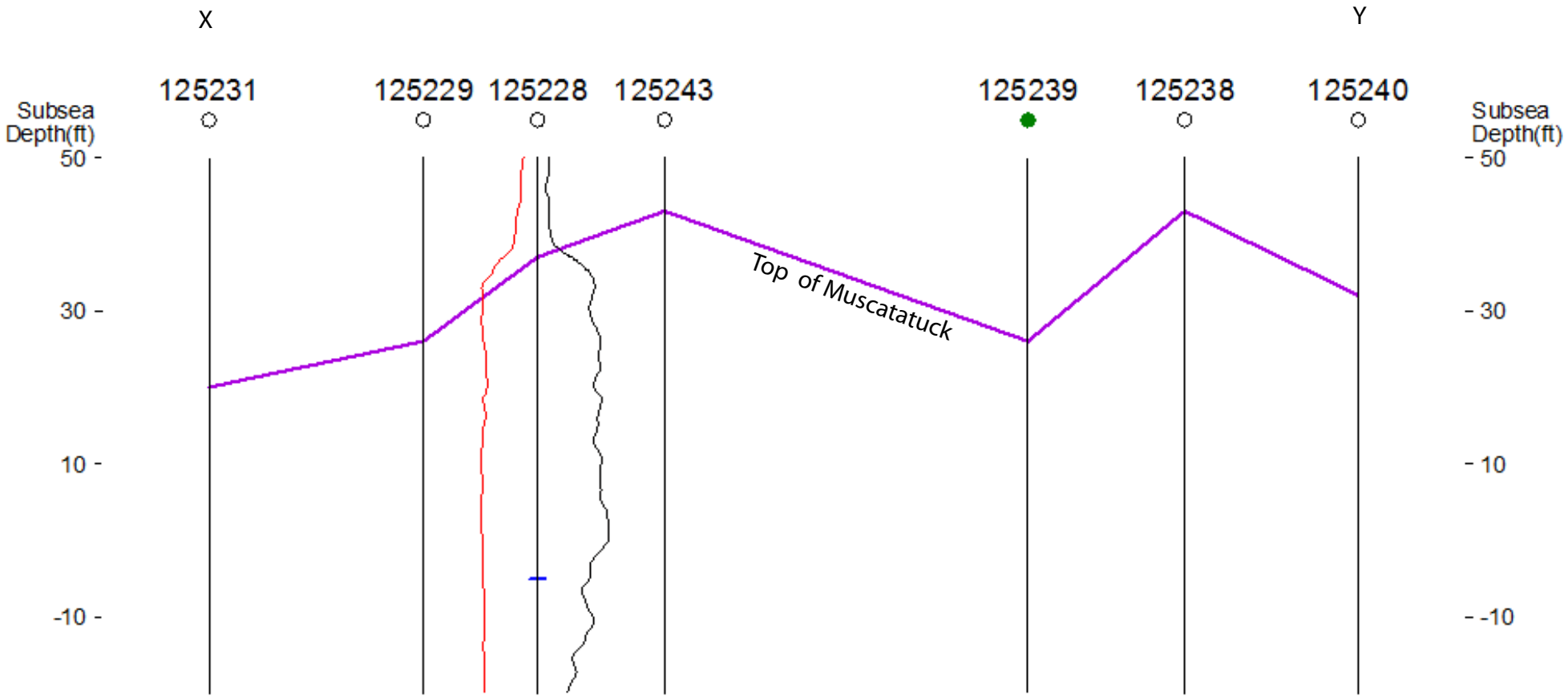

Figure 4: X-Y Cross section showing the Devonian subsurface structure across Hindustan GSP Field, Monroe County. For location of the cross section refer to Figure 1.

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Table-1: List of the wells used for subsurface structure mapping in Hindustan GSP Field, Monroe County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
125251	10	N	1	W	9	817						
125227	10	N	1	W	10	853	817					
125228	10	N	1	W	10	765	730	770	856	878		
125229	10	N	1	W	10	836	810					
125230	10	N	1	W	10	812	795					
125231	10	N	1	W	10	830	810					
125233	10	N	1	W	11	856	814					
125234	10	N	1	W	11	846	806	852				
125235	10	N	1	W	11	709						
125236	10	N	1	W	11	795	784					
125238	10	N	1	W	14	853	810					
125239	10	N	1	W	14	834	808					
125240	10	N	1	W	14	850	818					
125241	10	N	1	W	14	851	812					
125242	10	N	1	W	14	801	790					
125243	10	N	1	W	15	829	786					
125246	10	N	1	W	24	813	800					

Field name: White Rose

IGS ID: 10783

DOE ID: na

Location: Greene County, 7N-7W

Discovery date: 1993

Lower Paleozoic reservoir unit (depth):

Devonian, Muscatatuck Group, North Vernon Ls. (2,042 ft.)

Devonian, New Harmony Group (2,122 ft.)

Field type: natural gas

Total number production wells: 3

Area: na

Cumulative production: na

Other reservoir units: na

Deepest unit penetrated (depth): Ordovician, Trenton Limestone (3,450 ft.)

Field characteristic: Limited well control with no observable structure at Mississippian.

Reservoir characteristics:

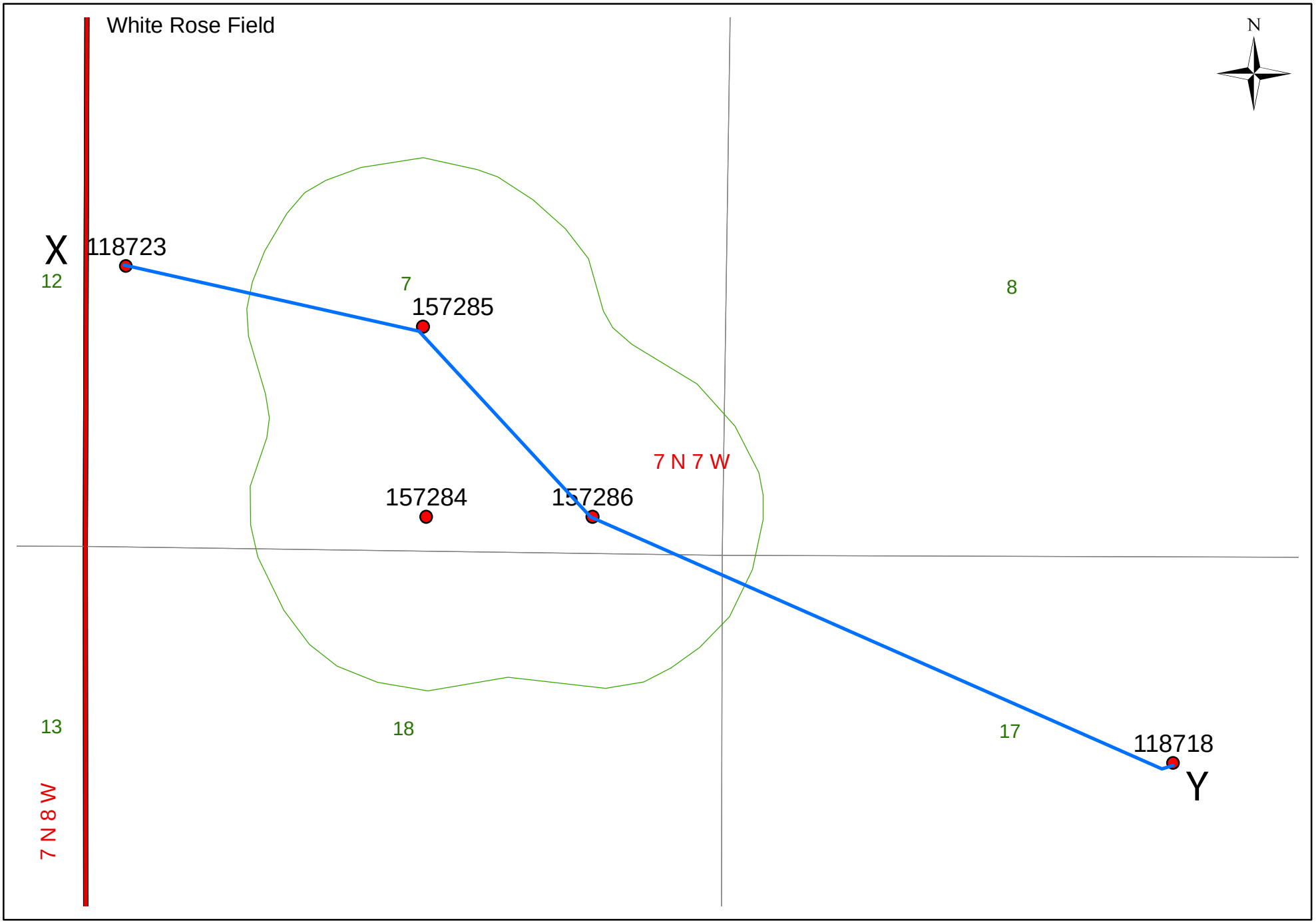

Figure 1: Map showing the location and wells at White Rose Field, Greene County. X-Y is the location of the cross section that shows the subsurface Devonian structure in Figures 3.

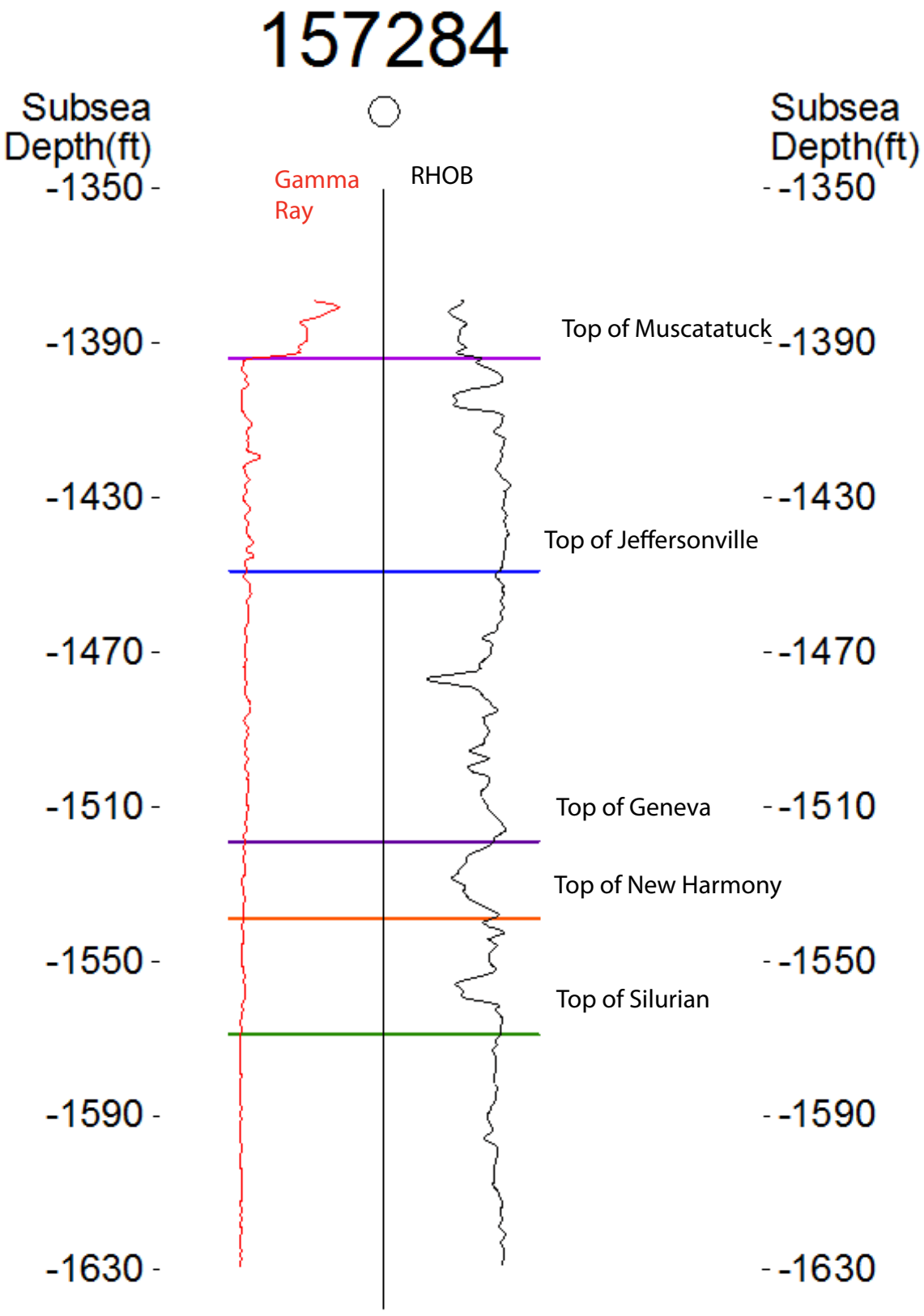

Figure 2: Type log section showing the Devonian formations at White Rose Field, Greene County.

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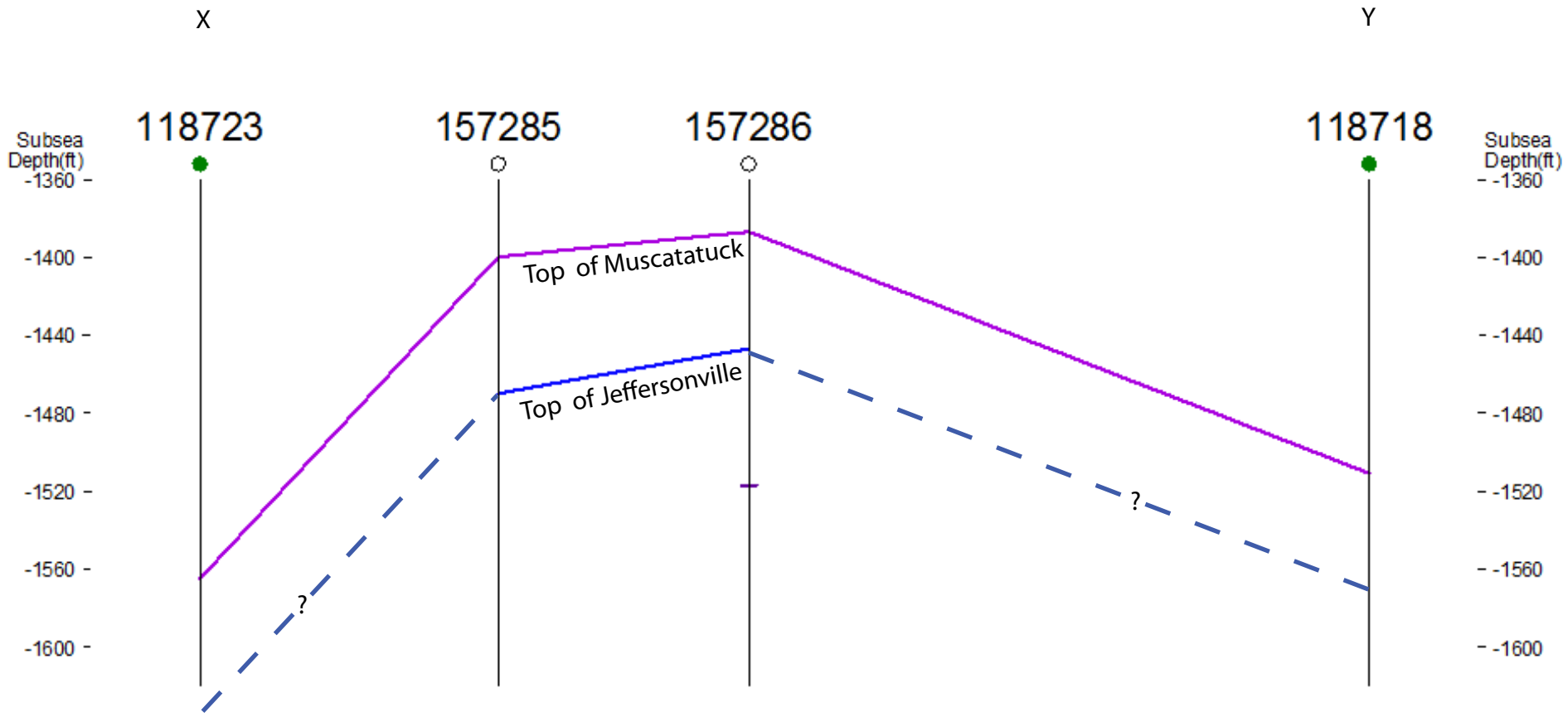

Figure 3: X-Y Cross section showing the Devonian subsurface structure across White Rose Field, Greene County. For location of the cross section refer to Figure 1.

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Table-1: List of the wells used for subsurface structure mapping in White Rose Field, Greene County

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/ Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of New Harmony	Top of Silurian	Oil_P	Gas_P
118723	7	N	7	W	7	585	2150						
157284	7	N	7	W	7	571	1965	2020	2090	2110	2140		
157285	7	N	7	W	7	580	1980	2050					600
157286	7	N	7	W	7	563	1950	2010	2080	2116			650
118718	7	N	7	W	17	508							

Field name: Wilfred

IGS ID: 10786 (oil), 10830 (gas storage)

DOE ID: 768942

Location: Sullivan County, 9N-8W

Discovery date: 1948 (oil), 1958 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (2,042 ft.)

Field type: oil & gas storage

Total number production wells: 18 (oil), 16 (storage), 8 (observation)

Area: 320 acres (oil), 1022 acres (gas storage)

Cumulative production: 203,652 bbls. (2002)

Total capacity: 3,417,091 mcf

Other reservoir units:

Deepest unit penetrated (depth): Ordovician, Black River Group (3,440 ft.)

Field characteristic: Domal anticline over probable Silurian reef with closure in excess of 100 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 12%

Average permeability – 84 md.

Approximate thickness – 30 ft.

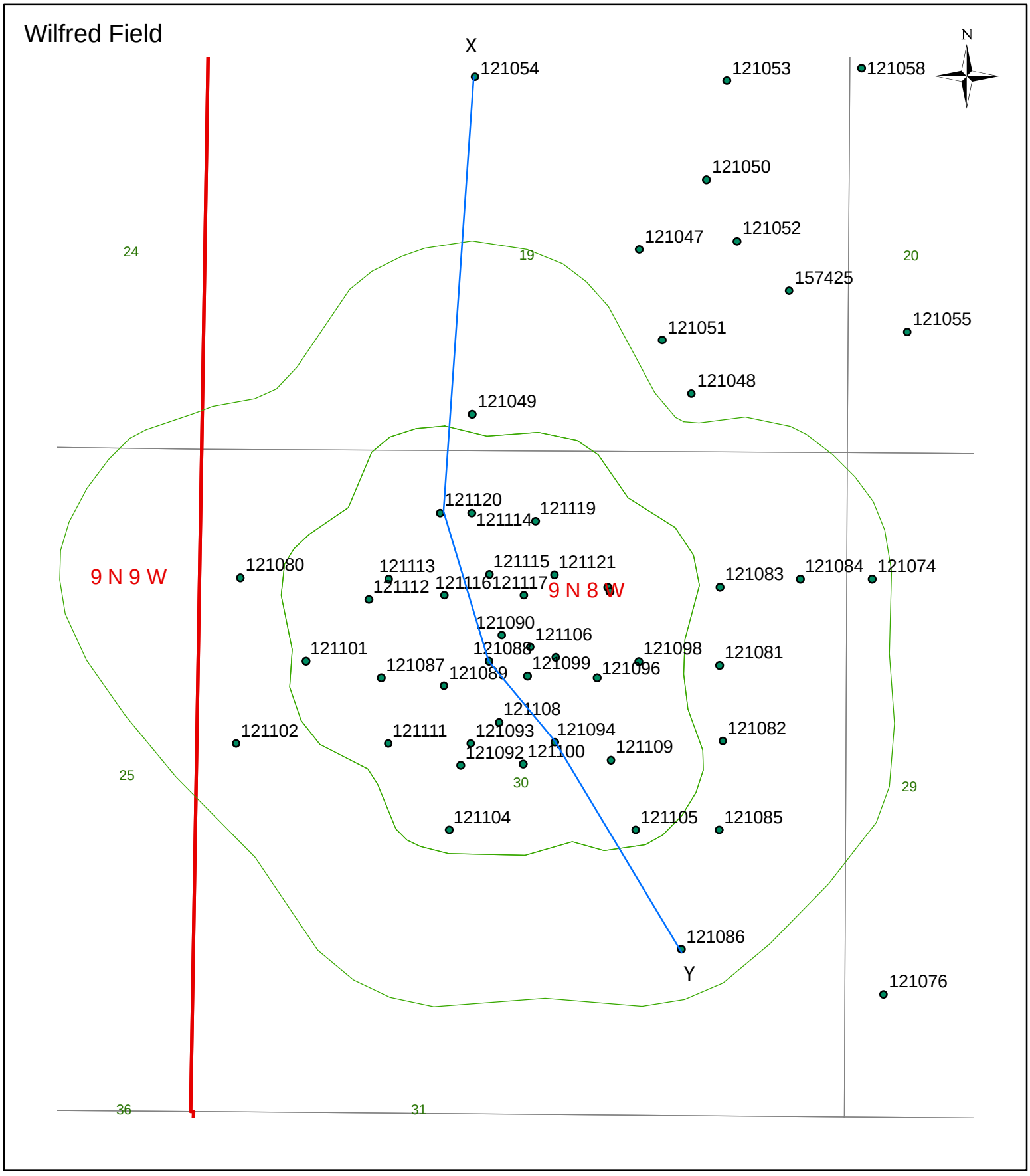


Figure 1: Map showing the location and wells at Wilfred Field, Sullivan County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 10). The wells depicted were used for subsurface maping and have a total depth (TD) of Devonian or deeper .

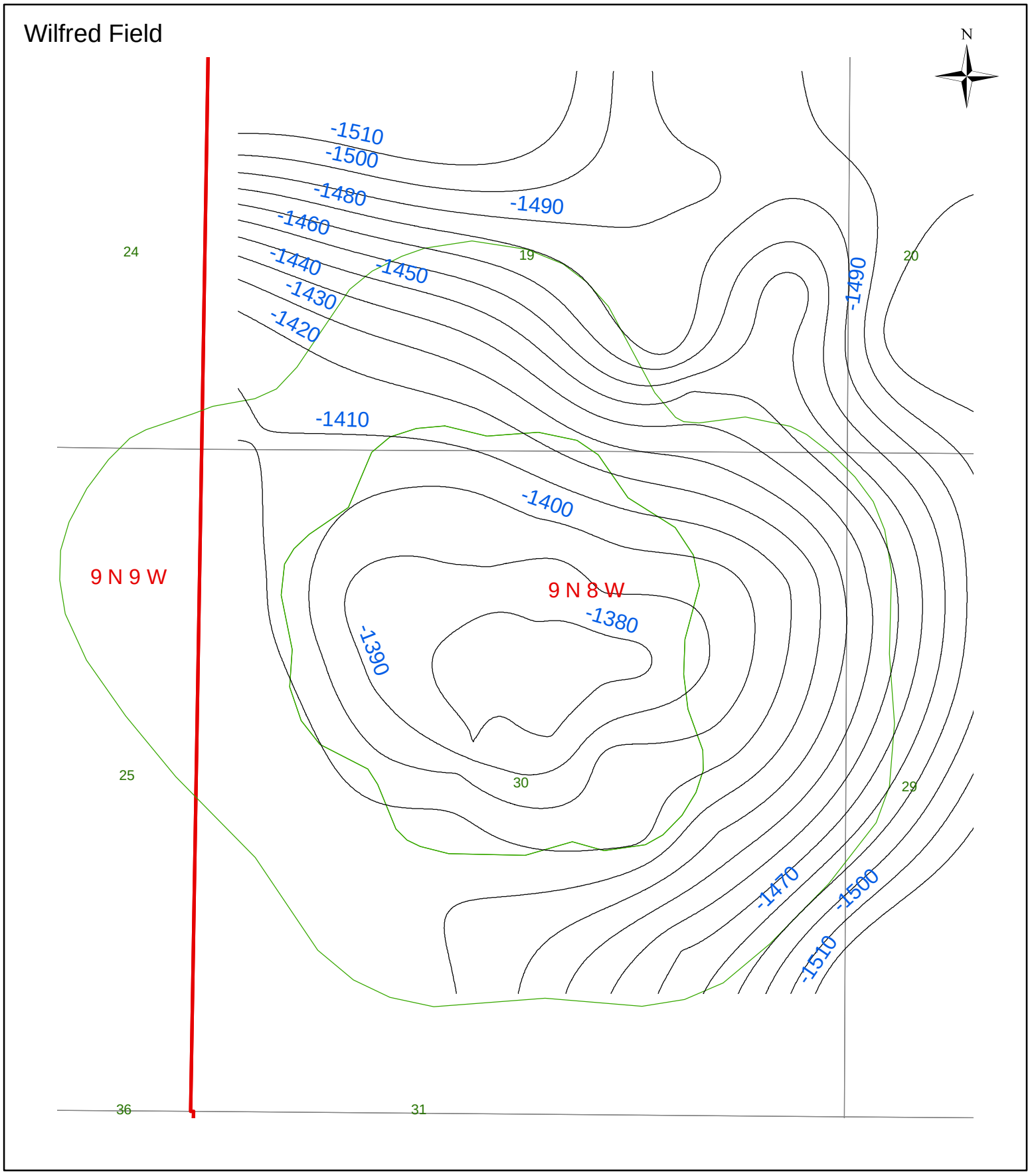


Figure 2: Structure map showing the top of subsurface Muscatatuck Limestone in Wilfred Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

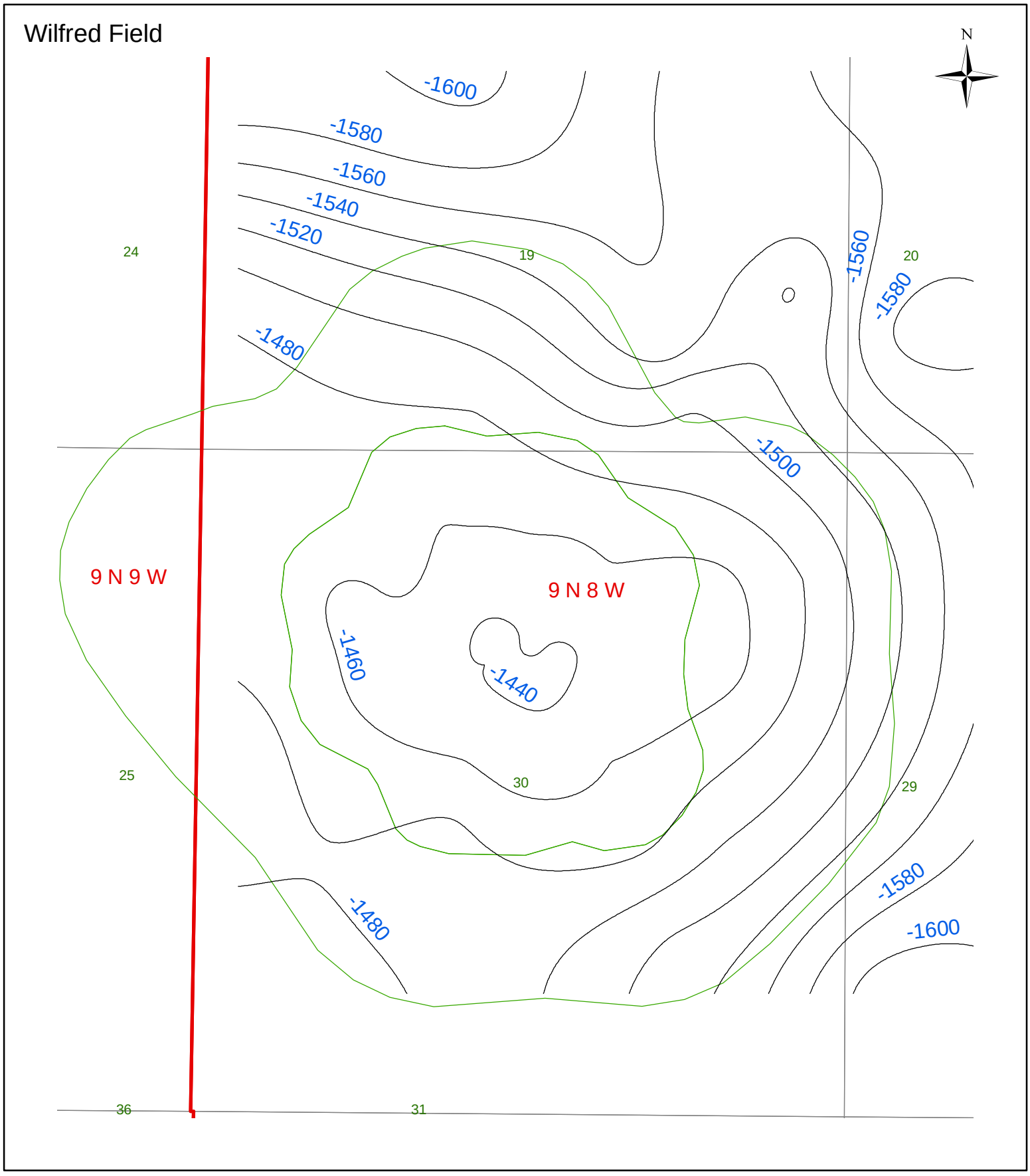


Figure 3: Structure map showing the top of subsurface Jeffersonville Limestone in Wilfred Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

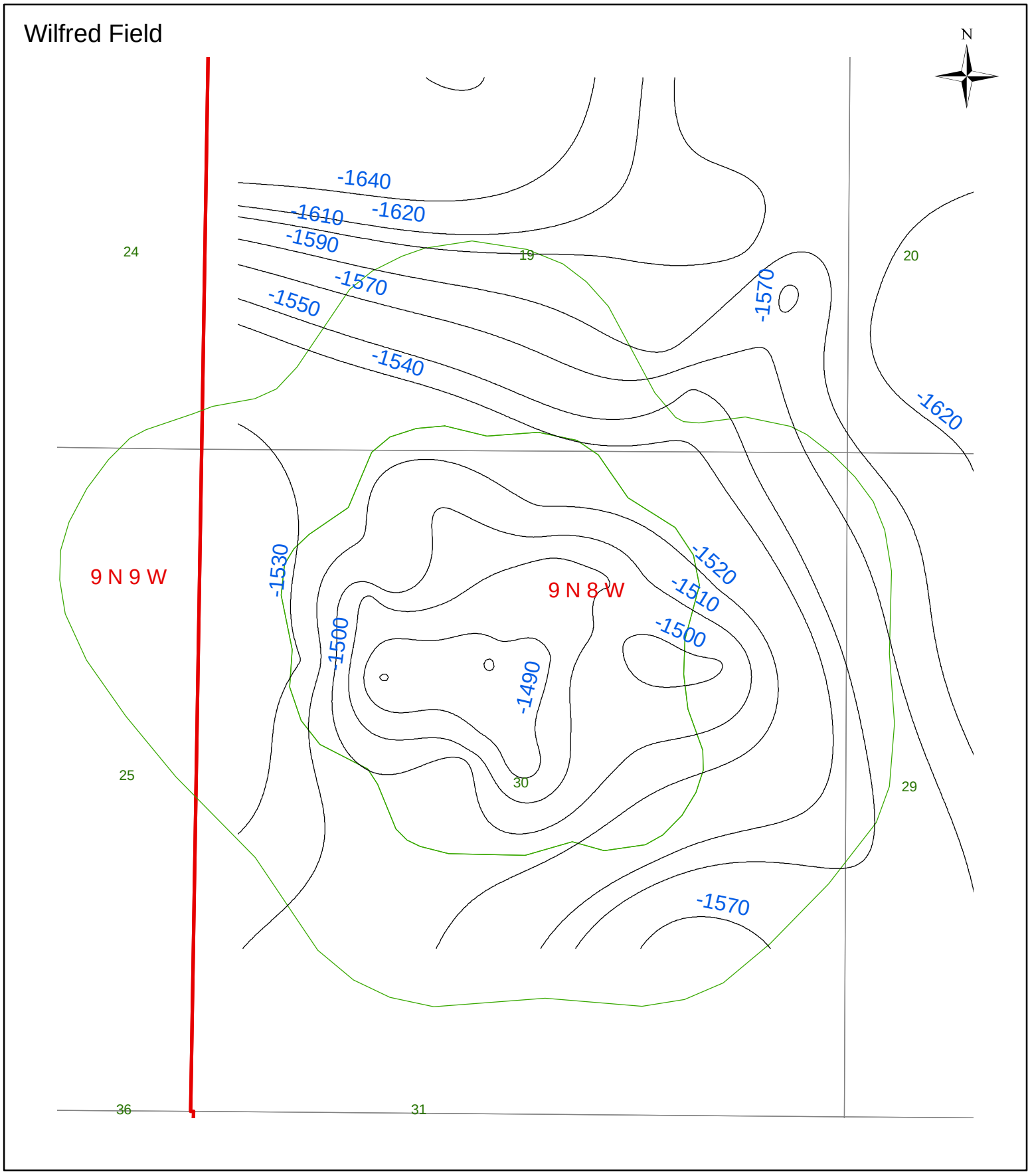


Figure 4: Structure map showing the top of the subsurface Geneva Dolomite Mbr. in Wilfred Field, Sullivan County. Contours show values below sea level, contour interval is 10 ft .

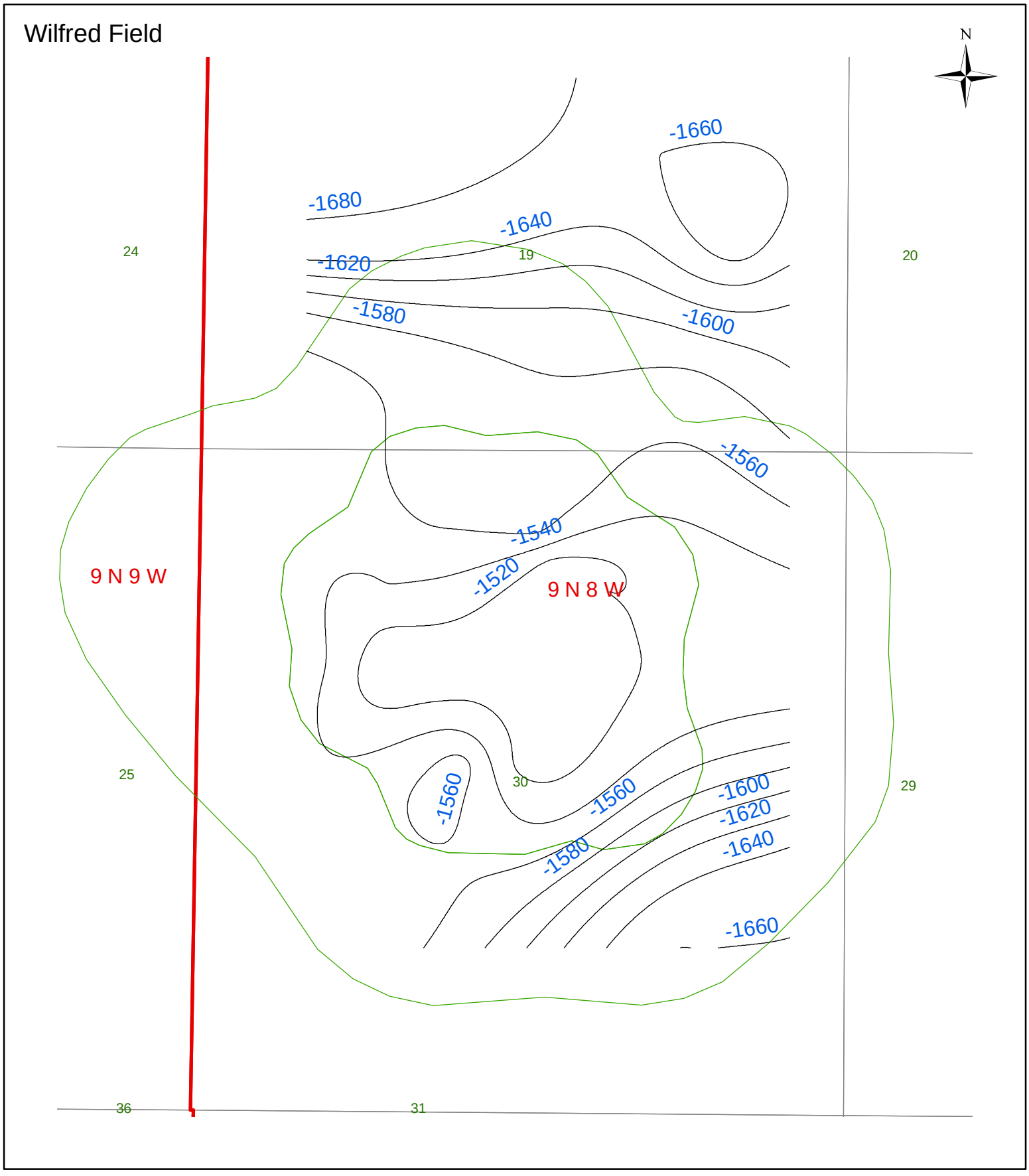


Figure 5: Structure map showing the top of the subsurface Silurian in Wilfred Field, Sullivan County. Contours show values below sea level, contour interval is 20 ft .

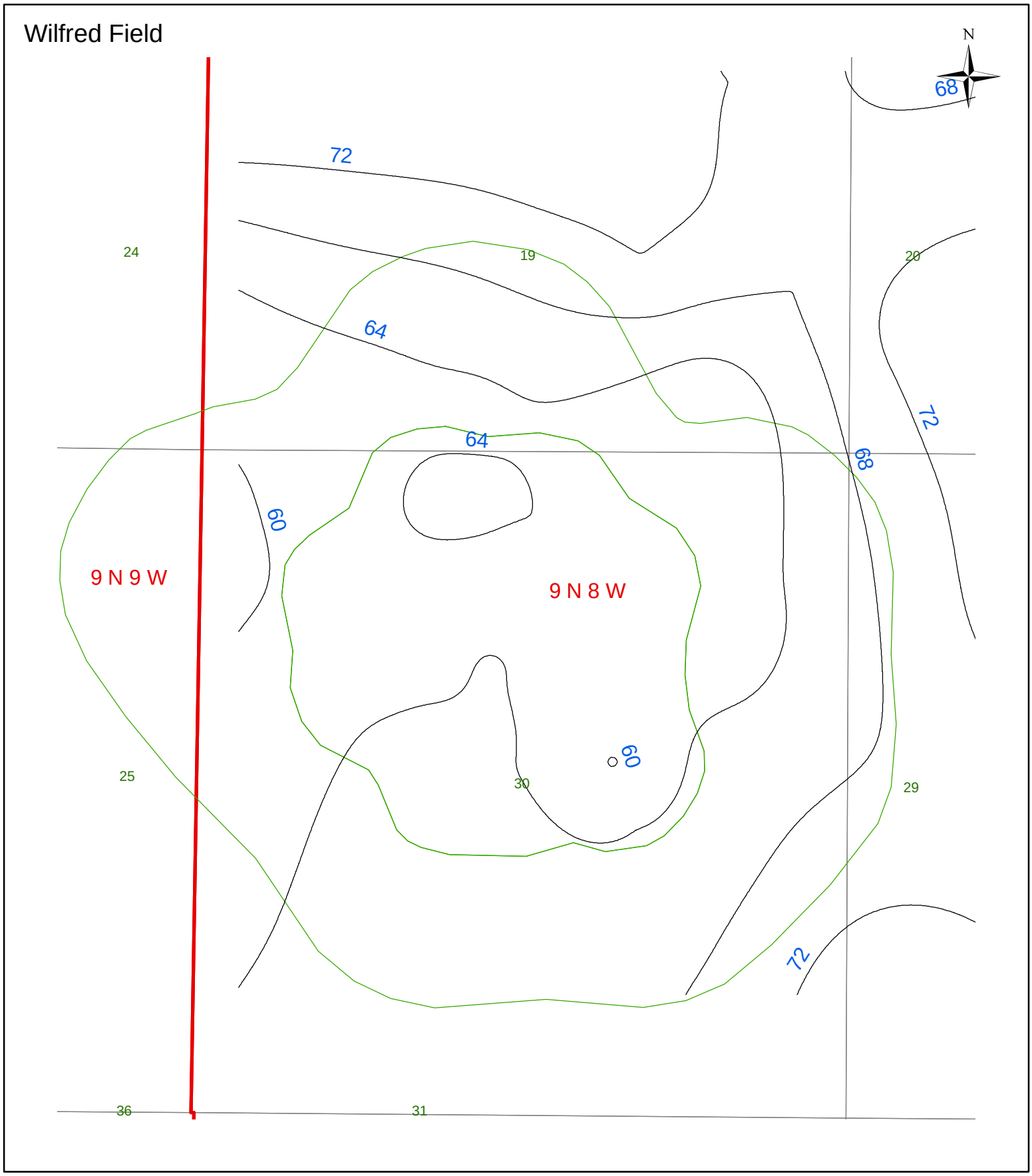


Figure 6: Isopach map showing the thickness of the North Vernon Ls. from Wilfred Field, Sullivan County. Contour interval is 4 ft.

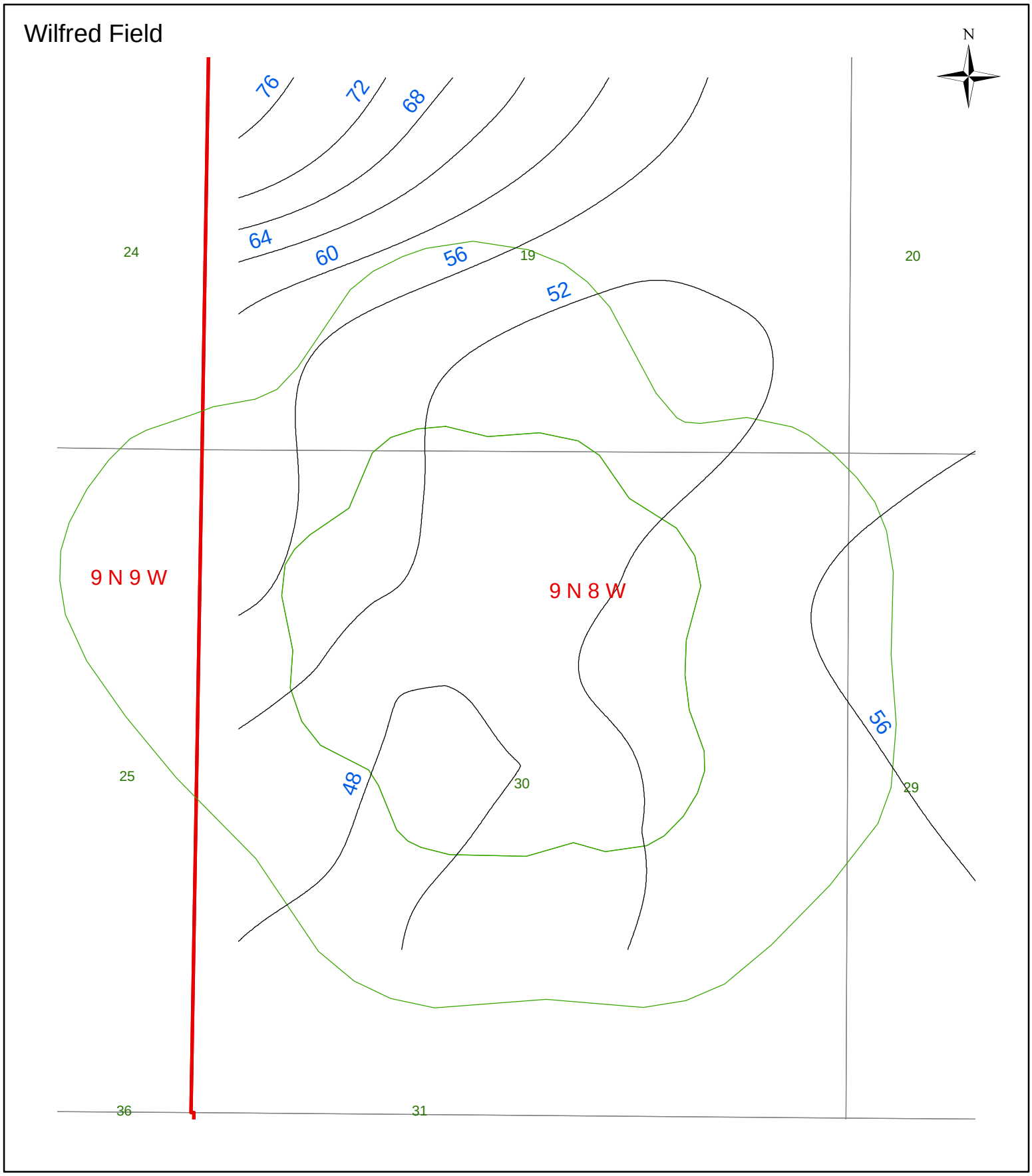


Figure 7: Isopach map showing the thickness of the Vernon Fork Member from Wilfred Field, Sullivan County. Contour interval is 4 ft.

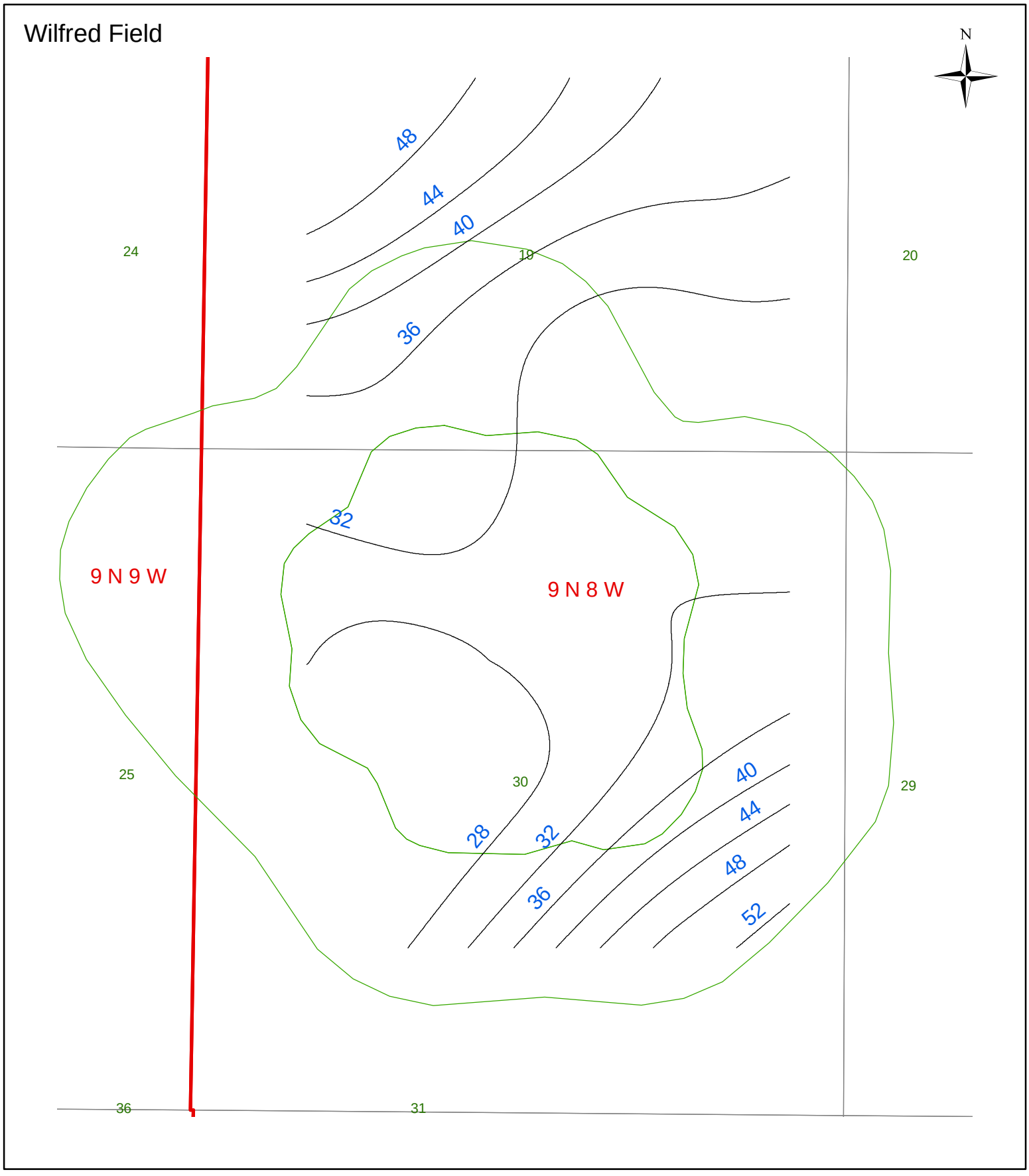


Figure 8: Isopach map showing the thickness of the Geneva Dolomite Member from Wilfred Field, Sullivan County. Contour interval is 4 ft.

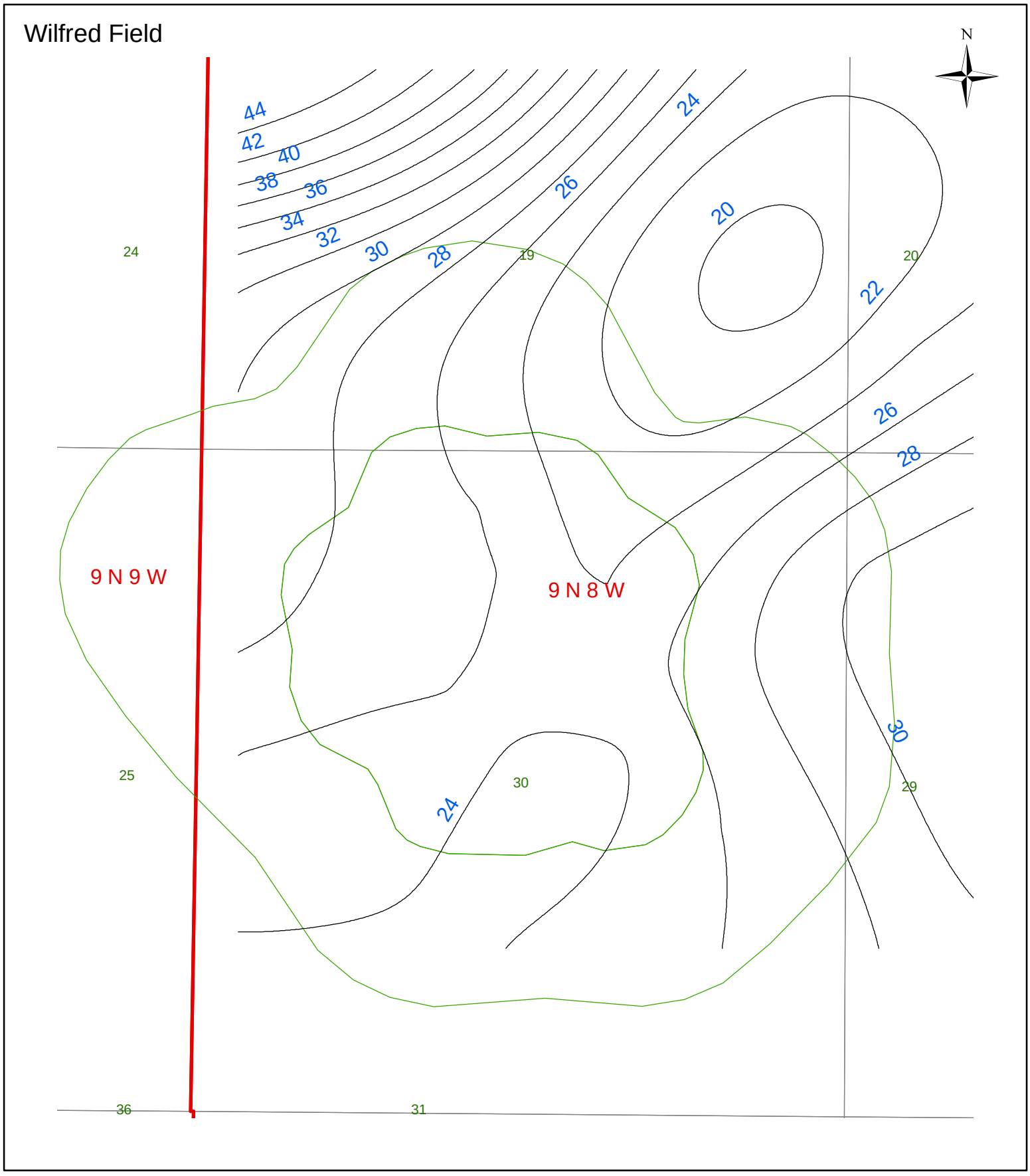


Figure 9: Map showing the net porosity feet greater than 10% from neutron logs for Vernon Fork Member in Wilfred Field, Sullivan County. Contour interval is 2 ft.

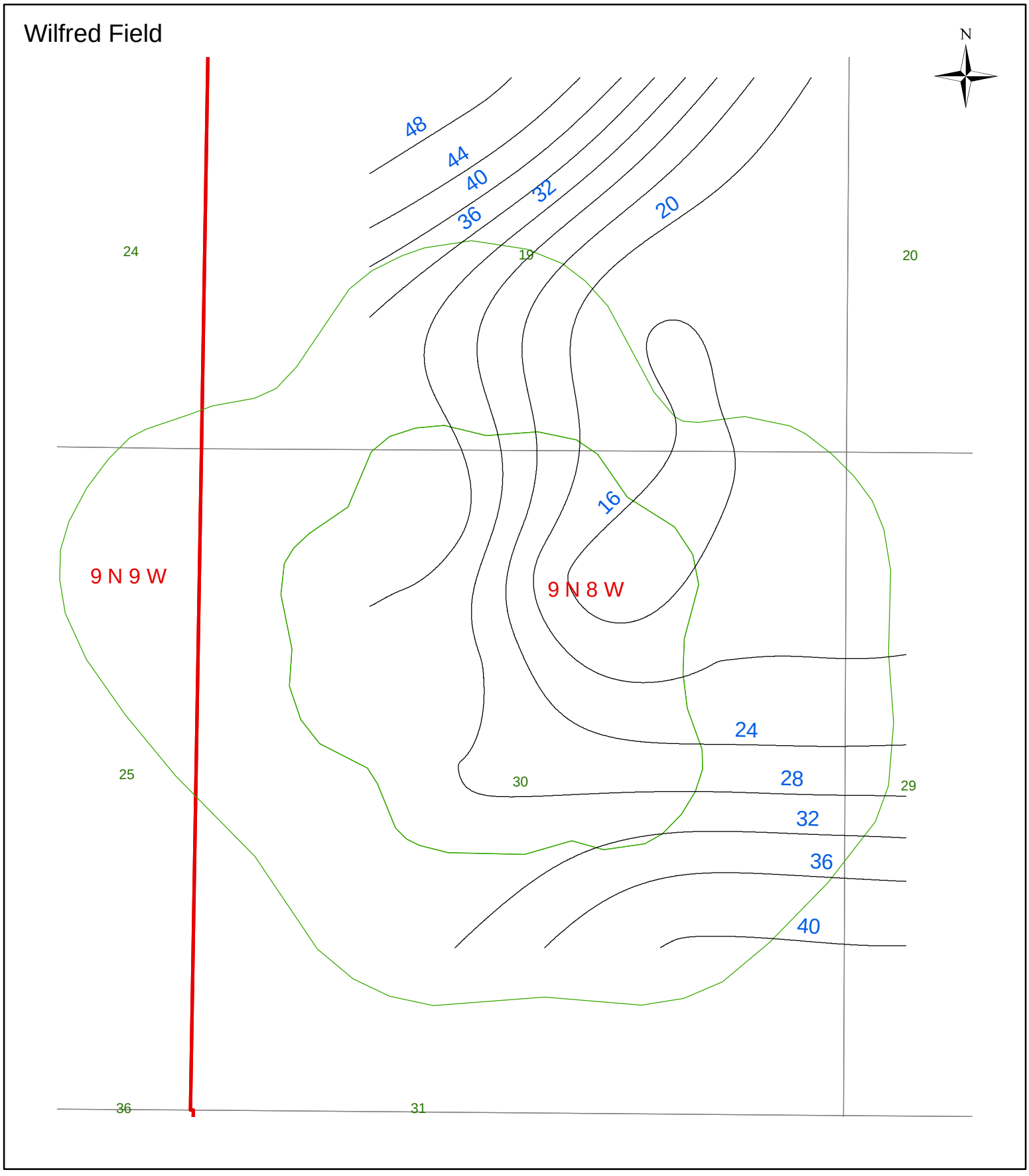
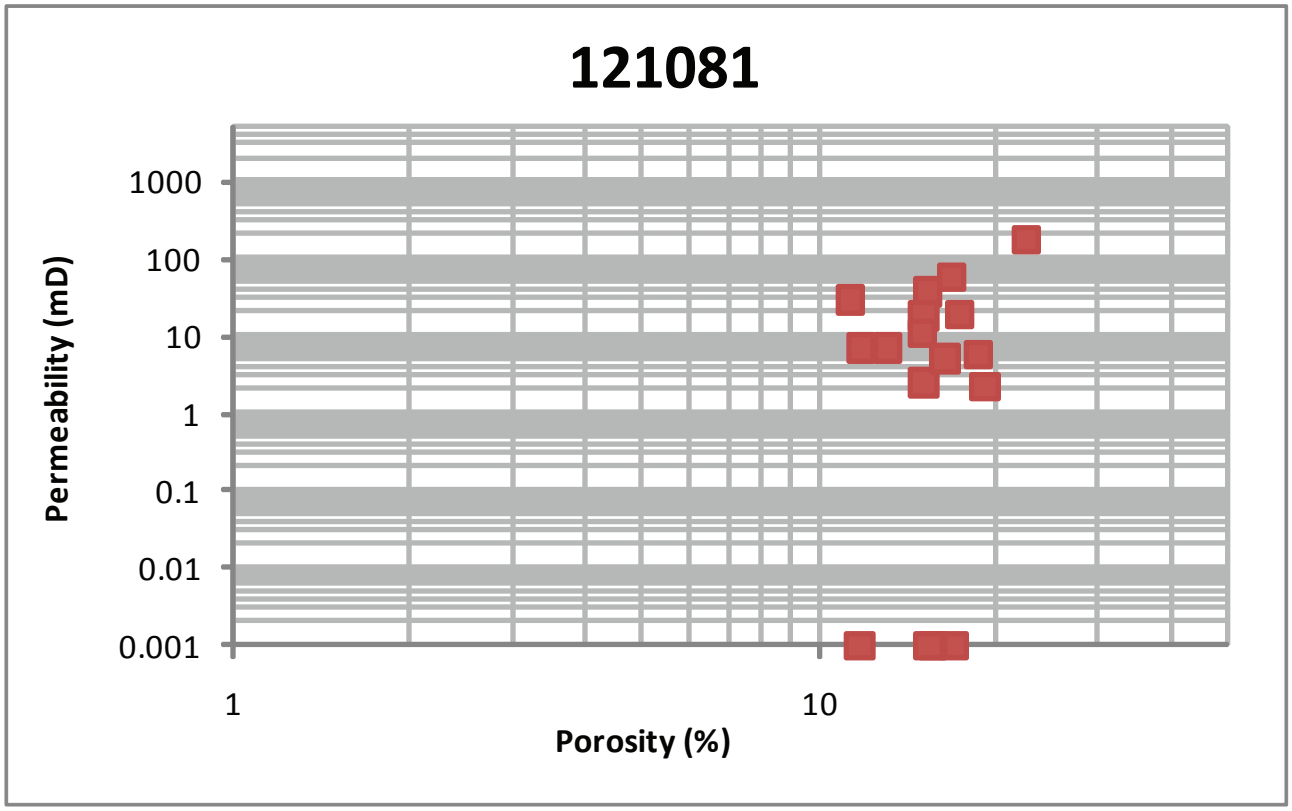


Figure 10: Map showing net porosity feet greater than 15% from neutron logs for the Geneva Dolomite Member in Wilfred Field, Sullivan County. Contour interval is 2 ft.

Figure 11: Porosity-permeability plots from core analysis for Wilfred Field, Sullivan County. The blue points are from North Vernon, the red points from the Vernon Fork Mbr, the green triangles from the Geneva Dolomite Mbr., and the crosses from the Silurian. The chart title lists the IGS Well ID. For the well locations see Figure 1.



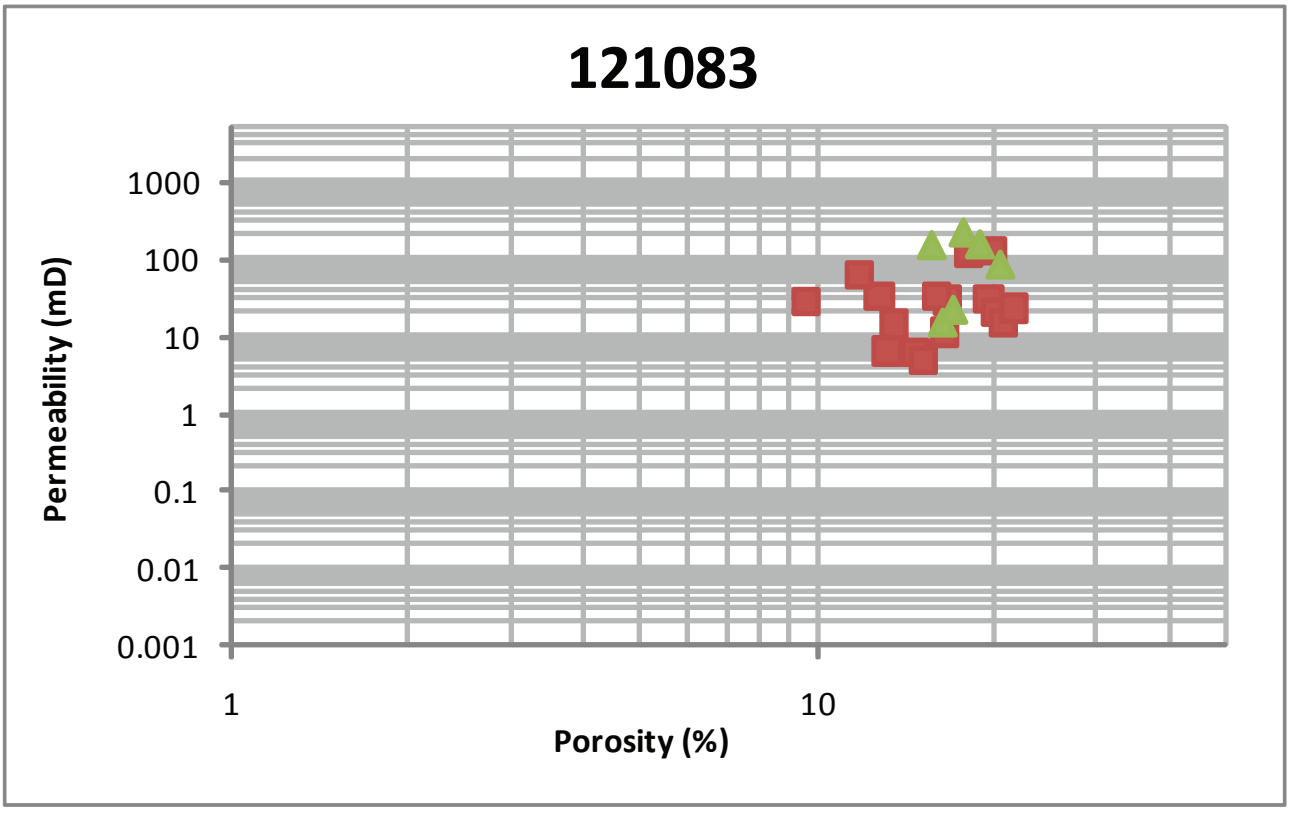
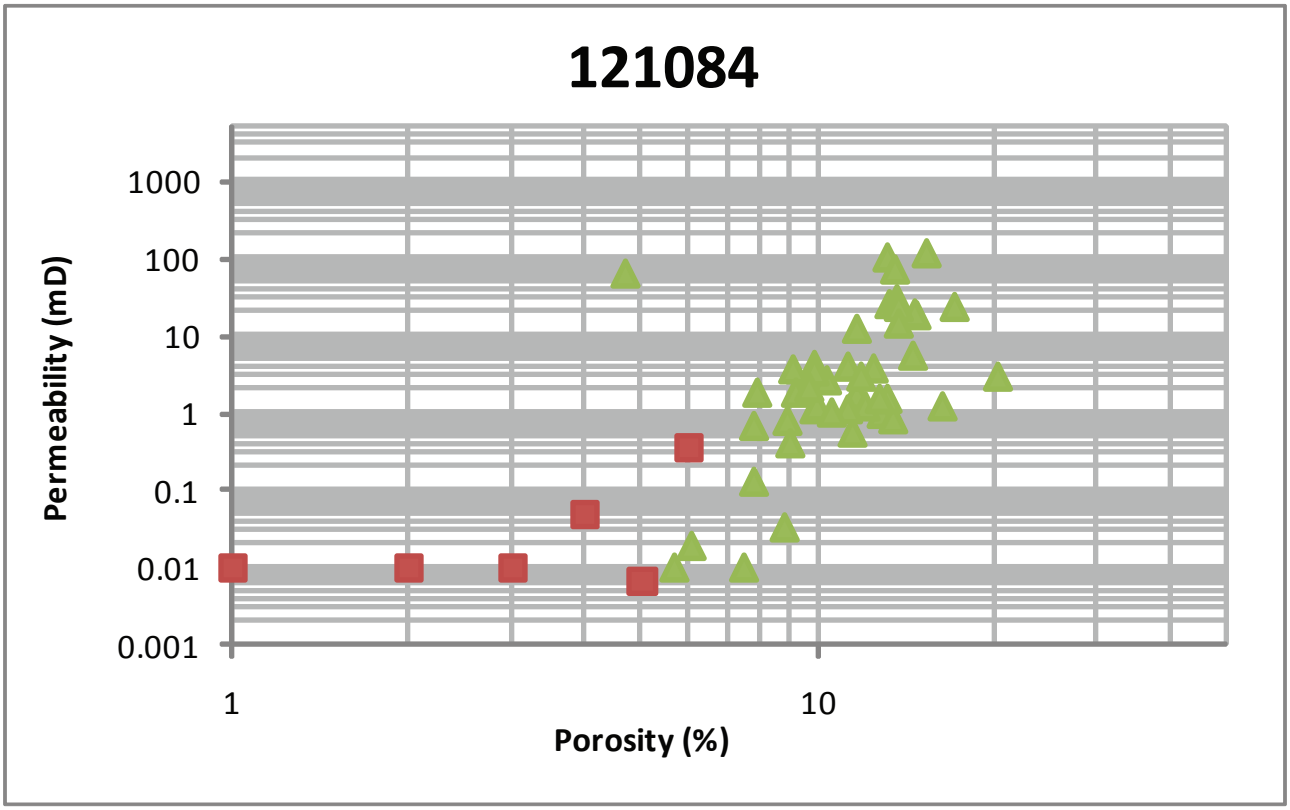


Figure 11: Continued....



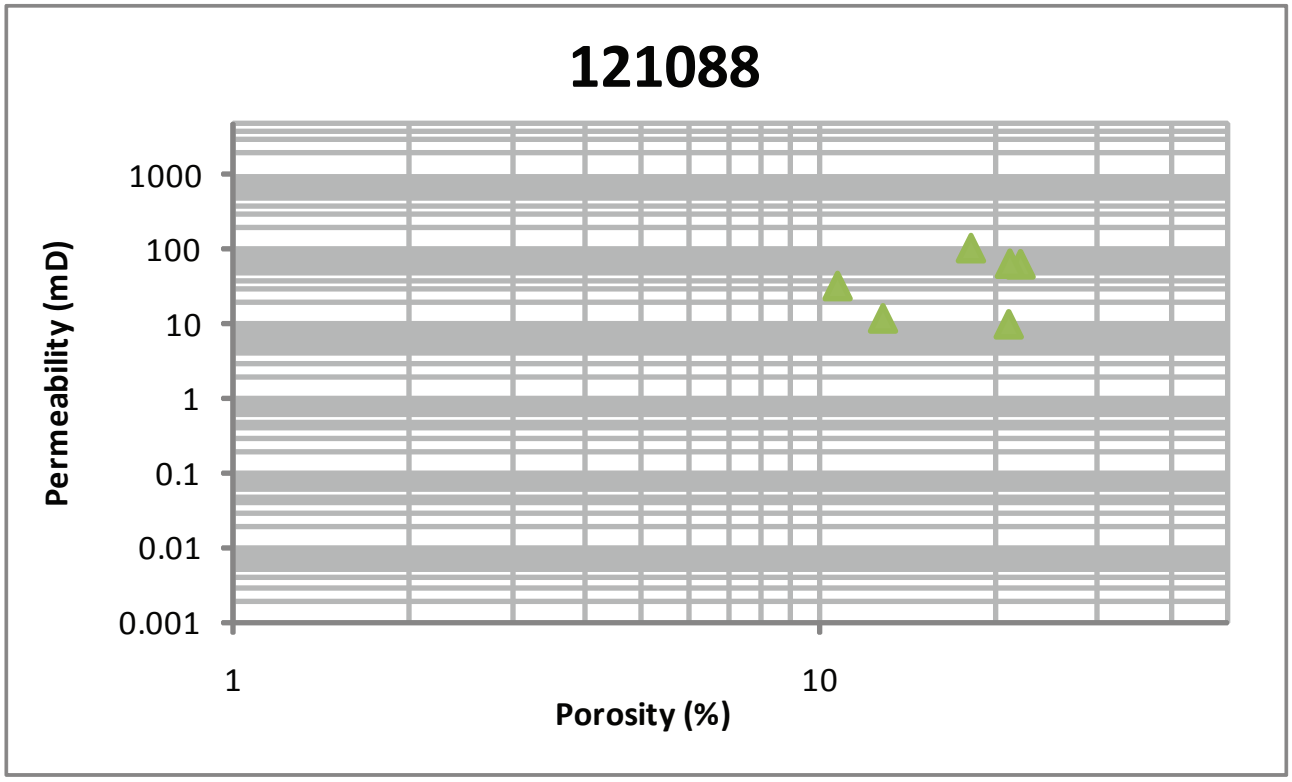
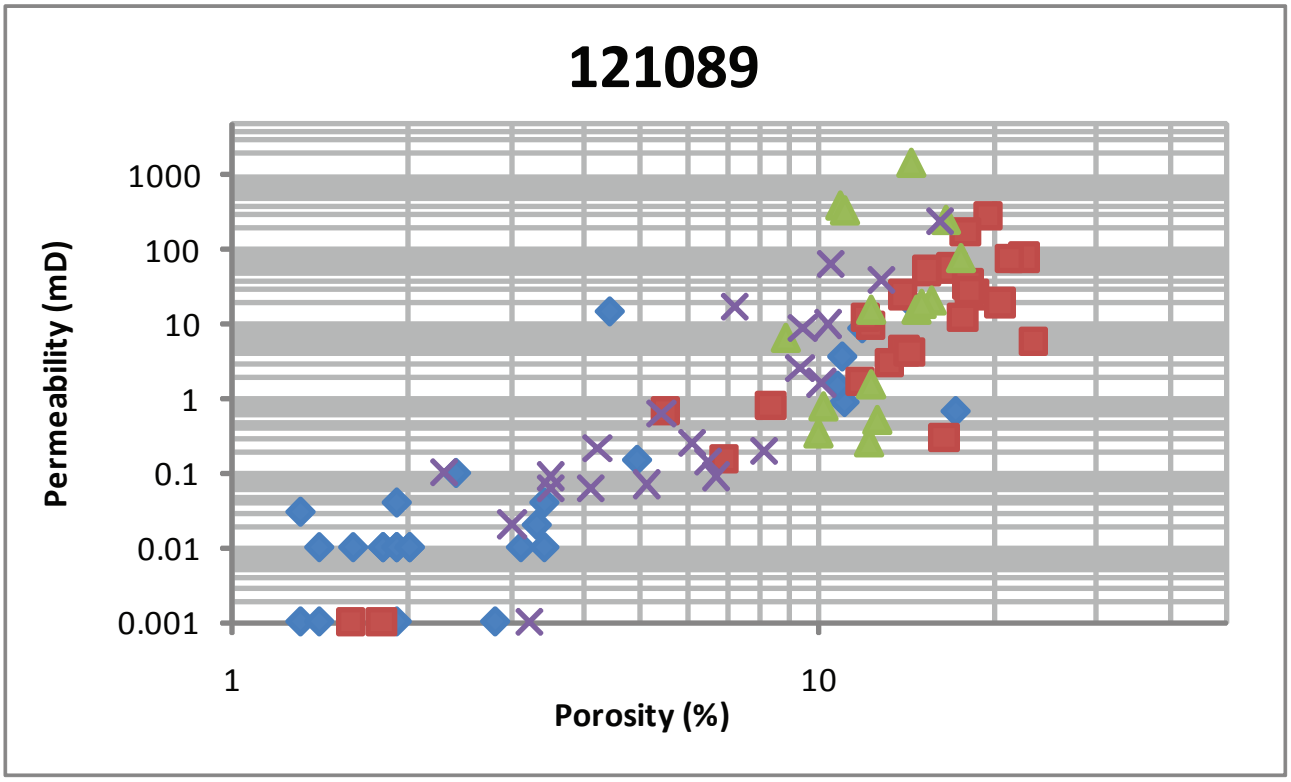


Figure 11: Continued....



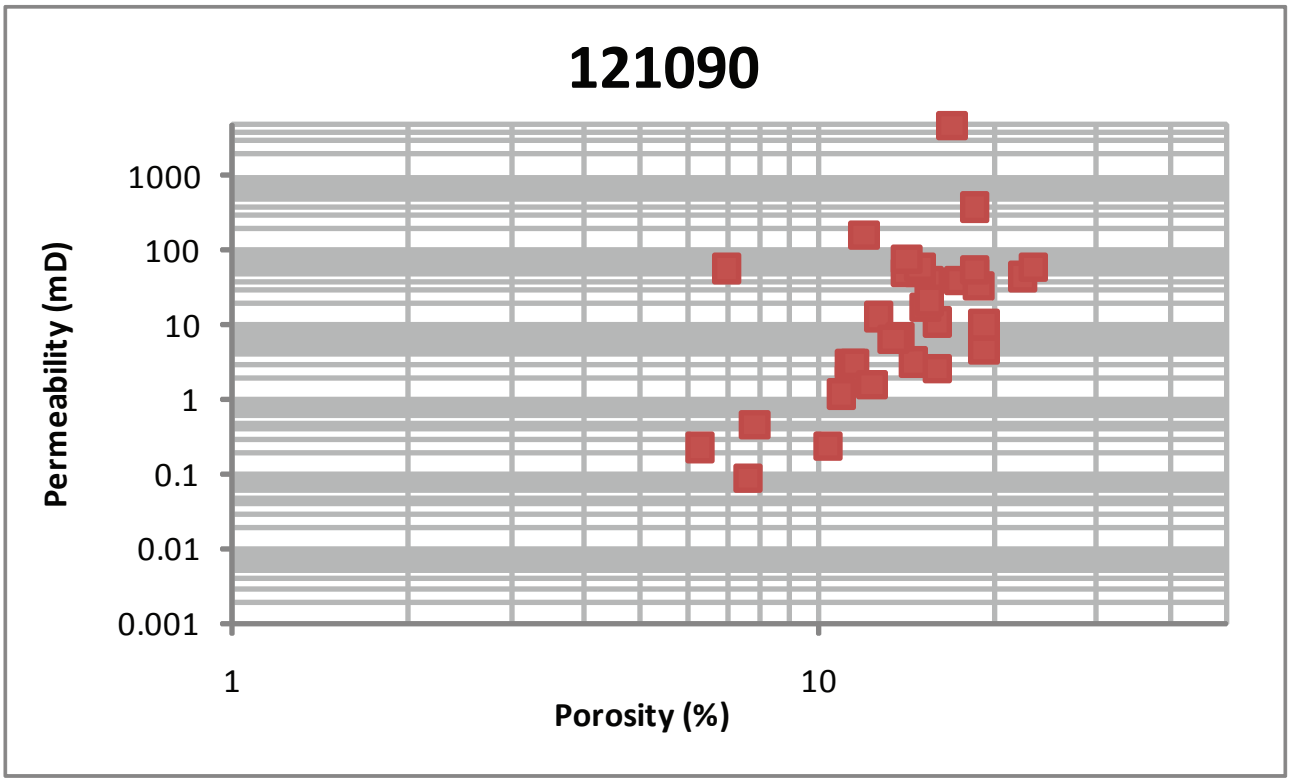
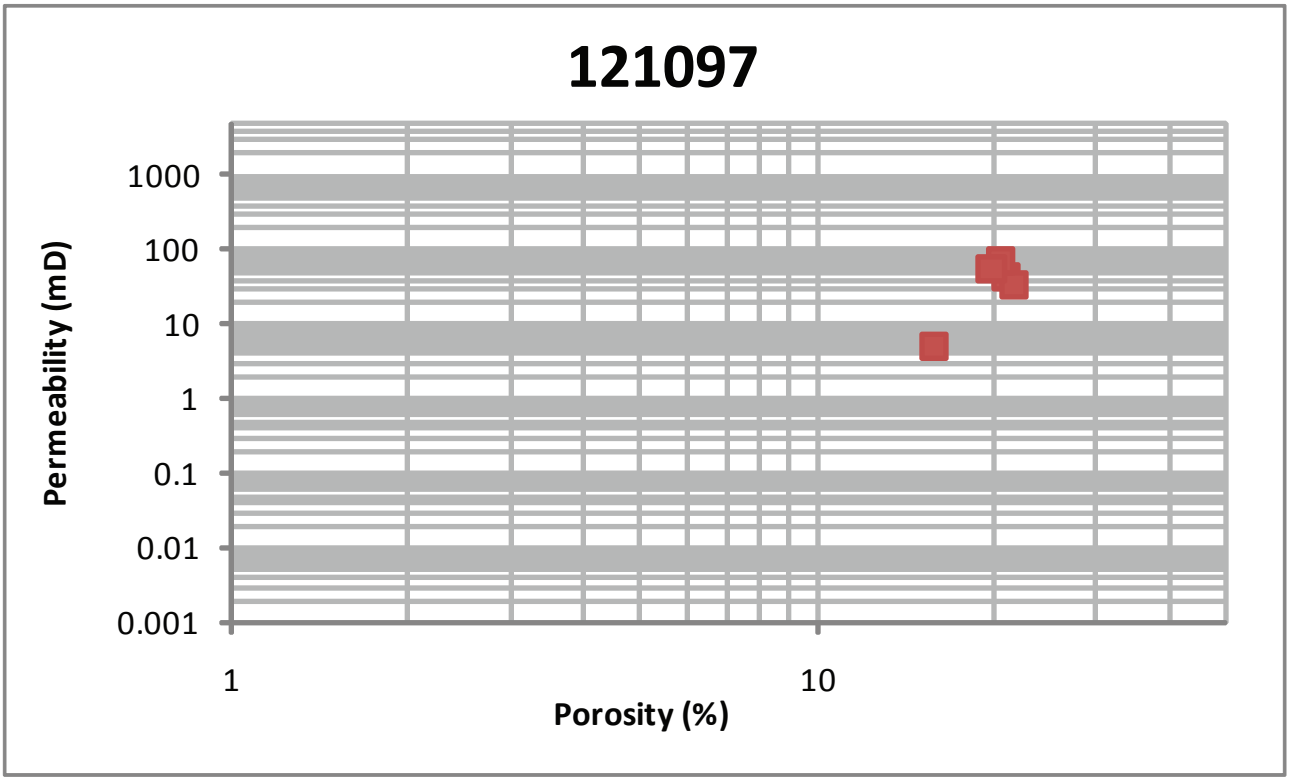


Figure 11: Continued....



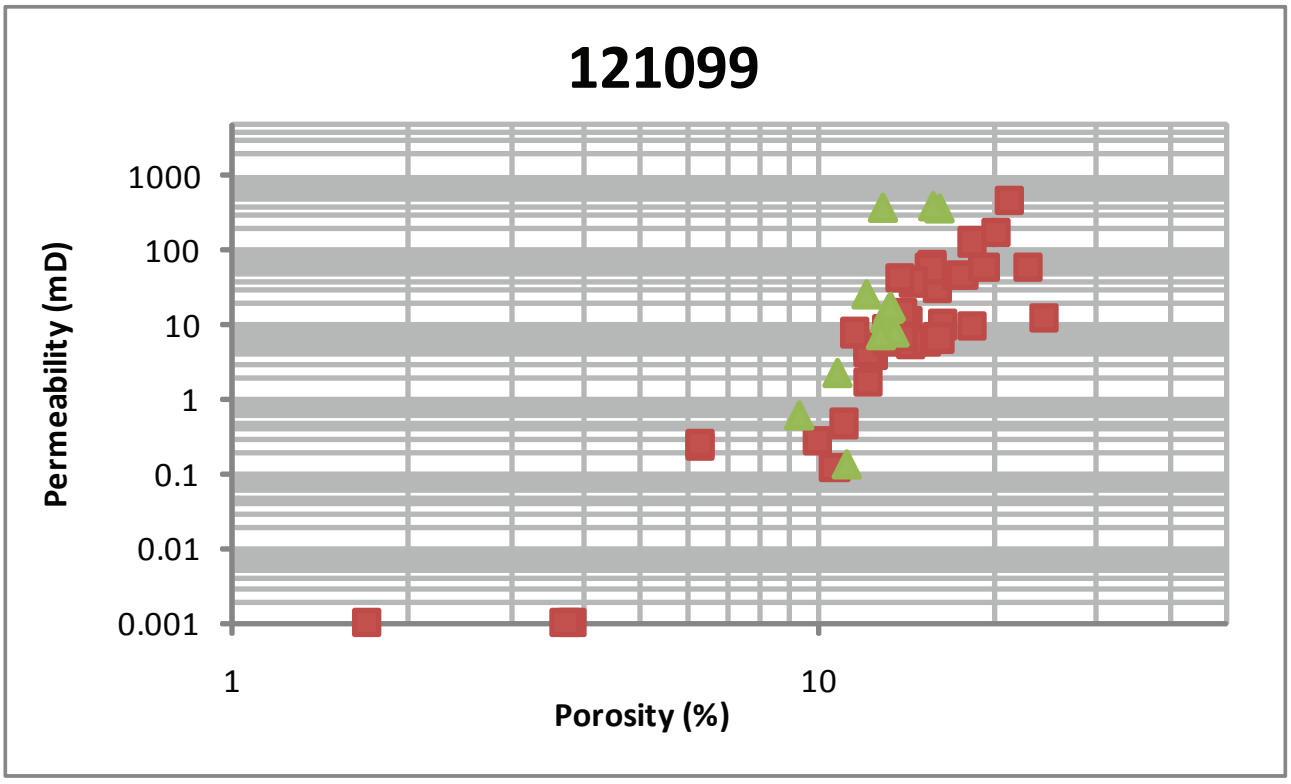
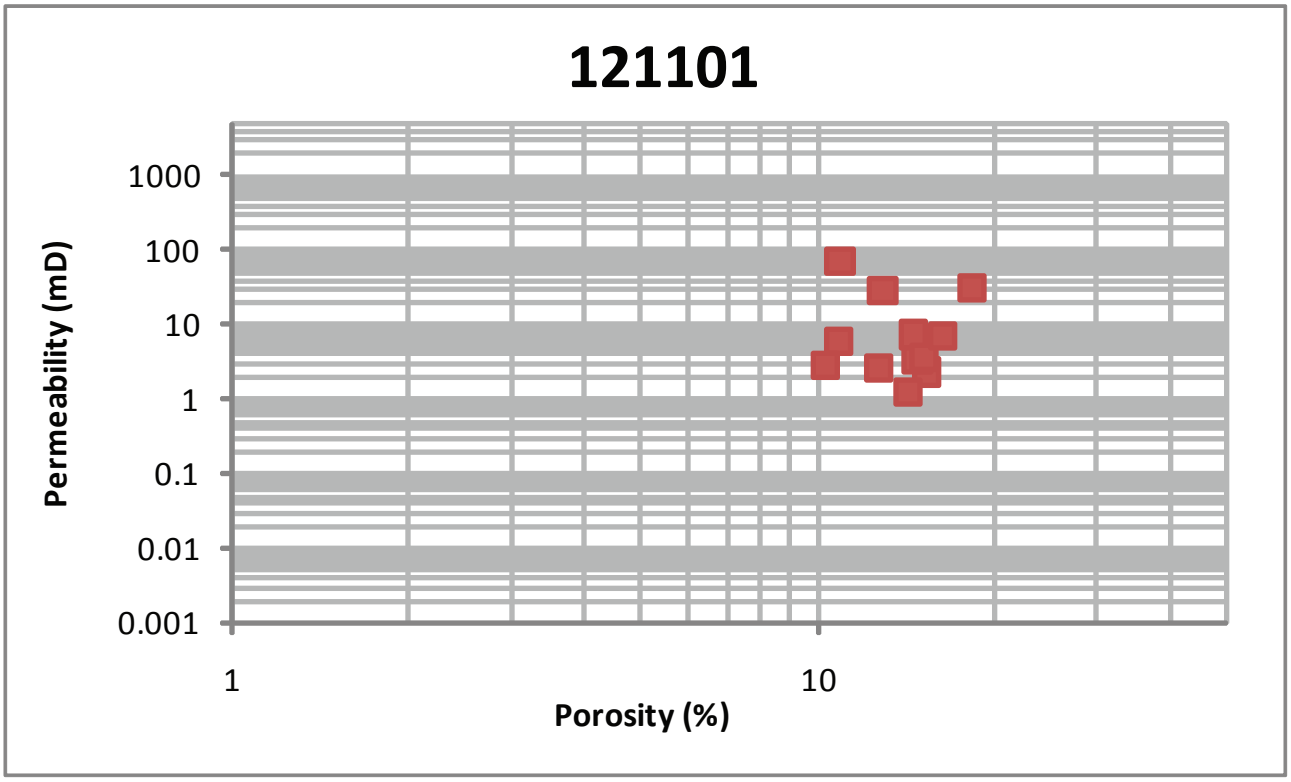


Figure 11: Continued....



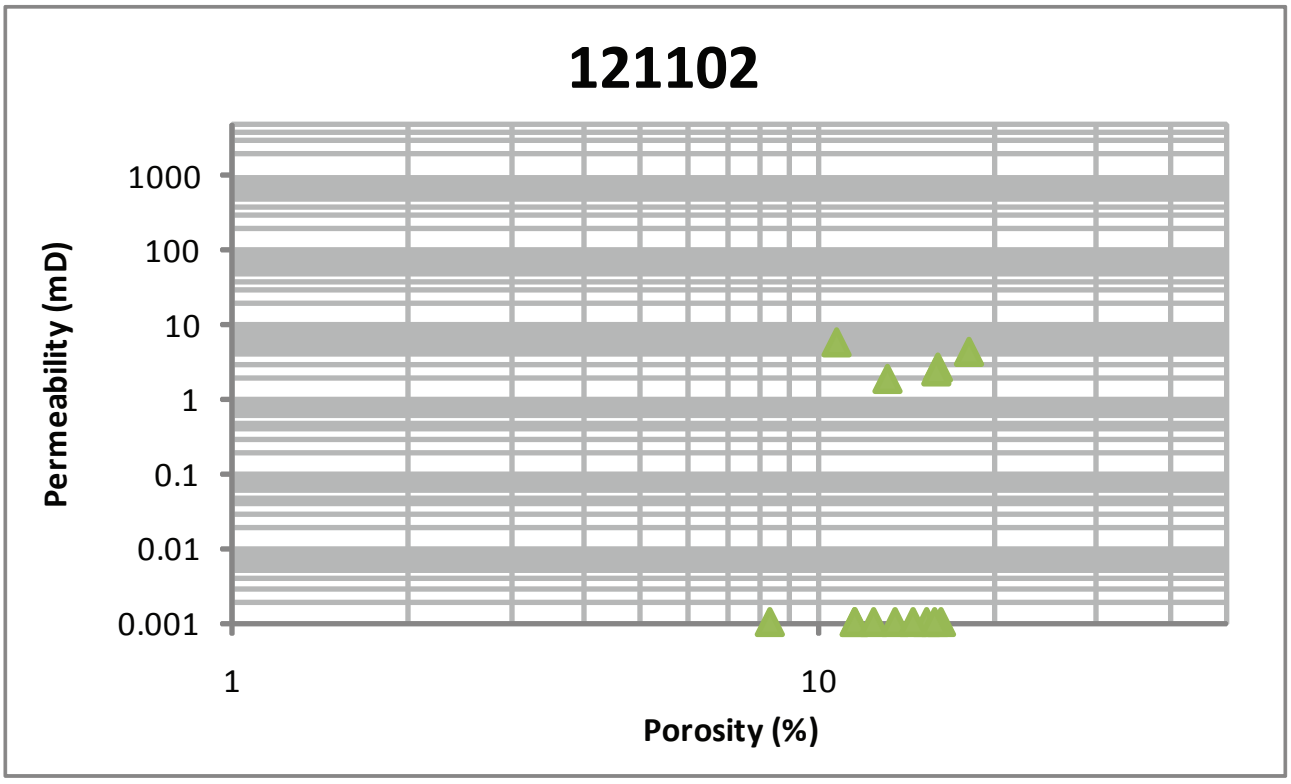
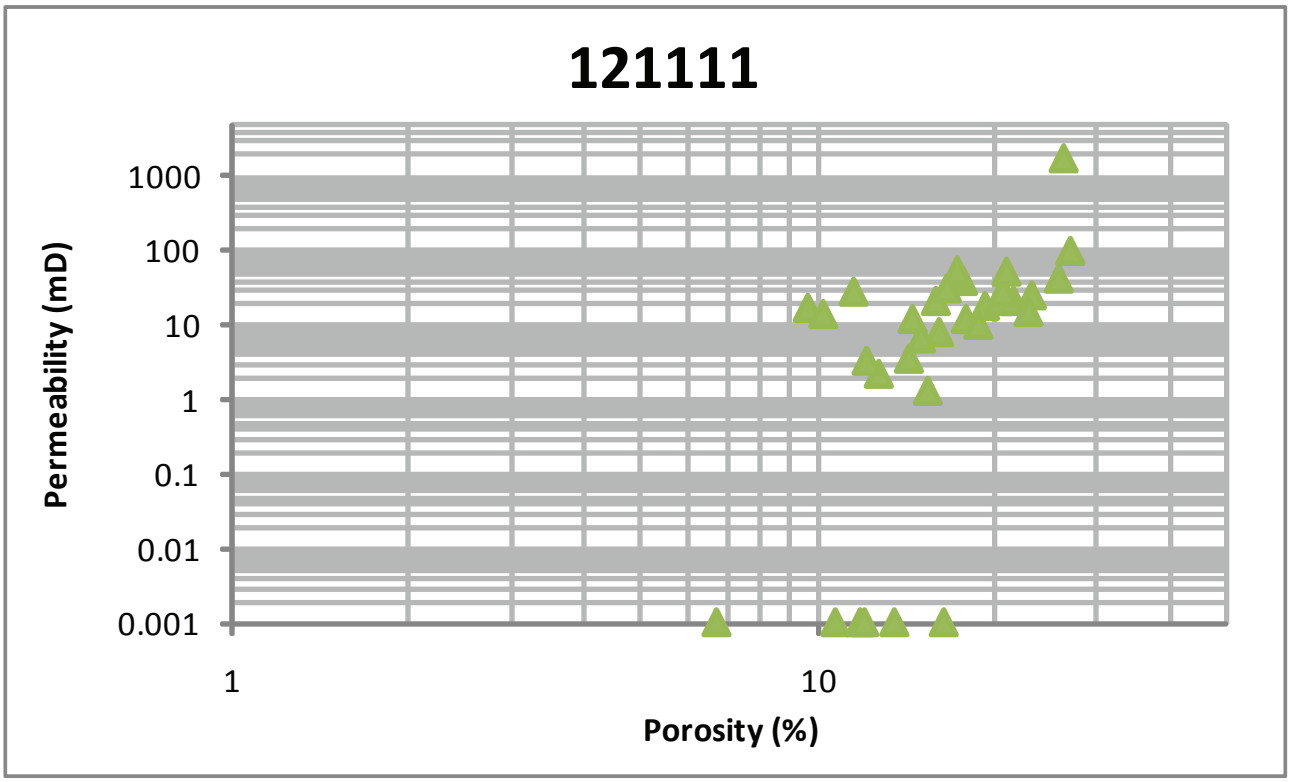


Figure 11: Continued....



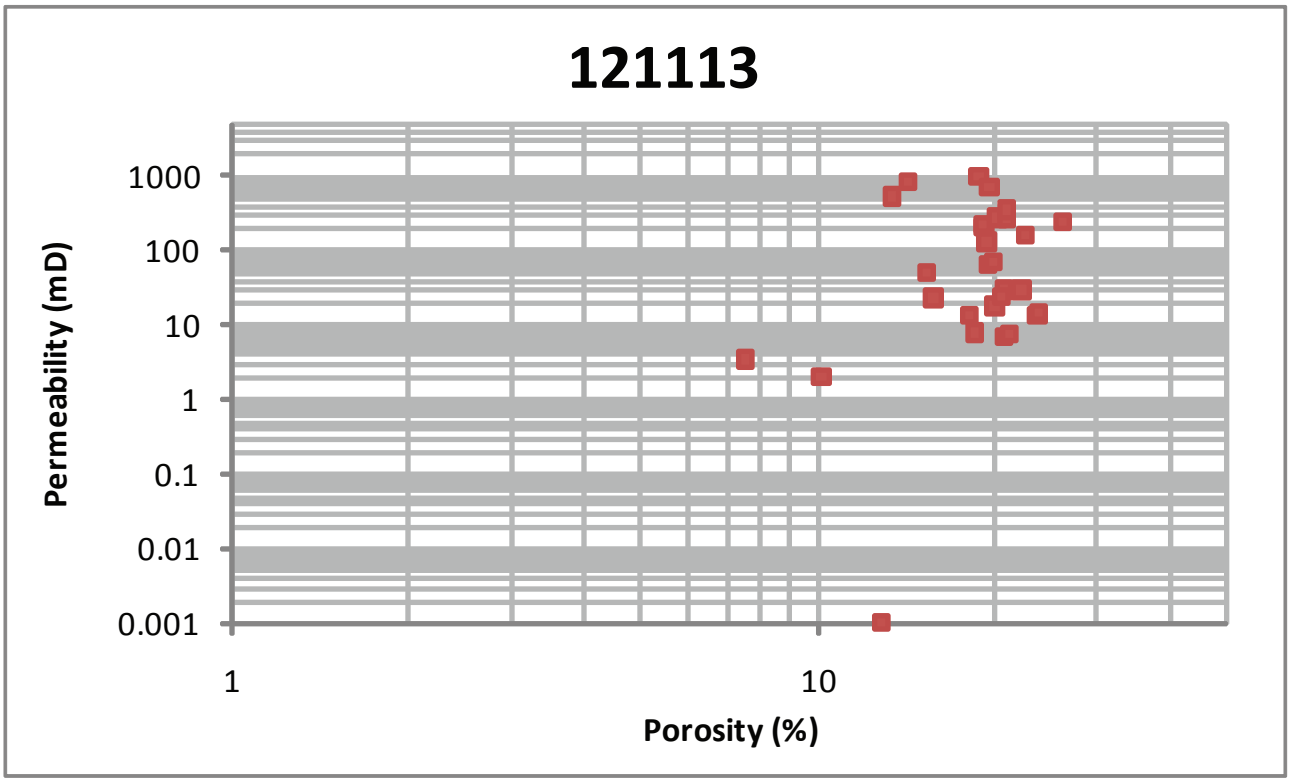
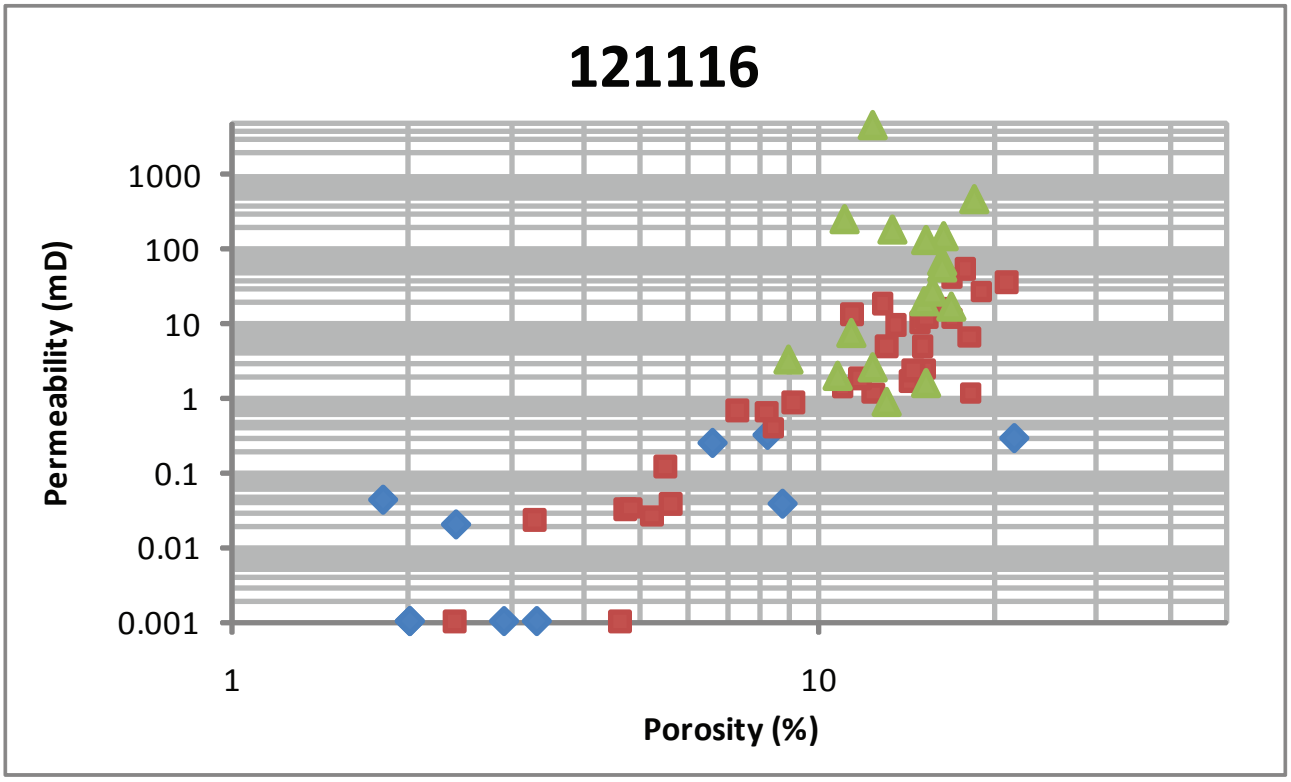
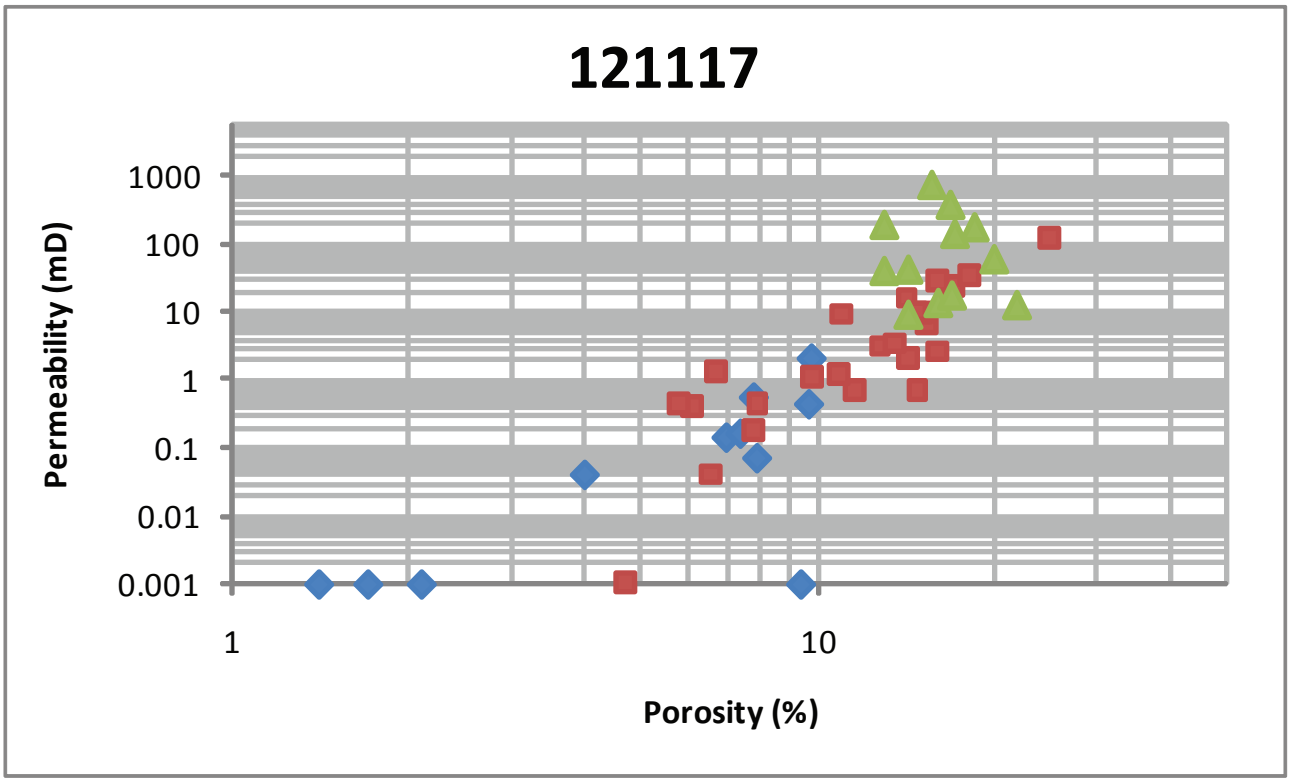


Figure 11: Continued....





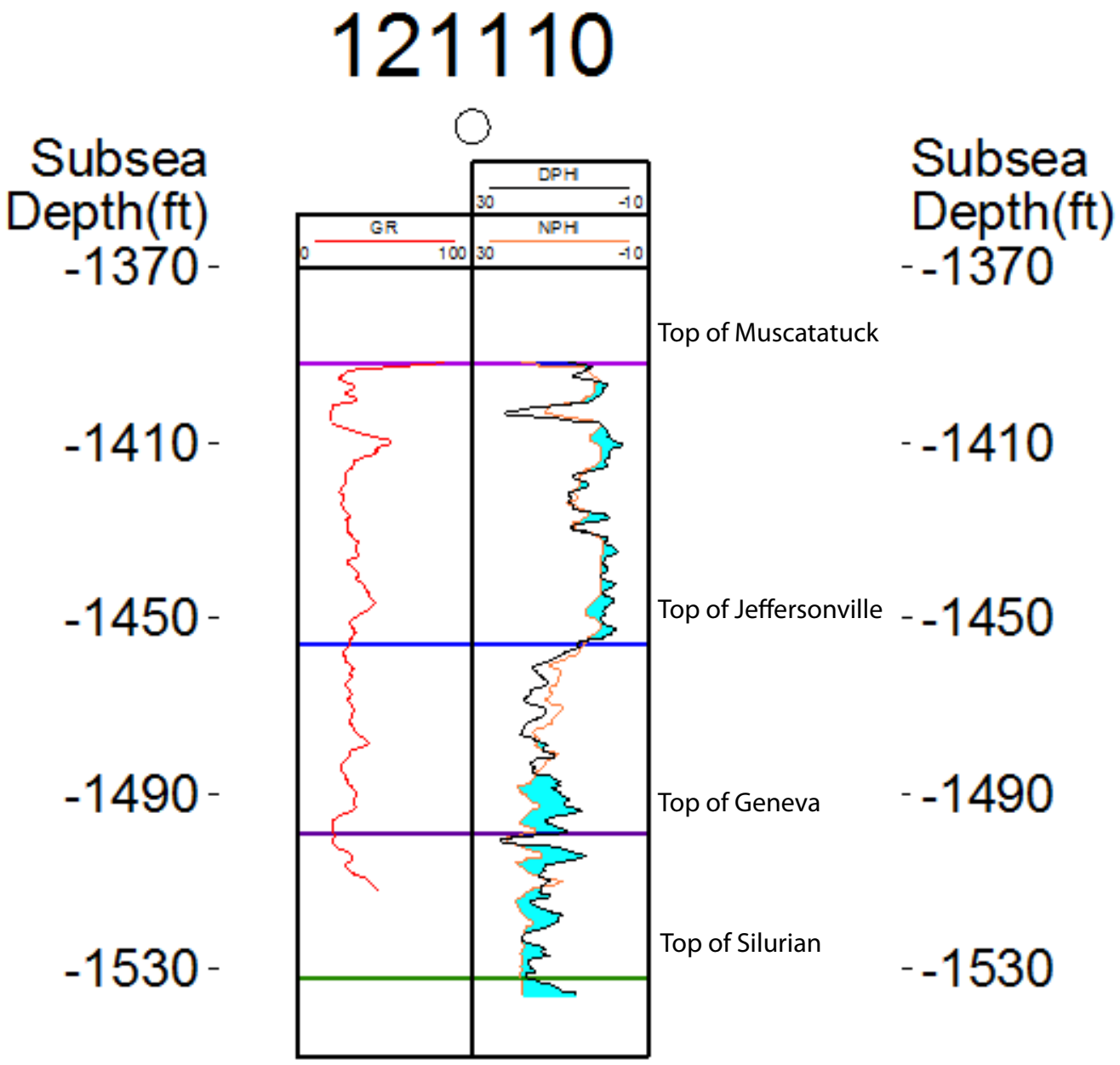


Figure 12: Type log section showing the Devonian formations at Wilfred Field, Sullivan County.

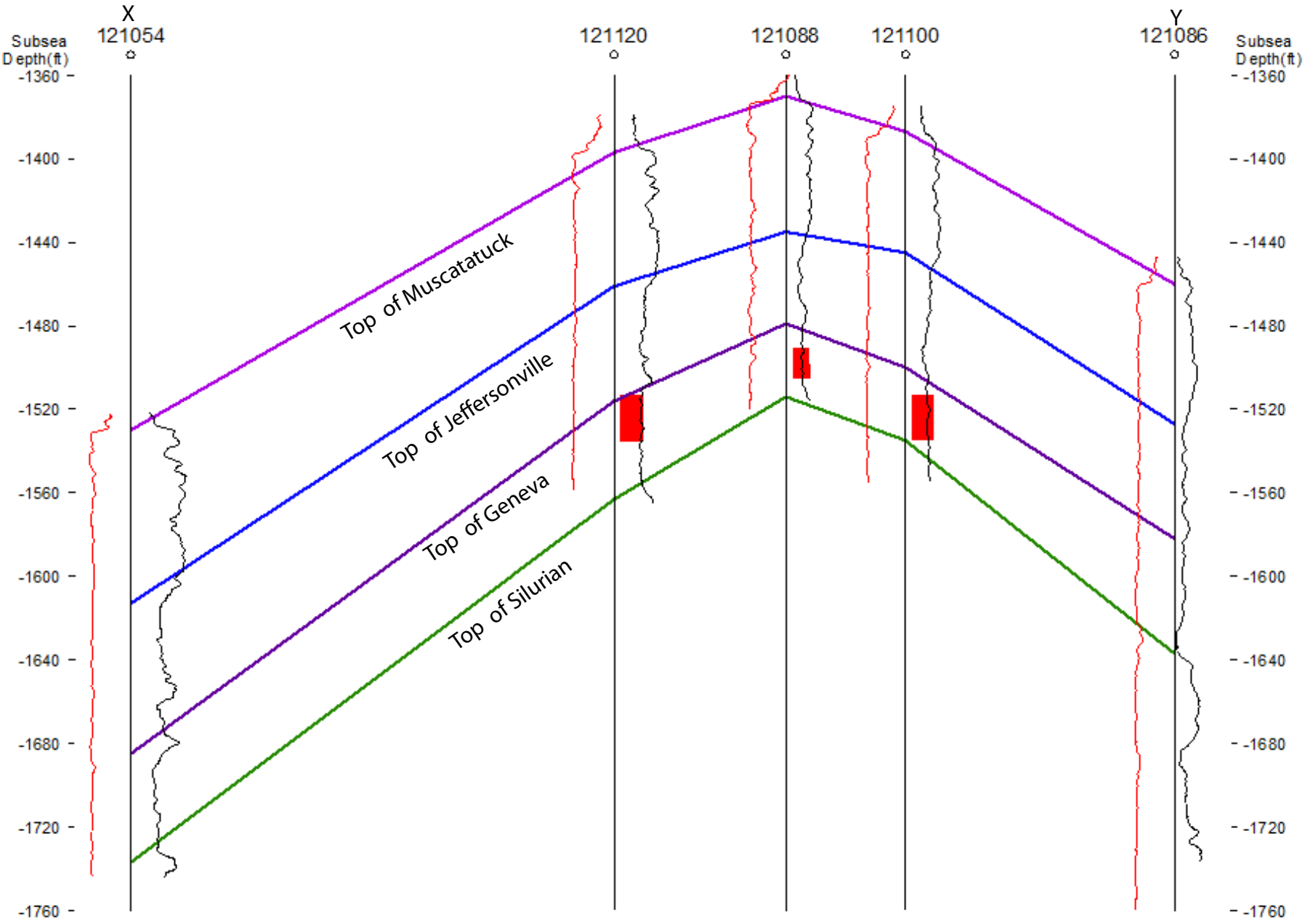


Figure 13: X-Y Cross section showing the Devonian subsurface structure across Wilfred Field, Sullivan County. The red color boxes show the completion intervals for the gas storage or gas production. For location of the cross section refer to Figure 1.

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Table-1: List of the wells used for subsurface structure mapping in Wilfred Field, Sullivan County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Muscatatcuk	Top of Jefferson-ville	Top of Geneva	Top of Silurian	Oil IP (BOPD)	Gas IP (MCF)
IGS_ID	Twp	wp_	Rng	ng_	and_	Kb	Muskat	Jeff	Geneva	Sil	Oil	Gas
121047	9	N	8	W	19	518	2006	2080	2130			
121048	9	N	8	W	19	510	1958	2014	2057	2084		6269
121049	9	N	8	W	19	541	1959	2020				1030
121050	9	N	8	W	19	540	2033					
121051	9	N	8	W	19	505	1994	2062	2105	2130		
121052	9	N	8	W	19	527	2004	2076	2146	2190		
121053	9	N	8	W	19	542	2019	2092	2142	2180		
121054	9	N	8	W	19	506	2036	2111	2188	2238		
157425	9	N	8	W	19	532	1984	2050	2098	2126		
121055	9	N	8	W	20	537	2048	2124	2178			
121058	9	N	8	W	20	560	2060	2126				
121073	9	N	8	W	29	501	2026	2094				
121074	9	N	8	W	29	524	1966	2034	2094			
121076	9	N	8	W	29	498	2033	2110				
121077	9	N	8	W	29	533	2048	2126	2184			
121080	9	N	8	W	30	528	1943	2000	2072			750
121081	9	N	8	W	30	501	1893	1952	2000		45	400
121082	9	N	8	W	30	511	1915	1984			60	250
121083	9	N	8	W	30	497	1891	1950	2018		40	
121084	9	N	8	W	30	517	1930	1996				
121085	9	N	8	W	30	508	1938	2004				
121086	9	N	8	W	30	533	1993	2060	2115	2170		
121087	9	N	8	W	30	543	1930	1992	2022	2032		
121088	9	N	8	W	30	540	1912	1980	2019	2050	430	
121089	9	N	8	W	30	531	1910	1972	2017	2050		
121090	9	N	8	W	30	505	1878	1940	1998			
121092	9	N	8	W	30	543	1941	2008	2059	2086		
121093	9	N	8	W	30	546	1926	1994	2040		16	50
121094	9	N	8	W	30	547	1928	1992	2044		100	1000
121096	9	N	8	W	30	503	1882	1948	2016			
121097	9	N	8	W	30	536	1908	1972	2027		48	
121098	9	N	8	W	30	501	1878	1941	1996		1400	250
121099	9	N	8	W	30	546	1918	1980	2030			
121100	9	N	8	W	30	545	1932	1994	2028	2050		
121101	9	N	8	W	30	537	1942	2006	2066	2102	65	
121102	9	N	8	W	30	551	1980	2040	2088			
121104	9	N	8	W	30	541	1956	2025			100	5000

Table-1: Continued....

121105	9	N	8	W	30	542	1947	2012	2068		70	
121106	9	N	8	W	30	547	1927	1990				
121108	9	N	8	W	30	544	1926	1990				
121109	9	N	8	W	30	540	1946	2000	2048			
121110	9	N	8	W	30	498	1890	1956	1996	2030		
121111	9	N	8	W	30	544	1941	2006			88	
121112	9	N	8	W	30	542	1925	1990	2039	2066		
121113	9	N	8	W	30	545	1942	2004	2066	2089	48	
121114	9	N	8	W	30	547	1942	2010			10	200
121115	9	N	8	W	30	538	1927	1984			30	160
121116	9	N	8	W	30	532	1920	1980	2034			
121117	9	N	8	W	30	509	1893	1958	2002			
121118	9	N	8	W	30	500	1890	1950	2008	2050		
121119	9	N	8	W	30	544	1943	2008	2061	2086		
121120	9	N	8	W	30	551	1945	2012	2060	2110		
121121	9	N	8	W	30	526	1911	1972	2019	2039	160	250

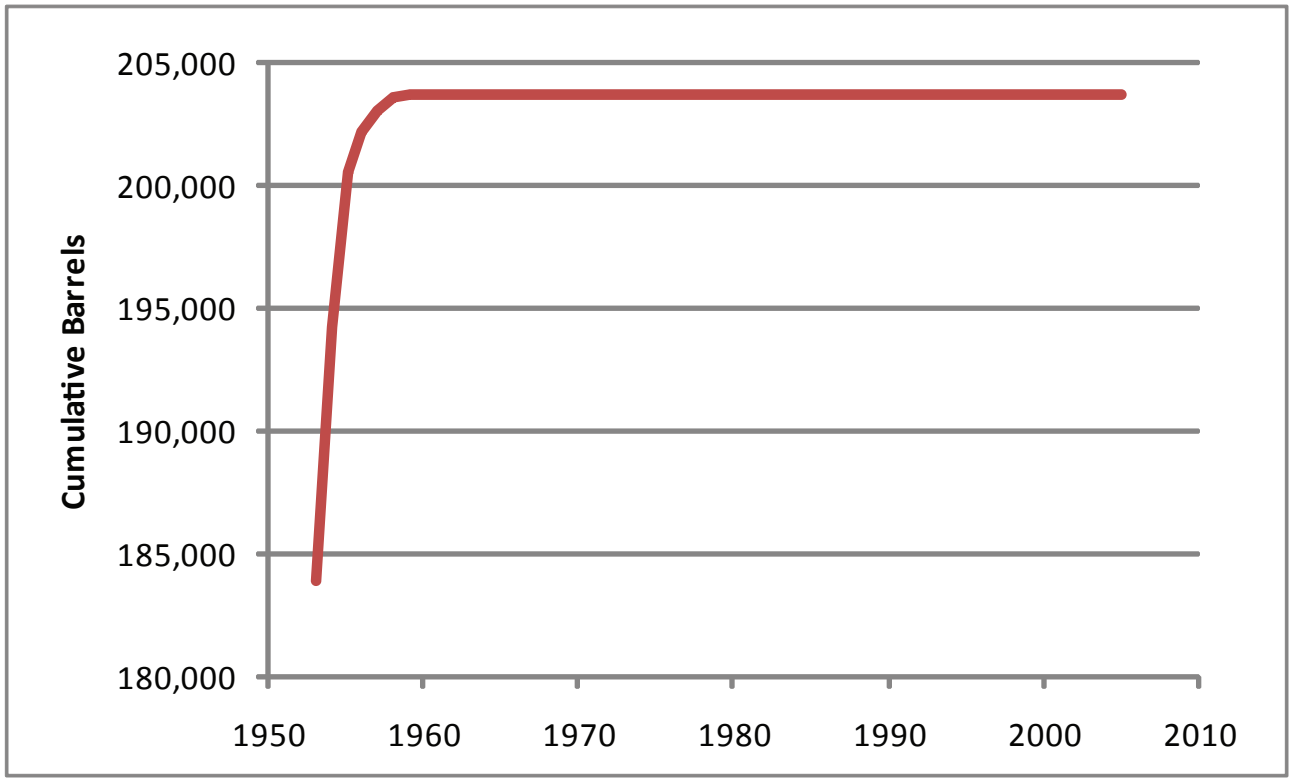


Figure - 14: Cumulative Oil production history from the Wilfred Field, Sullivan County since 1953.

Field name: Worthington

IGS ID: 10793

DOE ID: na

Location: Greene County, 8N-5W

Discovery date: 1960 (gas storage initiated)

Lower Paleozoic reservoir unit (depth): Devonian, Muscatatuck Group, Jeffersonville Ls. (1,425 ft.)

Field type: natural gas & gas storage

Total number production wells: 58 (storage), 25 (observation)

Area: 2000 acres

Total capacity: 13,200,000 mcf

Other reservoir units:

Deepest unit penetrated (depth): Ordovician, Trenton Ls. (2,644 ft.)

Field characteristic: Irregular domal anticline over probable Silurian reef with closure in excess of 80 ft. at top of Muscatatuck.

Reservoir characteristics:

Average porosity – 15%

Average permeability – 35 md.

Approximate thickness – 32 ft.

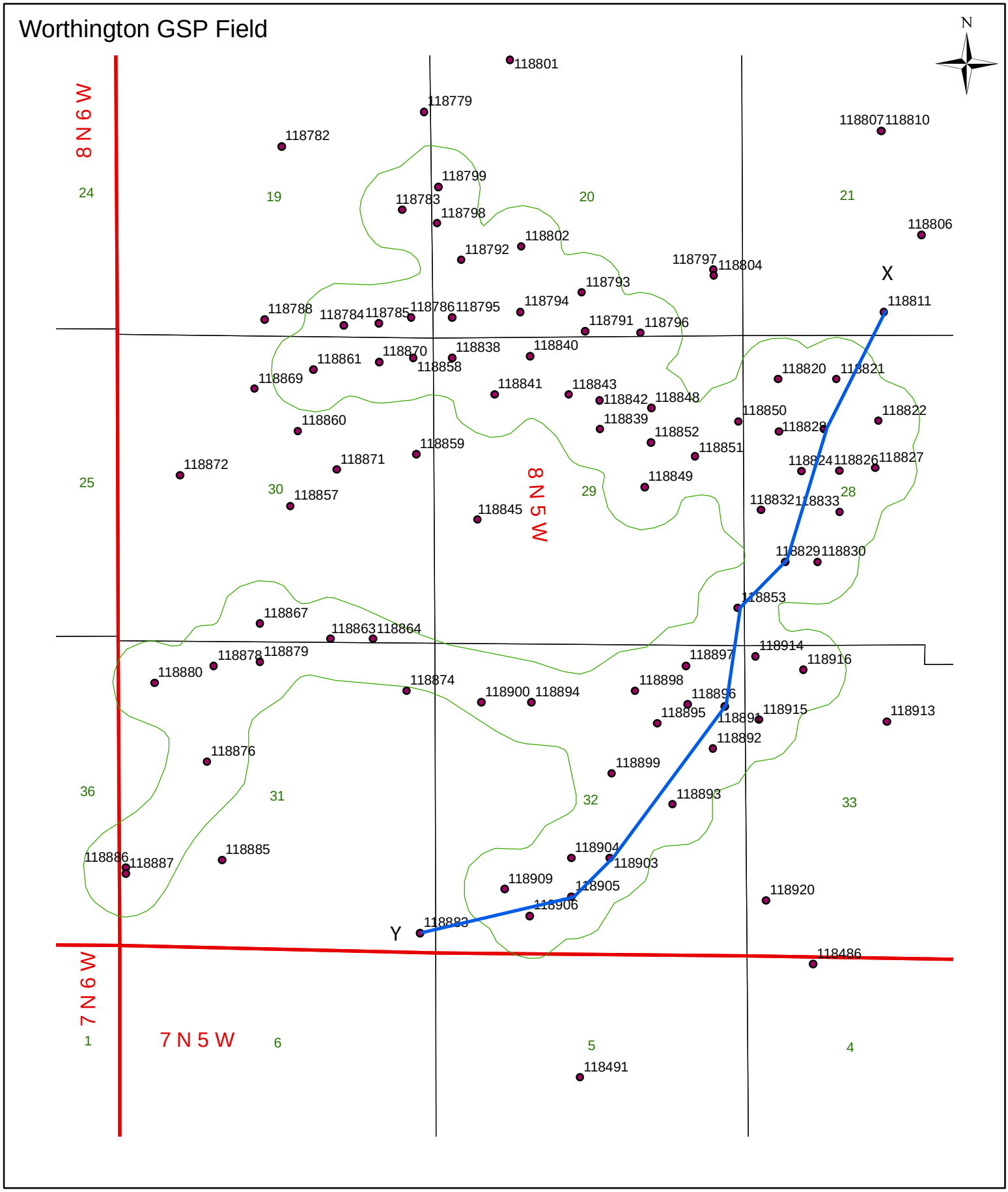


Figure 1: Map showing the location and wells at Worthington GSP Field, Greene County. X-Y is the location of the cross sections that shows the subsurface Devonian structure (Fig. 6). The wells depicted were used for subsurface maping and have a total depth (TD) of Devonian or deeper.

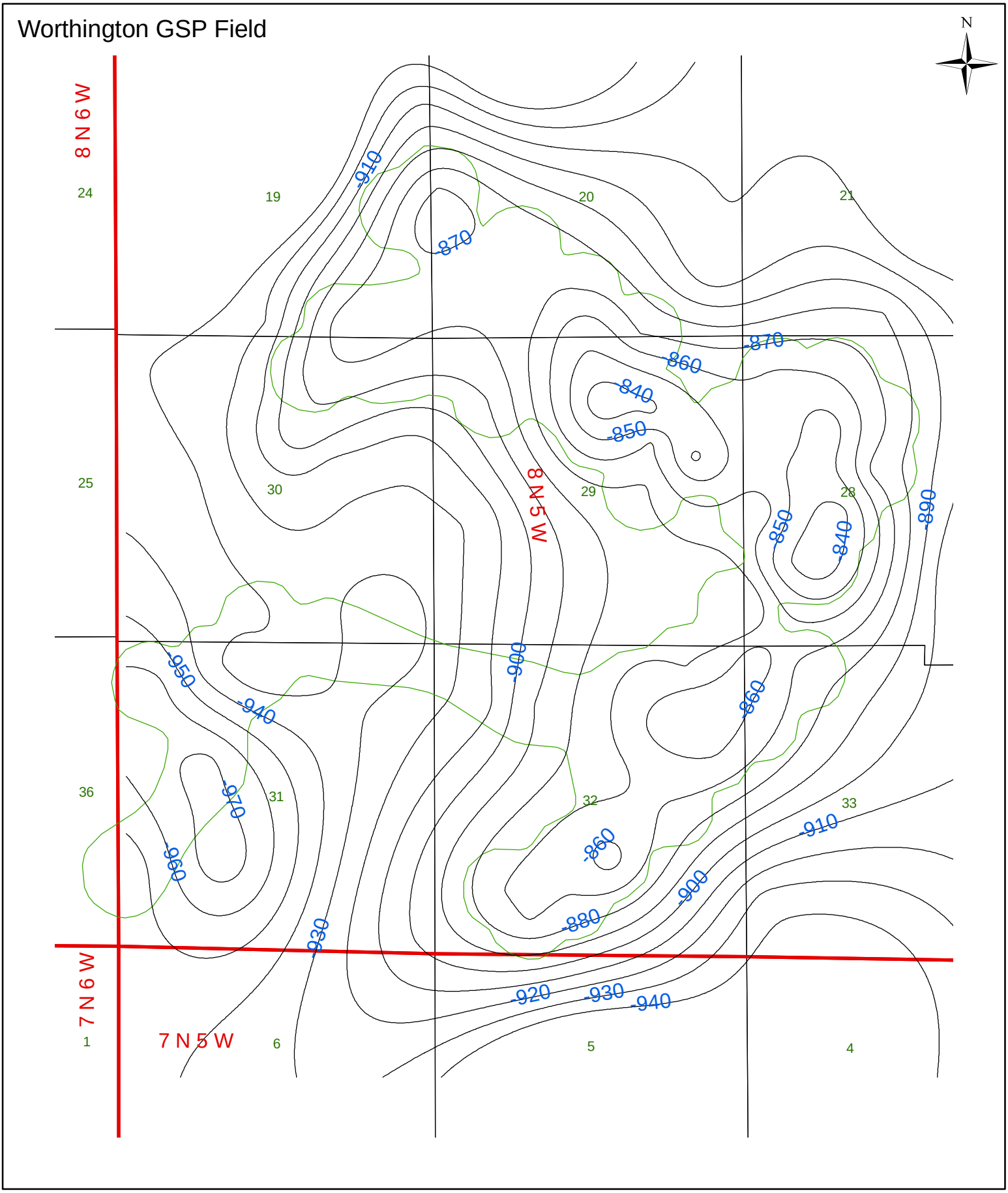


Figure 2: Structure map showing top of the subsurface Muscatatuck Limestone in Worthington GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

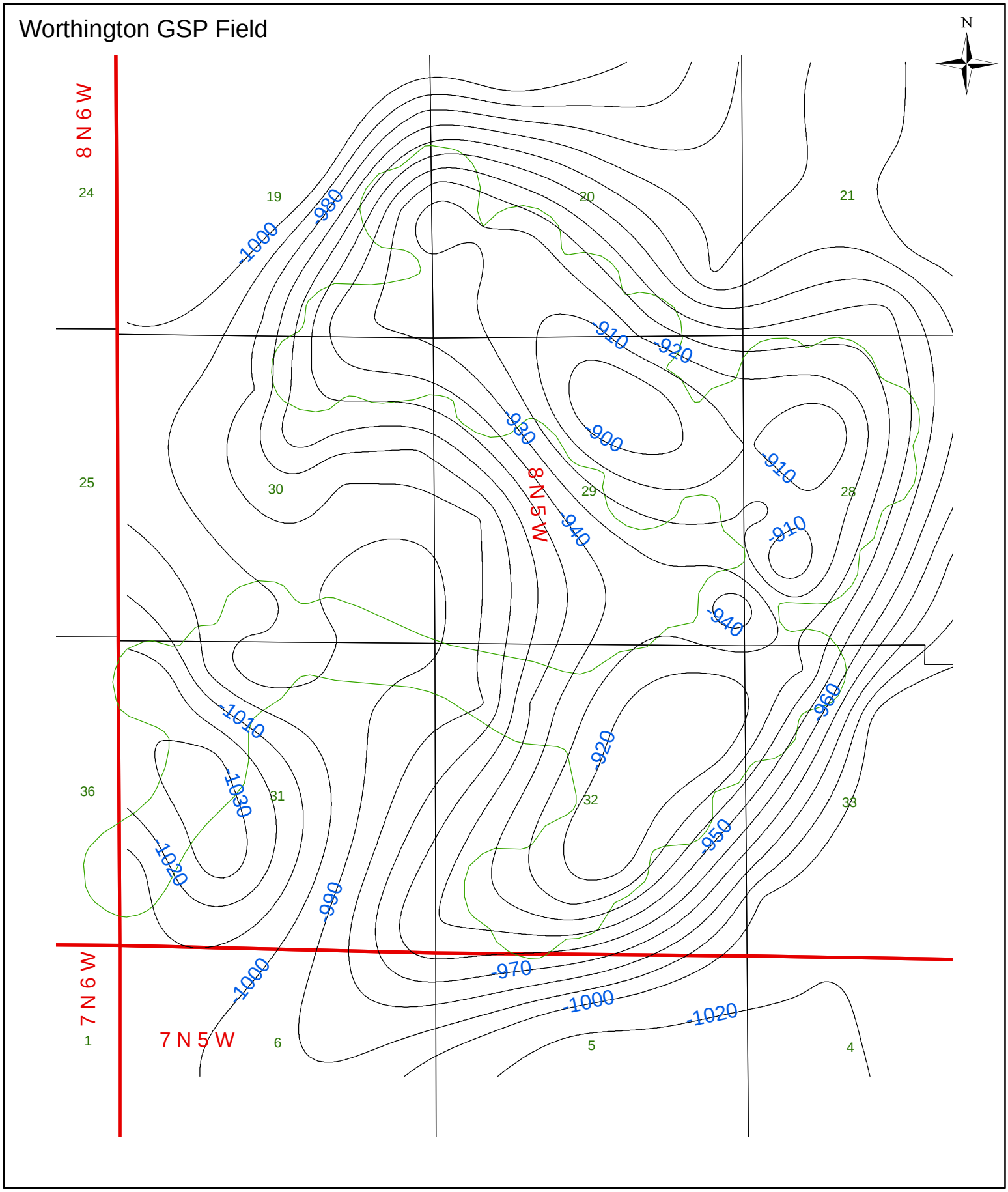


Figure 3: Structure map showing top of the subsurface Jeffersonville Limestone in Worthington GSP Field, Greene County. Contours show values below sea level, contour interval is 10 ft .

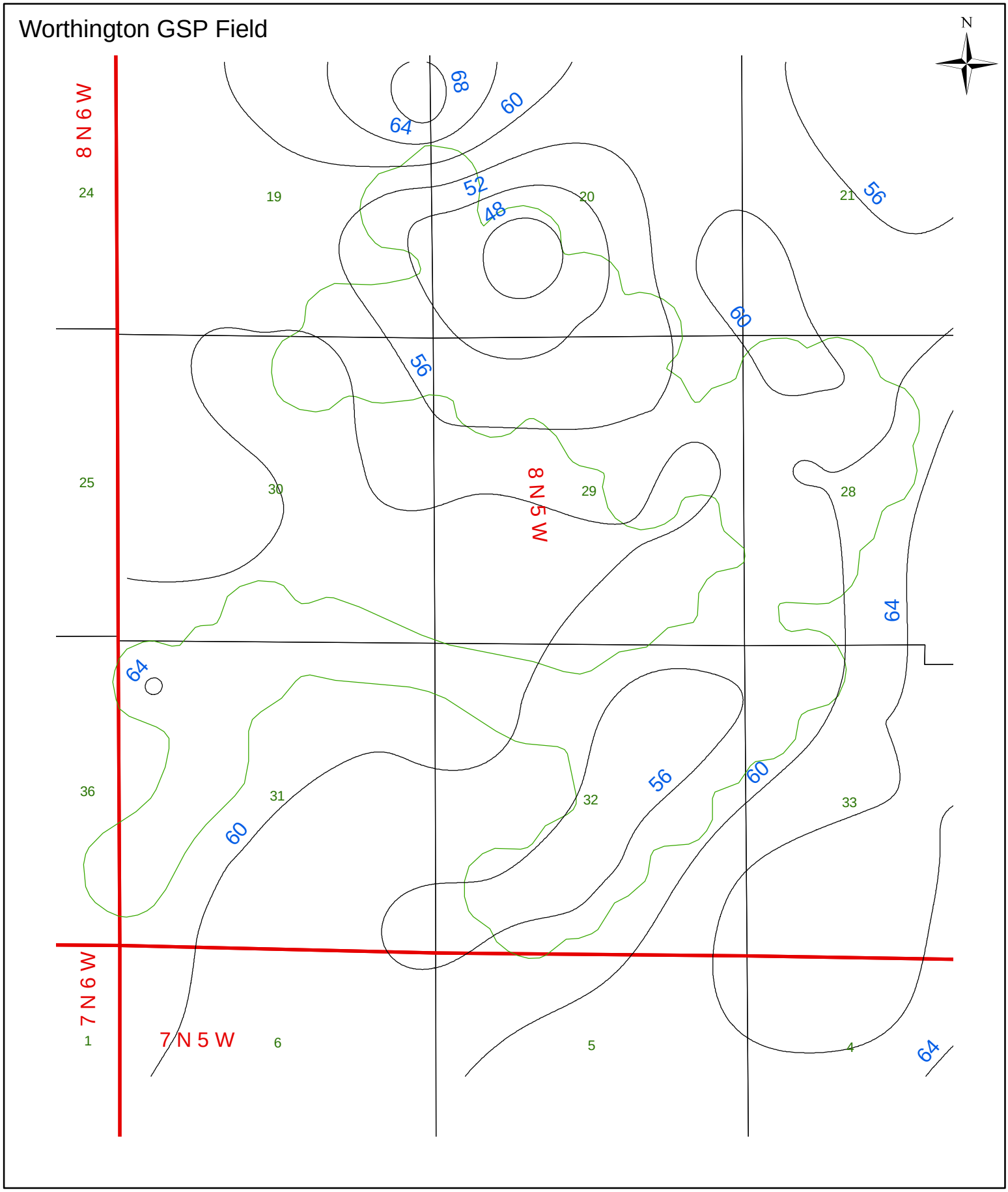
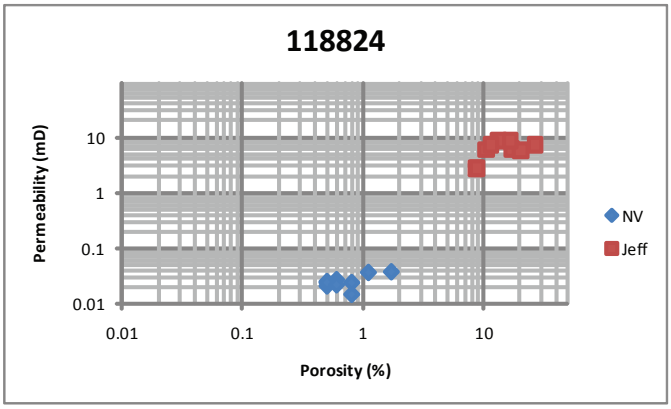
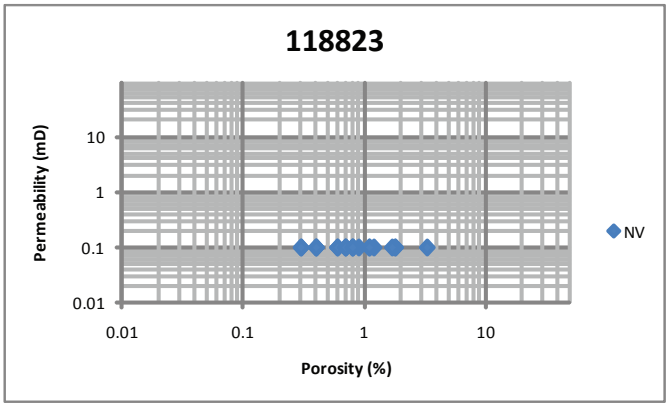


Figure 4: Isopach map showing the thickness of North Vernon Ls. in Worthington GSP Field, Greene County. Contour interval is 4 ft .

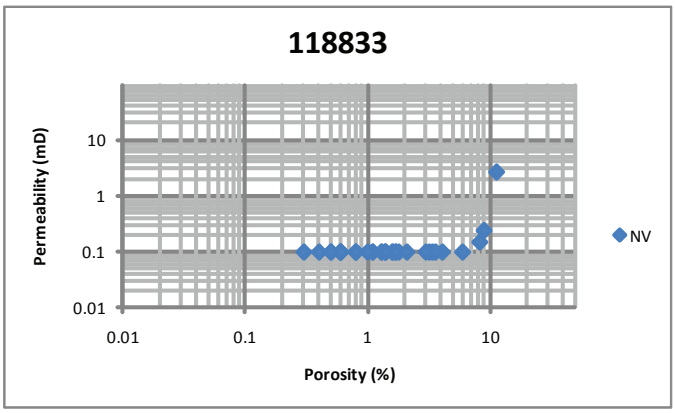
A



B



C



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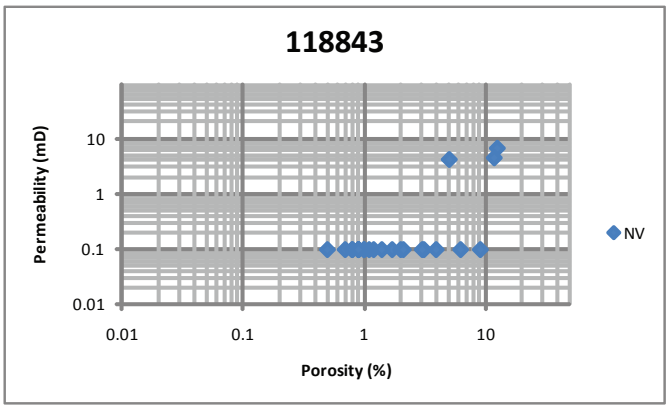

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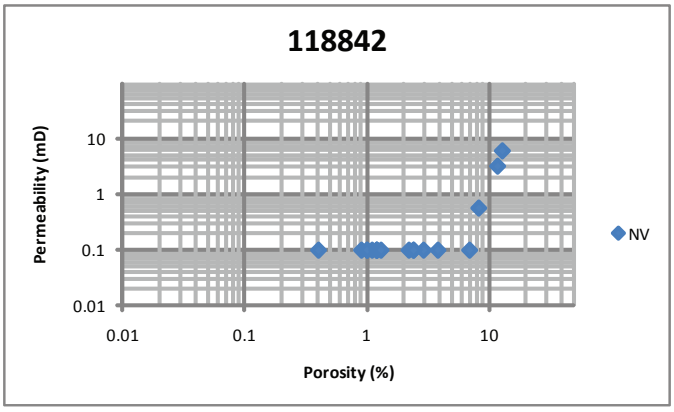

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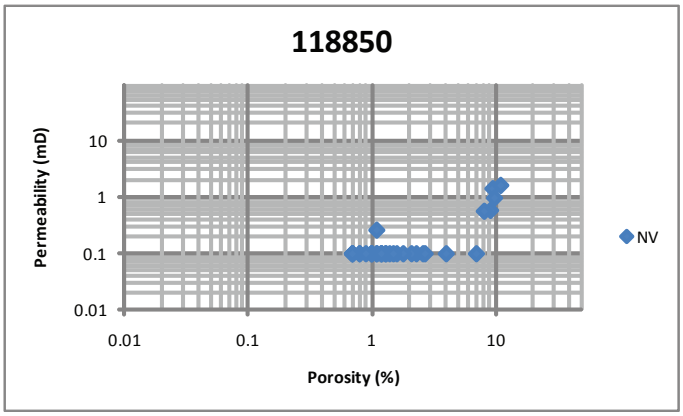
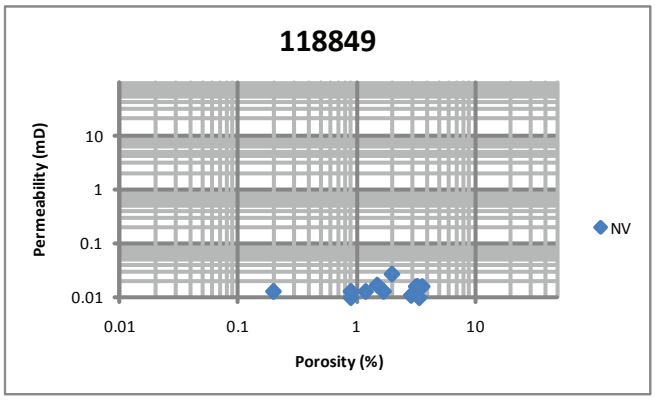
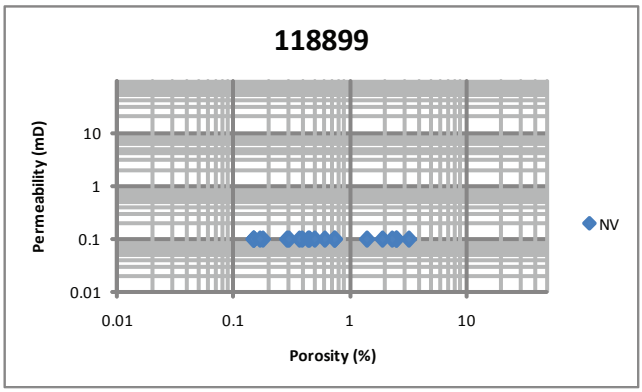


Continued...

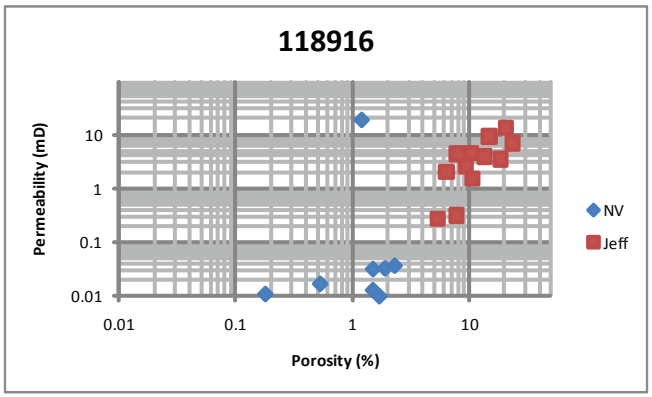
G



H



I



J

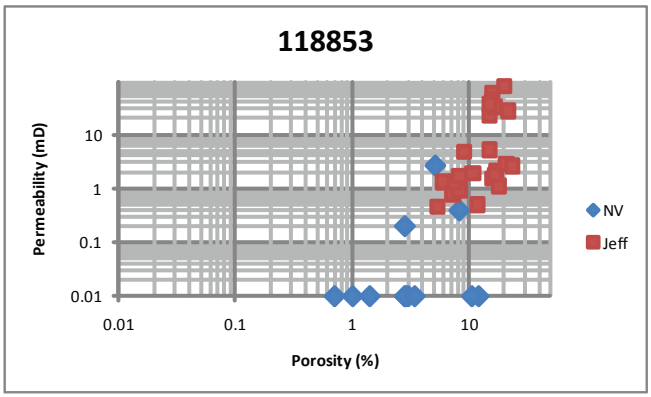


Figure 5: Porosity-permeability plots from core analyses of the Muscatatuck in the WorthingtonGSP Field, Greene County. A, B, C, D, E, F, G, H, I, J show data from different wells. For the well locations see Figure 1. The blue points on the charts show the data from North Vernon and the red points show data from the Jeffersonville. The chart title list the IGS Well ID.

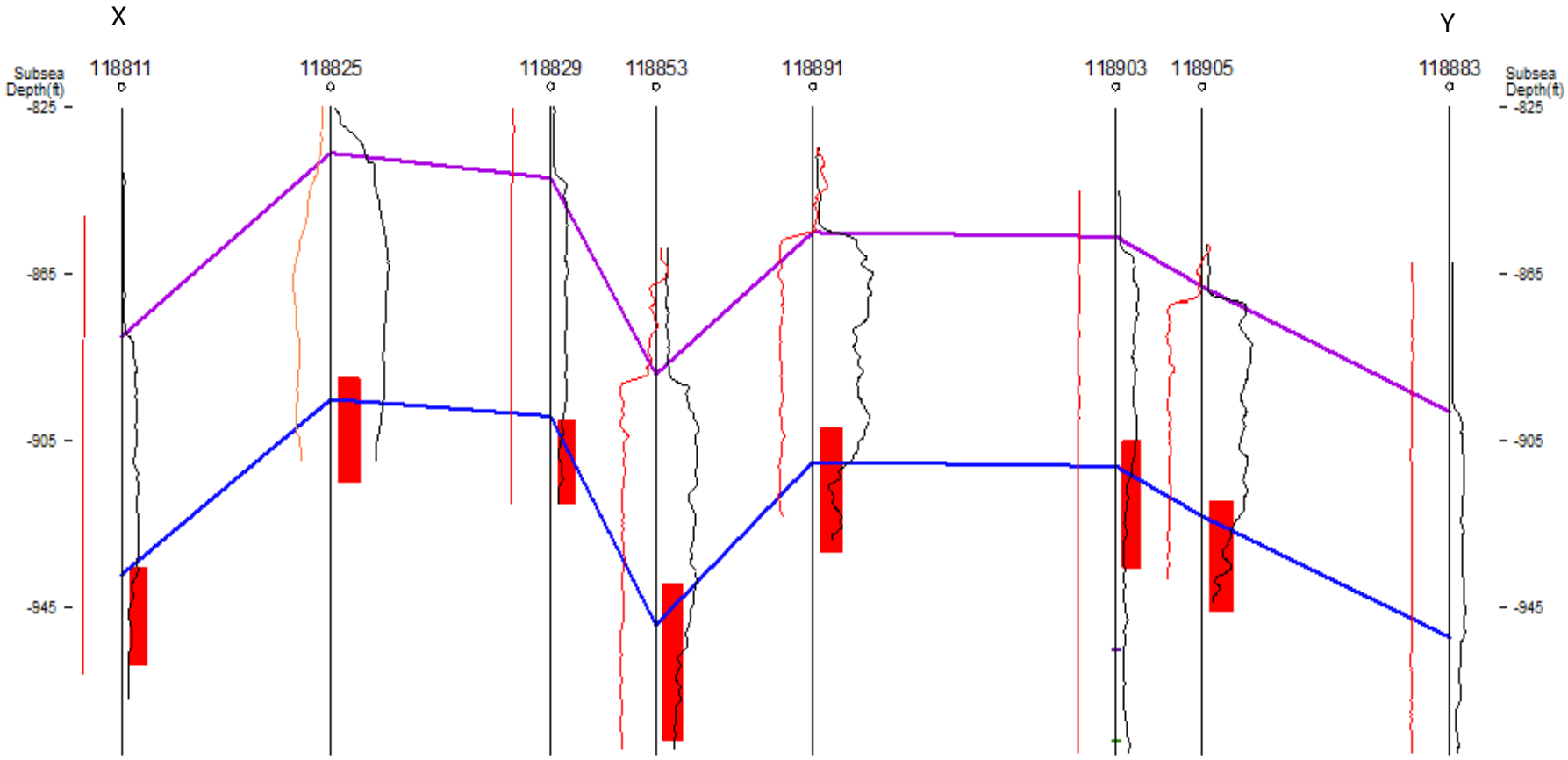


Figure 6: X-Y Cross section showing the Devonian subsurface structure across Worthington GSP Field, Greene County. The red color box shows the completion intervals for the gas storage, production or observation. For location of the cross section refer to Figure 1.

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Table-1: List of the wells used for subsurface structure mapping in Worthington GSP Field, Greene County. The wells selected have a TD of Devonian or deeper.

IGS_ID	Twp	Twp_D	Rng	Rng_D	Land_N	Elevation/Kb	Top of Musca-tatcuk	Top of Jeffer-sonville	Top of Geneva	Top of Silurian	Core Analysis
118486	7	N	5	W	4	560	1512	1579	1632	1666	
118491	7	N	5	W	5	566	1551	1615	1668	1760	
118779	8	N	5	W	19	529	1434	1508			
118782	8	N	5	W	19	545	1529	1589			
118783	8	N	5	W	19	543	1421	1472			
118784	8	N	5	W	19	508	1382	1440	1481		
118785	8	N	5	W	19	508					
118786	8	N	5	W	19	509					
118788	8	N	5	W	19	527	1448	1506	1548		
118791	8	N	5	W	20	510	1362	1416			
118792	8	N	5	W	20	508	1383	1434			
118793	8	N	5	W	20	511	1380				
118794	8	N	5	W	20	509	1385				
118795	8	N	5	W	20	509					
118796	8	N	5	W	20	512	1382	1434			
118797	8	N	5	W	20	515	1423	1486			
118798	8	N	5	W	20	511	1372	1422			
118799	8	N	5	W	20	520	1390	1446			
118801	8	N	5	W	20	511	1469	1532			
118802	8	N	5	W	20	509	1382	1423			
118804	8	N	5	W	20	516					
118805	8	N	5	W	21	507	1432	1488			
118806	8	N	5	W	21	608	1530	1586			
118807	8	N	5	W	21	516	1430	1483			
118810	8	N	5	W	21	516					
118811	8	N	5	W	21	589	1469	1526			
118818	8	N	5	W	28	507	1424	1492	1608	1656	
118819	8	N	5	W	28	504	1414	1484			
118820	8	N	5	W	28	533	1390	1452			
118821	8	N	5	W	28	559	1419	1480			
118822	8	N	5	W	28	587	1454	1512			
118823	8	N	5	W	28	504	1430	1500			
118824	8	N	5	W	28	520	1365	1427			P
118825	8	N	5	W	28	540	1382	1440			P
118826	8	N	5	W	28	540	1391				
118827	8	N	5	W	28	563	1437				
118828	8	N	5	W	28	528	1388				
118829	8	N	5	W	28	510	1352	1409			
118830	8	N	5	W	28	506	1338				
118832	8	N	5	W	28	513	1379	1436			
118833	8	N	5	W	28	511	1347				P

118838	8	N	5	W	29	508					
118839	8	N	5	W	29	513	1358				
118840	8	N	5	W	29	509					
118841	8	N	5	W	29	508	1396				
118842	8	N	5	W	29	511	1344	1398			P
118843	8	N	5	W	29	509	1360				P
118845	8	N	5	W	29	510	1428	1491	1532	1550	
118848	8	N	5	W	29	517	1355	1410			
118849	8	N	5	W	29	511	1382				P
118850	8	N	5	W	29	528	1385	1440			P
118851	8	N	5	W	29	514	1352	1416			
118852	8	N	5	W	29	511	1372				
118853	8	N	5	W	29	511	1400	1460			P
118857	8	N	5	W	30	510	1426	1486	1530	1556	
118858	8	N	5	W	30	509					
118859	8	N	5	W	30	508	1425	1480			
118860	8	N	5	W	30	508	1400	1460	1500	1520	
118861	8	N	5	W	30	505	1390	1454	1490	1512	
118863	8	N	5	W	30	507	1430	1494			
118864	8	N	5	W	30	507	1454	1516			
118867	8	N	5	W	30	507	1439	1500	1540	1564	
118869	8	N	5	W	30	508	1423	1488	1526		
118870	8	N	5	W	30	509					
118871	8	N	5	W	30	508	1424	1486	1524	1554	
118872	8	N	5	W	30	511	1445	1500	1540		
118874	8	N	5	W	31	507	1433	1492			
118876	8	N	5	W	31	505	1478	1540			
118878	8	N	5	W	31	507	1439	1502			
118879	8	N	5	W	31	507	1427	1488	1528	1552	
118880	8	N	5	W	31	507	1471	1536	1574		
118883	8	N	5	W	31	508	1406	1460			
118885	8	N	5	W	31	505	1482	1542			
118886	8	N	5	W	31	506	1448	1510			
118887	8	N	5	W	31	507	1450	1510			
118891	8	N	5	W	32	505	1360	1415			
118892	8	N	5	W	32	502	1360	1416			
118893	8	N	5	W	32	503	1374				
118894	8	N	5	W	32	509	1400	1458			
118895	8	N	5	W	32	508	1365	1418			
118896	8	N	5	W	32	513	1367				
118897	8	N	5	W	32	514	1384				
118898	8	N	5	W	32	511	1376				
118899	8	N	5	W	32	507	1381				P
118900	8	N	5	W	32	507	1422	1488			

118903	8	N	5	W	32	535	1391	1446	1490	1512	
118904	8	N	5	W	32	517	1382				
118905	8	N	5	W	32	522	1393	1448			
118906	8	N	5	W	32	515	1384				
118909	8	N	5	W	32	510	1380				
118913	8	N	5	W	33	505	1453	1518			
118914	8	N	5	W	33	509	1363				
118915	8	N	5	W	33	502	1366				
118916	8	N	5	W	33	500	1374	1430			P
118920	8	N	5	W	33	533	1468	1536	1584	1660	

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