BOEM 2016-027

Atlantic Well Folio: Georges Bank Basin

Lydonia Canyon Block 273 No. 1 Well

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1.8. Lydonia Canyon 273-1

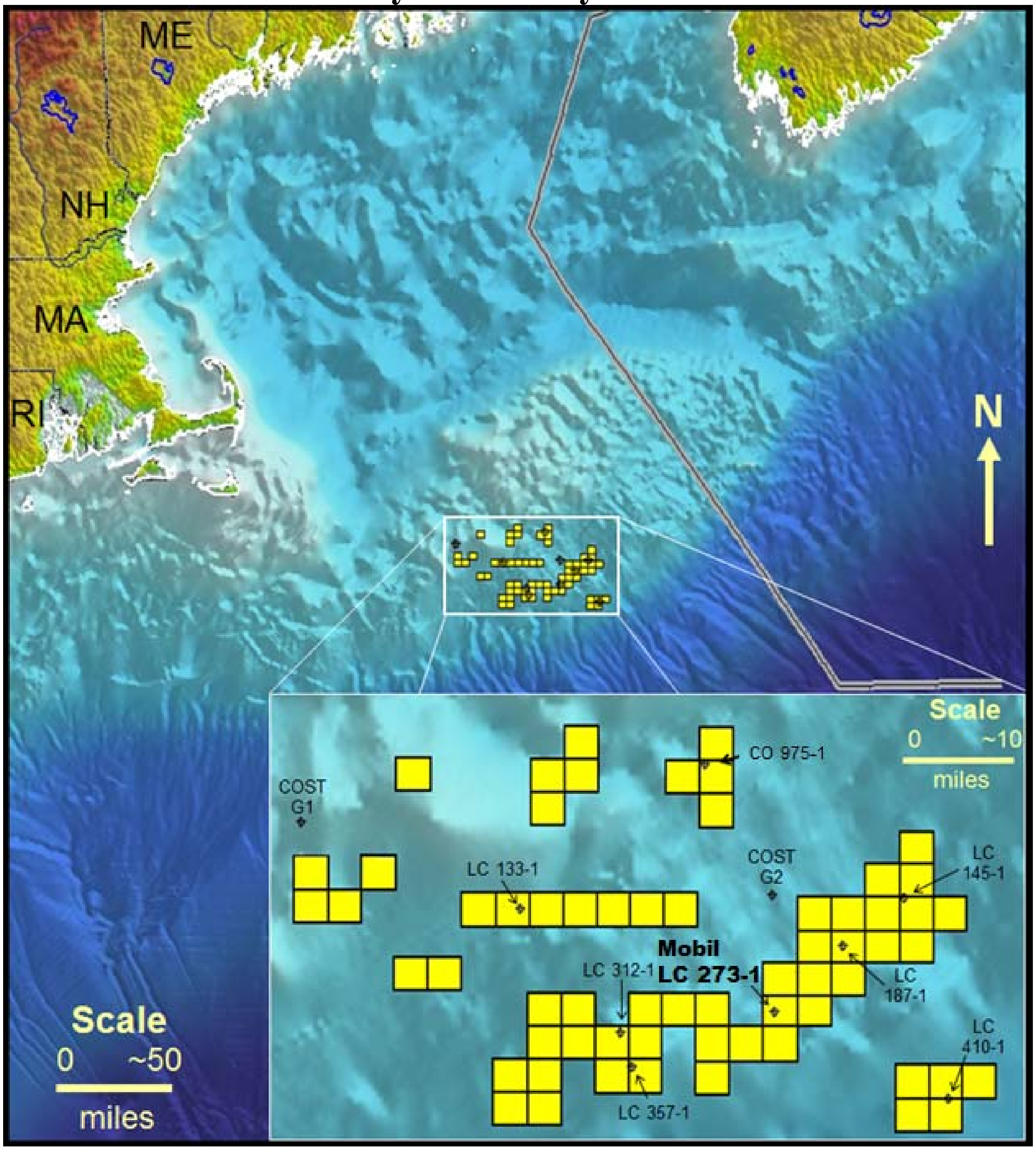

Figure 1. Location map of Georges Bank Basin (GBB), offshore Massachusetts, USA. Well locations are indicated by the symbol ⌖. Leases previously held in the area are shown in yellow.

Mobil, operator of Lydonia Canyon (LC) 273, spudded the LC 273-1 well in the Georges Bank Basin (GBB) ~11 miles south of the Continental Offshore Stratigraphic Test (COST) G-2 (Figure 1) using the semisubmersible Rowan *Midland* at latitude 40° 41' 03.706" N and longitude 67° 30' 12.199" W (Mobil Exploration & Producing (E&P) Services Inc., 1982) on June 30, 1982. The well reached a total depth (TD) of 15,580' on September 7, 1982. (All depths in this report are measured depth (MD) unless otherwise specified.) LC 273-1 was drilled based on information from comprehensive 2D seismic coverage, two COST wells, LC 312-1, and the then currently drilling well LC 187-1. It was plugged and abandoned as a dry hole on September 13, 1982. No significant oil or gas shows were encountered and low total organic carbon (TOC) was measured throughout the well, implying an absence of source rocks in the carbonate objectives. No tests were performed. Mobil did not take any conventional cores and there was no petrophysical analysis completed on any of the 32 recovered sidewall cores (Mobil Exploration & Production, 1982). No subsequent wells were drilled on the South Long Island prospect. Lease OCS A-0196 expired on January 31, 1985 (Edson *et al.*, 2000).

1.8.1 Objectives and Concepts

The primary reservoir objectives of LC 273-1 (Figures 2, 3, and 4 and Table 1) were interpreted as Late Jurassic oölitic limestones from -9,975' and ~10,775'. Secondary objective bioclastic limestones were interpreted between -10,775' and -13,350' (Mobil E&P Services, 1982). These center on the pre-drill Upper Jurassic (light blue) marker, and are bounded by the brown (Top Jurassic) and red (Middle Callovian) markers (Fig. 4) Mobil supported their selected location(s) by submitting structure maps of key horizons (Fig. 5) in their Application to Drill (APD) (Mobil E&P Services, 1982). The well was permitted to a proposed total depth (PTD) of 19,150'. Below ~17,500', dolomites and oölitic limestones were interpreted to be deeper, secondary objectives. However, these deeper targets were never reached. A structural-stratigraphic play was anticipated with the carbonate reservoirs associated with the 28-mile long, South Long Island structure, a partially salt-controlled anticline (Mobil E&P Services, 1982). Support for the salt-cored structural interpretation is the inferred presence of evaporites in the COST G-2, located ~11 miles to the north. This interpretation was based on a large increase in dissolved chlorides, poor cuttings returns, and an abrupt increase in drilling rate in the well from 21,800'–21,820'. Taken together these suggest the occurrence of evaporites, including salt and anhydrite. Structural interpretations by Mobil, the MMS, and the one done for this folio are similar. Our interpretation, shown in Figure 6, is that this is a ductile formation. Whether that is represented by evaporites, perhaps layered evaporites, is unclear. The MMS pre-sale resource/reserve estimate for the tract was 65,268 barrels (bbls) of oil and condensate and 548,495 thousand cubic feet (MCF) of gas. Neither was considered to be economically recoverable. Any hydrocarbons were projected to be gas with some condensates according to Mobil (Mobil E&P Services, 1982).

1.8.2 Results

Drilling

LC 273-1 was located in 301' of water, 140 miles southeast of Nantucket, approximately 15 miles from the present-day shelf edge. Tight micritic limestone was the prevalent lithology in the predicted reservoir zone (-9,975'– -13,350') rather than the expected porous oölitic and bioclastic limestones (Edson *et al.*, 2000). Sixty-four (64) sidewall cores were shot from 4,818'–15,580' with 32 recovered. No petrophysical analyses involving porosity or permeability measurements were performed on any of these cores (Mobil Exploration & Production, 1982). However, their lithologies were described. There were no significant shows of hydrocarbons, and only a few minor gas shows (<40 units) were encountered in the well.

A standard suite of wireline logs run from ~4,800' to TD indicated 86' of potential reservoir using our 10% porosity cutoff in the section from 9,090' to 15,060', with the thickest interval being 29' (MMS Staff, 1984). Because no conventional cores were cut, the more accurate porosity and permeability measurements from these were not available for comparison or calibration. The well bore had substantial washout. Consequently, the log-derived porosities may be overestimated. Given the tight characteristics of the target zones, secondary porosities related to fracturing and dolomitization would likely be necessary to create effective reservoirs. Clearly, this did not happen. Instead, porosities are low. These may have been reduced by diagenetic cementation, mineral replacement, fracture fill, calcite recrystallization, or secondary chert as was interpreted in LC 357-1, ~14 miles to the southwest.

Cuttings were taken throughout the well to determine lithology, paleontology-based sediment age, visually estimate thermal maturity (%R_o and TAI), and analyzed for source rock potential (visual kerogen analysis (VKA), TOC, and Rock-Eval pyrolysis). Much of the Jurassic, from ~5,700' to TD, consisted of microcrystalline and cryptocrystalline carbonates with interbedded shale and siltstone, and minor sandstone and anhydrite. The primary objective interval, -9,975' – -10,755', and the top of the secondary objective from -10,755' – -14,650' was more interbedded, and occasionally contained some oölitic limestone beds. However, the porosities were still low. The bottom part of the secondary objective is a massive carbonate that is more uniformly "tight". The dipmeter shows generally shallow, <10^o, dips to the south or southwest, although a few short intervals of steeper dip (10^o –20^o) are encountered. Below ~14,000' the measurements are too sparse to be of value, or are absent altogether. These dips are also evident on our structure maps (Figures 7 and 8).

The deeper secondary objectives of the well projected to occur below ~17,225' were never reached because the well stopped 3,920' short of the PTD. No operational issues were mentioned. However, it was stated that the operator would need to set additional casing to continue drilling. It appears Mobil chose to plug and abandon at 15,580' rather than incur the cost of the additional casing, drilling days, mud, consumables, *etc*. The disappointing data from the two COST wells, the discouraging results from the six previously drilled industry new field wildcat (NFW) wells in the GBB, and to that depth the lack of any significant hydrocarbon shows or reservoir development in LC 273-1, which had been drilled through both the primary and shallower secondary objectives, probably contributed to the decision to stop drilling, plug and abandon the LC 273-1.

Seismic

Mobil submitted 12 interpreted seismic lines related to their South Long Island prospect (Mobil E&P Services, 1982). Their interpretations used 2D time seismic, along with drilling results from previous GBB wells COST G-1, COST G-2, the Mobil operated LC 312-1, and the Mobil 30% owned LC 187-1, all of which were completed prior to LC 273-1 (Table 1). Well LC 187-1, ~9 miles to the northeast (updip) along the same paleoridge, had already encountered a gas show of 118 units from 9,277'– 9,287' prior to the LC 273-1 APD (Mobil E&P Services, 1982).

Mobil's APD covered proposed wells in blocks LC 273, LC 143, and LC 316. LC 273 was the priority block, with drilling on LC 143 and/or LC 316 being contingent on the results of LC 273-1 and other industry wells (Mobil E&P Services, 1982). Figure 4 shows Mobil's interpretation of line PR-116. Figure 6 shows our interpretation of the same line where we mapped 8 sequence boundaries (SBs). These SBs were initially identified and interpreted by GeoSpec, a CGG company, in their integrated seismic and well interpretation of the U.S. Atlantic OCS (GeoSpec, 2003). Mobil provided structure maps on the "Top Jurassic", their primary objective "Upper Jurassic", "Near Middle Callovian", and "Lower Jurassic" markers (Mobil E&P Services, 1982). Maps on secondary objectives listed as an oölite and bioclastic limestone anticipated at ~-10,755' (2.27 sec) and dolomite and oölitic limestones expected at ~-17,150' (3.1 sec) were not provided. As part of their pre-lease evaluation, MMS staff in 1977 mapped essentially the same four horizons, and the MMS and Mobil pre-drill interpretations for LC 273 block were virtually identical (MMS Staff, 1984).

Our interpretations in this report used post-drill, reprocessed, time-migrated, depth-converted data licensed from GeoSpec. Structure maps created and included in this folio are on the intra-Oxfordian (Fig. 7) SB, the base Bathonian (Fig. 8) SB, and the intra-Tithonian thru "base mid-Jurassic" isochore (Fig. 9). Mobil interpreted two normal faults within and adjacent to the Block 273 structure. These faults, which our maps and the earlier MMS interpretation do not include, were interpreted by Mobil to extend as shallow as their "Lower Jurassic" horizon.

We mapped the same anticlinal feature, which was targeted earlier in 1982 by the Tenneco *et al*., LC 187-1 dry hole, of which Mobil was a partner (Smith and Post, 2016). We believe that this structure may have been formed by transpressional forces related to the onset of rifting and subsequent drifting that shaped the Atlantic margin (Withjack *et al*., 2012). The structure affected Jurassic strata, with relief diminishing upward into the Cretaceous. No major faults were interpreted. Below the "base mid-Jurassic" (SB1), we interpret possible ductile sediment(s) filling void spaces created by the tectonic forces (Fig. 6). Given the relatively dry climate (PaleoMap Project, 2002) and possible sabkha environment interpreted to have existed during the late rifting phase and possibly early drifting phase, evaporites are likely below SB1. As noted above, an evaporite interval may have been encountered near TD of the COST G-2 well, and Mobil stated in their APD that the structure LC 273-1 was testing was salt-cored (Mobil E&P Services, 1982).

Structure (Figures 7 and 8) and isochore (Fig. 9) maps illustrate the southwest plunging paleoridge that LC 273-1 and the earlier drilled LC 187-1 tested. The orange blocks shown on the maps delineate what we interpret to be the LC 273-1 prospect area. The Jurassic isochore map (Fig. 9) shows interpreted faulting east and west of the LC 187-1. We interpret these deep-seated, high-angle faults to possibly be reactivated basin-bounding faults related to seafloor spreading of this part of the Atlantic (Withjack *et al*., 2012). None of these large displacement faults are interpreted to continue south towards the area of the LC 273-1; however, as noted above, low displacement faulting below seismic resolution may occur.

Biostratigraphy and Paleoenvironment

Mobil's paleobathymetry and environment of deposition (EOD) interpretations relied on microfossil, nannofossil, and palynology samples outlined in Table 2 (Mobil Oil Corporation, 1982a). Lithologic descriptions from mud logs, neutron-density crossplots, and wireline correlation to nearby well LC 187-1 were also used in our interpretation of depositional environments (Table 3). GeoSpec previously interpreted LC 187-1 and 4 other industry wells in GBB. Formations' ages and depths were also derived from the LC 187-1 well-tie. Shelf environments evolve with decreasing water depth associated with increasing depth/age. The bottom 2,000' of the well (~13,630'–TD) is interpreted as an episodically inundated sabkha environment because of the prevalence of dolomite and anhydrite (Fig. 3). Depositional water depth increased during the deposition of the ~8,000'–~13,630' interval in the Kimmeridgian thru Bathonian, fluctuating from supralittoral to middle shelf with limestone being the primarily carbonates deposited (Fig. 3). From the top of the well to ~8,000', inner and middle shelf deposited mud and siliciclastic sediments predominate (Fig. 3). Geohistory modeling of the data shows moderate to rapid basin subsidence from the Middle to Late Jurassic when the carbonates were being deposited and water depth was gradually increasing. The Cretaceous and Cenozoic had moderate to minimal subsidence as siliciclastics became dominant.

1.8.3 Operations and Costs

Block 273 was leased at OCS Sale 42 in 1979 for the winning bid of $75,238,000 (Mobil Oil Corporation, 1980b) or $260,957,000 in 2015 dollars (HBrothers, 2015). Lessees were Mobil Oil Corporation, 45% and operator, Amerada Hess Corporation (23%), Tenneco Oil Company (22%), and Transco Exploration Company (10%) (Mobil Oil Corporation, 1980b). The total well costs for LC 273-1 are unavailable. However, they can be estimated. The same Rowan *Midland* semisubmersible rig drilled LC 312-1 at an average cost per day of $445,000 ($1,112,000 in 2015 dollars) (Smith and Post, 2016). The LC 273-1 required 76 drilling days (Mobil Oil Corporation, 1982c), suggesting its total cost was ~$33,820,000 or $84,482,000 in 2015 dollars (HBrothers, 2015). Our seismic interpretation suggests that the prospect evaluated by LC 273-1 included blocks LC 316 and LC 317, outlined in orange on Figures 7, 8, and 9. These blocks were leased by Mobil *et al*., for a bonus of $8,836,000, and Exxon for $1,117,000, respectively. In its APD review, the MMS noted that LC 187-1 and LC 273-1 shared similarities as part of the same anticlinal trend on which the objective carbonate bank was interpreted (Mobil E&P Services, 1982).

1.8.4 Petroleum System Analysis

Magoon and Dow (1994) defined a petroleum system as "a natural system that encompasses a pod of active source rock and all related oil and gas and which includes all the geologic elements and processes that are essential if a hydrocarbon accumulation is to exist." Petroleum includes thermal or biogenic gas … or condensates, crude oils, and asphalts found in nature (Magoon and Dow, 1994).

Petroleum system elements are: source rock, reservoir rock, seal rock, and overburden rock (a thick enough rock column above the source rock interval to result in burial sufficient for temperatures to trigger hydrocarbon generation). Our guidelines for source, reservoir, and seal elements are shown in italics in Table 4.

Petroleum system processes include trap formation and hydrocarbon generation–expulsion–migration–accumulation, and preservation (modified after Magoon and Dow, 1994).

Timing is paramount in petroleum systems; *e.g.*, a reservoir in a sealed trap must exist when hydrocarbons are generated, expelled from the source rock, migrate into the trap, become entrapped and retained in the trap (Magoon and Dow, 1994). Not all processes will occur in all areas; *i.e.*, when there is no hydrocarbon generation and expulsion, there can be no migration or accumulation.

Geochemistry

There were 369 TOC measurements from 4,500' to 15,570' (Table 5), reported here as present-day values. Only 47 samples (12.7%) were above 0.5% measured TOC, with 2 of those above the 1% TOC required for consideration as a possible, but not effective, source rock. Rock-Eval pyrolysis was only performed on the 2 samples with TOC values above 1%. A sample with 2% TOC had a Hydrogen Index (HI) of 70.0 and a hydrocarbon potential of 1.41, characteristic of poor source potential with no generating capabilities. The second sample had a TOC of 1.02% and a HI of 38.2, also a poor to non-effective source rock. Both samples were from the immature Hauterivian from 5,160'–5,220', over 4,700' above the target zones. (Mobil Oil Corporation, 1982a).

VKA was performed separately by Mobil and the MMS on aggregated cuttings. The MMS sampled most of the well from 550'–TD. Mobil sampled from 4,500'–TD. Independently, the reports show low amounts of Type I kerogen, largely found in the immature Tertiary and Cretaceous intervals and decreasing with depth. Approximately a third of the TOC throughout the well is the inert Type IV kerogen. Type II and Type III kerogens were also consistent with depth, averaging approximately a quarter and a third respectively. The low HI values in the two Rock-Eval samples agree with these kerogen distributions.

Maturity was determined from vitrinite reflectance (%R_o) and thermal alteration index (TAI). %R_o analysis is performed by measuring via microscope the percentage of incident light reflected from a polished surface of vitrinite (U.S. Dept of Interior BLM, 2014). To obtain TAI values, the discoloration of pollen spores (palynomorphs) is examined. Darker colors correlate with higher thermal maturity. Like VKA, both methods rely on inherently subjective measurements. Since LC 273-1 was drilled, %R_o has become the accepted method. Modeling the %R_o data showed early maturity for oil generation at 6,000' in Tithonian age sediments. Main gas generation was reached at 16,450', in Bathonian or older strata (Table 6).

Exploration Implications

1. Very low TOC's are present throughout LC 273-1. The entire well was thoroughly sampled, yet only 2 samples were above 1% TOC. Consequently, modeling in BasinMod® showed hydrocarbon generation to be very low with no expulsion predicted. This is in good agreement with the few, small gas shows (<40 units) encountered while drilling.
2. Reservoir quality porosities where not present in either of Mobil's targets. Instead of the predicted oölitic and bioclastic reservoirs, "tight", micritic carbonates were encountered with wireline log calculated porosities averaging 7% in the target zones and only two values over 10% (MMS Staff, 1984).
3. Our interpretation and maps (Figures 6–9) did not indicate any faulting connecting better reservoir quality post-Jurassic strata with zones mature enough to generate hydrocarbons. Consequently, if any significant volumes of hydrocarbons had been generated and expelled (which they were not) those hydrocarbons would be unlikely to have reached those potential reservoirs. Table 7 summarizes the pre-drill interpretation and the post-drill results of LC 273-1.

Acknowledgements

The support of BOEM management and staff: R. Poling and M. Wilson are gratefully acknowledged. We are grateful to GeoSpec, a CGG company, for allowing the publication of their reprocessed, depth-converted, time-migrated seismic data and derivative maps produced by BOEM staff from this data. The assistance of J. Danford and M. Paton of GeoSpec is greatly appreciated.

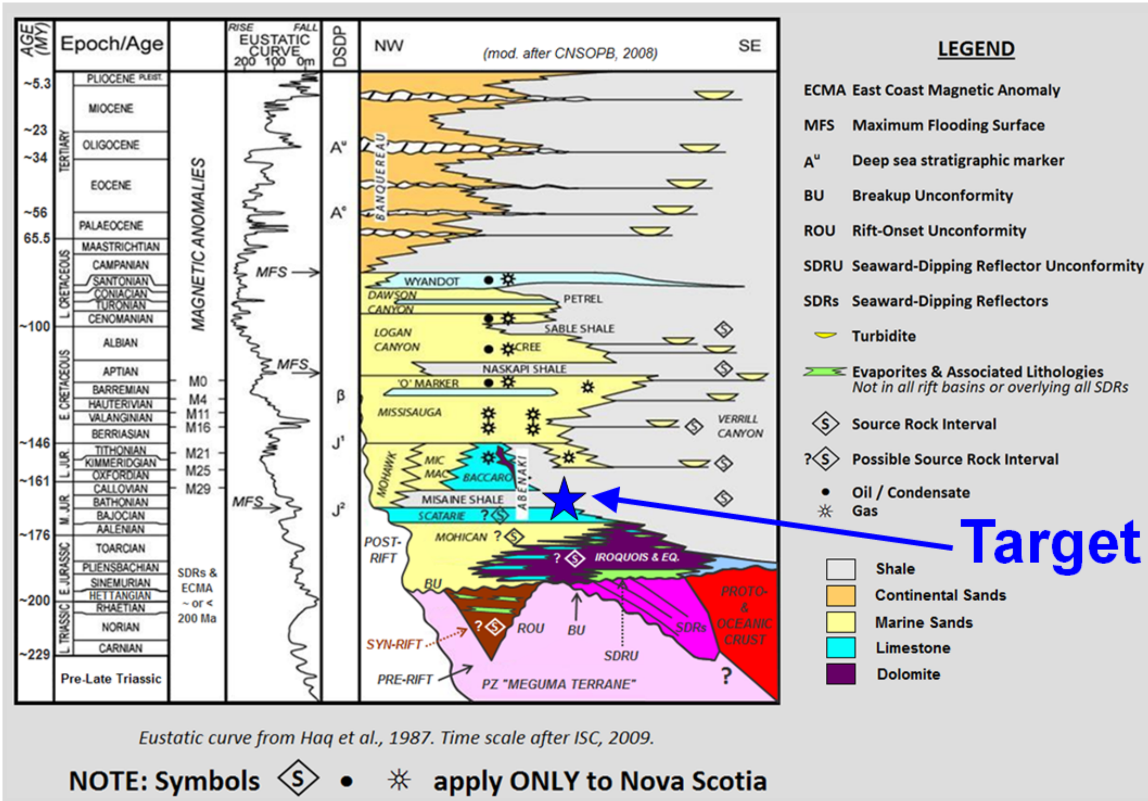

Figure 2. Stratigraphic chart showing the target interval for Mobil LC 273-1.

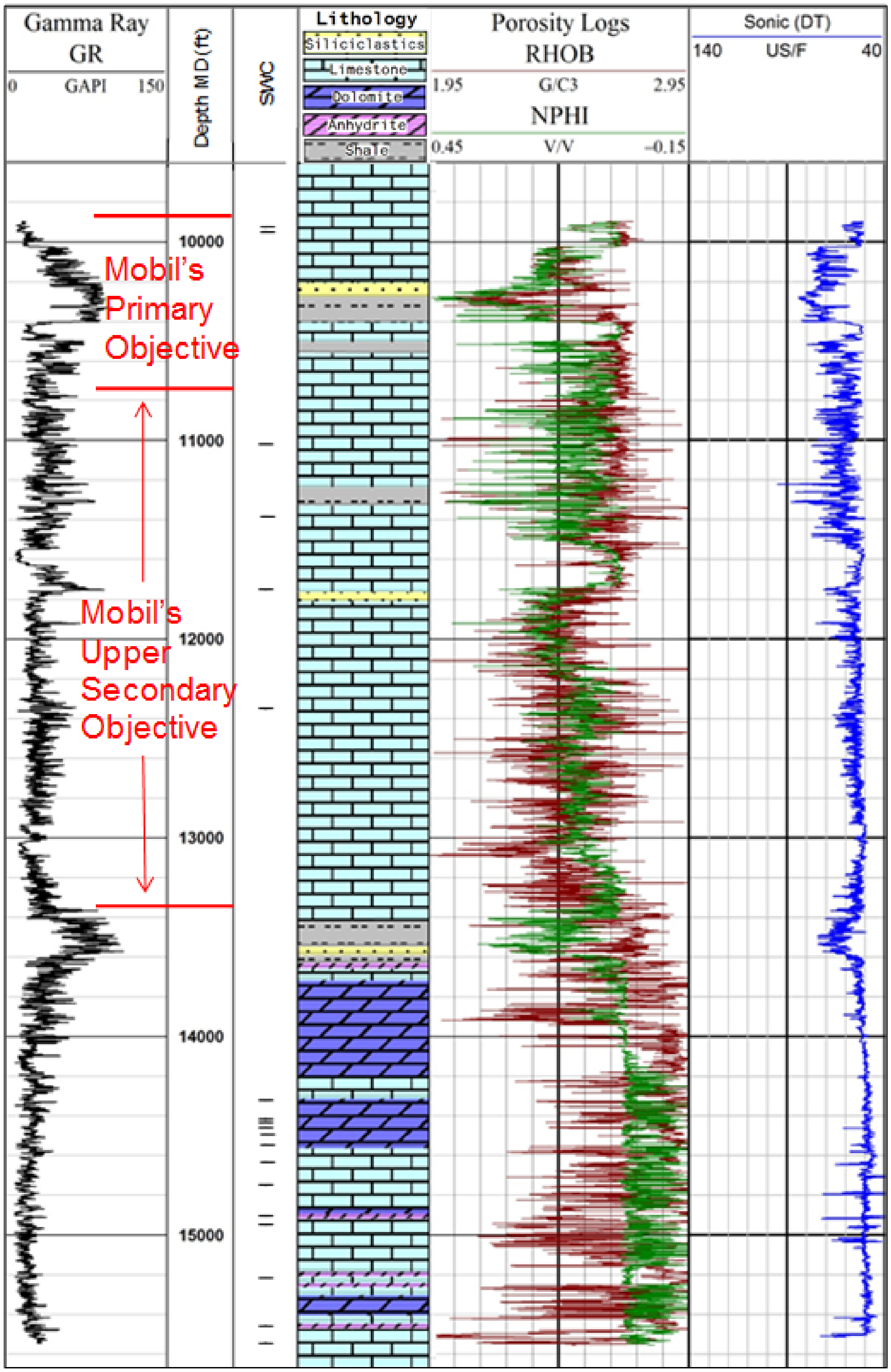

Figure 3. BOEM interpreted lithologies through the objective zones for LC 273-1 based on mud logs, sidewall core analysis, and crossplot of neutron-density curves. Location of sidewall cores and selected log curves are also displayed.

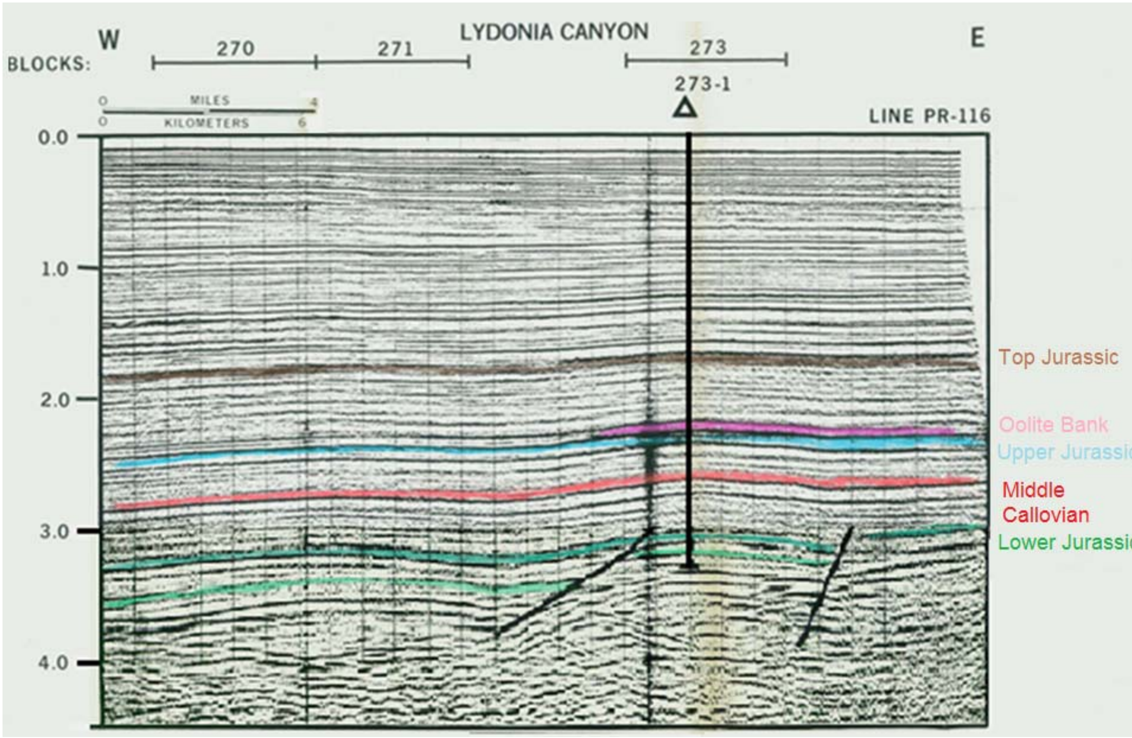

Figure 4. Seismic interpretation through LC 273-1 (Mobil E&P Services, 1982).

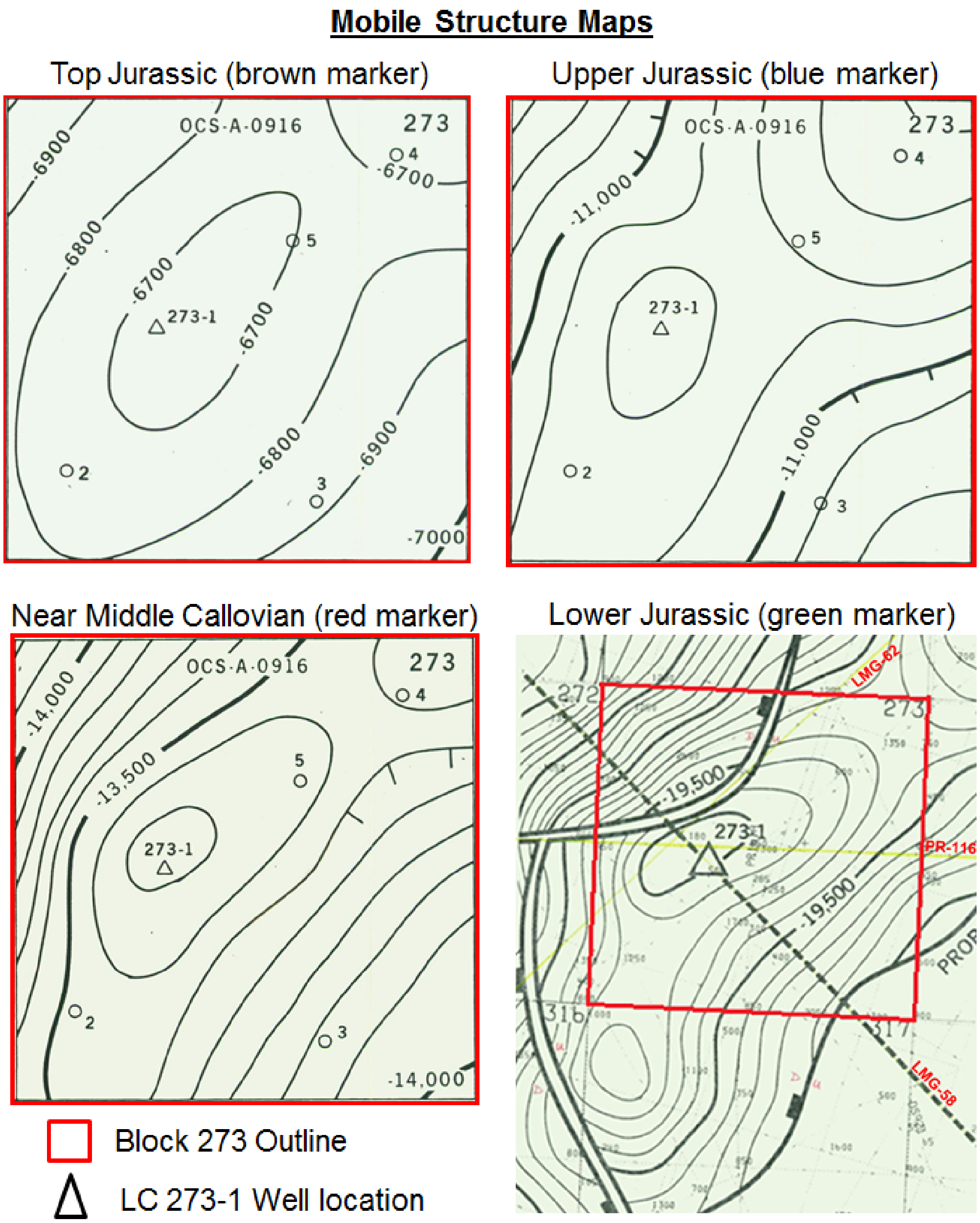

Figure 5. Mobil's pre-drill structure maps submitted in their APD (Mobil E&P Services, 1982).

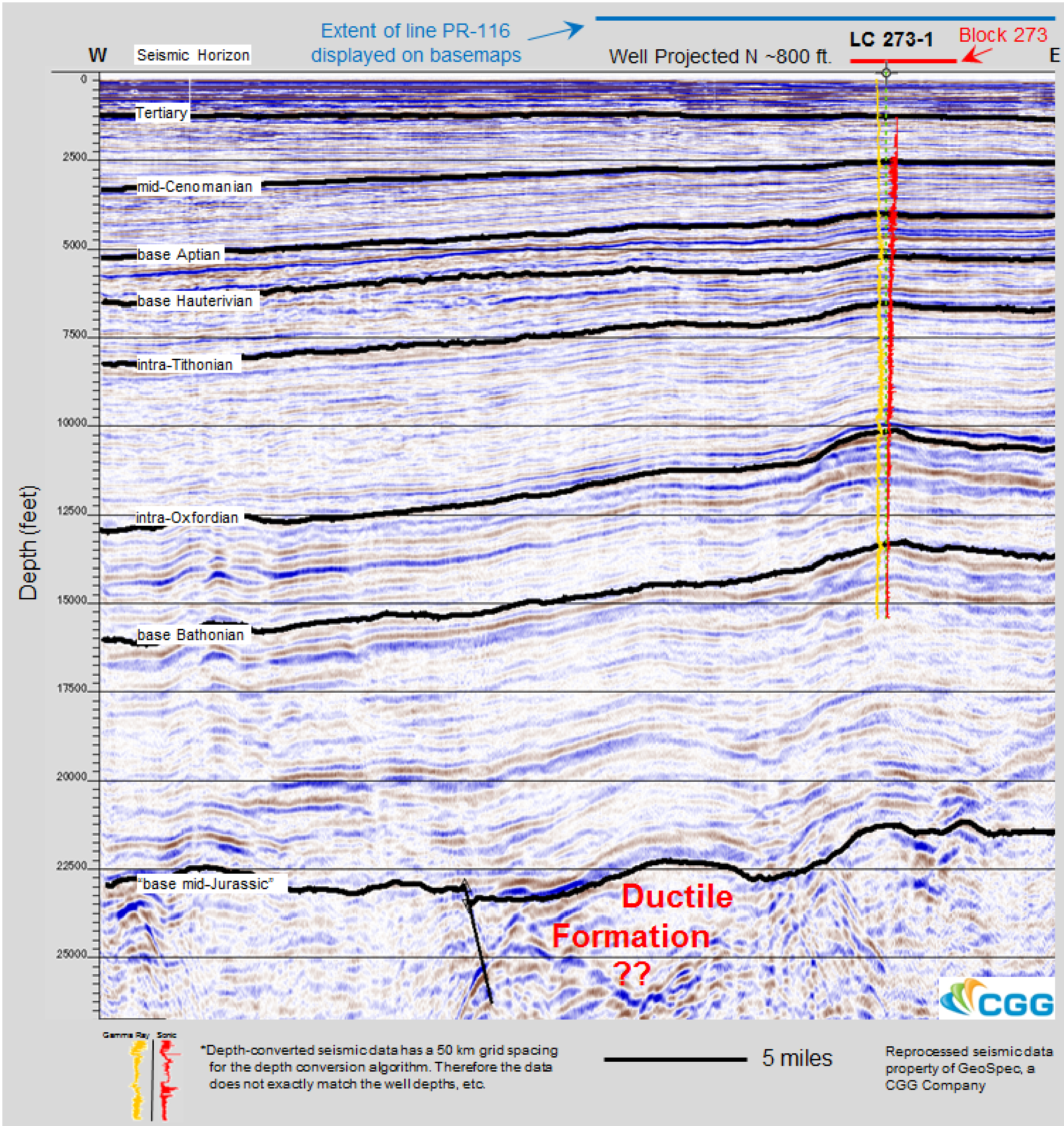

Figure 6. Seismic profile of W-E line PR-116 whose location is shown on the structure (Figures 5 [Lower Jurassic Horizon], 7, and 8) and the isochore (Figure 9) maps. Black horizons are BOEM's interpretations of the 8 SBs defined by Geospec.

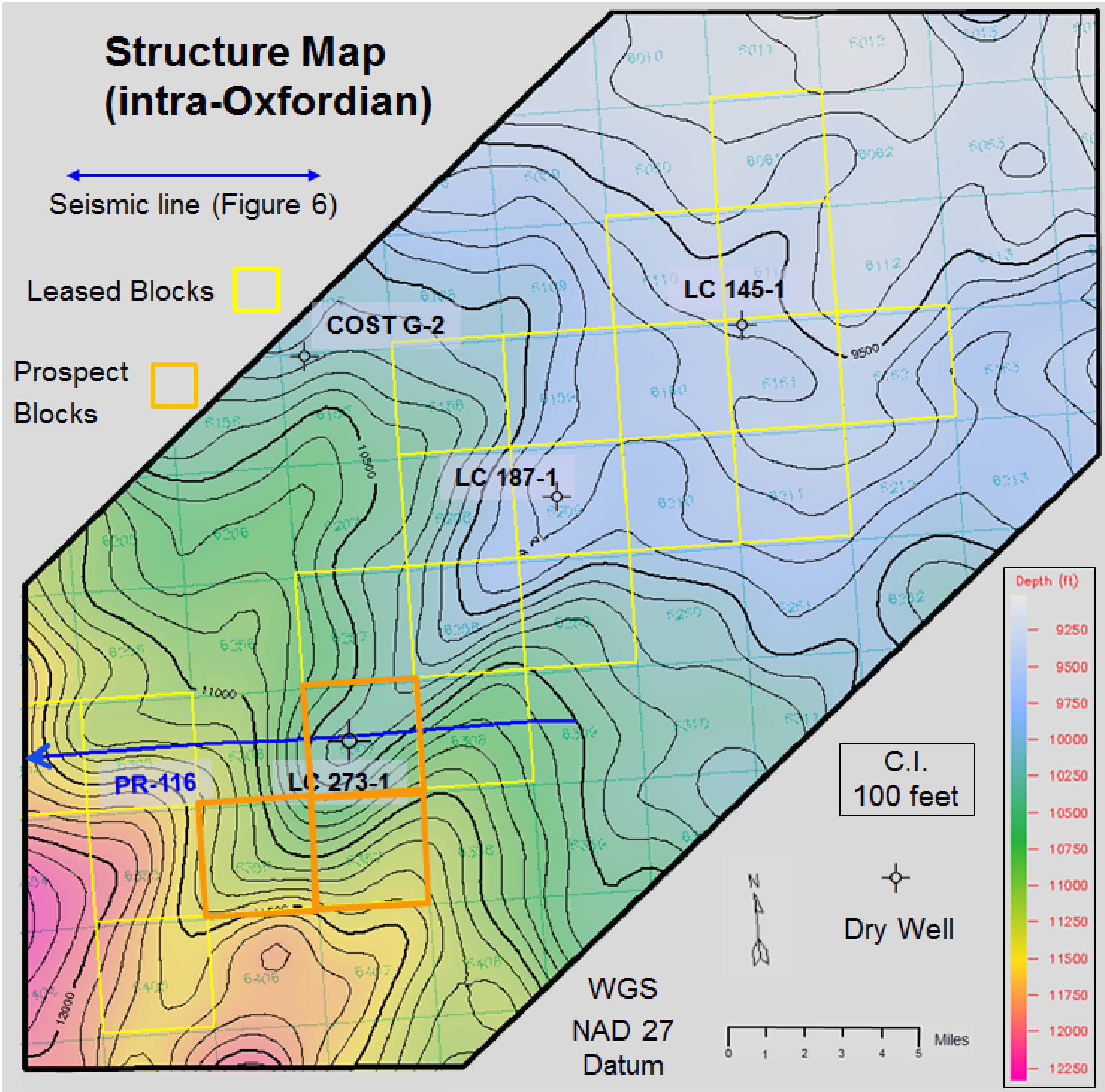

Figure 7. Structure map of the intra-Oxfordian horizon (Figure 6). Line shown in blue is the PR-116.

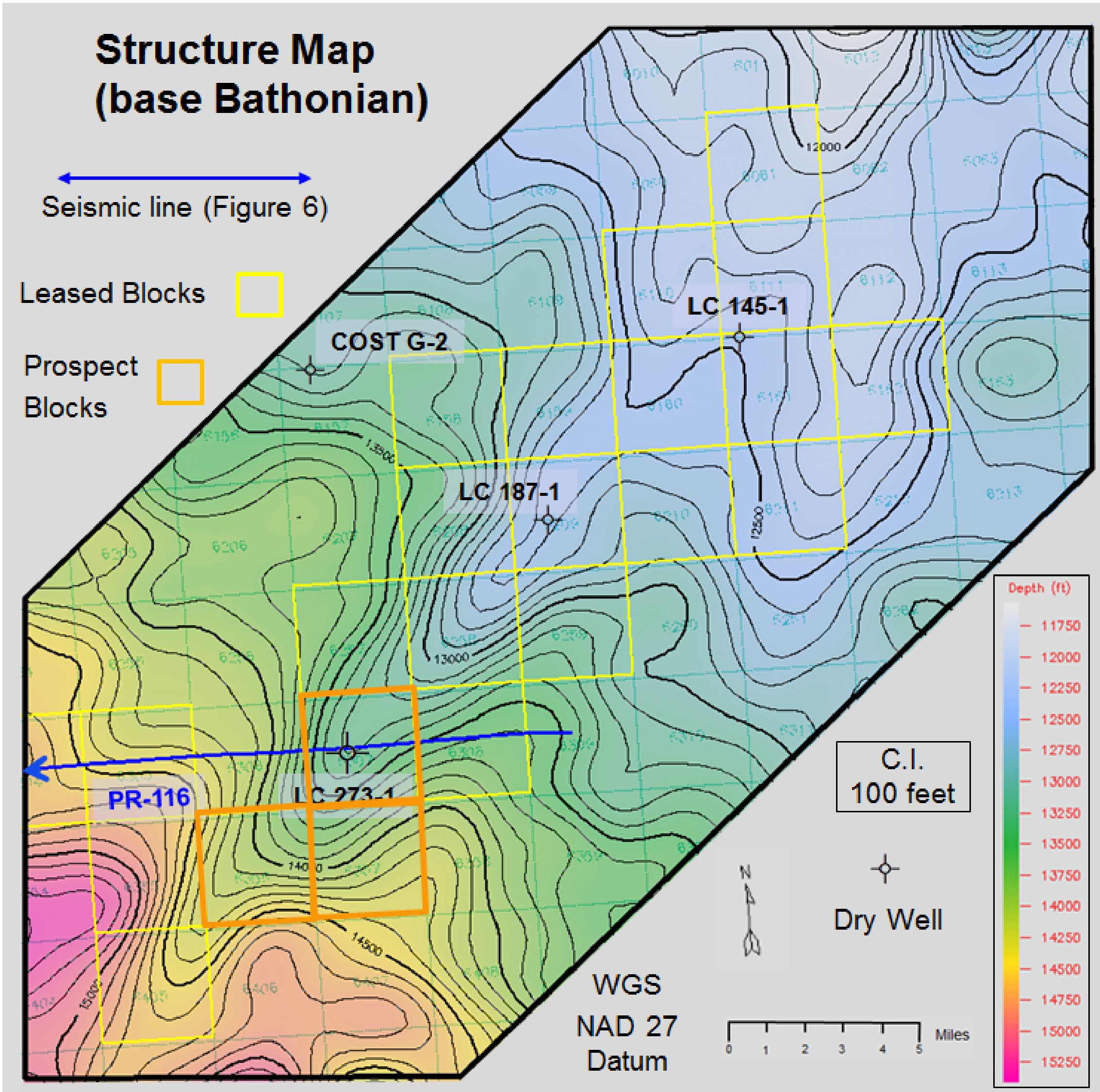

Figure 8. Structure map of the base Bathonian horizon (Figure 6). Line shown in blue is the PR-116.

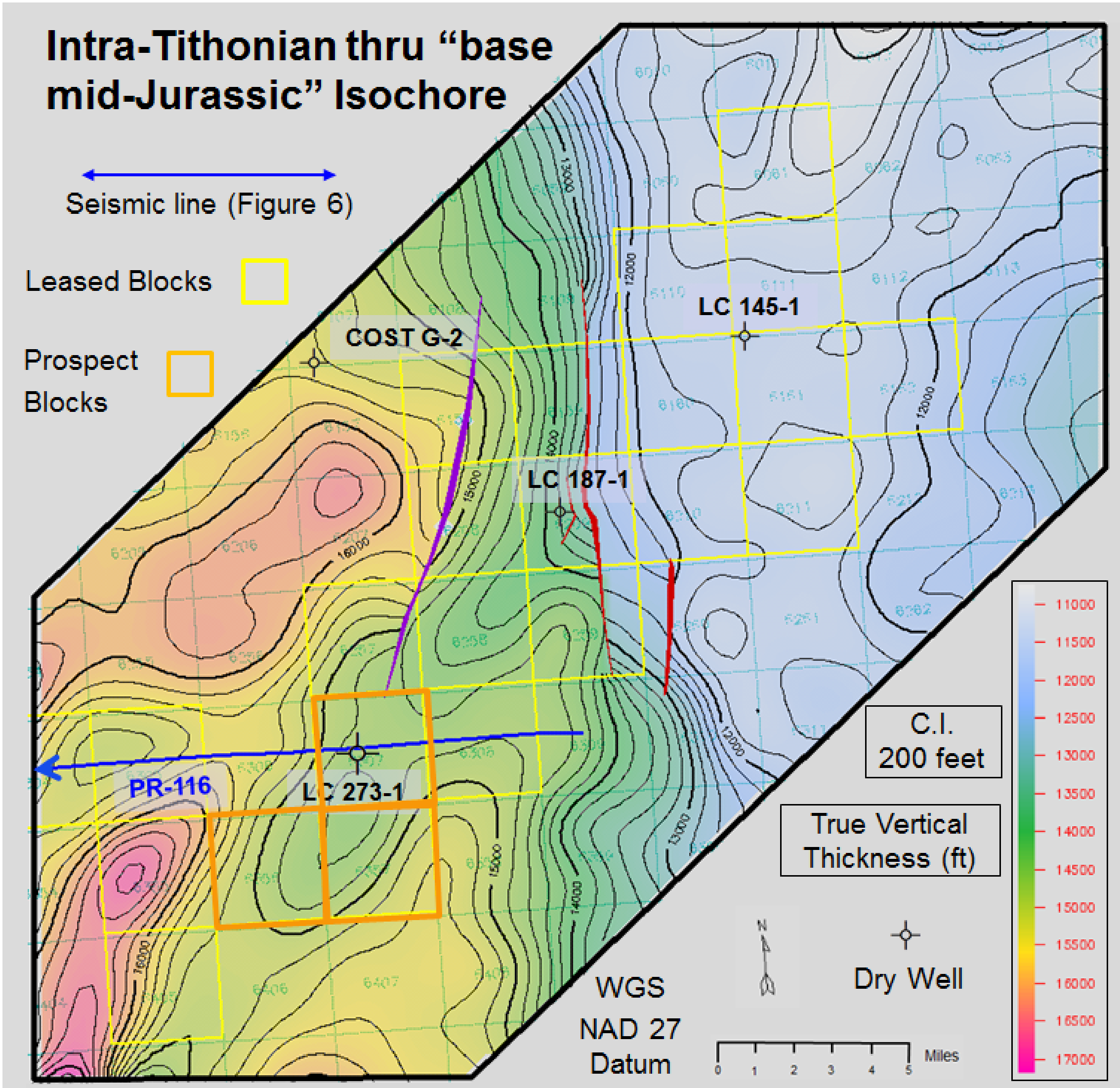

Figure 9. Isochore map for the entire Jurassic interval. Line shown in blue is the PR-116.

Table 1. Wells drilled in Georges Bank Basin

Well	Completion Date	Target	Actual
COST G-1	1977	n/a	n/a
COST G-2	1976	n/a	n/a
LC 133-1	1981	Callovian Reef	Volcanic Sequence
CO 975-1	1982	Bathonian porous shelf carbonate	Evaporite Lens
LC 410-1	1982	Jurassic Closure	Jurassic Closure poor porosity
LC 312-1	1982	Callovian Reef	"Tite" micritic Limestone
LC 187-1	1982	Jurassic age Limestones and Dolomites	Reservoir of poor quality
LC 145-1	1982	Jurassic Porous Shelf edge Calcarenites and Jurassic Carbonates	"Tite" micritic Limestones
LC 273-1	**1982**	**Four way closure, Jurassic oölitic and bioclastic limestones**	**"Tite" micritic Limestones**
LC 357-1	1982	Simple structural closure in Limestone, Dolomite, and anhydrite	"Tite" micritic Limestones

Table 2. From Mobil's paleontological report

Samples	**Interval Size**	**Range**	**Measured/Examined**
357 ditch samples	30'	4,950'–15,580' (TD)	Foraminifera and ostracods
99 ditch samples	30'	5,010'–7,920'	Nannofossils determinations
32 sidewalls	NA	5,010'–7,920'	Nannofossils determinations
124 ditch samples	90'	4,500'–15,580' (TD)	Palynological studies

Table 3. Formation names, ages, and tops determined via ties to wells with seismic data from GeoSpec. Depositional environment and lithology determined from Mobil's paleontological report and unpublished BOEM work using Log Evaluation System Analysis (LESA) software.

Depth (tops)	Age	Formation/Unit: Lithology	Depositional Environment
600	Miocene to Campanian	Unknown	Middle shelf, mud dominated
1425	Campanian to Cenomanian	Dawson Canyon Fm.: Top of formation is sandy with occasional lignite. Rest of formation is shale with fossils	Middle shelf, mixed mud and siliciclastic
2495	Cenomanian to Barremian	Logan Canyon Fm.: Interbedded sand and shale with occasional pyrite, lignite, and fossils	Middle shelf, mixed mud and siliciclastic
4220	Barremian to Hauterivian	Mississauga: Interbedded limestone and sandstone with some siltstone and shale and occasional fossils, pyrite, and lignite	Middle shelf, mixed carbonate and siliciclastic
5495	Hauterivian to Tithonian	Roseway Unit: Limestone with siltstone and sandstone in the upper part of the formation	Inner to middle shelf, mixed carbonate and siliciclastic
6890	Tithonian-Kimmeridgian	Abenaki: Limestone	Middle shelf, carbonate dominated
7600	Kimmeridgian	Mic Mac-Mohawk: Interbedded limestone, siltstone, shale, and sandstone with occasional pyrite, lignite, and fossils	Inner to middle shelf, mixed carbonate and siliciclastic
9580	Kimmeridgian-Callovian	Abenaki: Predominately limestone with a few, thin interbeds of siltstone, shale, and sandstone. Some pebbles and fossils	Inner to middle shelf, carbonate dominated
13250	Bathonian*	Mohican: Limestone with pebbles and fossils in the top half, silty sandstone in the bottom half	Shallow water (~20'), carbonate dominated shelf, supralittoral
13575	Bathonian* Seismic interpretation suggests possibly older (Bajocian – Aalenian?)	Iroquois: Top third is limestone with interbeds of anhydrite and siltstone, bottom is dolomite with some limestone, and some fossils.	Carbonate shelf and tidal flat, sabkha. Restricted shallow marine, littoral.

*Fauna interpreted as being reworked. Age interpretation considered unreliable.

Table 4. Petroleum System Elements

Element	LC 273-1 Lithology
Source rock *(>1% TOC) However, an effective source rock has an original TOC of ~2%*	Measured in only 2 samples both located in the Hauterivian at ~5,200' MD
Reservoir rock *(>10 % φ >1 mD k)*	Below 10,000' values are mostly below 10% according to the sonic curves
Seal rock *(10^{-3} mD k)*	Shale
Overburden rock	Sufficient (See onset hydrocarbon generation in Table 6.)

Table 5. Thermal maturation and geochemical data compiled from Mobil's paleontological report (Mobil Oil Corporation, 1982a) and MMS work for VKA (MMS Staff, 1984).

Samples	Interval Size	Range	Measured/Examined
37 ditch samples	300'	4,500'–15,300'	Mobil-Vitrinite reflectance
92 readings	300'	4,500'–12,840'	Mobil-TAI from bisaccate pollen
121 ditch samples	90'	4,500'–15,450'	Mobil-Visual Kerogen Analysis
167 ditch samples	90'	550-15420'	MMS-Visual Kerogen Analysis
367 ditch samples	30'	4,500'–15,580'	Mobil-TOC determinations
2 ditch samples	30'	5,160'–5,220'	Mobil-Rock-Eval pyrolysis

Table 6. Petroleum System Processes

Onset hydrocarbon generation	Early maturity for oil (%R_o 0.5) at ~6,000' in Tithonian age sediments. Main gas generation (%R_o 1.3) begins at ~16,450' in Bathonian or older strata, based on well data and modeling, and assumptions of kerogen type.
Expulsion	Overall, strata in the well contain insufficient initial TOC (< 2%) to generate and expel hydrocarbons. There were no significant hydrocarbon shows. The low TOC values result in source rocks too lean for hydrocarbons to have been expelled (Katz, 2012). Modeling using BasinMod® 2012 suggests that limited volumes of hydrocarbons generated are retained in the "source rock" (*in situ*).

Table 7. LC 273-1 Target Summary

Pre-Drill Interpretation	
Target	9,975'–13,350'
Trap Type	Structural-Stratigraphic
Hydrocarbon Expected	Oil and gas
Post-Drill Results	
Target Interval	Very low TOC (0.27% well average or 0.15% for the well penetrated objective zones
Hydrocarbon Shows	No significant shows

References:

Edson, G.M., D.L. Olson, and A.J. Petty, (eds.), 2000. Mobil Lydonia Canyon Block 273 No. 1 Well; Geological and Operational Summary: MMS 2000-036, 50 p. http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Resource_Evaluation/Geological_and_Geophysical_Data_Acquisition/AtlanticCOST2000-036.pdf (accessed July 10, 2014)

GeoSpec, a CGG Company, 2003. Frontier basins of the North Atlantic, 271 p.

HBrothers. "Inflation Calculator." DollarTimes, 2015. DollarTimes. http://www.dollartimes.com/calculators/inflation.htm (accessed March 30, 2015)

Katz, B.J., 2012. Hydrocarbon Migration: What We Know, What We Don't Know and Why It Is Important (abstract), HGS Bulletin, https://www.hgs.org/civicrm/event/info?reset=1&id=1235 (accessed 27 May, 2014)

Magoon, L.B., and W.G. Dow, 1994. The Petroleum System: *in* L.B. Magoon, and W.G. Dow (eds.), The petroleum system—from source to trap: AAPG Memoir 60, p. 3–24.

Minerals Management Service (MMS) Staff, 1984. Geologic Review, Well #1, OCS A-0196, Block 273, NK 19-12 (Lydonia Canyon), 48 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Mobil Exploration & Production, 1982. Sundry Individual Well Record, OCS A-0196 No. 1, Block 273 Georges Bank, U.S. Atlantic Offshore October, 1980, 2 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Mobil Exploration & Producing Services Inc., 1982. Application for Permit to Drill, Well No. 1, OCS A-0196, Block 273, NK 19-12 (Lydonia Canyon), 190 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Mobil Oil Corporation, 1982a. Biostratigraphic and Organic Geochemical Studies, OCS A-0196 No. 1, Block 273 Georges Bank, U.S. Atlantic Offshore October, 1982, 77 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Mobil Oil Corporation, 1980b. Lease Instrument, OCS A-0196 No. 1, Block 273 Georges Bank, U.S. Atlantic Offshore October, 1978, 8 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Mobil Oil Corporation, 1982c. Sundry Daily Drilling Report, OCS A-0196 No. 1, Block 273 Georges Bank, U.S. Atlantic Offshore October, 1980, 28 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Paleomap Project, 2002. Late Triassic and Early Jurassic Climate Maps (http://www.scotese.com/climate.htm, accessed 4-27-2015)

Smith, D., and P.J. Post, 2016. Atlantic Well Folio: Georges Bank Basin, Lydonia Canyon Block 187 No. 1 Well. 19 p. (currently in publication)

U.S. Department of the Interior, Bureau of Land Management, 2012 Oil Shale and Tar Sands Programmatic EIS Glossary/Acronyms, 2012. http://ostseis.anl.gov/glossacro/dsp_wordpopup.cfm?word_id=2288 (accessed July 24, 2014)

Withjack, M.O., R.W. Schlische, and P.E. Olsen, 2012. Development of the passive margin of eastern North America: Mesozoic rifting, igneous activity, and breakup: *in*: A.W. Bally and D.G. Roberts, eds., Principles of Phanerozoic Regional Geology, v 1, p. 301–335.