**BOEM 2016-025**

# Atlantic Well Folio: Georges Bank Basin

## Lydonia Canyon Block 187 No. 1 Well

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# 1.5. Lydonia Canyon 187-1

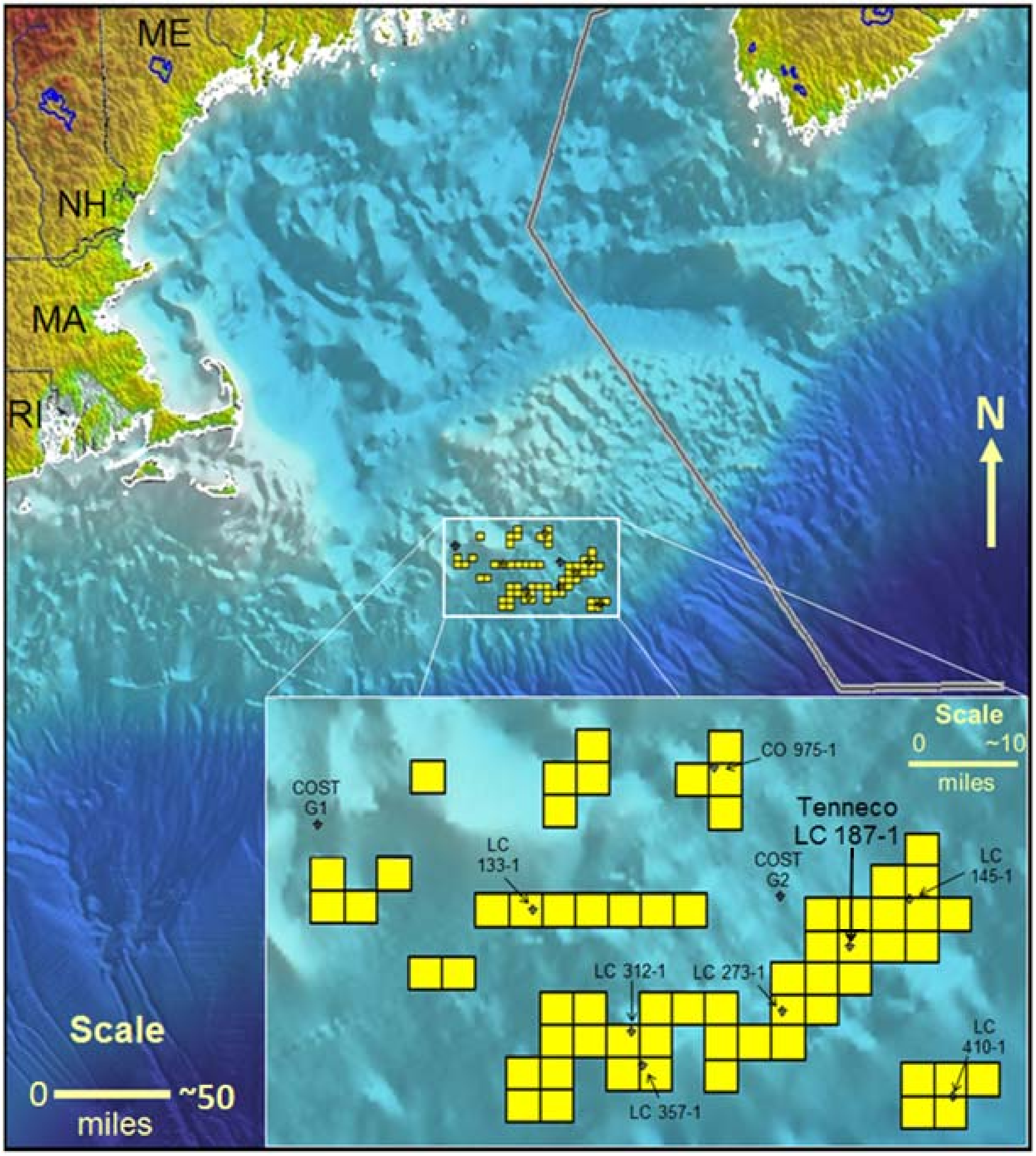


**Figure 1.** Location map of Georges Bank Basin (GBB), offshore Massachusetts, USA. Well locations are indicated by the symbol ⌖. Leases previously held in the area are shown in yellow.

Tenneco, operator of OCS-A 0182, Lydonia Canyon (LC) 187, drilled new field wildcat well LC 187-1 to a total depth (TD) of 18,127’ to test a combination structural-stratigraphic trap. According to the Application for Permit to Drill (APD) filed by Tenneco (Tenneco, 1982a), hydrocarbons were expected from 9,800’ to 15,000’, with only gas anticipated below 15,000’. (All depths in this report are measured depth unless otherwise specified.) The well was unsuccessful because anticipated reservoir intervals lacked porosity and permeability, and predicted source rock intervals were ineffective due to insufficient total organic carbon (TOC) content. This was the 5th industry well in the Georges Bank Basin (GBB) and the 7th overall including two Continental Offshore Stratigraphic Test (COST) wells.

The decision to lease the block and subsequently drill LC 187-1 was based on good quality 2-D seismic coverage in this part of the GBB, and the improved understanding derived from COST G-1 (1976) and G-2 (1977) wells. Block LC 187 was leased during Sale No. 42 on December 18, 1979 for a bonus bid of $15,819,000 (MMS Staff, 1985) or $54,867,000 in 2015 dollars (HBrothers, 2015). The selected drillsite was the primary one of four initially proposed in the APD for block 187 (Tenneco 1982a).

LC 187-1 was located on dip-oriented seismic line D 133 near a crossing strike-oriented line. The well was spudded on March 12, 1982 by the *Alaskan Star* semisubmersible and completed on August 21, 1982. The location was in 307’ of water about 8 miles to the southeast of COST G-2 (Fig. 1), ~215 miles east-southeast of Boston, MA at latitude 40° 46' 15" N, longitude 67° 23' 19" W. Two other new field wildcat wells (LC 145-1 and LC 273-1) were subsequently drilled in the area during 1982. Following the LC 187-1 dry hole, the lease was relinquished on January 28, 1985 (Edson *et al*., 2000).

### 1.5.1 Objectives and Concepts

According to the APD, LC 187-1 targeted a faulted anticline with primary objectives (~9,800’– ~17,000’?) being porous, Jurassic age, high-energy, oolitic calcarenite limestones (Table 1, and Fig. 2) and carbonates with porosity enhanced by dolomitization (Tenneco, 1982a). Underlying secondary objectives to the proposed total depth of 21,000’ were believed to be carbonates whose porosity was enhanced with secondary dolomitization. These objective strata were interpreted to have been deposited in, and affected by, a shallow paleobathymetric environment (Tenneco, 1982a).

Seismic interpretation from the APD (Tenneco, 1982a) showed a high-angle, reverse-faulted, structure (Fig. 3) with significant offset interpreted at their deepest Lower Jurassic Unconformity horizon that decreased upward (Fig. 4). The Minerals Management Service (MMS) interpretation was a three-way closure with the faulting not extending into the shallower targeted zones.

The pre-sale MMS resource estimates for the tract were 4,251,454 barrels (bbls) of oil and condensate with 33,332.5 million cubic feet (MMCF) of gas and associated gas. Total BOE was estimated at 10,182,510 (MMS Staff, 1985).

### 1.5.2 Results

*Drilling*

Carbonates were the dominant rock type below 9700’. However, the anticipated reservoirs were found to be cryptocrystalline micrites (wackestones and packstones) with very low porosity and permeability of Middle and Late Jurassic age.

Mud logs, wireline logs, and sidewall cores were used to construct Figure 5. Dolomite rather than limestone is the primary lithology from ~13,230'(Fig. 5), just above the interpreted base of the Bathonian, to TD with some interbeded limestone, sandstone, siltsone and anhydrite.

Several zones of interest, identified by modest natural gas shows were encountered while drilling through the target zones. The best mud log gas shows were from 9,277'–9,287' (118 units), 13,640'–13,660' (650 units), 14,310'–14,325' (950 units), and 14,340–14,370' (950 units). The shallowest show was in Late Jurassic carbonates. The other gas shows were in Middle Jurassic carbonates. Cased hole drill stem tests (DSTs); 13,650'–13,660', 13,664'–13,686', and 14,338'–14,355' were preformed following perforating and acidizing,with no hydrocarbon recovery per the Tenneco Well Completion Report (Tenneco 1982b). Sixty-five sidewall cores were recovered from 9,020'–18,020' ranging from 0.2 to 1.4 inches (Core Laboratories Inc., 1982). These provided porosity and permeability data for comparison with the log curve calculations, and because of their precise locations, supplemented lithology descriptions from the aggragated cuttings.

*Seismic Interpretation*

Tenneco submitted two pre-drill, 2-D time-migrated seismic lines with their APD (Tenneco, 1982a). Figure 4 shows line D 133 through the proposed LC 187-1 well, with their interpretation. A nearly perpendicular cross-line (GB 75-53), ~3,700' southeast of the proposed location, was also interpreted and submitted (Tenneco, 1982a). Tenneco staff interpreted a reverse fault on the western flank of an anticlinal structure creating a fault trap on the western flank of the feature at their Lower Jurassic Marker and Lower Jurassic Unconformity horizons (Figs. 3 and 4). The tested trap was on the flank of the anticline at the shallowest of the interpreted objective horizons, the Top Middle Jurassic (Fig. 3).

Our post-drill seismic interpretation used reprocessed time-migrated, depth-converted data licensed from GeoSpec, a CGG company. The 8 sequence boundaries (SBs) in our interpretation were originally identified and interpreted by GeoSpec, using the two COST wells, and 5 industry wells including 187-1 as part of their seismic interpretation of the U.S. Atlantic OCS (GeoSpec, 2003). The structure (Fig. 6) is interpreted to be inversion-related, caused by transpression/compression reactivation of basin-bounding faults during seafloor spreading of this part of the Atlantic (Withjack *et al*., 2012). These faults are interpreted as high-angle, cutting across our "base mid-Jurassic" (SB1), and uplifting the lower SBs. Uplift diminishes throughout the Jurassic with a small, but still visible, effect in the Cretaceous SBs. Overlying Tertiary sediments are interpreted as flat and unaffected (Fig. 6). The inversion structure is interpreted to be almost 12 miles long and ~9 miles wide at SB1.

A fracture system, possibly connected to a deep, basin margin fault system may have been intersected by the well. Between ~16,855'–16,885', two drilling breaks, each of which reached a maximum of 70' per hour, were encountered with an associated $CO_2$ influx and a 25 barrel pit gain (Exlog Inc., 1982). No geochemical data exists to determine the organic or inorganic origin of this $CO_2$ influx. Fitrianto *et al*., (2012) analyzed the origin, distribution, and prediction of $CO_2$ occurrences in South Sumatra and noted an association between $CO_2$ concentration and deep-penetrating faults in the Jabung block of South Sumatra, supporting an inorganic origin for the $CO_2$.

Our mapping (Figs. 7 and 8) failed to support Tenneco's pre-drill four-way closure (Fig. 3). Structure maps of the base Oxfordian (SB3) and base Bathonian (SB2), Figures 7 and 8 respectively, depict our interpretation of the southwest plunging inversion structure. A Jurassic isochore map (Fig. 9) between an upper horizon, the intra-Tithonian (SB4), and a lower horizon, the "base mid-Jurassic" (SB1), illustrates this structure plunging into the main depocenter. The depocenter-bounding faults are shown on this map, with the large offset of the main fault visible east of the LC 187-1 in true vertical thickness (TVT) contouring.

Subsequently, LC 145-1 was drilled updip and upthrown to the "base mid-Jurassic" faulting, and LC 273-1 was drilled downdip along the same southwest plunging structural trend as LC 187-1 (Figs. 7, 8, and 9).

*Biostratigraphy and Paleoenvironment*

Robertson Research conducted biostratigraphical analysis for Tenneco using microfaunas, nannofossils, and palynomorphs on cutting samples from 1,340' to TD. Only 3 of the 65 sidewall cores (9,520', 9,524, and 15,340') had enough material for nannoplankton and palynological analyses. From the fossil taxa (Table 2), they determined depths for the interpreted geologic ages, environment of deposition (EOD), and paleobathymetry (Robertson Research, 1982).

Fossils from the Mesozoic section appear to be reworked, being oxidized and displaying many disconformities. Cavings from uphole, along with fewer dateable microfossils in the shallow water paleoenvironments, tempered confidence in some age estimates (Robertson Research, 1982). Paleoenvironments transgressed from marginal marine and inner shelf in the Jurassic and Early Cretaceous to deep middle neritic during the Late Cretaceous. Water depths during the Late Cretaceous were generally comparable to the present-day 307' depth. Pre-drill, Tenneco staff (Tenneco Oil Company, 1982a) inferred the shallowest of the Jurassic carbonate objectives were deposited in shallow water environments. Deeper objectives were "basinal carbonates" (Tenneco Oil Company, 1982a). We interpret the EOD from ~13,000' to TD as marginal marine to transitional supratidal, sabkha (Friedman, 1980) based on the occurrence of dolomite and anhydrite throughout this section. Table 3 summarizes our biostratigraphic interpretation.

### 1.5.3 Operations and Costs

Block 187 was awarded at OCS Sale No. 42 in December 1979 for a high bid of $15,819,000. Valued at $54,867,000 in 2015 dollars (HBrothers, 2015), the interests were Mobil Oil Corp. 30%, Union Oil Co. of California 25%, Tenneco Oil Co. 20%, Amerada Hess Corp. 15%, and Transco Exploration Co. 10% (Tenneco Oil Company, 1980). Total well cost was $25 million ($62,500,000 in 2015 dollars) according to an MMS report citing the September 1982 issue of the AAPG Explorer. Prospect 187 ($15,819,000) also included blocks 143 ($13,758,000), 186 ($3,729,000), and 230 ($28,111,000) for a total prospect lease cost of $61,417,000 or $213,020,000 in 2015 dollars (HBrothers, 2015).

### 1.5.4 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 (Table 5), 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*

A full suite of geochemical analyses for LC 187-1 was lacking; *e.g.*, Rock-Eval Pyrolysis was not run. Therefore, $T_{max}$, $S_1$, $S_2$, HI, and OI data were not available. However, TOC values were recorded for 85 samples, and vitrinite reflectance (%$R_o$) was measured for 54 samples.

%$R_o$ is used as an indicator of thermal maturity to determine the maximum maturity level reached by vitrinite macerals in the well (U.S. Dept of Interior BLM, 2015). %$R_o$ data, along with bottomhole temperatures (BHTs) were used in the maturity models created in BasinMod® 2012. Modeling of LC 187-1 showed early mature oil (0.5% $R_o$) occurred early in the development of the basin, during the Late Jurassic. Consequentially, much of the sedimentary section mature today has been for a majority of the basin's history. High %$R_o$ values, which occur in the more siliciclastic-rich parts of the well, are interpreted to be reworked, recycled vitrinite derived from older sediments being eroded and redeposited in the basin. Best fit to the data results show present-day onset hydrocarbon generation in the Late Jurassic Tithonian.

Of the 86 TOC values, 70% were below 0.5% with an average of 0.42%, and only 4 were ≥1% (2 in the Callovian, 1 in the Aptian, and 1 in the Hauterivian) (Tenneco Oil Company, 1983). TOC values between 1% and 2% are typically classified as indicating good source rocks capable of having hydrocarbons expelled from them. However, wells in the GBB have shown that although hydrocarbons can be generated from a source rock with a 1% or less TOC, they are unlikely to be expelled. Modeling in BasinMod® 2012 predicts minor generation of hydrocarbons in the Jurassic from mature source rocks with initial TOC values ≥1%. The modeling accurately predicted that none of these hydrocarbons would be expelled, in agreement with the LC 187-1 well results. Table 6 cites these deficiencies in the post-drill results section.

Without pyrolysis, identification of kerogen type was limited to visual examination as reported by the MMS in Mr. Fry's report (MMS Staff, 1985). Inert, Type IV, non-source kerogen was reported present throughout most of the well in percentages ranging from 20% in the Cretaceous, and reaching 80% in the Jurassic from 11,417' down to TD. The oil-prone, Type I kerogens, contributed a smaller portion in the Cretaceous (~17%) and were not seen in the Jurassic. Type II (oil-prone) and Type III (gas-prone) kerogens made up about half of the organic matter from the Late Cretaceous until the Early Jurassic section of the well (MMS Staff, 1985).

*Exploration Implications*

1. TOC values in Jurassic strata were too low for these units to be considered source rocks, averaging 0.42% (Table 4). Modeling in BasinMod® 2012 showed that the volume of hydrocarbons generated would be low (~10 bbls/acre*ft) with none expelled from even the highest TOC intervals. This is collaborated by the indications of gas shows based on the mud logs, which wireline logs show to be in tight, Middle Jurassic carbonates. The general correlation between the best shows and the highest TOC intervals supports the interpretation that generated hydrocarbons remained *in situ* (Fig. 10). The kerogen in the well was often inert (Type IV), averaging 59.4% in the Jurassic, and 30.5% in the Cretaceous.
2. Low porosities and permeabilities eliminate potential reservoir intervals near the highest TOC intervals. Lack of vertical migration conduits would have prevented hydrocarbons from migrating to better quality, shallower reservoirs had hydrocarbons been generated and expelled. The main faults seen on the isochore map (Fig. 9) are not interpreted to cut horizons much shallower than the "base mid-Jurassic" (SB1). Intra-Tithonian and younger strata have porosities and permeabilities sufficient to be considered potential reservoirs. However, these sediments are immature and are bordered by low TOC intervals.

**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.

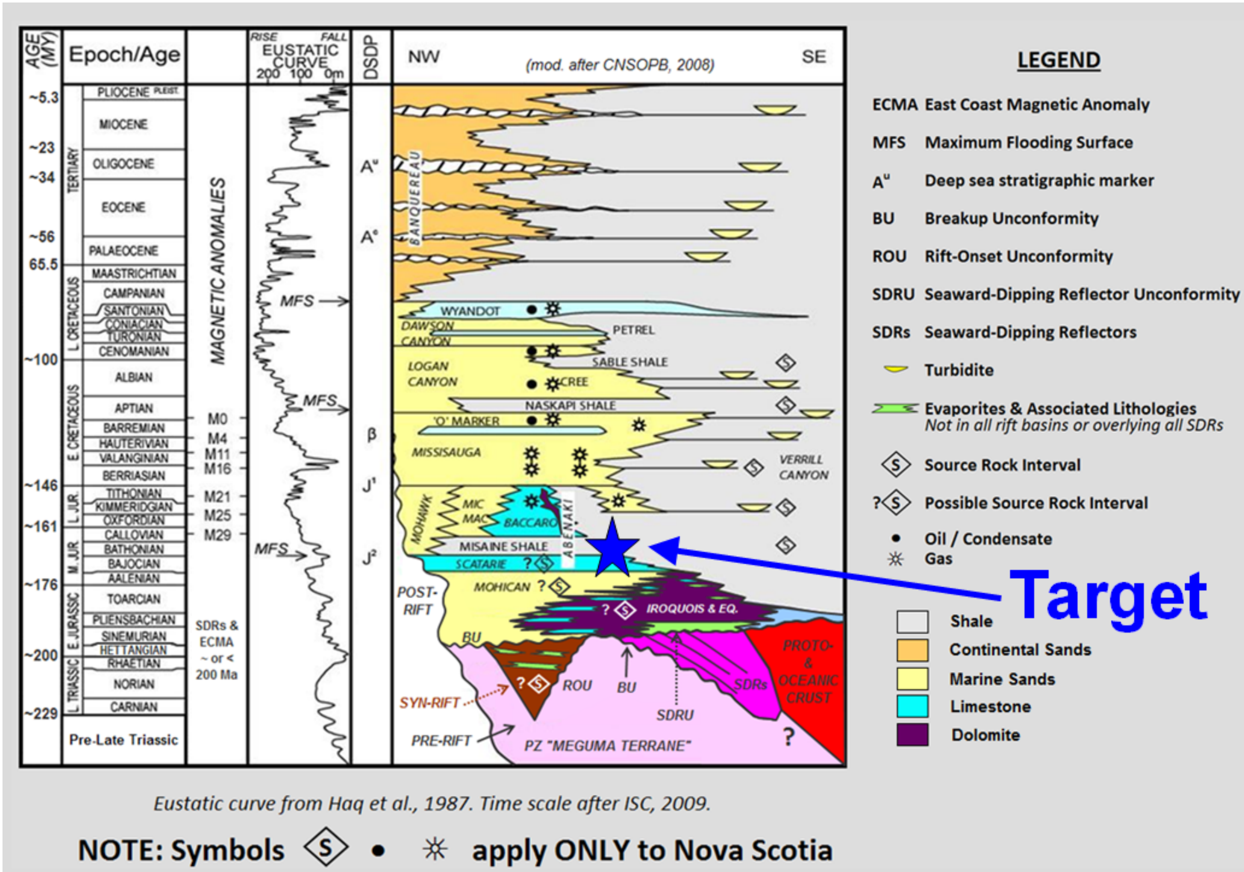


**Figure 2**. Stratigraphic chart showing the target interval for Tenneco LC 187-1.

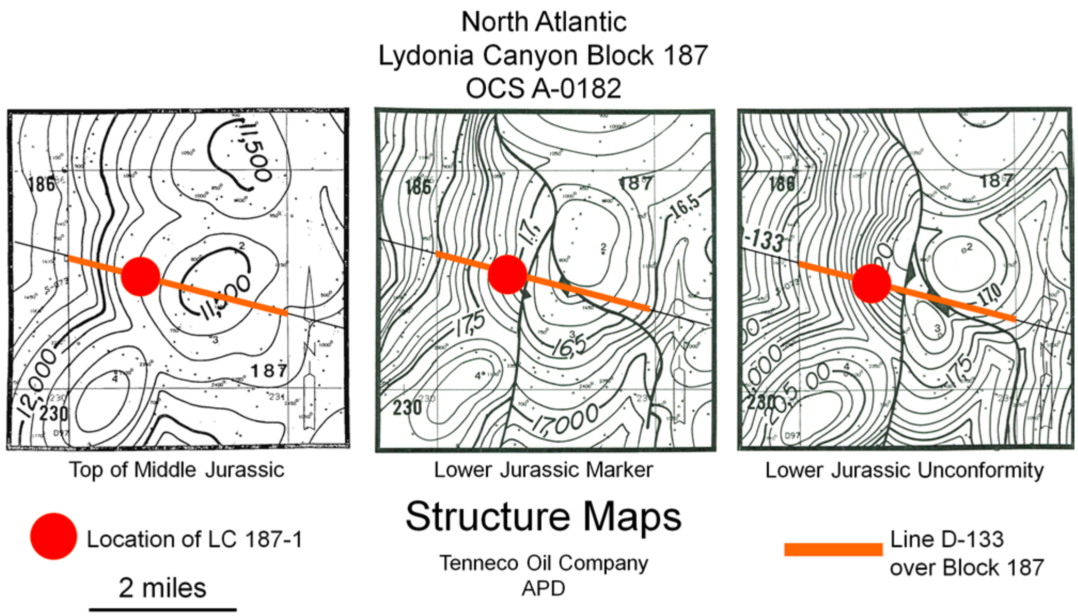


**Figure 3.** Structure maps showing Tenneco's top of Middle Jurassic, Lower Jurassic marker, and Lower Jurassic unconformity (Tenneco, 1982a).

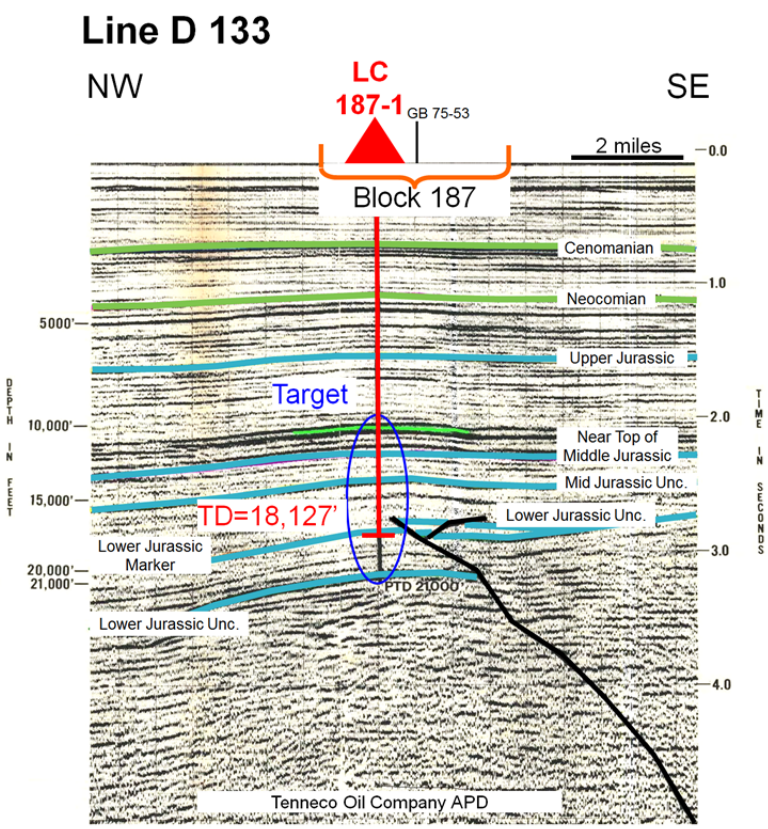


**Figure 4.** Tenneco's seismic interpretation through LC 187-1 (Tenneco, 1982a).

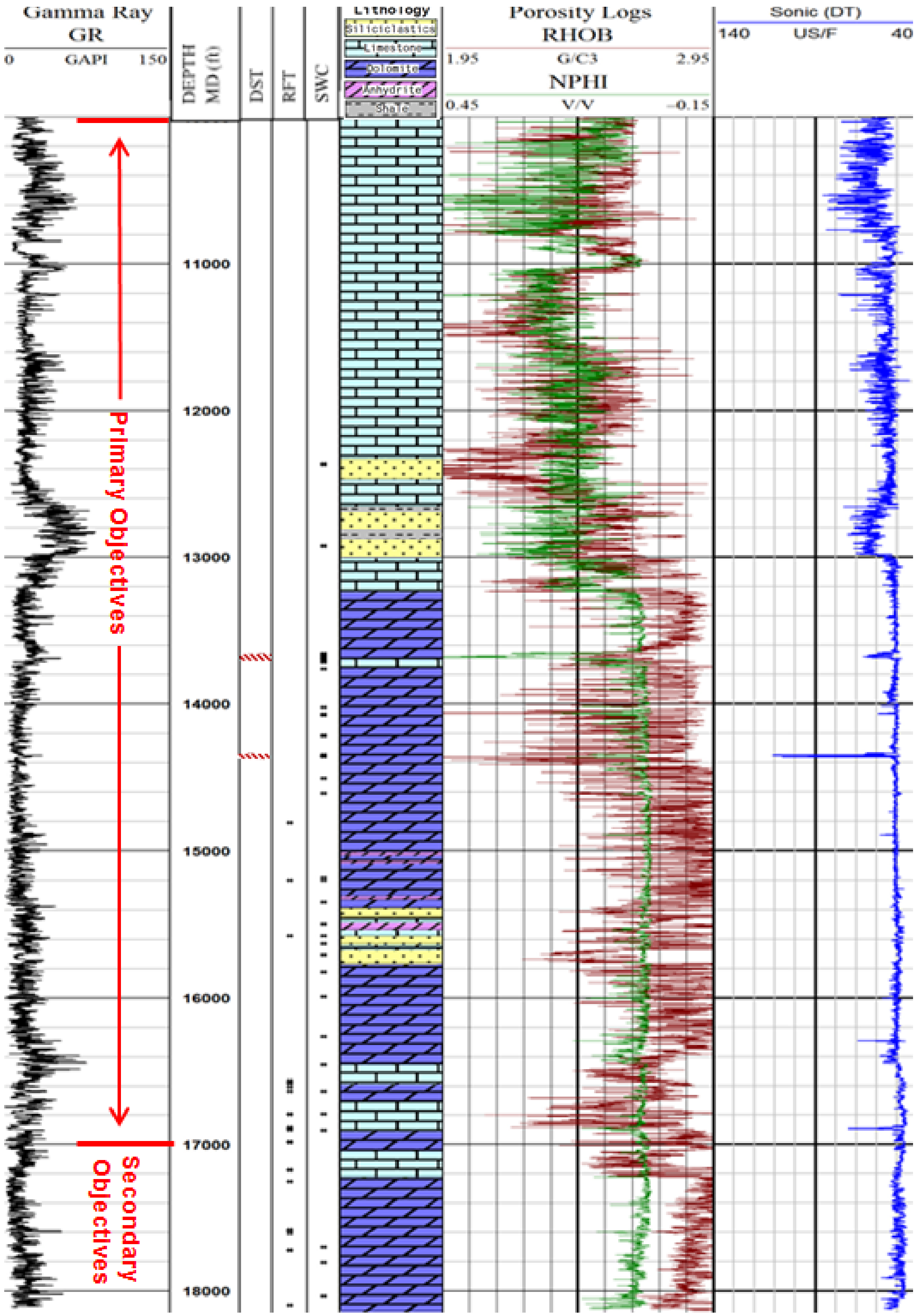


**Figure 5.** Objective zones for well LC 187-1 with interpreted lithologies based on mud logs, sidewall core analysis, and crossplot of neutron and density curves. Locations of drill stem tests, repeat formation tests, and sidewall cores are also shown.

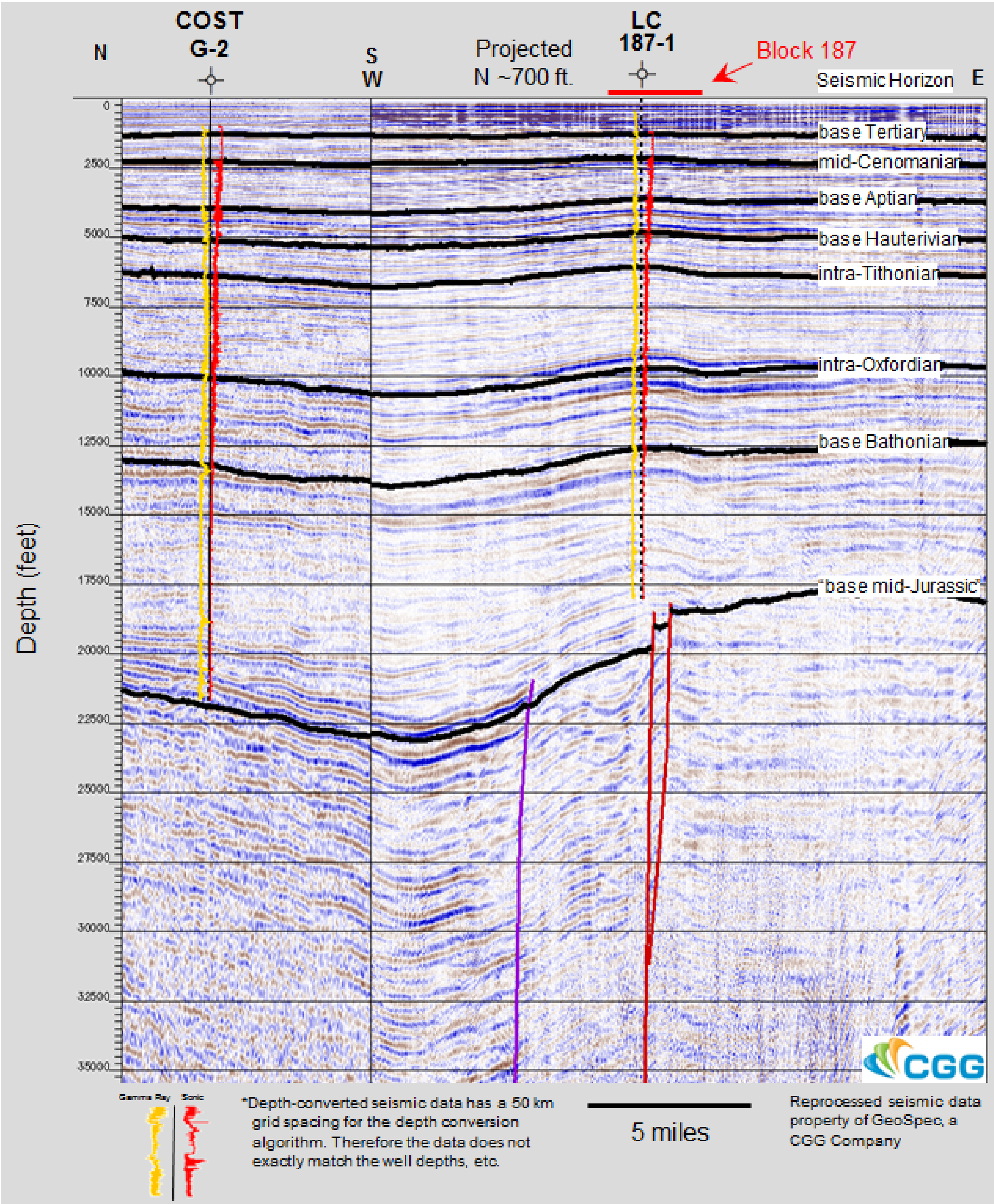


**Figure 6.** Seismic profile (north to southwest to east) with interpreted horizons (in black) and faults (red and purple). Structure maps of the intra-Oxfordian and base Bathonian horizons are shown in Figures 7 and 8.

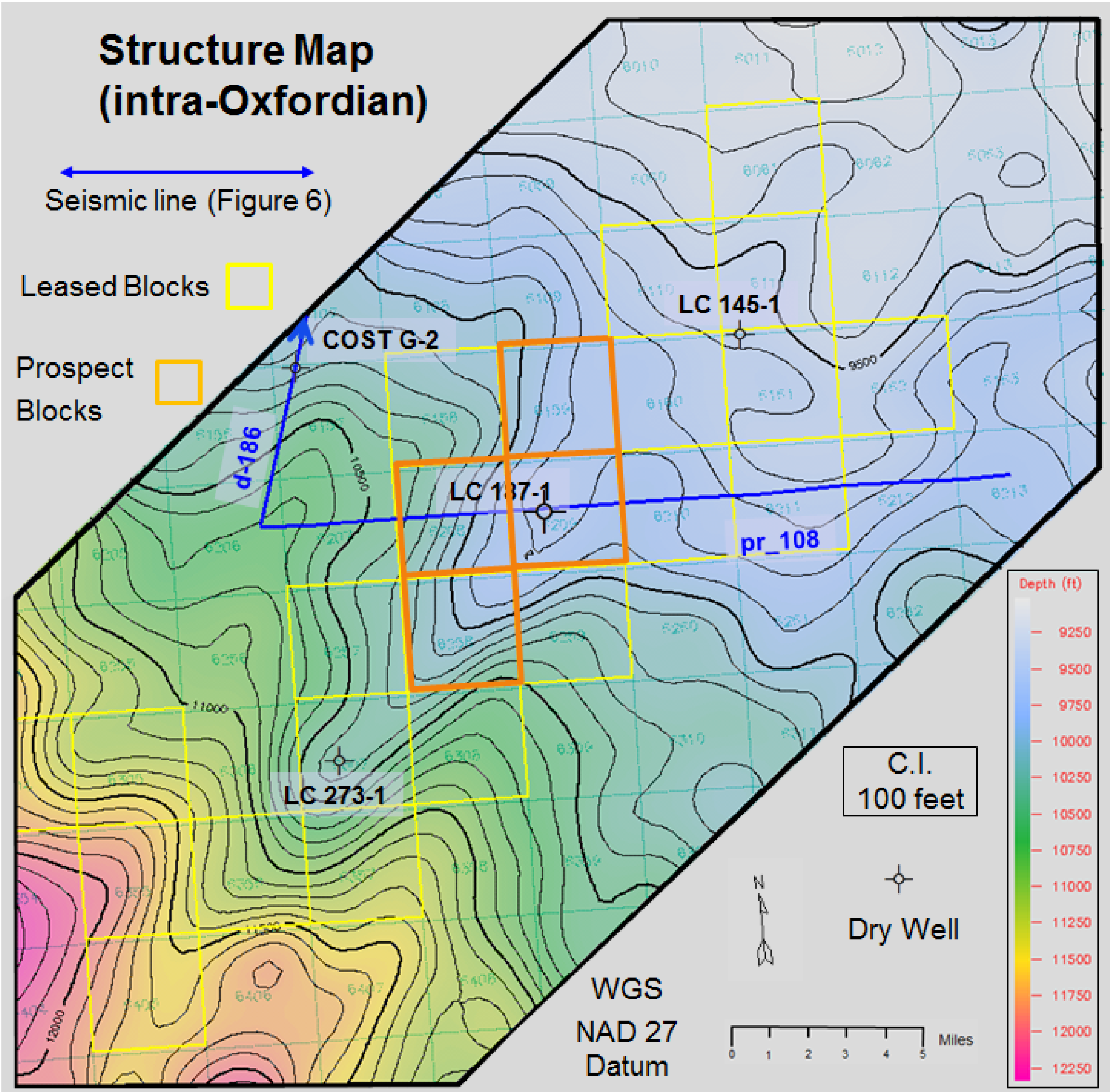


**Figure 7.** Structure map: datum intra-Oxfordian mapped horizon (Figure 6). Lines shown in blue are the d-186 and pr_108.

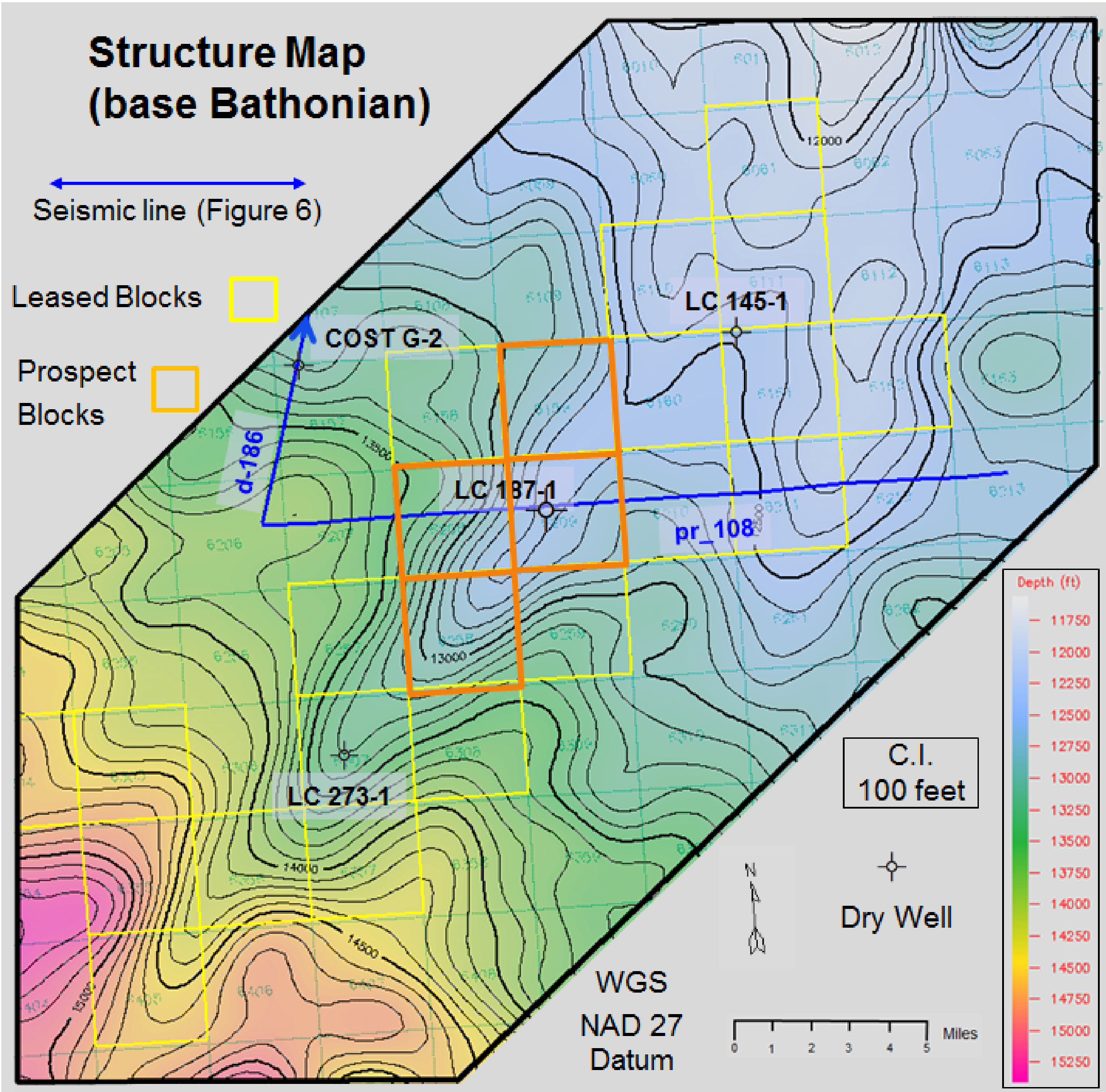


**Figure 8.** Structure map: datum base Bathonian mapped horizon (Figure 6). Lines shown in blue are the d-186 and pr_108.

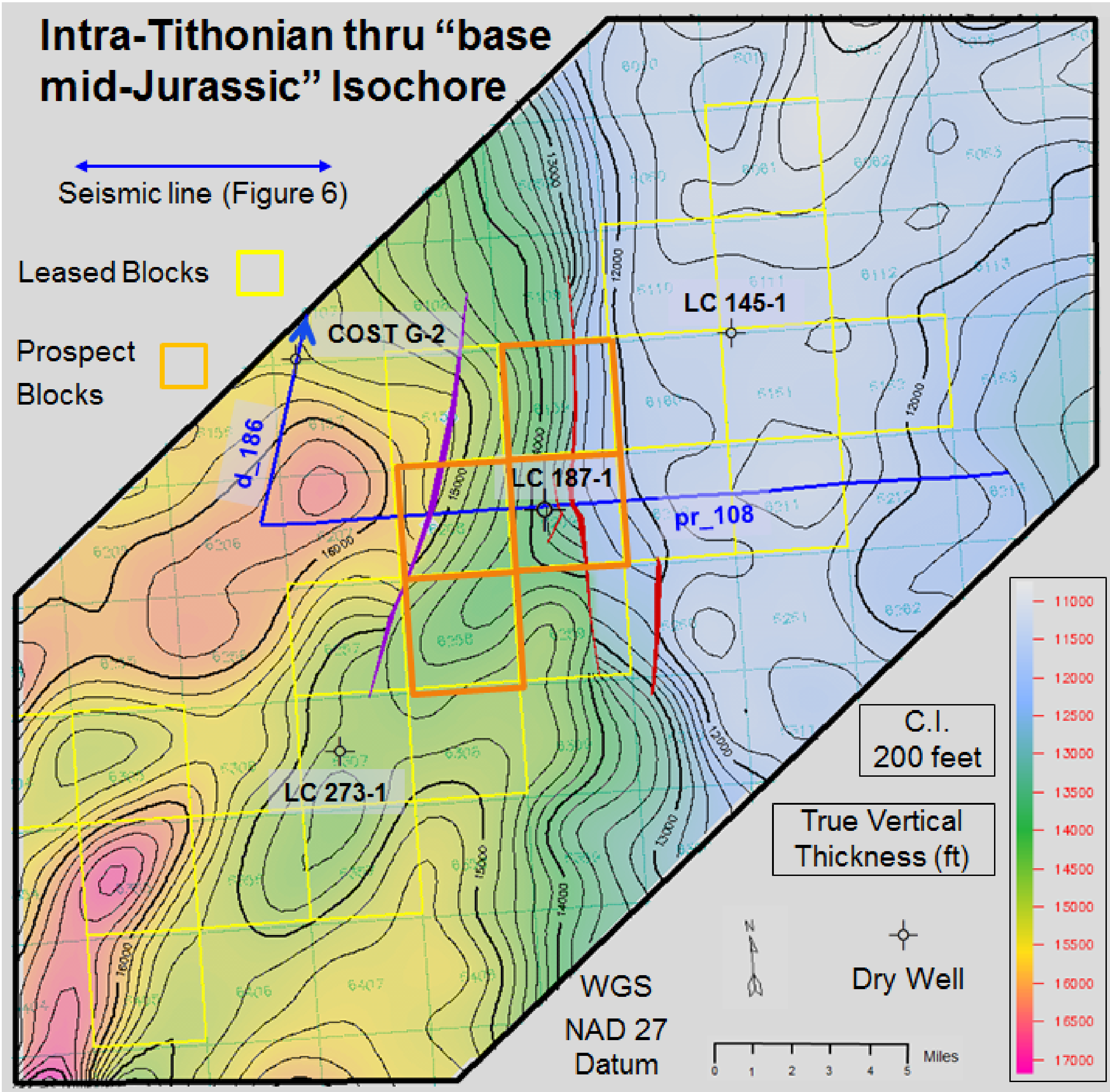


**Figure 9.** Isochore map for the entire Jurassic interval. Lines shown in blue are the d-186 and pr_108. High angle faults offsetting SB1 are shown in red and purple.

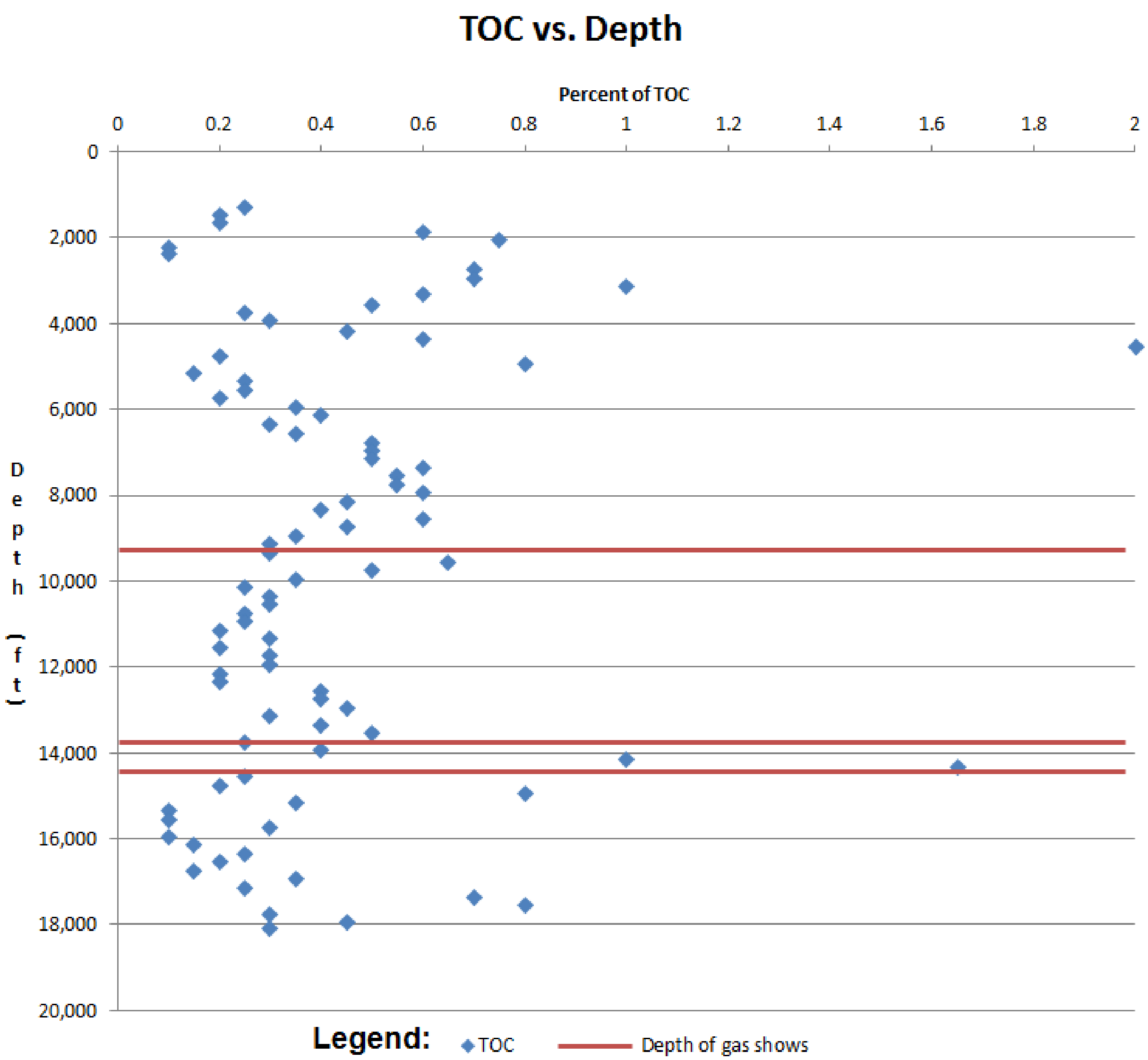


**Figure 10.** Correlation of the gas shows encountered while drilling with the higher TOC values measured from the cuttings supports our model's predictions that hydrocarbons remained *in situ*.

**Table 1.** Wells drilled in Georges Bank Basin

| Well | 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.** Available data integrated in the Robertson Reaseach biostratigraphic report with measurements made concurrent to drilling and later tied to COST G-2.

| Samples | Interval Size | Range | Measured/Examined |
|---|---|---|---|
| 308, used for clastics | 60’ | 1,340’ to TD | Micropaleontological |
| 170 thin sections, used for carbonates | 60’ | 1,340’ to TD | Microfaunal and calpionellid content |
| 298 ditch samples and 3 sidewall cores | Not specified | 1,340’ to TD | Calcareous nannofossils |
| 168 ditch samples and 3 sidewall cores | Not specified | 2,000’ to TD | palynomorphs |

**Table 3.** Formation names, ages, and tops for the LC 187-1 well were derived from GeoSpec's earlier work (GeoSpec, 2003). Lithology and depositional environment assembled from previously reported sources and from our analysis of mud logs, wireline logs using Log Evaluation System Analysis (LESA) software, and sidewall core descriptions.

| Depth (tops) | Age | Formation/Unit: Lithology | Depositional Environment |
|---|---|---|---|
| 600 | Miocene to Campanian | Unknown | Middle shelf (~300'), mud dominated |
| 1330 | Campanian to Cenomanian | Dawson Canyon Fm.: Fossiliferous mudstones | Middle shelf (~300'), mud dominated |
| 2235 | Cenomanian to Barremian | Logan Canyon Fm.: Mudstone with interbedded, unconsolidated sandstone and limestone, occasional chert | Shallow water (~50'–100'), mixed mud and siliciclastic dominated shelf |
| 3740 | Barremian to Hauterivian | Mississauga: Interbedded mudstone, calcareous siltstone, and poorly consolidated, calcareous cemented sandstone | Shallow water (~50'–100'), mixed mud and siliciclastic dominated shelf |
| 4940 | Berriasian to Tithonian | Roseway Unit: limestones and calcareous mudstones, locally pyritic, top of unit is fossiliferous | Shallow water (~50'–100'), mixed mud and carbonate dominated shelf |
| 6300 | Tithonian-Oxfordian (?) | Abenaki: Shale and limestone interbedded with sandstone and siltstone | Shallow water (~50'–100'), mixed mud and carbonate dominated shelf |
| 6990 | Oxfordian | Mic Mac-Mohawk: Interbedded sandstones and mudstones, often with calcite and anhydrite cements | Shallow water (~50'–100'), mixed clastic and mud dominated shelf |
| 8950 | Oxfordian-Bathonian | Abenaki: Oolitic limestone with interbedded siliciclatics and some shale | Shallow water (~25'–50'), mixed carbonate and clastic dominated shelf |
| 12645 | Bathonian* | Mohican: Interbedded siltstones and sandstones with carbonates | Shallow water (~25'–50'), mixed carbonate and clastic shelf |
| 12985 | Bathonian* | Iroquois: Dolomite and Oolitic limestone, locally anhydritic and lignitic stringers | Carbonate shelf and tidal flat, sabkha. Restricted shallow marine. |

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

**Table 4.** Petroleum System Elements

| Element | LC 187-1 Lithology |
|---|---|
| Source rock<br>*(>1% TOC) However, an effective source rock has ~2% TOC* | Below 5,600 there are TOC values of 1% and 1.65% for consecutive measurements at 14,200’ and 14,400’ respectively. Two additional samples >1% found in shallower, immature sections of Early Cretaceous age. |
| Reservoir rock<br>*(>10 % φ<br>>1 mD k)* | Cretaceous, Kimmeridgian, and Oxfordian sandstones |
| Seal rock<br>*($10^{-3}$ mD k)* | Shale, Anhydrite, impermeable Carbonates |
| Overburden rock | Early maturity for oil at 5,600’ (0.5% $R_o$)<br>Main dry gas generation at 17,200’ (1.3% $R_o$) |

**Table 5.** Petroleum System Processes

| | |
|---|---|
| Onset hydrocarbon generation | 5,600’ based on vitrinite reflectance data. |
| Expulsion | Overall, strata in the well contain insufficient TOC (<1%) to generate and expel hydrocarbons. There are no significant shows in reservoir lithologies. The low TOC values result in source rocks too lean for hydrocarbons to have been expelled (Katz, 2012). Modeling using BasinMod® 2012 suggests that the limited volumes of hydrocarbons generated are retained in the “source rock” (*in situ*). |

**Table 6.** LC 187-1 Target Summary

| | |
|---|---|
| **Pre-Drill Interpretation** | |
| Target | ~9,800’–21,000’ |
| Trap Type | Structural-Stratigraphic |
| Hydrocarbon Expected | Oil and gas |
| **Post-Drill Results** | |
| Target Interval | At ~9,700’, MD Jurassic carbonates were encountered. Insufficient TOC for hydrocarbon generation-expulsion-migration-accumulation existed to TD of 18,127’ |
| Hydrocarbon Shows | There were no reported oil shows and gas encountered was low volume and ephemeral |

**References:**

Core Laboratories Inc, 1982. Sidewall Core Analysis, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 5 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Dow, W., 1977, Kerogen studies and geological interpretations: Journal of Geochemical Exploration, v. 7, p. 79-99.

Edson, G.M., D.L. Olson, and A.J. Petty (eds.), 2000. Tenneco Lydonia Canyon Block 187 No. 1 Well; Geological and Operational Summary: MMS 2000-035, 59 p. http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Resource_Evaluation/Geological_and_Geophysical_Data_Acquisition/AtlanticCOST2000-035.pdf (accessed May 20, 2014)

Exlog Inc., 1982. Well Summary Report, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 30 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Fitrianto, T., H.N. Saputra, B. Syam, and A.H. Purwanto, 2012. The origin, distribution and prediction of $CO_2$ in south Sumatra, a case study: Jabung block and surrounding area. Proceedings, Indonesian Petroleum Association. Thirty-six annual convention and exhibition, p. 10. http://archives.datapages.com/data/ipa_pdf/083/083001/pdfs/IPA12-G-025.pdf

Friedman, G.M., 1980. Dolomite is an evaporite mineral: evidence from the rock record and from sea-marginal ponds of the red sea, SEPM Special Publication No. 28, p. 69–80.

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

HBrothers. “Inflation Calculator.” DollarTimes, 2015. DollarTimes. http://www.dollartimes.com/calculators/inflation.htm (accessed March 12, 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, 1985. Geologic Review, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 102 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Robertson Research, 1982. Biostratigraphical Analysis of the Tenneco Oil Co. OCS A-0182 #1 Well, Block 187, Georges Bank Area, North Atlantic, 95 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Tenneco Oil Company, 1980. Lease Instrument, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 28 p. (available at https://www.data.bsee.gov/homepg/data_center/other/WebStore/master.asp)

Tenneco Oil Company, 1982a. Application for Permit to Drill, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 45 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Tenneco Oil Company, 1982b. Well Completion Report, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 3 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

Tenneco Oil Company, 1983. Source Rock Evaluation Data, Well #1, OCS A-0182, Block 187, NK 19-12 (Lydonia Canyon), 2 p. (available at https://www.data.boem.gov/homepg/data_center/other/WebStore/master.asp)

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.

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 March 4, 2015)