BOEM 2012-101

Atlantic Well Folio: Georges Bank Basin

Corsair Canyon Block 975 No. 1 Well

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1.2. Corsair Canyon 975-1

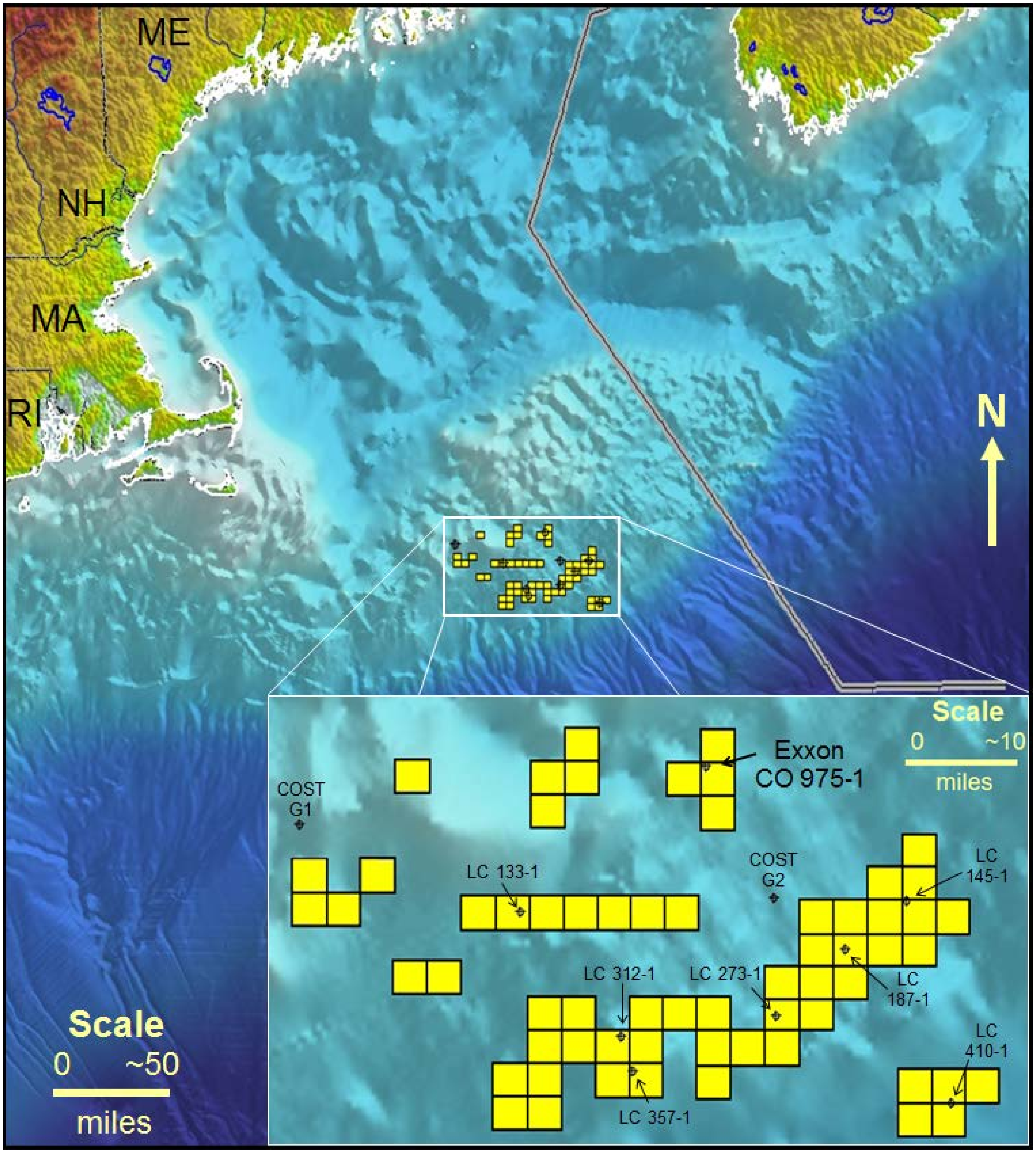

Figure 1. Location map of Georges Bank basin, offshore Massachusetts, USA. Well locations are indicated by the symbol ⌖. Leases previously held in the area are shown in yellow.

On November 25, 1981, Exxon (100%) spudded Corsair Canyon (CO) 975-1, the second industry exploration well and fourth well drilled in Georges Bank basin (GBB) (Figure 1, Table 1). Two Continental Offshore Stratigraphic Test (COST) wells preceded industry exploratory drilling in Georges Bank: COST G-1 (1976) and COST G-2 (1977). Exxon contracted the semi-submersible drilling vessel, *Alaskan Star*, to drill CO 975-1, located 36 miles east-northeast of G-1 and 13 miles north-northwest of G-2 in 209 feet (ft) of water. Total Depth (TD) of 14,605 ft was reached February 24, 1982. On March 10, 1982, CO 975-1 was abandoned as a dry hole with no significant hydrocarbon shows. While conventional and sidewall cores were taken and 11 repeat formation tests (rfts) were run, no drillstem tests were attempted.

1.2.1. Objectives and Concepts

The CO 975-1 well was drilled to test an interpreted porous shelf carbonate buildup of late Bathonian (Middle Jurassic) age at an approximate measured depth (MD) of 13,733 ft (Figure 2). The buildup was interpreted to be surrounded by low-energy carbonate sediment, creating effective top and lateral seals for the potential reservoir.

Included with Exxon's 1981 Application for Permit to Drill (APD) and Plan of Exploration (POE) submitted to the United States Geological Survey (USGS) were five original pre-drill interpreted seismic lines and three structure maps. However, the seismic lines referenced in the APD were removed and placed in another file that was not digitized. Therefore, an interpreted seismic line from Carpenter et al. (1982), presumed to be the original Exxon interpretation, was used in this folio. This data along with wireline and other well logs, cores, test results submitted by the operator, and pertinent literature were the basis for this report.

Two of Exxon's structure maps; on the top of the overlying Bathonian (Middle Jurassic) and on the top of the interpreted prospective hydrocarbon-bearing Bathonian porous carbonate buildup, are shown in Figure 3. The presumed original seismic data (from Carpenter et al., 1982) was acquired for Exxon by Digicon Geophysical Corporation from 1969–1972 and 1974–1975. Seismic data from Carpenter et al. (1982) depicts the overlying Bathonian horizon, green event in Figure 4 between 2.4 and 2.6 two-way travel time (TWTT), as a south-southwesterly plunging structural nose. The objective Bathonian anomaly (blue event in Figure 4) is located between 2.6 and 2.8 seconds TWTT. Gas was anticipated in the objective reservoir (Exxon, 1981).

Table 1. Wells drilled in Georges Bank basin

Well	Date	Target	Actual
COST G1	1977	n/a	n/a
COST G2	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

1.2.2. Results

Drilling

The targeted Bathonian anomaly was encountered at approximately 13,800 ft (Figure 5). Instead of the anticipated porous carbonate buildup, cuttings, a conventional core, wireline logs, and sidewall cores showed that the seismic objective interval consisted of 250 ft of anhydrite overlain and underlain by thin layers of salt (the entire package being termed in this folio an "evaporite lens") within a thick layer of anhydritic limestone.

A single conventional core was cut below the targeted anomaly from 14,133–14,161 ft MD (Figure 5) with 28 ft (entire cored interval) recovered. The core contained dark gray micritic limestone with silty amorphous salt-filled vugs, which were generally smaller than ¼ inch and not all of them visibly connected.

Sidewall cores were taken between 5,908 ft and 12,462 ft (above the evaporite lens) with recoveries ranging from 0.2 to 1.5 inches. Eleven drill stem tests were conducted between 13,200 ft and 13,300 ft MD. The majority of the tests showed that the rock was of low permeability and recovered only water.

Seismic Interpretation

Exxon's pre-drill 2D time-migrated seismic interpretation (Figure 4) from (Carpenter et al., 1982) shows a distinct high-amplitude anomaly between 2.6 and 2.8 seconds TWTT. This is the only occurrence of this type of anomaly in the GBB. There were originally two possible interpretations of this amplitude anomaly: a porous shelf carbonate containing gas or a salt lens (Anderson and Taylor, 1980). A third possibility, an igneous intrusive, was ruled out after modeling confirmed that this option did not adequately represent the anomaly in character or shape (Anderson and Taylor, 1980). Drilling confirmed that the anomaly was caused by the evaporite lens.

Figure 6 shows CO 975-1 projected southeast ~1200 ft onto a 2D seismic line, recently depth-converted and time-migrated (d-c, t-m) by Fugro Robertson (GeoSpec). This line traverses the Bathonian evaporite lens (Map Datum, Figure 6) at ~13,600 ft MD where there is a clearly defined high-amplitude anomaly. The anomaly exhibits a slightly convex structure that is ~300 ft thick and ~5.6 miles wide (Anderson and Taylor, 1980).

Beds above and below the evaporite lens seem to be continuous and of uniform thickness. The evaporite lens appears to have more vertical relief than the underlying beds, and may provide a 'core' for the overlying beds. One possible explanation for this type of feature is that it is the result of downbuilding. The concept of downbuilding, introduced by Barton in 1933, is a process where salt or evaporites stay at approximately the same vertical position while the surrounding sediments compact, resulting in the evaporites being structurally higher than the surrounding sediments (Barton, 1933; Nelson, 1991).

A "Map Datum" horizon, interpreted to be intra-Bathonian, (Figures 6) was chosen to best depict the top of the evaporite lens. A detailed structure map (Figure 7) was created by gridding 14 interpreted 2D d-c, t-m seismic lines within the extent of the high-amplitude anomaly. This structure map shows that the anomaly is complex; it is circular in nature and has two distinct structural highs, one of which was tested by CO 975-1. There are also two very small local highs in the southern potion of the anomaly.

Figure 8 is a regional d-c, t-m seismic line showing the setting of the evaporite lens in the context of the GBB. The GBB appears to be a silled basin plunging to the south-southwest (Figure 5.3 of Wade & MacLean, 1990). Throughout most of the Jurassic, this part of eastern North America was a desert with high paleotemperatures (Rees et al., 2000), and consequently conducive to evaporite deposition. The evaporite lens seems to have formed near the lowest point in the basin where intermittent influxes of sea water resulted in the deposition of evaporites. Salt above and below the anhydrite suggests two periods of rapid evaporation separated by a period of slower evaporation or a time the water column was recharged by less saline marine water represented by anhydrite.

Biostratigraphy and Palaeoenvironment

Biostratigraphic and palaeoenvironment information was derived from Edson et al. (2000). Re-deposition of early Mesozoic indicator fauna in younger Jurassic units results in questionable biostratigraphic reliability in these non-marine to shallow water environments of deposition (Edson et al., 2000).

Most of the sediments encountered in CO 975-1 were deposited in an interpreted non-marine environment; although some units were deposited in an inner to outer shelf environment (Edson et al., 2000).

Table 2. Biostratigraphy and probable palaeoenvironment of sediment intervals in CO 975-1.

Depth	Age	Lithology	Depositional Environment
1200	Rupelian	Banquereau Fm: Pure porous glauconite sandstone	Shelf
1260	Maastrichtian to Cenomanian	Dawson Canyon Fm.: Soft micritic limestone	Carbonate shelf
2250	Cenomanian to Barremian	Logan Canyon Fm.: Calcareous Mudstones and siltstones with well consolidated argillaceous sandstone interbeds	Mud shelf
3980	Barremian to Hauterivian	Mississauga Fm.: Well consolidated argillaceous sandstones with interbedded calcareous mudstones and siltstones.	Deltaic
4940	Berriasian to Tithonian	Roseway Unit: Microcrystalline, fossiliferous limestone overlain by calcareous and micritic mudstones and gray shales.	Mixed clastic and carbonate shelf
6250	Tithonian	Abenaki Fm.: Calcareous and micritic shales and mudstones	
6530	Kimmeridgian to Oxfordian	Mic-Mac-Mohawk Fm.: Calcareous mudstone	
10750	Oxfordian	Abenaki Fm.: Calcareous and micritic shales and mudstones	
12470	Oxfordian	Mohican Fm.: Calcareous mudstone	Shelf / Nonmarine
12920	E. to M. Jurassic*	Iroquois Fm.: Anhydritic micritic limestone	Marginal Marine
13805	L. Triassic*	Evaporites: Anhydrite, halite and anhydritic limestone	Marginal Marine

E. – Early M. –Middle L. –Late

*Sediment interpreted as being reworked; therefore, age interpretation considered unreliable.

1.2.3. Operations and Costs

The CO 975 prospect encompasses four OCS blocks (Figure 7). Exxon (100%) leased three blocks in Corsair Canyon that contained the high amplitude anomaly: 931, 974, and 975 in 1979 (Sale 42). Block CO 975 was leased in 1979 for a high bid of $21,318,000.00 (Carpenter et al., 1982). Exxon leased blocks CO 974 for $20,637,000.00 and CO 931 for $10,851,000.00 for a total lease bonus of ~$53 MM, or approximately $176,670,842 in 2012 dollars (HBrothers, 2012). A fourth block, containing the southern portion of the prospect (Lydonia Canyon 7), was leased by The Superior Oil Company (Sale 42) for $4,011,000.00, approximately 13.4 MM in 2012 dollars (HBrothers, 2012). Therefore, the total bonus for all four prospect-related leases was ~$57 MM or ~$190 MM in 2012 dollars. The total well cost for CO 975-1 was not available. Total drilling time was 106 days (from spud date to completion) including 9 days for blowout preventer repairs (Carpenter et al., 1982).

1.2.4. Petroleum System Analysis

Magoon and Dow (1994) describe 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 is defined as biogenic or thermal gas located in a reservoir or as naturally occurring surficial condensates, asphalts, and crude oils (Magoon and Dow, 1994).

Essential geologic elements are: source rock, reservoir rock, seal rock, and overburden rock (a thick rock column above the source rock interval to generate sufficient temperatures for hydrocarbon generation). Our guidelines for source, reservoir, and seal elements are shown in italics in Table 3.

Essential processes include trap formation and hydrocarbon generation, as well as hydrocarbon expulsion, migration, accumulation, and preservation (Magoon and Dow, 1994).

The essential processes must act on the geologic elements at specific times such that a reservoir and trap exist, 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 be present in all areas; i.e., when there is no hydrocarbon generation and expulsion, there can be no migration or accumulation.

Table 3. Petroleum System Elements

Element	CO 975-1 Lithology
Source rock *(>1% TOC)*	Shales in the interval ~6,500 ft – ~11,500 ft
Reservoir rock *(>10 % ϕ >1 mD k)*	Hauterivian–Barremian sandstones comprised of ~66% sandstone with interbedded mudstones and siltstones.
Seal rock *(10^{-3} mD k)*	Shale
Overburden rock	~11,000 ft above deepest source rock interval

Geochemistry

Analysis of Exxon's geochemical data shows that some intervals, primarily between ~6,500 ft and ~11,000 ft MD (Late Jurassic Tithonian–Oxfordian?), contain sufficient TOC (>1%) to generate hydrocarbons (Tables 3 and 4).

Rock-Eval Pyrolysis was used to establish the maturity of organic matter and its petroleum potential. This technique involves heating a sample in a helium atmosphere (Pimmel and Claypool, 2001). The thermal maturation of a sample is determined by T_{max}, "the temperature at which maximum release of hydrocarbons from cracking of kerogen occurs during pyrolysis" (Pimmel and Claypool, 2001). Thermally mature rocks for oil generation are those that reach a T_{max} of ~435 ^{o}C (incipient /early mature for oil generation) and remain at or below 470 ^{o}C (post-mature for oil generation).

Table 4. Petroleum System Processes

Onset hydrocarbon generation	Approximately 9,500 ft MD based on Rock-Eval Pyrolysis T_{max}.
Expulsion	The absence of significant shows indicates a lack of significant thicknesses of mature source rocks, expelled hydrocarbons, and/or vertical cross–stratal conduits to facilitate hydrocarbon migration or accumulation.
Migration	
Accumulation	

In CO 975-1, the T_{max} values indicate that rocks are thermally mature below ~9,500 ft MD; however, present-day TOC values below this point are between 1.0 and 1.15. Values near 1% TOC are generally considered inadequate contributors to the overall petroleum system (Jarvie, 1991). Maturity increases with depth, while TOC generally does not.

Rock-Eval Pyrolysis T_{max} data is relatively objective because it is based on kerogen kinetics and is therefore preferable to the more subjective thermal alteration index (TAI) technique, which relies on spore color to estimate the maximum thermal maturity of a sedimentary unit. Both TAI and

T_{max} data were used to determine and calibrate maturity in CO 975-1.

PRA's BasinMod® *Classic* software was used to define the kerogen type and hydrocarbon generation windows. All of the kerogen in CO 975-1 was classified as type III from a van Krevelan diagram (Oxygen Index vs. Hydrogen Index). Original TOC values were < 1.5 % and T_{max} values remained between 420°C and 440°C resulting in relatively small amounts of in situ gas and oil in the source rock intervals. No hydrocarbons appear to have been expelled from mature source rock intervals, explaining the lack of hydrocarbon shows in potential reservoir units.

Exploration Implications

CO 975-1 was a dry hole because the pre-drill interpretation of the high-amplitude seismic anomaly corresponded to an evaporite lens rather than an interpreted porous carbonate buildup containing hydrocarbons. Both a salt/anhydrite lens and a porous carbonate buildup would produce a lower impedance than the surrounding rock layers, resulting in an almost identical high-amplitude anomaly (Anderson and Taylor, 1980). Therefore, the actual source of the anomaly could only be identified by drilling. There were no noteworthy hydrocarbon shows in the well (Table 5).

Table 5. CO 975-1 Target Summary

Pre-Drill Interpretation	
Target	~13,733 ft MD Interpreted porous carbonate buildup
Trap Type	Stratigraphic
Hydrocarbon Expected	Gas
Post-Drill Results	
Target Interval	At ~13,800 ft MD the interval consisted of a 250 ft thick lens of anhydrite that was over and underlain by thin layers of salt.
Hydrocarbon Shows	No significant shows of either oil or gas.

Acknowledgements

The support of BOEM management and staff: R. Poling, M. Wilson, M. Celata, and D. Cooke, are gratefully acknowledged. We also thank R. Poling whose review and comments significantly improved the clarity and readability of the paper, and E. Klocek for her peer review. We are grateful to Fugro Robertson (GeoSpec) 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 Fugro Robertson (GeoSpec) is greatly appreciated.

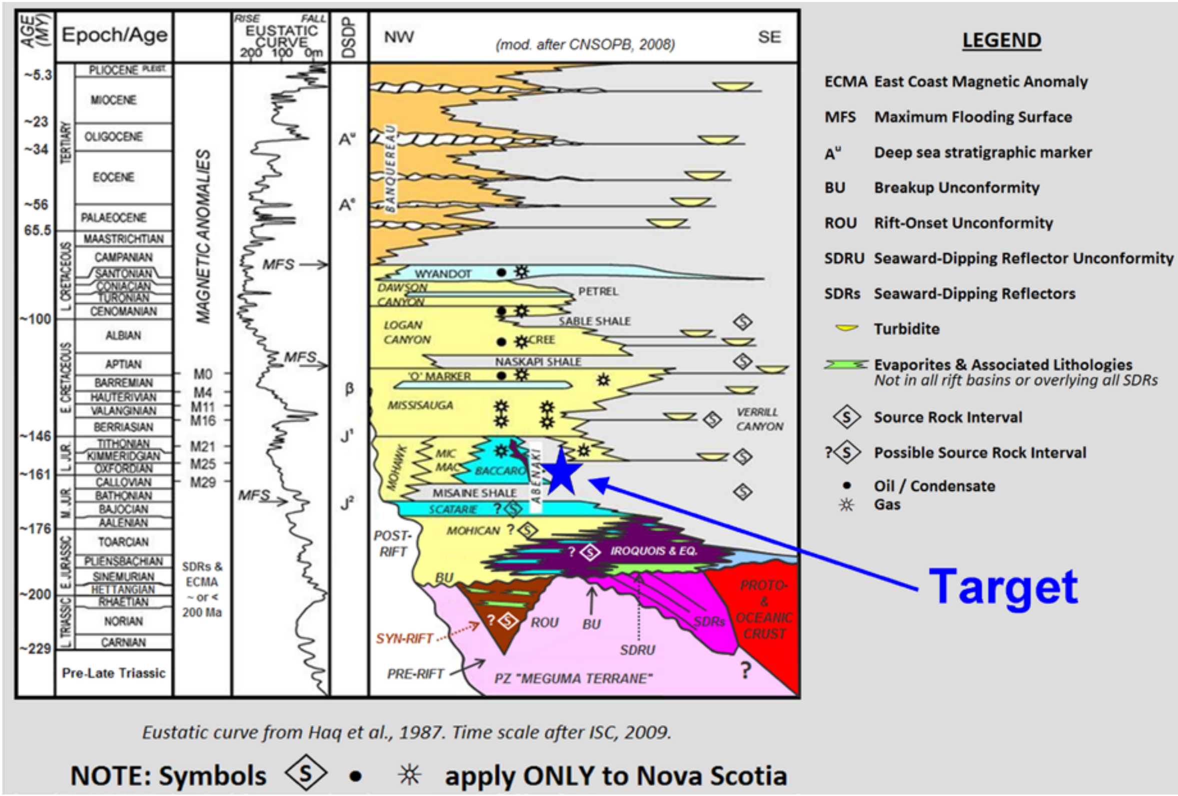

Figure 2. Stratigraphic chart and target interval for Exxon Corsair Canyon (CO) Well 975-1.

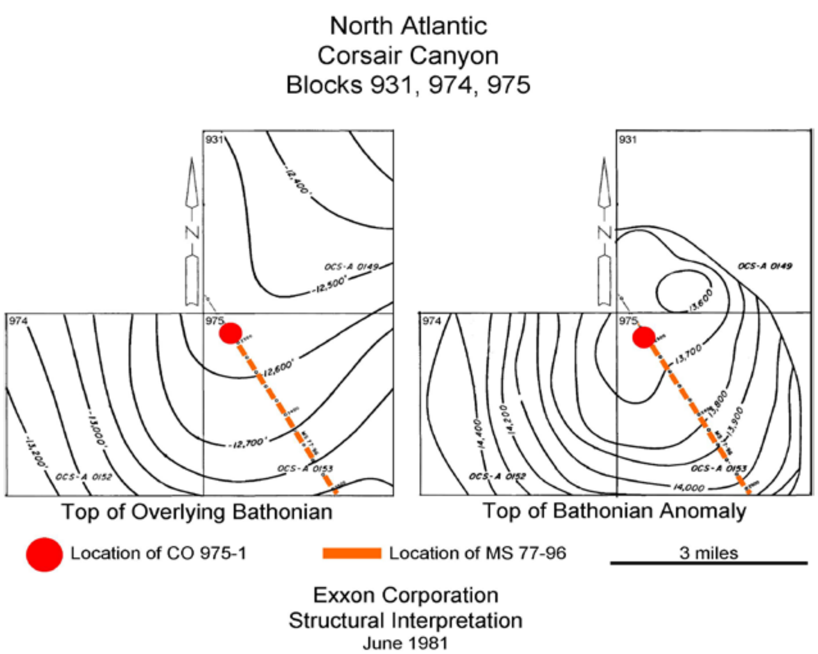

Figure 3. Structure map (after Exxon, 1981) showing the top of the Bathonian and the top of the Bathonian anomaly.

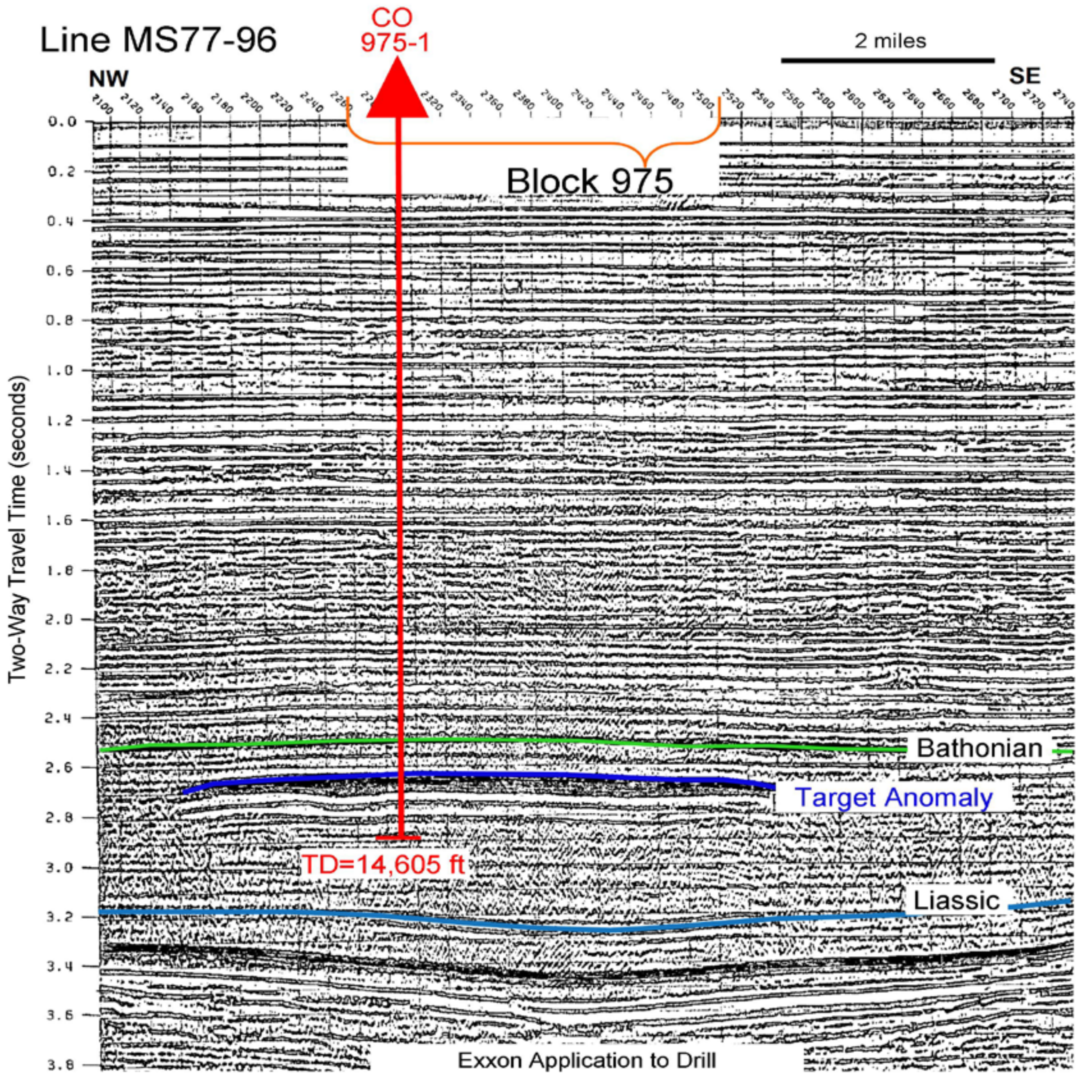

Figure 4. Interpreted seismic showing the targeted carbonate buildup (modified after Carpenter et al. 1982).

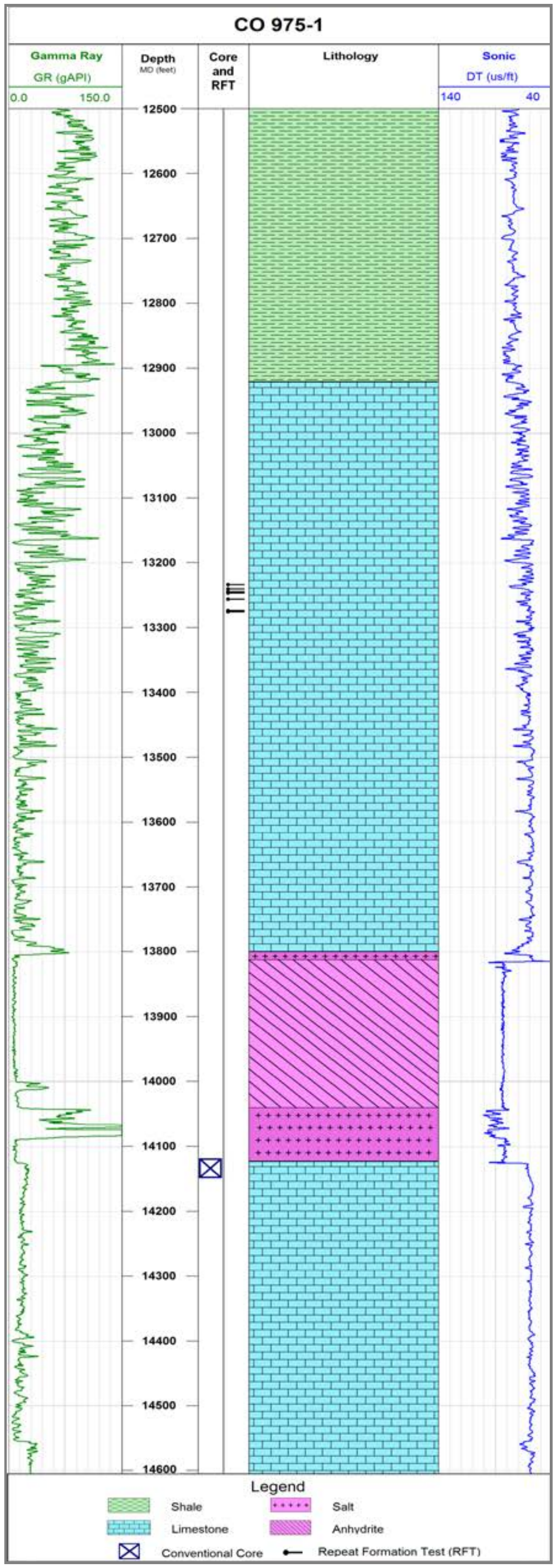

Figure 5. Well CO 975-1 target interval lithology based on gamma ray and sonic logs, conventional and sidewall cores, and drill cuttings.

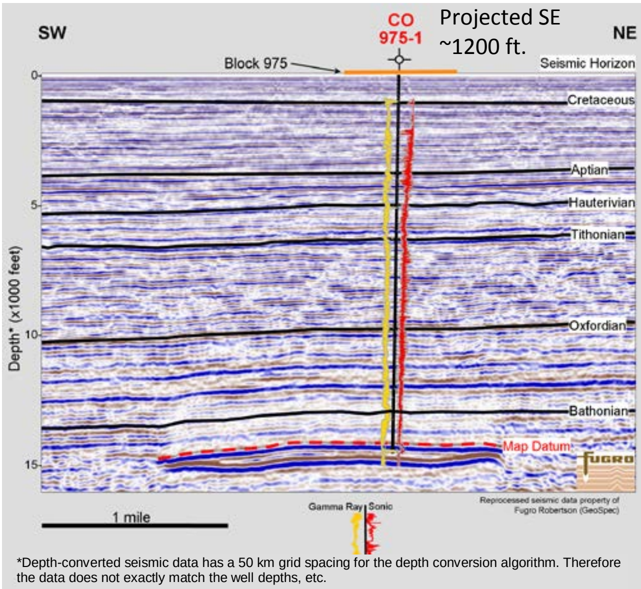

Figure 6. Depth-converted, time-migrated seismic profile through CO 975-1 showing interpreted horizons and "Map Datum."

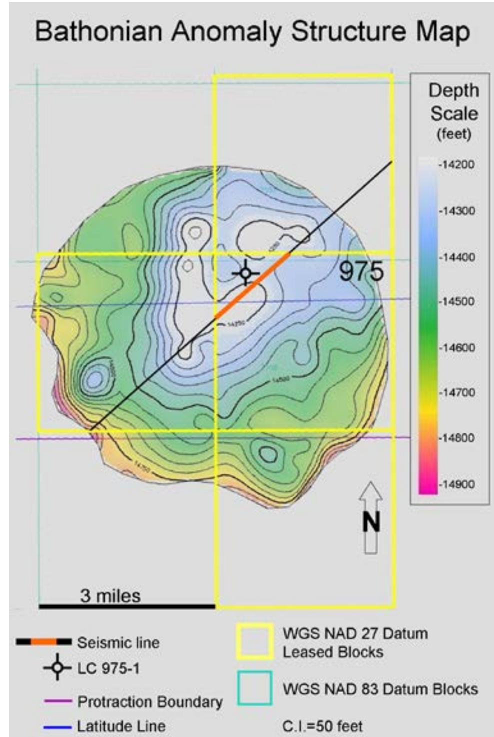

Figure 7. Regional depth structure map of anomaly on "Map Datum" from Figure 6.

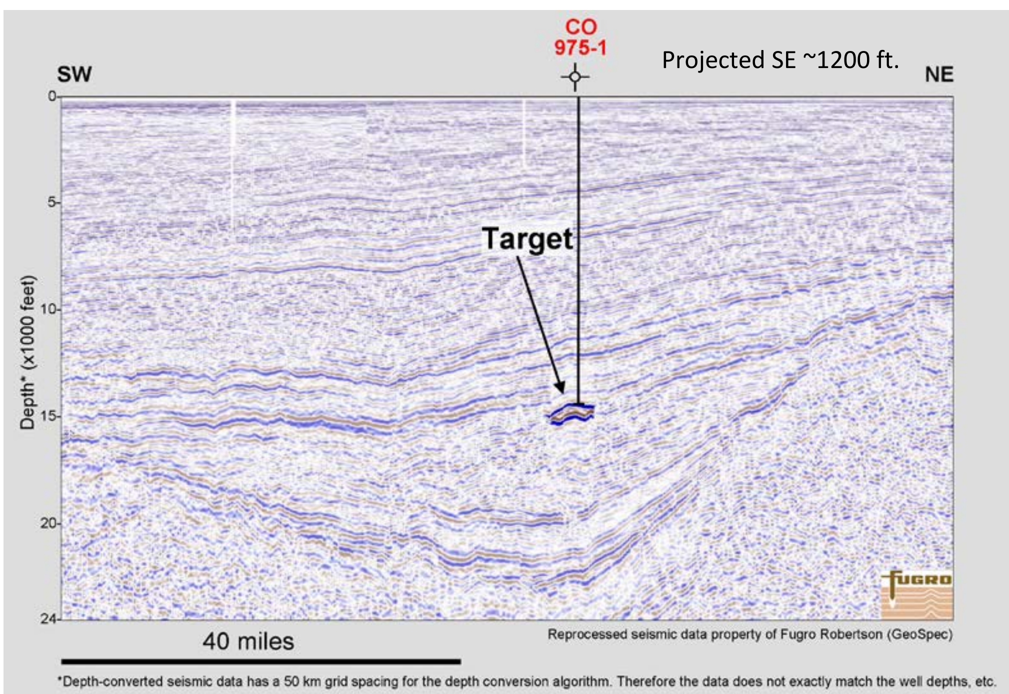

Figure 8. Depth-converted, time-migrated regional seismic profile through CO 975-1 showing the location of the high–amplitude target (evaporite lens) within The GBB.

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