Gulf of Mexico Gas Hydrate Joint Industry Project Leg II:
East Breaks 992 and Alaminos Canyon 21 Site Selection

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Introduction

The potential gas hydrate drilling targets in the AC 21/65 and EB 992 sites, collectively referred to as the "Diana Basin" sites (after Diana Field just to the northwest) were identified by MMS interpreters after observing elevated resistivities in a sand in an existing industry well above the calculated base of hydrate stability (BGHS) and a corresponding anomalous seismic signature well above the mapped bottom simulating reflector (BSR). The log of the well in East Breaks (EB) block 992, shows a clean, blocky sand with resistivities of ~2 Ω-m, as compared to wells in EB 990 and 994 that have stratigraphically equivalent clean sands with resistivities as low as .2 Ω-m. When tied to the seismic data covering the area, the sand top and base corresponded to a prominent peak and trough of a laterally distinct mounded event reminiscent of a basin floor levee deposit. Upon further investigation, large areas of similar anomalous seismic events suggestive of a basin floor fan complex were mapped, notably in Alaminos Canyon (AC) blocks 21 and 65. Though the resistivities seen in the EB 992 well were relatively low compared to other hydrate occurrences found in sands elsewhere, suggesting low hydrate concentrations, it was decided to recommend the area for drilling in JIP Leg II due to the size of the prospects, the rareness of documented low-gas hydrate saturated sands, and the need to further evaluate the reliability of the single LWD data point.

Geologic Setting

The Diana basin is an intra-slope basin located in the western Gulf of Mexico, approximately 160 miles south of Galveston, TX (Figure F1). Water depth in the basin center averages 4800 feet. The basin is bounded by relatively shallow salt bodies and contains mostly Pliocene- and Pleistocene-age sand sequences bounded by marine shales. Depositional environment throughout the Tertiary section is interpreted to consist of deepwater turbidites and mass transport systems. Existing well log and core data from industry wells in the Diana basin reveal a complex distribution of deepwater facies that includes confined feeder channel systems, weakly confined/distributary channel complexes, and distributary lobe and sheet complexes (Sullivan and Templet, 2002). The Diana basin contains five producing oil and gas fields in the EB and AC protraction areas, including Diana (EB 945), South Diana (AC 065), Marshall (EB 949), Madison (AC 024), and Hoover (AC 025) (Figure F1). The Rockefeller field in EB 992 is currently under development by the operator.

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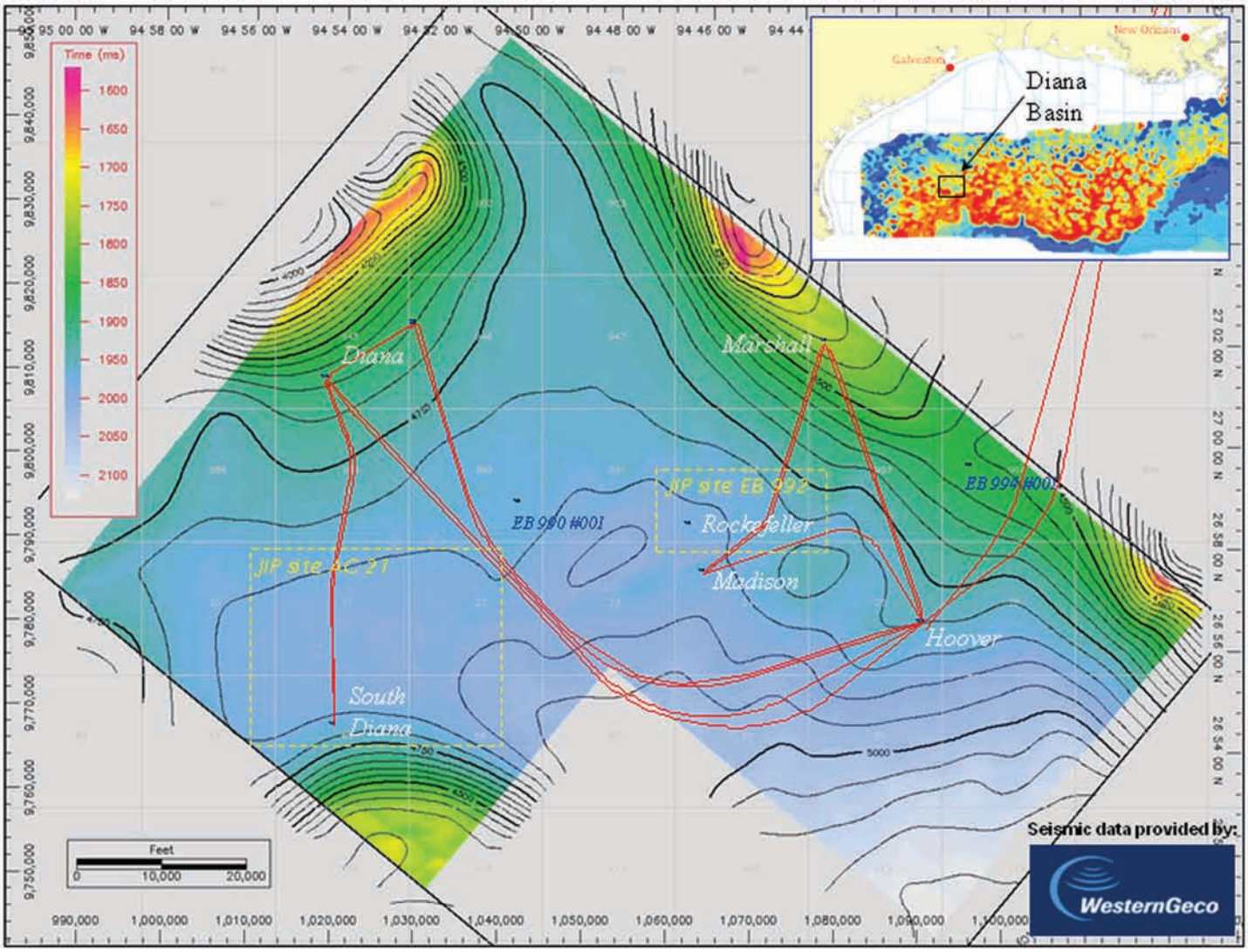

Figure F1: *Location map for the Diana basin in the western Gulf of Mexico. Water Depth for the basin shown as two way travel time (color grid) and feet (contours). JIP sites AC 021 and EB 992 are outlined by yellow dashed polygons. Surface locations of industry wells are shown as blue squares; oil and gas fields are labeled in White. Pipelines from producing fields are shown in red.*

Industry Wells

The industry wells used in the analysis of this area are shown in Table T1.

All of the shallow logs used in the pre-drill interpretation of possible gas hydrate occurrence are LWD data acquired in very large open holes, ranging from 24 to 30-inches in diameter. The large open holes often do not provide optimum measurement conditions for the logging tools, and the acquired log values and subsequent interpretations of lithology, fluid saturation, and other parameters were evaluated considering these limitations. Additionally, critical data including porosity, formation density, or acoustic measurements were not acquired in the potentially hydrate-bearing shallower section of the industry wells.

The key well for the gas hydrate play in this area was the EB 992 #001 drilled to 12,449 feet below rig floor for Pliocene objectives. It encountered a 135-ft thick clean, blocky sand at 5720 ft that had up to 2 Ω-m resistivity (Figure F2), compared to the wells in EB 990 and 994 that had stratigraphically equivalent clean sands with .2 - .4 Ω-m resistivities (Figure F3). Estimated gas hydrate saturations, calculated using the quick-look method presented by Collett (1998, 2000), are in the 30% to 40% range for this interval.

The EB 994 #001 well contains a shallow sand interval that exceeds 450-ft thick, with the top of the sand located at a depth of 389 feet below sea floor (fbsf) and the base at 844 fbsf. The entire sand interval is interpreted to be water-

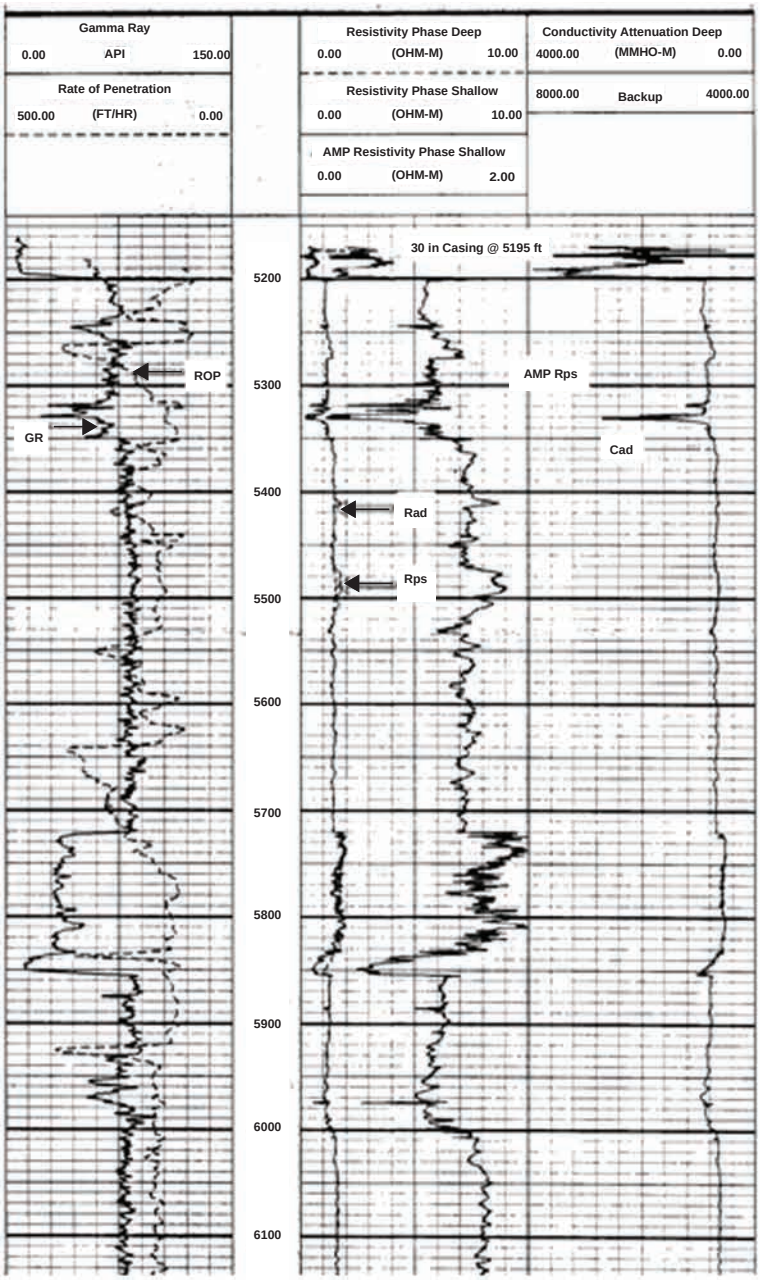

Figure F2: *LWD log of the EB 992 #001 well (GR and resistivity)*

Area	Block (bhl)	Lease	Well No.	API	WD (ft)	KB (ft)	Log Top (ft)	Log Bottom (ft)	Log Date	Operator	Longitude (surface)	Latitude (surface)
EB	945	G08211	#002	608044016200	4653	86	4984	11309	1996_Jan_13	Exxon Exploration	-94.875583	27.034778
EB	946	G08212	#003	608044018100	4653	48	4946	10546	1998_Sept_19	Exxon Upstream	-94.875411	27.034758
EB	949	G10949	#001	608044017600	4356	48	4674	11107	1998_Jul_08	Exxon Company USA	-94.724617	27.027453
EB	990	G23255	#001	606044023300	4825	83	5150	14955	2002_June_08	ExxonMobil	-94.837964	26.977644
EB	992	G10325	#001	608044016000	4867	86	5196	12449	1995_Oct_24	Exxon Exploration	-94.774639	26.970556
EB	994	G12629	#001	608044016500	4645	86	4902	12475	1997_May_01	BP Exploration	-94.67057	26.98945
AC	24	G19379	#001	608054000500	4856	48	5153	13450	1998_May_30	Exxon Exploration	-94.769322	26.954831
AC	65	G09249	#001	608054000300	4852	86	5184	1700	1997_Feb_14	Exxon Exploration	-94.905584	26.905945

Table T1: *EB 992 and AC 21 well information*

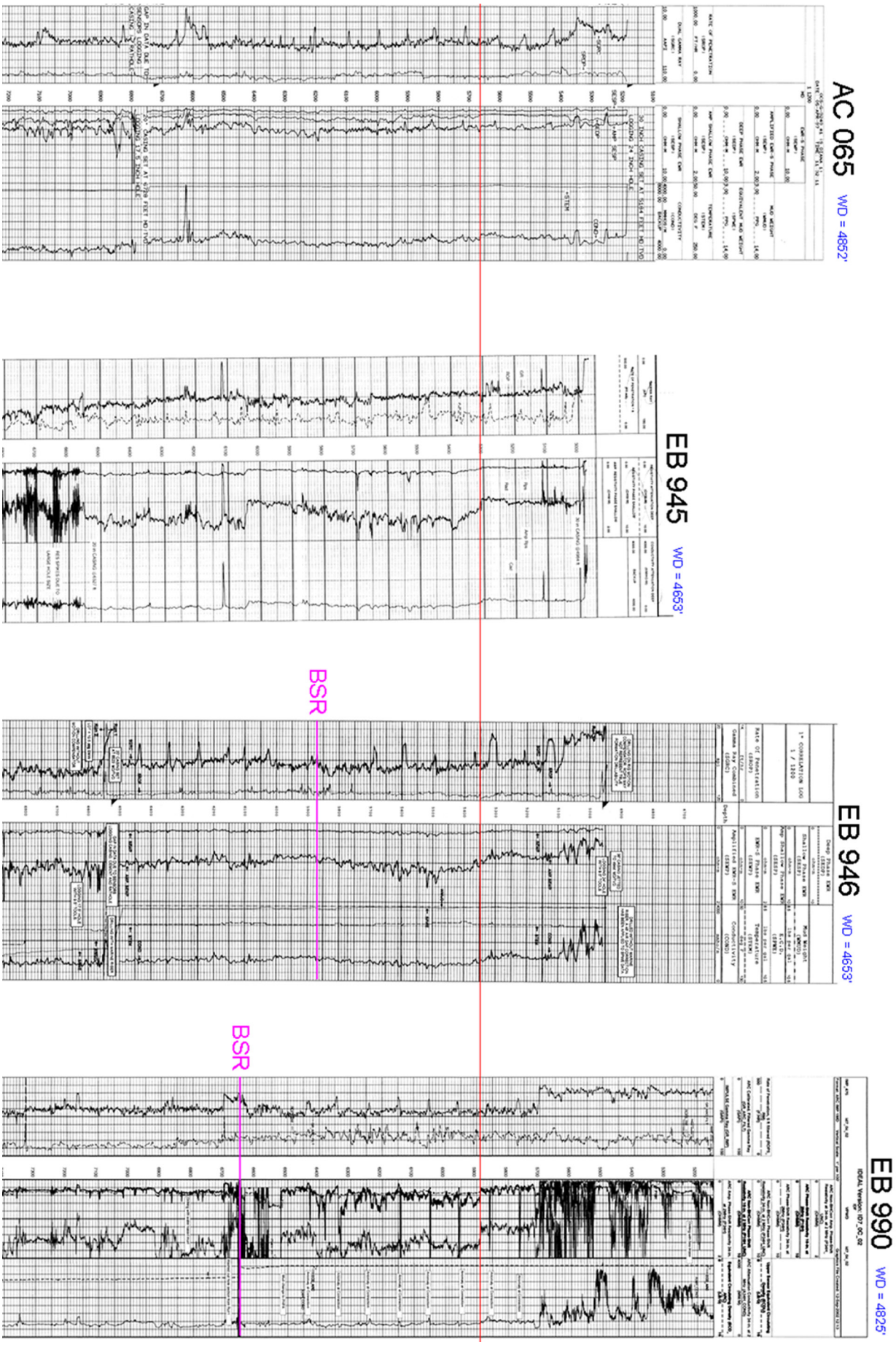

Figure F3: *Stratigraphic cross-section of the key wells in the area of the AC 21/EB 992 JIP drilling sites*

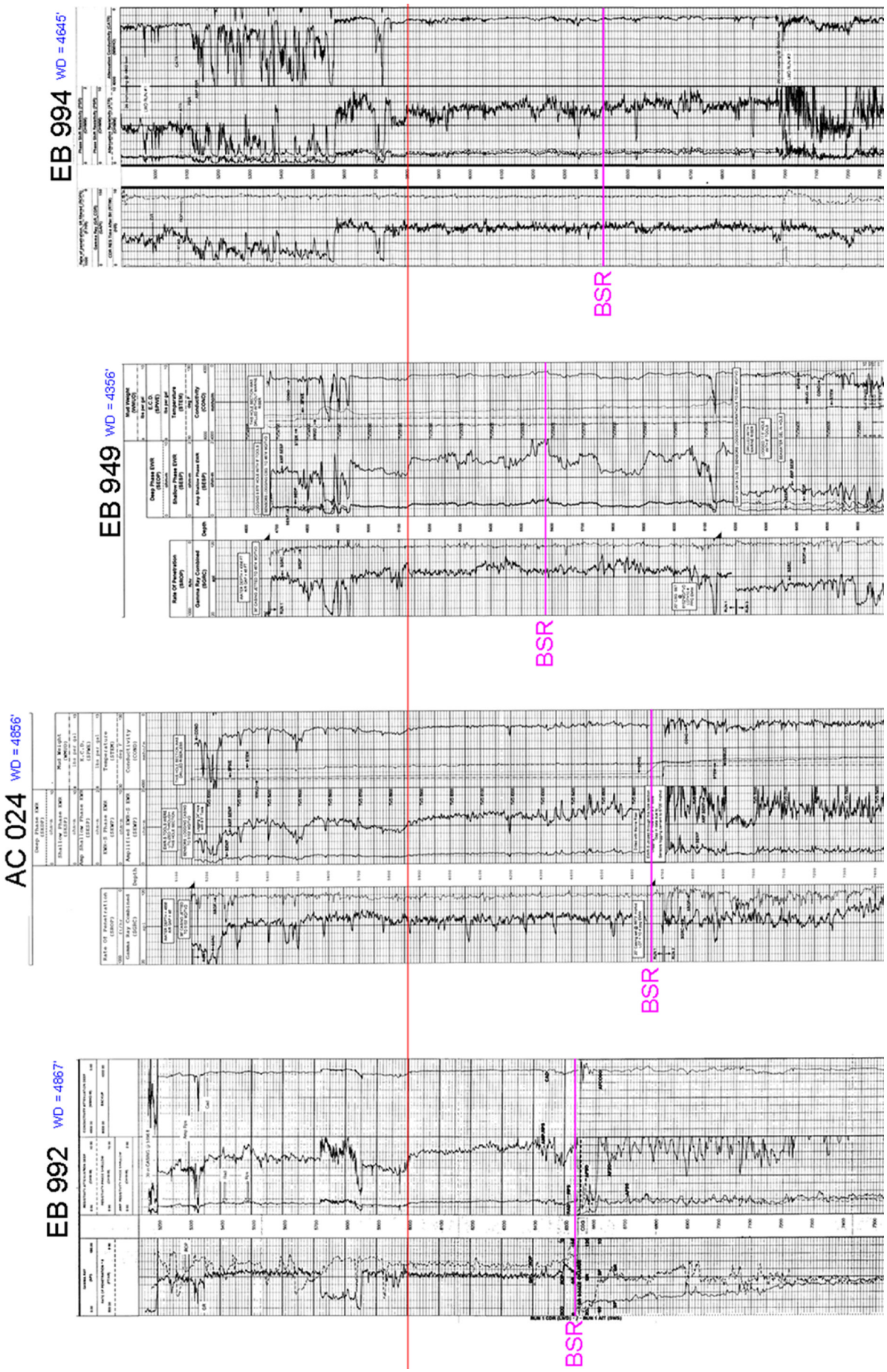

Figure F3 (cont.): *Stratigraphic cross-section of the key wells in the area of the AC 21/EB 992 JIP drilling sites*

saturated. The well is important, however, in that the low clay content sands (based on the tracking of low gamma ray response and low formation resistivity) provide high-confidence background resistivity (R_o) values (as low as 0.2 Ω-m) necessary for the quick-look saturation method used on the EB 992 #001 well. The EB 990 #001 well contains a sand sequence at least 550-ft thick (the top of the log is in sand) that is stratigraphically equivalent to the EB 992 sand and has clean gamma ray and resistivities as low as .2 Ω-m, as well.

Industry wells in AC 24, AC 65, EB 945, EB 946, and EB 949 all contain variable amounts of thin sands (~10-ft thick) shallower stratigraphically than the EB 992 sand and are interpreted to be water-bearing, and contain shale in the stratigraphic equivalent section of the EB 992 sand. These wells are considered valuable data points for the seismic stratigraphic analysis and seismic calibration.

Gas Hydrate Stability Conditions

Gas hydrate stability zone thickness across the Gulf of Mexico has been modeled in a number of studies (Milkov and Sassen, 2001; Marcucci and Forrest, 2007; Frye, 2008) that show pressure and temperature conditions are typically favorable where water depths that exceed 1000 ft. Locally in the Diana basin, where water depth averages 4,800 ft in the basin center, the base of gas hydrate stability is modeled to occur ~1500 feet below the seafloor (fbsf) assuming ambient conditions of salinitym (35 ppt), water bottom temperature (4 °C), and geothermal gradient (~25 °C/km). On the basin margins, where local salt is thought to increase both salinity (Bruno and Hanor, 2003; Hanor 2004, 2007) and heat flow (O'Brien and Lerche, 1988) in the shallow section, the thickness of the stability zone may be reduced significantly. Figure F9 shows the predicted thickness of gas hydrate stability in the Diana basin using the spatial model and methodology described by Frye (2008). The objectives in the JIP locations in this area are all well above the calculated BGHS and the BSR mapped in this area.

Well-Bore Velocity Data

Downhole check shot velocity data are available from four wells in the study area (EB 990, EB 992, EB 946, and EB 994). These data allow for a non-synthetic well tie to seismic using time versus depth relationships acquired from various depths in the wellbore.

Seismic Data

Most seismic data interpretation was performed on the East Breaks/Alaminos Canyon 8-Q multiclient 3-D Kirchhoff prestack time migration survey, acquired and licensed by Western Geco. The dominant frequency (~50 hz) is nearly twice that found in most industry seismic data, and the final processed sample rate of the seismic volume is 2 milliseconds. Both of these parameters contribute to the excellent quality of the Western Geco 8-Q data.

Seismic Stratigraphy

Seismic cross-sections through the EB 992 well at the target interval reveal an anomalous event with a strong positive top with a mounded shape and a strong, flat negative base, reminiscent of a basin levee deposit (Figure F4),which is overlain by a thick section of chaotic, weaker reflections. After generating several geophysical attributes, we determined that the RMS extraction (root mean square), generated with a 150 m/s window above a regional mapping horizon, showed a discrete, elongate anomaly at this site (Figure F5). When this same RMS extraction is expanded basin-wide, this anomaly is just a small part of large fan-shaped complex on the eastern side of the Diana Basin (Figure F6). This complex is discretely separated from a larger, seismically stronger anomalous fan to the west by a section of parallel-bedded, weaker reflections suggestive of fine grained, hemipelagic sediments. To test these prospective fans, the site selection team recommended four locations in the EB 992 fan. Three locations were picked in the western fan (Site AC 21/65): two in AC 21 and one in AC 65 (Figure F7). Figure F8 is a seismic traverse through all seven locations and the AC 65 and EB 992 wells that shows the two discrete fans and the section that separates them. We interpret the fans as being deposited on basin floors by two separate deep water turbidite complexes, one from the northwestern entry point into the basin and the other from the northeastern entry point (controlled by the three salt bodies that rim the northern side of the basin); the area that separates the fans is dominated by mud-prone deposits that could act as a lateral seal. Note the several "holes" (white to light blue areas) in the fan to the west in Figure F5 – we interpret these as mud-prone, as well. Figure F8 is a seismic traverse through the AC 65 #001, the AC 21/65 target locations, the EB 992 #001 well and the EB 992 target locations.

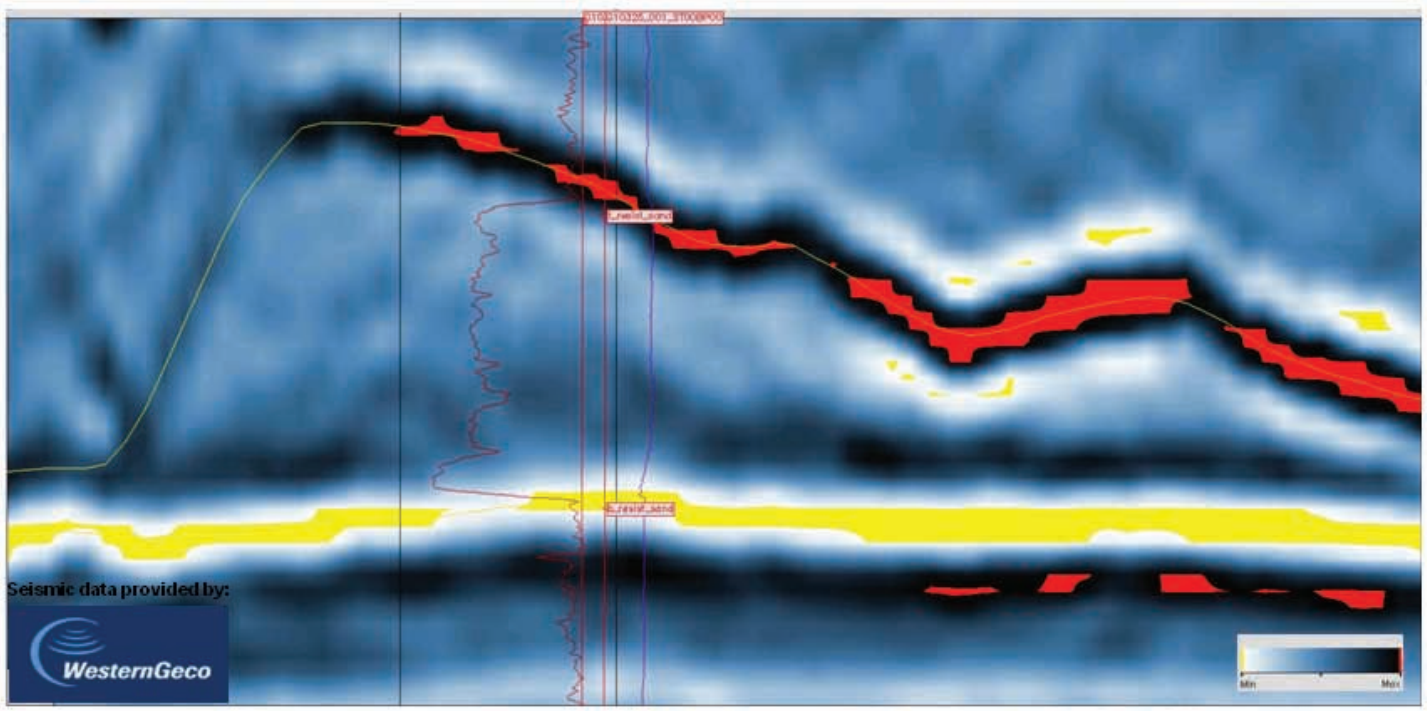

Figure F4: *Arbitrary seismic section through the EB 992 #001 well location. The top of the inferred sand corresponds to the strong seismic peak (red), and the base of the sand ties to the strong seismic trough (yellow). Sand interval measures 135 feet.*

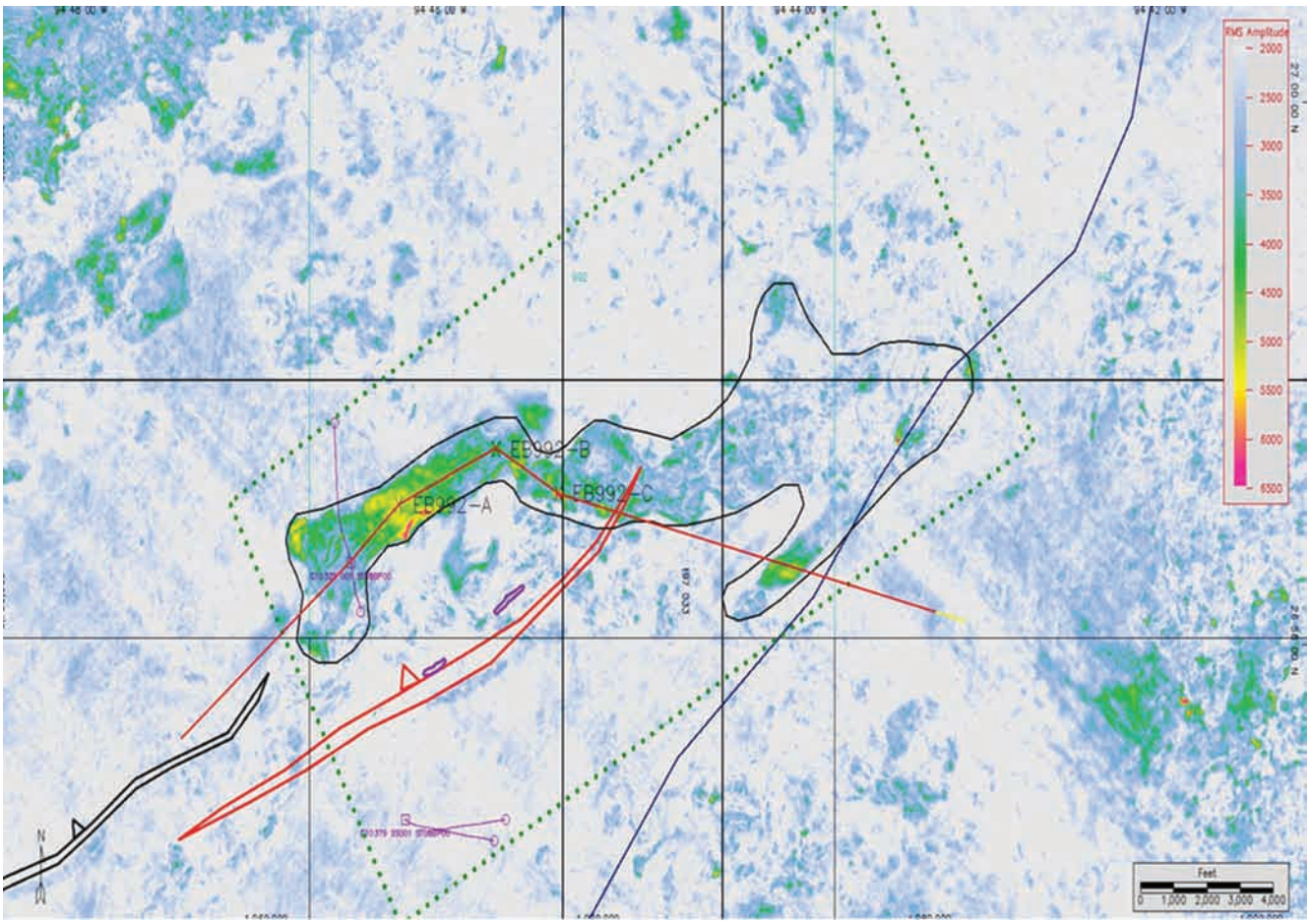

Figure F5: *RMS amplitude extraction over EB 992 sites.*

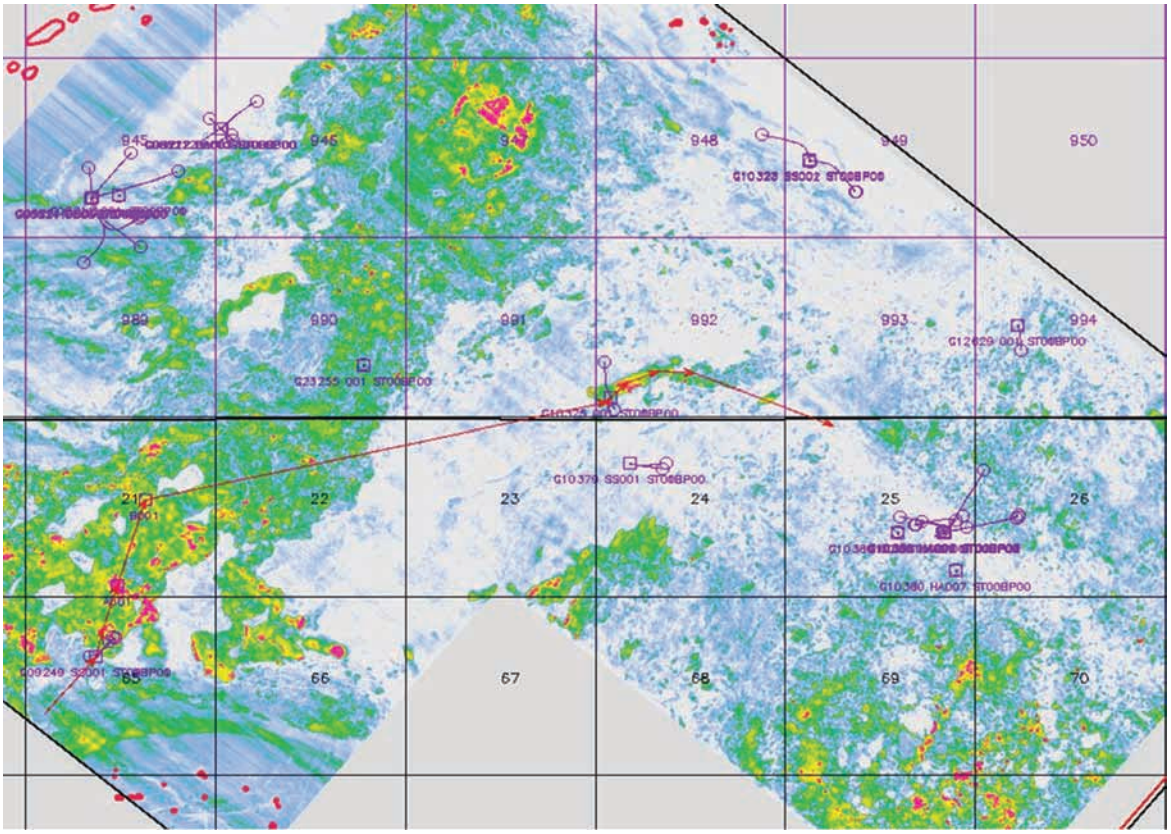

Figure F6: *RMS amplitude extraction over AC 21/65 and EB 992 JIP sites.*

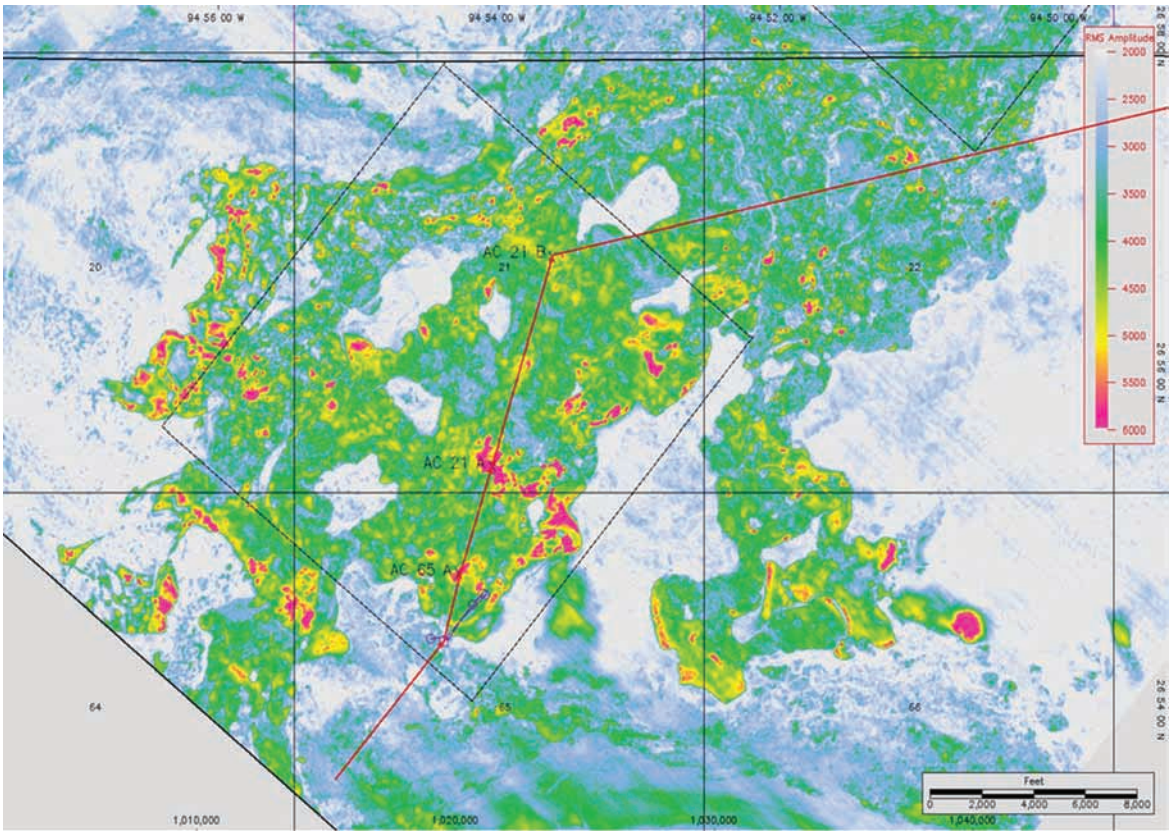

Figure F7: *RMS amplitude extraction over the AC 21/65 sites.*

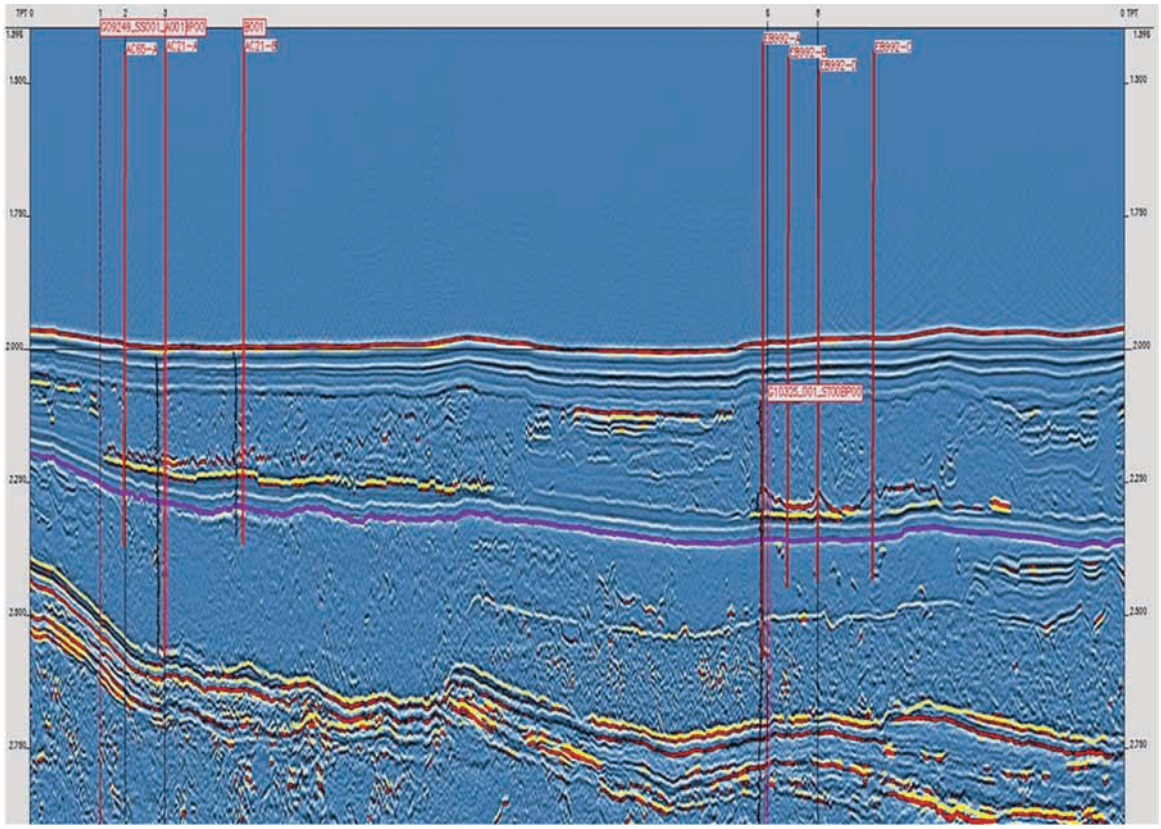

Figure F8: *Seismic traverse over AC 21/65 and EB 992 JIP sites.*

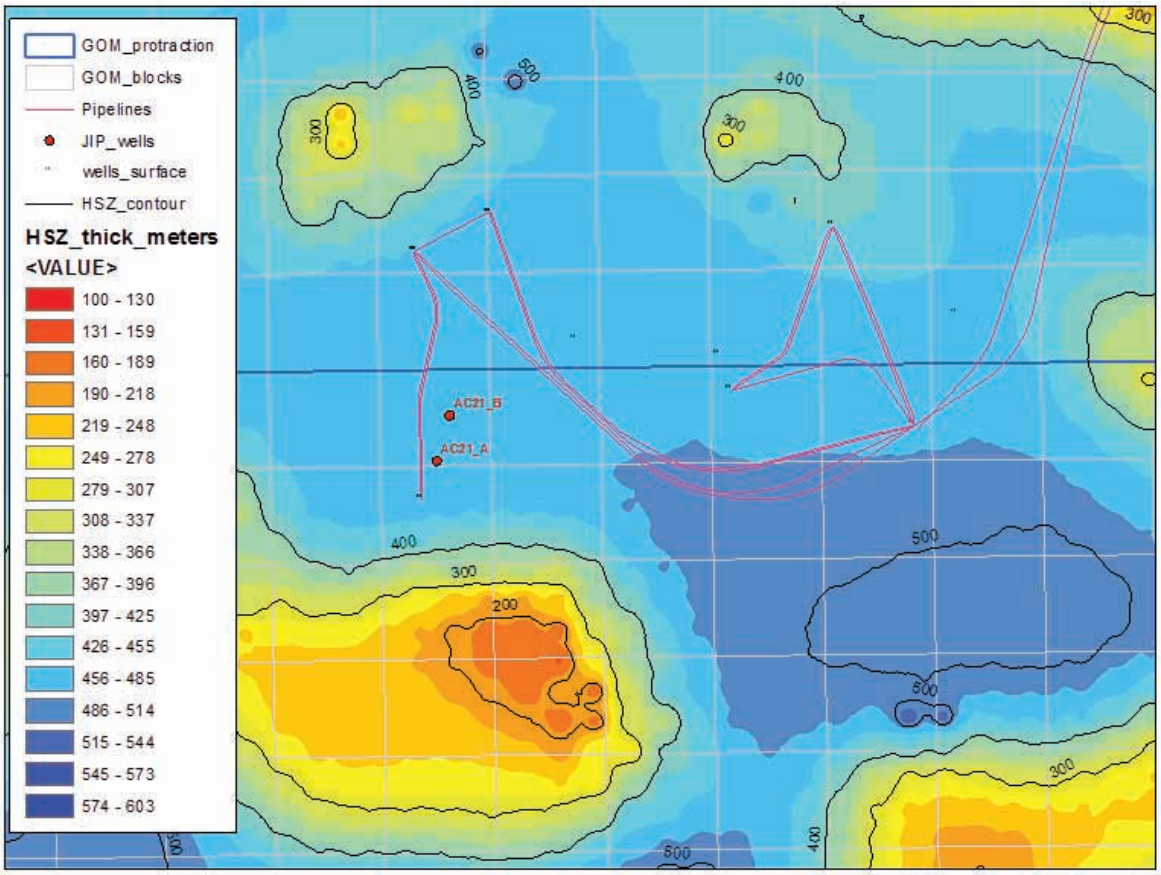

Figure F9: *Gas hydrate stability zone thickness calculated using spatial model and methodolgy presented by Frye (2008). Thickness reported in meters.*

Drill Location Name	Latitude	Longitude	Water Depth	Target Depth BML	Target Thickness
EB992-A	26.96947	94.77536	4860	819	167
EB992-B	26.97696	94.7624	4838	879	118
EB992-C	26.97653	94.75293	4833	803	208
EB992-D	26.97407	94.7706	4853	939	56
AC21-A	26.92299	94.89878	4877	602	129
AC21-B	26.94368	94.89316	4872	605	118
AC65-A	26.91078	94.90252	4853	620	60

Table T2: *Drilling location data for East Breaks and Alaminos Canyon proposed sites.*

Drilling Targets

Seven locations were picked to test the two fan complexes. Each location has a single target, which is thought to be stratigraphically correlative (Table T2).

Consensus recommendation: The site selection group agreed that it would be advisable for the JIP to drill test wells in both the AC 21/65 and EB 992 sites, with initial drilling occurring within EB 992. Within Site EB 992, the most favorable locations is EB 992-B which exhibits strong amplitudes in an area where thickness is thought more than sufficient to avoid the effects of tuning. In addition, the EB 992-B site showed slight evidence of a velocity pull-up on the basal trough reflector, suggesting a potential for higher internal velocities within the sand, and thus higher gas hydrate saturation. The EB 992-A site was recommended as a location in an area of significant target thickness, should the science team determine a need for a close step-out to the existing EB 992 #001 well. The EB 992-C was selected as one well offset from the existing well, but in close proximity to the only imaged gas migration pathway into the reservoir. The C- and the further offset D-wells could be drilled depending on the results found at the B-location (Table T3).

Drill Site (permit name)	Comment
B	Consensus #1
A, D, or C	Depending on results from B

Table T3: *Recommendations for EB 992*

At the AC 21/65 site: assuming success at EB 992, the site selection team recommended three sites in AC21/65 that could extend the findings over a large geographic region. The AC 21-A well location was selected to evaluate two closely-spaced peak/trough pairs at the target horizon level. This dual relationship is not widely distributed across the target area. The AC 21-B location was selected to test a thick interval in a proximal position of the distributary system. The AC 65-A location was permitted to test distal lobe facies that mark the presumed termination of the depositional system, where the gross target interval measures ~75 ft-thick.

Drill Site (permit name)	Comment
21A	Consensus #1
65A or 21B	Depending on results from B

Table T4: *Recommendations for AC 21/65*

Concerns about EB 992 and AC 21

There are a number of concerns about EB 992 and AC 21:

- The sites were recognized late in the program planning, and therefore, advanced seismic analysis and gas hydrate saturations could not be conducted prior to drilling. It is not thought that this compromised site selection in any way, given the high quality of the amplitude data and the general geologic simplicity of the targets.
- The site selection team could not adequately mitigate risk of limited charge. Although the seismic response (strong leading peak) is suggestive of gas hydrate, the interval is extremely shallow, and in a zone where the expected acoustic impedance of a wet sand within a shale package could also likely produce a peak. Initial analyses indicated that the peak is stronger (higher amplitude) than would be expected for a sand, but only so strong as to indicate low-to-moderate S_{gh}. However, the data and fundamental rock physics relationships upon which these interpretations are based are poor due to lack of data.
- The play shows very limited connections to deeper gas sources, faulting etc.

- The play shows relatively homogeneous seismic response, suggesting limited lateral variability in pore fill.
- Existing log data (EB992 well) suggests low to moderate S_{gh}. The resisitivities logged in that well, while suggestive of hydrocarbon, could be explained by other (less likely) factors, etc.

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Appendix 1: Site and Target Summaries

The following pages provide detailed summaries of each drilling target with four tables of factual information.

Explanation of Terms:

Site Name	the name used during permitting (generally AC 21-letter) and the name developed during the site selection process (generally JIP-name)
NAD27	datum used for latitude/longitude values (North America Datum 1927)
BSS	below sea surface
BML	below mud line
TGHO	top of gas hydrate occurrence
BGHS	base of gas hydrate stability
BSR	bottom simulating reflection

Target AC21-A
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test a seismic doublet, suggestive of 2 potential sand targets
Other Drilling in Vicinity	AC 65 #1

Table 2: Proposed Hole General Information

Site Name	AC 21A
General Area	*Diana Basin*
Location	26.92299 N, 94.89878 W
Coordinate Datum	*NAD 27*
Water Depth	*4877 ft*
OPD/Lease Block	*AC 21*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*6700 ft*
Seafloor slope	*<1 degree*
Expected lithologies and thicknesses	*Shale to 5479 ft, sand from 5479ft to 5608 ft, primarily shale from 5608ft to 6700 ft*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*5479 ft*
Estimated depth to BGHS	*6464 ft*
Estimated GH interval	129 ft
Estimated GH saturation	*30-50%*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey and AC65 #1 well*

BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability

Target AC21-B
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test a thick, single sand target
Other Drilling in Vicinity	AC 65 #1

Table 2: Proposed Hole General Information

Site Name	AC21B
General Area	*Diana Basin*
Location	26.94368 N, 94.89316 W
Coordinate Datum	*NAD27*
Water Depth	*4872 ft*
OPD/Lease Block	*AC 21*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*6650 ft*
Seafloor slope	*< 1 degree*
Expected lithologies and thicknesses	*Shale to 5477 ft, sand from 5477 ft to 5595 ft, primarily shale from 5595 ft to 6650 ft*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*5477 ft*
Estimated depth to BGHS	*6459 ft*
Estimated GH interval	*118*
Estimated GH saturation	*30-50%*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey an AC65 #1 well*

BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability

Target AC65-A
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test just updip of sand free AC 65 #1 well
Other Drilling in Vicinity	AC 65 #1 well

Table 2: Proposed Hole General Information

Site Name	AC65 A
General Area	*Diana Basin*
Location	26.91078 N, 94.90252 W
Coordinate Datum	*NAD 27*
Water Depth	*4853 ft*
OPD/Lease Block	*AC 65*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*6500 ft*
Seafloor slope	*< 1 degree*
Expected lithologies and thicknesses	*Shale to 5473 ft, sand from 5473 ft to 5533 ft, primarily shale from 5533 ft to 6500 ft*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*5473 ft*
Estimated depth to BGHS	*6440*
Estimated GH interval	*60 ft*
Estimated GH saturation	*30-50%*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey and AC 65 #1 well*

BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability

Target EB992-A
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test a thick spot close to the EB 992 #1 well
Other Drilling in Vicinity	EB 992 #1 well

Table 2: Proposed Hole General Information

Site Name	EB992-A
General Area	*Diana Basin*
Location	26.96947 N, 94.77536 W
Coordinate Datum	*NAD 27*
Water Depth	*4860 ft*
OPD/Lease Block	*EB 992*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*6900 ft*
Seafloor slope	*<1 degree*
Expected lithologies and thicknesses	*Shale to 5679 ft, sand from 5679 ft to 5846 ft, primarily shale from 5846 ft to 6900 ft*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*5679 ft*
Estimated depth to BGHS	*6665 ft*
Estimated GH interval	*167 ft*
Estimated GH saturation	*30-50 %*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey and EB 992 #1 well*

BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability

Target EB992-B
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test a thick to the northeast of the EBG 992 #1 well with higher amplitude, and what appears to be acoustic pull-up on the base of the sand, suggestive of faster velocity sands
Other Drilling in Vicinity	EB 992 #1 well

Table 2: Proposed Hole General Information

Site Name	EB992-B
General Area	*Diana Basin*
Location	26.97696 N, 94.7624 W
Coordinate Datum	*NAD 27*
Water Depth	4838
OPD/Lease Block	*EB 992*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*5450*
Seafloor slope	*<1 degree*
Expected lithologies and thicknesses	*Shale to 4956 ft, sand from 4956 ft to 5074 ft, primarily shale from 5074*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*4956 ft*
Estimated depth to BGHS	*6643 ft*
Estimated GH interval	*118 ft*
Estimated GH saturation	*30-50 %*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey and EB 992 #1 well*

BML: Below Mud Line
BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability

Target EB992-C
Drilling Target Documentation

Table 1: Background Information

General Site Objective	*Seismic sand anomaly*
Drilling target and Specific Hole Objective	Test the thickest spot at the EB 992 site, near the fault that traps the deep gas at Rockefeller Field
Other Drilling in Vicinity	EB 992 #1 well

Table 2: Proposed Hole General Information

Site Name	EB992- C
General Area	*Diana Basin*
Location	26.97653 N, 94.75293 W
Coordinate Datum	*NAD 27*
Water Depth	4833 ft
OPD/Lease Block	*EB 992*
Seismic lines at hole	*WesternGeco, T01_026 "Q" survey*

Table 3: Proposed Hole Drilling Information

Proposed penetration	*6250 ft*
Seafloor slope	*< 1 degree*
Expected lithologies and thicknesses	*Shale to 5636 ft, sand from 5636 ft to 5844 ft, primarily shale from 5844 ft*
Expected ages/section	*Upper Pleistocene*
Estimated depth to TGHO	*5636 ft*
Estimated depth to BGHS	*6648 ft*
Estimated GH interval	*208 ft*
Estimated GH saturation	*30-50 %*
Anomalous conditions?	
Other relevant information	
Source of Information	*WesternGeco, T01_026 "Q" survey and EB 992 #1 well*

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BSS: Below Sea Surface
TGHO: Top of Gas Hydrate Occurrence
BGHS: Base of Gas Hydrate Stability