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ADVANCED OIL RECOVERY TECHNOLOGIES FOR IMPROVED RECOVERY FROM SLOPE BASIN CLASTIC RESERVOIRS, NASH DRAW BRUSHY CANYON POOL, EDDY COUNTY, NM

Annual Report
October 1, 2000-September 30, 2001

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Strata Production Company
Roswell, New Mexico

National Energy Technology Laboratory
National Petroleum Technology Office
U.S. DEPARTMENT OF ENERGY
Tulsa, Oklahoma

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Advanced Oil Recovery Technologies for Improved Recovery from Slope Basin Clastic Reservoirs, Nash Draw Brushy Canyon Pool, Eddy County, New Mexico

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February 2002

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OBJECTIVE

The overall objective of this project is to demonstrate that a development program based on advanced reservoir management methods can significantly improve oil recovery at the Nash Draw Pool (NDP). The plan includes developing a control area using standard reservoir management techniques and comparing its performance to an area developed using advanced reservoir management methods. Specific goals are (1) to demonstrate that an advanced development drilling and pressure maintenance program can significantly improve oil recovery compared to existing technology applications and (2) to transfer these advanced methodologies to oil and gas producers in the Permian Basin and elsewhere throughout the U.S. oil and gas industry.

ABSTRACT

The Nash Draw Brushy Canyon Pool (NDP) in southeast New Mexico is one of the nine projects selected in 1995 by the U.S. Department of Energy (DOE) for participation in the Class III Reservoir Field Demonstration Program. The goals of the DOE cost-shared Class Program are to: (1) extend economic production, (2) increase ultimate recovery, and (3) broaden information exchange and technology application. Reservoirs in the Class III Program are focused on slope-basin and deep-basin clastic depositional types.

Production at the NDP is from the Brushy Canyon formation, a low-permeability turbidite reservoir in the Delaware Mountain Group of Permian, Guadalupian age. A major challenge in this marginal-quality reservoir is to distinguish oil-productive pay intervals from water-saturated non-pay intervals. Because initial reservoir pressure is only slightly above bubblepoint pressure, rapid oil decline rates and high gas/oil ratios are typically observed in the first year of primary production. Limited surface access, caused by the proximity of underground potash mining and surface playa lakes, prohibits development with conventional drilling.

Reservoir characterization results obtained to date at the NDP show that a proposed pilot injection area appears to be compartmentalized. Because reservoir discontinuities will reduce effectiveness of a pressure maintenance project, the pilot area will be reconsidered in a more continuous part of the reservoir if such areas have sufficient reservoir pressure. Most importantly, the advanced characterization results are being used to design extended-reach/horizontal wells to tap into predicted "sweet spots" that are inaccessible with conventional vertical wells.

The activity at the NDP during the past year has included the completion of additional zones in two wells, the design and drilling of the NDP Well #36 deviated/horizontal well, continued analysis of data, and the acquisition of interests belonging to non-consenting partners.

EXECUTIVE SUMMARY

The use of the advanced log analysis techniques developed from the NDP project have proven useful in defining additional productive zones and refining completion techniques. The

Advanced Log Analysis program proved to be especially helpful in locating and evaluating potential recompletion intervals, which has resulted in low development costs with only small incremental increases in lifting costs. To develop additional reserves at lower costs, zones behind pipe in existing wells were evaluated using techniques developed for the Brushy Canyon interval. Log analysis techniques developed in Phase I have been used to complete a total of 10 of the NDP wells in uphole zones. Four wells were recompleted in 1999, which allowed the development of economical reserves during a period of low crude oil prices. An additional four wells were recompleted during 2000, which resulted in 123,462 BO and 453,424 MCFG reserves being added at a development cost of $1.57 per B.O.E. Two wells, #29 and #38 were recompleted in 2001. The two most recent workovers have added 7,000 BO and 18 MMCFG to the reserves at a cost of $9.70 per BOE. Based on the technical and economic success of the 10 workovers, other project wells are being evaluated for completions in shallower zones. NDP Wells #1 and #20 are planned to be worked over in 2002.

In order to enhance the ultimate recovery from the NDP project, the plan submitted and approved for Phase II includes the drilling of directional/horizontal wells and consideration of early pressure maintenance designed to develop reserves under surface-restricted areas and potash mines. A major working interest owner sold its interest in the NDP. This has greatly simplified management of the project and has expedited the drilling of the first deviated/horizontal well during the second quarter of 2001.

Continued interpretation of the original 3-D seismic survey using the results from drilling NDP Well #36 has resulted in a more complete characterization of the Brushy Canyon reservoir. A new seismic survey is being designed for the north end of the NDP. This new survey will overlap the original survey in an attempt to determine undrained areas that are not pressure-depleted. Results of the new survey will be instrumental in identifying regions of the reservoir that will be targeted with deviated/horizontal wells in Phase II.

INTRODUCTION

The Nash Draw Pool (NDP) in Eddy County, New Mexico produces oil and associated gas from the Permian (Guadalupian) Brushy Canyon Formation. The Brushy Canyon is a relatively new producer in the Delaware Basin of West Texas, with most drilling having occurred since the late 1980s and many discoveries occurring in the 1990s. Regionally, the fine-grained sandstones of the Brushy Canyon contain as much as 400-800 MMbbls of oil-in-place and thus this formation represents a significant reservoir interval in the Permian Basin. However, low permeability and petrophysical heterogeneity limit primary recovery to only 10-16%.

The NDP is one of the project sites in the Department of Energy (DOE) Class III Field Demonstration Program for Slope-Basin Clastic Reservoirs. The objective of the NDP Class III project is to demonstrate that an advanced development drilling and pressure maintenance program can significantly improve oil recovery compared to existing technology applications. A further goal of the project is to transfer these advanced methodologies to oil and gas producers in the Permian Basin and elsewhere throughout the U.S. oil and gas industry.

In the first phase of the NDP project, an integrated reservoir characterization study was performed to better understand the nature of Brushy Canyon production and to explore options for enhanced recovery. Results obtained in the NDP project indicate that a combination of early pressure maintenance (gas injection) and secondary carbon dioxide flooding may maximize production in these complex, laterally variable reservoirs. Because of the low permeabilities involved and high water-to-oil relative permeabilities, the use of gas instead of water is suggested to be preferred as an oil-mobilizing agent.

The plan submitted and approved for Phase II is directed toward enhancing ultimate recovery from the project. The plan includes evaluation of prospects of early pressure maintenance and directional/horizontal drilling of new wells in order to develop reserves under surface-restricted areas and potash mines.

RESULTS AND DISCUSSION

This is the sixth annual progress report on the project. Results obtained in the first five years of the project are discussed in previous annual reports[1-5] and in technical papers.[6-13] Results obtained during this reporting period are summarized in this progress report.

Reporting

Early in the current project year, the Fifth Annual Technical Progress Report was prepared and submitted to the DOE. Four quarterly reports have been prepared and submitted for the period September 25, 2000 through September 25, 2001.

Well Drilling Plans

With the return of higher oil prices and the buyout of unsupportive non-consenting working interest owners, Strata was able to drill the NDP Well #36, a directional/horizontal well, in the second quarter of 2001. The well extended 3690 feet at a bearing of 296^o northwest with a bottomhole location in the SW/NE of Section 11 and the surface location in the NW/SW of Section 12.

The search for a 12,000-ft drilling rig to drill NDP Well #36 was initiated in December 2000. Due to the high demand for this size rig to drill Morrow gas wells, daily costs were increasing and availability diminished. Strata entered into a contract with J-W Drilling, Inc. of Artesia, New Mexico to take a new rig they were building and would have ready for service in the May-June time frame.

J-W Drilling Rig #3 was moved to the Nash Draw #36 location on June 21 and rigged up. The rig started drilling on June 25. Surface casing (13.375 in.) was set at 305 ft and cement was circulated on June 28. Intermediate casing (8.625 in.) was set at 3112 ft and cement was circulated to the surface on July 4. The directional drillers, triplex mud pump and mud cleaning equipment were installed and drilling resumed July 7. The well was drilled to a total measured depth of 9786 ft. and 5.5 in. casing was run to total depth (TD). In preparation for completion of the toe, 19 ft of 4.75 in. open-hole was drilled to 9805 ft. A summary of the daily log is presented in Table 1 and a three-dimensional plot of the actual well trajectory is presented in Fig. 1.

The proposed well plan (Fig. 2) called for a kick-off point (KOP) at 3171 ft with a build rate of 2°/100 ft to an inclination of 10°, then a KOP at 6422 ft with a build rate of 12°/100 ft to a inclination of 90°, continuing horizontally for 4000 ft at an azimuth of 296.39° (total planned section 4949.04 ft) with a change in inclination to 91.22°, to follow the main porosity updip as shown by the seismic.

The actual trajectory (Fig. 1) followed the planned trajectory within the window given to the directional drillers. Due to drilling problems, the section was shortened by 1259 ft, from 4949 ft to 3690 ft. The main objective was reached with the shortened section and the well achieved TD in the main seismic anomaly. The original plan was to drill completely through the anomaly and perform multiple completions spaced along the wellbore in strategic locations. The alternate plan was to perform one large frac treatment at the toe and multiple frac treatments adjacent to good shows and high seismic amplitudes.

One problem occurred that was related to the drilling of the intermediate hole blind. Below the 8.375 in. casing point at 3133 ft, the wellbore was deviated at 1.65° at an azimuth of 159.48°; at 3209 ft the wellbore was deviated at 1.66° with an azimuth of 252.05°. This rapid turn resulted in a change of direction of 92.57° in 76 ft, creating a potential dogleg problem. While the inclination was small and the deflection only ± 5 ft, the last trip out of the hole for bit #6 indicated drag through this part of the hole and the necessity to work the pipe through this interval. Subsequently, a keyseat wiper was run and the hole smoothed out from 3133 ft to 3600 ft. A vertical view of the well path trough at 3500 ft is presented in Fig. 3.

To alleviate this situation in future wells, a deviation survey should be run prior to reaching total depth on the intermediate hole so that any corrections can be made prior to setting casing.

Wellbore path steering problems resulted in numerous areas of high build rate. A correction in direction would be planned and the necessary slide would be applied, but little change in angle would be recorded. More severe slides were tried to build angle with only small changes in build rates. Finally, after numerous attempts to build angle, the path would make a sharp turn with the resulting build rate being too tight. A build angle of 12°/100 ft was planned for the curve section; with a 1.5° bent sub, a build angle of 10° to 11°/100 ft was achieved. This was only about two-thirds of the build rate that was expected. A 2.9° bent sub was run to build more angle, but this run resulted in a build rate in excess of 18°/100 ft. Through trial and error, the bottomhole assemblies (BHAs) and weight were determined to build the required angles.

With the numerous doglegs and the horizontal section, drag became a problem that limited the amount of weight that could be applied to the bit. An extreme pressure lubricant, EPL-50, was mixed in the mud at a 1% concentration, to aid in friction reduction. The use of EPL-50 reduced drag by as much as 50%. During the running of the 5.5-in. casing, a pill containing EPL-50 and glass beads was spotted in the horizontal section to reduce friction. The casing was run to TD without problems, but when the hole was circulated prior to cementing, the lubricant was displaced and the casing drag increased to the point that the casing could not be moved.

Drill bits used in the horizontal section had unsatisfactory run times. Bits 10, 11, 12 and 13 were short runs ranging from 24.5 hours to 48 hours (Table 2). The primary bit damage occurred to the gauge protection of the bit. The bits would become out of gauge and the motor stabilizer would drag excessively, which necessitated a bit change. Reed HP-52 bits were used because of their good gauge protection. Due to very abrasive sands, however, this gauge protection was inadequate and bit runs were unacceptable. On future wells the bit used in the horizontal section will have more gauge protection to allow longer bit runs and reduce trip time and setup time.

The "L" zone seismic amplitude was used to define the targets for the well path of NDP Well #36 (Fig. 4). While drilling the horizontal section a gamma ray and a mud log were obtained (Fig. 5). The logs showed close agreement with what was anticipated from the 3-D seismic survey. Drilling rates and shows increased in high amplitude areas while shows declined, drilling rates dropped, and shale content increased in low amplitude areas. Production will confirm the quality of the seismic anomalies, but preliminary results indicate a close relationship between the seismic amplitudes and reservoir quality. Figure 6 shows the well path in relationship to the seismic top of "L" zone. The top of the "L" zone was encountered at –6789 ft, with 971 ft of displacement from the surface location. This reference point was used to hang the calculated seismic "L" top to direct the well path updip as progress was made in the northwest direction. To acquire data along the axis of deposition, Strata plans to complete a supplemental 3-D seismic survey over the north end of the NDP.

Two options are available to complete the horizontal section, 1) cement casing in the horizontal section and perform multiple stimulation treatments at optimum spacing or, 2) run a ported liner and perform one large stimulation treatment to induce multiple fractures. By cementing the casing across the horizontal section and completing the well in stages, there is a high degree of confidence that hydraulic fractures would be initiated where desired. The ported sub system relies on a "limited entry" design to distribute fluid equally between the ported subs. It is unknown whether each set of ported subs will initiate a single large fracture system, or if the fluid will migrate in the annulus and initiate many uncontrolled fractures. Option #1 was selected to insure that all potentially productive intervals were stimulated. The first three intervals were scheduled for completion and testing in October 2001.

The well is currently being completed and a complete analysis of the completion will be presented in the next quarterly report. If this well is successful, this will be the first successful horizontal Brushy Canyon completion in southeastern New Mexico, the first coiled tubing-Mohave fracturing treatment in a horizontal well, and the first application of 2.375-in. diameter coiled tubing in the Permian Basin.

Data and Databases

The NDP production database was updated through September 2001. These data were added to the history of each well to update the decline curves and to project ultimate recoveries as well as to assess the effects of interference and production strategies.

Acquisition of Interests

The sale of the Murchison Oil and Gas, Inc. interests in the NDP were finalized on December 1, 2000. This purchase allowed the interested parties to proceed with the drilling of the NDP Well #36 and will allow future work on the NDP to be expedited.

Technology Transfer

Disseminating technical information generated during the course of this project is a prime objective of the project. A summary of technology transfer activities during this quarter is outlined below.

Internet Homepage: The address of the Website for the NDP project is: http://baervan.nmt.edu/REACT/Links/nash/strata.html. This site includes the annual reports and the final Phase I report, including graphics.

Nash Draw Meeting: In the course of acquiring the 50%+ interest from Murchison, multiple meetings were held to discuss planning, economics and financing. During these meetings the NDP project was discussed in detail and the results of the project were shown to many different companies and individuals.

SPE paper No. 70041, "Estimating Bulk Volume Oil in Thin-Bed Turbidites," was presented at the Permian Basin Oil and Gas Recovery Conference in Midland, Texas on May 15-16, 2001.

CONCLUSIONS

Several conclusions can be drawn from the work performed during the sixth year of the NDP project. The use of the advanced log analysis techniques developed from the NDP project have proven useful in defining additional productive zones and refining completion techniques. The 3-D seismic survey has proven to be a useful tool to define areas for potential development. Drilling a deviated/horizontal well to develop reserves in an area not accessible by vertical drilling is possible. Completion technology has not advanced as quickly as drilling technology and the completion of a deviated/horizontal well may be the most challenging phase of this project.

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Table 1. Daily Drilling Log

Date	Activity	TVD, Ft.	MD, Ft.	E-W	N-S	Dev.	Azimuth
6-26	Drilling 17 ½" hole	94	94	.94W	.05N	1.08	356.84
6-27	Setting 13 3/8" surface casing	305	305	1.05W	3.77N	.52	340.7
6-28	Nipple up B.O.P.	305	305	1.05W	3.77N	.52	340.7
6-29	Drilling 11" hole	770.9	771	3.38W	9.70N	.45	340.8
6-30	Drilling 11" hole	1704.8	1705	12.38W	8.34N	1.37	233.63
7-1	Drilling 11" hole	2205.6	2206	17.13W	5.98S	2.64	201.41
7-2	Drilling 11" hole	2519.3	2519	20.29W	19.39S	3.07	192.15
7-3	Setting 8 5/8" intermediate casing	3110.6	3112	15.47W	45.68S	1.98	150.08
7-4	Nipple up BOP	3110.6	3112	15.47W	45.68S	1.98	150.08
7-5	Drill out cement	3110.6	3112	15.47W	45.68S	1.98	150.08
7-6	P.U. MDW assembly #1	3110.6	3112	15.47W	45.68S	1.98	150.08
7-7	Drill 7 7/8" hole	3169.4	3171	14.8W	47.6S	1.2	183.62
7-8	Drill 7 7/8" hole	3378	3380	29.5W	45.9S	6.94	282.39
7-9	Drill 7 7/8" hole	3856.2	3865	102.1W	15.8S	10.38	299.44
7-10	Drill 7 7/8" hole	4085.1	4098	139.7W	7.5N	10.85	304.2
7-11	Drill 7 7/8" hole	4428.3	4447	192.9W	41.7N	10.95	303.25
7-12	Drill 7 7/8" hole	4814.7	4840	254.3W	80.8N	10.64	300.89
7-13	Drill 7 7/8" hole	5268.2	5300	317.9W	115.9N	10.02	298.31
7-14	Drill 7 7/8" hole	5672.4	5710	379.1W	146.2N	9.79	300.6
7-15	Drill 7 7/8" hole	6036.5	6080	442.8W	177.9N	9.39	295.62
7-16	Ream keyseat 3370-3400'	6036.5	6080	442.8W	177.9N	9.39	295.62
7-17	Drill 7 7/8" hole	6327.8	6340	483.3W	196.2N	10.01	293.5
7-18	Drill 7 7/8" hole	6410.2	6486	498.3W	202.5N	13.74	292.43
7-19	Drill 7 7/8" hole	6527.3	6607	538.1W	218.5N	26.78	292.05
7-20	Drill 7 7/8" hole	6581.7	6677	567.2W	230.9N	33.44	294.38
7-21	Drill 7 7/8" hole, 2.9^0 bent sub	6631.6	6756	600.2W	247.2N	39.42	298.14
7-22	Drill 7 7/8" hole, 2.12^0 bent sub	6716.8	6882	685.7N	295.9W	60.85	300.23
7-23	Drill 7 7/8" hole, 1.5^0 bent sub	6771.9	7022	810.4W	372.9N	75.81	302.94
7-24	Drill 7 7/8" hole	6785.4	7080	860.1W	407.3N	79.37	304.41
7-25	Drill 7 7/8" hole	6804.3	7200	963.5W	474.8N	83.58	301.12
7-26	Drill 7 7/8" hole, Completed turn	6815.7	7428	1155.1W	579.8N	90.34	297.28
7-27	Drill 7 7/8" hole	6816.4	7669	1380.3W	688.2N	89.79	293.58
7-28	Drill 7 7/8" hole	6814.9	8018	1696.4W	821.4N	91.55	292.93
7-29	Drill 7 7/8" hole	6814.4	8270	1923.9W	927.2N	90.79	296.02
7-30	Drill 7 7/8" hole	6813.7	8294	1976.1W	952.5N	90.68	295.70
7-31	Drill 7 7/8" hole	6812.4	8472	2117.6W	1020.5N	89.31	295.06
8-1	Drill 7 7/8" hole	6811.9	8634	2258.6W	1087.3N	92.41	295.66
8-2	Drill 7 7/8" hole, abrasive sand, bit #10, 48 hrs. 381', -3/8", problems holding angle	6810.0	8675	2291.1W	1102.6N	93.76	294.73
8-3	Drill 7 7/8" hole	6785.3	8898	2487.5W	1196.2N	96.02	296.20
8-4	Drill 7 7/8" hole, bit #11, 24.5 hrs., 258', -1/8"	6779.6	8953	2540.0W	1222.6N	94.82	297.15
8-5	Drill 7 7/8" hole	6767.7	9216	2786.6W	1358.7N	91.41	298.71
8-6	Drill 7 7/8" hole, bit #12, 29 hrs., 318', -3/16"	6768.9	9325	2865.3W	1402.4N	88.25	299.41
8-7	Drill 7 7/8" hole	6771.9	9475	3001.3W	1478.7N	89.45	299.73
8-8	Drill 7 7/8" hole, MWD quit	6765.6	9786	3283.8W	1641.2N	91.68	300.15
8-9	Logging vertical section		9786				
8-10	TIH to spot 140 bbls. "slick pill"		9786				
8-11	Run 5 ½" casing & cement, released rig 3:00 PM 8-11-01		9786				(Section 3671.2'@ 296.6^0)
9-29	TIH W/ Bit, motor & 2 7/8" 7.9 #/ft. PH-6, P-110 tubing, D.O. 9786-9805', 19' O.H.		9805 T.D.				Section 3690'@ 296.6^0

Table 2. Drill Bits

Drill Bits

	Size	Manufacturer	Style	Footage	Hours	Rate	Comments
1	17 1/2”	Security	EDT	305 ft.	8.50 hrs.		
2	11”	Security	ERA	2807 ft.	97.75 hrs.		
3	7 7/8”	Hughes	38-E	281 ft.	10.25 hrs.		
4	7 7/8”	Reed	HP-52	927 ft.	47.00 hrs.	19.72 ft./hr.	
5	7 7/8”	Reed	HP-52	1982 ft.	98.25 hrs.	20.2 ft./hr.	
6	7 7/8”	Reed	HP-53	406 ft.	35.50 hrs.	11.4 ft./hr.	Loose Bearing
7	7 7/8”	Reed	HP-53	270 ft.	25.00 hrs.	10.8 ft./hr.	
8	7 7/8”	Reed	HP-52	560 ft.	62.25 hrs.	9.0 ft./hr.	
9	7 7/8”	Reed	HP-52	1248 ft.	103.80 hrs.	12.03 ft./hr.	-3/8” out of gauge
10	7 7/8”	Hughes	MS30C	381 ft.	48.00 hrs.	7.94 ft./hr.	-3 /8” out of gauge
11	7 7/8”	Reed	HP-52	258 ft.	24.50 hrs.	10.5 ft./hr.	-1/8” out of gauge
12	7 7/8”	Reed	HP-52	318 ft.	29.00 hrs.	11 ft./hr.	-3/16” out of gauge
13	7 7/8”	Reed	HP-52	461 ft.	29.80 hrs.	15.5 ft./hr.	-1/8” out of gauge
	Total				619.60 hrs. (25.82 Days)		

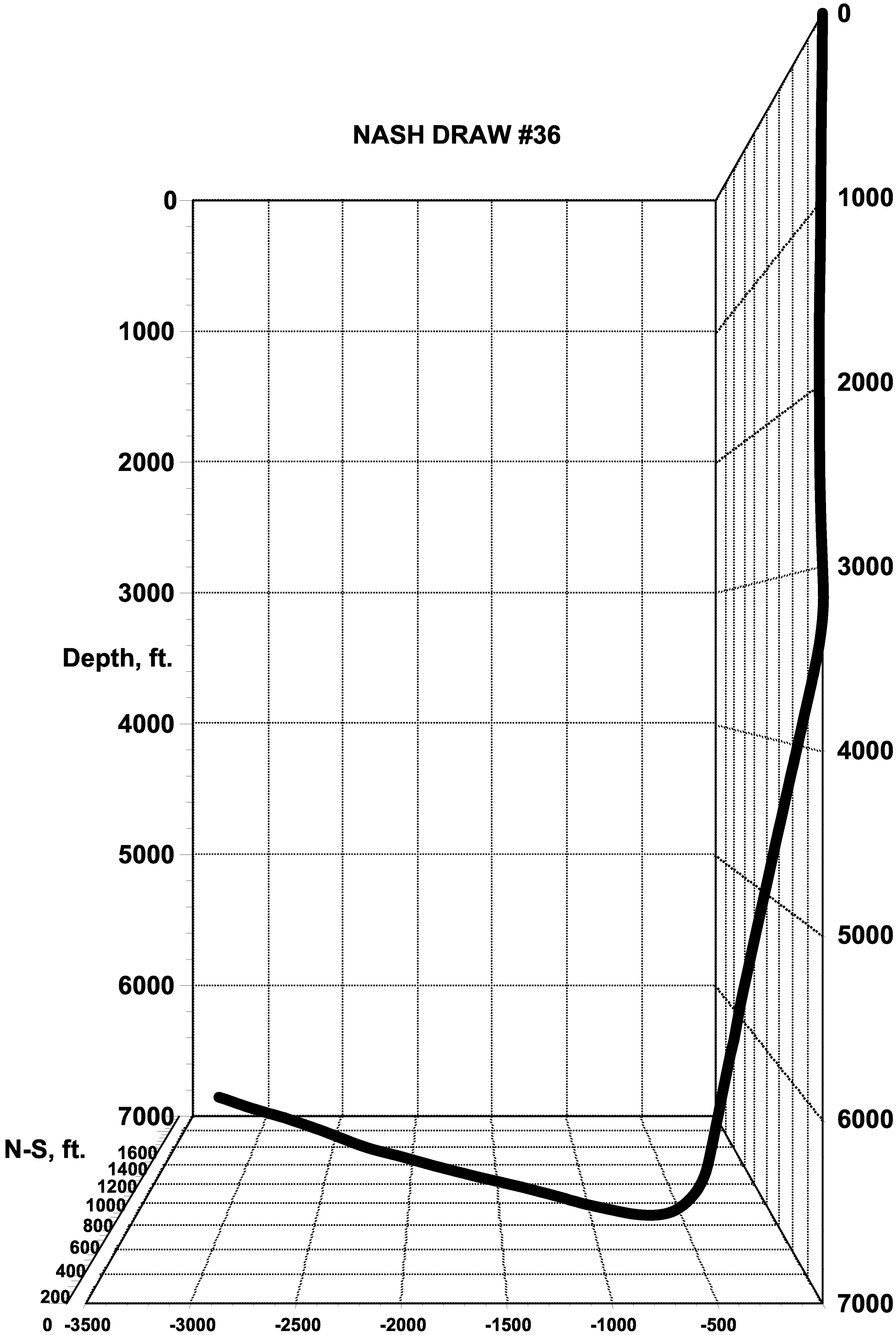

Fig. 1. Nash Draw #36 3-D view – actual trajectory as of 9-29-01.

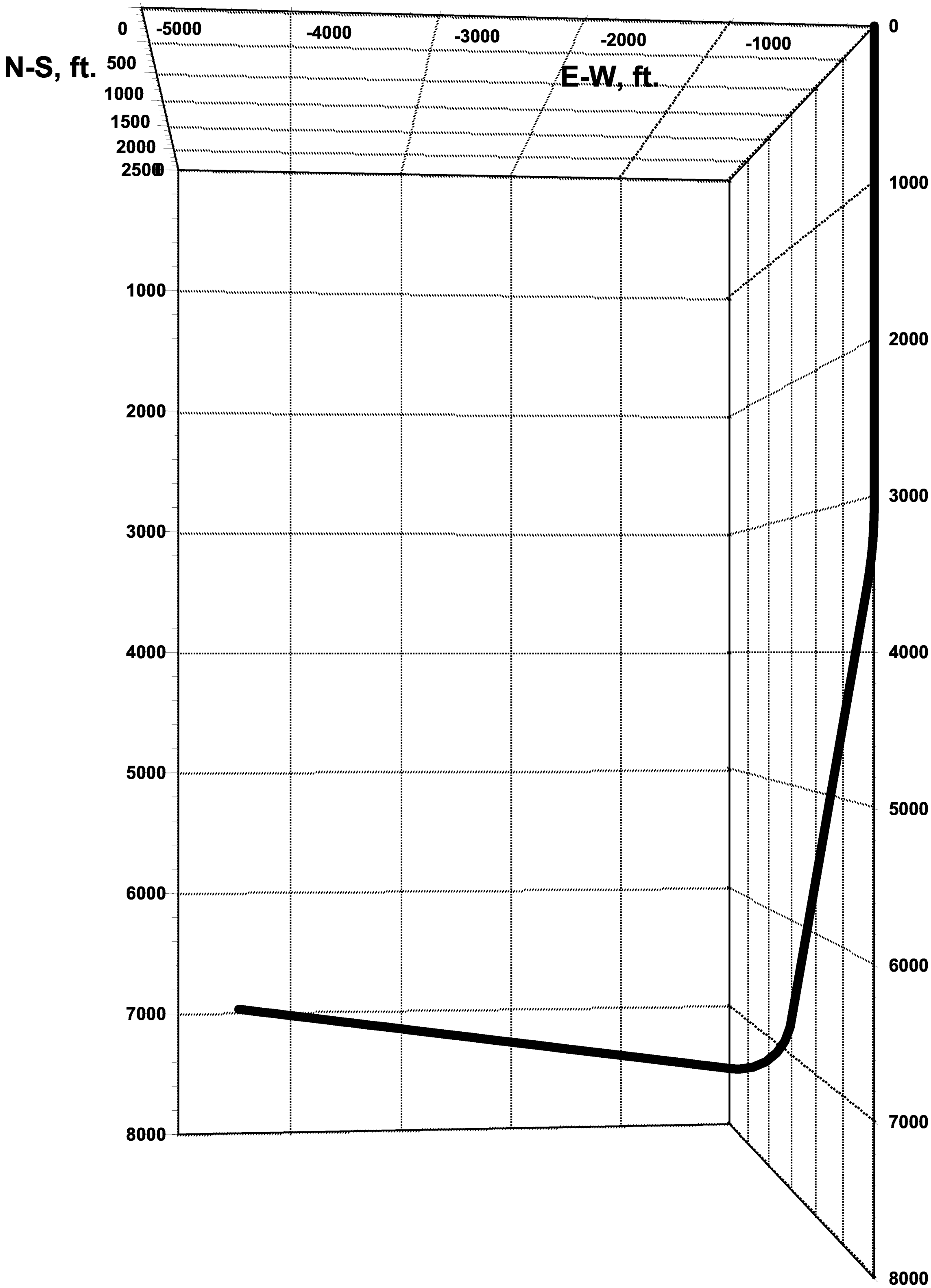

Fig. 2. Proposed well trajectory.

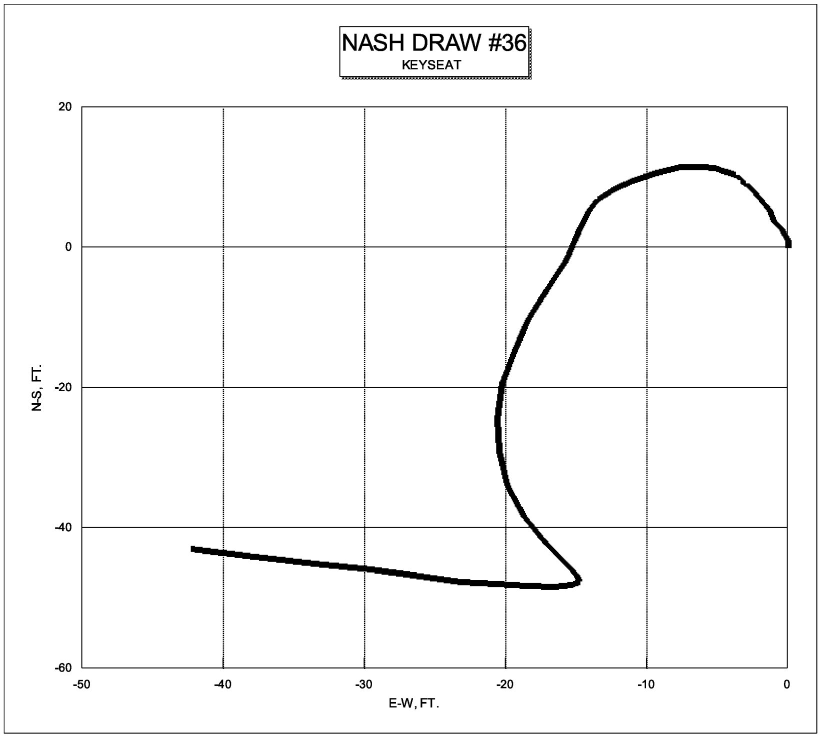

Fig. 3. Vertical view of well trajectory showing the potential keyseat.

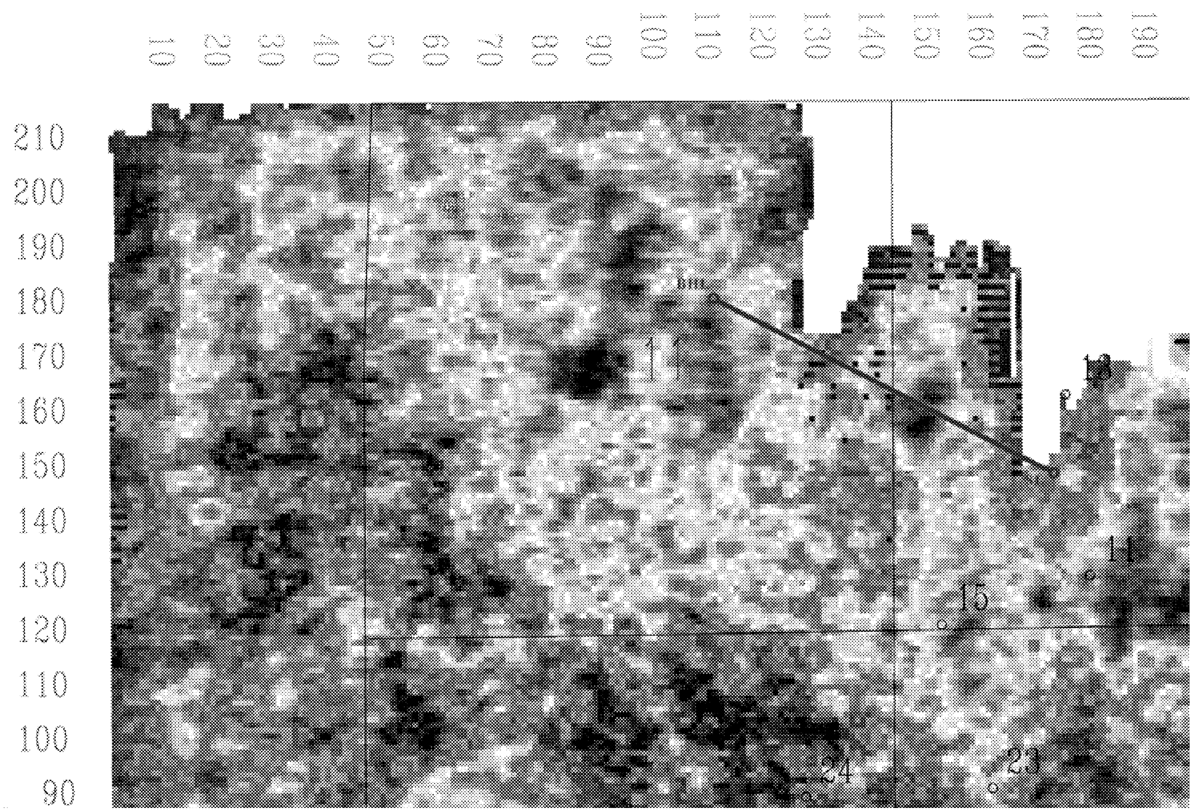

Fig. 4. Seismic amplitude map with Nash Draw #36 well path.

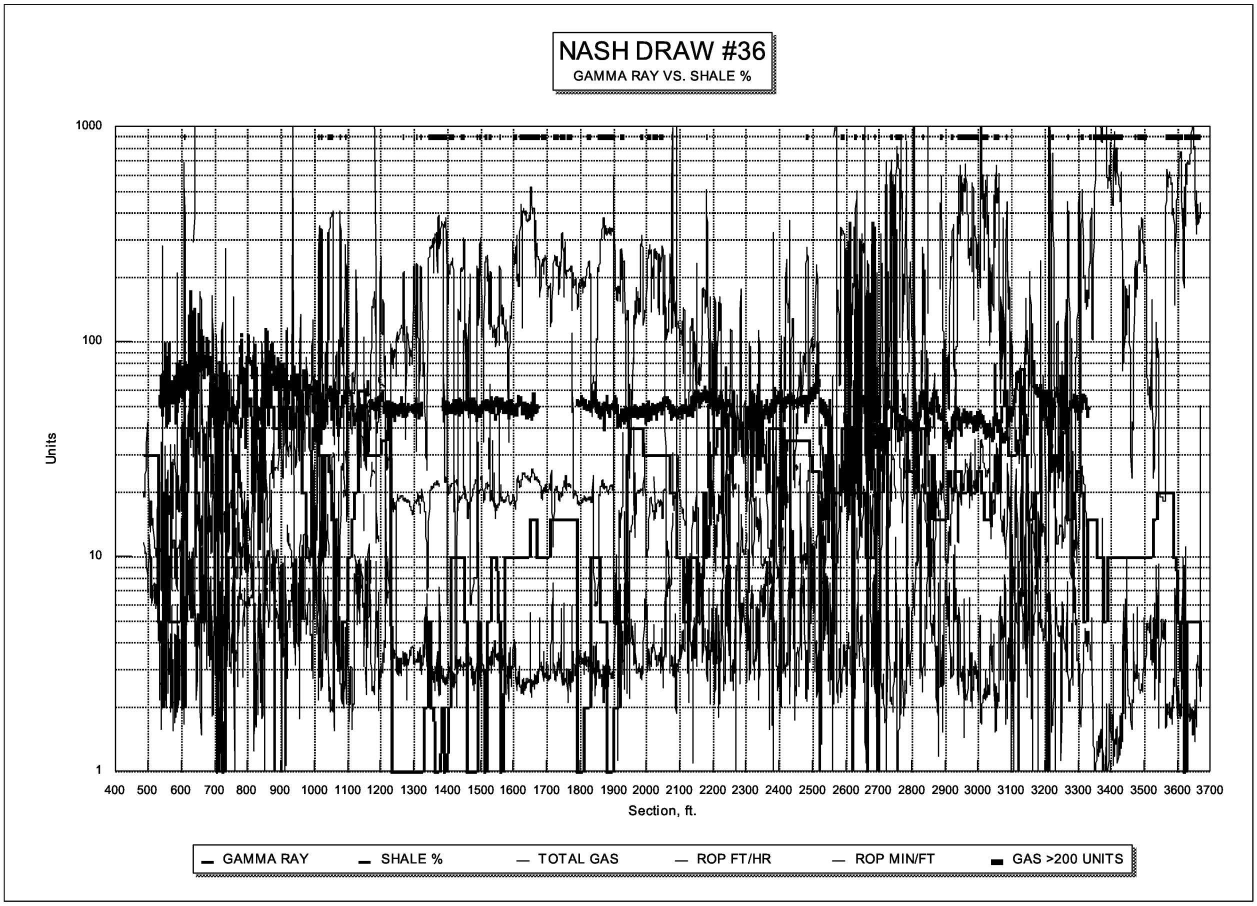

Fig. 5. Mud log and gamma ray.

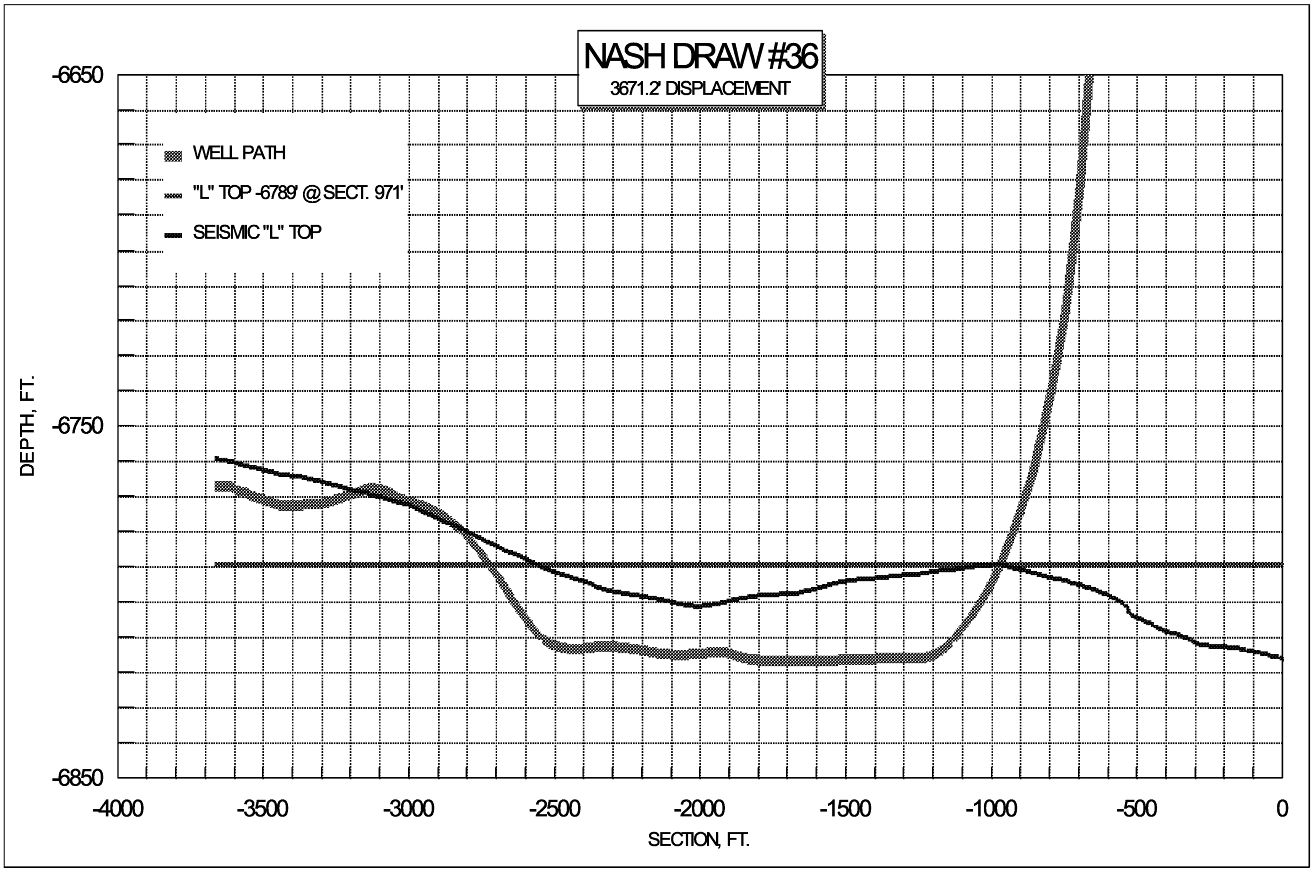

Fig. 6. Well path.