Chapter 4
Desert Springs, Playa-Lewis, and Desert Springs West Fields Sweetwater County, Wyoming

4.1
INTRODUCTION

The Desert Springs area fields are located about 30 miles (48 km) east of Rock Springs in the Wamsutter Arch area of south-central Wyoming (Figure 4.1). The fields are part of a large grouping of fields which produce gas from stratigraphic traps in Upper Cretaceous sandstones, located primarily in the Lewis Shale and the Almond Formation. As shown in Figure 4.2, the gas fields often connect with each other, so the distinction between Desert Springs Field and Patrick Draw, or between Playa-Lewis and Desert Springs West, is rather vague.

A single line was run in an east-west direction using 2,000-foot (610 m) dipoles. The line traversed the Desert Springs, Playa-Lewis, and Desert Springs West fields.

4.2
GEOLOGIC BACKGROUND

Exploration History of the Desert Springs Area

Although a few shallow holes were drilled north of the Wamsutter Arch during the early 1920s, exploration south of the arch was neglected until the 1940s due to the great depths to potentially productive sandstones and due to the lack of promising surface structures. The first productive well in the area was drilled into the crest of the Table Rock anticline in 1946. Gas was found at 3,300 feet (1,000 m) in the lower sandstone of the Hiawatha member of the Wasatch Formation, a Tertiary unit, but later drilling cast doubt upon the economic potential of Tertiary sands due to their discontinuous nature. Gravity and seismic methods were used extensively during the next decade, and while surface mapping was relatively unproductive, the combination of structural mapping and the search for production in deeper horizons known to be productive elsewhere led to a dramatic increase in leasing in the area. The result of these exploratory efforts was the 1954 Table Rock discovery well, which produced gas from sandstones in the Lewis Shale and the Almond Formation, both of Cretaceous age. This drilling, plus the success of a

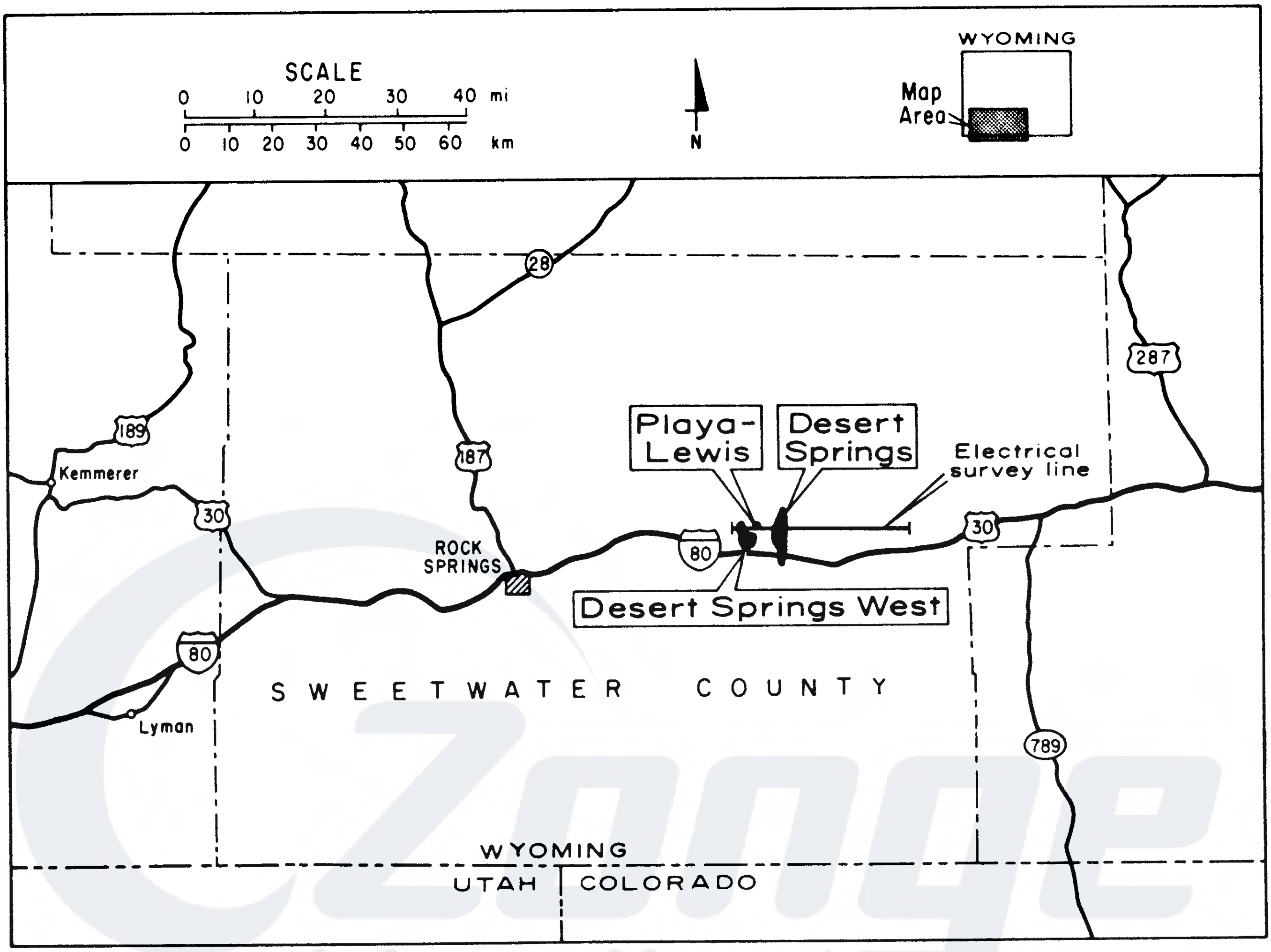

Figure 4.1. Location map of Desert Springs, Playa-Lewis, and Desert Springs West fields.

second well at Table Rock Southwest, constituted the first proof of stratigraphic reservoir potential in Cretaceous rocks in the Green River Basin.

In 1958, the El Paso Natural Gas Company drilled a well north of Table Rock based upon a seismic anomaly which was thought to represent a large, crescent-shaped fault closure. The seismic interpretation proved to be incorrect, but the well was fortuitously successful and produced gas from the Almond Formation from 5,887 to 5,954 feet (1,794-1,815 m). The new field, designated Desert Springs, was purely stratigraphic in nature. During 1959 and 1960, the Desert Springs production was rapidly extended southward (Arch Unit), and new discoveries were made at Patrick Draw, Playa-Lewis, and Beacon Ridge. Patrick Draw proved to be one of the most productive discoveries, and briefly ranked as the third most prolific producer in Wyoming. The discoveries of this period are summarized in Table 4.1, and are located on the map of Figure 4.2.

The future of gas production in the greater Green River Basin is fairly promising. McPeek (1981) estimates that more than 20 TCFG may be produced from a 3,000 square mile (7,800 sq km) geopressured zone of the eastern basin.

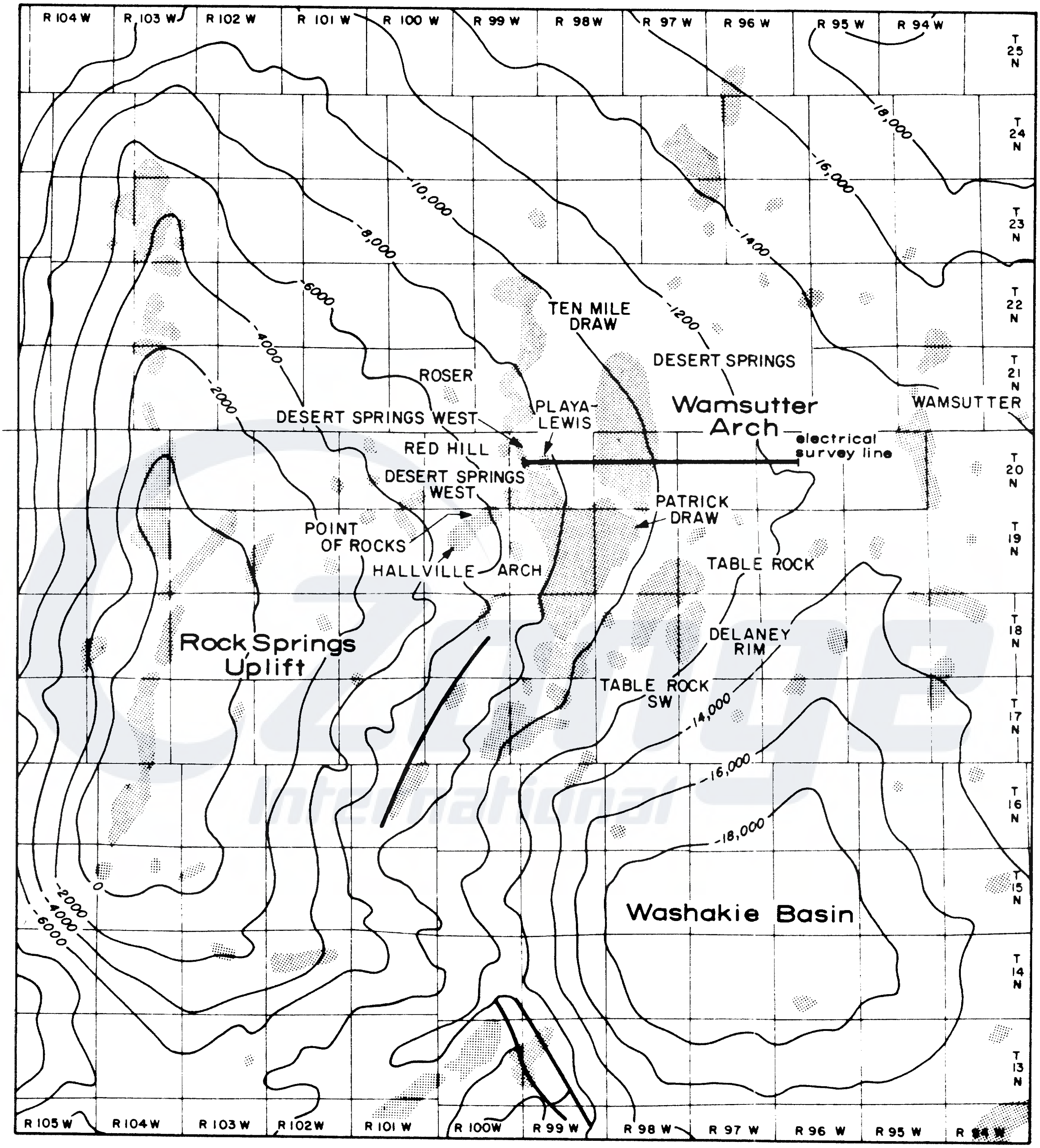

Figure 4.2. Map of oil and gas fields of the Wamsutter Arch area of southwestern Wyoming. Structure contours on top of the Phosphoria Formation. Contour interval: 2,000 feet (610 m). After Peppard-Soulders (1979).

TABLE 4.1
SOME OIL AND GAS FIELDS IN THE WAMSUTTER ARCH AREA

Field Name	Type of Trap	Productive Area (acres)	Producing Formation	Reserves	Discovery Date	Est. Ultimate Production Gas (BCFG)	Est. Ultimate Production Oil (MMBO)
Delaney Rim	Strat	3,360	Lewis	Oil	8/30/75	1.3	3.57
			Almond	Gas	5/17/76	0.2	– –
Desert Springs	Strat	28,800	Lewis "e"	Gas, oil	5/1/58	210	1.85
			Almond	Gas, oil	3/27/58	200	.65
Desert Springs West	Strat	3,880	Almond	Gas, oil	5/25/59	15	.74
Hallville	Struc-strat	80	Almond	Oil	12/20/62	– –	.06
Patrick Draw	– –	21,340	– –	– –	– –	?	66.47
Arch Unit, west	Strat	8,010	Almond	Oil	4/18/59	– –	23.43
Arch Unit, east	Strat	2,800	Almond	Gas	4/14/60	37	– –
Monell Unit	Strat	8,530	Almond	Oil, gas	11/11/59	considerable	39.39
North Unit	Strat	2,000	Fox Hills	Gas	8/28/61	4.4	– –
			Almond	Oil	5/22/61	2.6	3.65
Playa-Lewis	Strat	22,538	Almond	Gas	10/31/63	9	– –
Point of Rocks	Strat	?	Blair	Gas	9/27/63	2.3	– –
			Frontier	Gas	3/19/73	48	– –
Robin	Strat	640	Almond (upper)	Oil, gas	4/16/72	0.3	.21
			Almond (lower)	Oil, gas	10/18/71	2	?
Roser	Strat	320	Almond	Gas	10/7/71	?	– –
Table Rock, Table Rock SW	Struc-strat	15,000^{+}	Wasatch	Gas	5/4/46	1	– –
			Lewis	Oil, gas	3/9/54	50	.50
			Almond	Oil, gas	2/1/54	170	2.00
			Dakota	Gas	10/1/77	?	?
			Nugget	Gas	9/8/65	450	– –
			Weber	Gas	11/16/76	75	– –
			Madison	Gas	7/30/75	350	– –
Ten Mile Draw	Strat	1,500	Lewis	Gas	6/27/72	6	– –
			Almond	Gas	6/27/72	1.0	– –
Wamsutter	Strat	12,160	Lewis	Gas	4/29/77	25	– –
			Almond	Gas	6/13/58	118	0.4

Geologic History of the Desert Springs Area

The post-Jurassic geologic history of the Wamsutter Arch area of south-central Wyoming is dominated by major uplift and folding beginning in the late Cretaceous and by a succession of transgression-regression sequences of late Cretaceous seas. Since no wells have penetrated deeper than the upper-middle Cretaceous Ericson Sandstone in the area, little is known of the origins of the underlying rocks in the immediate vicinity. The stratigraphy common to the Wamsutter Arch fields is described in Table 4.2.

The Baxter Shale contains a sequence of silty shales and sandstones deposited on the floor of relatively shallow Cretaceous seas which crossed the North American continent in a relatively narrow north-south trough. Baxter deposition was accompanied by minor uplift in the area of southwestern Wyoming, resulting in a lenticular sandstone unit composed of reworked clastic sea sediments laid down in shallow waters. Subsequent fine-grained sandstones of the Blair Formation were deposited in connection with emergent sand islands and deltaic sands resulting from retreat of the Cretaceous seas.

TABLE 4.2: STRATIGRAPHIC DESCRIPTION OF DESERT SPRINGS, PLAYA-LEWIS, AND DESERT SPRINGS WEST FIELDS

System	Symbol	Formation	Lithologic Description
CENOZOIC ROCKS			
Tertiary			
Eocene	Tw	Wasatch Fm.	Shales
	Twh	Hiawatha Mbr.	Claystones and fluvial sandstones
		(unconformity)	
Paleocene	Tfu	Fort Union Fm.	Sandstones, siltstones, shales, and coal beds
MESOZOIC ROCKS			
		(unconformity)	
Cretaceous	Kl	Lance Fm.	Sandstones, siltstones, shales, and coal beds
	Kfh	Fox Hills Ss.	Sandstones
	Kle	Lewis Sh.	Shallow marine and littoral shales and sandstones; *sands form a major reservoir in Desert Springs area fields*
		Mesa Verde Group	
	Kal	Almond Fm.	Shales, siltstones, and sandstones
		Zone I	No production, minor gas shows
		Zone II, "B_1 sand"	*Productive zone in Desert Springs area fields*
		Zone III, "B_2 sand"	*Productive zone in Desert Springs area fields*
		Zone IV (Lower Almond)	Shales, siltstones, and coal beds; no significant reservoir potential
	Ke	Ericson Fm.	Sandstones; numerous gas shows
	Kr	Rock Springs Fm.	Facies change from carbonaceous shales, sandstones and coal beds northwest of the field area to littoral and shallow marine sandstones and shales toward the southwest
	Kbl	Blair Fm.	Fine-grained sandstone lentils
	Kba	Baxter Sh.	Silty shales with an intermediate sandstone and shale member (the "Airport Ss.")

The Rock Springs Formation consists of a sequence of non-marine to marine rocks deposited along the shoreline of the eastward-retreating late Cretaceous seas. The facies changes from sandstone/shale/coal-bed rocks in the northwest to fine-grained littoral, shallow marine sandstones and shales toward the southeast indicate that the seas deepened to the east. This depositional pattern was fairly stable until the uplift of the north-south trending Church Buttes Anticline. Uplifted material was eroded and carried away by braided streams in a large, fan-shaped delta which covered southern Wyoming, northwestern Colorado, and northeastern Utah. These deposits comprise the bulk of the Ericson Formation, which consists mostly of sandstones.

Deposition in a shallow embayment in the area of the future Rock Springs Uplift resulted in the Almond Formation, which consists of interbedded shales, siltstones, sandstones, and coal laid down in the low energy coastal plain, tidal flat, and swamp environments of the embayment. Littoral sands in the upper Almond constitute one of the two major reservoir rocks in the Desert Springs area.

After deposition of the Almond Formation, the seas began a final advance from the east, leaving the alternating sequences of shales, beach deposits, reworked Almond sands, and offshore bar sands which characterize the Lewis Shale. A single sandstone reservoir in the Lewis Shale constitutes a second primary reservoir of the Wamsutter Arch area. As was the case with the Rock Springs deposition, deeper seas toward the east resulted in a facies change from western shoreline sands to eastern shales (see Figure 4.3 for an illustration of these environments).

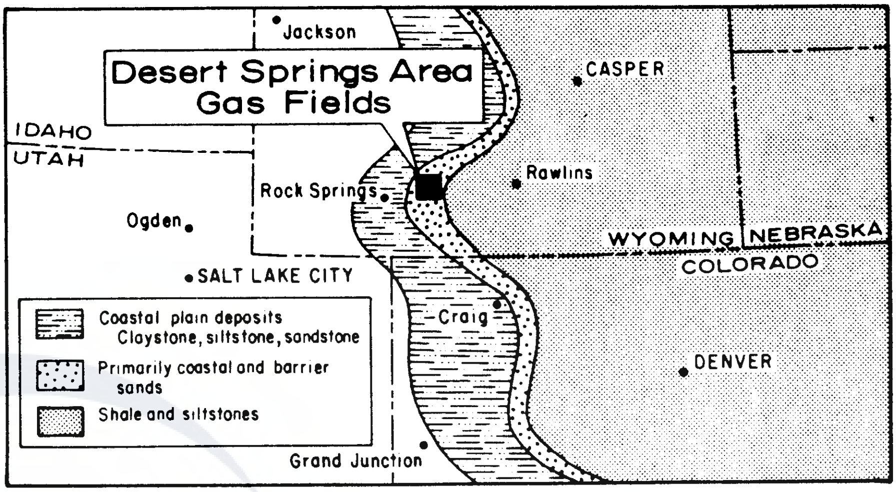

Figure 4.3. Map of the Cretaceous seas at the time of deposition of the Upper Almond Formation. The seaway formed a narrow corridor between the Gulf of Mexico and Canada. After Richers et al. (1982).

Beginning in the late Cretaceous, central Wyoming was subjected to extensive upwarping along a northeast trend extending from the Rock Springs uplift to northwestern Colorado. This trend was known as the Table Rock Platform or Anticline. The episode of uplift was followed by deposition of Lance (late Cretaceous) and Fort Union (Paleocene) sediments. These two units are virtually indistinguishable, and involve sandstones, siltstones, shales, and coal, all deposited in moist lowland environments. The gradual transition to higher, drier environments which resulted from continued sea regression and local uplift continued through the mid-Eocene. Sediments of this age include Hiawatha claystones and fluvial sandstones, which characterize flood plain and savanna environments.

During the early Eocene, the uplifting activity of the Table Rock Platform subsided, and structural activity shifted to the Overthrust Belt of western Wyoming and to the present-day locations of the Wind River Mountains and the Uinta Mountains. Sedimentation during this period of relative quiescence was characterized by the shallow lacustrine deposits of the Green River Formation. According to Ritzma (1963), sedimentation patterns were mostly unaffected by the Table Rock uplifting.

A resumption of structural activity began in the latter half of the Eocene and continued through the Oligocene. It was during this time that the Rock Springs Uplift and folding of the Wamsutter Arch occurred, possibly as a result of the emplacement of a batholith at depth. Folding was accompanied by a series of east-west normal faults extending along part of the fold axis. The Wamsutter Arch, which extends east-west from the Rock Springs Uplift past the Wamsutter gas field, plunges steeply toward the east. The structural relief is nearly 20,000 feet (6,000 m) from the deeper portions of the Washakie Basin to the projected crest of the Rock Springs Uplift. Rocks in the Table Rock Platform were tilted some five to eight degrees toward the east and southeast, allowing previously emplaced hydrocarbons to escape into new stratigraphic traps. Ritzma (1963) notes that oil traps currently occupy a higher structural position on the Wamsutter Arch than do gas traps, and he concludes that the trapped hydrocarbons did not migrate significantly when the local dip of sediments was slowly reversed during the folding episode.

By the end of the Oligocene, the major portion of the structural uplift and folding had ended, although some minor activity may have continued through the Pliocene. Volcanic activity commenced during this time, resulting in lava and ash flows. The source of this material was located in the Leucite Hills to the northeast of the Rock Springs Uplift, and volcanism may have continued into the late Pleistocene.

Current Geology

The electrical line location with respect to the producing fields is shown in Figure 4.4. The structure of the top of the Almond Formation is shown in Figure 4.5. The eastward dip of the structure represents the east flank of the Rock Springs Uplift. The dip is about five degrees, as illustrated in the geologic cross-section A-A′ of Figure 4.6. The fault running in an east-northeast direction near the Playa-Lewis and Desert Springs West fields is a tensional fault which is related to the Rock Springs Uplift. Richers et al. (1982) found high concentrations of light hydrocarbons in sub-parallel tensional faults towards the south.

Reservoir Characteristics

Desert Springs production occurs from the Almond Formation and the Lewis Shale, both of which are Upper Cretaceous in age. The reservoirs are stratigraphic and are located in sandstone units within the two formations. The producing zones from the two horizons are delineated in Figure 4.5; note that only Almond production occurs beneath the electrical survey line.

The Almond Formation is some 200 feet (60 m) thick at Desert Springs. The lower half consists primarily of carbonaceous shales, siltstones, and coal. The few sandstones in this section probably represent pinchouts of sand beneath a series of intraformational unconformities, an artifact of the erratic littoral depositional history of the Cretaceous seas. It is not surprising then, that this section of the Almond does not usually host hydrocarbons. The upper section consists of lagoonal and shallow marine facies, which include interbedded littoral marine sandstones that host most of the Almond gas. As shown in the stratigraphic description (Table 4.2), the Almond can be divided locally into Zones I, II, III, and IV, as done by May (1961). Most of the production is from the so-called "B_1 sand" of Zone II and the "B_2 sand" of Zone III. The two sand units are separated by a thin, impermeable shale layer which causes each to be associated with its own separate formation waters. Both sands pinch out on their updip sides by facies changes to impermeable lagoonal shale and siltstone sediments; they pinch out laterally (north and south) due to facies changes and structure. The gas production is limited downdip by the gas/water contact. The Almond drive involves pressure depletion.

The Lewis Shale in the vicinity of Desert Springs is approximately 1,500 feet (460 m) thick, and consists of marine shales and shallow marine sands. The so-called "e" sand, a north-south oriented off-shore bar sandstone, is the producing member of the Lewis Shale. The "e" sand has a maximum thickness of 38 feet (12 m). All production from the Lewis lies to the north of the survey line.

Other formations, such as the Wasatch, Fox Hills, and Ericson, have produced shows of gas in the Desert Springs area, but the discontinuous nature of their reservoir sands makes them uneconomic.

TABLE 4.3: RESERVOIR CHARACTERISTICS OF DESERT SPRINGS FIELD

General Field Data

Region: Green River Basin
Production: Gas, oil
Type of Trap: Stratigraphic; facies pinchout of sands in a westerly updip direction
Producing Formations and Depths: Lewis Sh., "e" sandstone, 5,100 ft
Almond Fm., 5,900 ft
Other Significant Shows: Fox Hills Ss.
Total Reserves: 410 BCFG, 2.5 MMBO
Productive Area: 28,800 acres
Field Operator: Champlin Petroleum, Prenalta, Mesa Petroleum, Kenneth Luff
Number of Producing Wells (1978): 40
Number of Shut-in Wells (1978): 0
Number of Dry or Abandoned Wells (1978): 18
Well Casing Data: 10-3/8 inch at 442 ft, 5½ inch at 6,468 ft (discovery well)

Discovery Well

Name: El Paso Natural Gas 1 Unit
Location: C-SE-26-T21N-R98W
Completion Date: 3/27/58
Total Depth: 6,510 ft
Perforations: 5,887-5,895 ft, 5,901-5,920 ft, 5,932-5,954 ft (Almond)
Initial Potential: Flow 7,700 MCFGPD
Treatment: SF 26,000 gals diesel with 15,000# 20/40 sand and 1,650 gals Adomite. Refraced with 55,000 gals diesel with 36,000# medium sand

Reservoir Data: Lewis Shale, "e" sandstone

Discovery: 5/1/58
Lithology: Sandstone
Age: Cretaceous
Type of Trap: Stratigraphic; facies pinchout of sands in a westerly updip direction
Drive Mechanism: Pressure depletion
Initial Pressure: 2,285 psi BHP
Recent Pressure (1980): 1,000 psi
Reservoir Temperature: Unknown
Gross Thickness of Reservoir Rock: 29 ft
Porosity: 15.9% (cores)
Permeability: 6.6 millidarcies average (cores), range 0.7 to 22 millidarcies
Gas Column: 850 ft
Gas/Oil Ratio: 81,000:1 (production)
Gas/Water Contact: +980 ft
Gas Character: 1,188 BTU/cu ft; 0.674 specific gravity; pour point 61.5° API
Gas Analysis:

	El Paso Nat. Gas No. 7 Unit C-SE-22-T20N-R98W	
Methane	88.94%	
Ethane	5.85	
Propane	1.96	
Isobutane	0.29	
Normal butane	0.32	
Isopentane	0.16	
Normal pentane	0.12	
Hexanes +	0.33	
Carbon dioxide	2.03	
Hydrogen sulfide	0	(trace reported in some wells)

TABLE 4.3 Continued

Water Saturation: 50% of pore space
Water Salinity: 70,000 ppm NaCl
Water Resistivity: 0.11 ohm-meters at 68°F
Daily Average Production (1980)[1]**:** 35-40 MCFGPD
Cumulative Production (1958-1978): 114,068 BCFG, 1,410,800 BO
Estimated Primary Recovery: 210 BCFG, 1,850,000 BO
Type of Secondary Recovery: None
Estimated Ultimate Recovery: 210 BCFG, 1,850,000 BO

Reservoir Data: Almond Formation, B-1 and B-2 sandstones

Discovery: 3/27/58, El Paso Natural Gas 1 Unit, C-SE-26-T21N-R98W
Lithology: Sandstone
Age: Cretaceous
Type of Trap: Stratigraphic; facies pinchout of sands in a westerly updip direction
Drive Mechanism: Pressure depletion
Initial Pressure: 2,180 psi
Recent Pressure (1980): 1,000 psi
Reservoir Temperature: Unknown
Gross Thickness of Reservoir Rock: B-1 sand, 18 ft; B-2 sand, 18 ft
Porosity: 16% (cores)
Permeability: 11.4 millidarcies average (cores), range 0.3 to 122 millidarcies
Gas Column: B-1 sand, 1,174 ft; B-2 sand, 241 ft
Gas/Oil Ratio: 166,000:1
Gas/Water Contact: B-1 sand, +680 ft; B-2 sand, +910 ft
Gas Character: Condensate gravity 52.3°API

Gas Analysis:	Methane	88.86%
	Ethane	5.14
	Propane	2.08
	Butane	1.0
	Other hydrocarbons	0.61
	Carbon dioxide	2.31
	Sulfur	0.03

Oil Character: Not reported
Water Saturation: 45% of pore space
Water Salinity: 8,000 to 10,000 ppm NaCl
Water Resistivity: 0.6 to 0.78 ohm-meters at 68°F
Cumulative Production (1958-1978): 98,529,195 MCFG, 583,148 BO
Estimated Primary Recovery: 200 BCFG, 650,000 BO
Type of Secondary Recovery: None
Estimated Ultimate Recovery: 200 BCFG, 650,000 BO

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[1] Includes Almond production

TABLE 4.4: RESERVOIR CHARACTERISTICS OF PLAYA-LEWIS FIELD

General Field Data

Region: Green River Basin
Production: Gas
Type of Trap: Stratigraphic
Producing Formations and Depths: Lewis Sh., "d" sandstone, 3,500 ft
Other Significant Shows: Almond Fm.
Total Reserves: > 9 BCFG
Productive Area: 2,000 acres
Field Operator: Mesa Petroleum, Prenalta, K.D. Luff

TABLE 4.4 Continued

Number of Producing Wells (3/78): 7
Number of Shut-in Wells (3/78): 0
Number of Dry or Abandoned Wells (3/78): 3
Well Casing Data: 5½ inch at 3,548 ft with 95 sx (discovery well); 10¾ inch at 385 ft, 5½ inch at 3,898 ft (Almond well at SW-NE-NE-17-T20N-R99W)

Discovery Well

Name: Pubco Petroleum 15-22 Playa Unit
Location: NW-NE-22-T20N-R99W
Completion Date: 10/31/63
Total Depth: 4,520 ft
Perforations: 3,443-3,449 ft (Lewis "d" sand)
Initial Potential: Flow 3,900 MCFGPD
Treatment: None

Reservoir Data: Lewis Shale, "d" sandstone

Discovery: 10/31/63, Pubco Petroleum 15-22 Playa Unit, NW-NE-22-T20N-R99W
Lithology: Sandstone
Age: Cretaceous
Type of Trap: Stratigraphic
Drive Mechanism: Pressure depletion
Initial Pressure: 1,459 psi (DST)
Recent Pressure (1978): 675 psi
Reservoir Temperature: 96-104°F
Gross Thickness of Reservoir Rock: 9 ft average
Porosity: 18 to 24% (logs)
Permeability: Unknown
Gas Column: 400 ft
Gas/Oil Ratio: Dry gas
Gas/Water Contact: Approx. +3,300 ft
Gas Character: 1,121 BTU/cu ft dry gas at 60°F, 14.65 psi; 0.642 specific gravity; condensate gravity 59.6°API
Water Salinity: 26,000 ppm NaCl
Water Resistivity: 0.3 ohm-meters at 56°F
Cumulative Production (1963-1977): 6,138,253 MCFG, 8,066 bbl condensate
Estimated Primary Recovery: Not reported
Type of Secondary Recovery: Not reported
Estimated Ultimate Recovery: 9,000,000 MCFG

TABLE 4.5: RESERVOIR CHARACTERISTICS OF DESERT SPRINGS WEST FIELD

General Field Data

Region: Green River Basin
Production: Gas, oil
Type of Trap: Stratigraphic
Producing Formations and Depths: Almond Fm., 3,800 ft
Other Significant Shows: Lewis Sh.
Total Reserves: Not reported
Productive Area: 3,880 acres
Field Operator: Texas National Petroleum, Kenneth Luff, Pubco, Union Pacific Railroad
Number of Producing Wells (1/78): 39
Number of Shut-in Wells (1/78): 1

TABLE 4.5 Continued

Number of Dry or Abandoned Wells: 21
Well Casing Data: 10¾ inch at 385 ft with 250 sx cement, 5½ inch at 3,898 with 500 sx cement (discovery well)

Discovery Well

Name: Texas National Petroleum 1 UPRR
Location: NE-NE-17-T20N-R99W
Completion Date: 5/25/59
Total Depth: 7,589 ft
Perforations: 3,818-3,830 ft (Almond)
Initial Potential: Flow 9,200 MCFGPD
Treatment: SF with 500 gals MCA, 30,000 gals Petrogel, 60,000# sand

Reservoir Data: Almond Formation

Discovery: 5/25/59, Texas National Petroleum 1 UPRR, NE-NE-17-T20N-R99W
Lithology: Sandstone
Age: Cretaceous
Type of Trap: Stratigraphic
Drive Mechanism: Solution gas
Initial Pressure: 1,240 psi
Recent Pressure (1/78): Unknown
Reservoir Temperature: Unknown
Gross Thickness of Reservoir Rock: 10 ft
Porosity: 18%
Permeability: 10 millidarcies
Oil/Gas Column: Not determined for individual sandstone stringers
Gas/Oil Ratio: 500:1
Gas/Water Contact: +3,140 ft (north of fault contact; not determined south of fault contact)
Oil Character: Amber-green, gravity 43.0 to 45.5° API
Oil Analysis: Sulfur 0.03%
Water Salinity: 3,600 ppm
Water Resistivity: 1.65 ohm-meters at 68°F (DST)
Cumulative Production (5/59-1/78): 14,666,046 MCFG, 742,466 BO, 24,058 BW
Estimated Primary Recovery: Not reported
Type of Secondary Recovery: Not determined
Estimated Ultimate Recovery: Not determined

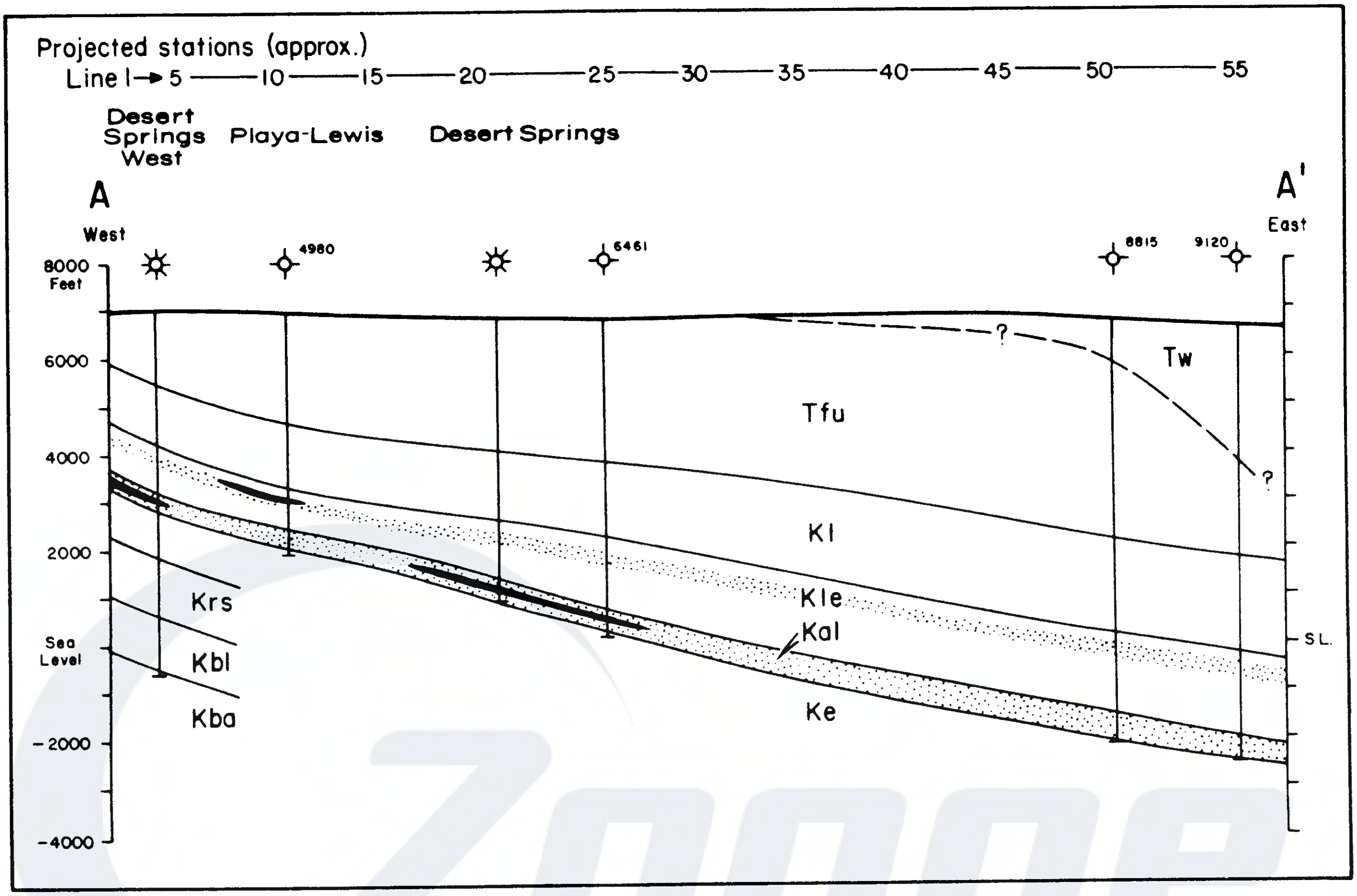


Figure 4.6. Geologic cross-section A-A' with 2:1 vertical scale exaggeration; this may be compared with the electrical data. Refer to Figure 4.4 for map location.

Playa-Lewis production is from Lewis "d" sands, whose plan view location is shown in Figure 4.4. The "d" sands are less than 10 feet (3 m) thick on the average. The driving mechanism is pressure depletion.

Desert Springs West produces gas and oil from the Almond Formation. The main productive unit lies south of the survey line; a narrow corridor of production extends north across the western end of the line. Production is from thin, discontinuous sands; the system has a solution gas drive.

An important consideration in evaluating the electrical data is that all three reservoirs over which the survey line is run are partially depleted in terms of pressure and gas reserves. As will be noted later, this appears to have a very significant impact upon the driving mechanism for electrochemical anomalies.

Well-Casing Information

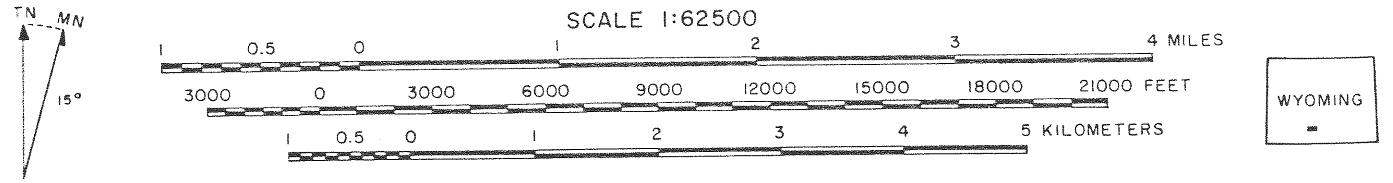
Well casings in the Desert Springs, Playa-Lewis, and Desert Springs West fields are set with 10-3/8-inch (26.4 m) surface casing at about 400 feet (120 m), and 5-1/2-inch (14.0 cm) production casing at total depth. Well-casing models presented in this chapter use 5-1/2 inch diameter casings.

Figure 4.4

LINE LOCATION MAP

Desert Springs, Playa-Lewis, and Desert Springs West Fields

Sweetwater Co., Wyoming



Sources
Base: U.S.G.S. 7.5′ Quad (Red Desert NW, Wyo., 1970; Tipton, Wyo., 1970; Desert Springs, Wyo., 1970; Bitter Creek NE, Wyo., 1968)
Well Data: Petroleum Information Lease-Ownership Maps (W-181, W-182; record take-offs 11/82-3/83); Mohl and Sasse (1979); Andrews (1979)

Explanation of Symbols

Standard Well Symbols

⊙	Drillhole for which information is unobtainable
○	Drilling in progress at time of map preparation
⌽	Shut in
ø	Abandoned
⌖ 10,420	Dry hole with total depth indicated
●	Oil well
☼	Gas well
✹	Oil and gas well
☼	Gas injection well
⚲	Water injection well
∘	Water well

Special Well Symbols

◉ DS 2000	Drilling in progress at the time of the electrical survey; number indicates the amount of drill stem in the hole at the time of data collection
◉	Well spudded in after completion of the electrical survey
● 0.7	Number indicates distance of well from the line in terms of a-spacings; all wells within 1.0 a-spacings indicated (pseudosections only)

Culture Symbols

⌽	Metal pipeline, presumed grounded
● UG	Ungrounded pipeline: non-metal or suspended
ǂ	Metal fence
≀	Electric fence
≀	Buried telephone or power cable
T	Telephone line or standard voltage power line
⩚	Major high voltage power line
Y	Radio, microwave, or other communications station or tower
⌂	DC pump

Other Symbols

U.S.G.S. standard symbols or as labeled

Map-Specific Symbols

Topographic contour interval: 100 feet

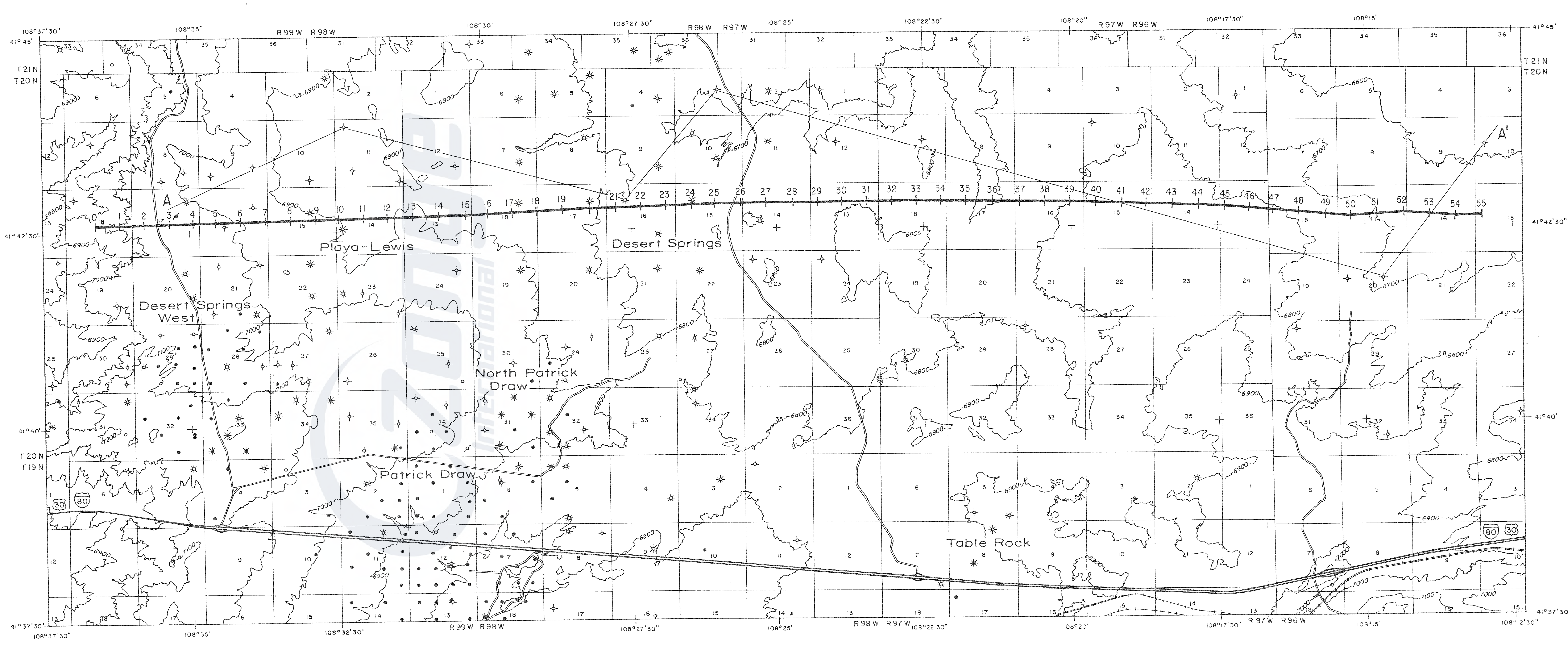
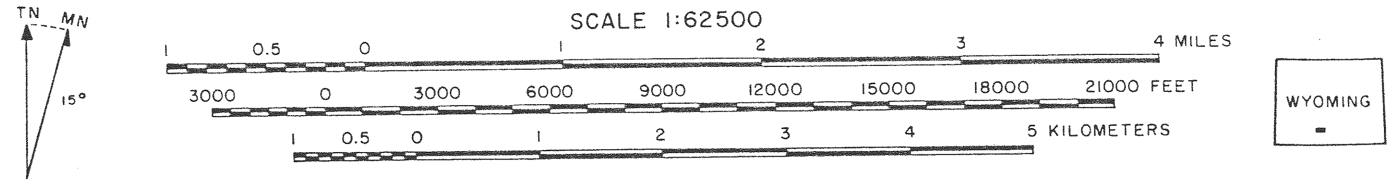


Figure 4.5

STRUCTURE MAP—TOP OF ALMOND FORMATION

Desert Springs, Playa-Lewis, and Desert Springs West Fields

Sweetwater Co., Wyoming



Sources

Base: U.S.G.S. 7.5′ Quad (Red Desert NW, Wyo., 1970; Tipton, Wyo., 1970; Desert Springs, Wyo., 1970; Bitter Creek NE, Wyo., 1968)
Well Data: Petroleum Information Lease-Ownership Maps (W-181, W-182; record take-offs 11/82-3/83); Mohl and Sasse (1979); Andrews (1979)
Geology: Mohl and Sasse (1979), Andrews (1979), Street (1979), Whitley (1979), Colburn (1979), May (1961)

Explanation of Symbols

Standard Well Symbols

⊙	Drillhole for which information is unobtainable
○	Drilling in progress at time of map preparation
⌽	Shut in
∅	Abandoned
⌖ 10,420	Dry hole with total depth indicated
●	Oil well
☼	Gas well
✸	Oil and gas well
☼	Gas injection well
○ W	Water injection well
∘	Water well

Special Well Symbols

◉ DS 2000	Drilling in progress at the time of the electrical survey; number indicates the amount of drill stem in the hole at the time of data collection
◉	Well spudded in after completion of the electrical survey
● 0.7	Number indicates distance of well from the line in terms of a-spacings; all wells within 1.0 a-spacings indicated (pseudosections only)

Culture Symbols

⌽	Metal pipeline, presumed grounded
● UG	Ungrounded pipeline: non-metal or suspended
‡	Metal fence
‡	Electric fence
⌇	Buried telephone or power cable
T	Telephone line or standard voltage power line
⩚	Major high voltage power line
Y	Radio, microwave, or other communications station or tower
⌐	DC pump

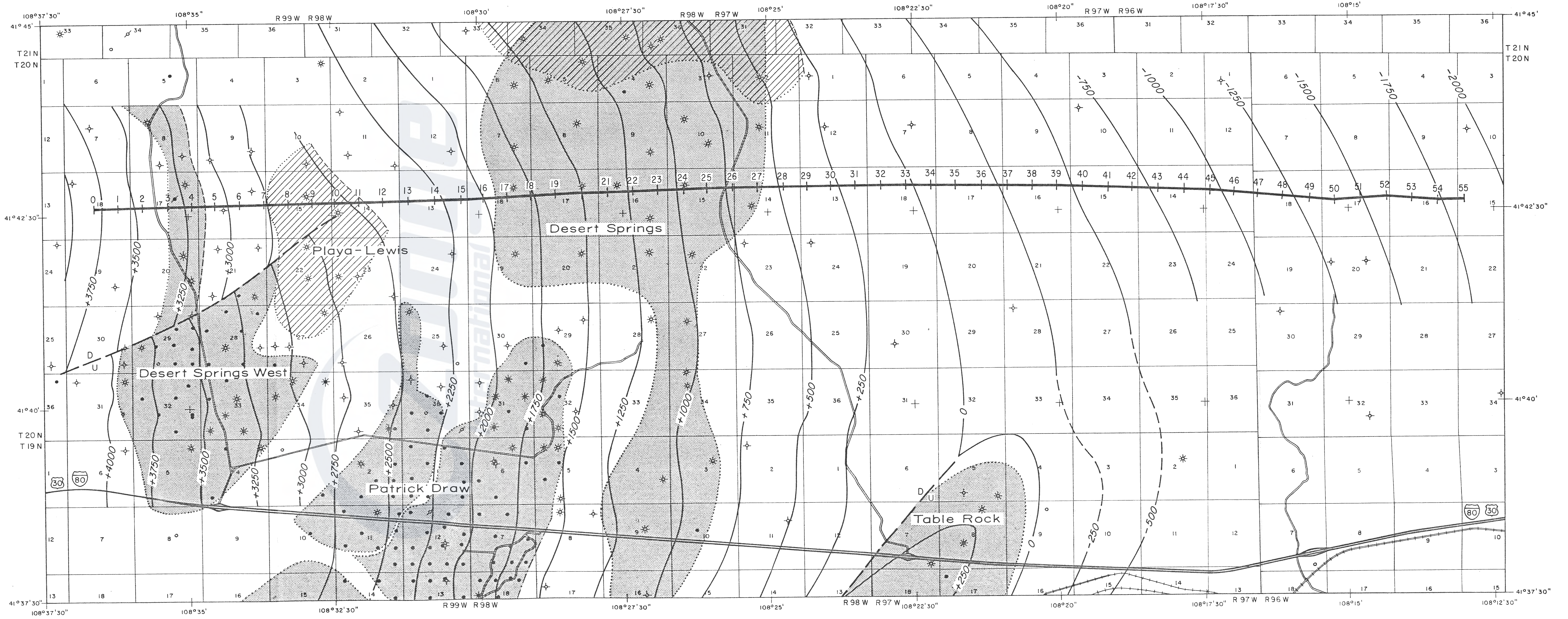
Other Symbols

U.S.G.S. standard symbols or as labeled

Map-Specific Symbols

Structure contour interval: 250 feet
Datum: Mean sea level
-·— — gas-water contact
· · · · · approximate field boundary
▩ Almond production
▨ Lewis production

Zonge Engineering & Research Organization, Inc.



4.3
DISCUSSION OF THE DATA

Introduction

A resistivity/phase crew of eight persons, headed by Zonge Engineering geophysicists Gary N. Young and Norman R. Carlson, was mobilized to the Desert Springs area on October 20, 1980. The survey line was begun with a dipole spacing of 1,900 feet (579 m), obtaining resistivity/phase data at 0.125, 0.25, 0.5, 1.0, 2.0, and 4.0 Hz up to transmitting dipole 33,34.

Beginning with the right-plunging 32,33 dipole, complex resistivity data were obtained in a four-electrode roll-along mode, at a harmonic frequency range of 0.125 to 1.375 Hz. The dipole spacing for this phase of the work was 2,000 feet (610 m). Two overlapping dipoles were measured in order to insure continuity between the two types of data collection. The final data were obtained on December 2.

A total of 20.2 surface line-miles (32.6 line-km) of data were obtained on the survey. Total subsurface coverage was 17.9 line-miles (28.7 line km).

Production on the survey was slowed by severe telluric noise, which may have been related to sunspot activity. Weather and equipment problems also caused some delays. Since the complex resistivity data represent the first time the GDP-12 complex resistivity system was used in petroleum exploration, the data were taken fairly slowly in order to verify proper operation.

The apparent resistivity, apparent polarization, and REM data are presented in Plate 4.1 at the back of this chapter. It may be unfolded for reference while reading the text.

Line Interpretation

As can be seen in Figure 4.5 and Plate 4.1, the electrical line traverses narrow zones of production from Lewis and Almond reservoirs at Playa-Lewis and Desert Springs West fields, and a wider Almond production zone at Desert Springs Field. Toward the east, the line traverses approximately 10 line-miles (16 line-km) of non-productive territory. Hence, the line provides an opportunity to evaluate data over fields of various plan-view sizes and to compare these data with an extensive amount of background data.

The field data are shown in Plate 4.1. The two repeat diagonals show resistivity/phase data above the plot point and complex resistivity below the plot point.

APPARENT RESISTIVITY DATA

The resistivity layering is low-over-high across the entire line. A slight easterly dip is suggested by the data. This is in agreement with the dip of subsurface lithology, as shown in Figure 4.6. The low-to-high resistivity interface appears to lie about 0.3 a-spacings deep, and the resistivity contrast is about 4:1. Since all available stratigraphic logs do not begin any shallower than 500 feet (120 m), or 0.25 a-spacings, these logs can provide no information on the nature of the conductive material at the surface.

The apparent resistivities of 50 to 55 ohm-meters at depth are uniform from the east end of the line up to about station 27 or so, where a significant change occurs. From station 27 to the west end of the line, the apparent resistivities at depth are lower by 5 to 15 ohm-meters. These lowered resistivities extend all the way across the western half of the line, and they show no correlation to the easterly dip of the stratigraphy. This abrupt change is therefore probably unrelated to subsurface stratigraphy per se, but is probably due to low-level brine water discharge from the gas traps on the west end of the line. Note that the correlation here is very good: all of the high-resistivity portion of the line is in the non-producing area, and all of the lower resistivity portion of the line is in the proximity of wells with shows or production.

The apparent resistivity data show two specific zones of potential interest in hydrocarbon exploration. The first is a broad conductive zone between stations 19 and 25, which correlates with the Desert Springs production. The second zone is a very shallow, limited conductive zone between stations 8 and 11 which correlates with the Playa-Lewis Field. In addition, two very minor diagonal effects are correlated with the narrow zone of Desert Springs West production near station 4.

In order to examine the influence of well casings upon the data, the "PIPE" model of Holladay and West (1982) was run (Figure 4.7). As explained in section 2.5, this algorithm often provides a worst-case approximation of well-casing effects. Some ambiguity exists as to which wells were cased, and which wells had had their casing pulled at the time of the survey. For example, the well near station 21.4 is not listed on recent Petroleum Information maps, yet it is known to have existed sometime in the past. It is possible that this and other casings were pulled prior to the survey. The model data of Figure 4.7 include only producing wells on the Petroleum Information maps; all such wells within 3 a-spacings of the line were included. Modeling was done using 5-1/2-inch (14.0 cm) diameter casings.

The first thing to note about the residual data of Figure 4.7 is that the change to lower resistivities west of about station 27 is still evident. In other words, this change in character cannot readily be attributed to well-casing effects, even in a worst-case model. A look at the locations of other cultural features, such as pipelines, also suggests that these features do not cause the overall change in character, although we shall see that specific features on the line do appear to be related to culture.

Desert Springs Field

Almond production at Desert Springs Field lies approximately between stations 16.5 and 27. A substantial conductive zone is found in this portion of the pseudosection, although it is smaller in lateral extent than the productive sands. While this anomaly is very impressive at first glance, its character is very similar to what one would expect of cultural effects. The peak surface responses are centered at the surface near stations 20 and 24; strong diagonal effects plunge left and right from these positions, and their effects are superposed to form a low resistivity zone between them at depth.

The well-casing model of Figure 4.7 shows a fair qualitative match to the data. The model correctly shows the conductive diagonals, flanking resistive diagonals, and the conductive zone at depth beneath station 24. The magnitude of the calculated effect is lower than that shown in the field data, and the strong surface response seen in the field data is not reproduced by the model. However, one can envision considerable enhancement of the cultural contamination at the surface due to grounded metal pipelines which cross near electrodes 20 and 24, and which connect to the offending wells just north of the line. Hence, the apparent resistivity anomaly at Desert Springs appears to be a classic example of cultural effects, with both surface pipelines and well casings producing strong effects. If these effects are taken into consideration, there is little or no evidence that any bona fide conductive anomaly exists in the apparent resistivity data over Desert Springs Field, outside of the generally anomalous data over the entire western half of the line. The reason for this may be related to pressure reduction in the reservoir, as described later in this chapter.

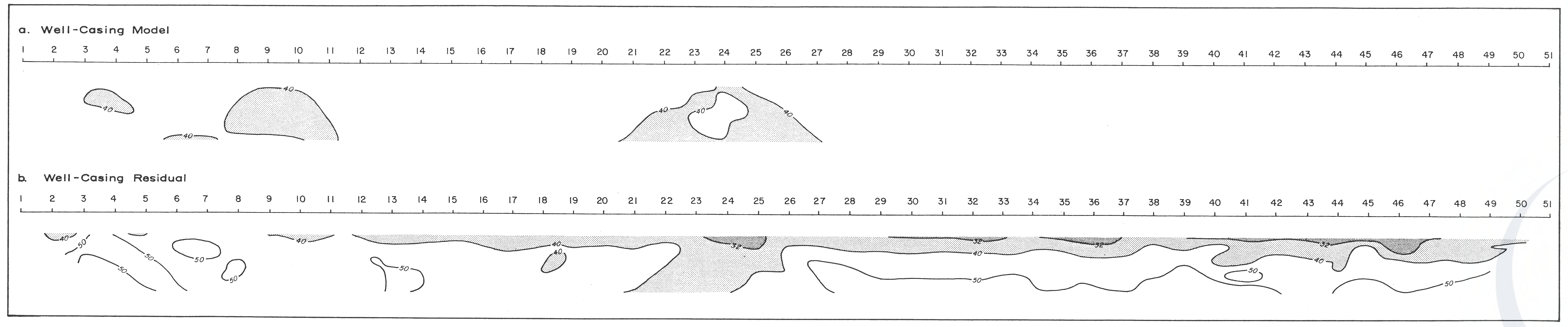


Figure 4.7. Well-casing model of apparent resistivity data for the Desert Springs area line. Model parameters: 24 cased wells, casing diameter = 5½ inches (14.0 cm), casing resistivity = 2.0 x 10^{-7} ohm-meters, surface impedance = 0.5 + 0.5i, background resistivity = 45 ohm-meters. All wells within 3 a-spacings of the line were included, except for the following wells not listed on Petroleum Information maps: C-NE-18-T20N-R98W, C-NW-16-T20N-R98W. Figure 4.4 shows well locations.

Playa-Lewis Field

The Playa-Lewis Field produces gas from the Lewis Formation. The literature (Whitley, 1979) shows two Almond wells near the line, but these are not shown on recent Petroleum Information maps. Hence, the issue of well-casing effects is rendered ambiguous. Only the wells which are listed on Petroleum Information maps are included in the well-casing modeling. The slight surface anomaly over the production may be partly caused by two pipelines which traverse the line at stations 9.2 and 10.0, but is more likely the result of a slight resistivity change in the near-surface. There is no evidence that a "deep anomaly" of the type described in Chapter 2 is specifically correlated to Playa-Lewis production, aside from the generally conductive zone at depth.

Desert Springs West Field

Lewis production occurs at Desert Springs West in a narrow zone between stations 3 and 4.5. Two weak, conductive diagonals are seen plunging left and right from dipole 3,4. Considering the well-casing problems encountered over Desert Springs and Playa-Lewis, one might initially suspect that these diagonal effects are caused by the shut-in oil well which lies 0.4 a-spacing north of station 3.3. However, the effects from this well should consist of a sharp chevron-shaped zone centered at the n=1 position at station 3.5, as shown in the well-casing model data of Figure 4.7. The discrepancy between the model and the field data results only in enhancement of the right-plunging 2,3 diagonal on the residual section. This suggests that the well does not produce any noticeable effect on the data. Since no surface culture, topographic, or structural influences are to be expected in the data, this very subtle feature may reflect a slight change in the resistivity of the surface rocks. The fact that this alteration lies directly over the producing zone suggests that a causal link may exist between the anomaly and the hydrocarbons. However, this anomaly is far from being a classic hydrocarbon-type feature, and would represent a very poor target if found in the course of exploration work.

APPARENT POLARIZATION (DECOUPLED PHASE ANGLE) DATA

Polarization layering is low-over-high across the line. The data show more variability than the apparent resistivity data, and they show no evidence of the eastward dip of the sediments.

The data are not heavily influenced by well-casing or pipeline effects, which should be greatest near the top of the pseudosection and decrease toward the bottom. Some 1 to 2 milliradians of anomalous behavior may be generated by culture on the line, but no classic chevron-shaped features are visible.

There is no correlation between high apparent polarization values and the lateral extent of any of the three hydrocarbon-producing zones. Instead, most of the variability across the line may be due to noise, minor mineralization changes, or clay alteration in shaly units. Stratigraphic logs show that fine-grained pyrite is observed across the length of the line, but that the amount of pyrite and the location of the mineralized zones is quite variable. No "shallow anomalies" of the type described in Chapter 2 are evident in these data.

RESIDUAL ELECTROMAGNETIC (REM) DATA

Unlike the apparent resistivity data, the REM data show high-over-low resistivity layering. This is due to the fact that REM penetration on this line appears to be significantly greater than that of the galvanic data. The thin, conductive surface layer observed earlier in the apparent resistivity data is almost totally transparent to REM. The resistive unit seen below n=1 in the apparent resistivity data dominates the top half of the REM pseudosection, and the conductive unit which is just barely sensed at depth by resistivity is shown extremely well by REM. Hence, a great deal of additional information can be discerned from the REM data.

One of the most important features shown by the REM data is the change in character of the data near station 27. Although a similar change was seen in the apparent resistivity data, it is particularly pronounced in the strong high-over-low (positive over negative numbers) effect seen in REM west of station 27. The data show a generally conductive area at depth in this region. The conductive material correlates with the region of gas production; the more resistive and rather homogeneous zone east of station 27 correlates with barren sands.

It is highly unlikely that culture causes this broad, conductive feature on the west side of the line, since the data are anomalous even in areas which are untouched by culture. In addition, contrary to what would be expected of culture, no strong effects are observed at the surface, and the anomaly is strongest at depth. This is not to say, however, that culture has no influence on the data. On the contrary, much of the diagonally-controlled data over Desert Springs Field seem to show clear indications of the pipeline-well casing combinations near stations 20 and 24. But the increasing conductivity at depth cannot be readily accounted for by cultural effects. So, while some details of the anomalies can be attributed to culture, the general conductive character of the region as a whole cannot be explained in this manner.

Since the broad anomaly cannot be explained by contamination due to culture, and does not correspond to the eastward dip of the stratigraphy, it can reasonably be concluded that it shows a deep, cross-formational zone of low resistivity which may be related to brine discharge from the gas traps. It is very interesting to note, however, that the specific fields in this area do not exhibit pronounced, classically-shaped anomalies which are well-bounded at the field perimeters (with the possible exception of a strong response at n=6 over Desert Springs). This may be related to depressurization of the reservoirs, as noted in the conclusions.

4.4
CONCLUSIONS

Review of the Data

The character of the apparent resistivity and REM data shows a distinct change near station 27. East of station 27, across 10 miles (16 km) of non-productive stratigraphy, resistivities are quite uniform, reflecting only the regional eastward dip of the sediments. West of station 27, a broad, cross-formational conductive zone is found at depth. This zone corresponds to the gas-producing portion of the line. The conductive zone is fairly subtle in the apparent resistivity data, but is much clearer in the REM data due to REM's increased depth of penetration. There are no apparent polarization anomalies on the line which correlate with the gas fields.

Possible Sources of the Anomalies

It is likely that the broad, conductive zone reflects low levels of brine water discharge from the reservoir sands. This would correspond to the "deep anomaly" described in Chapter 2. There is no corresponding "shallow anomaly" evident in either the apparent polarization or apparent resistivity data. Two possible explanations exist for this: 1) subsurface mineralization or clay alteration effects never resulted from upward migration of hydrocarbons, or 2) these effects diminished with depletion of the gas reserves due to oxidation or other disruptive effects.

Although the general region of gas production is clearly delineated in the apparent resistivity and REM data, the exact perimeters of the three distinct fields are not. Desert Springs Field shows the best apparent resistivity anomaly at first glance, but it is probable that these data are strongly influenced by pipelines and moderately influenced by well casings. The REM data, however, show significantly less contamination by culture, and they show a slight increase in the conductive zone at depth which correlates moderately well with Desert Springs production. Playa-Lewis and West Desert Springs fields cannot be specifically outlined on the basis of the data, except by very weak, low resistivity zones at the surface.

The lack of distinction between the three fields provides a good opportunity to learn something about the "deep anomaly" mechanism which seems to produce the strong anomalous responses seen over Ryckman Creek and Whitney Canyon Fields (Chapter 3). The first question one might raise is that, unlike the huge anticlinal traps at Ryckman Creek and Whitney Canyon, the Desert Springs area fields are purely stratigraphic in nature; therefore, little hydrostatic pressure difference would be found within the reservoirs themselves, limiting the hydraulic mechanism which drives the anomalies. However, a close look at the geology shows that, at least over Desert Springs, this is not true. Table 4.3, for instance, shows that the reservoir sands at Desert Springs are about 30 feet (9 m) thick in a down-dip direction. Considering the width of the field and the 5 degree dip of the stratigraphy there, the reservoir exhibits a total east-west relief of some 1,900 feet (580 m), which would certainly result in a reasonable hydrostatic gradient. Moreover, the hydraulic action which moved the hydrocarbons to their traps in the first place, if it is still active, would certainly be sufficient to discharge some saline water from the trap. This saline discharge seems to be the effect which is being measured with the REM data, although it is likely that the response is seriously diminished from what it was before the exploitation of the reservoir sands.

A much better explanation for the lack of separate, distinct anomalies in the three Desert Springs area fields is that the anomaly mechanism has been diminished in strength by pressure reduction in the reservoir sands. As summarized by Tables 4.3, 4.4, and 4.5, reserves at the time of the electrical survey had been seriously depleted. At Desert Springs, in the Lewis reservoir, over 50 percent of the gas and over 90 percent of the oil had been recovered. At the Playa-Lewis Field, some 70 percent of the gas reserves had been recovered. Desert Springs West is also believed to have been similarly developed. More importantly, reservoir pressures in the fields had dropped some 50 percent or more. Such drastic changes in reservoir pressure would result in a serious reduction of solubility of salts in the upward migrating waters; hence, the waters above the trap would have a lower brine concentration than before depressurization of the reservoir. This would result in three effects: 1) the overall salinity above the trap would decrease, resulting in a lesser anomaly; 2) the brine would not extend as far towards the surface; and 3) the brine would be more "spread out" at depth due to the increased importance of groundwater diffusion relative to the upward migration of brine water. All three of these effects are consistent with the data.

Hence, we might conclude that pressure depletion in the reservoirs has degraded the brine supply to the "deep anomaly," and that reduction of vertical hydrocarbon migration by depletion of reserves in the trap has limited the resupply of the "shallow anomaly," if indeed it existed at all. This provides important evidence which supports the anomaly mechanism outlined in Chapter 2.

REFERENCES

Andrews, J.A., 1979, Desert Springs, West, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 2: Wyoming Geol. Assn., p. 132-133.

Colburn, J.A., 1979, Table Rock, and Table Rock, Southwest, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 2: Wyoming Geol. Assn., p. 378-383.

DeVoto, R.H., and Bitter, R.K. (editors), 1965, Sedimentation of late Cretaceous and Tertiary outcrops, Rock Springs Uplift: 19th annual field conference guidebook, Wyoming Geol. Assn.

Earl, J.H., 1961, Desert Springs gas field, Sweetwater County, Wyoming: Geophysics, v. 26, p. 673-681.

Holladay, J.S., and West, G.F., 1982, Effects of well casings on surface electrical surveys (abs.): Geophysics, v. 47, p. 439. Full paper available in Technical papers, 51st Annual International Meeting and Exposition, SEG, Los Angeles, v. 2, p. 815-838.

May, B.E., 1961, The Desert Springs Field: 16th annual field conference guidebook, Wyoming Geol. Assn., p. 290-293.

McPeek, L.A., 1981, Eastern Green River Basin: a developing giant gas supply from deep, overpressured Upper Cretaceous sandstones: AAPG Bull., v. 65-66, p. 1078-1098.

Mohl, K.L., and Sasse, C., 1979, Desert Springs, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 1: Wyoming Geol. Assn., p. 130-131.

Peppard-Soulders, 1979, Hydrocarbon production map of the greater Green River Basin, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 2 (pocket): Wyoming Geol. Assn.

Petroleum Information, 1982, Lease-ownership maps W-181, W-182 (record takeoff dates 11/82-3/83).

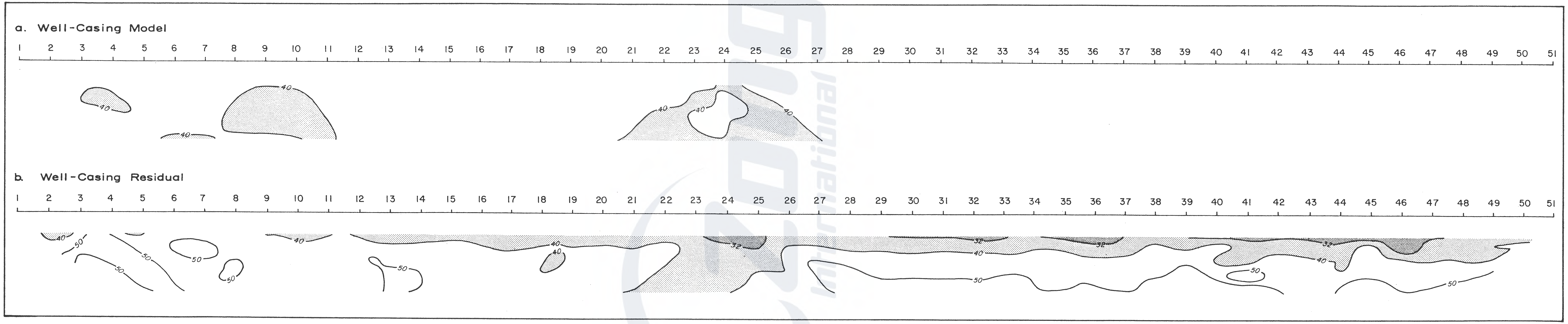
Richers, D.M., Reed, R.J., Horstman, K.C., Michels, G.D., Baker, R.N., Lundell, L., and Marrs, R.W., 1982, Landsat and soil-gas geochemical study of Patrick Draw Oil Field, Sweetwater County, Wyoming: AAPG Bull., v. 66, p. 903-922.

Ritzma, H.R., 1963, Geology and occurrence of oil and gas, Wamsutter Arch, Wyoming, *in* Backbone of the Americas: AAPG Memoir No. 2, p. 188-195.

——— 1968, Geology and occurrence of oil and gas, Wamsutter Arch, Sweetwater County, Wyoming: AAPG Memoir No. 9, v. 1, p. 817-827.

Street, B.A., 1979, Patrick Draw and Patrick Draw, North, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 2: Wyoming Geol. Assn., p. 274-277.

Whitley, W.W., 1979, Playa-Lewis, *in* Wyoming oil and gas fields symposium, Green River Basin, vol. 2: Wyoming Geol. Assn., p. 290-291.



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