Chapter 5
Little Buck Creek Field
Niobrara County, Wyoming

5.1 INTRODUCTION

Little Buck Creek Field is located on the extreme southeast boundary of the Powder River Basin, some 20 miles (32 km) north of Lusk, Wyoming and about 6 miles (10 km) east of the prolific Lance Creek Field. The general location is shown in Figure 5.1. Production at Little Buck Creek is almost exclusively oil, trapped in sandstone members of the Cretaceous Fall River Sandstone and the Permian to Pennsylvanian Minnelusa Formation. The oil is retained by a north-south trending anticline. Production has totalled nearly 12 million barrels as of early 1983. Most of the oil has now been recovered, and a number of wells are shut in.

Two perpendicular lines of resistivity/phase data were obtained over Little Buck Creek, using a dipole spacing of 1,000 feet (305 m).

5.2 GEOLOGIC BACKGROUND

Exploration History of the Little Buck Creek Area

Although the occurrence of oil in Wyoming had been noted as early as 1833, commercial exploitation did not begin until the 1880s. The first producing oil well in the state was drilled in 1884 at Dallas Dome, near Lander. This was followed five years later by the first producing well in the Powder River Basin, drilled by the Pennsylvanian Oil and Gas Company north of the present-day Salt Creek Field. Other, minor discoveries followed at Moorcroft Field in 1887 and Shannon Field in 1889, and by 1895 enough oil was being produced to support the state's first refinery at Casper.

Development of the Powder River Basin was quite slow during the first 30 years of the twentieth century because of the remoteness of the producing fields. Raw crude had to be transported at first by 12- and 16-team coaches and later by truck, making the long trip to commercial centers in the East a profitless venture. This was especially true prior to World War II, when prices for crude dipped as low as ten cents per barrel.

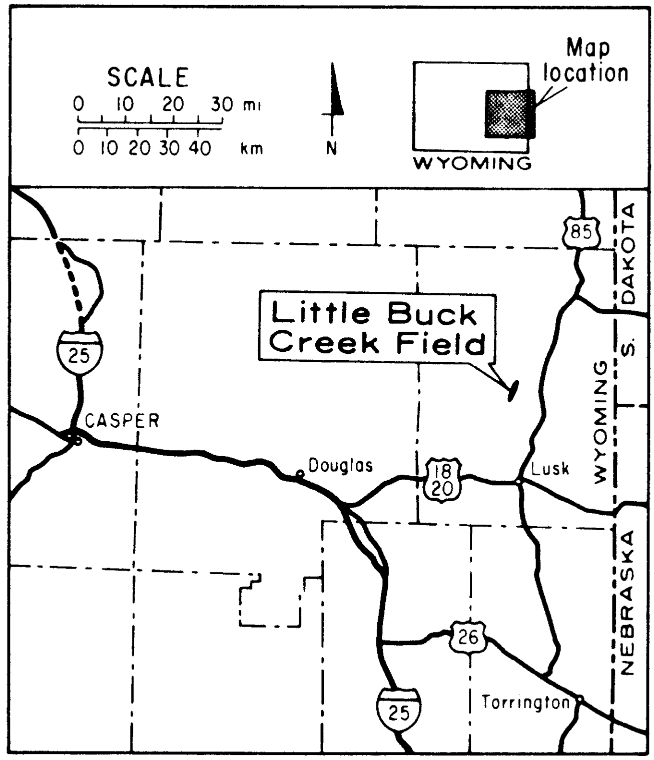

Figure 5.1. Location map of Little Buck Creek Field.

In spite of these difficulties, several discoveries during the early part of the century sparked a series of exploration booms. Salt Creek Field was the first and certainly the most prolific discovery in the early days of Powder River Basin exploration. The discovery well, drilled in 1908, was a gusher, and a dam had to be constructed in order to hold the uncontrolled oil (Maynard et al., 1981). Other finds of the era included Teapot Field in 1914, and Big Muddy in 1916. In 1918, the Ohio Oil Company completed a well at the crest of an east-west trending anticline at Lance Creek, producing oil from upper Cretaceous sands at 2,689 feet (820 m). This well, which was later deepened to a second producing horizon in the Fall River Sandstone at 3,663 feet (1,116 m), set off a boom in leasing activity from 1918 through the summer of 1921. In 1930, the upper unit of the Sundance Formation was found to be productive, followed in 1935 by a major discovery well which produced an initial 2,000 barrels per day from the lower Sundance. These events sparked a sustained boom in leasing and drilling activity in the area, leading to the extension of Lance Creek production to the Minnelusa Formation.

At this time, a single, east-west trending anticlinal structure was known in the Lance Creek area, with Lance Creek Field located at its crest. The crest of the anticline was known to plunge gradually toward the east, and in 1936, Conoco decided to search for new structural closures along that trend. True-dip data obtained from reflection seismic work indicated the presence of two such closures. In 1937, Conoco drilled the largest target, opening up the East Lance Creek Field in the Fall River Sandstone.

In 1942, a seismic correlation map of the Fall River Sandstone was made on the basis of the 1936 seismic data and Fall River wells in the area. This map, which is redrawn in Figure 5.2, more clearly outlined the second structural closure found

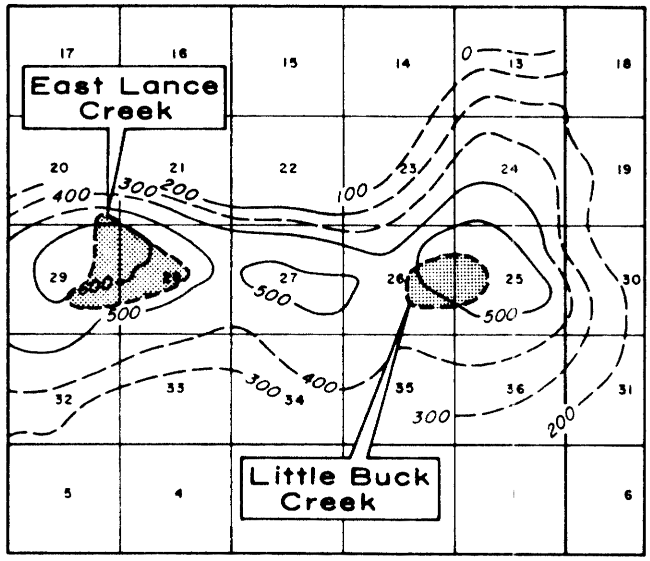

Figure 5.2. Reflection seismograph correlation map, contoured on top of the Fall River Sandstone (Dakota Sandstone), compiled by Conoco in 1942 in a re-interpretation of their 1936 seismic data. Contour interval: 100 feet (15 m). After Swan (1947).

earlier. Conoco followed this work by drilling the Little Buck Creek discovery well, #1 Wright, at NW-SW-NW-25-T36N-R64W. The well was completed in the Fall River on June 18, 1944, producing 43° API gravity oil at 3,850 feet (1,173 m). Development continued with the extension of production to the Upper Minnesula in 1948 and to the first and second Leo sands of the Middle Minnelusa in 1949. Fall River production was extended southward in 1951 with the discovery of Little Buck Creek South. Total production at Little Buck Creek has totalled nearly 12 million barrels, making the field a respectable producer for the area, although it falls well short of the 100 million-plus barrels produced at Lance Creek.

The pattern of development in the Powder River Basin has been steadier since the 1940s due to increasing crude prices and more efficient transportation. By 1958, Powder River oil had accounted for 48 percent of Wyoming's total production, and while recent discoveries in the Overthrust area have shifted exploration emphasis toward the western part of the state, the Powder River Basin continues to play an important role in exploration activity today. Ver Ploeg and Oliver (1981) report that 46 percent of all exploratory wells drilled in Wyoming in 1979 were located in the Powder River Basin. Since most of the post-Mississippian structures along the basin margins have already been explored, the search for stratigraphic traps is being given increased importance. It is hoped that electrical exploration techniques such as the one presented in this volume will be more fully utilized in order to explore for the more subtle traps in this area.

Geologic History of the Powder River Basin

Table 5.1 provides a stratigraphic description of the Little Buck Creek area. As noted by some of the authors referenced at the end of this chapter, the formation nomenclature in the Powder River Basin is somewhat confused. Alternative formation names are placed in parentheses in Table 5.1. Please note that the Dakota Sandstone, which is widely present in the basins to the south and west, is known as the Fall River Sandstone in the Little Buck Creek area.

TABLE 5.1: STRATIGRAPHIC DESCRIPTION OF LITTLE BUCK CREEK FIELD

System	Symbol	Formation	Lithologic Description
CENOZOIC ROCKS			
Tertiary			
Miocene	Ta	Arikaree Fm.	Buff to tan, very fine grained, poorly bedded sandstone containing tiny grains of magnetite
Oligocene	Twr	White River Fm.	Interbedded brown, pink, gray, and green tuffaceous siltstone and conglomerate
		(unconformity)	
Eocene	Tw	Wasatch Fm.	Gray, brown, and reddish-pink conglomeratic to fine grained arkosic sandstones, siltstones, carbonaceous shales, and coal beds
		(unconformity)	
Paleocene	Tfu	Fort Union Fm.	
	Tftr	Torgue River mbr.	
	Tfl	Lebo Sh.	Light to dark gray, very fine grained to conglomeratic sandstone interbedded with siltstones, claystones, carbonaceous shales, and coal beds
	Tft	Tullock mbr.	Interbedded sandstones, siltstones, shales, carbonaceous shales, and thin coal beds
MESOZOIC ROCKS			
Cretaceous	Kl	Lance Fm.	Gray carbonaceous shale and massive lenticular concretionary sandstone, with many thin coal beds in the lower half
	Kfh	Fox Hills Ss.	Light gray sandstone
	Kp	Pierre Sh.	Gray shale
	Kn	Niobrara Sh.	Gray calcareous shale; flecked with chalk near the top
	Kcl	Carlisle Sh.	Dark gray shales with shaly sands and calcareous matter
	Kg	Greenhorn Ls.	Dark gray shales with shaly sands and calcareous matter
	Kbf	Belle Fourche Sh.	Dark gray shales and sandy shales
	Kmr	Mowry Sh.	Gray siliceous shale
	Knc	Newcastle Ss.	Light gray to buff, fine grained sandstone with numerous black shale partings; hosts oil at Lance Creek
	Ksc	Skull Creek Sh.	Dark gray to black shale
		Inyan Kara Group	
	Kfr	Fall River Ss. (Dakota Ss. in west Powder River Basin)	Fine grained gray to brown sandstone with interbedded mudstone, some coal beds; *hosts oil at Little Buck Creek*; also hosts oil at Lance Creek, Lance Creek East, and other nearby fields
		(unconformity)	
	Kfu	Fuson Sh.	Variegated shales with some yellowish sandstone
	Kla	Lakota Ss.	Coarse to conglomeratic, gray to brown sandstone containing coal beds
		(unconformity)	
Jurassic	Jm	Morrison Fm.	Variegated shales, thin sandstones, minor limestones; hosts minor amount of oil at Lance Creek

TABLE 5.1 Continued

System	Symbol	Formation	Lithologic Description
	Js	Sundance Fm.	
		Upper unit	Slightly glauconitic, gray-green shales and sandstones; 1st Sundance sand productive at Lance Creek
		(unconformity) ------------------------------------	
		Lower unit	Slightly glauconitic sandstone with some gray-green shale; lowermost part is the "basal Sundance sand," which hosts oil at Lance Creek and Lightning Creek
		(unconformity) ------------------------------------	
Triassic	Ꞧs	Spearfish Fm. (Chugwater Fm.)	Red-brown shale, with limestone and anhydrite near the base
		(unconformity) ------------------------------------	
PALEOZOIC ROCKS			
Permian		Goose Egg Fm.	
	Pm	Minnekahta Ls. mbr.	Gray to pink limestone
	Po	Opeche Sh. mbr.	Red-brown shale
		(unconformity) ------------------------------------	
	Pml	Minnelusa Fm.	
		Upper mbr.	
	Pmc	Converse sands (1st and 2nd sands; also known as the "Tensleep" sands)	Red to buff sandstones; *hosts oil at Little Buck Creek*; also hosts oil at Lance Creek
		Carbonates	Limestones, anhydrites and some dolomites; includes a prominent red shale marker bed, which is radioactive
		(unconformity) ------------------------------------	
Pennsylvanian	₱ml	Middle mbr.	Limestones, dolomites, and anhydrites, with up to four sandstone horizons (called the 1st, 2nd, 3rd, and 4th Leo sands, in order of increasing depth); *Leo sands host oil at Little Buck Creek*, also at Lance Creek
		(unconformity) ------------------------------------	
		Lower mbr.	
		Carbonates	Cherty limestones and dolomites, and dolomitic sands; hosts oil at Lance Creek
	₱mb	Bell sand	Cross-bedded, pink to white shaly sandstone
		(unconformity) ------------------------------------	
Mississippian	Mm	Madison Ls.	
		Upper mbr.	Crystalline, light tan to light gray limestone with thin shale beds
		(unconformity) ------------------------------------	
		Lower mbr.	Dolomitized limestones, thin-bedded dolomites and thin-bedded limestones
		(unconformity) ------------------------------------	
Cambrian/Ordovician	Ꞓd	Deadwood Fm.	
		(unconformity) ------------------------------------	
Precambrian	pꞒ		Metamorphics and intrusives

In general, the geologic record of the Powder River Basin does not show the extreme tectonic deformation which characterizes the Overthrust region of western Wyoming and eastern Utah, but the area was subjected to several periods of tectonism which strongly influenced sedimentation patterns. The first major activity seems to have occurred in the Precambrian. Micaceous shales, ferruginous sandstones, siltstones, and quartzose sandstones, deposited by several transgressions of Precambrian waters, were intensely folded and uplifted. Some of the rocks were strongly mineralized by intrusive events at this time.

Paleozoic sedimentation was largely controlled by the northerly dip which characterized the paleotopography in the area. Cambrian through Ordovician sedimentation involved an onlap of sediments across this shelf, with thicker sediments lying to the west and north of the Little Buck Creek area. The slow eastward transgression of the seas did not actually reach the southeast portion of the basin until Ordovician time. Several unconformities indicate breaks in the deposition of dolomites, shales, and limestones of the Ordovician and Mississippian.

During late Mississippian time, vast areas of the Rocky Mountains and the Ozark Highlands of Oklahoma and Arkansas were elevated. This event subjected them to erosion and solution, leading to the development of karst topography and soils which characterize the top of the Mississippian in many of the interior western states. The Mississippian uplift appears to have created a depressed area in Converse and Niobrara counties of eastern Wyoming. This depression, known as the Lusk Embayment, is the northwest extension of the broad depositional Denver-Julesburg Basin which covered western Nebraska and northeastern Colorado during Pennsylvanian time. It was in this embayment that the oil-productive rocks of the Minnelusa Formation were deposited. The basal unit is the Bell sandstone, probably eolian, which was laid down near the edge of the Pennsylvanian sea. Deposition of cherty carbonates of the Lower Minnelusa was followed by erosion. The Middle Minnelusa consists primarily of carbonates, shales, and clastics deposited in broad, shallow lagoons. Interbedded among these rocks are four sandstone horizons known as the "Leo sands"; according to Tromp, et al. (1981), these are probably at least partly eolian. The source of these sands was probably the uplifted areas to the west or north. The top two Leo sands host much of the oil production at Little Buck Creek and Lance Creek fields. An erosional unconformity separates the Middle Minnelusa from the carbonates and anhydrites of the Upper Minnelusa. The anhydrites are probably reworked materials of Pennsylvanian age transported from the west. The two Converse sands, which host some oil at Little Buck Creek and Lance Creek fields, lie near the top of the Minnelusa and also appear to have been derived from the west. A radioactive red shale marker lies atop these sands. The overlying shales, mudstones, carbonates, and anhydrites of the Goose Egg and Spearfish formations were deposited in lagoonal and shallow marine waters similar in nature to those which led to the Minnelusa sediments.

During the Jurassic, four transgressive pulses originated from waters to the north, the first two of which did not reach the area of the Powder River Basin. The third transgressive sequence inundated much of Utah, northwestern Colorado, and western Nebraska, depositing the Lower Sundance Formation, in which sand members host oil at Lance Creek. The fourth transgression covered more area than the third and resulted in deposition of the Upper Sundance strata.

The sequence of early Cretaceous rocks which form the Inyan Kara Group indicates variable depositional environments at the edge of the Cretaceous seas. The Lakota and Fuson formations were probably of littoral and non-marine origin. The Fall River Sandstone, in which oil was first discovered at Little Buck Creek, is a fine-grained, occasionally massive sandstone deposited in a shallow, oscillating shelf environment. The source of the sands was probably from the south or southeast. Overlying Cretaceous strata are primarily marine, lagoonal, and coastal sediments. The Pierre Shale (equivalent to the Lewis Formation in the Green River Basin) consists of marine sediments deposited during the final transgression of the Cretaceous seas. The Fox Hills Sandstone was deposited during the regressive sequence, and the Lance Formation is attributed to continental deposition following this regression.

It was not until the late Cretaceous and early Tertiary that the Powder River Basin was formed, although the basic structural trend appears to have been in existence at least since Permian times (Strickland, 1958). As illustrated by the structure contour map of Figure 5.3, the axis of the basin has a north-northwest orientation and an asymmetrical shape. The asymmetry is due to intense folding and thrust faults with up to two miles (3 km) of vertical displacement. Many of the steep flanks to the south appear to be due to high-angle reverse faults which resulted from the Laramie, Hartville, and Black Hills uplifts. The reverse fault located north of the Hartville Uplift appears to have played a role in the oil accumulations found at Lance Creek, East Lance Creek, and Little Buck Creek.

Current Geology

Surface material at Little Buck Creek involves Mesozoic marine sediments of the Lance Formation, except toward the south and in some spotty areas, where the White River Formation of Oligocene age is exposed.

As indicated in the surface geology and structure map of Figure 5.4, the Lance Creek and East Lance Creek oil production is controlled by a meandering anticlinal trend. Little Buck Creek production is largely controlled by a similar anticline oriented roughly northeast-southwest—perpendicular to the Lance Creek anticline. The specific reason for this abrupt change is not known, although the deformation on this flank of the Powder River Basin is quite severe.

The locations of the resistivity/phase survey lines are shown in Figure 5.5; the Fall River structure is shown in plan view in Figure 5.6.

The geologic cross-section of Figure 5.7 shows that the sediments in the area of Little Buck Creek itself are relatively flat-lying. The close-up cross-section of Figure 5.8 is an electric log correlation cross-section which has been tied in to nearby stratigraphic logs. Formation resistivities are typically less than 10 ohm-meters in the top 4,000 feet (1,200 m) of sediments, which are Cretaceous in age. The underlying sediments are quite variable in resistivity, but these units are beyond the zone of influence of the electrical data reported here.

Stratigraphic logs in the field reveal the occasional presence of pyrite in the Niobrara and Muddy formations, but it is not possible to determine from the logs whether or not the pyrite occurs in sufficient quantity to produce a polarization response in the data. There is very little indication of pyrite in the near-surface formations, although micron-sized grains could have been missed in hand-sample analyses.

Reservoir Characteristics

As summarized by Wenger and Reid (1958), Powder River Basin oils can be divided into two types, based upon sulfur content and age. The first type is found in formations of Jurassic age or younger and has a low sulfur content, generally less than 0.5 percent. These oils are typically light in color, waxy, and are mainly paraffinic or naphthenic. The second type of oil generally comes from formations of Jurassic age or older. They generally are higher in sulfur content, have a dark color,

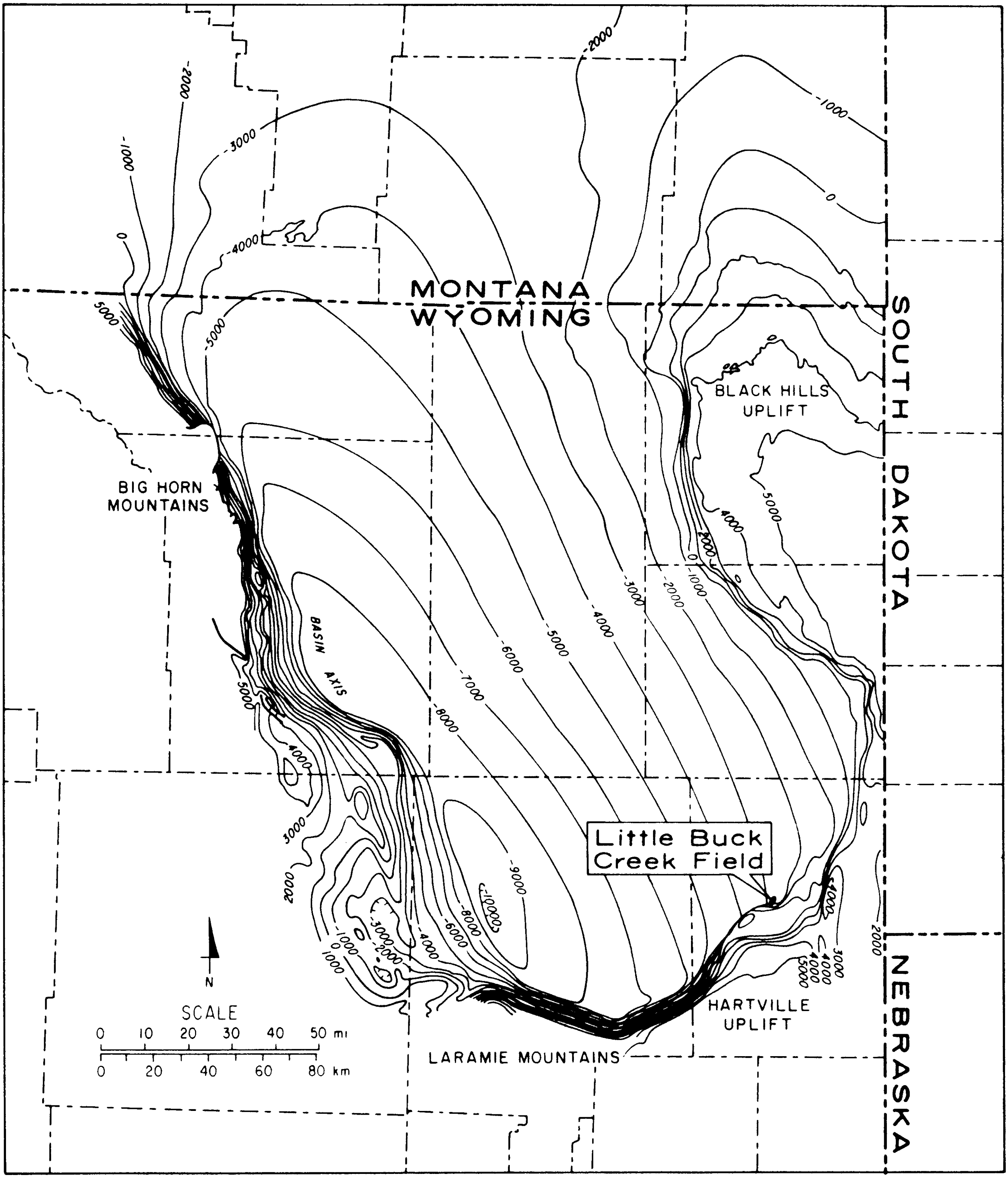

Figure 5.3. Structure map of the Powder River Basin, contoured on top of the Fall River Sandstone (Dakota Sandstone). Contour interval: 1,000 feet (305 m).

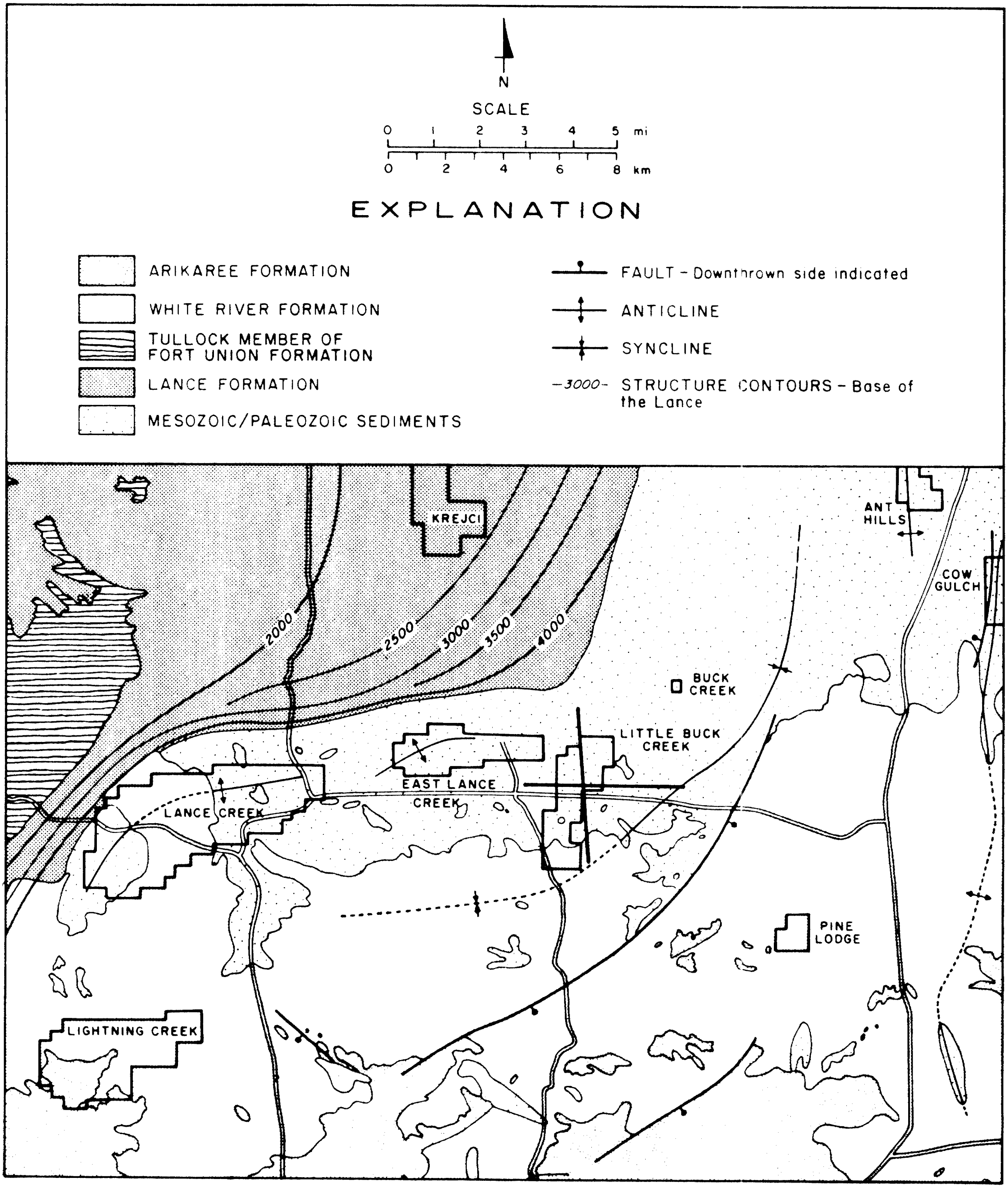

Figure 5.4. Surface geology and structure map of the Little Buck Creek area. After Denson and Horn (1975).

Plate 4.1
RESISTIVITY/PHASE AND COMPLEX RESISTIVITY PSEUDOSECTION DATA
Desert Springs, Playa-Lewis, and Desert Springs West Fields

Sweetwater Co., Wyoming

Line 1

a = 1,900 feet for resistivity/phase data
a = 2,000 feet for complex resistivity data

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
- 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
- Telephone line or standard voltage power line
- Major high voltage power line
- Radio, microwave, or other communications station or tower
- DC pump

Other Symbols

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

Figure 5.5
LINE LOCATION MAP
Little Buck Creek Field
Niobrara Co., Wyoming

SCALE 1:24000

Sources
Base: U.S.G.S. 7.5' Quad (Telephone Draw, Wyo., 1981; Rabbit Mountains, Wyo., 1981)
Well Data: Petroleum Information Lease-Ownership (W-79, record take-offs 1-2/82; W-80, record take-offs 4-5/82)

Explanation of Symbols

Standard Well Symbols
- Drillhole for which information is unobtainable
- Drilling in progress at time of map preparation
- Shut in
- Abandoned
- Dry hole with total depth indicated
- Oil well
- Gas well
- Oil and gas well
- Gas injection well
- Water injection well
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Culture Symbols
- Metal pipeline, presumed grounded
- Ungrounded pipeline: non-metal or suspended
- Metal fence
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- Radio, microwave, or other communications station or tower
- DC pump

Special Well Symbols
- 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
- Number indicates distance of well from the line in terms of a-spacings; all wells within 1.0 a-spacings indicated (pseudosections only)

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

Map-Specific Symbols
Topographic contour interval: 100 feet

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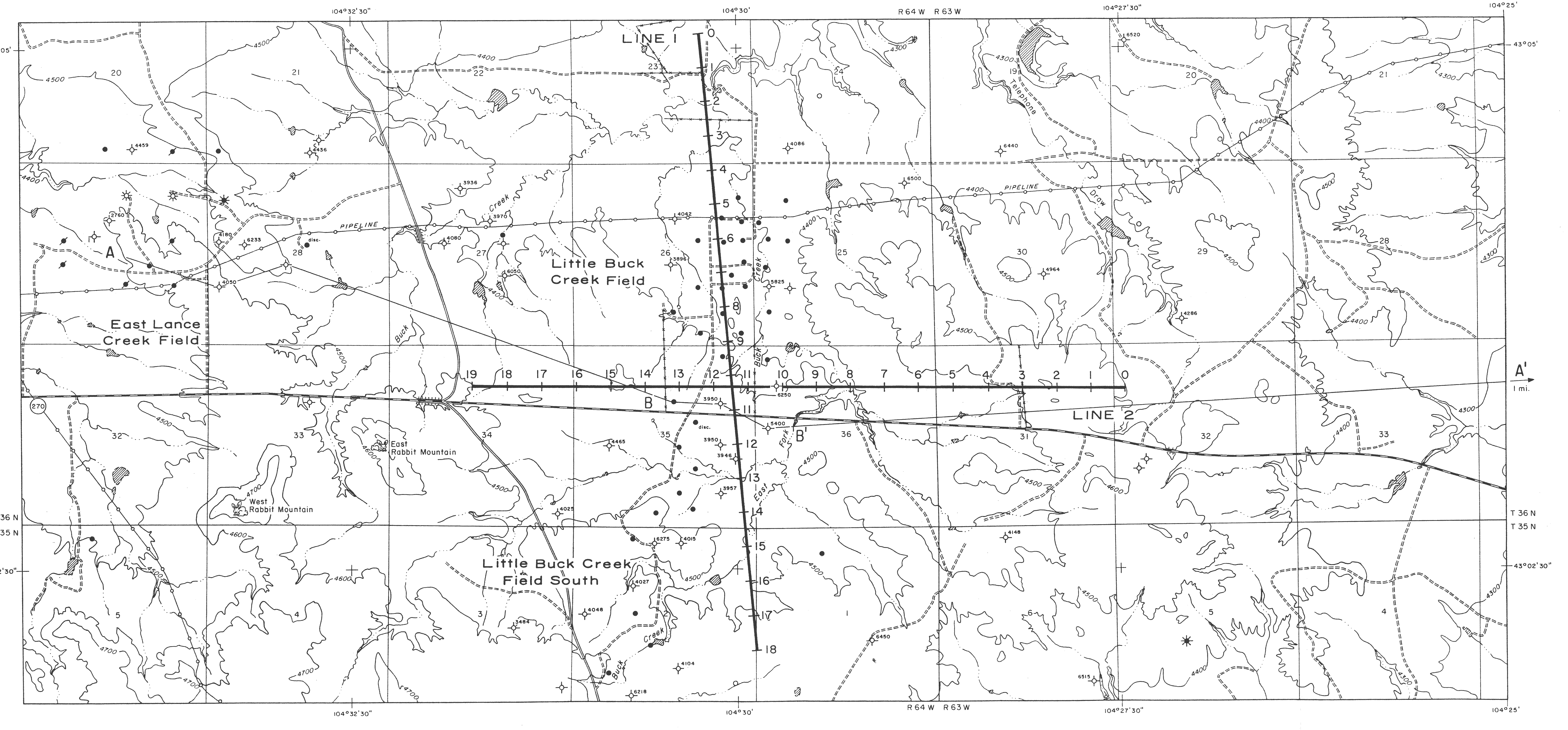

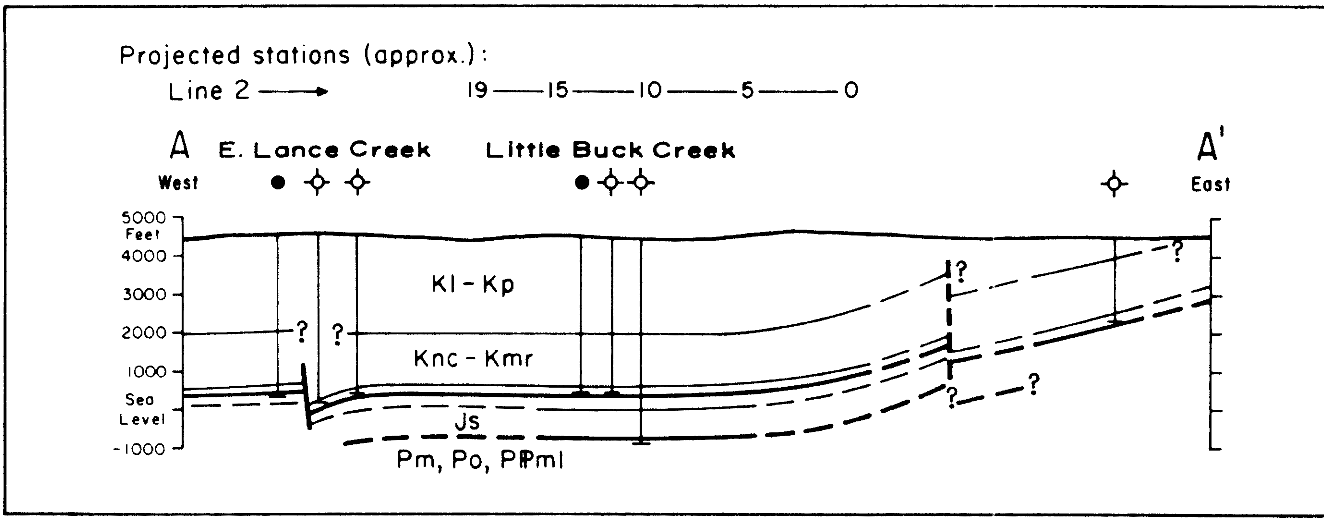

Figure 5.7. Geologic cross-section A-A', with 2:1 vertical scale exaggeration; this may be compared with the data from line 2 of the electrical survey. Compiled from long-normal resistivity logs, which were correlated with stratigraphic logs. Refer to Figure 5.5 for map location.

and are asphaltic. As indicated in the tabulated reservoir data of Table 5.2, the Fall River oils at Little Buck Creek are of the first type, while the Minnelusa oils have characteristics between the two types.

The origin of Fall River oils is not certain, but Strickland (1958) notes that the source may be the black shales in the overlying Mowry and Skull Creek formations. The sulfur content at Little Buck Creek is about typical for Cretaceous oils in the Powder River Basin, and the specific gravity is somewhat higher. Connate water resistivities are about 0.1 to 0.3 ohm-meters.

Minnelusa oils, which are found exclusively in the Converse and Leo sands, are believed to have migrated from the carbonates and black shales which are interbedded with the sands. This opinion seems to be fairly widely held, and Strickland (1958) notes that maximum oil production in the Middle Minnelusa often corresponds to maximum thickness of the black shales. Converse oils at Little Buck Creek have a much higher specific gravity than is typical of Upper Minnelusa oils in the basin, which average 27° API, and the sulfur content of oils in the Converse is lower than that of oils from most other Permian reservoirs. Oils trapped in the Leo sands are fairly typical of most basin oils of Pennsylvanian age in terms of gravity and sulfur content. Connate water resistivities in the Minnelusa reservoirs at Little Buck Creek are uniformly low.

Both the Little Buck Creek and Little Buck Creek South oilfields have a water drive. The fields are nearly pumped out now; Little Buck Creek currently produces some 39 BOPD, with a total of 11.8 MMBO recovered, and Little Buck Creek South produces 9 BOPD, with a total of 0.01 MMBO recovered.

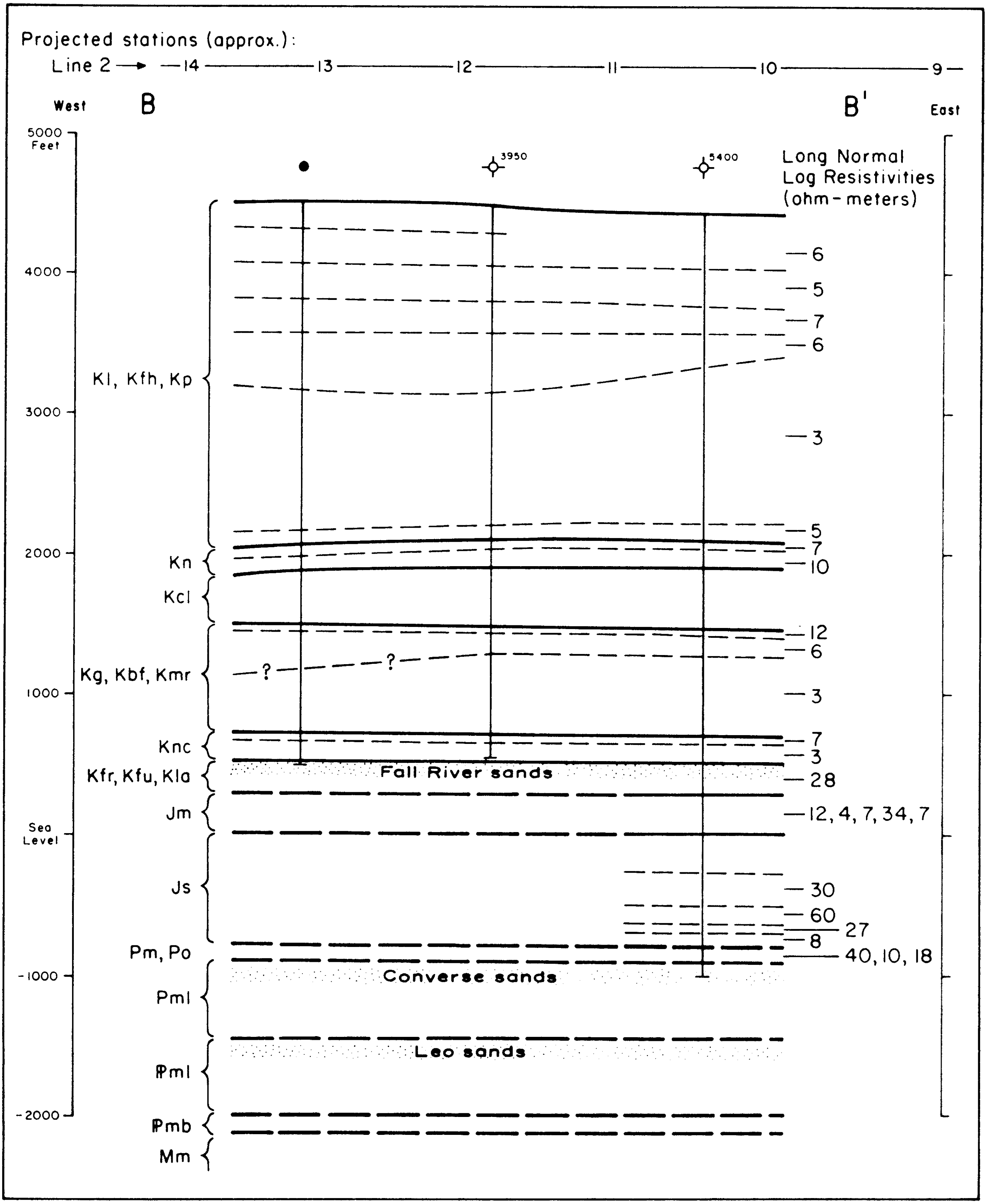

Figure 5.8. Geologic cross-section B-B', with no vertical scale exaggeration; this may be compared with the data from line 2 of the electrical survey. Compiled from long-normal resistivity logs, which were correlated with stratigraphic logs. Refer to Figure 5.5 for map location.

TABLE 5.2: RESERVOIR CHARACTERISTICS OF LITTLE BUCK CREEK FIELD[1]

General Field Data

Region: Southeast Margin of the Powder River Basin
Production: Oil
Type of Trap: Structural; anticline
Producing Formations and Depths: Fall River Ss. (Dakota Ss.), 3,850 ft.
Upper Minnelusa Fm., 1st & 2nd Converse sands, 5,200 ft
Middle Minnelusa Fm., 1st & 2nd Leo sands, 5,900 ft
Other Significant Shows: None
Total Reserves: 12 MMBO
Productive Area: 740 acres
Field Operator: Conoco
Number of Producing Wells (4/82): 34
Number of Shut-in Wells (4/82): 0
Number of Dry or Abandoned Wells (4/82): 18
Well Casing Data: Surface casing typically 13-3/8 inch at 200-350 ft, but sometimes 9-5/8 or 8-3/8 inch; production casing 5½ or 7 inch at 6,500 ft; all holes cemented

Discovery Well

Name: Conoco #1 Wright
Location: NW-SW-NW-25-T36N-R64W
Completion Date: 6/18/1944
Perforations: 3,850 ft (Fall River Ss.)

Reservoir Data: Fall River Sandstone

Discovery: 6/18/44, Conoco #1 Wright, NW-SW-NW-25-T36N-R64W
Lithology: Sandstone
Age: Lower Cretaceous
Type of Trap: Structural; anticline
Gross Thickness of Reservoir Rock: 65 ft
Oil Character: Brownish-green; gravity 41.9°API; pour point 50°F
Oil Analysis:

Light gasoline	7.5%
Naphtha	26.9
Kerosene & gas oil	30.2
Lubricating oil	17.1
Residuum	17.8
Nitrogen	0.027
Sulfur	0.06

Cumulative Production (1944-1958): 3,571,351 BO at Little Buck Creek; 294,288 at Little Buck Creek South
Estimated Primary Recovery: Not reported
Type of Secondary Recovery: Not reported
Estimated Ultimate Recovery: Not reported

Reservoir Data: Minnelusa Formation, 1st & 2nd Converse Sands

Discovery: 1948
Lithology: Sandstone
Age: Permian
Type of Trap: Structural; anticline
Oil Character: Brown to black; gravity 35.0°API; pour point less than 5°F

TABLE 5.2 Continued

Oil Analysis:	Light gasoline	8.6%
	Naphtha	25.4
	Kerosene & gas oil	33.0
	Lubricating oil	15.8
	Residuum	16.5
	Nitrogen	0.09
	Sulfur	0.77

Water Resistivity: 0.1 to 0.3 ohm-meters[2]
Cumulative Production (1948-1958): 792,585 BO
Estimated Primary Recovery: Not reported
Type of Secondary Recovery: Not reported
Estimated Ultimate Recovery: Not reported

Reservoir Data: Minnelusa Formation, 1st and 2nd Leo Sands

Discovery: 1949
Lithology: Sandstones interbedded with carbonates and clastics
Age: Pennsylvanian
Type of Trap: Structural; anticline
Oil Character: Brown to black; gravity 33.4°API; pour point less than 5°F

Oil Analysis[3]:	Light gasoline	7.7%
	Naphtha	24.7
	Kerosene & gas oil	32.5
	Lubricating oil	16.3
	Residuum	18.5
	Nitrogen	0.136
	Sulfur	0.63

Water Resistivity: 0.1 to 0.3 ohm-meters[2]
Cumulative Production (1949-1958): 2,144,266 BO
Estimated Primary Recovery: Not reported
Type of Secondary Recovery: Not reported
Estimated Ultimate Recovery: Not reported

[1]Includes Little Buck Creek South
[2]Average for the entire Minnelusa
[3]Refers to 1st Leo sand only

Well-Casing Information

Surface casing 8-3/8 to 13-5/8 inches (21.3-34.6 cm) in diameter is set to between 200 and 350 feet (61-107 m). Production casing is typically 5-1/2 or 7 inches (14.0 or 17.8 cm) in diameter, is set to total depth, and is cemented. Well-casing models use a worst-case 7-inch casing diameter. It should be noted, however, that there is considerable ambiguity as to how many and which wells were actually cased at the time of the survey. Since production from Little Buck Creek is in steep decline, many of the wells are shut in or abandoned, and some wells are pumped only periodically. Casings from other wells have probably been pulled. Hence, well-casing models should be regarded with even more caution than usual.

5.3 DISCUSSION OF THE DATA

Introduction

A resistivity/phase crew of eight persons, headed by geophysicist Norman R. Carlson, was mobilized to the Little Buck Creek area on August 22, 1979. Data were collected using 1,000 foot (305 m) dipoles along two lines which intersected near the center of the field. Frequencies of 0.125, 0.25, 0.5, and 1.0 Hz were used. Data acquisition was slowed by some unexpected permitting problems, afternoon thunderstorms, and noise due to culture. The field work was completed on September 3. Total surface coverage for the project was 7.0 line-miles (11.3 line-km); total subsurface coverage was 4.0 line-miles (6.4 line-km).

Cultural effects were particularly troublesome on this survey. The numerous powerlines and cathodically-protected pipelines caused a significant amount of noise. Fortunately, the crew was able to have the cathodic protection on the pipelines turned off during most of the data acquisition. In addition to noise, surface culture at Little Buck Creek also created intensive current channeling effects which must be considered in the interpretation.

The apparent resistivity, apparent polarization, and REM data are presented as Plates 5.1 and 5.2 at the back of this chapter. They may be unfolded for reference while reading the text.

Line 1 Interpretation

Line 1 was run along the long axis of the Little Buck Creek Field at an orientation of N 5° W. The field data are presented in Plate 5.1.

APPARENT RESISTIVITY DATA

Background resistivities on line 1 are about 7 to 8 ohm-meters, and a subtle high-over-low resistivity layering situation can be seen. These observations are in substantial agreement with electric log resistivities, which are summarized in Figure 5.8.

A very dramatic, chevron-shaped anomaly is centered on station 7. The low resistivity, right-plunging 5,6 and 6,7 diagonals, and the even lower resistivity left-plunging 7,8 and 8,9 diagonals, are due to near-surface features. These features are almost certainly caused by culture, in the form of well casings, pipelines, powerlines, or fences. The data are so badly contaminated by cultural effects that they are severely restricted for purposes of hydrocarbon interpretation. As indicated in section 2.2, this kind of contamination occurs over roughly 10 percent of the lines run over oil and gas fields. This particular example is one of the most spectacular cases we have seen.

The source of the contamination is of relatively minor interest, so it will be discussed only briefly. As noted earlier, it is not known which of the many wells were cased at the time of the survey. It is assumed for the sake of well-casing modeling that all wells were cased. Figure 5.9 presents the modeling results from the Holladay and West (1982) "PIPE" algorithm; 30 wells within 2.2 a-spacings of the line were included in the model. The strongest calculated effect from these casings occurs at depth; the strong, near-surface, low resistivity zone and associated diagonals are not shown, even in a qualitative sense. The model grossly "overmodels" the field data, possibly because not all wells were cased at the time of the survey. Modeling selective well-casings shows a better qualitative match to the data, although the magnitude of the effect is much lower than that seen in the data. As an experiment, two specific well casings (0.3 a-spacings from station 7.2, and the one directly on line at station 7.4) were used in a model to achieve a best fit; the addition of any

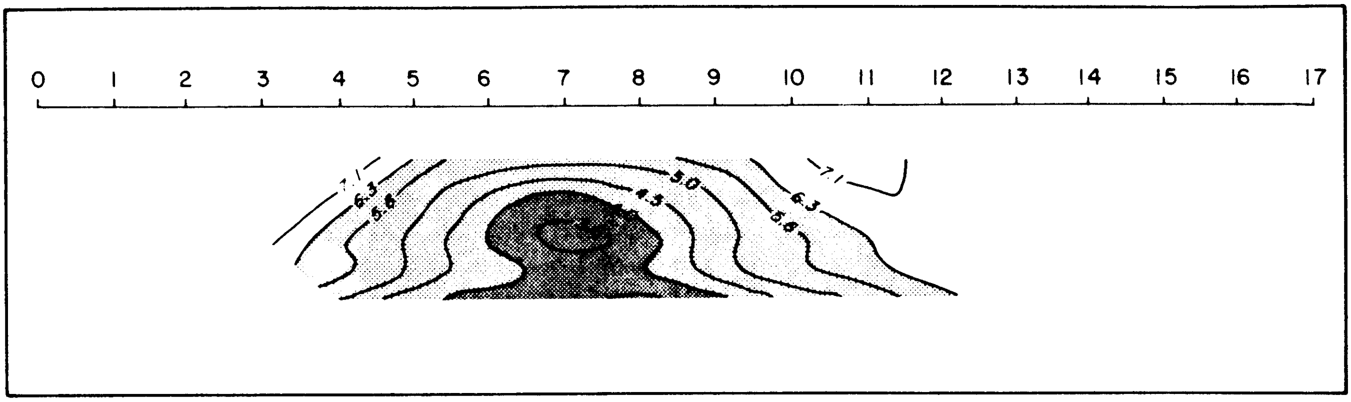

Figure 5.9. Well-casing model of apparent resistivity data for line 1, Little Buck Creek Field. Model parameters: 30 cased wells, casing diameter = 5-1/2 inches (14.0 cm), casing resistivity = 2.0 x 10^{-7} ohm-meters, surface impedance = 0.5 + 0.5i, background resistivity = 7 ohm-meters. Figure 5.5 shows well locations.

other casings destroyed any resemblance to the field data. Therefore, it is unlikely that well-casing effects contribute heavily to contamination of the data.

The most likely explanation for the contamination is the combined effect of pipelines crossing the line at stations 6.3, 6.7, and 7.4. The pipeline effect appears to overwhelm any well-casing effects present in the data.

It is curious to note the unpredictability of contamination by surface culture on line 1. Effects due to the pipelines between stations 6 and 8 dominate the pseudosection, while the pipeline at station 4.3 seems to have no effect at all. Similarly, the fence at station 1.1 shows a strong near-surface response (right-plunging 1,2 diagonal), yet the fences at stations 2.6 and 11.2 show no response, despite the fact that all fences in the area are similar in construction. This illustrates the difficulty of modeling such features.

APPARENT POLARIZATION (DECOUPLED PHASE ANGLE) DATA

The relatively non-responsive background polarization on the line is dominated by effects due to surface culture. Modeling (Figure 5.10) suggests that surface pipelines, rather than well casings, cause the chevron-shaped anomaly. The data are heavily contaminated, but there is a slight indication of a mildly polarized zone which may be correlated with the lateral extent of the hydrocarbons. However, the case for this observation is rather weak, and the response seen in the data would represent a very poor drilling target if this project were a wildcat survey.

RESIDUAL ELECTROMAGNETIC (REM) DATA

The REM data are severely contaminated by culture, probably in the form of surface pipelines, and no residual anomaly which correlates with the hydrocarbons can be discerned. The broad, weaker conductive REM anomaly at depth could be due to hydrocarbon alteration, but the strong near-surface conductive feature tends to override the weak response at depth.

Line 2 Interpretation

Line 2 was run east to west, roughly perpendicular to line 1. The field data are presented in Plate 5.2.

APPARENT RESISTIVITY DATA

Resistivity layering is a very subtle high-over-low, with most apparent resistivities falling in the 6 to 8 ohm-meter range. This is in agreement with the results for line 1 and with the electric log resistivities of Figure 5.8.

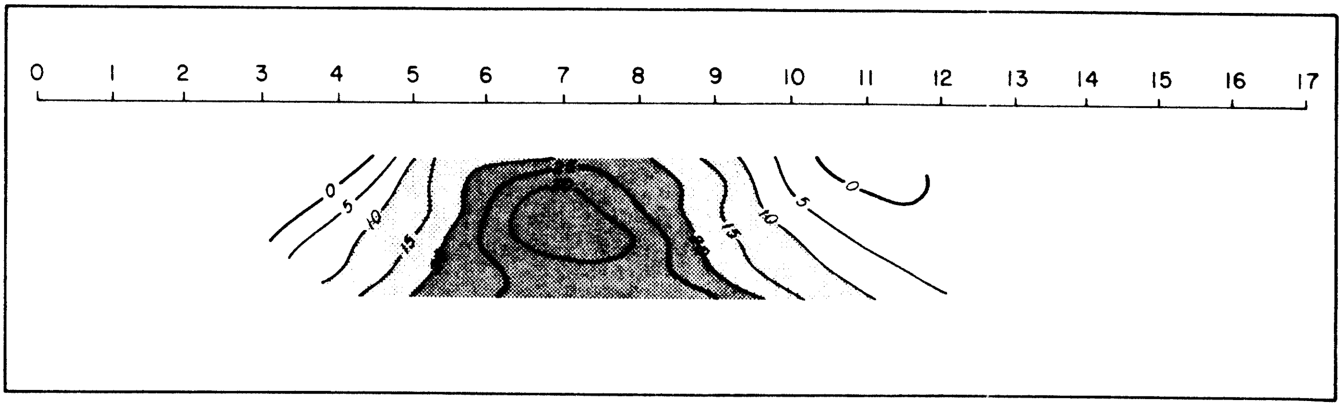

Figure 5.10. Well-casing model of apparent polarization data for line 1, Little Buck Creek Field. Model parameters: same as in Figure 5.9. Figure 5.5 shows well locations.

A 1 ohm-meter (20 percent) depression in the observed apparent resistivities occurs at depth on the western end of the line. This low resistivity zone shows a moderately good correlation to the lateral extent of the hydrocarbons, although the zone of lowest resistivities is offset to the eastern edge of the field.

In order to obtain a qualitative estimate of well-casing effects, the "PIPE" program of Holladay and West (1982) was applied to the data. A total of 28 wells within 4.9 a-spacings of the line were included. As noted earlier, it is not known how many of these wells were cased at the time of the survey, so this modeling exercise is very subjective; hence, no well-casing residual data have been calculated.

Figure 5.11 shows the model results. The calculated well-casing effect is fairly symmetrical about the field, centered on station 12. The magnitude of the calculated well-casing effect matches the field data very well, and the appearance of the model data strongly resembles the appearance of the field data. However, note that the model calculates a maximum effect at depth which is approximately 1,500 feet (450 meters) west of the anomaly in the field data. In order to explain the anomaly completely in terms of well-casing effects, one would have to postulate that the shift is due to a much higher response from wells toward the east (a statistical improbability, since all wells are roughly the same age, and hence should have similar surface impedances), or that wells toward the west are mostly uncased (which is untrue, according to Conoco (1983)).

From the preceding discussion, it is probably safe to conclude that, while the match between model and field data suggests that a portion of the field response may be due to casing effects, there is a residual, low-amplitude response at depth on the eastern edge of the field which is probably not due to well casings. This response cannot be explained in terms of surface culture; indeed, there is no evidence that any of the surface culture encountered on line 2 affects the data at all. Neither can the response be explained by topographic effects, which are negligible on this survey, or by subsurface structure, which is horizontally layered over the field. Instead, the response is probably due to a very subtle, lateral resistivity change in the sediments above the field.

There are two points to be noted about the anomaly. First, its magnitude is so low that, assuming well-casings have had the effect described above, the residual target would probably be overlooked in rank exploration work. Hence, for all practical purposes, only a very poor anomaly is seen in the apparent resistivity data. Secondly, since the anomaly is not very well correlated with the lateral extent of the

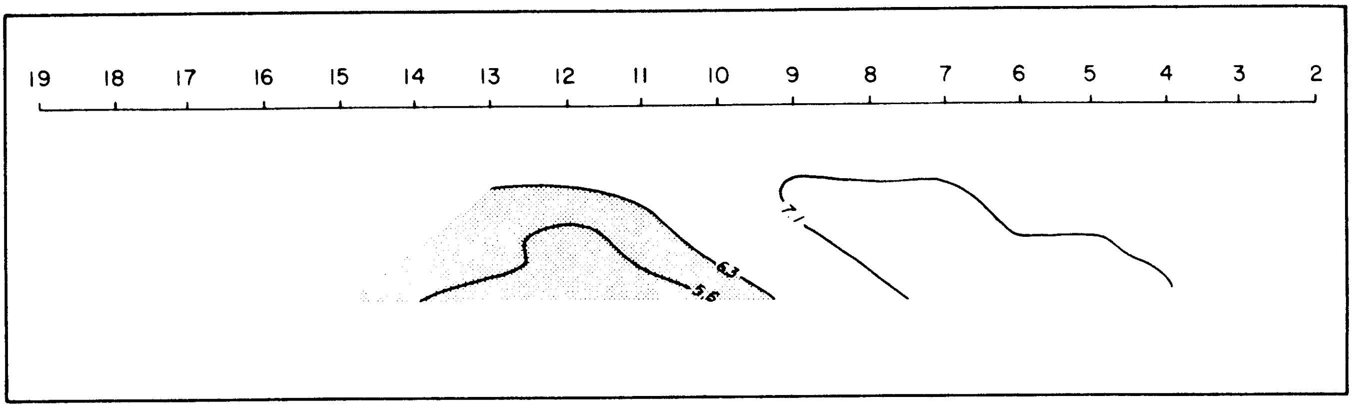

Figure 5.11. Well-casing model of apparent resistivity data for line 2, Little Buck Creek Field. Model parameters: 28 cased wells, casing diameter = 5-1/2 inches (14.0 cm), casing resistivity = 2.0×10^{-7} ohm-meters, surface impedance = $0.5 + 0.5i$, background resistivity = 7 ohm-meters. Figure 5.5 shows well locations.

hydrocarbons, it could easily be a slight facies variation within the Cretaceous shales and sandstones of the Fox Hills and Pierre formations—a variation which would have no causal link to the hydrocarbons at depth. Alternatively, the anomaly could be due to a column of weak, hydrocarbon-related electrochemical alteration which, perhaps due to local horizontal groundwater flow, is displaced from the oilfield to the east. Since no substantive information on groundwater flow has been found, this possibility cannot be confirmed or disproved.

The lack of a well-defined apparent resistivity anomaly on line 2 may be related to the fact that reserves at Little Buck Creek Field are nearly depleted and reservoir pressures are reduced. This matter is discussed in the Conclusions at the end of this chapter.

No other conductive features are found at depth. Two shallow zones whose resistivities are slightly lower than background are found between stations 8 to 9 and between stations 3.5 to 5. There is some chance that these are related to a conductive REM anomaly found at depth on the east end of the line, as will be noted in the discussion of the REM data.

APPARENT POLARIZATION (DECOUPLED PHASE ANGLE) DATA

Polarization layering is low-over-high on line 2, although the background rocks are all considered to be relatively non-polarizable. A slight amount of noise is evident in the pseudosection, although the overall interpretation is not affected. Only the small zone of values in the 10 to 15 milliradian range on the west-central portion of the line is of much interest. This zone corresponds to the low-resistivity zone noted earlier; it lies on the eastern edge of the producing field.

A well-casing model of the polarization data was run, and the results are shown in Figure 5.12. Although the model shows too high a polarization effect, note that the calculated response is centered at depth between stations 11 and 13, or between stations 10 and 14 near the surface. The model response is thus shifted 2,000 to 3,500 feet (600-1,100 m) to the west of the peak field response. Thus, it seems that a small polarization effect independent of well-casing effects is observed on the eastern edge of the field. Again, there are no obvious effects due to surface culture or subsurface culture, so the remaining possibilities are either that the slight rise in polarization is due to a slight facies change which is unrelated to the hydrocarbons at depth, or that it is due to alteration of Cretaceous sediments by upward migrating hydrocarbons from their traps below.

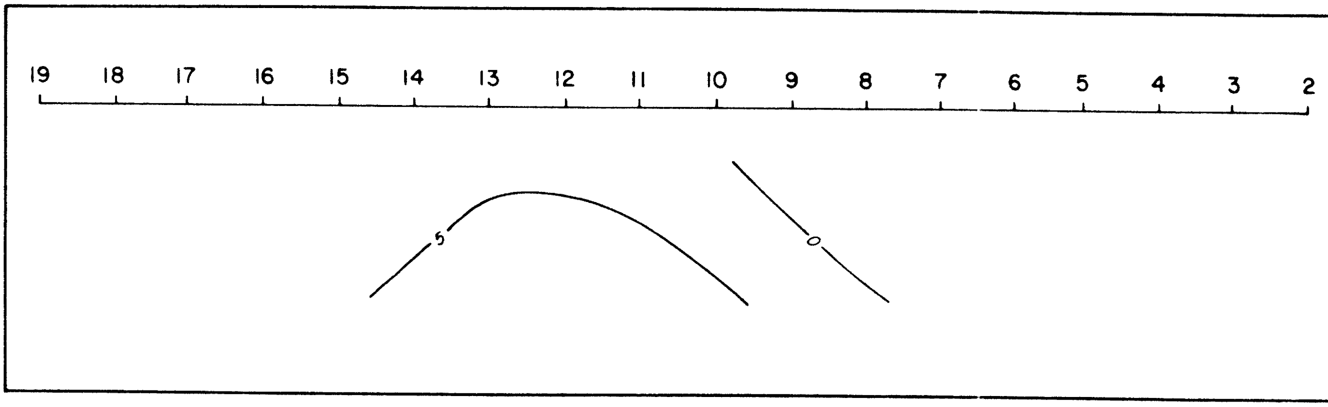

Figure 5.12. Well-casing model of apparent polarization data for line 2, Little Buck Creek Field. Model parameters: same as in Figure 5.11. Figure 5.5 shows well locations.

In any case, the polarization anomaly, while better defined than the apparent resistivity anomaly, is considered poor to fair at best. It would not make a strong exploration target if found on a line run over a prospect. The lack of a good anomaly may be due to depletion of the reservoir at depth, as discussed in the Conclusions.

RESIDUAL ELECTROMAGNETIC (REM) DATA

The REM data show a high-over-low resistivity layering picture, as seen in the apparent resistivity data. Superimposed upon this layering are two conductive zones at depth, one in the west-central portion of the line, and the other on the eastern end of the line.

The anomaly in the west-central portion of the line is fairly well defined but its magnitude with respect to background is not very impressive except at the n=6 level. The most conductive zone lies on the eastern edge of Little Buck Creek Field, and therefore the correlation to the hydrocarbons is not particularly good. This displacement is identical to the displacement of the apparent resistivity and polarization anomalies. The conclusion is the same as before: even assuming that the calculated well-casing effect is correct, a very subtle, residual anomaly unrelated to well casings lies at depth on the eastern edge of the field. Since the REM data appear to have a greater depth of penetration on this survey than do the galvanic data, it is not surprising that the REM anomaly is better defined than the galvanic anomalies, although it is no better than "fair" in quality. The lack of evidence for cultural or structural effects in the data indicates that the anomaly is due to some lateral resistivity change in Cretaceous sediments. This change could involve a minor facies change which is unrelated to the presence of hydrocarbons at depth, or it could be due to an alteration column caused by upward migration of hydrocarbons from the trap at depth.

The most interesting REM feature on line 2 is found on the east end of the line, in a region in which hydrocarbon production has not been established. The anomaly is fairly well defined; if well-casing effects on the REM data to the west could be removed, the relative definition of this feature would appear to be even better. There is little evidence of an associated anomalous response in the apparent resistivity or apparent polarization data. The very subtle, near-surface, low-resistivity zone between stations 3.5 and 5 may be due to some sort of alteration which is associated with the deeper data.

5.4 CONCLUSIONS

Little Buck Creek Field

REVIEW OF THE DATA

The data for line 1 of the Little Buck Creek survey are overwhelmingly contaminated by strong effects due to surface pipelines, with possible secondary contributions from well-casings, a fence, and a powerline. The apparent resistivity and REM data are virtually impossible to use for hydrocarbon interpretation. The apparent polarization data are also severely affected, but there is some indication that slightly high polarization values may be associated with the sediments which overlie the hydrocarbon trap.

The situation from a cultural standpoint is better on line 2. Apparent resistivity, REM, and polarizable anomalies are seen at depth on the eastern edge of the producing field. These features cannot be explained by well-casing effects, although such effects may very well increase the magnitude of these anomalies. Surface culture appears to have a minimal impact on these data. The effects of subsurface structure and topography are also minimal due to the flat-lying stratigraphy and the essentially flat ground. Therefore, it is believed that lateral alteration features in Cretaceous sediments between 1,000 and 2,000 feet (300-600 m) produce the very subtle, low resistivity anomaly and the slightly more obvious polarization and REM anomalies.

The changes in the data may or may not be related to the presence of hydrocarbons at depth. For example, they might be due to a lateral facies change. However, the limited lateral size, substantial depth extent, high correlation of low resistivities to high polarizations, and proximity of the anomalies to the producing oilfield make this explanation somewhat unlikely. Instead, it is more probable that the lateral electrical changes in Cretaceous sediments are causally connected to the hydrocarbons at depth.

GEOLOGIC INTERPRETATION

The subtlety of the anomalies measured over Little Buck Creek may provide important confirming information regarding the anomaly mechanisms discussed in section 2.4. As noted in the geologic description, some 12 million barrels of oil have been recovered from Little Buck Creek and Little Buck Creek South over the past 39 years. Currently, 34 intermittently producing wells yield a field total of less than 50 barrels of oil per day. Hence, the recoverable reserves in the field are nearly exhausted.

The decrease in reservoir pressurization which certainly accompanies the depletion of oil has probably greatly diminished the driving mechanism for vertical migration. As noted in section 2.4, the chief mechanism for expelling light hydrocarbons and saline waters from a trap is believed to be hydraulic in nature. With decreased reservoir pressure, the solubility of salts in the local water system would be greatly reduced. The result would be salt precipitation and a consequent increase in pore fluid resistivity. Hence, the apparent resistivities would be increased over the trap. On the other hand, the shallower anomaly, which consists of mineralization and alteration phenomena, might remain as a fossil anomaly, providing it were not subject to disruptive effects, such as oxidation from surface water recharge.

The subtle anomalies on the eastern edge of the Little Buck Creek Field may reflect the final phase of vertical migration from the field, calling to mind the disappearing geochemical anomaly measured by Horvitz (1969) over Hastings Field in Texas. The remnants of the deep anomaly are picked up in a weak REM response and a weaker resistivity response; these data suggest that the anomaly mechanism is not yet completely neutralized. The polarization anomaly may reflect some low-grade mineralization or clay alteration over the field. The fact that the anomalies are shifted toward the east side of the field is enigmatic; perhaps local trends in ground-water flow have contributed a slight horizontal component to the otherwise vertical migration pattern.

The Undrilled Anomaly

The conductive REM anomaly between stations 3 and 6 on line 2 represents a potentially attractive drilling target on the basis of this set of data. The anomaly has a fairly well defined pattern and shows a 2:1 contrast with respect to background. It is not associated with any anomalous polarization values, but there may be a subtle conductive surface expression in the apparent resistivity data.

In order to exploit this target properly, we would suggest running a north-south cross line, intersecting line 2 at station 4. The data should then be correlated with subsurface geology and seismic data in order to determine the attractiveness of a drilling program. On the basis of the electrical data alone, the best drilling location would probably be directly on station 4.

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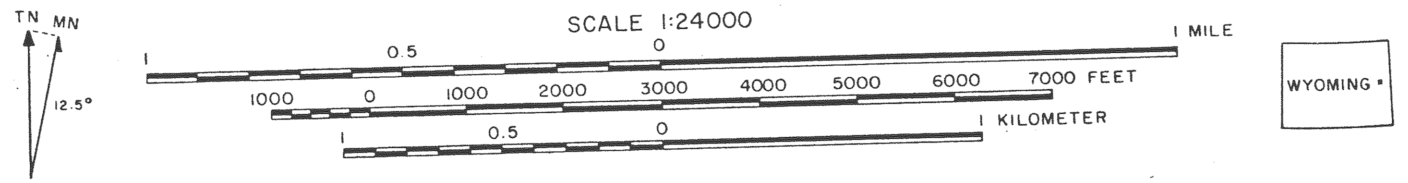
Figure 5.6
STRUCTURE MAP—TOP OF FALL RIVER SANDSTONE
Little Buck Creek Field
Niobrara Co., Wyoming



Sources
Base: U.S.G.S. 7.5' Quad (Telephone Draw, Wyo., 1981; Rabbit Mountains, Wyo., 1981)
Well Data: Petroleum Information Lease-Ownership (W-79, record take-offs 1-2/82; W-80, record take-offs 4-5/82)
Geology: Conoco (1955); Hoyle et al. (1981)

Explanation of Symbols

Standard Well Symbols
- Drillhole for which information is unobtainable
- Drilling in progress at time of map preparation
- Shut in
- Abandoned
- Dry hole with total depth indicated (10,420)
- Oil well
- Gas well
- Oil and gas well
- Gas injection well
- Water injection well
- Water well

Culture Symbols
- Metal pipeline, presumed grounded
- Ungrounded pipeline: non-metal or suspended (UG)
- Metal fence
- Electric fence
- Buried telephone or power cable
- Telephone line or standard voltage power line
- Major high voltage power line
- Radio, microwave, or other communications station or tower
- DC pump

Special Well Symbols
- 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 (0.5, 2000)
- Well spudded in after completion of the electrical survey
- Number indicates distance of well from the line in terms of a-spacings; all wells within 1.0 a-spacings indicated (pseudosections only) (0.7)

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

Map-Specific Symbols
Structure contour interval: 10 feet

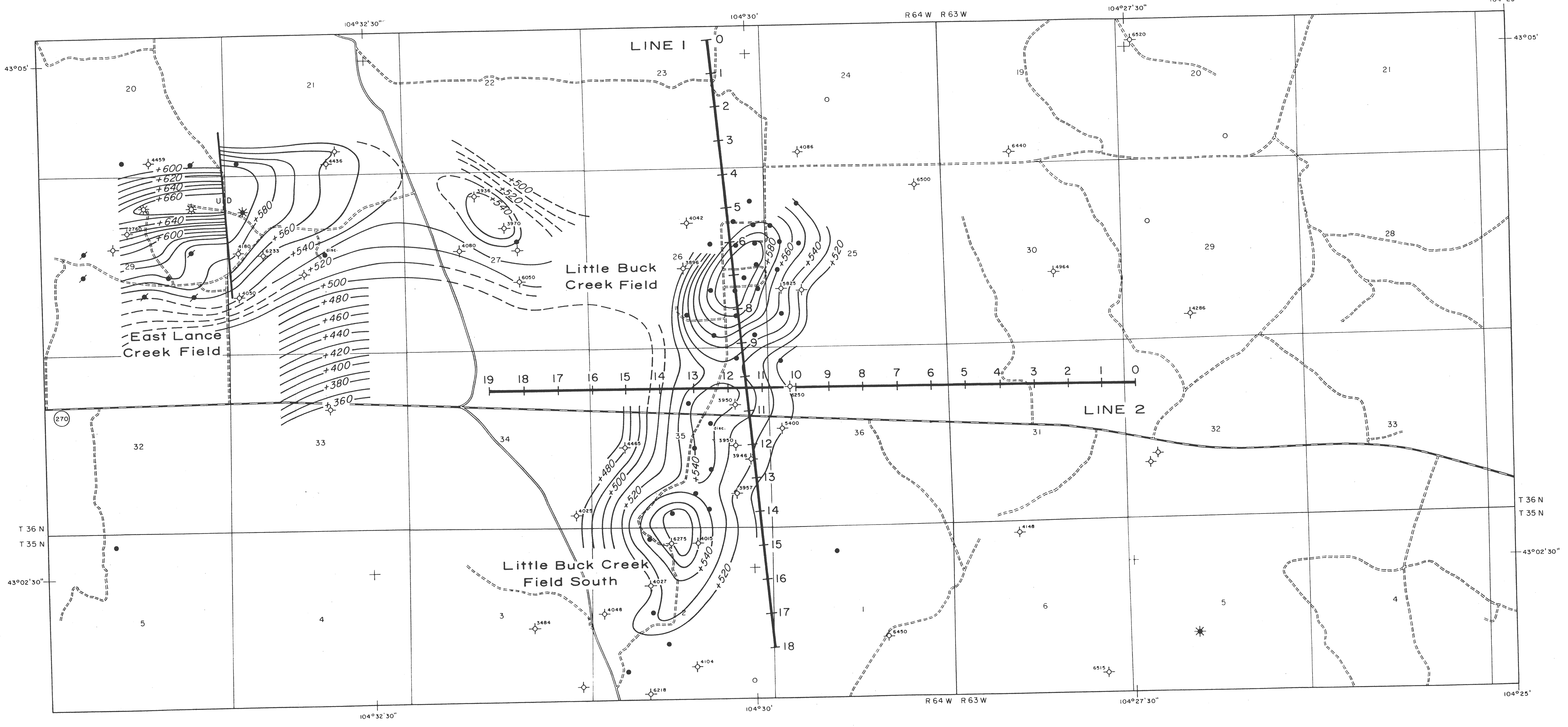


Plate 5.1

RESISTIVITY/PHASE PSEUDOSECTION DATA

Little Buck Creek Field

Niobrara Co., Wyoming

Line 1

a = 1,000 feet

Explanation of Symbols

Standard Well Symbols

- Drillhole for which information is unobtainable
- Drilling in progress at time of map preparation
- Shut in
- Abandoned
- Dry hole with total depth indicated (10,420)
- 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
- Metal fence
- Electric fence
- Buried telephone or power cable
- Telephone line or standard voltage power line
- Major high voltage power line
- Radio, microwave, or other communications station or tower
- DC pump

Other Symbols

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