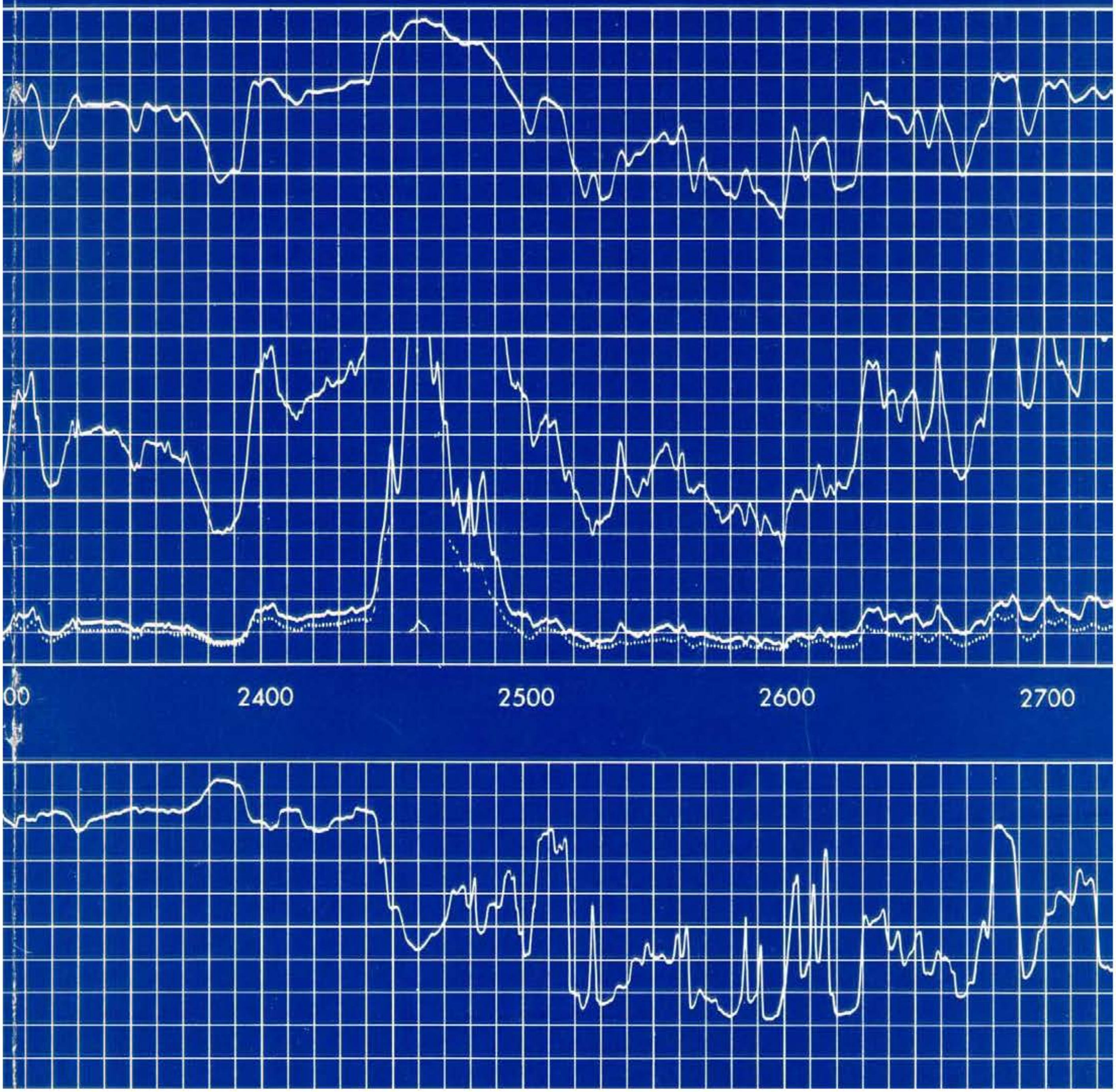
MIST GAS FIELD: EXPLORATION AND DEVELOPMENT 1979-1984

OIL AND GAS INVESTIGATION 10

1985

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST



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MIST GAS FIELD: EXPLORATION AND DEVELOPMENT

1979-1984

By

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by
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1985

Conducted in conformance with ORS 516.030.

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Abbreviations used in this report

abd	abandoned
ac	acres
API	American Petroleum Institute
bbl	barrel
BHP	bottom-hole pressure
Btu	British thermal unit
cfd	cubic feet per day
csg	casing
DST	drill stem test
ft	foot, feet
in.	inch
Kb	Kelly bushing
Mcf	thousand cubic feet
Mcfd	thousand cubic feet per day
MMcf	million cubic feet
MMMcf	billion cubic feet
md	millidarcys
P&A	plugged and abandoned
ppm	parts per million
psi	pounds per square inch
psia	pounds per square inch, absolute
psig	pounds per square inch, gauge
sec.	section
TD	total depth
R.	Range
T.	Township
RD	redrill

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INTRODUCTION

PURPOSE AND SCOPE

The oil and gas exploration history of Oregon goes back to the turn of the century and includes over 200 attempts to discover hydrocarbons in the state. These dry holes, mostly in the western third of the state, explored the Tertiary sediments to depths ranging from several hundred to a few thousand feet. Not until 1979, however, was a commercial discovery made. The discovery of the Mist gas field added Oregon to the ranks of 32 other states that have hydrocarbon production.

This report summarizes the first five years of exploration and development at Mist. Michael Alger, Reichhold Energy Corporation (REC), has provided a chapter on the geology of the field, a subject about which there have been numerous questions from industry personnel who would like to explore in Oregon. Other sections include well design and production methods. Drilling data on all wells in the field are presented in Appendix A; production statistics comprise Appendices B through F.

ACKNOWLEDGMENTS

The authors wish to thank the following people for assistance on this report through personal discussions: Tom Amies and Henry Judd, Northwest Natural Gas Company (NNG), for gas constituents; Bill Caro, Beaver Drilling Fluids, for information on drilling fluids; Dan McKeel and James Moore, consulting micropaleontologists, and Alan Niem, Oregon State University, for help with biostratigraphy and geology. We are also grateful to Reichhold Energy Corporation for the use of confidential information on the geology of the field.

The arrangement and organization of the report were enhanced by help from John Beaulieu, Oregon Department of Geology and Mineral Industries (DOGAMI). In addition, we are grateful for review of the report by William King, DOGAMI; Vernon Newton, consulting geologist; Todd Thomas, REC; and Charles Stinson, NNG.

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GEOGRAPHY AND HISTORY

GEOGRAPHY

The Mist gas field is located 45 mi northwest of Portland, Oregon, in western Columbia County and eastern Clatsop County. The field name is derived from the nearby community of Mist. The topography in the field has a relief of 1,300 ft and consists of hills, many capped by basalt of the Columbia River Basalt Group, that have been dissected by the Nehalem River and its tributaries. The elevation of the river through the field ranges from 600 down to 500 ft. A temperate marine climate dominates the area, with wet, cool winters and dry, warm summers. The terrain is heavily forested, but large areas have been clearcut by ongoing logging operations.

Figure 1 shows the location of the gas field.

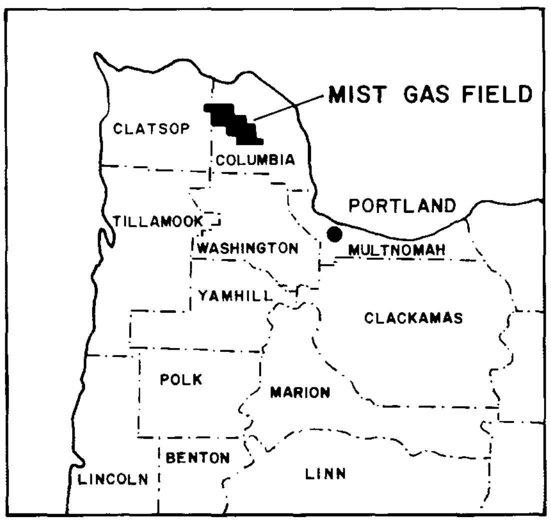

Figure 1. Map of northwest Oregon showing location of Mist gas field.

HISTORY

The earliest interest in the oil and gas potential of northwestern Oregon was expressed in 1896 by J.S. Diller in a U.S. Geological Survey (USGS) report. In 1945, an important study was conducted in the area by Warren, Norbisrath, and Grivetti for the USGS.

In 1969, the Oregon Department of Geology and Mineral Industries (DOGAMI) published a study of the oil and gas prospects of the region (Newton, 1969), pointing out the Nehalem basin in particular as having good potential. Then, in 1976, DOGAMI published a report specifically studying the natural-gas possibilities of the Mist area (Newton and Van Atta, 1976) and recommending the area near the community of Mist for exploration.

The exploratory drilling history of the Mist area began in 1945, when the Texas Company, later to become Texaco, Inc., drilled Clatskanie 1 in sec. 36, T. 7 N., R. 4 W. The well reached a total depth of 5,660 ft, where drilling was halted due to stuck pipe. Clatskanie 1 was a dry hole. Although it encountered intervals of basalt and other volcanic rock, the well also penetrated several hundred feet of reservoir-quality sandstone in the upper Cowlitz Formation. Cores of the sandstone had intervals of 25-percent porosity. The following year, the company drilled Clark and Wilson 6-1 in sec. 19, T. 6 N., R. 5 W., to a depth of 8,501 ft. This well also discovered sandstone in the upper Eocene Cowlitz Formation as well as a deeper sandstone at about 7,900 ft. This deeper sandstone was initially called the lower Cowlitz Formation but more recently the Yamhill Formation after studies of the paleontology had been performed (V.C. Newton, personal communication, 1985). Traces of gas were found, as well as porosities of up to 32 percent and permeabilities of up to 1,300 md. These wells, while not commercial, confirmed that reservoir rocks did exist in the Cowlitz Formation.

Between 1950 and 1970, Shell Oil Company, Standard Oil Company of California, and Mobil Oil Company conducted extensive exploration studies in Columbia and Clatsop Counties, but no drilling took place during that period. Standard Oil culminated its work by drilling a well in 1955 near Astoria in Clatsop County. Superior Oil and Pan American Oil (Amoco Production Company) did geologic studies in Columbia County during the years from 1960 to 1962, and Superior then leased about 50,000 acres in the county. Mobil Oil and Standard Oil leased land in the county during the period from 1969 to 1971, and Mobil conducted extensive field work. No drilling took place in Columbia County during this period, but Charles Newell, a consultant from Olympia, Washington, mapped extensively in the area in the 1950's, and his work was later used by others in the search for gas.

Not until 1974 were additional attempts at further exploration made. As a result of a shortage of energy supplies, Northwest Natural Gas Company (NNG) cut back the amount of pipeline gas delivered to the Reichhold Chemicals, Inc., plant near St. Helens in that year. Production of ammonium nitrate at the plant fell when gas deliveries went below the needed 9 MMcfd. Reichhold Chemicals then formed the subsidiary Reichhold Energy Corporation (REC) to try to solve the gas shortage by looking for new energy resources. Wesley Bruer revised and expanded the Newell maps of the Mist area for Reichhold, and in 1975 the company leased 80,000 acres on several prospects, including Mist, in Oregon.

In the same year, REC and NNG drilled four wells as partners in Oregon, including one well in Columbia County. All were dry holes. Then, in the summer of 1977, partners REC and Diamond Shamrock Corporation drilled Columbia County 1 in sec. 11, T. 6 N., R. 5 W., 3 mi northwest of the Texas Company's Clark and Wilson 6-1 well. The mineral owner was Columbia County. Columbia County 1 was located on the flank of an anticline that had been mapped at the surface.

The well penetrated over 650 ft of upper Eocene Clark and Wilson sandstone, which was later recognized as the primary gas reservoir at Mist. A small interval of gas was found at the top of the Clark and Wilson sandstone, but the well was determined to be noncommercial. Sidewall cores showed porosity as high as 37 percent and permeability up to 683 md. The total depth of the well was 3,111 ft.

Also in 1977, the partners, with REC as operator, chose another location half a mile south of Columbia County 1. They chose the site based on dipmeter results from the first well, drilling for a higher structural position. But the new well, Longview Fiber 1, encountered the Clark and Wilson sandstone 85 ft lower than it was in Columbia County 1. A 1980 redrill of Longview Fibre 1 was also dry. Despite these failures, dipmeter results were used successfully in later years to interpret subsurface structure.

After conducting a seismic survey, the two companies drilled Columbia County 2 in sec. 14, southeast of the previous two wells. This well turned out to be structurally higher but was also dry.

By 1979, NNG had become more interested in finding a gas-storage site for pipeline gas. Such a site would enable them to buy imported gas at a steady rate throughout the year, storing the gas during summer months and withdrawing it during periods of high demand. To prepare for such exploration, NNG entered into an operating agreement with REC and Diamond Shamrock for further drilling near Mist.

The three partners agreed to try once more for a gas discovery by redrilling Columbia County 1 to the southwest in 1979. This redrill resulted in Oregon's first commercial gas discovery, located in what was later to be named the Bruer pool. The Clark and Wilson sandstone was higher than in the original hole and had 40 ft of net gas at its top. The initial flow test produced gas at the rate of over 1.6 MMcfd through perforations in the casing at 2,448 to 2,460 ft. The gas contained 92 percent methane and provided a heating value of 950 Btu per cubic foot.

Stimulated by the discovery, the companies followed this success with more exploration, including the drilling of Columbia County 4, which was completed in a new pool, later named the Newell pool, in sec. 15, T. 6 N., R. 5 W. Columbia County 3 was then drilled to develop the pool into which Columbia County 1 had been completed, becoming the second well in the Bruer pool.

Exploration and development continued in 1979 with several dry holes and unsuccessful redrills but also with two additional producers by year's end: Columbia County 6, second redrill, and Columbia County 10, which discovered the Flora pool. The discovery year 1979 at Mist resulted in the drilling of five producing wells and six dry wells and redrills by REC and its partners. In addition, as a result of the gas discovery, American Quasar Petroleum Company drilled three exploratory wells several miles to the southeast of the successful wells during the year.

To provide for transport of the gas to market, NNG built a 12-in. pipeline to meet a main line at Clatskanie, and Columbia County 6 was put on line by year's end. By February 1980, Columbia County 1 and 3 were also producing.

The Mist gas field discovery occurred after more than 200 dry holes had been drilled throughout the state, including five in the Mist area itself. In the years following the Mist gas field discovery, REC has been the most active operator in the area, usually working with partners such as Diamond Shamrock Corporation, Oregon Natural Gas Development Corporation, and American Quasar Petroleum Company. Since the field discovery, these companies have drilled an average of 15 wells and redrills per year in and around the field, resulting in a total of 15 wells completed to production by the end of 1984, five years after the first well was put on line (Table 1). During this time, 65 dry holes and redrills were also drilled.

The Mist gas field was formally named and defined in 1979 after public hearings to receive input on field rules. The 42-mi^2 field was expanded to 141 mi^2 in 1983 to its present configuration (Figures 2 and 3).

TABLE 1. *Producing wells of Mist gas field, Oregon: Pool depths and gas properties*

Pool name	Well name (all are operated by Reichhold Energy Corp.)	Kb elev. (ft)	Perforated interval (true vertical depth in ft)	Tested rate (Mcf/day)	Btu/cf	Completion date
Bruer	Columbia County 1 RD	1,031	2,409-2,420	1,630	902	5/79
Bruer	Columbia County 3 RD	869	2,184-2,270	3,750	901	6/79
Bruer	Columbia County 6 RD2	754	2,036-2,143	6,500	896	8/79
Newell	Columbia County 4	765	2,316-2,324	865	914	5/79
Newell	Columbia County 4 RD	765	2,248-2,333	2,250	925	7/82
Flora	Columbia County 10	1,100	2,668-2,710	4,300	960	10/79
Flora	Columbia County 33-3	1,039	2,467-2,646	6,000	954	6/80
- -	Columbia County 13-1	1,174	2,398-2,426	2,600	781	8/81
- -	Columbia County 13-1 RD	1,174	2,380-2,409	1,920	785	5/82
Crown	Crown Zellerbach 42-1	1,303	1,750-1,760	900	908	7/80
Newton	Longview Fibre 12-33 RD	899	2,209-2,286	4,860	979	9/81
Adams	Columbia County 13-34	1,266	2,642-2,650	473	973	12/82
Paul	Paul 34-32	626	2,521-2,556	1,400	984	11/82
Al's	Columbia County 23-22	566	Confidential	3,000	962	12/83
Schlicker	Columbia County 43-22	709	Confidential	1,290	959	2/84
Busch	Busch 14-15	571 ±	Confidential	3,000	958	8/84
Baldwin	Columbia County 43-27	911 ±	Confidential	1,460	909	8/84

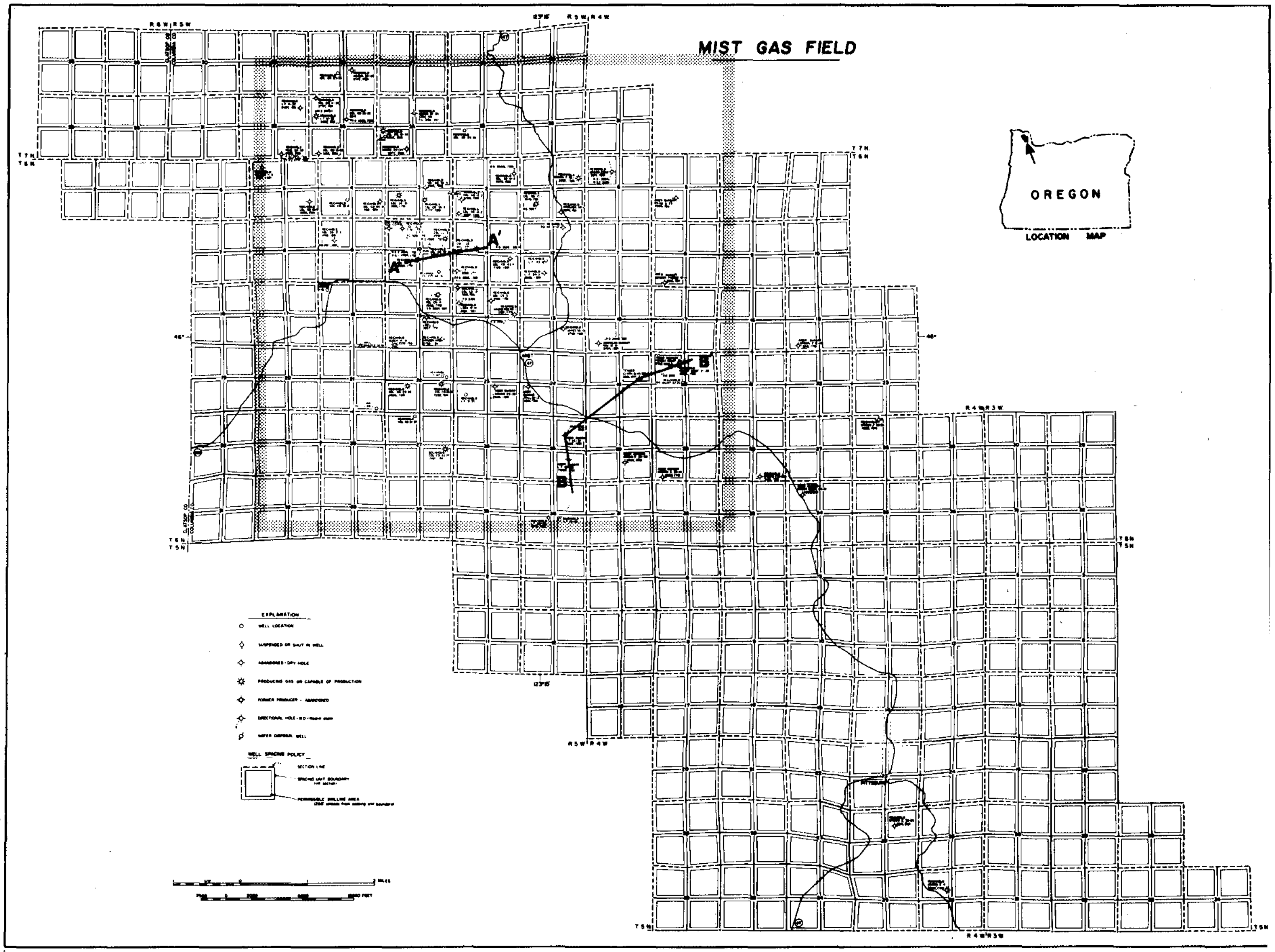

Figure 2. Mist gas field as of December 1984. This map is periodically updated and released by the Oregon Department of Geology and Mineral Industries. Area outlined in gray is shown at larger scale in Figure 3. Cross section A-A' appears in Figure 5; cross section B-B' is shown in Figure 6.

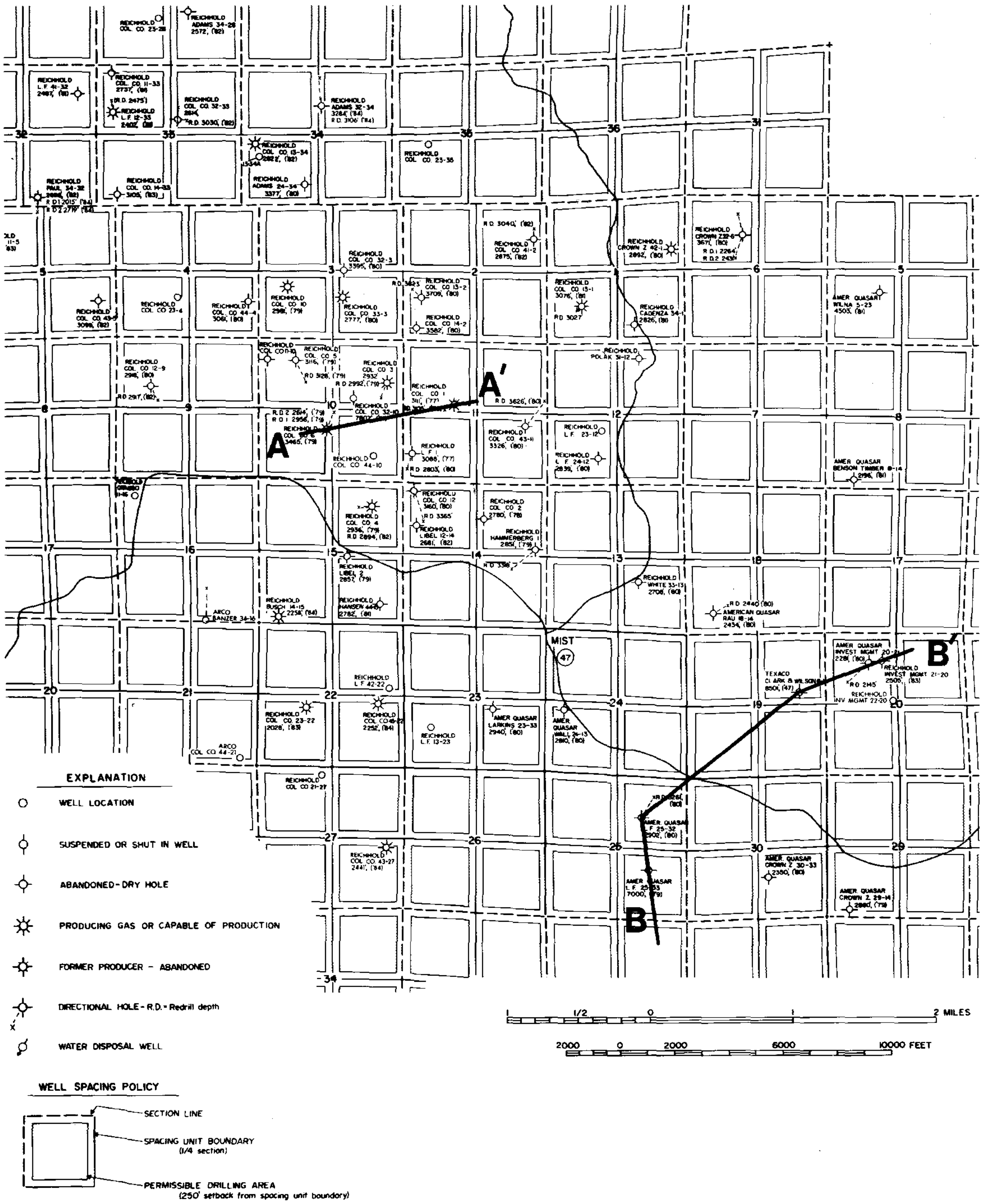

Figure 3. Detail of productive area of Mist gas field as of December 1984. Cross sections A-A' and B-B' appear in Figures 5 and 6, respectively.

GEOLOGY*

GEOLOGIC HISTORY

The oldest rocks in the Mist area are the middle to upper Eocene Tillamook Volcanics, which consist predominately of submarine to subaerial basalt flows and breccias. The geochemistry of the Tillamook Volcanics is similar to that of seamounts, suggesting their source may have been an offshore volcanic center that was active during late Eocene time. Possibly these submarine rocks were transported by plate-tectonic motion toward the continent, as were the slightly older Siletz River Volcanics to the south.

Locally interfingering with the Tillamook Volcanics are the middle Eocene sediments here included in the Yamhill Formation. These sediments include mostly tuffaceous siltstones and shales, with local occurrences of quartzitic sandstone. A sandstone occurring in the Yamhill Formation in the Mist area is referred to locally as the Clatskanie sandstone. In some previous work, the Yamhill section described here has been included in the lower Cowlitz Formation (Newton, 1969). In Clatsop County to the west, Niem and Niem (1985) include this same section in the Cowlitz Formation. For these reasons, middle Eocene sediments are called Yamhill Formation(?) in this report.

The exact relationship of the Yamhill Formation(?) of the Mist area to the Tillamook Volcanics is a matter of some debate. Near its type locality, the Yamhill Formation underlies flows of the Tillamook Volcanics, although this may only be a local interfingering. It appears, at least in the Mist area, that Tillamook Volcanics underlie units here assigned to the Yamhill Formation(?). These volcanic rocks may be the economic basement, that is, the deepest rocks in which one would expect to find economically productive hydrocarbons.

Predominately deep-water conditions existed, with local exceptions, during the deposition of the Yamhill Formation(?) in the Mist area. Near-shore shelf environments were present during the deposition of the Clatskanie sandstone east and south of the field. The Clatskanie sandstone is locally clean, well sorted, and quartzitic, grading laterally into poorly sorted sandstones and siltstones.

The top of the Yamhill Formation(?) is marked by a regional unconformity, with extensive erosion in places. This unconformity can be traced in the subsurface from Clatsop County, through Mist, and well into the Willamette Valley.

Overlying the unconformity is the Clark and Wilson sandstone of the upper Eocene Cowlitz Formation. It is the main reservoir sandstone producing in the Mist gas field and is a very clean, friable, well-sorted, micaceous, quartzitic sandstone with porosities in the 25- to 32-percent range and permeabilities ranging from 20 to 1,500 md, averaging about 200 md.

Deposition of the Clark and Wilson sandstone occurred apparently during a volcanically quiet period, probably while the subduction zone of the Farallon-Kula Plate relocated westward (Snavely and others, 1980). The absence of volcanic debris coupled with a high-energy depositional environment allowed for the accumulation of high-quality reservoir sand.

There are many interpretations for the depositional environment of the Clark and Wilson sandstone. Bruer

*This section was written by Michael P. Alger, Reichhold Energy Corporation.

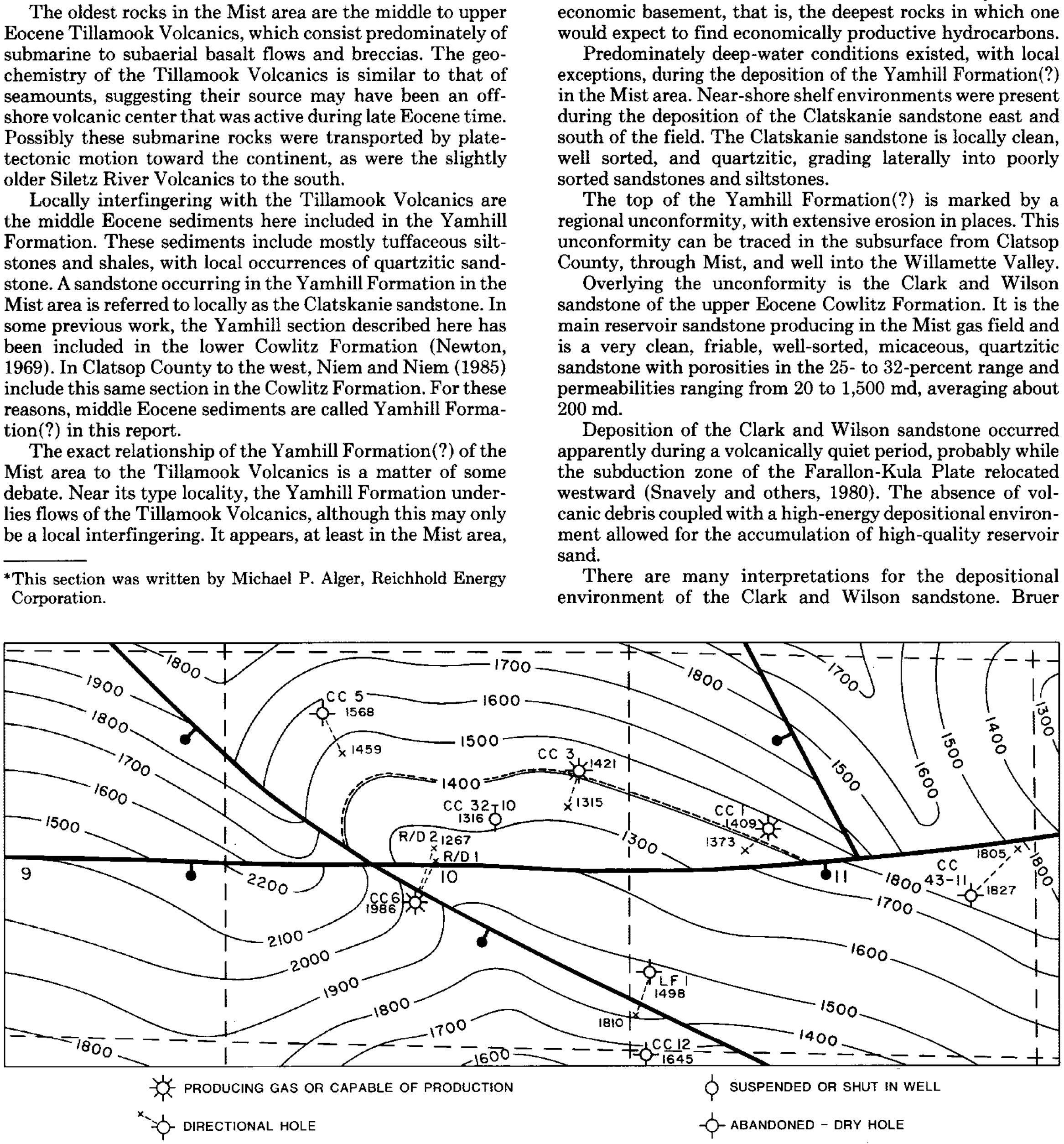

Figure 4. Structure contours, top of Clark and Wilson sandstone. Dashed line shows gas-water interface.

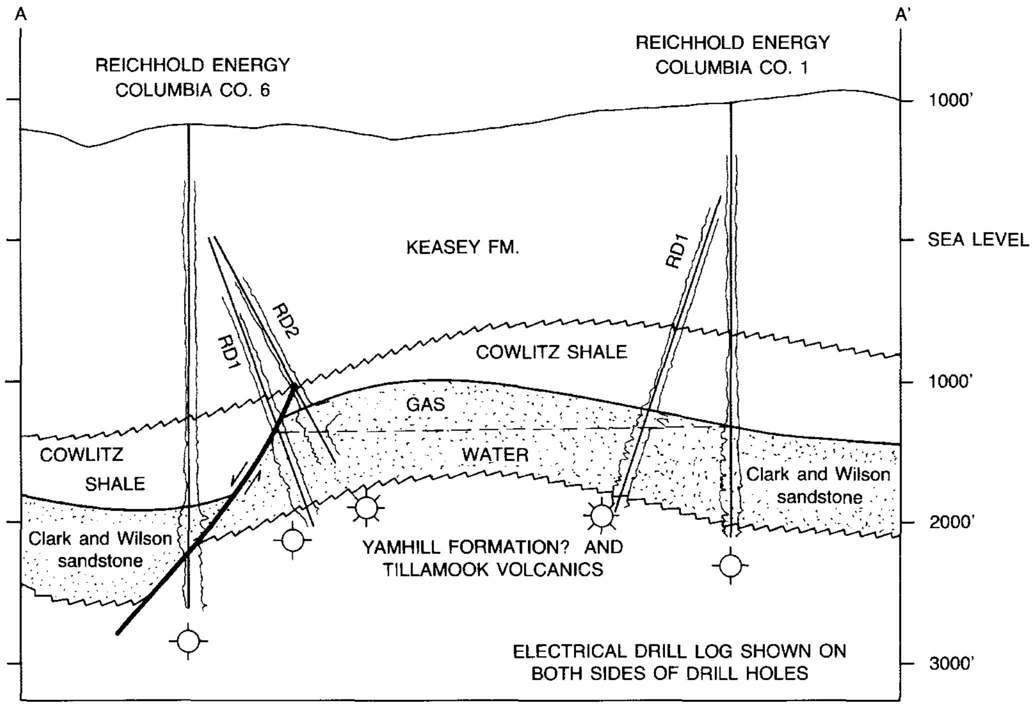

Figure 5. Cross section A-A', Bruer pool. Location of cross-section line is shown in Figures 2 and 3. The Cowlitz Formation, which in this cross section consists of Cowlitz shale and the Clark and Wilson sandstone, is bounded by unconformities.

(1980) proposed that the Clark and Wilson sandstone was analogous to deep-water sands of the modern Straits of Juan de Fuca in northwest Washington, with the sands deposited in deep water between volcanic highs in a narrow channel. These sands were later reworked by moderately strong currents.

This author, however, interprets the sands as nearshore, predominately shallow-water shelf and/or possibly deltaic sands. Examination of cores from Texaco's Clark and Wilson 6-1 shows evidence of ripple structures and bioturbation in the sandstone. Ostracods in the sandstone are interpreted to be found only in very shallow water (less than 40 ft deep) (D. McKeel, personal communication, 1983). The occurrence of lignite and vitreous, conchoidally fractured bituminous coal suggests the possible relationship to a deltaic environment. Coeval units in the Skookumchuck Formation in southwestern Washington are interpreted in much the same way, particularly in regard to the relationship to an ancient delta (Armentrout and others, 1980).

Timmons (1981) and Jackson (1983) both indicate that outcrops of the Cowlitz Formation suggest near-shore deposition in a wave-dominated shelf environment, with storm channels, root casts, and bioturbation very common.

Lying on top of the Clark and Wilson sandstone are siltstones, shales, and minor sandstones of the Cowlitz Formation. Reichhold's Crown Zellerbach 42-1 well produced from one of these minor sandstones, the Crown sandstone. The depositional environment within these units was mostly deep water, with a gradual transgression of the seas to a maximum transgression stage about midway from the top of the Clark and Wilson sandstone to the top of the Cowlitz Formation (D. McKeel, personal communication, 1983).

Deposition of the Cowlitz Formation ended abruptly with very active tectonism and erosion. Most of the major faults mapped in the subsurface in the Mist area truncate at this unconformity between the Cowlitz Formation and the overlying Keasey Formation. As much as 3,000 ft of the upper Cowlitz section may have been eroded locally during this period. Lateritic soils have been observed at this contact.

The upper Eocene (to lower Oligocene?) Keasey Formation overlies the unconformity and consists of predominately tuffaceous siltstones and shales. The Keasey Formation is exposed at the surface throughout much of the Mist field. Other formations seen at the surface in the Mist area include, in decreasing age, the Pittsburg Bluff and Scappoose Formations, both Oligocene in age.

FORAMINIFERAL ZONATIONS

Micropaleontology has proven to be very useful in correlations of stratigraphic units and in determination of paleoenvironments. The oldest foraminifera observed at Mist may belong to the Ulatisian (Lamings B-1A) Stage, but it is more likely that the lower Narizian is the oldest observed faunal stage (J. Moore, personal communication, 1984). The upper Narizian Stage is represented within the Yamhill Formation(?) section and continues upward to the top of the Cowlitz section. The Keasey Formation is characterized by the appearance of Refugian-age foraminifera. Useful marker foraminifera include *Uvigerina cocoensis,* limited to the Refugian Stage; *Cibicides natlandi,* marking the first appearance of the Narizian; and *Valvulineria cf. jacksonensis,* generally occurring within a few hundred feet of the Clark and Wilson sandstone, if the paleoenvironment was deep

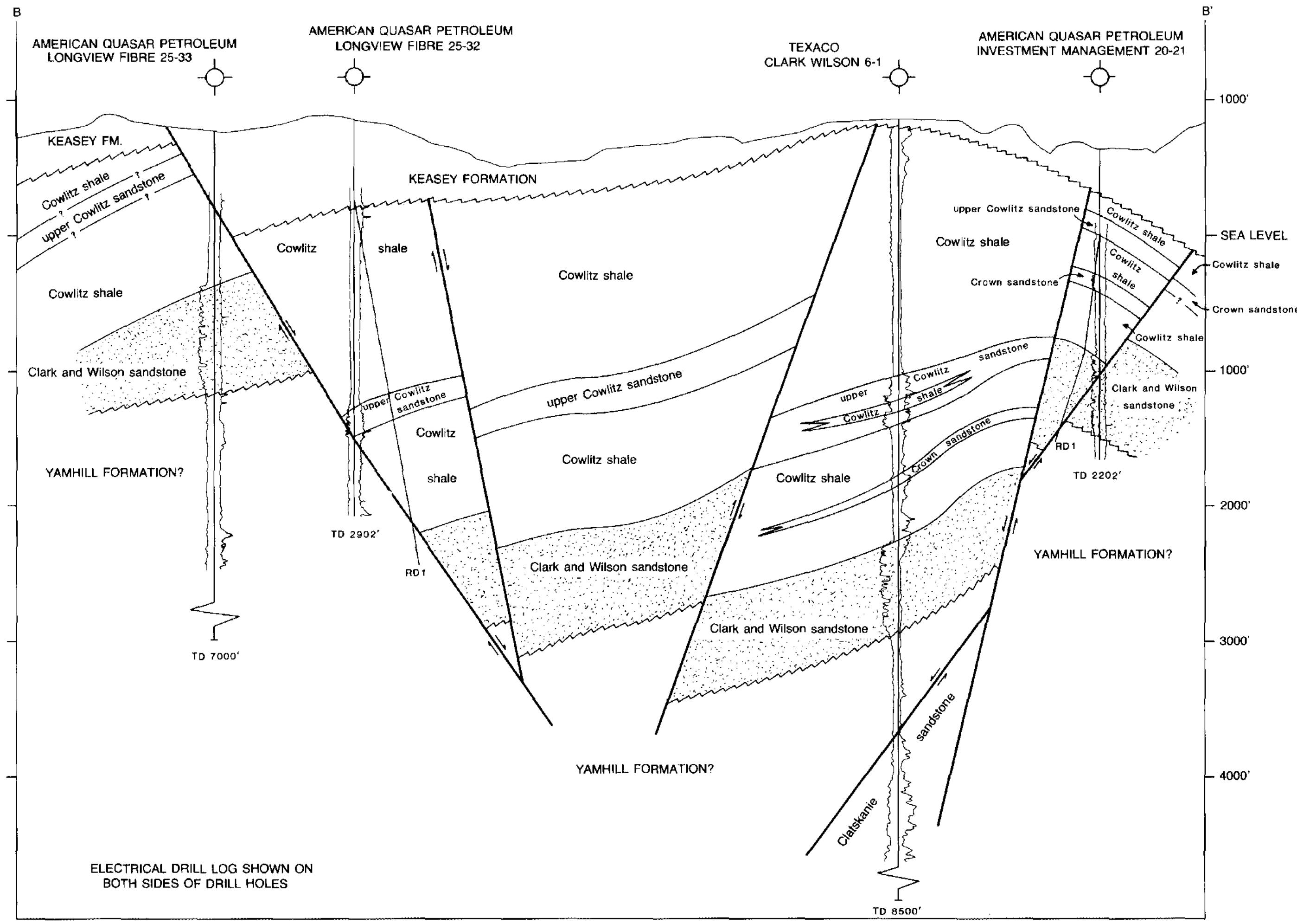

Figure 6. Cross section B-B'. Location of cross-section line B-B' is shown in Figures 2 and 3. The Cowlitz Formation, which is bounded by unconformities, consists in this figure of the following informal units: Cowlitz shale, upper Cowlitz sandstone, Crown sandstone, and Clark and Wilson sandstone.

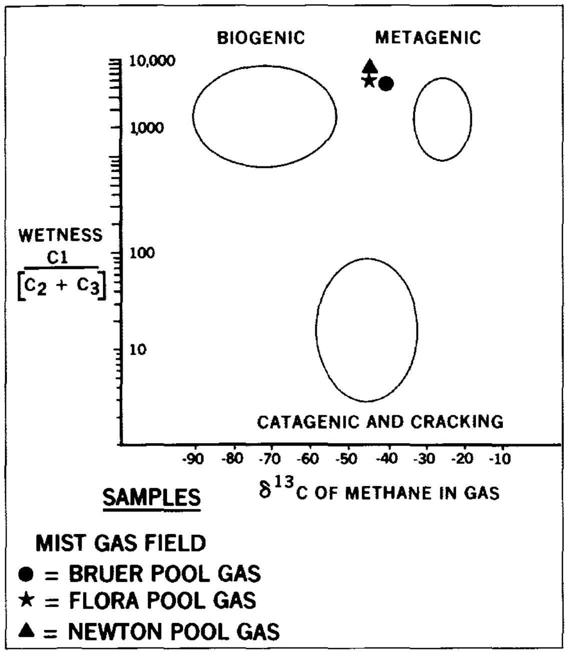

Figure 7. Natural gas classification (Bernard and others, 1976) showing classification of gas samples from three pools of the Mist gas field (figure reprinted by permission from Armentrout and Suek, 1985).

enough (J. Moore, personal communication, 1984). The biostratigraphy of the area is also treated by McKeel (1983).

STRUCTURE AND TRAPS

The structure in the Mist area is very complex (Figure 4). Normal and strike-slip faulting is common, with occasional high-angle reverse faulting also present. Though no coherent fault pattern exists, a relatively strong northwest trend suggests a structural relationship to the Portland Hills lineament on trend to the southeast. Many of the major northwest-trending faults exhibit considerable strike-slip movement, and vertical offsets may change drastically over very short distances. A very large northwest-trending strike-slip fault may control much of the faulting in the area (Alger, 1984). There also appear to be a number of east-west- and northeast-southwest-trending faults. As might be expected, prediction of fault strike in the area is very difficult. A possible wrench-fault pattern may occur locally (Alger, 1984).

Most major faults truncate at the Cowlitz-Keasey unconformity with little or no expression at the surface (Figures 5 and 6). However, several faults, mostly trending northwest, show residual movement at the surface. Many linears are visible at the surface on aerial photos, but it is uncertain if they are expressions of deeper faulting or if many are simply near-surface jointing patterns with no subsurface displacement (A. Niem, personal communication, 1984).

With the exception of the Crown Zellerbach 42-1 well, all traps in the Mist field are interpreted by the author to be fault controlled. Longview Fibre 12-33 RD1 (Newton pool) may involve an erosional truncation of the Clark and Wilson sandstone.

The aerial extent of the pools is small, with sizes ranging from less than 40 acres to approximately 160 acres (Bruer pool). The thickest gas column found to date is 225 ft in the Reichhold Columbia County 33-3 well. Gas columns of at least 20 ft are generally needed for commercial production.

ORIGIN OF GAS

A great deal of uncertainty remains concerning the origin of the gas found at Mist. The field is located on a saddle formed by the Tillamook Highlands to the south and the Willapa Hills uplift to the north. It is flanked on the west by the Astoria basin and on the southeast by the Tualatin basin, which is considered by some to be the north Willamette basin (Armentrout and Suek, 1985). These basins are potential source areas for the gas generation. It is not likely that the gas was generated in situ. Vitrinite reflectance values of less than 0.4 percent in the shales surrounding the reservoirs indicate immature source material locally.

Even though the gas found at Mist is primarily methane, detectable amounts of heavier hydrocarbons up to pentanes have been measured. Armentrout and Suek (1985) have plotted ^{13}C-isotope ratios from samples taken in the Mist field and determined that the gas was thermally generated (metagenic). A catagenic origin must also be considered, with the preponderance of methane possibly being due to "molecular filtering" caused by long migration paths. The ^{13}C-isotope ratio is centered over the normal catagenic range (see Figure 7).

Assuming a nonbiogenic origin, the most likely source of gas is from the deeper parts of the Astoria and/or Tualatin basins, with migration up the bedding planes.

DRILLING PRACTICES

WELL SPACING

Following the discovery of the Mist gas field in 1979, the Oregon Department of Geology and Mineral Industries (DOGAMI) held public hearings to consider spacing-unit sizes for the field. The spacing is based upon spacing plans that follow the Interstate Oil Compact Commission model and that have been used successfully in other states. Statewide spacing units are surveyed sections, quarter sections, or quarter-quarter sections. For gas production shallower than 7,000 ft, a maximum of one producing well may exist on a 160-acre quarter section. For gas production from deeper than 7,000 ft, one producer may exist on each 640 acres or a section. The well location for purposes of spacing is the location of the well bore at the top of the producing horizon and must be at least 500 ft from the spacing unit boundary.

Special field rules in the Mist field, however, allow a set-back distance of 250 ft from the spacing unit boundary to allow a more effective search for the small pools that characterize the field. The unit sizes are the same as for statewide spacing and apply to each pool. More than one well could be drilled in a quarter section, for example, if each produced from a different pool. The set-back requirement was designed to protect correlative rights by reducing or eliminating drainage across spacing unit boundaries. An operator may request exceptions to the spacing rules on the basis of geology, productivity, topography, enhancement requirements, or environmental protection. Several wells that had been completed to production before the spacing rule was written were granted exceptions to the rule.

SITE PREPARATION

Most wells at Mist require a flat well pad of 100 ft by 200 ft in size. Operators avoid steep slopes to minimize slope-stability problems and to reduce the amount of earth moving required. A contractor spreads gravel or crushed rock to a depth of as much as several feet to support the heavy equipment. Sites are designed to contain the drilling rig, mud pumps, mud pits and sump, pipe rack, logging and supervisors' trailers, spare-parts storage, and space for vehicles (Figure 8). Construction of the drill site usually occurs immediately before the drilling rig is to be moved in and the well begun. Wells in the Mist field are generally located near existing public roads or logging roads, but sometimes additional gravel or new roads must be added to reach a site.

DRILLING FLUIDS AND LOGGING

Mud is the drilling fluid used thus far at Mist. Besides bringing cuttings to the surface, the mud also cools and lubricates the bit and drill pipe, forms a wall cake on the sides of the hole, and controls subsurface pressures. Formulation of the mud depends upon the particular formations that will be penetrated and downhole fluid pressures that will be encountered. Other factors, such as economics, hole temperature, contamination by cement or water, and the type of water to be used in making the mud, come also into play.

At Mist, the wells usually reach depths of only 2,500 ft, and the formations do not present many problems of high pressures or troublesome chemistry. The 400- to 500-ft-deep hole drilled for surface casing can be drilled with a mixture of

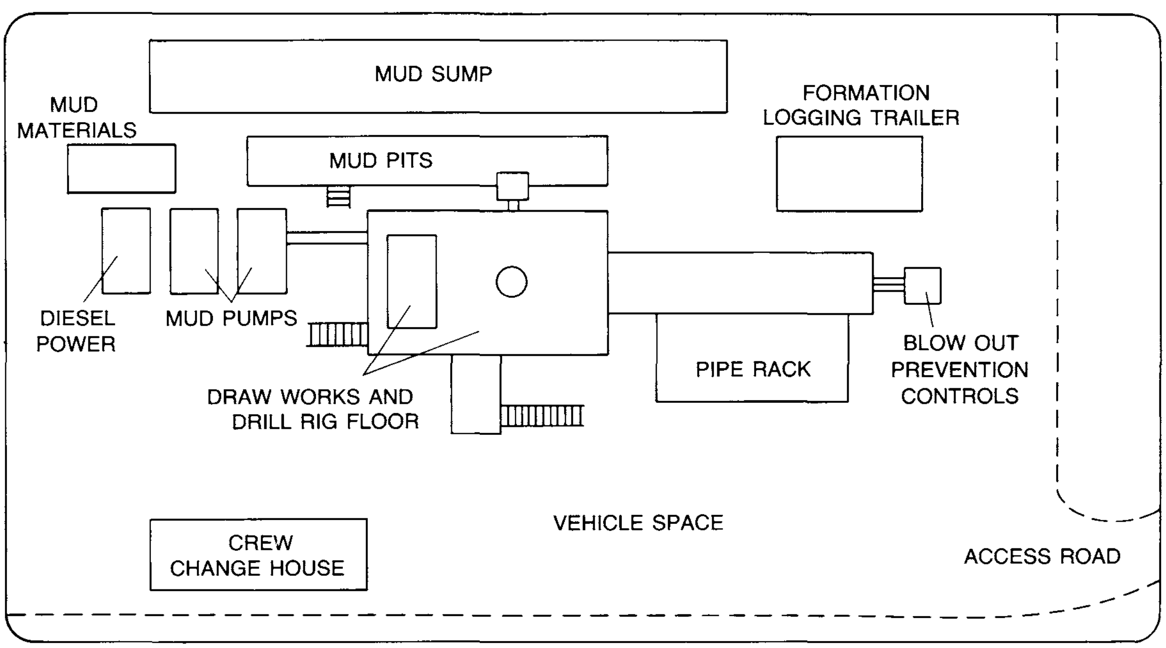

Figure 8. Schematic drawing of typical Mist gas field drill site.

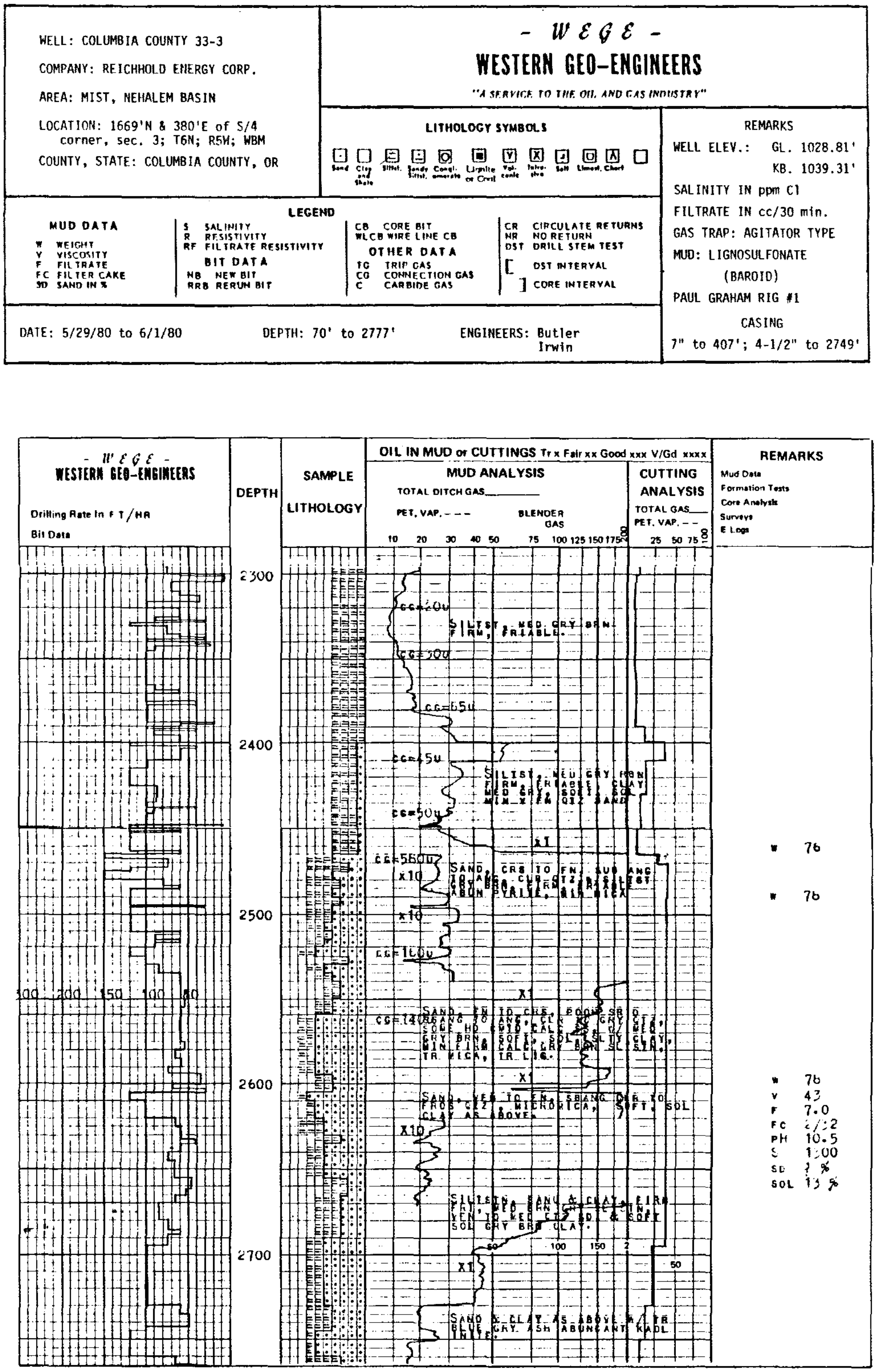

Figure 9. Sample mud log through completion interval, Columbia County 33-3.

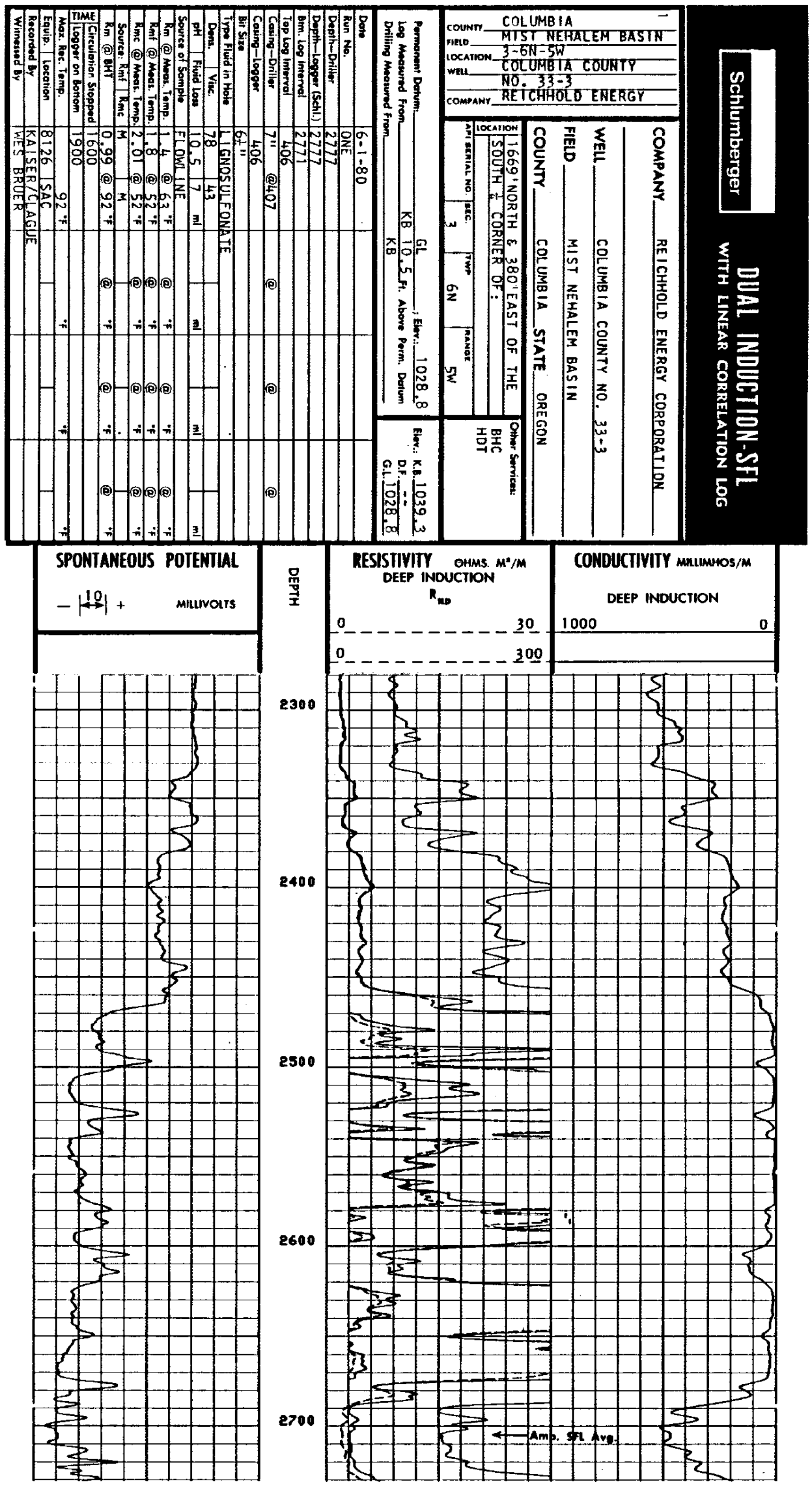

Figure 10. Sample induction log through completion interval, Columbia County 33-3.

water and bentonite. From this point to total depth, additives are sometimes used to control mud properties and enable it to perform properly. These include caustic soda to control pH and to give the bentonite a better yield, lignite to act as a thinner, and polymers to control water loss (W. Caro, personal communication, 1984). Overpressured formations have not been a problem in most wells, so weighting material, such as barite, is seldom needed.

If the mud is being displaced by cement or must be replaced to improve its properties, the old mud is temporarily stored in the mud sump. Permanent disposal is later accomplished by hauling the fluid to a disposal site approved by the Oregon Department of Environmental Quality.

In most cases, operators of wells at Mist use a mud-logging service company to examine samples and produce a mud log of the well (Figure 9). At the completion of drilling, which usually means after drilling several hundred feet into the Clark and Wilson sandstone, the drilling fluid is circulated and logs are run. Reichhold Energy Corporation (REC), the primary operator to date, typically runs the following logs on most wells in addition to the mud log: dual induction log (Figure 10), acoustic velocity log, and dipmeter.

If gas appears to be present, a long string of 4½ -in. or 5½ -in. casing is run and cemented through the gas zone. A later section entitled "Well Completions" describes completion techniques.

SURFACE CASING AND BLOWOUT PREVENTION

The first wells in the Mist area were drilled by the Texas Company, who employed a casing program of 20-in. casing to a depth of about 100 ft in a 24-in. hole, followed by 13⅜-in. casing to about 1,050 ft in a 17½-in. hole. For testing purposes, one of the wells was also cased to 8,100 ft with 5½ -in. casing in a 10⅝-in. hole. The depths of these wells dictated the use of such large-diameter casing, but subsequent shallower wells by other operators have been cased with 7- or 8⅝-in. casing to depths of 400 to 600 ft. Cement is pumped through the shoe of the casing and circulated back to the surface. If cement returns are not attained, more cement is pumped down the annulus through small-diameter pipe. The casing and cement seal the ground water from contamination as well as serving as an anchor for blowout preventers. This string of casing is the only casing used if the well turns out to be a dry hole.

Blowout preventers (Figure 11) are installed on the surface casing after the cementing of the casing. These are pressure tested before drilling proceeds. Any failure to hold pressure due to surface leaks or downhole casing or cementing problems is corrected at this time.

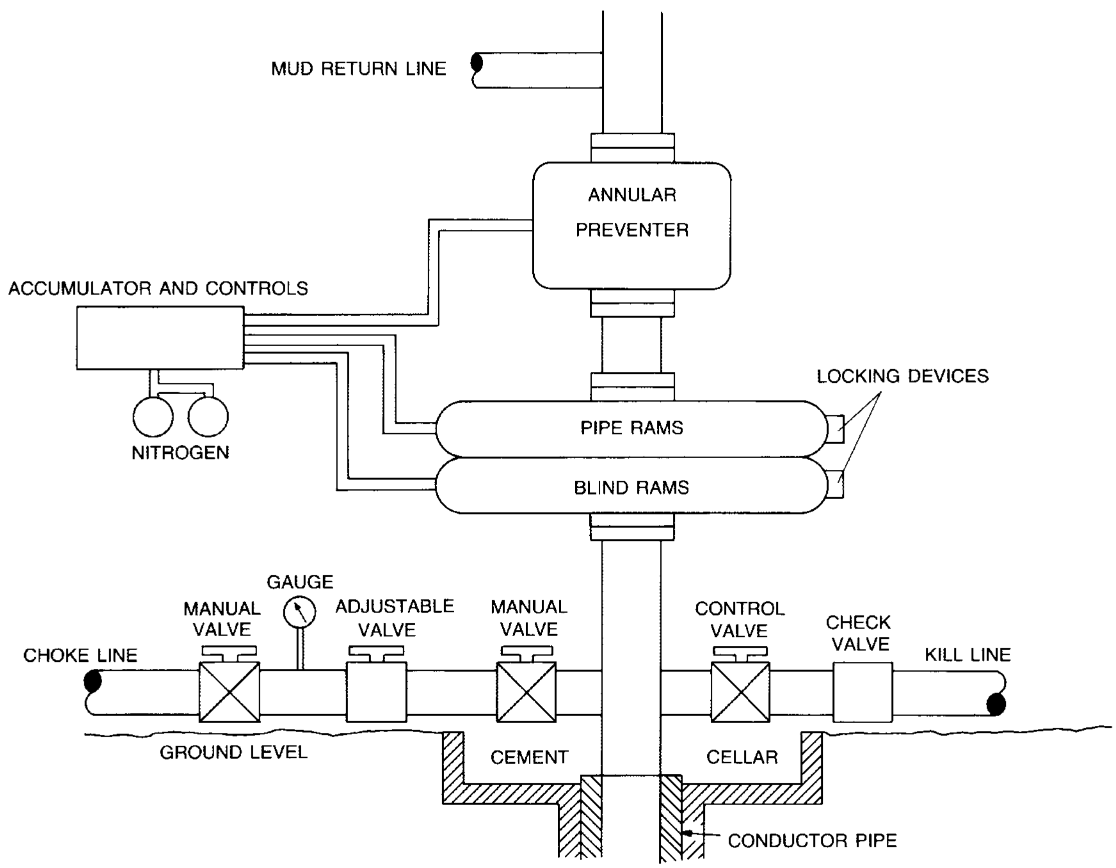

Figure 11. Blowout prevention equipment, Mist gas field.

WELL COMPLETIONS

From the shoe of the surface casing to total depth, a hole with a diameter of 6¼ or 7⅞ in. is drilled. If logs indicate production, casing with a diameter of 4½ or 5½ in. is run and cemented. The cement is circulated through the shoe to isolate any fluid zones that may have been encountered while drilling. The cement will often extend all the way to the surface. Cementing operations at Mist are accomplished with Class-G cement and water, using the jet hopper mixing technique. Calcium chloride is often used as an accelerator.

Tubing with a diameter of 2⅜ in. is hung just above the intended zone of production (Figure 12), and the christmas tree is installed on the tubing spool. Potassium chloride water is then circulated to become the new hole fluid. A service company is employed to jet perforate the casing to open the gas intervals to the well bore, and production is stimulated through the tubing by evacuating the hole fluid using high-pressure nitrogen. The well is allowed to flow to remove any water or drilling fluid that may be in the gas interval (Figure 13).

Northwest Natural Gas Company (NNG), buyer of much of the gas produced, takes samples for analysis of components

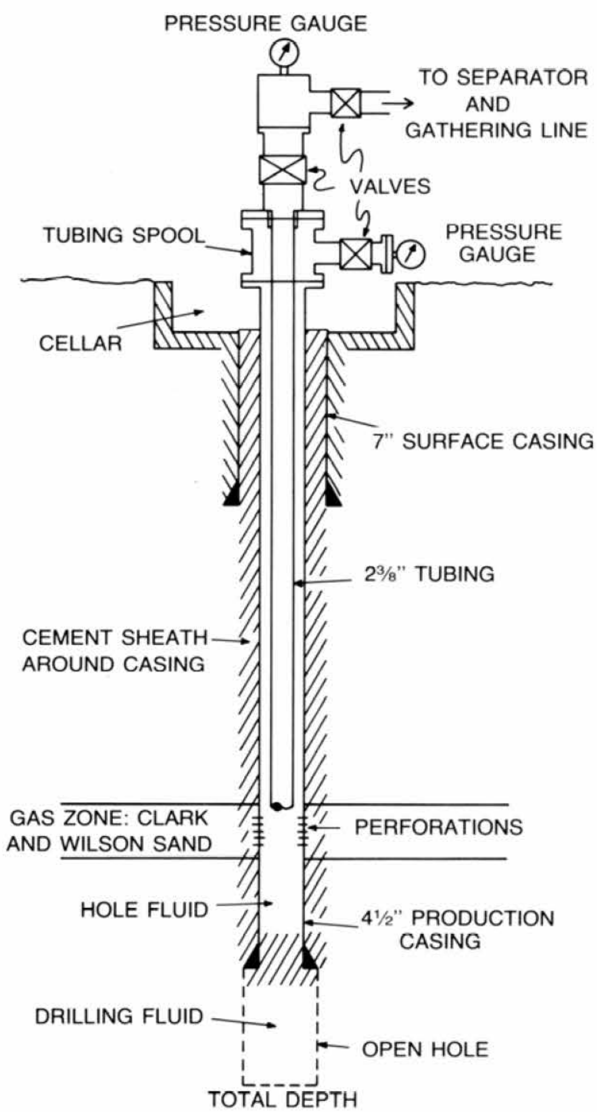

Figure 12. Schematic of completed well, Mist gas field.

Figure 13. Flaring gas during initial production test of Reichhold Energy's Columbia County 13-34.

and determination of Btu content. The operator or gas company personnel calculate flow rates and casing and tubing pressures. When the water has been removed, the well is shut in to await connection to the pipeline.

The gas reservoirs at Mist have been, for the most part, at hydrostatic pressure, with the exception of pools in the southern part of the developed area. The gas is mainly methane, with some nitrogen and heavier hydrocarbon fractions to pentane (Appendix B). These fractions indicate metagenic or catagenic rather than biogenic origin and therefore imply a mature basin as a source.

WELL ABANDONMENT

In spite of the success at the Mist gas field, there have been 65 dry holes and dry redrills within the present field boundaries through the end of 1984. As a result, well plugging is a very important procedure in the field, not only to prevent a dry hole from damaging a nearby producer but also to protect fresh ground water from contamination by other fluids that could migrate from elsewhere in the well.

Plugging is performed through drill pipe soon after the well has been logged and determined to be a dry hole. The drilling mud becomes the abandonment fluid for the intervals without cement plugs. The first plug is usually placed across the top of the Clark and Wilson sandstone to prevent migration in the well bore in the event of a nearby producer at a later date. In the event of a productive zone or any fluid zone in the well at greater than hydrostatic pressure, a 100-ft plug is required across the top of the zone. These plugs generally are not needed at Mist, however, unless the well to be plugged is a former producer. Fresh waters are protected by surface casing, so the next plug to be placed is a 100-ft plug across the shoe of the surface casing. Finally, a 10-ft surface plug completes the abandonment.

Cleanup of a drill site includes cutting off casing at least 4 ft below ground level, removing the cellar, and hauling the contents of the sump to a dump site. Finally, the gravel pad is removed, and the site is returned to its natural contours. In the Mist area, it is common for logging companies to request that the gravel pad be saved for log storage, and in these cases, the last steps of site reclamation are not performed.

PRODUCTION METHODS

WELL HEADS AND PIPELINES

In the event of a successfully completed well, the well head is installed on the production casing to control and direct the flow of gas (Figure 14). Then the well is shut in to await pipeline construction.

Northwest Natural Gas Company (NNG) then installs pipelines with diameters of 4, 6, or 8 in. on newly completed wells to deliver the gas to Miller Station, the gas treatment facility at the Mist gas field (Figure 15). The facility was built and is operated under codes administered by the Public Utility Commissioner of Oregon for the Federal Office of Pipeline Safety.

Most newly discovered gas pools have pressures in the range of 950 psig, enough to push the gas to Miller Station and into the pipeline at Clatskanie. Drops of pressure as a result of production have brought about the need for natural-gas-driven compressors at some wells to increase the gathering-line pressure and to allow the well to be produced to lower reservoir pressures. The life of wells can therefore be prolonged, thereby delaying the need for abandonment or conversion to gas storage.

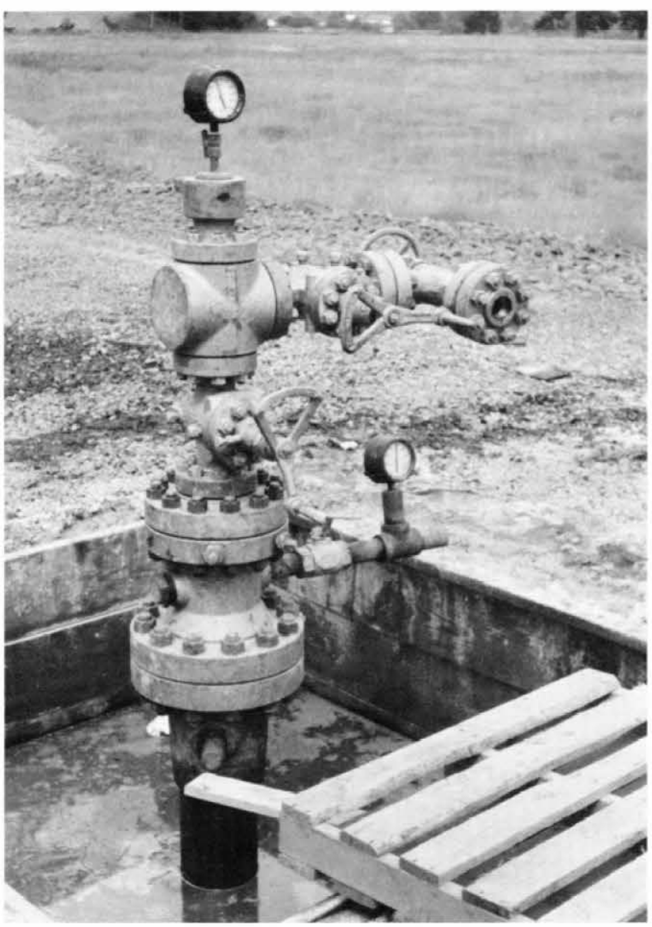

Figure 14. Well head, Reichhold Energy's Busch 14-15.

Figure 15. Gathering and treatment facility at Miller Station.

GAS MEASUREMENT AND TREATMENT

Gas volumes are continuously measured by an orifice meter at each wellhead (Figure 16). The meter mechanism consists of a round orifice to constrict flow, pressure sensors, and a temperature recorder. Recorded pressure values, along with the temperature and other known parameters, are used to calculate volumes of gas produced. Production to date is summarized in Appendix C.

Gas produced at Mist is nearly ready for use as it comes from the reservoir. Some treatment is necessary, however, before the gas is transported to consumers. At each well, a separator is installed to remove water. In some cases, a 10,000-gallon holding tank has been used for storage until the water can be hauled for disposal. After the gas is transported to Miller Station via gathering lines, additional separators remove any water that has condensed in the gathering lines, and pressures are equalized among the lines so all gas can be moved in one pipeline. The gas travels through a large triethylene glycol dehydrator to lower the humidity to about 5 lb of water per MMcf of gas. The gas is then odorized with mercaptain odorant, measured, and delivered into the 12-in. pipeline to Clatskanie. At that point, the gas enters the grid of pipelines distributing natural gas to industrial, commercial, and residential customers.

GAS PRICING

Natural gas prices in the United States have been controlled by the Natural Gas Policy Act since December 1, 1978. Beginning in 1985, certain types of gas, including that produced at Mist, have been deregulated and are sold at the market value. Prices are determined by the heat energy of the gas, measured in British thermal units (Btu) at standard test conditions: saturated with water vapor at a temperature of 60° F and a pressure of 14.73 psia. Mist gas provides an average of 920 Btu per cubic foot.

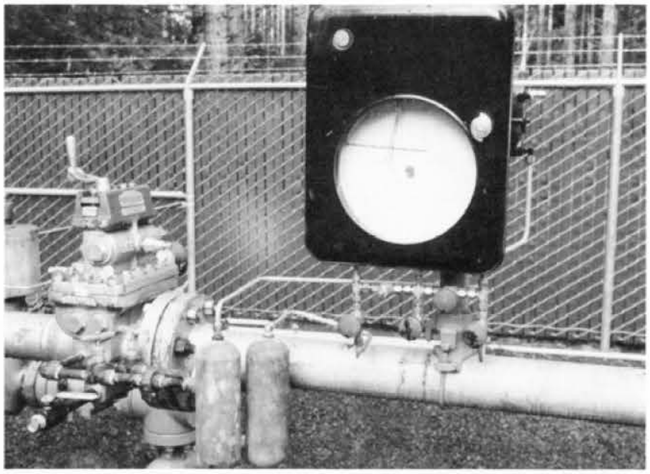

Figure 16. Orifice meter.

When the first gas from Mist was sold in 1979, the ceiling price set by the Federal Energy Regulatory Commission (FERC) was $2.34 per million Btu, or $0.234 per therm. The maximum lawful price gradually increased to $3.84 per million Btu by December 1984. Through May 1984, Mist gas was sold at the ceiling price. Beginning that month, however, the contract selling price was less than the federal ceiling price.

Table 2 shows the production by well and the value of gas produced from the Mist gas field from its discovery through December 31, 1984. The annual value of the gas produced has averaged over $10 million since 1980.

TABLE 2. *Individual well production and values, Mist gas field, Oregon*

Pool name	Well name	Cumulative production through 12/31/84 (Mcf)	Value ($)
Bruer	Columbia County 1	571,134	1,406,589
Bruer	Columbia County 3	2,350,989	6,189,022
Bruer	Columbia County 6	4,367,025	10,735,742
Newell	Columbia County 4	944,806	2,780,324
Flora	Columbia County 10	2,810,293	7,255,039
Flora	Columbia County 33-3	4,355,213	11,667,229
- -	Columbia County 13-1	37,726	90,348
Crown	Crown Zellerbach 42-1	19,987	55,122
Newton	Longview Fibre 12-33	1,622,976	4,988,934
Adams	Columbia County 13-34	501,433	1,444,437
Paul	Paul 34-32	468,679	1,436,842
Al's	Columbia County 23-22	620,690	1,710,555
Schlicker	Columbia County 43-22	264,648	724,607
Busch	Busch 14-15	209,417	567,531
Baldwin	Columbia County 43-27	71,189	164,087
Field total	— —	19,216,205	51,216,408

PRODUCTION DATA AND RESERVOIR PROPERTIES

Operators of gas wells report production monthly to the Oregon Department of Geology and Mineral Industries (DOGAMI). During 1980, the first full year of production at Mist, from one to four wells were on line, producing a total daily flow averaging 13.5 MMcf. In subsequent years, up to the fifth anniversary of production, as many as 10 wells have been producing at a time, while average daily production fell to about 7.5 MMcf in 1984.

Table 2 and Appendix C give gas production figures for the field over its first five years.

Well logs and measurements made on rock and gas samples have revealed much about the Clark and Wilson sandstone and its gas. Table 3 lists several reservoir properties of seven of the pools in the field.

WATER PRODUCTION AND DISPOSAL

Gas production at the Mist gas field is known as dry gas, meaning it is not associated with oil production. The gas is not truly dry, however, as water vapor is also produced with the gas. As described above, separators and dehydrators are needed to remove water from the gas before transport and sale (Figure 17).

Occasionally, gas wells will also produce large quantities of water from the zone below the gas. During the first five years of production at Mist, four wells have produced such water along with the gas. These wells require collection of water in large tanks for disposal. The water has a total dissolved solids content of about 27,000 ppm, mostly sodium chloride, and therefore is hauled by vacuum truck to tanks at a disposal well.

Disposal is accomplished by flowing or pumping the waste water through tubing into a depleted gas pool through a

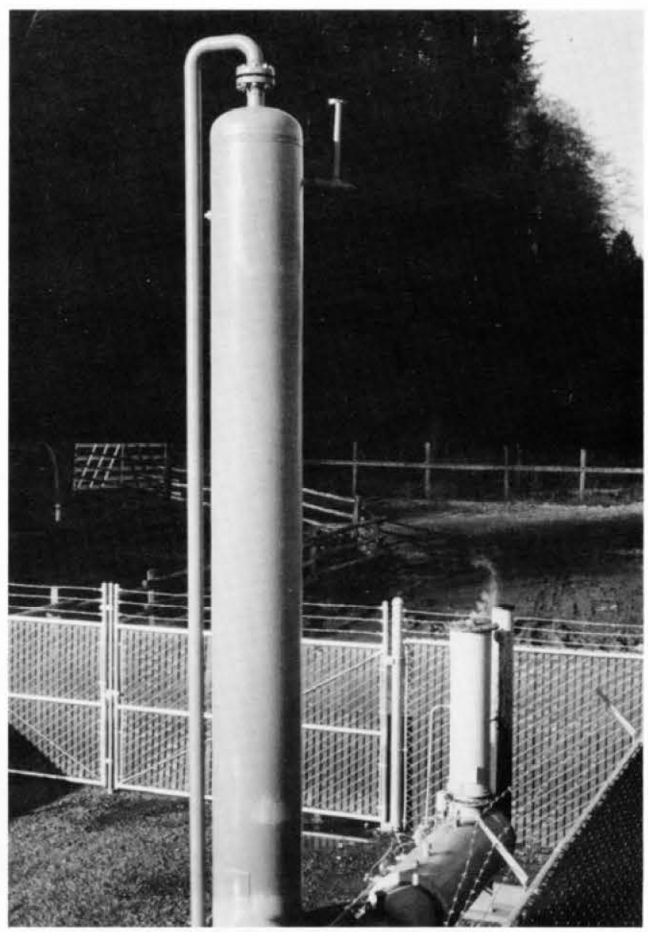

Figure 17. Dehydrator at Reichhold Energy's Paul 34-32.

TABLE 3. *Reservoir properties, Mist gas field, Oregon*

Pool name	Bruer	Newell	Flora	Crown	Newton	Adams	Paul
Depth (ft below sea level)	1,282	1,483	1,425	447	1,310	1,375	1,895
Porosity (%)	26 to 35	26 to 35	26 to 35	26 to 35	26 to 35	26 to 35	26 to 35
Initial pressure (psia)	965	1,055	1,072	620	972	978	1,205
Interstitial water (%)	10 to 30	10 to 30	10 to 30	10 to 30	10 to 30	10 to 30	10 to 30
Net gas sand thickness (ft)	160	90	200	10	90	30	45
Productive area (acres)	160	80	160	80	100	100	50
Gas specific gravity (air=1)	0.591	0.585	0.570	0.592	0.561	0.565	0.560
Gas heating value (Btu)	900	922	956	902	977	956	984
Est. initial gas in place (MMcf)	8,830	1,950	8,820	20	4,010	3,600	1,180

NOTE: Data are still confidential for newer pools at time of publication.

Data for this table are from Amies, T., personal communication, 1984; Alger, M., personal communication, 1985; Stinson, C., personal communication, 1985.

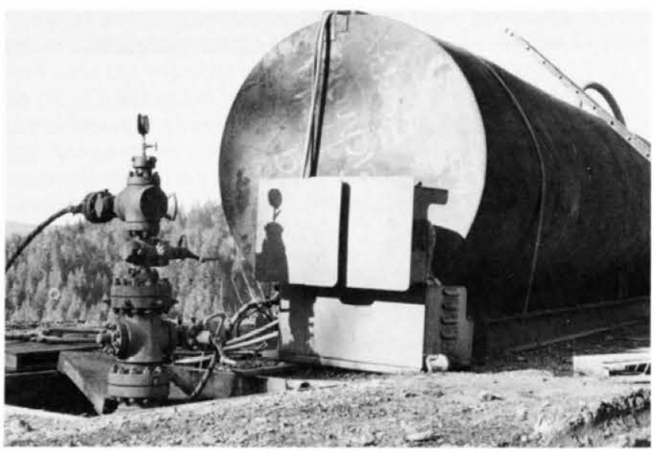

Figure 18. Water-disposal well with holding tank, Reichhold Energy's Columbia County 13-1.

former producing well, Columbia County 13-1 (Figure 18). The well was already completed and cased through the Clark and Wilson sandstone but was no longer a commercial producer. It was therefore a good candidate for conversion to a water disposal well. Such disposal is permitted by DOGAMI as an approved disposal technique. This permitting authority has been delegated to the state by the Environmental Protection Agency under the Safe Drinking Water Act of 1974.

A second disposal method is to spread the produced water on nearby gravel roads during periods of dry weather only. This method of disposal is permitted by the Department of Environmental Quality under a Water Pollution Control Facilities Permit. The preferred method of disposal is by underground injection, however. Appendix F gives water-production data for the field during its first five years.

PROPOSED GAS STORAGE

Northwest Natural Gas Company (NNG) is the gas utility with a service area that includes over three-quarters of Oregon's population. The company buys the majority of its gas supply from Northwest Pipeline Company, which can offer a relatively constant volume of gas throughout the year. However, customer requirements result in a demand that varies widely, depending primarily on the season.

Gas that could be stored during periods of low customer demand and released from storage for high demand would enable the utility to meet the demand easily and quickly. Gas storage reservoirs allow this to be done.

Oregon Natural Gas Development Corporation, a subsidiary of Northwest Natural Gas Company, proposed to the Oregon Energy Facility Siting Council (EFSC) a project to convert the Mist gas field to an underground storage facility. This would be done one pool at a time as each became depleted of gas. The Underground Storage Site Certificate Application outlined a plan to alternately store and withdraw 10 MMMcf of gas using the Bruer pool for 56 percent of the capacity and the Flora pool for the remaining 44 percent.

EFSC issued the site certificate for storage on June 19, 1981. As of the date of this report, the Bruer and Flora pools have been depeleted and the wells shut in, but no storage has taken place. Agreements and contracts are still being negotiated. The depleted gas pools will be replenished from about April to September and drawn down between October and March each year. Depleted gas pools offer good storage sites in most cases due to their known ability to hold gas. In addition, the former producing wells are already present for gas injection and withdrawal, as well as all the necessary pipelines and the Miller Station facility. Additional wells and pipelines will also be needed to permit more rapid filling and emptying of the pools. Figure 19 depicts a well specifically designed for gas storage.

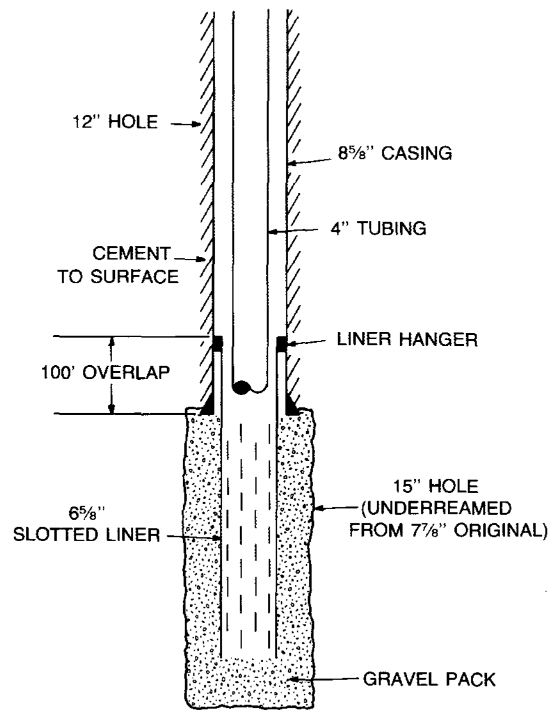

Figure 19. Downhole detail of gas storage well, Mist gas field (from Oregon Natural Gas Development Corporation, 1981, Mist underground storage site certificate application).

CONCLUSIONS

The Mist gas field became Oregon's first commercial hydrocarbon discovery after over 75 years of exploration in the state. In the first five years of development, twelve separate pools of gas were found, producing a total of 19 MMMcf of gas. Reichhold Energy Corporation, operator of the producing wells, drilled most wells with partners such as Diamond Shamrock Corporation, Oregon Natural Gas Development Corporation, and American Quasar Petroleum Company.

The productive formation to date has been the Cowlitz Formation of late Eocene age. All but one well produced from the Clark and Wilson sandstone at depths of 1,329 to 2,710 ft. Traps for the gas are faulted anticlines, while the source is probably the Tualatin basin in the southeast or the Astoria basin to the west.

The data presented in this report are a summary of available information. Detailed well information, including histories, logs, production records, and cuttings, is available from the Portland office of the Oregon Department of Geology and Mineral Industries. All information is open to the public after two years. Also available is a map (scale 1:24,000) of the Mist gas field, shown in reduced form in this publication as Figure 2. Other publications in the Oil and Gas Investigation series will be very useful as a companion to this report, especially those by Newton and Van Atta (1976), McKeel (1983), and Armentrout and others (1983). King and others (1982) will be useful for finding available well records. Out-of-print publications by this Department as well as other journals and books are available for use at the library of the Portland office.

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APPENDICES

APPENDIX A. Wells in Mist gas field, Oregon

Permit no.	Operator, API number	Well name	Location	Total depth (ft)	Year drilled, production interval (ft)	Status
—	The Texas Co.	Clatskanie 1	NE¼ sec. 36 T. 7 N., R. 4 W.	TD:5,650	1945	Abandoned.
—	The Texas Co. 009-00005	Clark and Wilson 6-1	NE¼ sec. 19 T. 6 N., R. 5 W.	TD:8,501	1947	Abandoned.
68	Reichhold Energy Corporation 009-00006	Crown Zellerbach 2	SW¼ sec. 8 T. 4 N., R. 3 W.	TD:5,805	1975	Abandoned.
69	Reichhold Energy Corporation 009-00007	Columbia County 1	NW¼ sec. 11 T. 6 N., R. 5 W.	TD:3,111 RD:3,105	1977 1979, 2,448-2,460	Abandoned. Completed; gas; Mist discovery well.
71	Reichhold Energy Corporation 009-00008	Columbia County 2	NE¼ sec. 14 T. 6 N., R. 5 W.	TD:2,780	1978	Abandoned.
72	Reichhold Energy Corporation 009-00010	Columbia County 3	NE¼ sec. 10 T. 6 N., R. 5 W.	TD:2,932 RD:2,992	1979 1979, 2,268-2,362	Abandoned. Completed; gas.
73	Reichhold Energy Corporation 009-00009	Longview Fibre 1	SW¼ sec. 11 T. 6 N., R. 5 W.	TD:3,088 RD:2,803	1977 1980	Abandoned. Abandoned.
86	Reichhold Energy Corporation 009-00011	Columbia County 4	NE¼ sec. 15 T. 6 N., R. 5 W.	TD:2,936 RD:2,894	1979, 2,316-2,324 1982, 2,321-2,409	Completed; gas. Completed; gas.
87	Reichhold Energy Corporation 009-00012	Columbia County 5	NW¼ sec. 10 T. 6 N., R. 5 W.	TD:3,116 RD:3,128	1979 1979	Abandoned. Abandoned.
91	Reichhold Energy Corporation 009-00015	Columbia County 6	SW¼ sec. 10 T. 6 N., R. 5 W.	TD:3,466 RD1:2,956 RD2:2,614	1979 1979 1979, 2,240-2,373	Abandoned. Abandoned. Completed; gas.
94	American Quasar Petroleum Company 009-00018	Longview Fibre 25-33	SE¼ sec. 25 T. 6 N., R. 5 W.	TD:7,000	1979	Abandoned.
96	Reichhold Energy Corporation 009-00020	Libel 2	SE¼ sec. 15 T. 6 N., R. 5 W.	TD:2,857	1979	Abandoned.
99	Reichhold Energy Corporation 009-00022	Columbia County 10	SW¼ sec. 3 T. 6 N., R. 5 W.	TD:2,981	1979, 2,668-2,710	Completed; gas.
115	Reichhold Energy Corporation 009-00038	Columbia County 12	NW¼ sec. 14 T. 6 N., R. 5 W.	TD:3,160 RD:3,365	1980 1980	Abandoned. Abandoned.
118	American Quasar Petroleum Company 009-00039	Crown Zellerbach 29-14	SW¼ sec. 29 T. 6 N., R. 4 W.	TD:2,880	1979	Abandoned.
119	American Quasar Petroleum Company 009-00040	Wall 24-13	SW¼ sec. 24 T. 6 N., R. 5 W.	TD:2,810	1980	Abandoned.
121	American Quasar Petroleum Company 009-00042	Longview Fibre 25-32	NE¼ sec. 25 T. 6 N., R. 5 W.	TD:2,902 RD:3,261	1980 1980	Abandoned. Abandoned.
122	American Quasar Petroleum Company 009-00043	Crown Zellerbach 14-21	NW¼ sec. 14 T. 5 N., R. 5 W.	TD:1,832	1980	Abandoned.

APPENDIX A. Wells in Mist gas field, Oregon—Continued

Permit no.	Operator, API number	Well name	Location	Total depth (ft)	Year drilled, production interval (ft)	Status
124	Reichhold Energy Corporation 009-00045	Columbia County 33-3	SE¼ sec. 3 T. 6 N., R. 5 W.	TD:2,777	1980, 2,467-2,646	Completed; gas.
125	Reichhold Energy Corporation 009-00046	Columbia County 43-11	SE¼ sec. 11 T. 6 N., R. 5 W.	TD:3,326 RD:3,626	1980 1980	Abandoned. Abandoned.
126	Reichhold Energy Corporation 009-00047	Crown Zellerbach 42-1	NE¼ sec. 1 T. 6 N., R. 5 W.	TD:2,892	1980, 1,750-1,760	Completed; gas.
129	Reichhold Energy Corporation 009-00050	Columbia County 44-4	SE¼ sec. 4 T. 6 N., R. 5 W.	TD:3,061	1980	Abandoned.
131	Reichhold Energy Corporation 009-00052	Columbia County 32-3	NE¼ sec. 3 T. 6 N., R. 5 W.	TD:3,395	1980	Abandoned.
135	Reichhold Energy Corporation 009-00056	White 33-13	SE¼ sec. 13 T. 6 N., R. 5 W.	TD:2,708	1980	Abandoned.
140	Reichhold Energy Corporation 009-00057	Longview Fibre 24-12	SW¼ sec. 12 T. 6 N., R. 5 W.	TD:2,839	1980	Suspended.
143	Reichhold Energy Corporation 009-00059	Adams 24-34	SW¼ sec. 34 T. 7 N., R. 5 W.	TD:3,377	1980	Abandoned.
146	Reichhold Energy Corporation 009-00062	Columbia County 11-33	NW¼ sec. 33 T. 7 N., R. 5 W.	TD:2,737	1981	Abandoned.
147	Reichhold Energy Corporation 009-00063	Columbia County 12-9	NW¼ sec. 9 T. 6 N., R. 5 W.	TD:2,918 RD:2,917	1980 1982	Abandoned. Abandoned.
153	Reichhold Energy Corporation 009-00069	Columbia County 13-2	SW¼ sec. 2 T. 6 N., R. 5 W.	TD:3,709 RD:3,823	1980 1980	Abandoned. Abandoned.
154	American Quasar Petroleum Company 009-00070	Investment Management 34-21	NW¼ sec. 34 T. 6 N., R. 4 W.	TD:4,080	1980	Abandoned.
155	American Quasar Petroleum Company 009-00071	Larkins 23-33	SE¼ sec. 23 T. 6 N., R. 5 W.	TD:2,940	1980	Abandoned.
156	American Quasar Petroleum Company 009-00072	Rau 18-14	SW¼ sec. 18 T. 6 N., R. 4 W.	TD:2,434 RD:2,440	1980 1980	Abandoned. Abandoned.
157	American Quasar Petroleum Company 009-00073	Crown Zellerbach 30-33	SE¼ sec. 30 T. 6 N., R. 4 W.	TD:2,350	1980	Abandoned.
158	Reichhold Energy Corporation 009-00074	Columbia County 14-2	SW¼ sec. 2 T. 6 N., R. 5 W.	TD:3,582	1980	Suspended.
162	Reichhold Energy Corporation 009-00076	Crown Zellerbach 22-6	NW¼ sec. 6 T. 6 N., R. 4 W.	TD:3,671 RD1:2,264 RD2:2,431	1980 1980 1980	Abandoned. Abandoned. Abandoned.
164	American Quasar Petroleum Company 009-00077	Investment Management 20-21	NW¼ sec. 20 T. 6 N., R. 4 W.	TD:2,281 RD:2,145	1980 1980	Abandoned. Abandoned.

APPENDIX A. Wells in Mist gas field, Oregon—Continued

Permit no.	Operator, API number	Well name	Location	Total depth (ft)	Year drilled, production interval (ft)	Status
175	American Quasar Petroleum Company 009-00080	Wilna *et al.* 5-23	SW-¼ sec. 5 T. 6 N., R. 4 W.	TD:4,503	1981	Abandoned.
180	Reichhold Energy Corporation 009-00082	Columbia County 32-10	NE¼ sec. 10 T. 6 N., R. 5 W.	TD:7,807	1981	Suspended.
182	Reichhold Energy Corporation 009-00084	Columbia County 13-1	SW¼ sec. 1 T. 6 N., R. 5 W.	TD:3,076	1981, 2,398-2,426	Abandoned.
				RD:3,027	1982, 2,380-2,412	Completed; gas.
184	Reichhold Energy Corporation 009-00086	Longview Fibre 41-32	NE¼ sec. 32 T. 7 N., R. 5 W.	TD:2,487	1981	Abandoned.
191	Reichhold Energy Corporation 009-00089	Paul 34-32	SE¼ sec. 32 T. 7 N., R. 5 W.	TD:2,698	1982, 2,521-2,556	Completed; gas.
				RD1:2,912	1984	Abandoned.
				RD2:2,719	1984	Abandoned.
192	American Quasar Petroleum Company 009-00090	Benson Timber 8-14	SW¼ sec. 8 T. 6 N., R. 4 W.	TD:2,196	1981	Abandoned.
197	Reichhold Energy Corporation 009-00091	Longview Fibre 12-33	NW¼ sec. 33 T. 7 N., R. 5 W.	TD:2,407	1981	Abandoned.
				RD:2,475	1981, 2,268-2,343	Completed; gas.
200	Reichhold Energy Corporation 009-00093	Hansen 44-15	SE¼ sec. 15 T. 6 N., R. 5 W.	TD:2,782	1981	Abandoned.
201	Reichhold Energy Corporation 009-00094	Cadenza 34-1	SE¼ sec. 1 T. 6 N., R. 5 W.	TD:2,826	1981	Abandoned.
203	Reichhold Energy Corporation 009-0095	Columbia County 41-2	NE¼ sec. 2 T. 6 N., R. 5 W.	TD:2,875	1982	Abandoned.
				RD:3,040	1982	Abandoned.
205	Reichhold Energy Corporation 009-00097	Columbia County 32-33	NE¼ sec. 33 T. 7 N., R. 5 W.	TD:2,614	1982	Abandoned.
				RD:3,030	1982	Abandoned.
206	Reichhold Energy Corporation 009-00098	Adams 34-28	SE¼ sec. 28 T. 7 N., R. 5 W.	TD:2,572	1982	Abandoned.
208	Reichhold Energy Corporation 009-00099	Wilson 11-5	NW¼ sec. 5 T. 6 N., R. 5 W.	TD:2,827	1983	Suspended.
209	Reichhold Energy Corporation 009-00100	Columbia County 43-5	SE¼ sec. 5 T. 6 N., R. 5 W.	TD:3,099	1982	Abandoned.
211	Reichhold Energy Corporation 009-00102	Crown Zellerbach 32-26	NE¼ sec. 26 T. 5 N., R. 4 W.	TD:6,501	1982	Abandoned.
224	Reichhold Energy Corporation 009-00109	Libel 12-14	NW¼ sec. 14 T. 6 N., R. 5 W.	TD:2,681	1982	Abandoned.
225	Reichhold Energy Corporation 009-00110	Columbia County 13-34	SW¼ sec. 34 T. 7 N., R. 5 W.	TD:2,822	1982, 2,642-2,650	Completed; gas.
230	Reichhold Energy Corporation 009-00113	Columbia County 14-33	SW¼ sec. 33 T. 7 N., R. 5 W.	TD:3,105	1983	Abandoned.

APPENDIX A. Wells in Mist gas field, Oregon—Continued

Permit no.	Operator, API number	Well name	Location	Total depth (ft)	Year drilled, production interval (ft)	Status
232	Reichhold Energy Corporation 009-00115	Polak 31-12	NE1/4 sec. 12 T. 6 N., R. 5 W.	TD:2,750	1984	Abandoned.
237	Reichhold Energy Corporation 009-00116	Columbia County 23-22	SW1/4 sec. 22 T. 6 N., R. 5 W.	TD:2,028	1983, *	Completed; gas.
243	Reichhold Energy Corporation 009-00117	Investment Management 21-20	NW1/4 sec. 20 T. 6 N., R. 4 W.	TD:2,505	1983	Abandoned.
248	Reichhold Energy Corporation 009-00118	Crown Zellerbach 23-26	SE1/4 sec. 26 T. 6 N., R. 4 W.	TD:4,382	1984	Abandoned.
249	Reichhold Energy Corporation 009-00119	Busch 14-15	SW1/4 sec. 15 T. 6 N., R. 5 W.	TD:2,258	1984, *	Completed; gas.
253	Reichhold Energy Corporation 009-00122	Adams 32-34	NE1/4 sec. 34 T. 7 N., R. 5 W.	TD:3,284 RD:3,109	1984 1984	Abandoned. Abandoned.
256	Reichhold Energy Corporation 009-00124	Columbia County 43-22	SE1/4 sec. 22 T. 6 N., R. 5 W.	TD:2,252	1984, *	Completed; gas.
258	Reichhold Energy Corporation 009-00126	Crown Zellerbach 34-28	SE1/4 sec. 28 T. 6 N., R. 4 W.	TD:3,654	1984	Suspended.
264	Reichhold Energy Corporation 009-00129	Columbia County 11-10	NW1/4 sec. 10 T. 6 N., R. 5 W.	TD:3,215	1984	Abandoned.
265	Reichhold Energy Corporation 009-00127	Columbia County 43-27	NE1/4 sec. 27 T. 6 N., R. 5 W.	TD:2,441	1984, *	Completed; gas.
266	Reichhold Energy Corporation 009-00130	Columbia County 23-4	SW1/4 sec. 4 T. 6 N., R. 5 W.	TD:3,034	1984	Abandoned.
277	Reichhold Energy Corporation 009-00132	Longview Fibre 23-36	SW1/4 sec. 36 T. 6 N., R. 5 W.	TD:1,879	1984, *	Completed; gas.

*Completion interval confidential

APPENDIX B. Composition of natural gas, Mist gas field, Oregon*

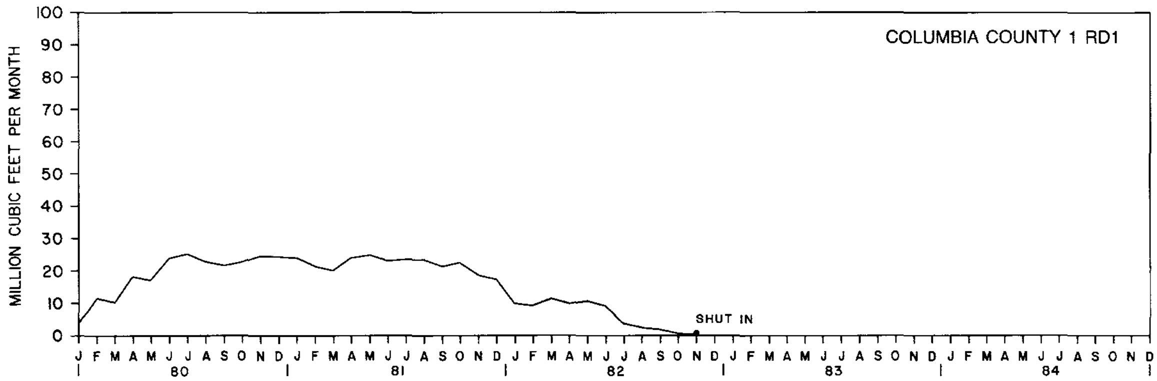
Pool name	Well name	Methane (%)	Ethane (%)	Propane (%)	Butane (%)	N_2 (%)	CO_2 (%)	Btu	Specific gravity (air=1.0)
Bruer	Columbia County 1 RD	90.84	<0.01	<0.01	<0.01	9.16	<0.01	907	0.592
Bruer	Columbia County 3	90.94	0.03	<0.01	<0.01	9.02	0.01	901	0.589
Bruer	Columbia County 6 RD2	90.47	0.02	<0.01	<0.01	9.50	0.01	896	0.591
Newell	Columbia County 4 RD	92.78	0.03	<0.01	<0.01	7.19	<0.01	925	0.585
Flora	Columbia County 10	96.51	<0.01	<0.01	<0.01	3.48	0.01	960	0.569
Flora	Columbia County 33-3	95.97	0.01	0.01	<0.01	4.01	<0.01	954	0.570
—	Columbia County 13-1 RD	78.88	<0.01	<0.01	<0.01	21.11	0.01	785	0.645
Crown	Crown Zellerbach 42-1	91.01	0.05	<0.01	<0.01	8.92	0.02	908	0.592
Newton	Longview Fibre 12-33 RD	98.34	0.02	<0.01	<0.01	1.64	<0.01	979	0.561
Adams	Columbia County 13-34	97.68	0.01	<0.01	<0.01	2.31	<0.01	973	0.565
Paul	Paul 34-32	98.77	0.02	<0.01	<0.01	1.21	<0.01	984	0.560
Al's	Columbia County 23-22	96.76	0.02	<0.01	<0.01	3.22	<0.01	962	0.567
Schlicker	Columbia County 43-22	96.46	0.01	<0.01	<0.01	3.53	<0.01	959	0.568
Busch	Busch 14-15	96.15	0.02	<0.01	<0.01	3.83	<0.01	958	0.571
Baldwin	Columbia County 43-27	91.17	0.02	<0.01	<0.01	8.81	<0.01	909	0.592

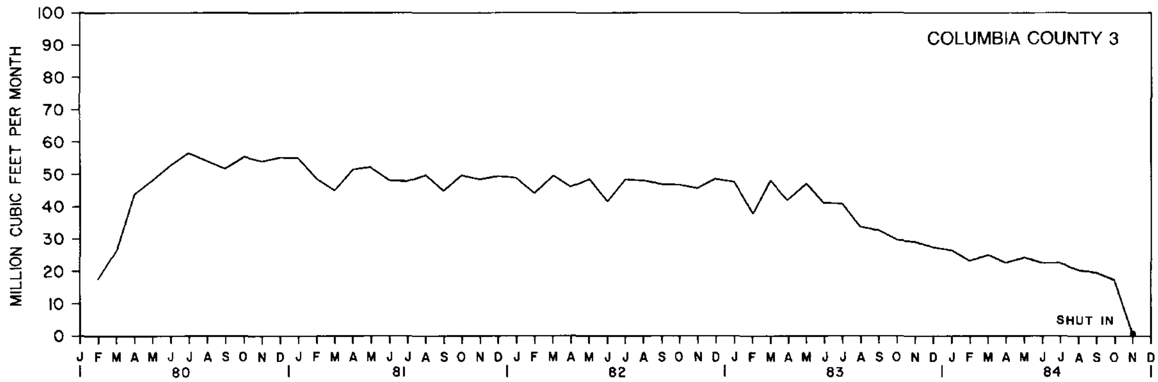
*Data from Amies, T., personal communication, 1984; and Judd, H., personal communication, 1984.

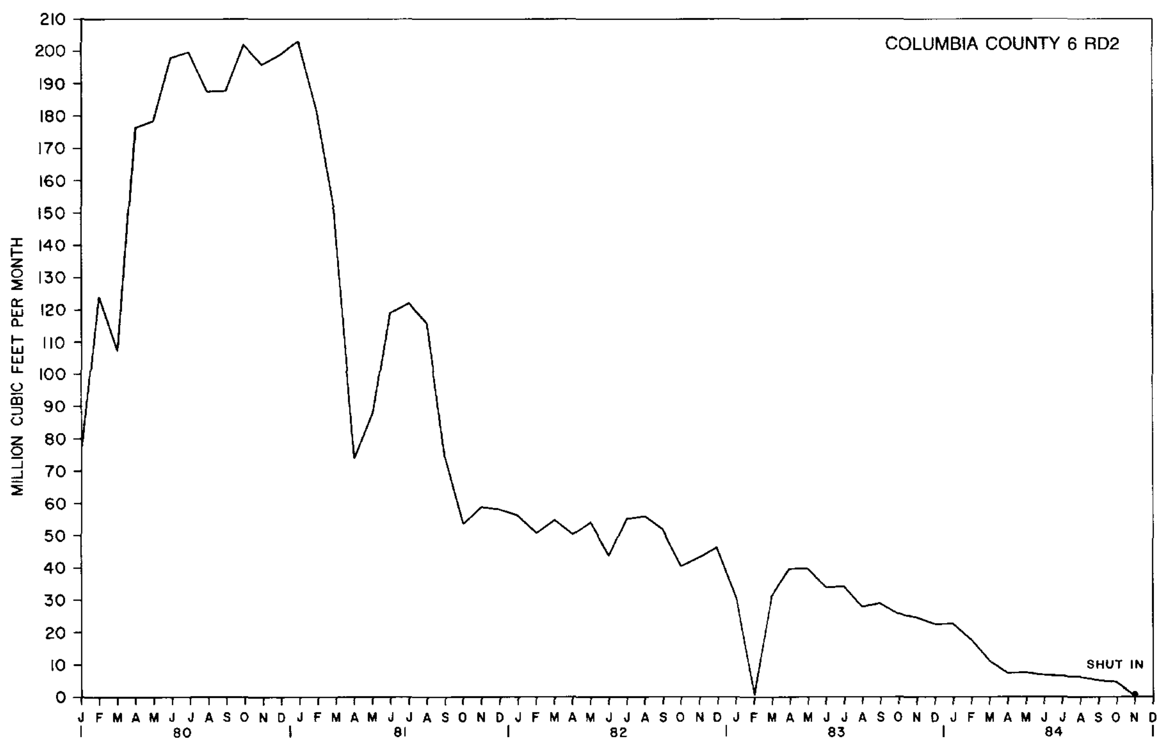
APPENDIX C. Annual gas values, Mist gas field, Oregon

Year	Mcf (million)	Therms (million)	Ave. price ($/therm)	Total value ($ million)
1979	0.002	0.014	0.22	—
1980	4.93	44.8	0.25	11.2
1981	4.94	45.8	0.28	12.8
1982	3.40	31.8	0.31	9.9
1983	3.16	29.8	0.32	9.5
1984	2.79	26.8	0.29	7.8
Total	19.22	179.0	——	51.2

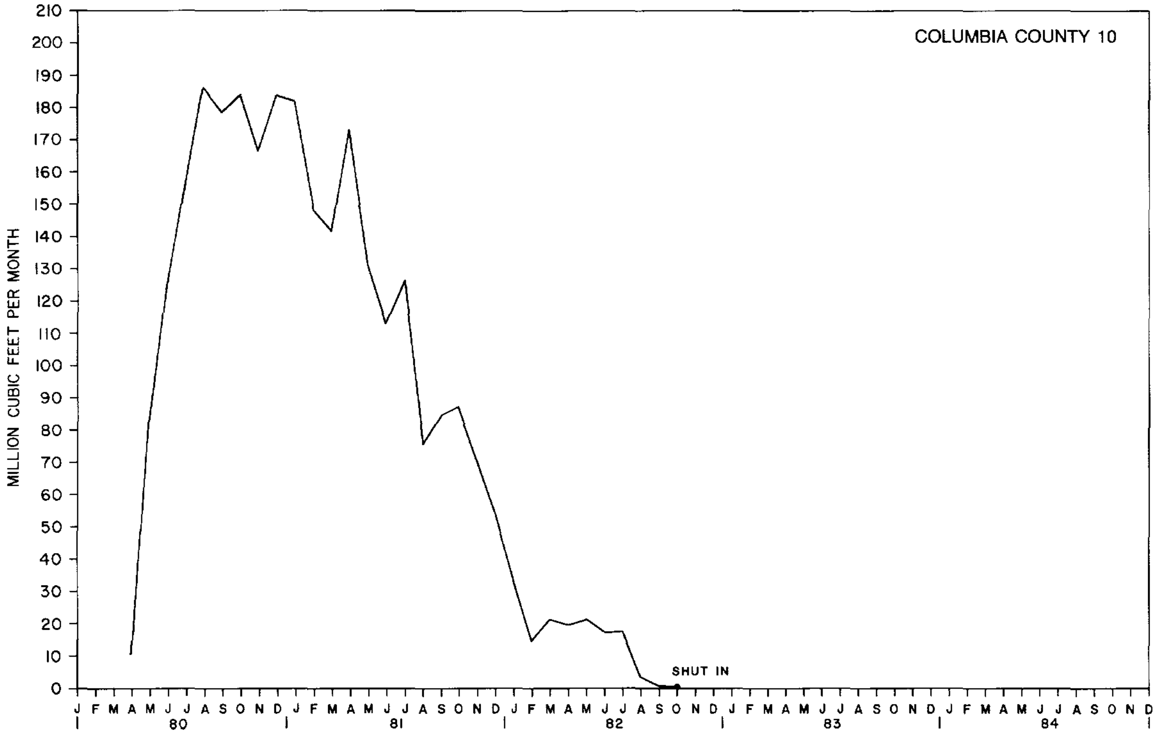
APPENDIX D. Production by well, 1979-1984, Mist gas field, Oregon

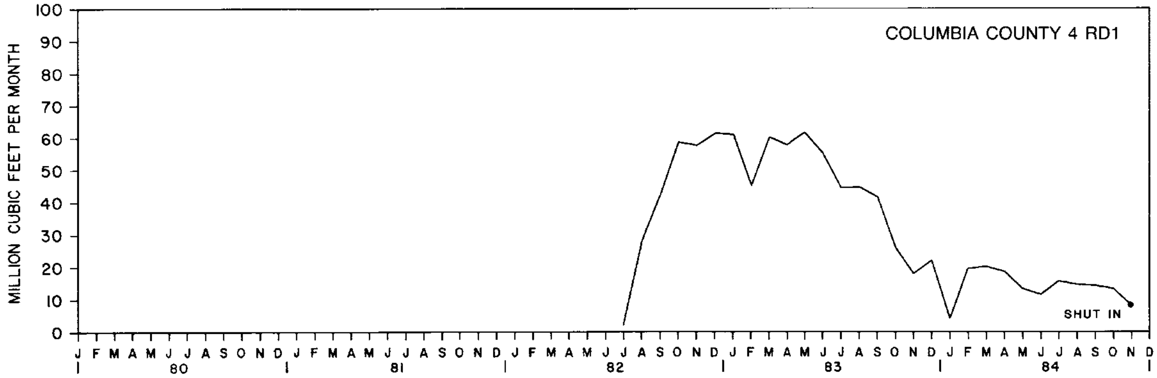


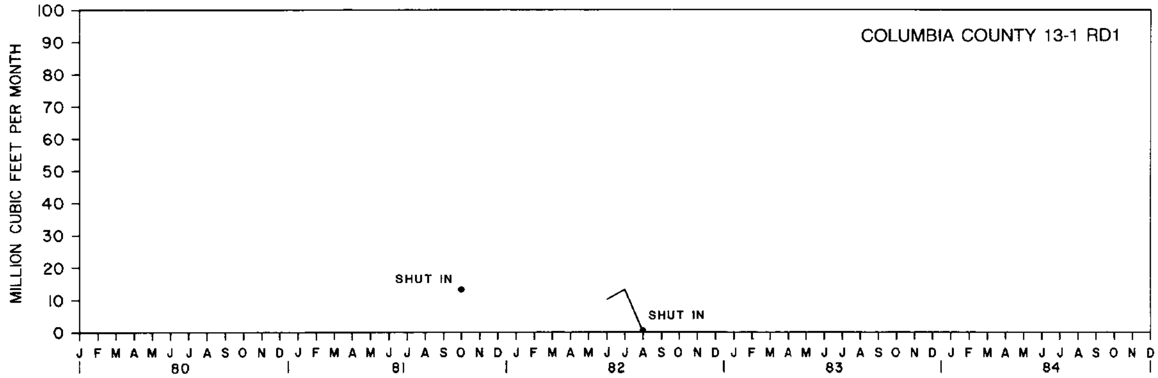


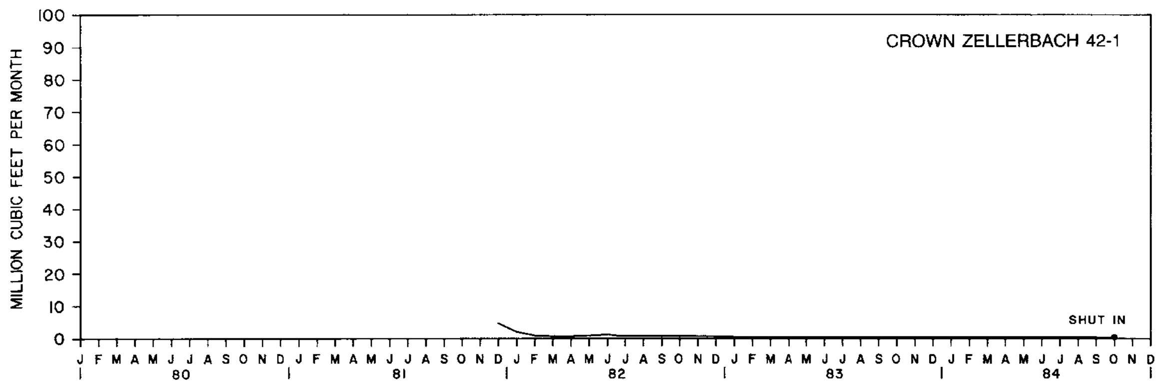


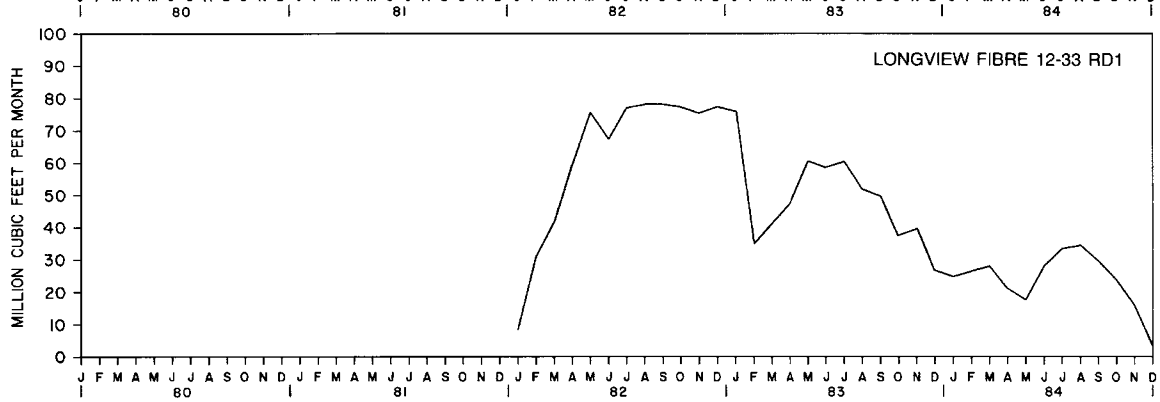
APPENDIX D. **Production by well, 1979-1984, Mist gas field, Oregon**—Continued

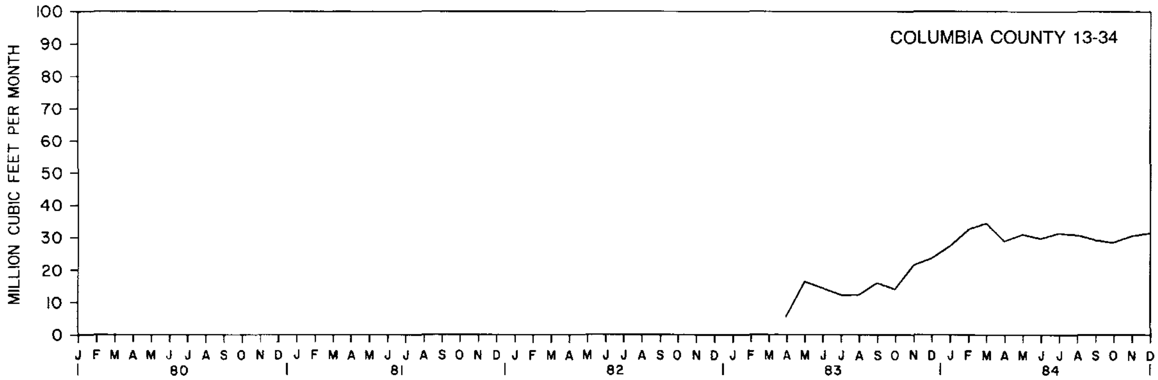


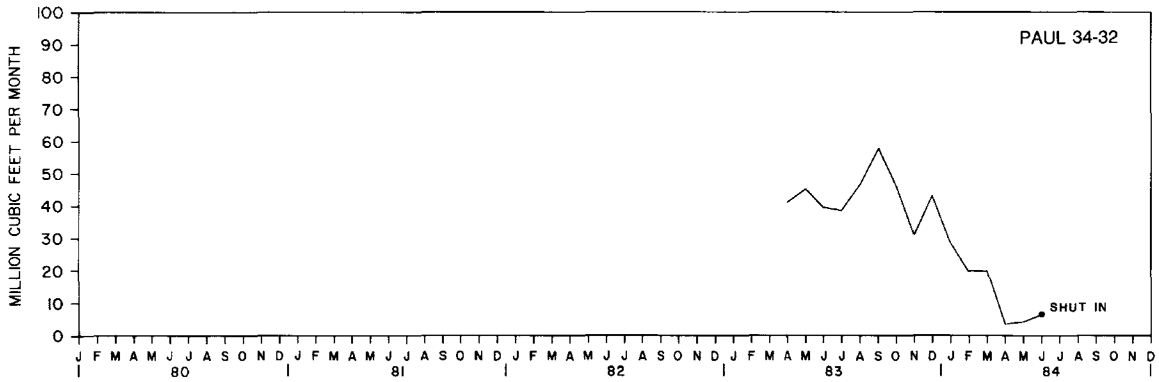

COLUMBIA COUNTY 4 RD1
MILLION CUBIC FEET PER MONTH
SHUT IN
80
81
82
83
84


COLUMBIA COUNTY 13-1 RD1
MILLION CUBIC FEET PER MONTH
SHUT IN
SHUT IN
80
81
82
83
84


CROWN ZELLERBACH 42-1
MILLION CUBIC FEET PER MONTH
SHUT IN
80
81
82
83
84


LONGVIEW FIBRE 12-33 RD1
MILLION CUBIC FEET PER MONTH
80
81
82
83
84


COLUMBIA COUNTY 13-34
MILLION CUBIC FEET PER MONTH
0 10 20 30 40 50 60 70 80 90 100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
80 81 82 83 84


PAUL 34-32
SHUT IN
MILLION CUBIC FEET PER MONTH
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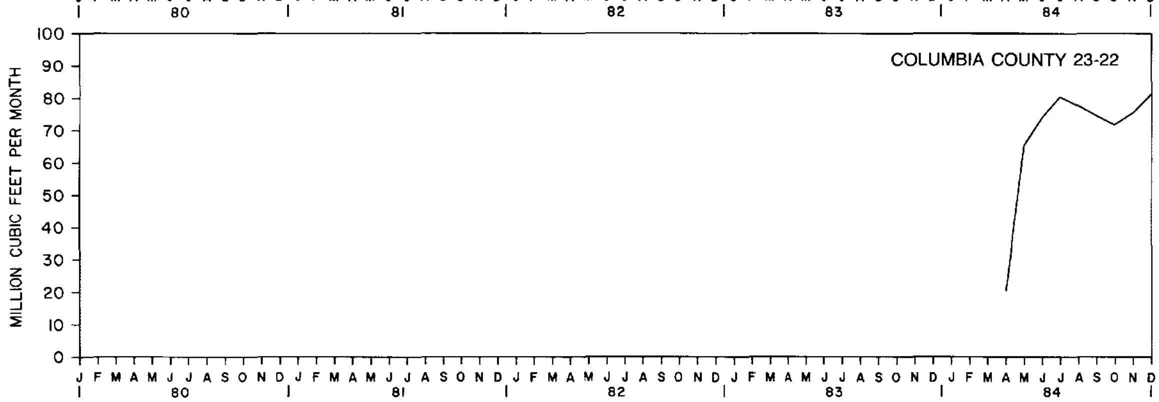
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
80 81 82 83 84


COLUMBIA COUNTY 23-22
MILLION CUBIC FEET PER MONTH
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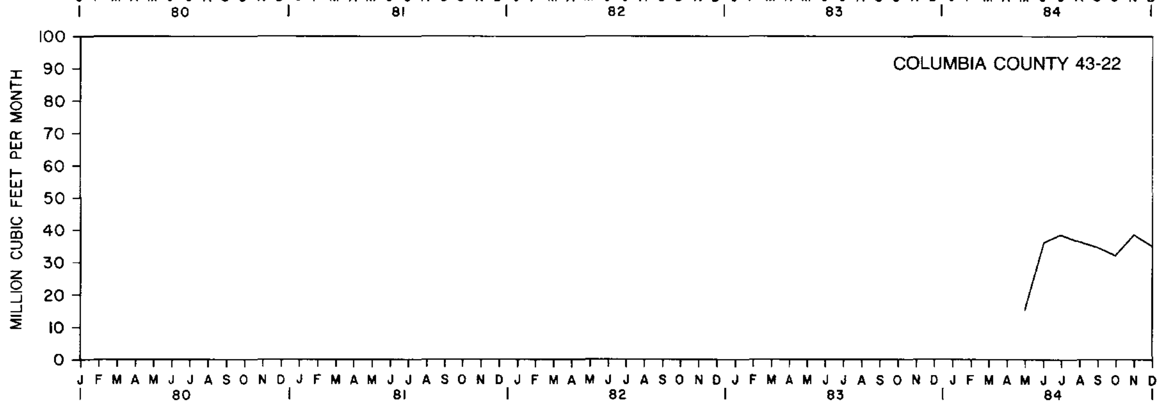
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
80 81 82 83 84


COLUMBIA COUNTY 43-22
MILLION CUBIC FEET PER MONTH
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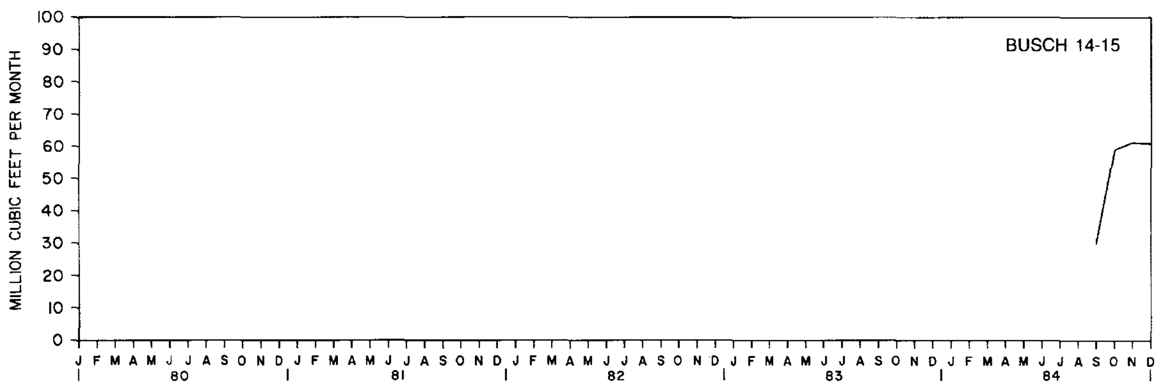
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
80 81 82 83 84


BUSCH 14-15
MILLION CUBIC FEET PER MONTH
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10
20
30
40
50
60
70
80
90
100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
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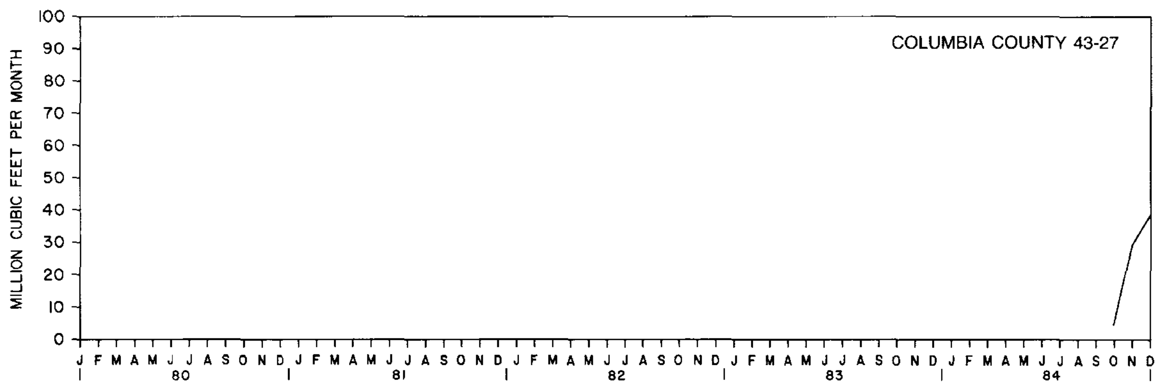
COLUMBIA COUNTY 43-27
MILLION CUBIC FEET PER MONTH
0
10
20
30
40
50
60
70
80
90
100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
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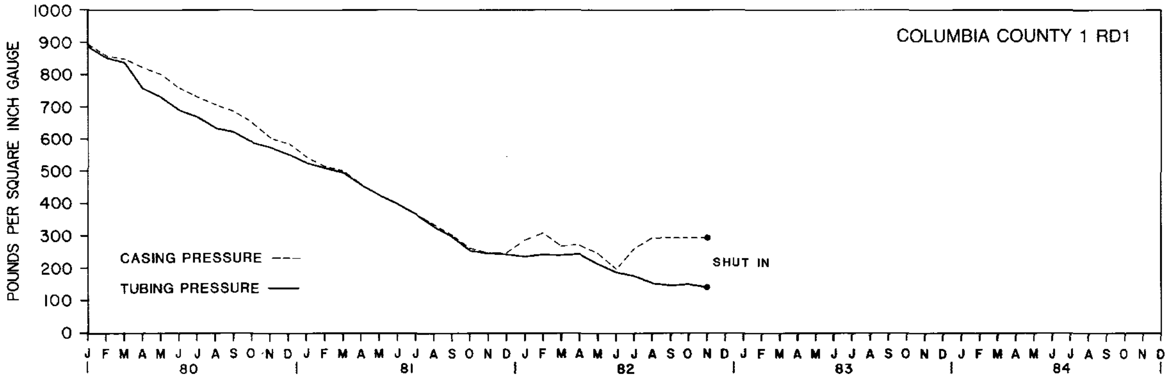
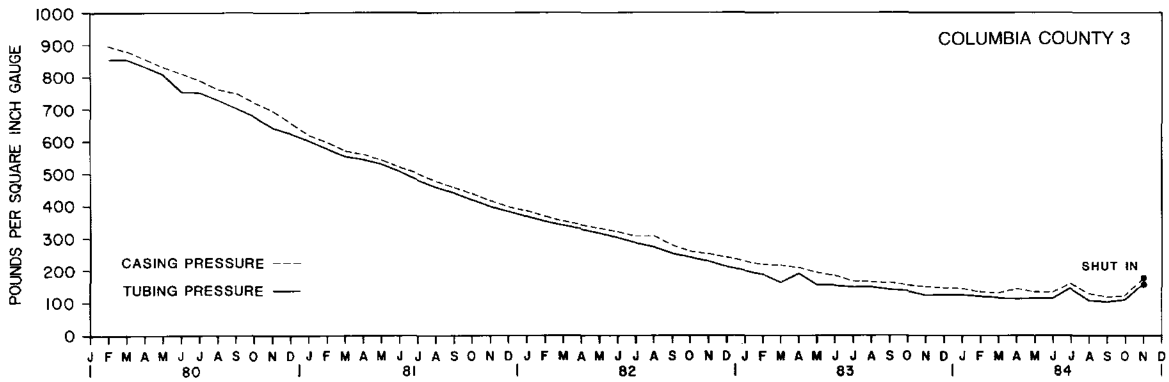
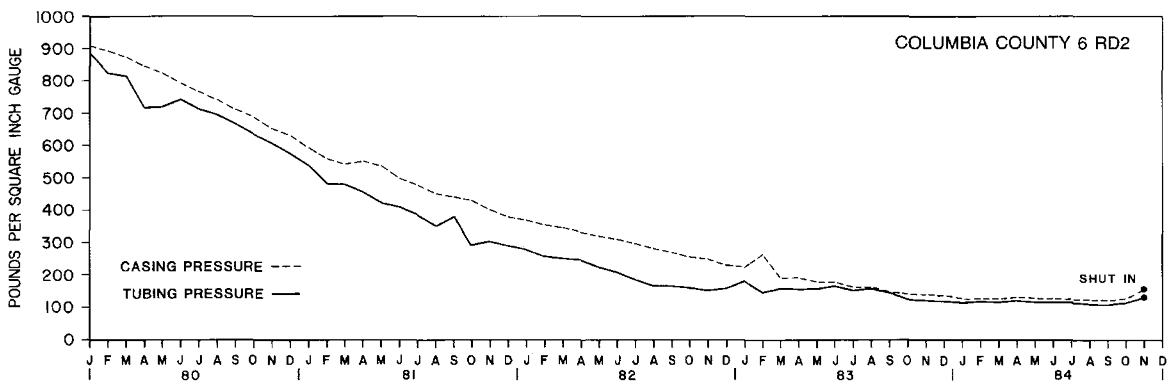
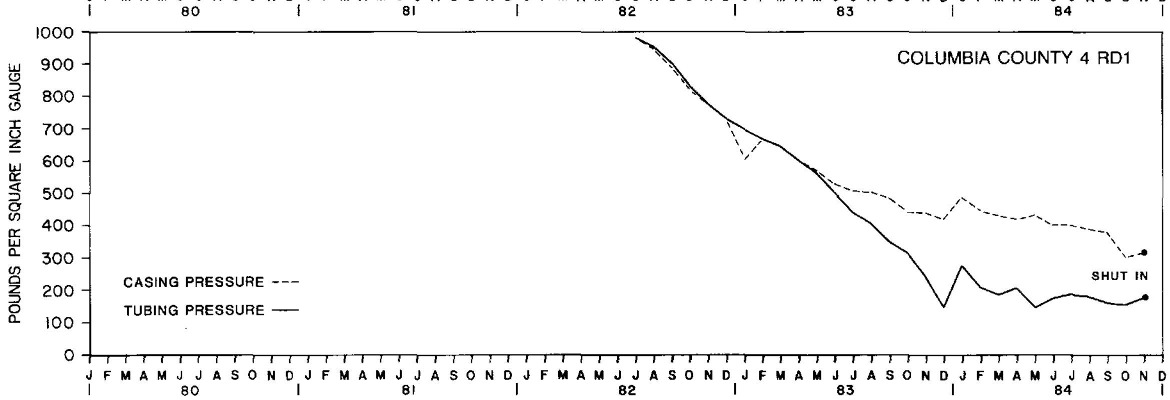
APPENDIX E. Tubing and casing pressures by well, 1979-1984, Mist gas field, Oregon

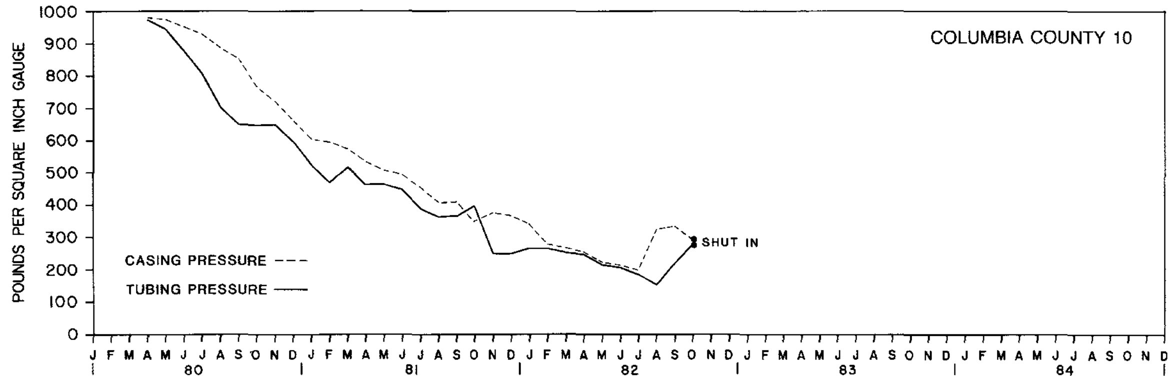


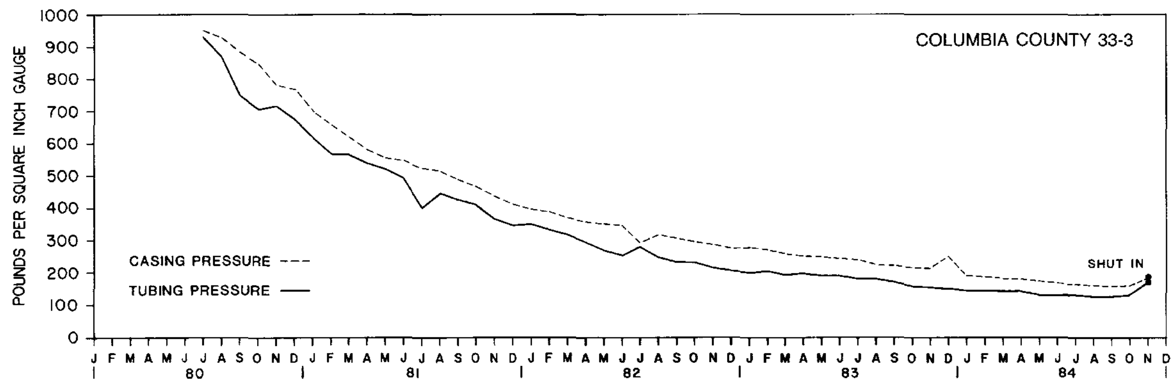


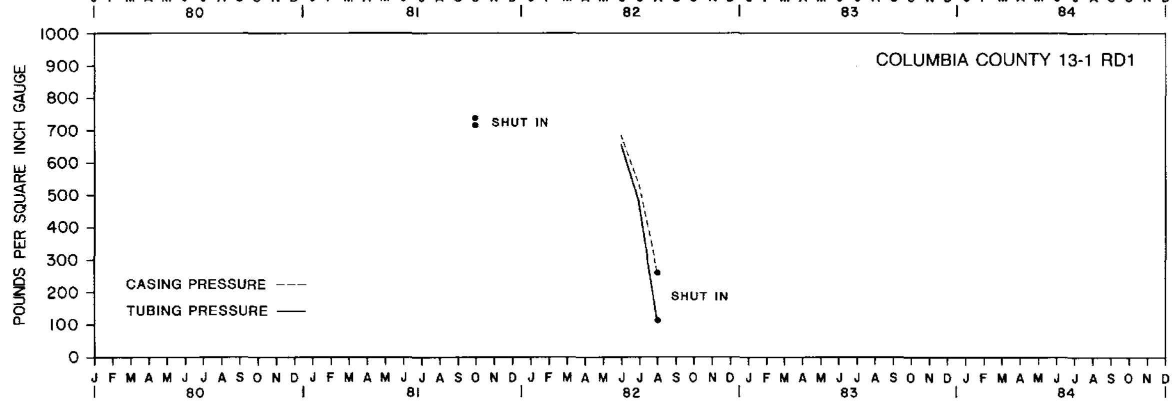


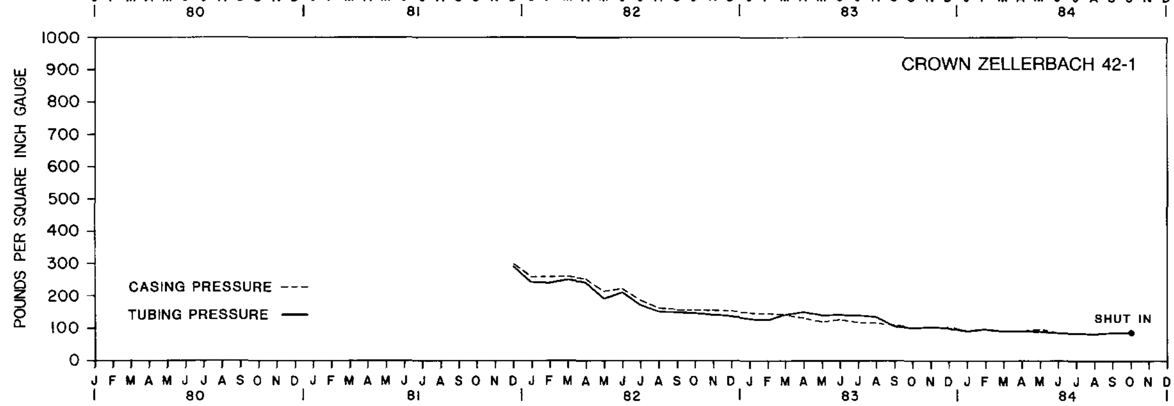


APPENDIX E. **Tubing and casing pressures by well, 1979-1984, Mist gas field, Oregon**—Continued

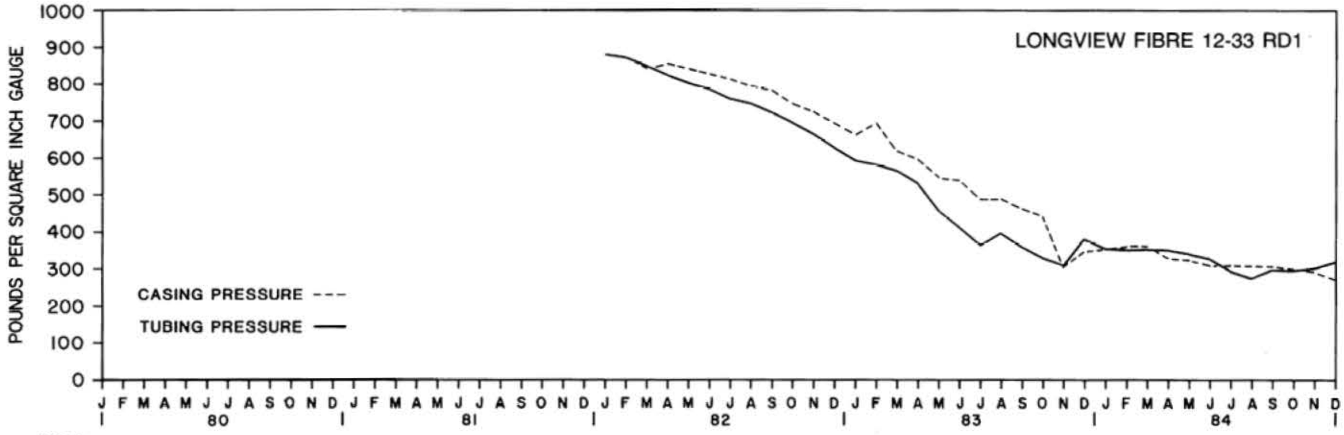


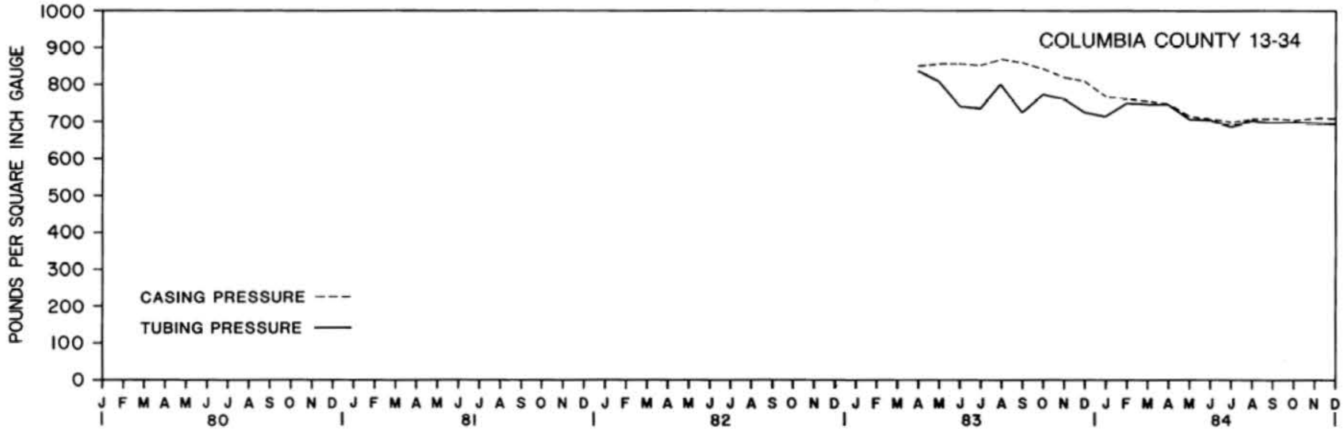


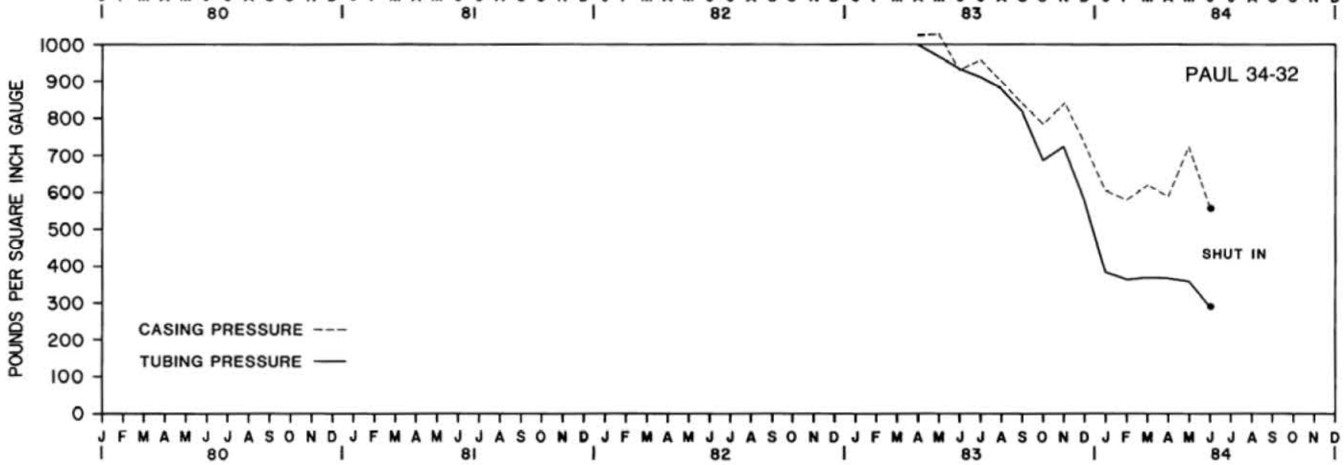


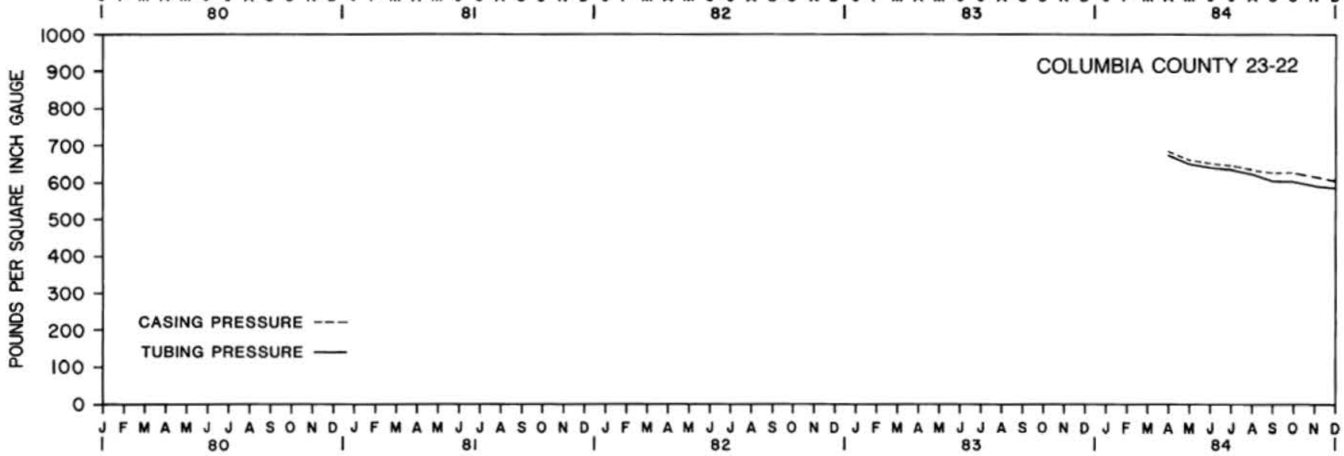


APPENDIX E. Tubing and casing pressures by well, 1979-1984, Mist gas field, Oregon—Continued

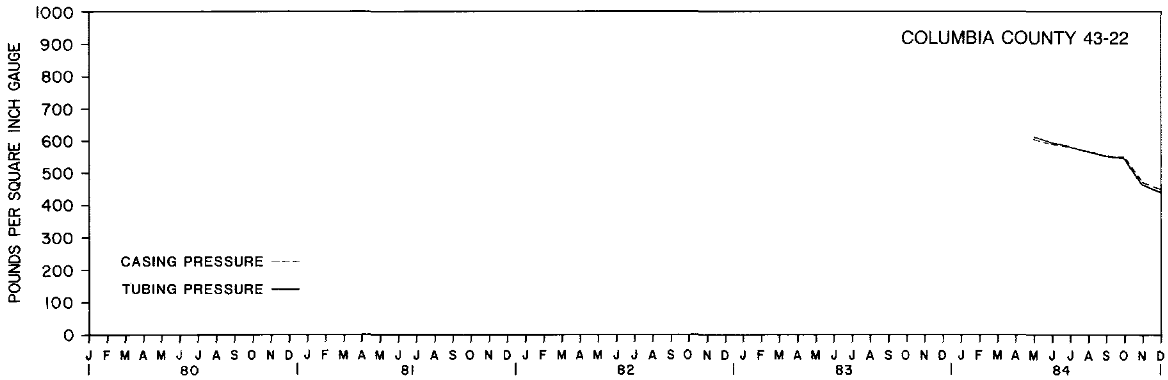


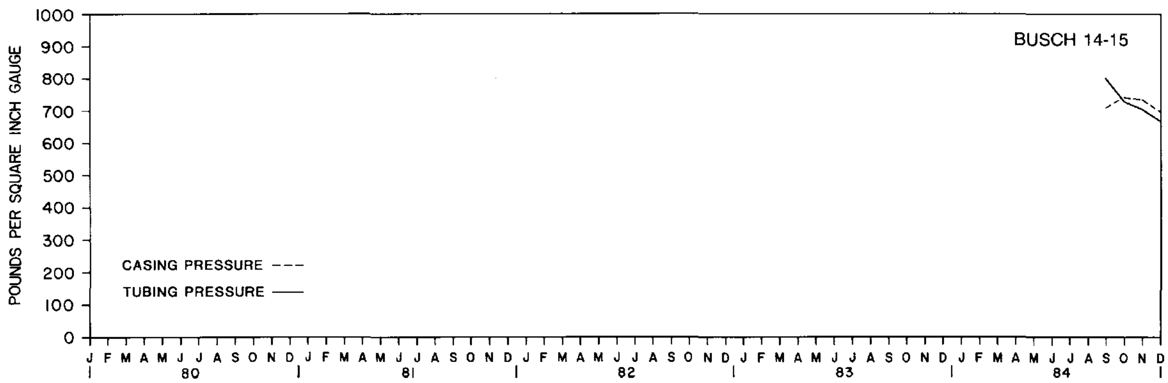


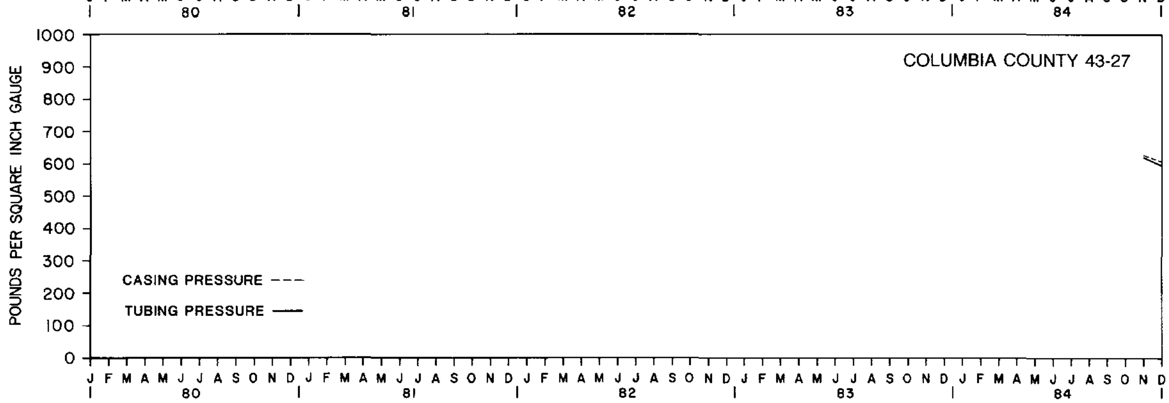




APPENDIX E. Tubing and casing pressures by well, 1979-1984, Mist gas field, Oregon—Continued







APPENDIX F. Water production and disposal summary, 1983-1984, Mist gas field, Oregon

Well producing water	1983			1984		
	Water produced (BBL)	Disposal by injection (BBL)	Surface disposal (BBL)	Water produced (BBL)	Disposal by injection (BBL)	Surface disposal (BBL)
Columbia County 4	20,678	14,218	6,460	79,325	62,776	16,549
Columbia County 6	1,000±*	0	1,000±*	0	0	0
Longview Fibre 12-33	9,917±	4,940±	4,977±	12,136	10,328	1,808
Paul 34-32	4,241	3,572	669	28,694	28,362	332
Total	35,836±	22,730±	13,106±	120,155	101,466	18,689

*Includes 1982 production.