GREASEWOOD OIL FIELD, WELD COUNTY, COLORADO[1]

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ABSTRACT

The Greasewood oil field is located in Secs. 13 and 24, T. 6 N., R. 61 W., at the eastern boundary of Weld County, Colorado.

The early geology of the area by the Hayden Survey was concerned with the stratigraphy in relation to other areas of the Great Plains. The writer was engaged by the Greeley Chamber of Commerce to make a reconnaissance of the oil possibilities of the county in 1923, which study resulted in the discovery of the Greasewood anticline. Later work under the direction of R. D. George resulted in the drilling of a test well, which discovered oil in the Greasewood sandstone on October 10, 1930.

Surface rocks of the area belong to the Laramie and Fox Hills (Cretaceous) formations, and oil is produced from the lower part of the Cretaceous series at depths of 6,639–6,683 feet. The producing area is very small and the reservoir rocks are very erratic. Only three wells out of nine drilled in the immediate area were commercial producers. One well is still producing 15–30 barrels of oil per day, flowing naturally.

Accumulation of oil in the Greasewood sandstone is due to a combination of stratigraphic and structural factors.

INTRODUCTION

The Greasewood oil field, which derives its name from Greasewood Lake, a landmark of the area 3 miles west of the field, is located in Secs. 13 and 24, T. 6 N., R. 61 W., at the eastern boundary of Weld County, northeastern Colorado. It is 32 miles by road slightly north of east from Greeley, the County Seat, and about the same distance northwest of Fort Morgan, the County Seat of Morgan County. The nearest railroad point is Orchard, a small village in the Platte River Valley and on the Julesburg-Denver branch of the Union Pacific Railroad. Regionally the area lies in the Great Plains province 52 miles east of the Rocky Mountain Front, and 36 miles south of the Wyoming line.

In the vicinity of the field, the terrane is flat or gently sloping farm land 4,645 feet above sea-level. It rises northward to the Laramie sandstone escarpment and 5 miles northeast attains an elevation of 5,000 feet or more. Sand hills 8 miles west of the field rise to an elevation of slightly more than 4,800 feet. The general slope of the land is toward the east and south, and the Platte River, which flows eastward 12 miles south of the field, with its dry tributaries forms the drainage. There are no perennial

[1] Manuscript received, January 22, 1941. Published with the permission of Continental Oil Company.

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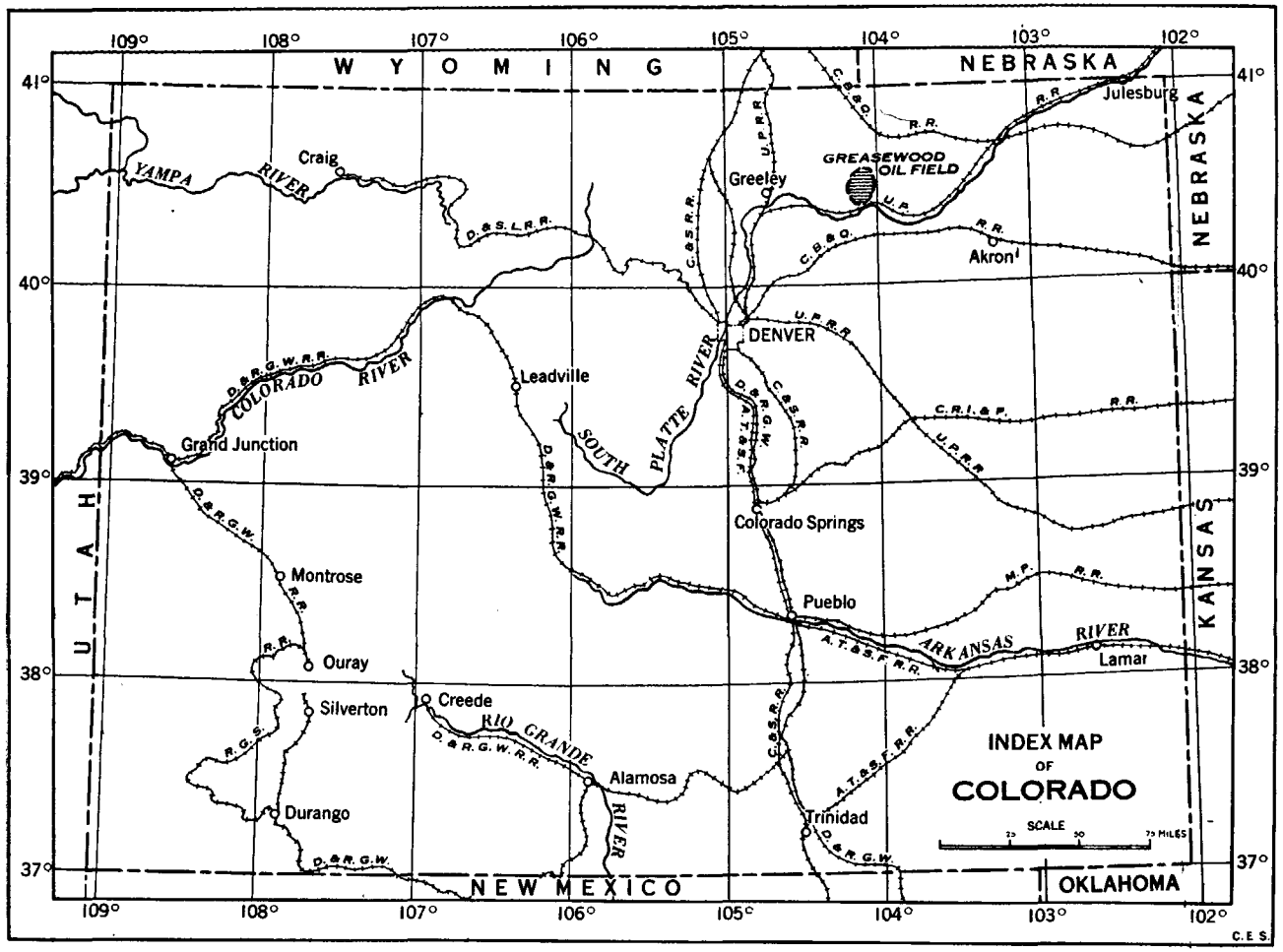

FIG. 1.—Index map showing location of Greasewood oil field.

streams in the vicinity of Greasewood and the run-off is carried by gentle, shallow draws.

History

The early geological work in this region was mainly concerned with the study of the paleontology, stratigraphy, and correlation of the strata of this area with other areas of the Great Plains and the Rocky Mountains. The occurrence on the South Platte River of beds correlative with the Fox Hills was mentioned by Meek and Hayden[3] as early as 1861 and the name was thus carried into this region. Fossils were collected from Laramie strata and the stratigraphy studied along the Crow Creek Valley 13 miles northwest of the present site of the Greasewood field by C. A. White[4] in 1877. This is the type locality for eight or more species and is a classic collecting area for Laramie invertebrates.

In 1912 Junius Henderson[5] collected fossils from, and studied the stratigraphy of, the Greasewood Lake area for the Colorado Geological Survey, and this part of the areal geological map of Colorado published by R. D. George, then State geologist, in 1913, was based on his work.

Following the discovery of oil and gas near Wellington, Larimer County, Colorado, in November, 1923, the Greeley Chamber of Commerce engaged the writer to make a reconnaissance of the oil possibilities of Weld County[6] which was undertaken during December, 1923, and January, 1924, with the assistance of Chas. R. Burger, Jr. During this work, evidence of a low-dipping anticline in the vicinity of Greasewood Lake was discovered, and, in an oral report made at a meeting of the Chamber in the early part of January, 1924, the writer stated that the Greasewood area was a favorable place to drill for oil, but that the drilling depth to the Dakota series would be 6,800–7,000 feet, which at that time was almost prohibitive. At a membership banquet of the Chamber on the evening of February 11, 1924, State geologist George, in an address, stated that he believed " . . . the Dakota or Muddy sand will be found at an average depth of 4,200 to 4,400 feet in much of the Weld County Area . . . ." A reprint of this address from the Greeley *Tribune-Republican* was included with every copy of the writer's published report, and George's

[3] *U. S. Geol. Geog. Survey Terr. (Hayden Survey) 1st Ann. Rept.* (1867 reprint).

[4] C. A. White, "Report of Paleontological Field Work for Season of 1877," *U. S. Geol. Geog. Survey Terr. (Hayden Survey) 11th Ann. Rept.* (for 1877), pp. 163–75 (1879).

[5] Junius Henderson, "The Cretaceous Formations of Northeastern Colorado," *Colorado Geol. Survey Bull. 19* (1920), pp. 44–47.

[6] Chas. S. Lavington, "Reconnaissance of the Cretaceous Area of Weld County, Colorado," *Greeley Chamber of Commerce Pub.* (1924).

optimism probably greatly influenced the starting of exploration work. A short time later George sent a geological party in charge of Ralph Koenig to detail the Greasewood fold. Several geologists in the employ of oil companies examined the area subsequently, but failed to find the anticline. Later, during the summer of 1924, the United States Geological Survey studied and mapped the geology of northeastern Colorado[7] and on page 105 of *Bulletin 796 B* described the "Greasewood Lake Anticline." On page 117, under "Search for New Fields," they state: "It seems altogether unlikely that the Dakota lies within reasonable drilling depth on the Greasewood Lake Anticline." Between the time the field work was finished and the formal report published, the United States Geological Survey published a press bulletin with a small map which showed the Greasewood fold.

Based on the results of Koenig's detailed survey, George made a location for a test well for the Platte Valley Petroleum Corporation, which was financed largely around Chicago, and drilling was started, May 6, 1926.[8] After many difficulties, the test reached a depth of 6,661 feet, where it started flowing oil at 4 A.M., October 10, 1930, at the rate of 184 barrels daily,[9] after encountering several showings of oil in the overlying 400 or more feet of strata. At first there was considerable speculation as to whether or not the well was bottomed in a sandstone, but subsequent deepening not only proved it to be in sandstone, but also increased the flow to more than 300 barrels per day.

GEOLOGY

STRATIGRAPHY

The rocks cropping out in the vicinity of the Greasewood field represent the uppermost Cretaceous deposition in this part of Colorado and the final withdrawal of the Cretaceous sea. The Laramie formation, of fresh- and brackish-water deposition, forms the higher lands, and the marine Fox Hills formation occupies the lower and is the surface formation in the field proper. There is some interfingering of these fresh- and brackish-water Laramie beds with the marine Fox Hills strata and, in general, the Laramie sedimentation comes lower in the stratigraphic section westward. The Fox Hills formation is composed of littoral deposits

[7] Kirtley F. Mather, James Gilluly, and Ralph G. Lusk, "Geology and Oil and Gas Prospects of Northeastern Colorado," *U. S. Geol. Survey Bull. 796 B* (1928).

[8] Harry A. Aurand, "Present Development in Greasewood Area, Weld and Morgan Counties, Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 4 (April, 1933), p. 433.

[9] Harry W. Oborne, "Discovery of Oil at Greasewood Flats, Weld County, Colorado," *ibid.*, Vol. 16, No. 3 (March, 1932), p. 256.

TABLE I

SUMMARY OF ROCK FORMATIONS EXPOSED AND DRILLED IN GREASEWOOD OIL FIELD

Age	*Group and Formation*		*Character*	*Thickness (Feet)*
Upper Cretaceous	Laramie		Upper part consists of blue to gray clays and shales, black and brown lignitic shales, lignite, ironstone, and a few thin sandstones. Lower part contains gray to white sandstone, gray sandy shale, and lignite. Fresh- and brackish-water fossils are characteristic. Uppermost Cretaceous deposition	220
	Fox Hills		Two sandstone members with intervening gray marine shales. Upper sandy member has gray or white to yellowish sandstone and sandy shales and interfingers with overlying Laramie. Basal sandy zone is buff to gray, fine-grained sandstone and sandy shale with buff fossiliferous sandstone concretions. Mainly of marine deposition	295
	Pierre shale		Upper division consists of gray marine shale and silty shale with a few thin sandstone and sandy shale beds, and limestone concretions. Middle division is mainly silty shale and silty sandstone with one prominent medium-grained glauconitic sandstone locally called "Hygiene." Lower division is mainly gray clay shale, with ironstone and limestone concretions and thin bentonite beds. Characteristic black shale at base. Entirely of marine deposition, fossiliferous throughout and has three or more foraminiferal zones	5,750 to 5,800
	Niobrara		Gray to light gray speckled calcareous shale with 25–30 feet of gray to white bedded limestone at base (Fort Hays limestone)	300 Average
	Benton		Mainly dark gray to black shale with a calcareous zone near middle and persistent 7-foot gray sandstone (Codell) with black chert and glauconite grains at top. Fish scales abundant in basal part	405
	Dakota group 379 feet	Greasewood sandstone	Thin-bedded gray sandstone, in places quartzitic, with interbedded black shale	10 to 36
			Dark gray to black marine shale with some bentonite in upper part—fish scales	47 to 68
		Dakota sandstone	Gray massive uniformly grained sandstone with one 10-foot shale parting in upper part, in western part of field. Contains salt water	160
Lower Cretaceous ?			Dark gray to black shale and sandy shale	124
		Lakota sandstone	Hard dense gray sandstone interbedded with dark shale in lower part	26
		Unconformity		
Jurassic?	Morrison		Mainly green, gray and red shale and clay and sandy clay. Minor amount of limestone in lower part and sandstone at base. Lower part not drilled in this area	185?
		Unconformity		

along the margins of the subsiding Cretaceous sea, and represents the last marine Cretaceous deposition.

Laramie formation.—The Laramie formation is composed of sandstone, shale, lignitic shale, and coal beds, and forms bluffs and somewhat rugged topography immediately north of the field. Several miles west of the field it forms low hills covered by wind-blown sand. On account of the character of deposition, there are no persistent marker beds, although some of the fossil beds can be used locally on which to map structure. The formation is essentially continental in origin and contains several genera of fresh- and brackish-water Mollusca. However, about 3 miles northeast of the field, a marine sandstone finger of the Fox Hills comes in near the base. On account of post-Laramie erosion, the thickness varies considerably, but the log of a well drilled for oil in Sec. 13, T. 7 N., R. 61 W., 6 miles north of the field, shows a thickness of 220 feet.

Fox Hills formation (restricted).—Until 1932 the Fox Hills of the Platte Valley included all of the sandstone and siltstone strata between the fresh- and brackish-water deposits of the Laramie formation and the clay shales of the Pierre. Its lower limit was based entirely on paleontology, and its contact with the underlying Pierre was always in question. In May of that year, however, the Rocky Mountain Association of Petroleum Geologists[10] held a field conference at which the United States Geological Survey was officially represented by John B. Reeside, Jr., and it was agreed to restrict the term to include only the mappable series of sandstones and intervening shale at the top of the original formation. This formation as now defined is composed of an upper sandy zone of 65–120 feet, a medial shale of about 90 feet, and a lower sandstone 80–135 feet in thickness. The upper sandy series has the characteristic white sandstone at the top. This sandstone passes into a fresh- and brackish-water series of the Laramie toward the west, but becomes marine toward the east and is included in the Fox Hills. The medial shale has two oyster-shell beds in the upper part and a thin marine sandstone 25 feet below. The lower 35 feet is marine shale. Three miles northwest of the field, coal comes into the section shortly above the oyster-shell beds, but toward the east the beds which contain the oyster shells pass into strata with marine fossils. The two oyster-shell beds and the thin marine sandstone below serve as excellent marker beds for mapping structure. The lower sandstone is very characteristic of Fox Hills and is persistent. It is buff, fine-grained,

[10] T. S. Lovering, H. A. Aurand, C. S. Lavington, and J. H. Wilson, "Fox Hills Formation, Northeastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 7 (July, 1932), pp. 702–03.

and contains two or more beds of large, hard, brown, fossiliferous sandstone concretions. The wells of the field are located in or above this sandstone.

Pierre shale.—At least three of the five zones[11] of the Pierre, so apparent on the east and south, can be recognized in this area, but on account of lithologic changes here, the formation is considered in three parts. The upper 2,700 feet is made up of gray clay shales with numerous silty limestone concretions at the top and considerable sandstone and sillstone in the following 1,200 feet. One sandstone member encountered at about 1,050 feet in the wells contains water over a considerable area. The upper part of this upper division represents the "Transition zone" of southeastern Colorado.

The middle division, which is about 2,000 feet in thickness, consists of gray sandstone and intervening gray silty shales which represent the Hygiene series of the Front Range. One well developed sandstone, commonly referred to as the "Hygiene sand," is encountered in the wells at about 3,200 feet. This sandstone contained showings of oil and gas in at least two wells, one of which was cored. It is composed essentially of medium to fine, sub-angular quartz grains, with a considerable number of glauconite and black mineral grains.

The upper part of the lower division consists of gray shales with numerous concretionary limestone and ironstone beds and a few bentonite beds, which represent the "Rusty zone" of southeastern Colorado. The basal part of this division is composed of dark gray to black clay shale with gray septarian limestone concretions and several bentonite beds. Fish scales are abundant in places, although as a rule fossils are scarce. These basal shales, which represent the "Barren zone" so prominent on the margins of the Denver basin, are readily recognizable in well cuttings. The formation has a thickness of 5,750–5,800 feet, the major portion of which is fossiliferous. There are three or more prominent foraminiferal zones.

Niobrara formation.—The upper part of the Niobrara, which is essentially gray to light gray calcareous shale, with a thin limestone bed here and there, is distinguished in drill cuttings by the first appearance of the speckled shale, which is commonly accompanied by a considerable lightening of the color, and a considerable increase in the calcareous content. The speckled appearance is caused by numerous minute, white to brownish calcareous spots, some of which are elongate, in the gray shale matrix.

[11] Chas. S. Lavington, "Montana Group in Eastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 4 (April, 1933), pp. 398–405.

Some of these spots are the tests of Foraminifera, as *Globigerina* and *Gümbelina* are commonly abundant in this formation. This upper part has a thickness of 250–290 feet and is correlative with the Smoky Hill chalk of western Kansas. The basal part of the formation is composed of 25–30 feet of white chalky limestone in beds ranging from 3 inches to 2 feet in thickness, with intervening thin, dark calcareous shale partings. It represents the Fort Hays limestone of western Kansas and its base is an excellent marker throughout the Denver basin. The average total thickness is about 300 feet, but it increases considerably east and south.

Benton formation.—A diastem at the top of the Benton represents the removal by erosion, or non-deposition, of several feet of shale which is present in other areas between the basal limestone of the Niobrara and the Codell (Frontier) sandstone, which lies at the top of the Benton in this area. The Codell, which is correlative with the Frontier sandstone of eastern Wyoming, is gray, fine-grained, glauconitic sandstone and averages 7 feet in thickness. It contains the characteristic black chert grains, except that they are much finer, which distinguish it in eastern Wyoming. The remainder of the formation consists essentially of dark gray shale, with minor amounts of limestone and bentonite. The shales ordinarily contain abundant *Globigerina*, and at the base many fish scales. Waldschmidt[12] has recognized Mowry shale in the lower part of this formation in cores and cuttings from Greasewood wells. The total thickness averages 405 feet at Greasewood, but increases considerably north, west, and south. Its contact with the overlying Niobrara is an excellent marker in a large part of the Great Plains region. Although it was cored in several of the Greasewood wells to determine structural position, it can be determined accurately by the change in the rate of drilling.

DAKOTA GROUP

This group consists of three sandstone members with intervening black or dark gray shale, and has a total thickness of 379 feet in Briggs well No. 2. The upper sandstone, locally known as the "Greasewood sand," is the producing zone of the field. Cores of this member in several wells show it to be composed of a succession of thin sandstones up to 12 or more inches in thickness, with shale partings and sandy shale. The thickness varies from 10 to 36 feet in the field. The "Greasewood sand" has been called the "Muddy" and correlated with the sandstone of that name in the Fort Collins-Wellington district in northern Colorado. Studies by Hendrick-

[12] W. A. Waldschmidt, "Characteristics of Older Cretaceous Formations of Northeastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 4 (April, 1933), p. 417.

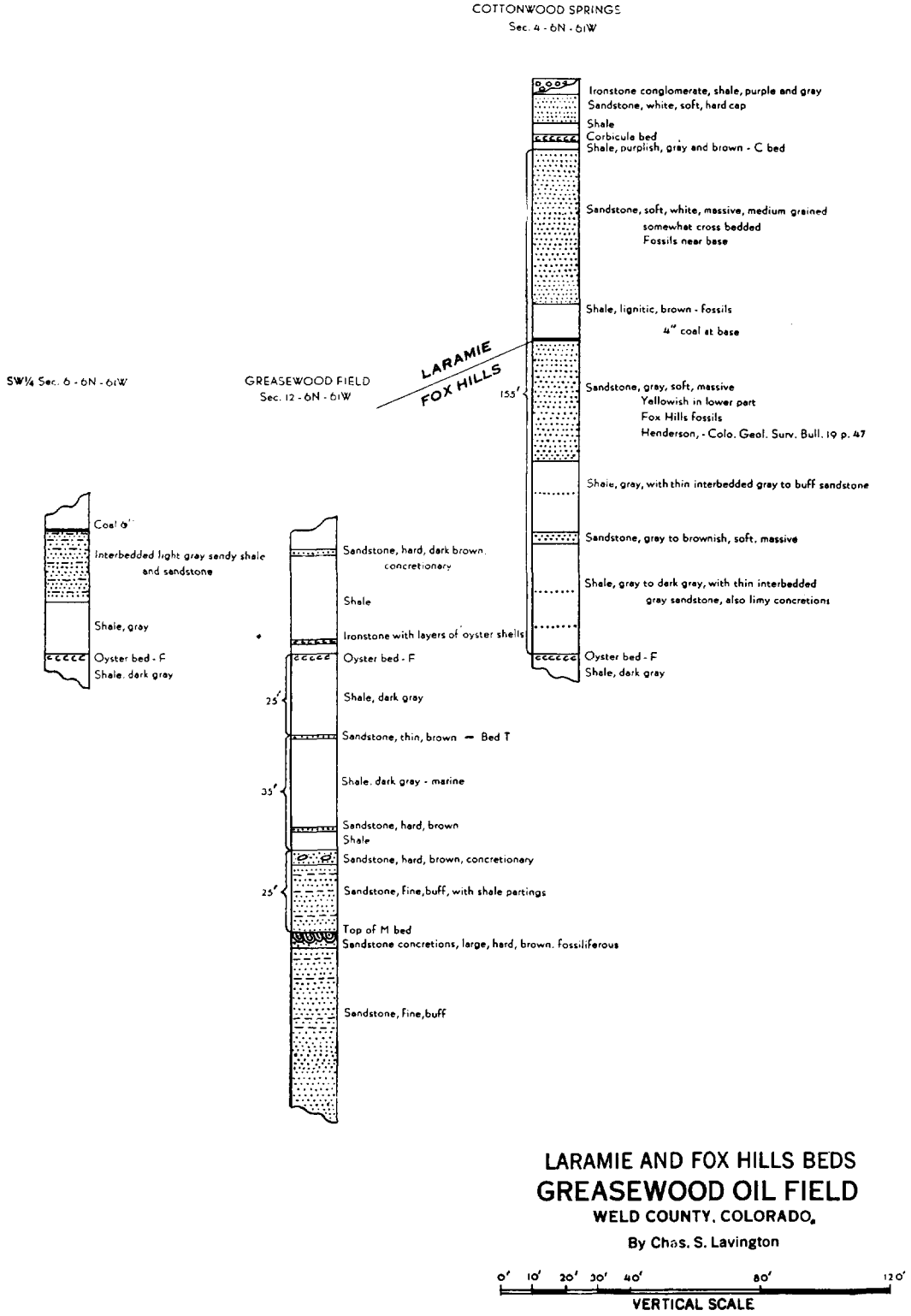

FIG. 2.—Laramie and Fox Hills beds, Greasewood oil field.

son[13] have revealed, however, that the sediments forming the Greasewood sandstone were derived from the east or northeast; whereas, those forming the Muddy were derived from the west. The Greasewood sandstone may properly belong in the Benton formation since it appears to be correlative with the Newcastle sandstone of eastern Wyoming. This has not been definitely established, however, and the common procedure of placing it in the Dakota group is followed.

The middle sandstone member, the Dakota proper, lies from 69 to 78 feet below the top of the Greasewood sandstone, with black marine shale intervening. It is massive gray sandstone with very few shale partings, and has a thickness of approximately 160 feet in two wells that have been drilled through it. It contains salt water in this area, as in the region at the south. The basal sandstone of the group, commonly known as the Lakota, although it has not been definitely proved to be a correlative of the Lakota of Wyoming, is separated from the overlying Dakota sandstone by 124 feet of dark gray or black shale and sandy shale. It has a thickness in Briggs well No. 2 of 26 feet, of which the lower 16 feet contain a large proportion of shale. The typical Fuson shale, which separates the Dakota and Lakota sandstones in eastern Wyoming, is not present as such in this area. This basal sandstone has been placed in the Lower Cretaceous[14] in Southern Colorado, but Lee[15] states,

> . . . the Dakota group in Northern Colorado is not divisible on physical grounds into Lower Cretaceous and Upper Cretaceous, as the subdivisions are generally understood, but is a single group of variable beds formed near the margin of a transgressing Cretaceous sea, and as such constitutes the basal portion of an indivisible Cretaceous series.

Pre-Dakota formations.—Formations which underlie the Dakota group, but which have not been drilled in this area, are the Morrison (Jurassic) about 185 feet thick, the Lykins (Triassic and Permian) about 760 feet, and older Paleozoic rocks of not definitely known character and thickness.

RESERVOIR ROCKS

The only stratum which has produced oil in commercial quantities is the Greasewood sandstone, although the Hygiene, Codell, and Dakota sandstones, and the Benton shale have yielded substantial showings of oil and gas. In the Continental Oil Company's Gadbois No. 1, considerable

[13] V. J. Hendrickson, unpublished data.

[14] G. W. Stose, "Apishapa," *U. S. Geol. Survey Geol. Atlas Folio 186* (1912), p. 4.

[15] Willis T. Lee, "Continuity of Some Oil-Bearing Sands of Colorado and Wyoming," *U. S. Geol. Survey Bull. 751 A* (1923), p. 21.

oil showed on the pits while coring the Codell sandstone. Cores of the Timpas and Codell in Briggs No. 1 showed some oil in both the limestone and the sandstone. In Briggs No. 2, oil showed on the pits from the shale just above the Greasewood sandstone and in the same well, which had no porosity and only little sandstone in the Greasewood, cores showed 14 feet of partly saturated oil sand in the top of the Dakota.

Porosity and permeability in the producing zone are low, although some oil saturation has been found in this sandstone in all wells cored. It has not shown water in any of the wells. The Greasewood sandstone is lenticular and pinches out entirely downdip or westward in a distance of 7 miles. There is considerable variation in thickness across the field. In Johnson-Juhl No. 1, only 10 feet of sandy shale was logged at this horizon, while in Briggs No. 1, one-half mile east, cable-tool drillers logged 36 feet of sandstone. In Briggs No. 2, one-fourth mile north of Briggs No. 1, there was about 22 feet of quartzitic sandstone made up of beds $\frac{1}{2}$–1 inch thick, with intervening shale. The Greasewood sandstone has marine shale above and below, and is apparently of marine deposition. There was bentonite below it in Briggs No. 2. Wells outside the producing area have shown the sandstone beds to be quartzitic, and cores from at least one neighboring well show secondary silicification around the original sand grains.

STRUCTURAL GEOLOGY

FOLDING

The Greasewood field is located on a very low-dipping anticline which plunges gently N. 70° W. into a great geosyncline, the axis of which commences in the vicinity of Fowler, Colorado, on the Arkansas River. This downfold reaches a low point in the vicinity of Denver, rises to a low saddle just south of Greeley, and plunges again into a "low" in southeastern Wyoming.

Locally the axis of the Greasewood anticline is rather sinuous with several constrictions of little or no closure arranged in a sort of *en échelon* fashion. Surface dips on the southwest flank average about 7 feet per mile, while those on the northwest flank attain a maximum of about 20 feet per mile. There is little, if any, surface closure at the locality of the oil pool, but there appears to be a cross axis trending northeast and southwest. The base of the Fort Hays limestone shows 17 feet of west dip between Briggs well No. 1 and Johnson-Juhl well No. 1, in a distance of $\frac{1}{2}$ mile, and 78 feet of northeast dip between Briggs No. 1 and Niles No. 1 in a distance of $\frac{3}{4}$ mile. The latter dip is due to faulting, however. No

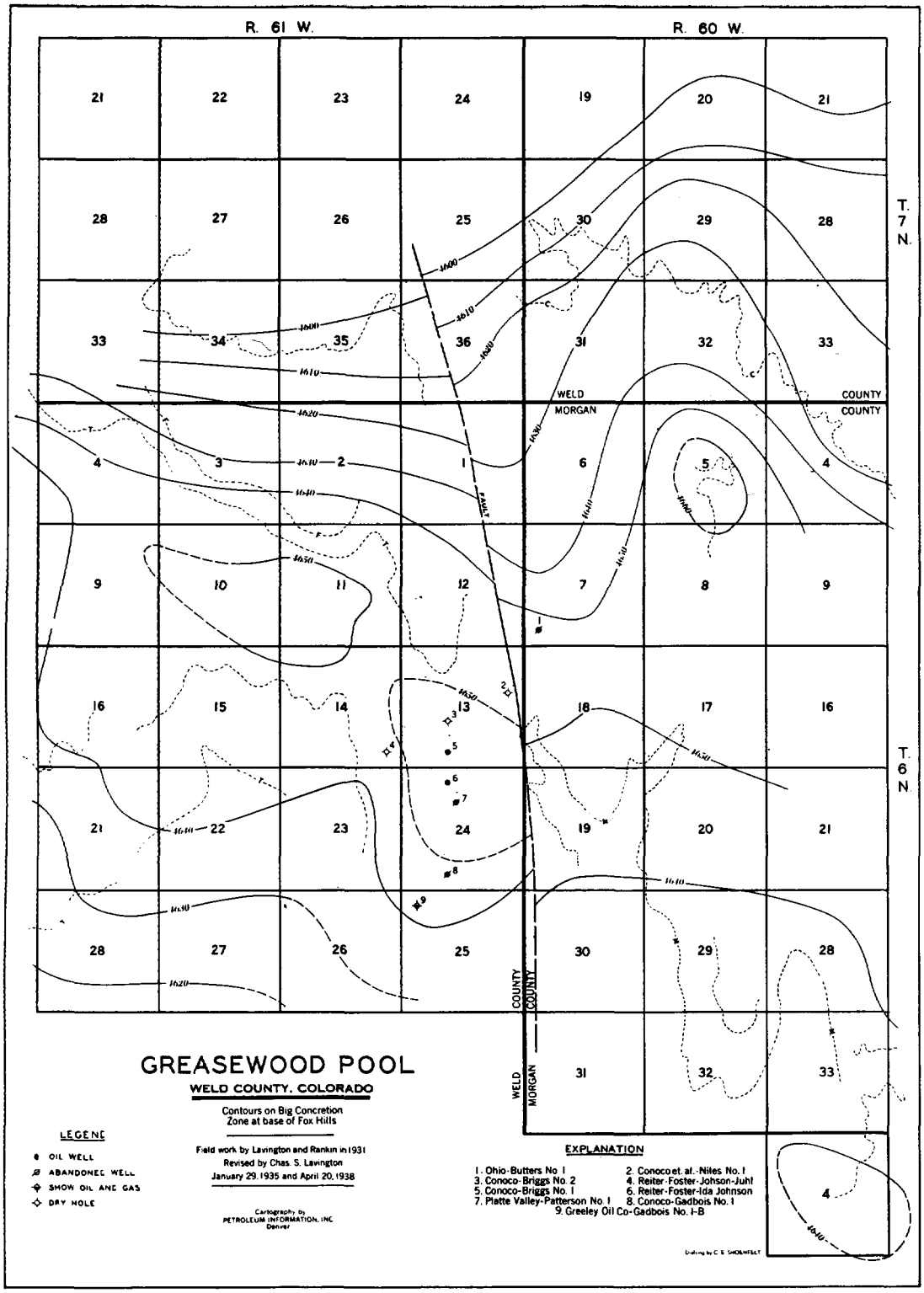

FIG. 3.—Structure of Greasewood pool, contoured on Big Concretion zone at base of Fox Hills.

drilling has been done on the east or southeast to establish the subsurface dip in those directions.

FAULTING

The Niles well No. 1, located in the center of the SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 13, passed through a fault between the Fort Hays limestone and the Dakota sandstone. In this well the Fort Hays was found to be about 87 feet lower than expected, and the normal interval between the limestone and the Dakota sandstone was shortened 99 feet. The Greasewood sandstone in this well was very thin, but it is not definitely known whether this was due to faulting or to lensing. Two feet of this sandstone found in coring was saturated with oil, but the Dakota sandstone contained salt water. There is very little if any surface evidence of this fault. Geophysical surveys, although they do not actually show the fault, do show anomalies in an approximate north-south arrangement in the vicinity of the fault.

CONVERGENCE

There is an average convergence between the Fox Hills and the Dakota sandstones of about 29 feet per mile between the Prairie Oil and Gas Company's O'Toole No. 1, $9\frac{1}{2}$ miles northwest of the field, and the Colorado Associated Oil Company's Pumphrey No. 1, 20 miles S. 60° E. The maximum convergence in the vicinity of the field is about 32 feet per mile. This convergence is due mainly to the eastward thinning of the Pierre shale. Rankin[16] has shown that the eastward thinning of the Pierre shale takes place chiefly within the Hygiene sandstone series.

GEOLOGIC HISTORY

The westward divergence between the top and bottom of the Upper Cretaceous beds shows that there was subsidence during deposition, and isopachs drawn on the interval between the top of the Fox Hills and the Dakota places the area of thickest Cretaceous deposition east of the Front Range, in the vicinity of Boulder.

The diastem at the top of the Benton covers a considerable area throughout eastern Colorado and indicates uplift or subsidence of sea-level with its consequent subaerial erosion in some places, and non-deposition in others, of the uppermost shale of the Benton.

The general folding of the area and of the region as a whole is post-Laramie in age.

[16] Charles H. Rankin, Jr., "Study of Well Sections in Eastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 4 (April, 1933), p. 423.

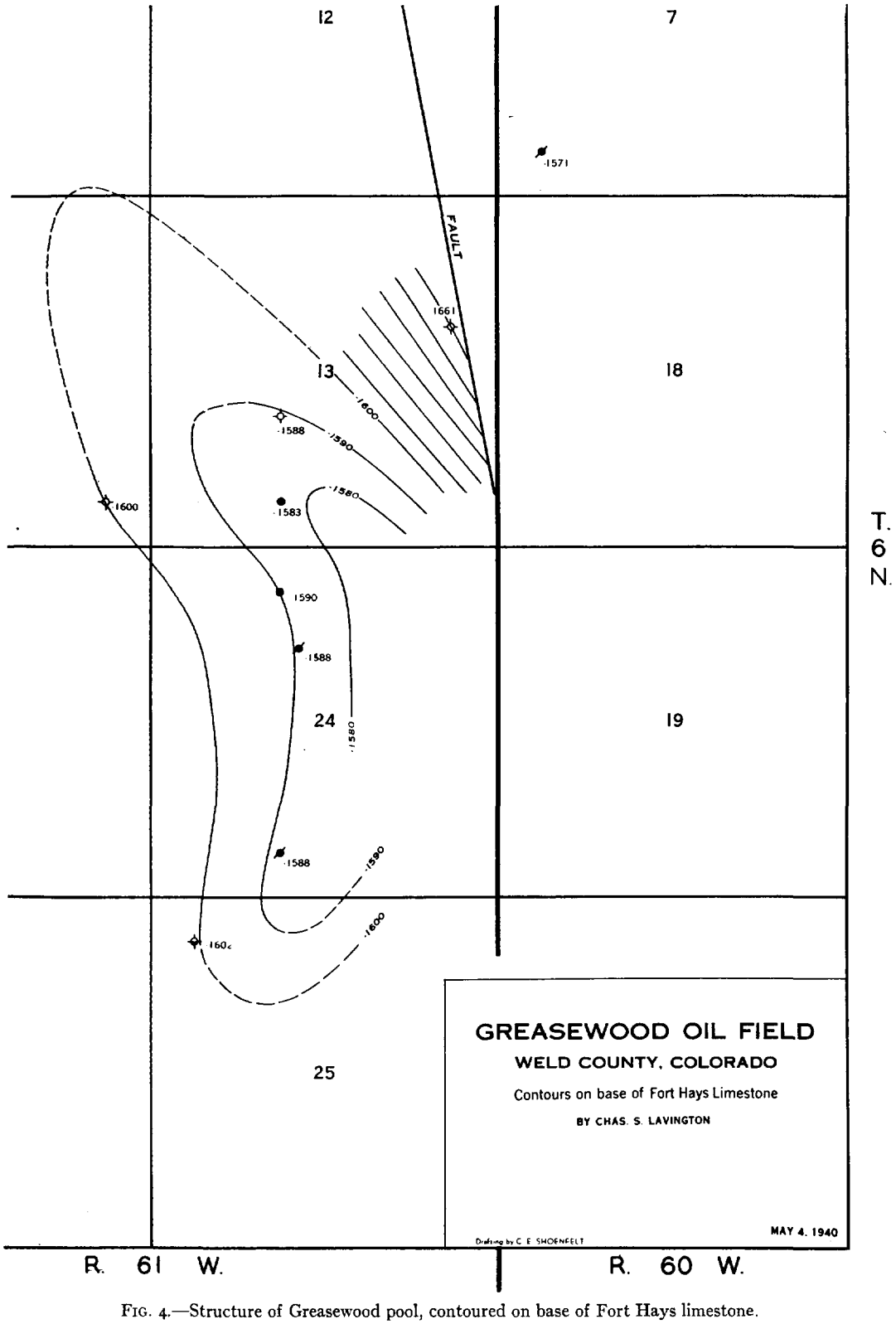

FIG. 4.—Structure of Greasewood pool, contoured on base of Fort Hays limestone.

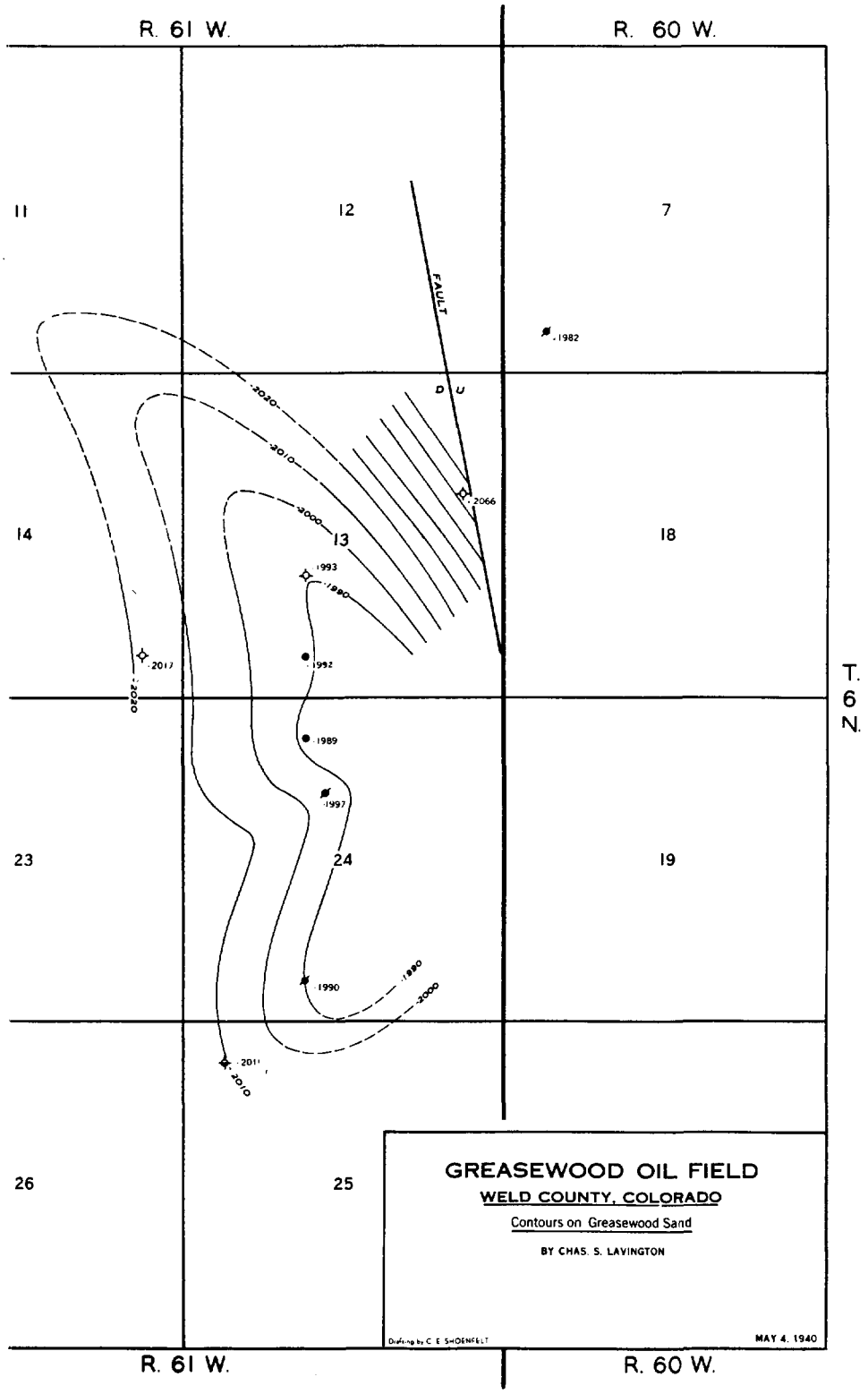

FIG. 5.—Structure of Greasewood pool, contoured on Greasewood sand.

DEVELOPMENT

After the completion of the discovery well in October, 1930, no more wells were begun until May of the following year. Ida Johnson No. 1 of the Reiter-Foster Oil Company was completed, August 26, 1931, producing initially 636 barrels. An immediate decrease in the rate of Patterson No. 1, the discovery well, was noticed. The third well, Briggs No. 1 of the Continental Oil Company, was completed, October 4, 1931, with an initial production of 937 barrels per day. Five other wells were completed in the field during 1932, three of which produced only very small amounts of oil, and two of which had only small showings of oil. One of these, Niles No. 1 (a joint test), was completed, August 8, 1932, after finding the base of the Timpas limestone considerably lower than expected. This well was drilled through a fault at the Greasewood sandstone horizon and only a few feet of saturated sandstone with very low porosity was found. It encountered the Dakota sandstone at a normal depth of 6,709 feet and salt water rose 5,700 feet in the hole.

There were no more completions until December 12, 1936, when Briggs No. 2 of the Continental Oil Company (an offset to Briggs No. 1) failed, after a good showing of oil and gas above, to find any porosity in the Greasewood sandstone and was drilled on to the top of the Morrison formation. Fourteen feet of partly saturated sandstone with a porosity of 14 per cent were cored in the top of the Dakota, but after setting pipe, a test failed to show commercial gas or oil. The lower part of the Dakota and the Lakota sandstones contained water.

PRODUCTION

The depth to the "Greasewood sand" varies from 6,639 to 6,686 feet through the field, and the thickness of the pay zone, in the three wells which have produced commercially, varies from 21 to 36 feet. These wells were drilled into the pay zone with cable tools. Tests on samples of cores from a neighboring well, which was drilled with rotary tools, showed a maximum porosity of 9 per cent.

Gas production in each of the three wells mentioned was about three million cubic feet per day, and although no bottom-hole tests were made, Donald L. Jones[17] estimated the reservoir pressure at the beginning to be about 1,800 pounds.

The oil has a gravity of 40.1° Bé., with a low sulphur content, and a 52-octane rating. The percentage of gasoline runs about 37.4.

[17] Donald L. Jones, petroleum engineer, oral communication.

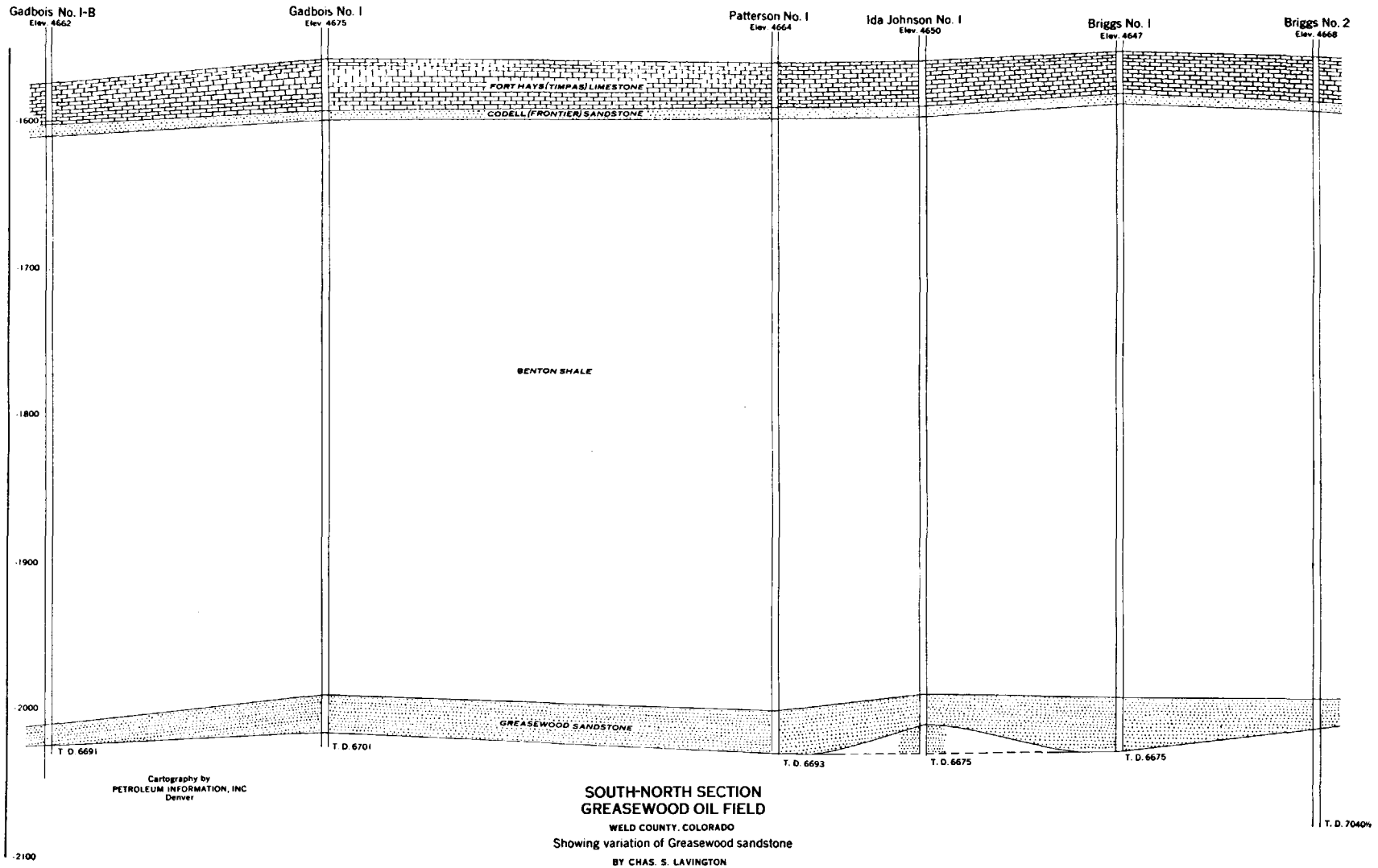

FIG. 6.—South-north section, Greasewood field, showing variation of Greasewood sandstone.

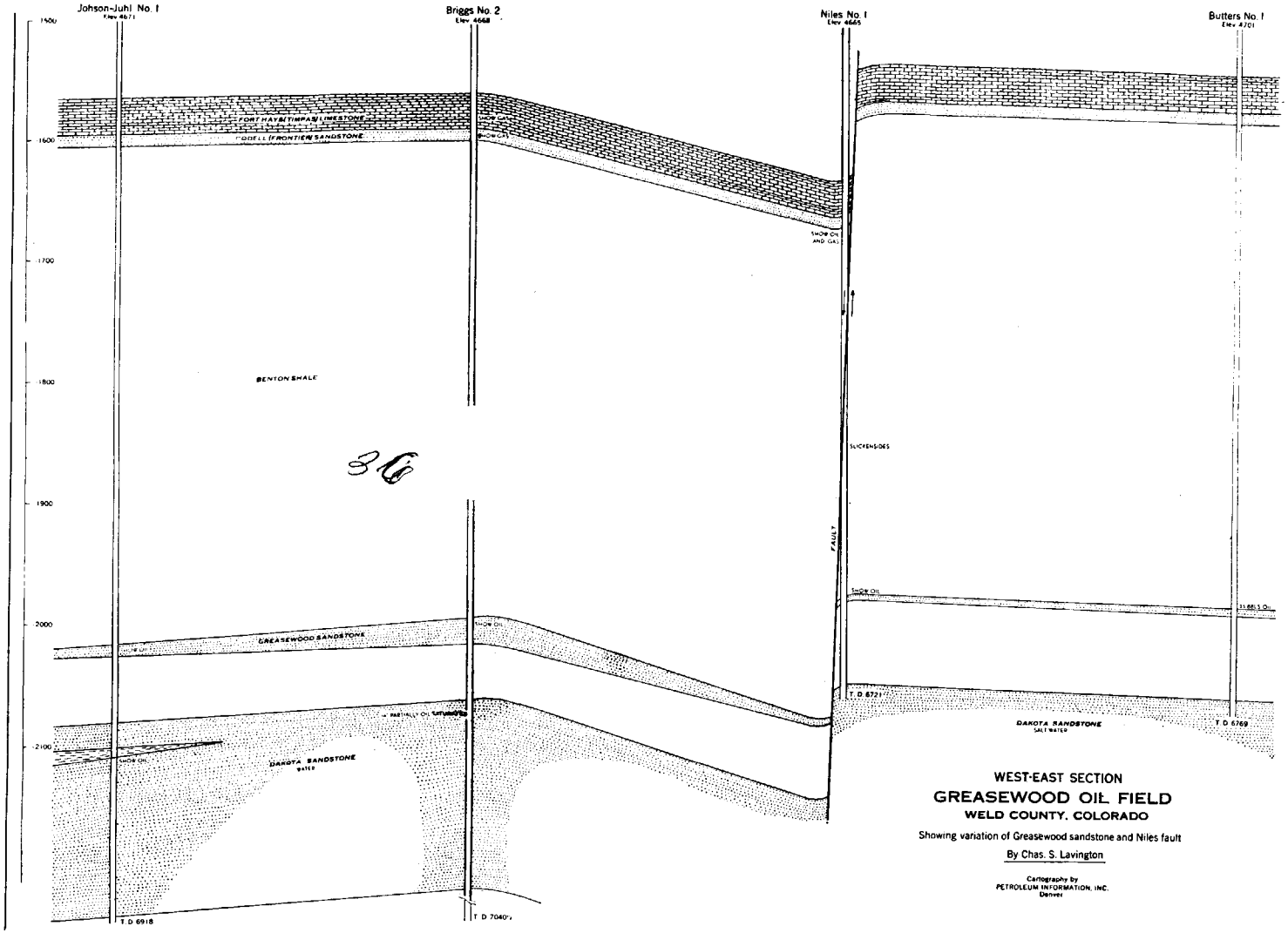

FIG. 7.—West-east section, Greasewood field, showing variation of Greasewood sandstone and Niles fault.

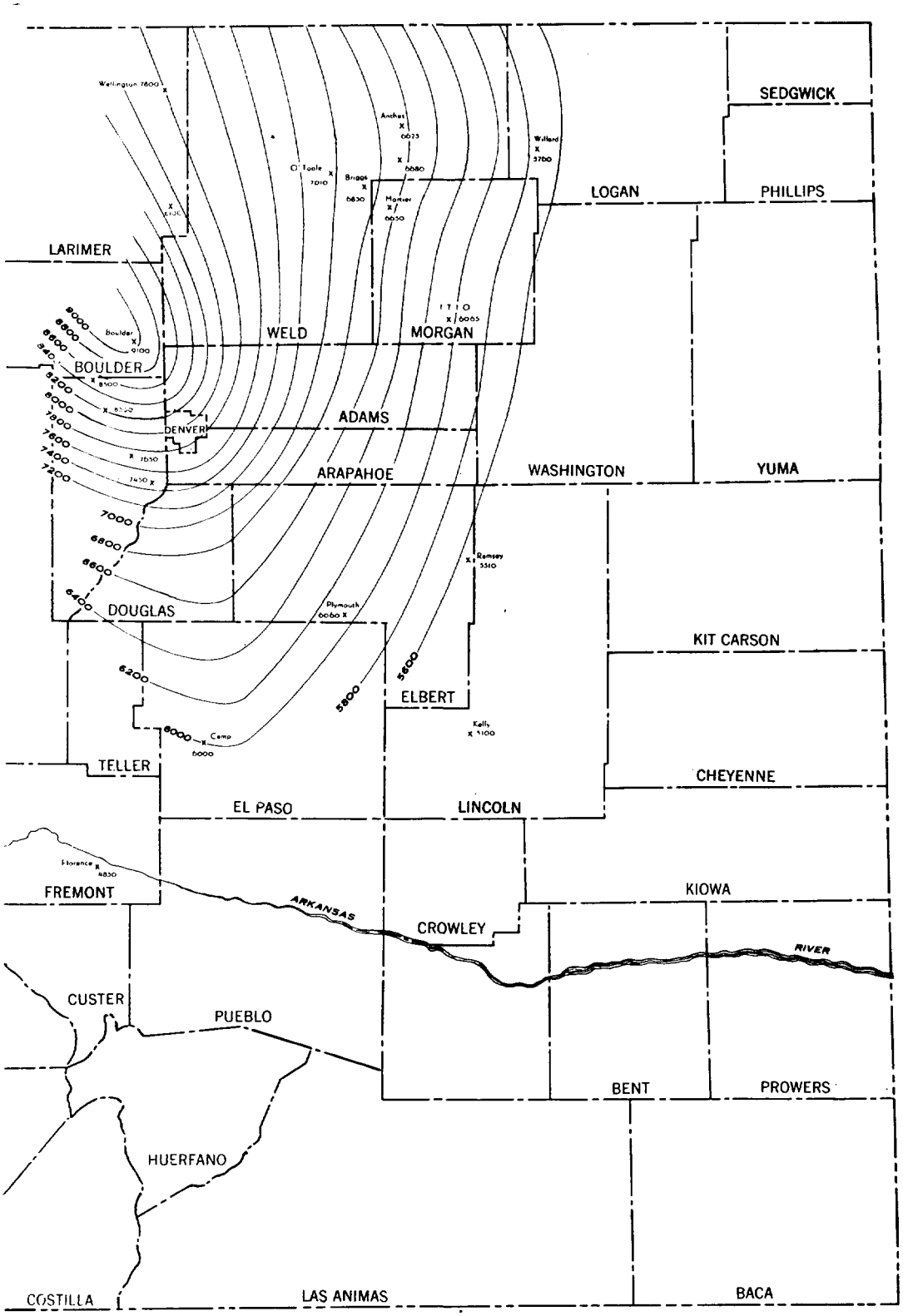

FIG. 8.—Isopach lines of Denver basin, eastern Colorado, showing thickness from top of Fox Hills to top of Dakota series.

TABLE II

WELL DATA, GREASEWOOD OIL FIELD

Company	*Lease and Well*	*Location, Section in T. 6 N., R. 61 W.*	*Initial Production (Barrels)*	*Derrick Floor Elevation (Feet)*	*Greasewood Sandstone Figures in Feet*			*Depth Total (Feet)*
					Depth	*Elevation*	*Thickness*	
Platte Valley Petrol. Corp.	Patterson No. 1	NE SE NW 24	184	4,664	6,661	−1,997	32	6,693
Reiter-Foster	Ida Johnson No. 1	C NE NW 24	636	4,650	6,639	−1,989	21	6,675
Continental Oil Company	Briggs No. 1	C SE SW 13	937	4,647	6,639	−1,992	36	6,675
Continental Oil Company	Gadbois No. 1	C SE SW 24	27	4,675	6,665	−1,990	25	6,701
Reiter-Foster	Johnson-Juhl No. 1	C SE SE 14	0	4,671	6,688	−2,017	10	6,918
Greeley Oil Company	Gadbois No 1-B	C NW NW 25	20	4,662	6,673	−2,011	12	6,691
Continental *et al.*	Niles No. 1	C SE¼ NE 13	0	4,665	In fault		2?	6,721
Continental	Briggs No. 2	C NW SW 13 *T 6N—R 60W*	0	4,668	6,661	−1,993	22	7,040½
Ohio Oil Company	Butters No. 1	C SW SW 7	25	4,701	6,683	−1,982	10	6,769

As of September 15, 1940, there are two of the original wells now producing. Briggs well No. 1, which is now operated by Manning and Martin, Incorporated, is producing 29 barrels per day, but requires occasional swabbing. Ida Johnson well No. 1, now operated by the Pipe and Mining Supply Company, produces intermittently, but is reported to average about 10 barrels per day. This well requires swabbing daily. Briggs No. 1 to July 1, 1940, had produced 213,234 barrels flowing naturally. Production figures for Ida Johnson well No. 1 are not available, but with the last $3\frac{1}{2}$ years estimated, a figure of 100,554 barrels is obtained. The total production for the field to July 1, 1940, was approximately 462,088 barrels.

It is impossible to define accurately the productive area, mainly on account of lenticularity of the reservoir bed, but also on account of nondevelopment on the east. Each successive well completed in the producing area adversely affected the production of the offset well, and it is probable that the reservoir is very limited in extent.

Gas alone is the propelling medium for the oil, and no water follows depletion.

TECHNOLOGY

After the discovery well, which was drilled entirely with cable tools, the next three wells were drilled with rotary tools to about 6,200 feet, and completed with cable tools. All the later wells were completed with rotary tools.

The early practice was to set 100–300 feet of $15\frac{1}{2}$-inch surface pipe, and then 5,500–6,200 feet of 9-inch as a safety measure. Seven-inch pipe was then set at the top of the producing zone. In later wells no pipe except the surface pipe was set until the producing zone was reached.

High bottom-hole temperatures, which reached as much as 230°F., caused considerable trouble in cementing pipe in the first two or three wells, and ice water was used in mixing the cement. Special cement was later used and no further trouble was experienced.

The oil was originally produced through $2\frac{1}{2}$-inch tubing through a choke. Separators were used to carry off the gas which was used for drilling fuel. No gas was returned to the reservoir for repressuring, and none of the wells was pumped.

A spacing program of one well in the center of each 40-acre tract was adopted and maintained after the discovery well.

GREASEWOOD PRODUCTION BY YEARS PER WELL IN BARRELS

Year	*Patterson No. 1*	*Ida Johnson No. 1*	*Briggs No. 1*
1930	13,782	None	None
1931	97,109	31,142	43,627
1932	21,465	27,191	58,902
1933	7,871	13,027	30,961
1934	4,367	9,429	20,774
1935	2,932	4,752	17,313
1936	774*	2,233*	17,182
1937	None	12,780 est.†	6,168
1938			8,138
1939			5,838
1940			4,331†
	148,300	100,554	213,234

* Figures not complete.
† To July 1, 1940.

CRUDE OIL ANALYSIS
(Lab. No. 37–039)

Colorado
Weld County
Greasewood field

Greasewood sandstone
6,639–6,675 feet

Continental Oil Company
Briggs Well No. 1
SE. ¼, SW. ¼, Sec. 13, T. 6 N., R. 61 W.

Sample taken from stock tank, August 27, 1936. Analyzed, October 10, 1936

GENERAL CHARACTERISTICS

Specific gravity: .816
A.P.I. gravity: 41.9
Per cent sulphur: Less than 0.1%
Pour point: Below 5°F.
Saybolt universal viscosity at 100°F. 39 sec.
Color: Green
Base: Paraffine-intermediate

DISTILLATION, BUREAU OF MINES, HEMPEL METHOD

Dry distillation. Barometer 648 mm. First drop: 30°C. (86°F.)

Temperature °C.	*Per Cent Cut*	*Sum, Per Cent*	*Sp. Gr. of Cut*	*°A. P. I. of Cut*	*Viscosity at 100°F.*	*Cloud Test, °F.*	*Temperature, °F.*
Up to 50	1.7	1.7	.689	73.9			Up to 122
50– 75	3.9	5.6	.699	70.9			122–167
75–100	7.6	13.2	.710	67.8			167–212
100–125	9.1	22.3	.736	60.8			212–257
125–150	6.9	29.2	.757	55.4			257–302
150–175	4.3	33.5	.771	52.0			302–347
175–200	4.1	37.6	.783	49.2			347–392
200–225	4.5	42.1	.795	46.5			392–437
225–250	4.3	46.4	.808	43.6			437–482
250–275	6.3	52.7	.820	41.1			482–527
Vacuum distillation at 40 mm.							
Up to 200	3.3	3.3	.848	35.4	41	20	Up to 392
200–225	5.9	9.2	.852	34.6	45	40	392–437
225–250	4.8	14.0	.858	33.4	51	60	437–482
250–275	4.6	18.6	.867	31.7	67	70	482–527
275–300	5.2	23.8	.877	29.9	101	80	527–572

Carbon residue of residuum 3.8% Carbon residue of crude 0.95%

APPROXIMATE SUMMARY

	Per Cent	*Sp. Gr.*	*°A.P.I.*	*Viscosity*
Light gasoline	13.2	.704	69.5	
Total gasoline and naphtha	37.6	.738	60.2	
Kerosene distillate	15.1	.809	43.4	
Gas oil	11.0	.851	34.8	Below 50
Non-viscous lubricating distillate	10.2	.857–.877	33.6–29.9	50–100
Medium lubricating distillate	2.6	.877–.882	29.9–28.9	100–200
Viscous lubricating distillate	—	—	—	
Residuum	22.1	.923	21.8	
Distillation loss	1.4	—	—	

WATER ANALYSIS

Dakota sandstone—Johnson-Juhl well No. 1 Depth, 6,785 feet

	P.P.M.	*Per Cent*
$CaCO_3$	0	0
$CA(HCO_3)_2$	0	0
Na_2CO_3	0	0
$NaHCO_3$	1,830	12.2
Total carbonates	1,830	12.2
$CaSO_4$	354	2.4
Na_2SO_4	0	0
$MgSO_4$	196	1.3
Total sulphates	550	3.7
$NaCl$	12,580	83.7
$MgCl$	58	0.4
$CaCl_2$	0	0
Total chlorides	12,638	84.1
Total solids	15,018	100

COST OF DRILLING

The completion cost of the first three or more wells following the discovery well varied from $125,000 to $140,000 each. For later wells, this cost was reduced to $100,000 or less per well.

DISPOSITION OF OIL

Originally, the oil was purchased in the field by the Continental Oil Company and transported through its 4-inch line a distance of 16 miles to the Union Pacific Railroad at Hardin, and thence by tank car to its Denver refinery. This pipe line was sold during 1939 and the oil is now transported by motor truck to the Denver market.

RELATION OF OIL ACCUMULATION TO GEOLOGY

The Greasewood pool is not an example of a true "stratigraphic trap" accumulation, because the "wedge-edge" of the reservoir sandstone is downdip from the accumulation and the sandstone continues, with some thickness variations, updip far beyond the locality of the pool. Accumulation of oil has been controlled in three directions by sandstone, thick-

ness, and porosity, but toward the east, the updip movement of the oil was stopped by the Niles fault which acts as the barrier. Two wells east of the fault cored oil-saturated sandstone, but were not commercial. In fact, all wells drilled in the area have found some oil in the Greasewood sandstone. The fact that there is considerably more dip on both the Fort Hays limestone and the variable Greasewood sandstone than on the surface beds, is important. The localization of the oil pool on an anticline, even so gentle as this one, shows that the movement of oil toward the reservoir bed was guided to some extent by folding, even though actual accumulation is due partly to sand variation.

Conclusion

The discovery well of the Greasewood oil field was originally located on a gentle anticline mapped on surface beds. Subsequent development has shown that the reservoir sandstone is variable in thickness and porosity, and that it "wedges out" downdip toward the west. It has also shown that a general north-south trending fault downthrown on the west limits the eastward extension of the oil pool. It is, therefore, demonstrated that the oil accumulation in the Greasewood pool is due to a combination of stratigraphic as well as structural factors.