CIRCULAR 87

Preliminary Investigations of the Oil Shale Potential in New Mexico

by *ROY W. FOSTER*

PHILIP B. LUCE

LEWIS G. CULVER

BURHANUDDIN B. MARAS

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO

CIRCULAR 87

Preliminary Investigations of the Oil Shale Potential in New Mexico

by ROY W. FOSTER
PHILIP B. LUCE
LEWIS G. CULVER
BURHANUDDIN B. MARAS

1966

STATE BUREAU OF MINES AND MINERAL RESOURCES
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
CAMPUS STATION SOCORRO, NEW MEXICO

For sale by the New Mexico Bureau of Mines and Mineral Resources
Campus Station, Socorro, N. Mex.—Price $0.50

Abstract

More than 4800 qualitative and quantitative tests were conducted on New Mexico shales to determine the presence of commercial deposits of oil shale. To date, this testing has not revealed any extensive deposits of this type. Testing was restricted to gray and black shales that occur in quantity only in rocks of Devonian, Pennsylvanian, Cretaceous, and Tertiary ages. Low-yield deposits of oil shale were found in Pennsylvanian shales, particularly near Abo Pass; in the Cretaceous Mancos Shale at Carthage and in the northwestern part of the San Juan Basin; in the Cretaceous Graneros Shale near Springer; and in the Tertiary Raton Formation near Raton. Additional testing of these intervals and of the gray to black shales exposed in southwestern New Mexico is needed to complete an oil shale evaluation of the state.

Introduction

Oil shale is a fine-grained sedimentary rock that will yield a petroleumlike substance by destructive distillation. Other bituminous rocks that contain soluble hydrocarbons and that will yield oil by heating, such as asphaltic sandstones and bituminous limestones, are not included in this report, as well as shales containing crude oil that may be extracted by conventional drilling and production methods.

The organic matter in oil shale generally is referred to as kerogen and consists mostly of aquatic plant algae of high-molecular-weight hydrocarbons containing nitrogen, oxygen, and sulphur. Upon heating, the organic matter in the shale converts to a soluble bitumen over a wide range of temperatures beginning at about 200 C. Vapors emitted at approximately 350° C condense to form a highly viscous liquid that may be refined to produce gasoline, kerosene, fuel oil, asphalt, waxes, and other petroleum products.

Oil shales range from black to brown and yellow, plus various shades of gray. They may be massive, with a conchoidal fracture, or they may consist of fissile, "paper, " shales. Some have a waxy luster; others are dull and stony in appearance. Some oil shales are not true shales but consist largely of calcium and magnesium carbonates. Some oil shales are intimately associated with coal beds, such as those in Spain, Scotland, France, and Australia; others, such as those in the United States, Estonia, and Sweden, are not. Beds of oil shale occur in rocks representing almost all the geologic ages. Deposits in Sweden are Cambrian or Silurian in age; some beds in Canada are Devonian; in Brazil, Permian; Austria, Triassic; Germany, Jurassic; Israel, Cretaceous; and the United States, Tertiary.

With the exception of a small amount of production in the eastern United States during the late nineteenth century, shale oil has not been produced commercially in this country. This production ceased when drilling provided an inexpensive method for the extraction of liquid hydrocarbons. The cost difference between conventional oil and shale oil has decreased in recent years as the result of technical advances in the mining and retorting of oil shales and the increased cost of locating new and deeper reserves of conventional oil.

For many years, the production of shale oil has been an important industry in countries that have only small reserves of, or are lacking in, deposits of conventional oil. Shale oil is being produced in several countries in Europe; other countries have made plans to build retorts and refineries. Present production is not sufficient to meet the petroleum demands in any of these areas, and importation of oil from the Near East has curtailed the domestic production of shale oil in recent years. Nonetheless, the possible importance of oil obtained from shale cannot be overlooked, particularly in those countries where the supply of crude petroleum cannot meet present or future demands and where political problems endanger the free flow of oil. The important known deposits of oil shale occur in Australia, France, New Zealand, Russia, Sweden, Germany, Estonia, Republic of South Africa, Scotland, Thailand, Spain, Manchuria, Canada, Brazil, and the United States.

ration in the United States has been limited mostly to an exhaustive study of the Green River Formation in Colorado, Utah, and Wyoming. From a technical and exploratory standpoint, these deposits probably have been studied more closely than any in the world.

Known oil shales range in oil yield from a trace up to 200 gallons of oil per ton of shale. The highest yields come from thin beds of torbanite in Australia. The richest deposits in Europe are found in Estonia, where yields of 90 gallons a ton have been reported. Deposits in Scotland, worked for many years, average 26 gallons a ton; France, from 15 to 30; Thailand, 70; Brazil, 18 to 100; Manchuria, 25 to 50; New Zealand, 46; Spain, 5 to 40; and Sweden, 20 (Guthrie and Klosky, 1951; Kraemer, 1950; Kraemer and Thorne, 1951; Jaffe, 1962; and Thorne and Kraemer, 1954). Exclusive of the Green River Formation (average yields from 20 to 40 gallons a ton), oil yields up to 70 gallons a ton have been reported from rocks of Devonian, Mississippian, Pennsylvanian, Permian, and Upper Cretaceous ages in states in the Rocky Mountain area (Winchester, 1923).

There are no known oil shale deposits in New Mexico, but until the past few years, there was no active exploratory program in the state. The only published reference concerning oil shale is by Winchester (1933), who stated, "A small sample of black shale from the upper part of the Magdalena formation 'near Scholle', ...was subjected to distillation and found to yield oil at the rate of 41 gallons a ton. This is exceptionally rich for shales of Pennsylvanian age. Several of the black shale beds of the section were tested by the writer and found capable of yielding oil on distillation." In 1961 a limited exploratory program was begun by the New Mexico Bureau of Mines and Mineral Resources. Additional support was given this project in 1963 by the State Planning Office. Since the project was initiated, 'more than 4800 qualitative and quantitative tests have been conducted on New Mexico shales. Results of these tests were negative. However, because of the present exploratory interest in oil shale, publication at this time of the completed test data seems advisable. Considerable investigative work remains to be done; hopefully, duplication of effort can be avoided with the release of this information.

Shale is the most abundant rock type that occurs in New Mexico. Even if limited to gray or black shales, the task of sampling and testing every likely section becomes a major undertaking. The most rapid method for evaluating the oil shale potential of an area is by the testing of well cuttings. This is done by selecting a few chips from favorable sample intervals, placing the chips in a test tube, and heating over a Bunsen burner. Vapors and condensation that occur are examined for amount and color. Yellow to brown vapors and similarly colored droplets on the walls of the tube indicate the presence of distillable oil in the shale. Quantitative tests of favorable zones were made by heating surface samples of shale in a modified Fischer retort similar to that used by the U. S. Bureau of Mines (Stanfield and Frost, 1949). A refrigeration system for use in cooling the gas condenser was not available, and reported oil yields are considered to be below the maximum obtainable with this equipment. Quantitative tests we re conducted primarily on shales that appeared favorable, based on the information from the qualitative tests. Additional surface samples were collected in areas remote from oil tests or where particular parts of the stratigraphic section had not been penetrated in drilling operations.

ACKNOWLEDGMENTS

The authors are indebted to Miss Teri Ray and Dr. Frank E. Kottlowski for editing, to Mr. William E. Arnold for drafting of the figures, and to Mrs. Lois Devlin and Mrs. Wilma Nicholson for typing the manuscript.

Test Results

Shales that are potential sources for oil in New Mexico are restricted almost entirely to rocks of Devonian, Pennsylvanian, Cretaceous, and Tertiary ages. Sampling and testing for this report have been limited to these stratigraphic intervals.

DEVONIAN

The outcrop distribution of Devonian rocks is shown in Figure 1. Exposures are restricted to various ranges in the south-central and southwestern parts of the state. Of particular interest are the exposures in the Black Range, and the Peloncillo, Big Hatchet, San Andres, and Sacramento mountains. Devonian shales underlie, but are deeply buried in, southeastern and northwestern New Mexico. Where exposed, the interval is thin and outcrops are limited to steep slopes beneath thick, resistant Mississippian limestones. Because of the narrow outcrop belt and thick limestone caprock, underground mining would be necessary. Unless yields were exceptionally high, it is doubtful that these shales would be of commercial importance.

Sampling was limited to two localities in Sierra County. Both sections consist of light-gray and pale-olive, silty, calcareous shales interbedded, in the upper part, with nodular limestones. These beds are similar to the upper unit or Box Member of the Percha Shale. At locality 88-1 in the Mud Springs Mountains beds of this type are all that are present. In the Black Range, the lower unit, or Ready Pay Member, crops out in the vicinity of Kingston. This unit consists of black fissile shale considered typical of the Percha. Samples collected in the Black Range at locality 99-1 were from incomplete exposures of the Box Member; the Ready Pay Member has not been tested for this report.

Qualitative tests conducted on the 33 samples collected in the two areas failed to reveal the presence of any distillable oils (table 1). Further testing of the Devonian in southwestern New Mexico is warranted but probably should be restricted to the dark-gray shale intervals. Testing of oil well cuttings east and south of the Sacramento Mountains would be of value in determining the potential of these shales in the south-central part of the state.

PENNSYLVANIAN

Rocks of Pennsylvanian age underlie most of New Mexico, being absent only over such late Paleozoic features as the Pedernal, Zuni, Florida, and Sierra Grande uplifts. In most of eastern and western New Mexico, these rocks are buried beneath thick sequences of younger Paleozoic, Mesozoic, and Cenozoic sediments. Extensive outcrops occur in the major north-south-trending ranges in the central and southwestern parts of the state, including the Sangre de Cristo, Nacimiento, Sandia, Manzano, Los Pi?Cos, Ladron, Caballo, Fra Cristobal, Sacramento, San Andres, Oscura, Black, Big Hatchet, and Peloncillo ranges. Exceptionally thick shale intervals are found in the southeastern foothills of the San Mateo Mountains and west of Mora in the Sangre de Cristo Mountains. The total Pennsylvanian section ranges in thickness from a few hundred to more than three thousand feet and is composed, predominantly, of an interbedded sequence of marine shales and limestones. In much of central and northern New Mexico the interval has been subdivided into two formations; the Sandia below and Madera above. The Sandia Formation consists of light to dark gray, commonly carbonaceous shale, interbedded with gray and brown sandstone, and dark-gray fossilifrous limestone. Very thin, impure coal beds occur in this part of the section in some areas. The Madera Formation includes two members, a lower Gray Limestone and an upper Arkosic Limestone. The lower member is composed of light to dark gray fossiliferous, cherty limestone, thin beds of light to dark

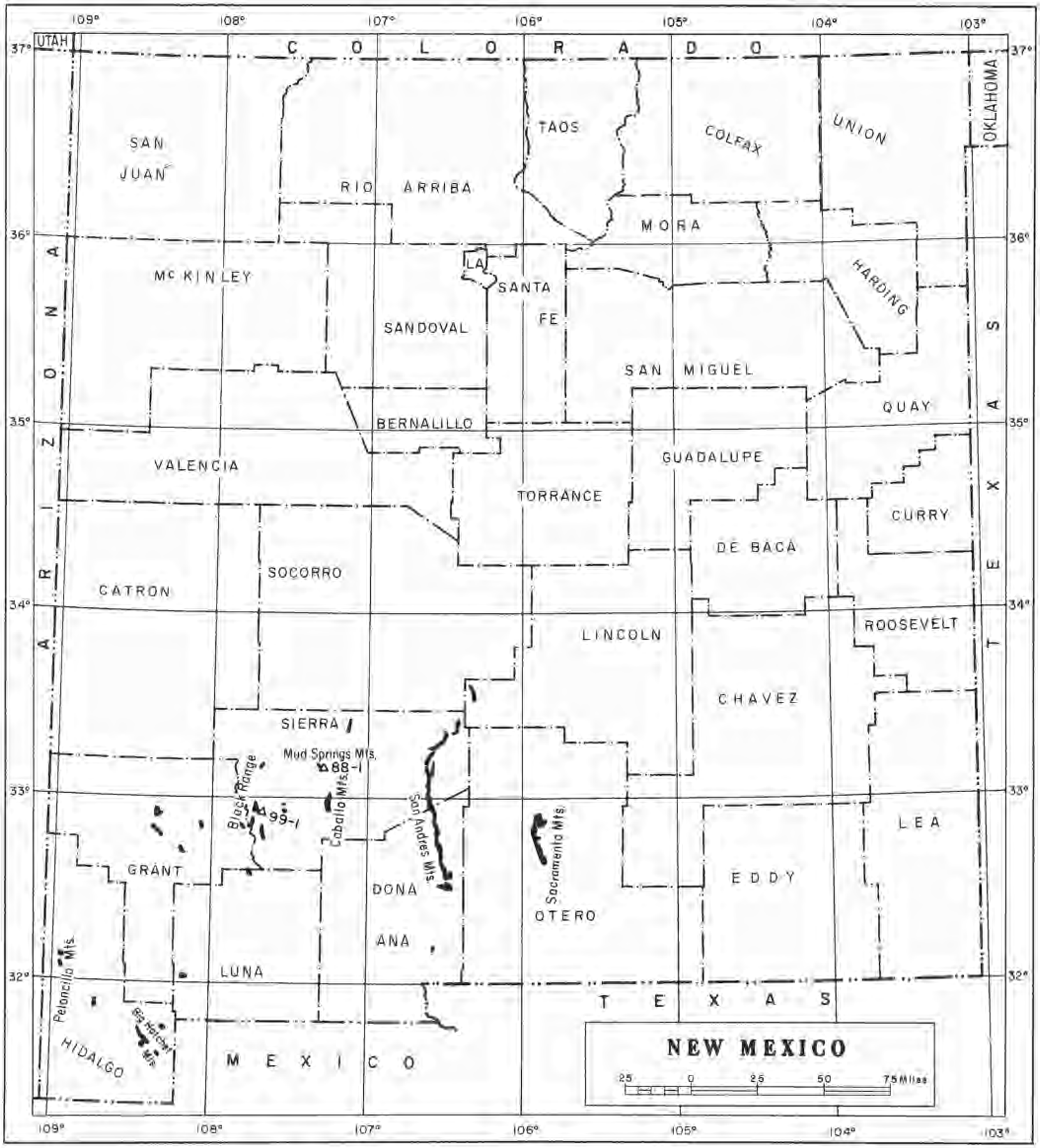

Figure I

SAMPLE LOCALITIES AND OUTCROPS OF DEVONIAN ROCKS (△ SURFACE SAMPLES)

TABLE 1. TESTS CONDUCTED ON DEVONIAN SHALES

Section number	Qual. tests	Quant. tests	Location	Remarks
			Sierra County	
88-1	16	--	C sec. 24, T. 13 S., R. 5 W.	Box Member of Percha Shale; Mud Springs Mts.
99-1	50	--	SW1/4NE1/4 sec. 5, T. 16 S., R. 8 W.	Box Member of Percha Shale; Black Range

gray shale, and minor sandstone. The upper member consists of a complex sequence of shale, limestone, sandstone, and arko se . Shales in this unit range in color from gray to green, red, and purple.

A total of 1666 shale samples was collected from wells and outcrops. The samples were subjected to 169 quantitative and 2176 qualitative tests. As can be seen in Figure 2, almost all the testing completed thus far is on samples from sections in the northern and central parts of the state. Results of tests of surface sampies were not encouraging (table 2). Traces of oil were obtained from a few of the shales at localities in the Manzanita Mountains (42-6), at Bishops Cap (113-2), and west of Mora (20-4). These traces occurred in both the upper and lower parts of the Pennsylvanian sequence. Between 1 and 5 gallons of oil per ton of shale were distilled from samples in the Sandia Formation near Lamy (31-1). The oil was obtained from highly carbonaceous shales containing thin coal seams. Faint traces of oil were found in shales from well samples in San Miguel County, east and south of the Sangre de Cristo Mountains (44-1 and 32-2), but the intervals were thin and occurred at different parts of the section.

Careful sampling and testing were conducted on the shales in the Abo Pass area (65-1 and 66-1) where oil shales were reported to be present in the Madera interval by Winchester (1933). No indication of oil was obtained from tests run on the surface samples, but qualitative tests on well cuttings from this area and from west of the Ladron Mountains indicated the presence of a fairly thick interval of possible oil shales in the Sandia Formation. In the Spanel and Heinze No. 1-9608E Santa Fe test (52-1), fairly heavy condensation of oil was noted in the lower part of the Madera Formation and throughout the Sandia Formation. In the Eidal No. 1 Mitchell test (54-3) drilled east of Abo Pass, considerable brownish vapors were emitted along with a fair amount of oil condensation from the Sandia interval. Minor traces of oil also were observed in the lower part of the Arkosic Limestone Member in this well. Shales in the Sandia Formation do not crop out in the southern Manzano Mountains, so in order to test the oil indications from the well samples, surface sampling was conducted in the Joyita Hills and Lemitar and Ladron mountains. The dark shales in the Joyita Hills (65-2) proved barren, as did similar shales from the Lemitar (65-4) and Ladron (64-2) mountains. Apparently, the yield is low and most of the organic material near the surface has been removed. Other minor indications of oil were found in cuttings from wells drilled on the east side of the Manzano Mountains (54-6) and north and west of the Oscura Mountains (78-1 and 78-2).

Based on tests of surface and well samples, there appears to be little possibility of finding thick, high-yield oil shales in the Pennsylvanian section. To fully evaluate the potential of this interval, some testing should be conducted on shales from the Nacimiento Mountains and from the ranges of southwestern New Mexico. Before making a definite statement regarding the shales of the Abo Pass area, it would appear to be necessary to core this section and conduct quantitative tests of unweathered material. Whether or not this is warranted from the fragmentary information in the literature and from tests of well samples is problematical.

CRETACEOUS

By far the most extensive outcrops of gray to black shales occur in beds of Cretaceous age. Upper Cretaceous shales are thick and underlie large areas in the northwestern and northeastern parts of the state (fig. 3). Other important exposures are found south of Santa Fe, around Capitan in Lincoln County, and east of the Caballo Mountains in Sierra County. Lower Cretaceous shales crop out in several ranges in the southern part of the state. Fairly complete testing of Upper Cretaceous shales has been done in the San Juan Basin and in Colfax County. Limited testing was conducted on shales exposed south of the Zuni Mountains, in Santa Fe County in the vicinity of Madrid and Cerrillos, and at Carthage southwest of Socorro.

Complete outcrop sampling of all the shales present in the Cretaceous interval in the

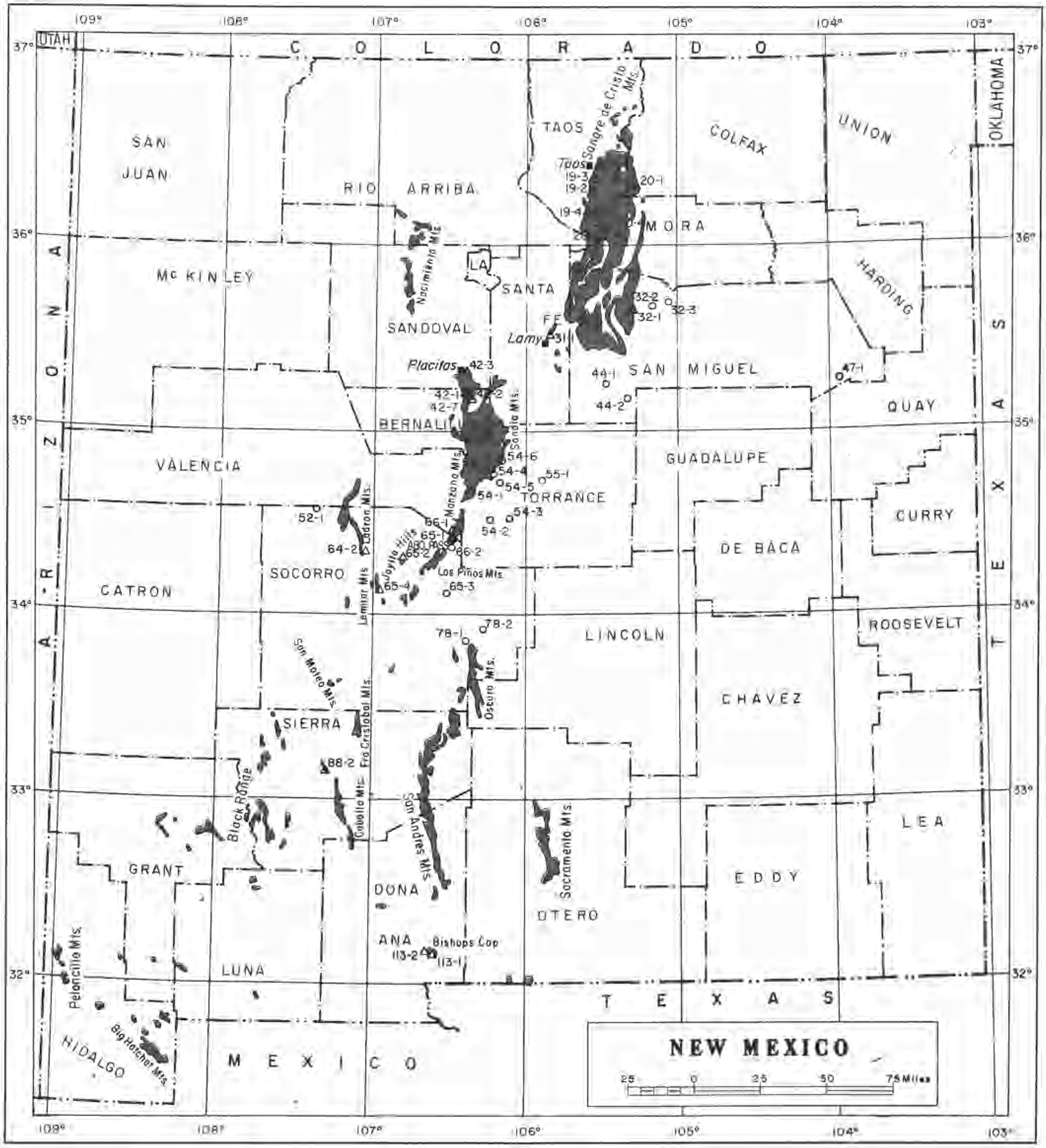

Figure 2
SAMPLE LOCALITIES AND OUTCROPS OF PENNSYLVANIAN ROCKS
(△ SURFACE SAMPLES, ○ WELL SAMPLES)

TABLE 2. TESTS CONDUCTED ON PENNSYLVANIAN SHALES

Section number	Qual. tests	Quant. tests	Location	Remarks
			Bernalillo County	
42-1	4	--	SE1/4SE1/4 sec. 4, T. 11 N., R. 5 E.	Arkosic Limestone Member of Madera Formation; Sandia Mts.
42-2	2	--	NE1/4 sec. 15, T. 11 N., R. 5 E.	Sandia Formation; Sandia Mts.
42-6	--	5	SE1/4 sec. 18, T. 9 N., R. 6 E.	Madera Formation; Kinney Clay Pit; trace of oil
42-7	--	8	NW1/4 sec. 24, T. 11 N., R. 5 E.	Sandia Formation; Sandia Mts.
			Colfax County	
20-1	11	--	secs. 6, 7, 17, T. 24 N., R. 16 E.	Upper Pennsylvanian; Black Lake
			Dona Ana County	
113-1	34	--	SW1/4SW1/4 sec. 25, T. 24 S., R. 3 E.	Upper Pennsylvanian; Bishops Cap
113-2	--	1	NE1/4 sec. 35, T. 24 S., R. 3 E.	Upper Pennsylvanian; Bishops Cap; trace of oil
			Mora County	
20-4	285	75	N. Mex. 3 between Holman and Taos-Mora County Line	Lower Pennsylvanian; Sangre de Cristo Mts.; trace of oil from few samples
			Sandoval County	
42-3	10	--	SE1/4 sec. 34, T. 13 N., R. 5 E.	Lower Pennsylvanian; Placitas

TABLE 2. TESTS CONDUCTED ON PENNSYLVANIAN SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			San Miguel County	
31-2	1	1	SE1/4 sec. 12, T. 16 N., R. 12 E.	Arkosic Limestone Member; Vallecitos
32-1	5	--	N. Mex. 65 at Montezuma	Lower Pennsylvanian
32-2	78	--	660N 1980E sec. 25, T. 17 N., R. 16 E.	Hancock No. 1 Sedberry; trace of oil 5100-10 ft
32-3	143	--	1980N 1880E sec. 28, T. 17 N., R. 18 E.	Conoco No. 1 Shoemaker
44-1	163	--	990N 330E sec. 20, T. 12 N., R. 14 E.	Lubar No. 1 Gonzalez; traces of oil at 2700-30; 2810-20; 2980-90 ft
44-2	186	--	650S 1980E sec. 15, T. 11 N., R. 15 E.	Frankfort No. 1 Lucero
47-1	281	--	660N 660W sec. 14, T. 12 N., R. 28 E.	Miami No. 1 Hoover Ranch
			Santa Fe County	
31-1	24	1	NE1/4 sec. 23, T. 15 N., R. 10 E.	Sandia Formation; Lamy; approx 5 gal/ton (carbonaceous)
			Sierra County	
88-2	2	--	NE1/4 sec. 24, T. 13 S., R. 5 W.	Lower Pennsylvanian; Mud Springs Mts.
			Socorro County	
52-1	62	--	1980N 2000W sec. 17, T. 4 N., R. 5 W.	Spanel and Heinze No. 1-9608E Santa Fe; good oil indications at 4270-75; 4285-90; 4320-25; 4450-55; 4460-65; 4680-90; 4705-10; 4713-20; 4730-35; 4740-45 ft
64-2	--	17	SW1/4NE1/4 sec. 31, T. 2 N., R. 2 W.	Sandia Formation; Ladron Mts.
65-1	120	20	NE1/4 sec. 10, T. 2 N., R. 4 E.	Madera Formation; Abo Pass

TABLE 2. TESTS CONDUCTED ON PENNSYLVANIAN SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			Socorro County (cont)	
65-2	5	--	North end, Joyita Hills	Sandia Formation
65-3	130	--	1980S 1980E sec. 22, T. 2 S., R. 4 E.	Skelly No. 1 Goddard
65-4	--	9	NW1/4NW1/4 sec. 18, T. 2 S., R. 1 W.	Sandia Formation; Lemitar Mts.
66-2	19	--	1980S 660W sec. 23, T. 2 N., R. 4 E.	Laing No. 1 Sanchez; trace of oil 490-500; 520-30 ft
78-1	85	--	660S 660W sec. 23, T. 5 S., R. 5 E.	Sun No. 1 Bingham; trace of oil 2180-90; 2340-50; 2640-50; 2830-40; 3090-3100 ft
78-2	122	--	660N 660W sec. 33, T. 4 S., R. 6 E.	Lockhart No. 2 Fee; good oil indications at 2230-35; 2365-70; 2385-2400; 2410-15; 2550-55; 2690-95 ft; Lower Pennsylvanian
			Taos County	
19-1	18	--	secs. 14, 24, T. 22 N., R. 13 E.	Lower Pennsylvanian; Tres Ritos
19-2	12	--	Roadcuts N. Mex. 3 south of Talpa	Lower Pennsylvanian
19-3	23	--	secs. 22, 24, T. 25 N., R.13 E.	Lower Pennsylvanian east of Taos
19-4	6	--	Junction N. Mex. 3 and 75	Lower Pennsylvanian
20-2	24	--	secs. 5, 6, T. 21 N., R. 14 E. and secs. 30, 32, T. 22 N., R. 14 E.	Lower Pennsylvanian east of Tres Ritos
20-3	18	--	secs. 24, 30, T. 25 N., R. 14 E.	Lower Pennsylvanian east of Taos
			Torrance County	
54-1	30	5	SE1/4 sec. 11, T. 5 N., R. 5 E.	Lower part of Madera Fm; Manzano Mts.
54-2	4	--	1980S 660W sec. 32, T. 4 N., R. 7 E.	Mountainair No. 1 Veal
54-3	61	--	660N 1980E sec. 33, T. 4 N., R. 8 E.	Eidal No. 1 Mitchell; traces of oil at 2510-19; 2540-48; 3379-86; 3475-83; 3483-3542 ft; from Madera and Sandia fms

TABLE 2. TESTS CONDUCTED ON PENNSYLVANIAN SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			Torrance County (cont)	
54-4	3	--	990S 1320W sec. 5, T. 6 N., R. 7 E.	Munoz No. 1 Strong
54-5	15	--	1640N 660W sec. 23, T. 6 N., R. 7 E.	Witt No. 1 Meadows; trace of oil at 1740-62 ft in Sandia Formation
54-6	11	--	1100S 2310W sec. 12, T. 7 N., R. 7 E.	Sinoco No. 2 DeHart; trace of oil at 1165-90; 1223-40 ft in Sandia Fm
54-7	8	--	1650N 330E sec. 32, T. 7 N., R. 7 E.	Drice No. 1 Garland
55-1	9	--	550N 1050W sec. 20, T. 6 N., R. 10 E.	Randall No. 1 Estancia
			Valencia County	
66-1	162	27	NE1/4 sec. 26, T. 3 N., R. 4 E.	Madera Formation; Abo Pass

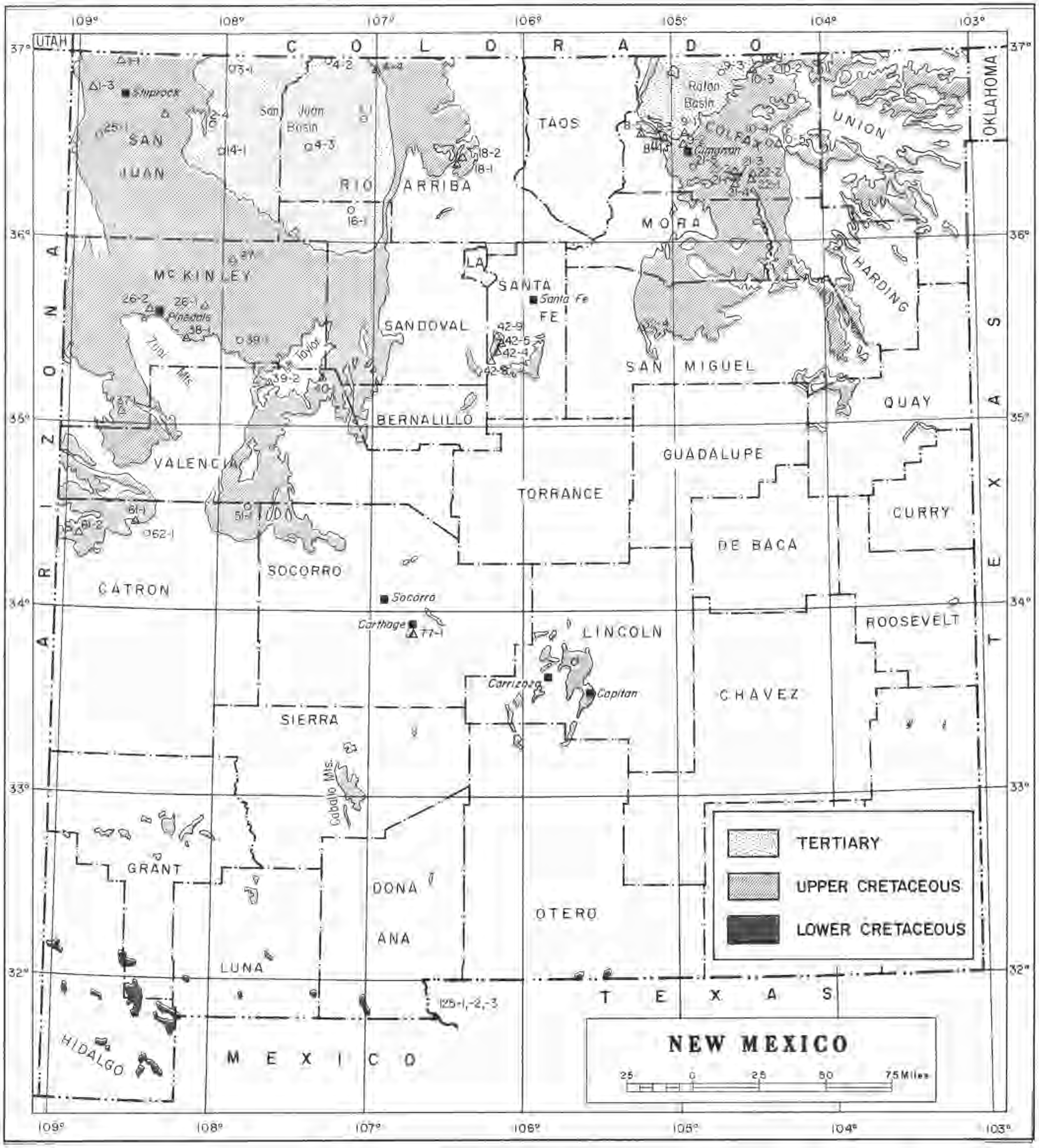

Figure 3

SAMPLE LOCALITIES AND OUTCROPS OF CRETACEOUS AND TERTIARY (RESTRICTED) ROCKS

(△ SURFACE SAMPLES, ○ WELL SAMPLES)

San Juan Basin would be virtually impossible. A continuous sequence of shades cannot be collected at any locality, and each part of the section should be sampled at several places to evaluate the potential of such a large area. Surface samples were collected from incomplete exposures of the Dakota, Mancos, Crevasse Canyon, Menefee, and Fruitland formations. These tests were negative (table 3) with the exception of a little more than 1 gallon of oil per ton of shale from the lower part of the Mancos Shale west of Shiprock (1-3). When placed in a furnace at 1800°F, shales from this locality burned for a short period of time. Qualitative tests of well cuttings from the Gulf No. 1 Blackrock Federal "C" test (14-1) in San Juan County showed fairly strong oil condensation in the lower part of the Mancos.

Surface sampling of the Cretaceous section of northeastern New Mexico has been fairly detailed with the exception of the thick Pierre—Niobrara shales. Qualitative tests were made on these formations from well cuttings. Although each part of the sequence has been tested in a vertical sense, considerable sampling of individual units over the outcrop area would be necessary to complete evaluation of the area.

Qualitative tests of well cuttings, all in Colfax County, indicated traces of oil in the Carlile and Graneros shales. From sixteen surface samples of Carlile Shale (10-5), traces of oil were obtained from two. All ten samples of Graneros Shale (22-1), tested in the Fischer retort, yielded slightly less than 1 gallon of oil per ton of shale. Although this is a negligible amount, the fact that the Graneros appears to contain some kerogen over a fairly large area suggests that additional testing of this interval is in order.

Slight amounts of oil were found in Crevasse Canyon, Gallup, and Mancos shales in the Huckleberry No. 1 Federal well (62-1) in Catron County. No traces of shale oil were observed in tests conducted on samples, through the same intervals, in the Spa.nel and Heinze No. 1-9609 test (51-1) in the eastern part of the same county. At Carthage, traces of oil were obtained from six surface samples of the Mancos Shale and from most of the seventeen samples of Mesaverde shales (77-1). The Mesaverde shales are highly carbonaceous and normally contain thin seams of coal. A sample of waste material from one of the coal mine dumps yielded 9.5 gallons of oil per ton of shale.

Based on the present data, the possibilities of finding high-yield oil shales in the Cretaceous appear remote. Additional testing should be conducted on the lower part of the Mancos Shale in the San Juan Basin and on the Graneros Shale in northeastern New Mexico. Minor amounts of oil were obtained from other parts of the Cretaceous section in these areas, but intervals were thin and do not appear to have any lateral continuity as far as oil yield is concerned. To complete testing of shales of this age, some sampling should be done of both Upper and Lower Cretaceous rocks in southern New Mexico.

TERTIARY

Rocks of Tertiary age are exposed throughout most of New Mexico, but only in the central part of the San Juan and Raton basins (fig. 3), and in small exposures in the Sierra Blanca and Caballo Mountains areas are they of interest from the standpoint of oil shale. In these areas, green, dark gray, and brown shales are interbedded with red and purple shales, gray and yellow sandstones and conglomerates, and, locally, as in the Raton Basin, coal beds.

Surface samples of probable Tertiary shales were collected in the Raton area (table 4). From twenty-three samples of the Raton Formation exposed on the east side of Maloya Dam (10-2), yields of from 4.2 to 8.6 gallons of oil per ton of shale were obtained from four samples. The shales are highly carbonaceous and contain fragments and thin seams of coal. Samples collected west of Raton (10-3) yielded only traces of oil from shales lithologically similar to those at Maloya Dam. Shales from well cuttings in the Raton Formation were tested qualitatively from one well (9-3); only minor traces of oil were observed.

Tertiary shales in the San Juan Basin were

TABLE 3. TESTS CONDUCTED ON CRETACEOUS SHALES

Section number	Qual. tests	Quant. tests	Location	Remarks
			Catron County	
51-1	215	--	550N 740W sec. 19, T. 4 N., R. 9 W.	Spanel and Heinze No. 1-9609 Santa Fe
61-1	--	1	SE1/4 sec. 30, T. 3 N., R. 16 W.	Upper part of Mesaverde Formation; trace of oil (carbonaceous)
61-2	--	1	NE1/4 sec. 15, T. 2 N., R. 20 W.	Lower Mancos Shale
62-1	101	--	330N 330E sec. 11, T. 2 N., R. 16 W.	Huckleberry No. 1 Federal; trace of oil in Crevasse Canyon, Gallup, and Mancos fms
			Colfax County	
8-3	--	10	Roadcuts U. S. 64; 4 miles east of Ute Park	Vermejo Formation
8-4	--	6	Roadcuts U. S. 64; 5 miles east of Ute Park	Pierre Shale; trace of oil in upper part
8-5	5	--	U. S. 64 N Eagle Nest Dam	Cretaceous shales
9-1	--	8	Ponil Creek; N. Mex. 204	Vermejo Formation; trace of oil (carbonaceous)
9-2	31	--	Slate Hill; Cimarron	Pierre Shale
9-3	323	--	2600N 700E sec. 26, T. 31 N., R. 21 E.	Conoco No. 2 St. Louis; trace of oil from Carlile and Graneros shales
10-4	44	--	330S 1650W sec. 35, T. 27 N., R. 24 E.	Kates and Sidwell No. 1 A Sauble; trace of oil from Carlile, Graneros, and Dakota formations
10-5	--	16	NE1/4 sec. 5, T. 26 N., R. 25 E.	Trace of oil from two samples in Carlile Shale
21-1	--	10	South of Rodeo Grounds at Springer	Ft. Hays Limestone Member of Niobrara Formation; trace of oil
21-2	--	9	1/2 mi W Springer; N.M. 199	Niobrara Formation; trace of oil
21-3	4	--	Roadcuts 1/2 mile south of Springer; U.S. 85	Ft. Hays Limestone Member of Niobrara Formation
21-4	5	--	Roadcuts 3 mi S Springer; US 85	Niobrara Formation
21-5	140	--	2740S 338W sec. 18, T. 25 N., R. 20 E.	Hedges No. 1 Mackie; trace of oil from Niobrara, Carlile, and Graneros fms

TABLE 3. TESTS CONDUCTED ON CRETACEOUS SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			Colfax County (cont)	
22-1	--	10	NW1/4 sec. 9, T. 24 N., R. 23 E.	Graneros Shale; approx 1 gal/ton throughout interval
22-2	--	10	SE1/4 sec. 4, T. 24 N., R. 23 E.	Greenhorn Limestone; trace of oil from thin beds of shale
			Dona Ana County	
125-1	6	--	SE1/4 sec. 8, T. 29 S., R. 4 E.	Lower Cretaceous; Brickland
125-2	6	1	SW1/4 sec. 9, T. 29 S., R. 4 E.	Lower Cretaceous; Brickland; trace oil
125-3	1	--	SE1/4 sec. 9, T. 29 S., R. 4 E.	Lower Cretaceous; Brickland
			McKinley County	
25-1	77	--	660N 1980E sec. 10, T. 15 N., R. 19 W.	National Minerals No. 1 Gamerco; trace of oil from thin interval in Mancos Shale
26-1	10	4	NW1/4 sec. 16, T. 16 N., R. 12 W.	Crevasse Canyon Formation; 1-10 gal/ton from carbonaceous, coaly shales
26-2	8	1	SW1/4 sec. 13, T. 16 N., R. 16 W.	Mancos Shale; Pinedale
27-1	4	2	SW1/4 sec. 6, T. 19 N., R. 10 W.	Menefee Formation 1+ gal/ton from coaly intervals
37-1	--	4	NE1/4 sec.31, T. 10 N., R. 17 W.	Mancos Shale; Horsehead Canyon
38-1	1	--	NW1/4 sec. 4, T. 14 N., R. 13 W.	Mancos Shale; Mount Powell
39-1	51	--	330S 2310E sec. 3, T. 14 N., R. 10 W.	Jenkins and McQueen No. 1 Santa Fe
			Rio Arriba County	
4-4	6	--	SW1/4 sec. 12, T. 31 N., R. 2 W.	Lewis Shale; Dulce
18-1	4	--	NW1/4 sec. 1, T. 25 N., R. 4 E.	Dakota Sandstone
18-2	8	--	SE1/4 sec. 30, T. 26 N., R. 5 E.	Mancos Shale

TABLE 3. TESTS CONDUCTED ON CRETACEOUS SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			Sandoval County	
16-1	39	--	790N 790W sec. 33, T. 23 N., R. 3 W.	Reynolds No. 1 D Jicarilla; Kirtland—Fruitland intervals; trace of oil in Fruitland Formation
			San Juan County	
1-1	--	1	11 mi N Shiprock; E side US 666	Mancos Shale; trace of oil
1-3	--	1	13 mi W Shiprock; S side NM 504	Lower Mancos Shale; 1-5 gal/ton
2-1	--	1	Navajo Coal Mine	Fruitland Formation
2-4	112	--	1650N 1650E sec. 34, T. 28 N., R. 12 W.	Benson and Montin No. 4 Gallegos: Kirtland-Fruitland-Pictured Cliffs intervals
14-1	503	--	990N 1650W sec. 21, T. 26 N., R. 11 W.	Gulf No. 1 Blackrock Federal "C"; complete Cretaceous section; traces of oil in Mesaverde Group; good in lower Mancos Shale
			San Miguel County	
32-4	12	--	Roadcuts US 85 at Romeroville	Dakota and Graneros intervals
			Santa Fe County	
42-4	1	--	1/2 mi N Madrid; E side NM 10	Mesaverde Formation
42-5	4	1	SW1/4 sec. 17, T. 14 N., R. 8 E.	Mancos Shale; Cerrillos; trace of oil
42-8	--	5	Ortiz Mts. 1 mi N junc. NM 10 and 22	Mancos Shale
42-9	--	6	SW1/4 sec. 2, T. 14 N., R. 7 E.	Mancos Shale west of Cerrillos

TABLE 3. TESTS CONDUCTED ON CRETACEOUS SHALES (cont)

Section number	Qual. tests	Quant. tests	Location	Remarks
			Socorro County	
77-1	--	23	secs. 8, 14, 15, 16, 21, 23, T. 5 S., R. 2 E.	Mancos and Mesaverde Fms, Carthage; trace of oil from Mancos and Mesaverde; 9.5 gal/ton from coal mine waste
			Valencia County	
39-2	1	--	NE1/4 sec. 33, T. 12 N., R. 8 W.	Mesaverde Formation; Mount Taylor
40-1	4	--	1.7 miles east of Cebolleta; north side of N. Mex. 334	Mancos Shale

TABLE 4. TESTS CONDUCTED ON TERTIARY SHALES

Section number	Qual. tests	Quant. tests	Location	Remarks
			Colfax County	
9-3	63	--	2600N 700E sec. 26, T. 31 N., R. 21 E.	Conoco No. 2 St. Louis; Raton Formation; trace of oil
10-2	--	23	East side of Maloya Dam	Raton Fm; 4.2-8.6 gal/ton from carbonaceous shales
10-3	--	11	Old Raton Pass Road	Raton Fm; trace of oil from carbonaceous shales
			Rio Arriba County	
4-1	141	--	330S 330E sec. 6, T. 28 N., R. 2 W.	Conoco No. 1 South Dulce; San Jose-Nacimiento formations
4-2	165	--	330S 330W sec. 14, T. 32 N., R. 5 W.	Stanolind No. 32-5 San Juan Unit
4-3	102	--	660N 1980E sec. 10, T. 26 N., R. 6 W.	Doswell No. 1 Scott-Federal; good indication at 640-50 ft
			Sandoval County	
16-1	67	--	790N 790W sec. 33, T. 23 N., R. 3 W.	Reynolds No. 1 D Jicarilla; trace of oil 1210-1460 ft from nine shale intervals
			San Juan County	
3-1	54	--	600N 1550E sec. 2, T. 31 N., R. 11 W.	Standard of Texas No. 1 State

examined qualitatively using oil well cuttings from five widely spaced wells. A good indication of oil was noted from a thin interval in the Doswell No. 1 Scott—Federal test in Rio Arriba County (4-3) and very slight traces of oil from a fairly thick sequence in the Reynolds No. 1 D Jicarilla well (16-1) in Sandoval County.

Based on present testing, the possibilities of finding appreciable amounts of oil shale in the Tertiary section do not appear good. Surface testing in areas near the qualitative indications from well cuttings is necessary. Tertiary sequences containing gray shales east of Carrizozo and near Elephant Butte have not been tested but do not appear promising because of the thin shale intervals and interbedded sandstones and conglomerates.

References

Guthrie, Boyd, and Klosky, Simon (1951) The oil-shale industries of Europe, U. S. Bur. Mines, Rpt. Inv. 4776.

Kraemer, A. J. (1950) Oil shale in Brazil, U. S. Bur. Mines, Rpt. Inv. 4655.

----, and Thorne, H. M. (1951) Oil-shale operations in New South Wales, Australia, U. S. Bur. Mines, Rpt. Inv. 4796.

Jaff, F. C. (1963) Oil shale: nomenclature, uses, reserves, and production, Colo. School Mines Research Foundation, Mineral Industries Bull. , v. 5, n. 2, pt. 1.

Stanfield, K. E. , and Frost, I. C. (1949) Method of assaying oil shale by a modified Fischer retort, U. S. Bur. Mines, Rpt. Inv. 4477.

Thorne, H. M. , and Kraemer, A. J. (1954) Oil-shale operations in the Union of South Africa, October 1947, U. S. Bur. Mines, Rpt. Inv. 5019.

Winchester, D. E. (1923) Oil shale of the Rocky Mountain region, U. S. Geol. Surv. , Bull. 729.

---- (1933) The oil and gas resources of New Mexico, N. Mex. Inst. Min. and Tech. State Bur. Mines and Mineral Res. , Bull. 9.