768

U. S. GEOLOGICAL SURVEY
Field Library
Albuquerque, New Mexico

TEI-768
OPEN FILE

A summary of the geology of sedimentary basins of the United States, with reference to the disposal of radioactive wastes

By J. D. Love and Linn Hoover

Trace Elements Investigations Report 768

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

metadc304691

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A SUMMARY OF THE GEOLOGY OF SEDIMENTARY BASINS OF THE
UNITED STATES, WITH REFERENCE TO THE DISPOSAL OF
RADIOACTIVE WASTES*

By

J. D. Love and Linn Hoover

May 1960

Trace Elements Investigations Report 768

This report is preliminary
and has not been edited for
conformity with Geological
Survey format and nomenclature.

*Prepared on behalf of the
U. S. Atomic Energy Commission.

CONTENTS

	Page
Introduction-----	2
Atlantic Coastal Plain (1)-----	4
Eastern Triassic Basins (2)-----	4
Appalachian Basin (3)-----	5
Gulf Coastal Plain (4)-----	6
Florida (4a)-----	7
Alabama (4b)-----	7
Mississippi (4c)-----	8
Desha Basin, Arkansas-Mississippi (4d)-----	9
Louisiana (4e)-----	9
Tyler Basin, Texas (4f)-----	11
Texas Gulf Coast (4g)-----	12
Michigan Basin (5)-----	13
Illinois Basin (6)-----	14
Forest City Basin, Iowa-Missouri (7)-----	15
Salina Basin, Kansas-Nebraska (8)-----	15
McAlester-Arkansas Basin, Arkansas-Oklahoma (9)-----	15
Anadarko Basin, Oklahoma (10)-----	16
Ft. Worth Basin, Texas (11)-----	17
Val Verde Basin, Texas (12)-----	17
Midland Basin, Texas (13)-----	17
Delaware Basin, New Mexico-Texas (14)-----	18
Palo Duro Basin, Texas (15)-----	18
Dalhart Basin, Texas (16)-----	19

	Page
Denver Basin, Colorado (17)-----	19
Powder River Basin, Wyoming (18)-----	19
Williston Basin, North Dakota (19)-----	20
Rio Grande Basins, New Mexico (20)-----	22
Southwestern New Mexico (21)-----	23
San Juan Basin, Colorado-New Mexico (22)-----	23
Black Mesa Basin, Arizona (23)-----	24
Kaiparowits Basin, Utah (24)-----	25
San Luis Basin, Colorado-New Mexico (25)-----	25
Paradox Basin, Utah-Colorado (26)-----	25
Piceance Basin, Colorado (27)-----	26
Uinta Basin, Utah (28)-----	27
North and Middle Parks, Colorado (29)-----	29
Laramie Basin, Wyoming (30)-----	30
Hanna Basin, Wyoming (31)-----	30
Washakie Basin-Sand Wash Basin area, Colorado-Wyoming(32)	31
Red Desert Basin, Wyoming (33)-----	33
Green River Basin, Wyoming (34)-----	35
Jackson Hole, Wyoming (35)-----	37
Wind River Basin, Wyoming (36)-----	38
Bighorn Basin, Montana (37)-----	39
Crazy Mountains syncline, Montana (38)-----	40
Western Montana (39)-----	41
SNAKE RIVER downwarp, Idaho-Oregon (40)-----	41
Salt Lake-Utah Lake area, Utah (41)-----	42

	Page
West-central Utah (42)-----	43
Southwestern Utah (43)-----	45
Elko-Humboldt area, Nevada (44)-----	46
Carson-Black Rock area, Nevada (45)-----	47
Muddy Creek Mountains, Nevada (46)-----	48
East-central California (47)-----	48
Mojave Desert, California (48)-----	49
San Joaquin Valley, California (49)-----	49
Sacramento Valley, California (50)-----	50
Harney Basin, Oregon (51)-----	51
Central Oregon (52)-----	51
Western Oregon (53)-----	52
Central Washington (54)-----	52
Western Washington (55)-----	53
Selected references-----	54
Index to references-----	86

ILLUSTRATION

Figure 1. Sedimentary basins of the United States

and map index----- in envelope

A SUMMARY OF THE GEOLOGY OF THE SEDIMENTARY BASINS
OF THE UNITED STATES WITH REFERENCE TO THE DISPOSAL
OF RADIOACTIVE WASTES

By

J. D. Love and Linn Hoover

ABSTRACT

A possible method of disposing of liquid radioactive wastes that result from the production of atomic energy is to inject them through wells into subsurface rock units in various sedimentary basins. To insure that this method of disposal is not hazardous, the physical characteristics of the proposed storage basins must be determined. Approximately 60 separate areas in the United States are considered as potential waste disposal sites, and their location, gross geologic features, and natural resources are summarized.

INTRODUCTION

In the production of atomic energy waste liquids with various levels of radioactivity are produced. In general terms, the level of radioactivity is referred to as low, intermediate, or high. Thus far, the high-level wastes have not been released to a natural environment but have been stored in steel tanks. Because these wastes will remain radioactive for several hundred years, this type of storage is regarded only as an interim measure, pending a solution for their ultimate disposal. Also, as the future demand for atomic energy increases, a larger quantity of high-level waste will be created than is feasible or desirable to retain in tank storage. One possible procedure being considered for future disposal of high-level and other

liquid wastes is to inject them through wells into rock units in the subsurface in various sedimentary basins. However, as a first step in considering this method, it is necessary to determine the physical characteristics of the proposed storage basins, because the radioactive wastes must be disposed of in such a manner that they cannot contaminate underground natural resources or cannot otherwise come into contact with the human environment for a period measured in hundreds of years. For each sedimentary basin the characteristics that should be determined include its depth and areal extent, the thickness, lithology, and geologic structure of the rock units therein, the nature and extent of its natural resources, such as coal, oil and gas, ground water, and mineral deposits of present or potential value, and the pattern of land utilization within the basin.

The U. S. Geological Survey, on behalf of the Division of Reactor Development, U. S. Atomic Energy Commission, has begun a study of sedimentary basins as an aid in appraising their potential for radioactive waste storage. This report summarizes the location, gross geologic features, and natural resources of the major sedimentary basins in the United States, excluding Alaska and Hawaii. It is not intended that this general summary will be sufficient for an appraisal of the deep-well disposal possibilities of individual basins, but it should assist in selecting basins for the additional detailed studies that are to follow.

The sources of information for this report are articles in scientific journals, reports published by the U. S. Geological Survey and other Federal and State government agencies, and data collected by the Geological Survey.

The location of the basins discussed in this report are shown on plate 1.

Atlantic Coastal Plain (1)

The Atlantic Coastal Plain extends southward from Cape Cod, Mass., to Florida and is bordered on the west by crystalline rocks of the Piedmont region. The stratigraphy and structure of this region is poorly known and, as far as is now known, the base of the Cretaceous-Tertiary sequence, which in most parts of the coastal plain is the base of the sedimentary section, does not exceed a depth of 10,000 feet except in the area offshore from Cape Hatteras, N. C. The Standard Oil Company of New Jersey drilled a test well in Dare County, adjacent to Cape Hatteras, that bottomed in basement rocks at a depth of 10,054 feet. The well penetrated Tertiary, Upper Cretaceous, and Jurassic strata. Seismic data also indicate that basement rocks are below 10,000 feet 50 miles oceanward from the coast of Virginia and 10 miles east of the coast of Maryland.

Eastern Triassic Basins (2)

The eastern Triassic Basins are present discontinuously along the east margin of the United States northeastward from South Carolina to Connecticut. From southwest to northeast, the principal basins are the Deep River, Dan River, Richmond, Culpepper, Gettysburg, Newark, and Connecticut Basins. The Newark and Connecticut Basins are the largest.

The rocks in these depressions are chiefly red sandstone, siltstone, and shale, with conglomerate locally present near the basin margins. The sedimentary rocks are interbedded with many flows or sills of igneous rock and are cut by basalt dikes. Apparently sedimentation occurred in northeast-trending fault troughs that continued to sink as the sediments were

deposited. In Connecticut the Triassic rocks have an estimated thickness of 10,000 to 13,000 feet and in New Jersey they may be more than 20,000 feet thick.

Because the Triassic strata occur in elongate troughs bounded by faults on one or both of the longer sides, they are of moderate interest as reservoirs for liquid radioactive wastes. However, the strata are not homogeneous because of the abundance of basic igneous rocks. In addition, the deepest basins are in areas with dense population (400 to 600 people per square mile) and extensive industrial development.

Appalachian Basin (3)

The Appalachian Basin, which has a surface area of more than 225,000 square miles, has many thick sequences of sedimentary rocks. For example, Cambrian, Ordovician, and Silurian rocks have a combined thickness ranging from 5,000 to 19,000 feet, with the maximum thickness in south-central Pennsylvania and parts of Maryland, Virginia, and West Virginia. Most of these rocks are conglomerate, sandstone, and shale, but significant thicknesses of limestone and dolomite are present in central and southern Pennsylvania, and this carbonate sequence extends southwestward to Alabama. As much as 11,000 feet of Devonian rocks, chiefly sandstone with some shale and mudrock, is present in the central Appalachian Mountains, with the area of greatest thickness in northeastern Pennsylvania. Mississippian rocks, which attain a maximum thickness of 5,000 feet, are predominantly sandstone and shale, but in southern Virginia the middle part of the sequence contains as much as 4,000 feet of limestone. Pennsylvanian rocks in the Appalachian region range in thickness from 1,000 to 12,000 feet,

with the thickest sections in Alabama. These rocks are essentially all clastic.

Tight folds, thrust faults, and normal faults are common throughout the Appalachian region. Facies changes throughout thick sequences of rock occur in short distances and unconformities are numerous. Stratigraphic and structural interpretations that involve great thicknesses of rock and major facies changes are therefore matters of disagreement among many workers.

There are many synclinal areas where both carbonate and silicate rocks are buried at depths greater than 10,000 feet. About 6,000 feet of Cambrian and Ordovician rocks lies below this depth in northwestern Pennsylvania.

The density of population in the Appalachian Basin ranges from 39 to 299 per square mile and averages 122 (1950 Census). The region contains one of the greatest concentrations of both heavy and light industry in the United States, but also has extensive areas of little industrial development.

Gulf Coastal Plain (4)

The Gulf Coastal Plain is so vast an area, extending from Florida westward to Texas, that its geology is best summarized by separate sub-provinces, as follows:

Florida (4a)

Alabama (4b)

Mississippi (4c)

Desha Basin, Arkansas-Mississippi (4d)

Louisiana (4e)

Tyler Basin (4f)

Texas Gulf Coast (4g)

Florida (4a)

Sedimentary rocks are present at depths greater than 10,000 feet in the southern and western parts of Florida. More than 35 wells have been drilled to depths of more than 10,000 feet; one well in the southern tip of Florida bottomed in Lower Cretaceous rocks at 15,455 feet. In the southern part of the peninsula there is nearly 15,000 feet of limestone and dolomite with lesser amounts of gypsum and anhydrite. More clastic rocks are present in the panhandle area of Florida, where the deepest test well is 12,515 feet deep.

The surface geology of Florida is relatively simple. Both surface and subsurface structure are uncomplicated, with only slight folding and a minor amount of faulting.

Alabama (4b)

The surface geology of southern Alabama is relatively simple but the subsurface stratigraphy and structure are somewhat more complicated. As of 1956, 11 wells had been drilled to depths greater than 10,000 feet, the deepest of which bottomed in Jurassic rocks at 15,729 feet. All the deep tests are in southwestern Alabama. Six wells bottomed in Lower Cretaceous rocks and five in Jurassic rocks. The character and thickness of the underlying rocks are not known. In the Citronelle oil field, 2,000 feet or more of Lower Cretaceous rocks are at depths below 10,000 feet. The basement rocks are at depths greater than 15,000 feet in southern Alabama. They are overlain by at least 3,000 feet of Upper Jurassic rocks, a maximum

of 7,000 feet of Lower Cretaceous rocks, 3,000 feet of Upper Cretaceous, and a maximum thickness of 6,000 feet of Cenozoic rocks. The strata thicken southward and change in facies from predominantly intertongued sandstone and shale to intertongued shale and limestone of marine origin.

The proximity of the area of thickest stratigraphic section to Mobile² and other large towns and industrial establishments, the variability of the known stratigraphic units, the incomplete knowledge of pre-Cretaceous formations, and the abundance of underground water will pose problems in the subsurface disposal of radioactive waste.

Mississippi (4c)

The southern part of Mississippi is underlain by more than 10,000 feet of sedimentary rocks and the total thickness may be more than 30,000 feet in the southwestern part of the State. The surface geology is relatively simple but the subsurface stratigraphy and structure are more complex. In the southern part of Mississippi, several thousand feet of Lower Cretaceous and Jurassic rocks are below 10,000 feet. The Lower Cretaceous strata are chiefly intertonguing lenticular shale and siltstone, with some sandstone. To the south they become more limy and grade into limestone. The known thickness of these carbonate rocks is 7,000 feet or more. A test well in Stone County, near the coast, is reported to have bottomed in Upper Jurassic rocks at a depth of 20,450 feet. The thickness of Jurassic rocks is not known, but it is probably more than 3,000 feet. Paleozoic limestone is reported to occur below 10,000 feet east of Jackson, Miss., but the total thickness of this carbonate sequence and the nature of the underlying rocks are not known. Nearly 50 salt domes have been recognized in Mississippi.

The lack of detailed stratigraphic data on the deeper part of the section in southern Mississippi, the poorly consolidated strata in the upper part of the section, the abundance of underground water, the density of population, and the numerous oil and gas fields and industrial establishments are factors unfavorably affecting the possibilities for radioactive waste disposal.

Desha Basin, Arkansas-Mississippi (4d)

The Desha Basin is an area of downwarped Mesozoic and Paleozoic rocks that are concealed beneath Tertiary sediments of the Mississippi embayment of the Gulf Coastal Plain. Few wells have been drilled in the basin and descriptions in the literature are inadequate to provide a clear understanding of its geology.

Louisiana (4e)

The surface strata in Louisiana are all of Cenozoic age and commonly have gentle dips southward toward the Gulf of Mexico. Much of the State is underlain by more than 10,000 feet of strata of many types and many ages. In fact, it is thought that the depth to basement rocks exceeds 10,000 feet throughout the State. In the northern part the most important sedimentary rock sequence is of Jurassic age and is at least 5,000 feet thick. Older strata are less well known. Jurassic and younger rocks are at greater depths toward the south.

In northern Louisiana three formations of Jurassic age and one formation of Permian(?) age are of some interest in the present study. The uppermost of these, the Schuler formation, 1,500 to 2,500 feet thick, consists of variegated shale and sandstone that grade southward into gray

shale, limestone, and sandstone. Stratigraphically below this sequence is the Bossier formation, 500 to 2,000 feet thick, consisting of marine gray shale and sandstone. Below the Bossier is the Smackover formation, 1,200 feet or more in thickness. This is an oolitic to dense limestone with minor amounts of shale and sandstone. Below the Jurassic section is the poorly known Eagle Mills formation of Permian(?) age, which consists of 1,200 feet or more of red shale, sandstone, and salt. Twenty-five salt domes are known in northern Louisiana. The deepest well in northern Louisiana, in the Cotton Valley field, bottomed in salt at a total depth of 14,967 feet.

In the southern part of Louisiana many wells have been drilled to depths greater than 16,000 feet. A well drilled by Richardson and Bass in Plaquemines Parish, southeast of New Orleans, bottomed in Miocene rocks at a total depth of 22,570 feet. The amount of stratigraphic section below this depth is not known, but probably the total thickness above basement rock is in excess of 30,000 feet. In central and southern Louisiana there are at least 7,000 feet of Lower Cretaceous, 3,000 feet of Upper Cretaceous, and 20,000 feet or more of Cenozoic rocks, essentially all of which are marine. The depth to salt in southern Louisiana may be 25,000 to 45,000 feet.

The most homogeneous and continuous sequences more than 1,000 feet thick are of latest Cretaceous, Paleocene, and Eocene ages and consist of shale interbedded with some sandstone. Oligocene, Miocene, and younger strata are composed chiefly of complexly intertongued lenticular sandstone

and shale with minor amounts of limestone in central Louisiana. These beds of limestone increase in number and thickness in the southern part of the State.

The coastal area of Louisiana is cut by 93 known salt domes. Except in the vicinity of salt domes, the structure of Louisiana is relatively simple. The gentle southward monoclinial dip is interrupted by minor gentle folds and faults with small amounts of displacement. Fold and fault traps, stratigraphic traps, and traps associated with salt domes have yielded large quantities of oil and gas.

Some of the Upper Cretaceous, Paleocene, and Eocene shales are thick enough and have adequate cover for waste disposal. However, the abundance of oil and gas fields, the density of population and industrial establishments, the poorly consolidated nature of strata above 10,000 feet, particularly in the Gulf Coast area, the abundance of underground water, and the fact that this may not be a completely closed hydrodynamic system in an oceanward direction make this area of less interest for waste disposal than many other areas.

Tyler Basin, Texas (4f)

The Tyler (East Texas) Basin is located on the Gulf Coastal Plain in northeastern Texas and is a structural downwarp area containing a thick sequence of Cretaceous and Tertiary rocks. The surface geology of the basin is relatively uncomplicated. In the deeper part of the basin, the maximum thickness of Tertiary rocks is more than 5,000 feet and of Cretaceous rocks, about 11,000 feet. A large area contains Jurassic rocks at depths of more than 10,000 feet. All of the Jurassic formations vary greatly in thickness and lithology.

From 10,000 to 20,000 feet of Lower Pennsylvanian rocks is reported to be present in parts of the Tyler Basin, but these rocks have not been reached in drilling in the deepest part of the basin so their thickness and lithology are not known.

Twenty salt domes are known in the Tyler Basin. Some have oil and gas around the margins. A large number of major oil and gas fields unrelated to salt domes also are present in this basin.

Texas Gulf Coast (4g)

A thick sequence of Tertiary, Cretaceous, and older sedimentary rocks is present in the Texas Gulf Coast area. One estimate shows 25,000 feet or more of Cretaceous and Tertiary rocks, but this may be conservative as another shows 12,000 feet of Paleocene and Eocene rocks alone. The deepest well along the Texas Gulf Coast bottomed in Eocene rocks at a depth of 19,056 feet.

Cretaceous rocks have not been drilled near the coast. Probably they lie below 20,000 feet and are several thousand feet thick. Upper Cretaceous rocks are thought to be 4,000 to 6,000 feet thick in this area and Cenozoic rocks to be 15,000 to 20,000 feet thick.

The structure in the Texas Gulf Coast area, except in the vicinity of salt domes, is relatively simple, consisting of gentle folds and some faults. In general, the dips are toward the Gulf. Fifty-six salt domes are known in the coastal area and there are 38 similar domes in which salt has not yet been found. Farther west, in the Rio Grande salt basin, six salt domes are known. The top of the parent salt bed near Galveston is estimated to be at a depth of nearly 40,000 feet and is probably of Jurassic age.

The Texas Gulf Coast area has one of the greatest concentrations of oil and gas fields in the United States. Many of its large cities and industrial establishments are dependent on the petroleum industry.

Michigan Basin (5)

The rocks in the Michigan Basin occupy a volume of about 108,000 cubic miles and consist of about 47 percent carbonate rocks, 23 percent sandstone, 18 percent shale, and 13 percent evaporite rocks. The basal part of the Paleozoic sequence, of Cambrian age, is composed of as much as 3,000 feet of quartz sandstone with some dolomite. These rocks, which locally are important aquifers, are overlain by about 10,000 feet of sediments that range in age from Early Ordovician to Middle Devonian and consist of limestone, dolomite, anhydrite, gypsum, and salt. The greater part of the salt deposits of the Michigan Basin occur in the Salina formation, of Silurian age; near the center of the basin this formation is about 3,200 feet thick. Upper Devonian and Mississippian strata in the Michigan Basin are about 2,500 feet thick and are composed mainly of shale, siltstone, and sandstone, but they also include some evaporite and carbonate rocks. In the central part of the basin the Paleozoic sequence also includes up to 1,100 feet of rocks of Pennsylvanian and Permian(?) age, consisting of alternating beds of sandstone, siltstone, and shale, and some coal, limestone, and gypsum.

In 1950 the population of Michigan averaged more than 100 people per square mile, but the deepest part of the basin underlies one of the more sparsely populated areas. Adjacent large cities, however, include Detroit, Flint, Lansing, Saginaw, and Grand Rapids. Oil and gas are produced from many fields overlying the deeper part of the basin.

Illinois Basin (6)

Most of the sedimentary formations that fill the Illinois Basin increase in thickness toward the center. These rock units represent every Paleozoic period except the Permian and have a total thickness in excess of 12,500 feet. About 2,200 feet of arkosic and quartzitic sandstone of Cambrian age overlies the basement rocks and is succeeded by 3,000 feet of Upper Cambrian and Ordovician sediments, consisting of about 50 percent limestone and dolomite and 50 percent sandstone and shale. About 1,100 feet of limestone and dolomite forms the Silurian section, but the Devonian period is represented by less than 400 feet of limestone and shale. The lower part of the Mississippian section is predominantly limestone with a thin sequence of shale at the base, and the upper part consists of 1,000 to 1,400 feet of alternately deposited sandstone and limestone. Rocks of Pennsylvanian age have a thickness of slightly more than 2,000 feet and are composed of sandstone and shale with numerous coal beds and a few thin beds of calcareous rocks.

Numerous unconformities are present in the Illinois Basin. Drill holes have revealed a number of folds within the basin, one of which, the LaSalle anticline, has sufficient structural relief to divide the northern part of the basin into two separate lobes. Intrusive igneous rocks occur locally along the faulted south margin of the basin.

For many years the rocks in the Illinois Basin have produced substantial quantities of coal, oil, and gas. Petroleum has been obtained from rocks of Ordovician, Devonian, and Mississippian ages, and the Pennsylvanian rocks contain many thick beds of bituminous coal.

Forest City Basin, Iowa-Missouri (7)

The Forest City Basin covers an area surrounding the corners of Kansas, Nebraska, Iowa, and Missouri. It is a shallow basin, with depths of only about 3,000 feet to the top of the Arbuckle limestone of Cambrian and Ordovician age. This limestone unit has a maximum thickness of about 1,000 feet and is overlain by a fairly complete but thin sequence of Paleozoic rocks of Ordovician to Pennsylvanian age. Dips into the basin are gentle from the north, east, and south; the west side is downfaulted against granite of Precambrian age. A few small oil fields are present in the basin.

Salina Basin, Kansas-Nebraska (8)

The Salina Basin in Kansas and Nebraska is a broad shallow basin, which has a maximum depth of about 4,000 feet. Thin sequences of rocks of Cambrian to Mississippian age are overlain by about 2,000 feet of Pennsylvanian and 1,500 feet of Permian rocks. The Pennsylvanian and Permian rocks consist of many lithologic types which are characteristically thin and widespread.

McAlester-Arkansas Basin, Arkansas-Oklahoma (9)

The McAlester-Arkansas Basin, a relatively long and deep trough, lies on the north side of the Ouachita thrust belt. For a distance of more than 100 miles in an east-west direction the top of the Arbuckle-Ellenburger sequence, of Cambrian and Ordovician age, is at a depth of more than 10,000 feet and may be 3,000 to 5,000 feet thick. Some 10,000 to 20,000 feet of Lower Pennsylvanian rocks are present in this area. The McAlester-Arkansas Basin contains many coal and gas fields.

Anadarko Basin, Oklahoma (10)

The Anadarko Basin extends northwestward through southwestern Oklahoma and into north Texas. The basin is broad and deep. It is estimated that the Arbuckle-Ellenburger carbonate sequence of Cambrian and Ordovician age lies below 10,000 feet in an area of more than 10,000 square miles and below 20,000 feet in an area of 1,500 square miles. This sequence ranges in thickness from 2,000 feet in the northwestern part of the basin to 6,000 feet in the southeastern part. The sequence has been divided into nine formations. Limestone predominates in the upper part and cherty dolomite in the lower. There is a little sandstone or shale.

Pre-Arbuckle rocks are not of interest in the present study but some younger units have sufficient thickness and depth to deserve attention. Several thousand feet of black shale of Mississippian age and shale, limestone, and sandstone of Pennsylvanian age are present below a depth of 10,000 feet. Up to 1956, ten wells had been drilled below 15,000 feet in the basin, and on the basis of data from these wells and subsequent tests, fairly accurate estimates on the depth and structure of the lower part of the section can be made. The deepest test wells in Oklahoma are in the Anadarko Basin. A well in Grady County encountered Mississippian rocks at a depth of 18,158 feet and a deep test in Caddo County bottomed in the limestone of Mississippian age at 20,426 feet.

Southeastward from the town of Anadarko there are many oil and gas fields. Most of the remainder of the basin is fairly shallow but has a relatively sparse population.

Ft. Worth Basin, Texas (11)

The Ft. Worth Basin in north Texas plunges southeastward beneath the cities of Ft. Worth and Dallas. Flat-lying rocks of Cretaceous age are at the surface and the basin is developed in strata of Paleozoic age. The Arbuckle limestone of Cambrian and Ordovician age, the oldest known sedimentary formation, is overlain by a thin sequence of lower Paleozoic rocks. Above these strata is a wedge of sandstone and shale of Late Mississippian and Early Pennsylvanian age, which thickens southeastward at least 8,000 feet. There has been little deep drilling in the Ft. Worth Basin. The rocks drilled to date are characterized by low permeability.

Val Verde Basin, Texas (12)

The Val Verde Basin is a narrow basin that trends east-west for about 100 miles in southwest Texas. Beneath a thin cover of Cretaceous rocks is a thick sequence of lower Paleozoic dark shale with thin impure sandstone beds. Few deep wells have been drilled and the geology is little known. The region is sparsely settled and the principal industry is ranching.

Midland Basin, Texas (13)

The Midland Basin is located in northwestern Texas and consists of a faulted downwarp elongated in a northwesterly direction. A large part of the Midland Basin contains sedimentary rocks at depths of 10,000 to 15,000 feet or more.

Many oil and gas fields and many large cities and industrial establishments are in the Midland Basin, which will present problems in radioactive waste disposal. The area is largely dependent on underground water for domestic and industrial purposes.

Delaware Basin, New Mexico-Texas (14)

The Delaware Basin is a deep elongate basin extending from southeastern New Mexico into west Texas. The sedimentary section is at least 20,000 feet thick in the deeper part of the basin and consists of sandstone, shale, limestone, and dolomite that range in age from Cambrian to Permian. Much of this sequence lies more than 10,000 feet below the surface. The southwest and northeast sides of the basin are structurally complex.

Within the New Mexico part of the Delaware Basin is a gray shale sequence of Pennsylvanian(?) and Mississippian age that is more than 1,000 feet thick and relatively homogeneous. The stratigraphy of this sequence is imperfectly known. The shale may underlie a thousand square miles or more of the New Mexico part of the basin at a depth of more than 10,000 feet. In much of this area, oil and gas fields are abundant. Oil fields also are present in the Texas part of the basin.

Palo Duro Basin, Texas (15)

The Palo Duro Basin of the Panhandle of west Texas is about 100 miles long and 75 miles wide and has a maximum depth of about 10,000 feet. Thin Tertiary and Cretaceous sediments are the surface rocks. Beneath them lies about 2,000 feet of alternating strata of sandstone, shale, anhydrite, and salt of Triassic and Late Permian age. These in turn are underlain by strata of earlier Permian, Pennsylvanian, and Mississippian age, consisting mostly of limestone and dolomite with some shale and evaporite rocks. Few deep wells have been drilled and these have yielded only minor shows of oil and gas. The area is generally sparsely settled and the chief industries are ranching and farming on land irrigated by water from shallow aquifers.

Dalhart Basin, Texas (16)

The Dalhart Basin underlies the northwest corner of the Texas Panhandle. It is generally less than 10,000 feet deep and beneath a thin Tertiary caprock is underlain by clastic rocks of Pennsylvanian and Permian age. Red beds and arkosic sandstone are present in the western part and interfinger eastward into dark shale and sandstone. The geology of the basin is incompletely known. It is a sparsely populated area of ranching and irrigated farming.

Denver Basin, Colorado (17)

The Denver Basin is a structural downwarp that trends in a northerly direction east of the Colorado Front Range. In the vicinity of Denver the floor of the basin is at a depth greater than 10,000 feet. Paleozoic rocks generally are only several thousand feet thick and Triassic and Jurassic rocks may be less thick. Beds of Cretaceous age, however, are well over 5,000 feet thick and in places approach a thickness of 10,000 feet. The basin is very large and has a wide diversity of geological, population, and industrial aspects which would require detailed study should it be considered for waste disposal.

Powder River Basin, Wyoming (18)

The Powder River Basin, in northeastern Wyoming, is the largest structural basin in the State, but it is by no means the deepest. Both the stratigraphy and structural geology of the basin are moderately well known because deep oil tests provide important subsurface data.

The basin contains a shale sequence known as the Cody shale in the western part and the Pierre shale in the eastern part. The lower 2,000 to

3,000 feet of shale is largely devoid of sandstone, whereas the upper part contains lenticular beds of sandstone that pinch out into the main mass of shale to the east and south. The most uniform part of the shale averages about 3,000 feet in thickness; it is soft, gray, and marine, moderately calcareous in the lower 1,000 feet and less so higher up. An argillaceous limestone and limy shale is present near the middle of the shale sequence in the northeastern part of the basin.

In the deepest part of the Powder River Basin, about 30 miles north-east of Casper, is a northwestward-trending elliptical area of about 175 square miles in which the top of the Cody shale is at a depth greater than 10,000 feet. The shale is about 3,000 feet thick and is relatively homogeneous except for two interbedded sandstone units. These range in thickness from 0 to 200 feet, are about 400 feet apart, and occur in the upper middle part of the Cody shale.

There are no towns or oil and gas fields within the deepest part of the Powder River Basin. However, the Salt Creek oil field, the largest in Wyoming, is 15 miles to the west, and about equally distant to the southwest are 5 other major oil fields. Casper, a town of about 20,000 people, is 30 miles to the southwest.

Williston Basin, North Dakota (19)

The Williston Basin is a saucer-shaped structure in western North Dakota and adjacent parts of Montana and Saskatchewan. It contains a maximum of about 17,000 feet of sedimentary rocks. Many wells have been drilled for oil and gas in the basin so the subsurface stratigraphy is moderately well known.

About 400 feet of Cambrian rocks consist of sandstone, shale, and limestone. Rocks of Ordovician age, which attain a thickness of about 1,000 feet, consist primarily of limestone and dolomite, with a basal 80- to 200-foot thick section of sandstone and shale. Silurian rocks are represented by a dolomite 800 to 1,000 feet thick in the central part of the basin. This is a moderately homogeneous sequence with only thin stringers of variegated shale and sandstone at the base. Strata of Devonian age have a thickness of 1,400 to 1,800 feet in the deepest part of the Williston Basin. They comprise a variable sequence of dolomite, limestone, shale, salt, and anhydrite. Many formation names have been applied to individual lithologic units. The thickest of the Devonian formations consists of 650 feet of salt with minor amounts of dolomite and anhydrite. Overlying it are several carbonate formations with variable lithology and a thickness of less than 1,000 feet. Mississippian rocks have a maximum thickness of 2,500 feet. About 1,300 feet of limestone is at the base of the Mississippian section. A unit composed predominantly of sandstone represents the Pennsylvanian.

Rocks of Mesozoic age include Triassic and Jurassic shale and sandstone in the central part of the basin, and overlapping sandstone, shale, chalk, and coal-bearing rocks of Cretaceous age. Most of the Cretaceous rocks are marine shale.

Rio Grande Basins, New Mexico (20)

The Rio Grande Basins are structural downwarps along and near the valley of the Rio Grande in central and southern New Mexico. They include the Tularosa, Jornada del Muerto, Caballo, San Marcial, Albuquerque, Acoma, Estancia, and Santa Fe Basins. The maximum thickness of pre-Cenozoic rocks in the Estancia Basin is thought to be 2,500 feet (Pennsylvanian to Permian); in the Tularosa Basin 6,000 feet (Cambrian to Permian); and in the Jornada del Muerto 8,000 feet (Cambrian to Cretaceous). The section of sedimentary rocks in the San Marcial, Caballo, and Albuquerque Basins is presumed to be considerably greater, but little specific information on the section below a depth of 10,000 feet has been obtained by drilling. A test well in the Albuquerque Basin, 30 miles southwest of Albuquerque, was drilled to a depth of 12,691 feet and was in Cretaceous rocks at the bottom of the hole. Other parts of this basin are thought to contain greater thicknesses of sedimentary rocks. Their character and structure, however, can only be inferred. About 2,500 to 3,500 feet of Paleozoic rocks, consisting of sandstone, shale, and carbonate rocks, and 2,000 to 4,000 feet of Cretaceous rocks is reported to be in the area directly east of this basin.

The Santa Fe Basin is long and narrow, and the subsurface stratigraphy and structure are little known. The basin is occupied by the city of Santa Fe.

The sedimentary rocks in the Tularosa Basin are somewhat more than 10,000 feet thick.

Southwestern New Mexico (21)

The basins in southwestern New Mexico are thought to be small, shallow, and complex and to contain only a thin sequence of sedimentary rocks. However, approximately 20,000 feet of Lower Cretaceous rocks has been reported in the southwest corner of New Mexico. These rocks are involved in a very complex structure and are cut by many intrusives.

San Juan Basin, Colorado-New Mexico^{1/} (22)

A 20,000-square-mile area in northwestern New Mexico and adjacent Colorado is the site of the San Juan Basin, a structural depression that locally contains more than 13,000 feet of sedimentary rocks. The basin is bounded on the north by the San Juan upwarp, on the east by the Nacimiento uplift, by the Zuni upwarp to the south, and the Defiance upwarp to the west.

The basal 5,000 to 6,000 feet of strata in the San Juan Basin are of Paleozoic age, and nearly all of this thickness was deposited in Pennsylvanian and Permian time. Rocks of Cambrian age, present only in the northwestern part of the basin, are about 250 feet thick and consist of well-cemented sandstone, limestone, and dolomite. They are succeeded by sandstone and sandy dolomite of Devonian age and then by 100 to 200 feet of carbonate rocks of Mississippian age. Limestone, evaporite rocks, and red siltstone comprise the Pennsylvanian section, which has a maximum thickness of more than 3,000 feet. The Permian rocks, locally more than 2,000 feet thick, consist principally of fine-grained sandstone and siltstone.

^{1/} Repenning, C. A., 1959, Geologic summary of the San Juan Basin, New Mexico, with reference to disposal of liquid radioactive waste: U. S. Geol. Survey open file report TEI-603, 57 p., 18 figs.

Between 7,000 and 8,000 feet of Mesozoic rocks are present in the San Juan Basin, including as much as 1,700 feet of Triassic strata, 1,000 to 1,200 feet of Jurassic rocks, and up to 6,000 feet of beds of Cretaceous age. The Mesozoic section, of which nearly half is sandstone, includes both continental and marine deposits. Limestone and evaporite rocks are rare. The San Juan Basin also contains as much as 2,000 feet of Cenozoic rocks (Paleocene and Eocene), composed of continental mudstone, claystone, and some sandstone.

Structurally the San Juan Basin is an ovate intermountain basin, consisting of a relatively flat floor surrounded by uplifts. These positive areas generally are considered to be the result of warping, although a high-angle reverse fault forms the west boundary of the Nacimiento uplift, on the east side of the basin. The south side of the basin is not sharply defined.

Petroleum and natural gas are produced from the Cretaceous rocks in the San Juan Basin, and small amounts of oil and gas are known to occur in the Pennsylvanian rocks. Some of the more porous strata in the basin are important aquifers, but below a depth of about 2,000 feet the ground water is generally saline.

Black Mesa Basin, Arizona (23)

The Black Mesa Basin is a broad, shallow, structurally simple basin in northeastern Arizona. It contains a sequence of rocks that range in age from Cambrian to Late Cretaceous, but little is known about their variations in thickness and lithology.

Kaiparowits Basin, Utah (24)

The Kaiparowits Basin, in southern Utah, is a northward extension of the Black Mesa Basin. It is a broad and shallow structure, bounded on the west by the Paunsaugunt fault. About 12,000 feet of Paleozoic and Mesozoic rocks are in this general area. Several oil tests have penetrated the major part of the stratigraphic section.

San Luis Basin, Colorado-New Mexico (25)

The San Luis Basin, located in southern Colorado, is 75 miles long and about 30 miles wide. The east side is downfaulted. Volcanic rocks are present on the north, west, and south sides of the basin and Precambrian rocks on the east side. The structure and depth of the basin are not known and the deepest well has not gone below volcanic rocks. No wells are as deep as 10,000 feet. One well penetrated 8,024 feet of Cenozoic deposits without reaching the base. There may be a thick sedimentary section below the volcanic rocks but this has not been demonstrated.

Paradox Basin, Utah-Colorado (26)

The Paradox Basin is a northwest-trending elliptical downwarp extending from southwestern Colorado to southeastern Utah. An unusual and important feature of the geology of the Paradox Basin is the presence of salt anticlines. These are not anticlines in the normal sense but represent areas of thickening as a result of salt flowage. A well near the northwest end of the Salt Valley area, in Grand County, Utah, bottomed in salt at a depth of nearly 14,000 feet. However, an adjacent test, only 3 miles north, encountered Precambrian rocks at a depth of slightly more than 4,000 feet.

It has been estimated that the depth to Precambrian rocks in the Paradox Valley may be 14,000 feet. A well in this area bottomed in salt in the Paradox member of the Hermosa formation (Pennsylvanian) at 10,847 feet. The Paradox has a total thickness of 6,000 feet or more in the deepest part of the basin of deposition, and of this thickness as much as 4,000 feet is salt, the remainder being chiefly shale.

Piceance Basin, Colorado (27)

The Piceance Basin is a northwestward-trending structural downwarp in northwestern Colorado. It is separated from the Uinta Basin to the west by the Douglas Creek arch. The basin generally is shallow, but in the vicinity of the Piceance gas field and for 20 miles south, it contains an oval-shaped area of about 250 square miles in which the top of the Mancos shale is thought to be below 10,000 feet.

The marine Mancos shale, of late Cretaceous age, is estimated to be 4,000 to 5,000 feet thick throughout the Piceance Basin, although all the control points are along the basin margins. The shale is soft, gray, calcareous, and relatively homogeneous. Thin sandstone beds are present in the upper part.

A test well within the gas field was drilled to a total depth of 12,019 feet, at which depth the hole is considered to be still above the top of the Mancos shale. Geophysical data suggest that the deepest part of the basin is to the south of the gas field, but probably in no extensive area is the top of the Mancos shale much below 13,000 feet.

The Nugget sandstone of Jurassic age or the Navajo sandstone of Jurassic(?) and Jurassic age, which is much lower in the section, is estimated to be less than 1,000 feet thick. Still lower in the stratigraphic

section, the Weber sandstone of Pennsylvanian age is about 1,000 feet thick in the Rangely oil field, northwest of the Piceance Basin. Although the sandstone may thin southeastward, lateral equivalents undoubtedly underlie the basin.

The basin is sparsely populated and the only major economic deposits are oil, gas, and oil shale. The Piceance gas field is of considerable commercial interest. The oil-shale deposits are remarkable, containing more than 1,000 feet of continuous shale of commercial grade. These oil shale beds are either on or near the surface and constitute a major oil reserve.

Uinta Basin, Utah (28)

The Uinta Basin, in northeastern Utah, is about 125 miles long from east to west and 50 to 80 miles wide. The basin is asymmetrical, with a gentle south flank and a steep north flank.

The sedimentary section is very thick in the deepest part of the basin. Lower Tertiary rocks have a combined maximum thickness of 18,000 feet, and Cretaceous strata are 12,000 feet thick. Thus rocks of Jurassic age, which range in thickness from less than 1,000 feet on the southeast side of the basin to more than 5,000 feet in the western part, may be at a depth of 30,000 feet in the center of the basin. Triassic rocks range in thickness from 1,100 feet in the eastern part of the basin to 7,500 feet in the western part. The thickness of the Paleozoic strata is not known because they lie at such great depth that they have not been drilled. Along the north margin of the basin they range in thickness from 4,000 to 5,000 feet.

The rocks of Tertiary age consist of black, gray, brown, and red lacustrine and fluviatile sandstone, siltstone, shale, and limestone. Some sequences of oil shale contain substantial amounts of petroleum throughout a continuous thickness of more than 300 feet. In the southern part of the basin near the Green River there is a conspicuous sandstone nearly 3,000 feet thick.

The upper part of the Upper Cretaceous sequence consists of several thousand feet of strata of variable lithology. However, in the western part of Duchesne County it includes a sandstone sequence that is relatively homogeneous and 1,000 to 2,000 feet thick. The thickness of this unit is variable because of an unconformity at the top.

The Mancos shale, of Late Cretaceous age, is a soft, gray, slightly calcareous marine shale. It is present throughout the Uinta Basin and is remarkably homogeneous except in the upper part. Its thickness ranges from 1,300 to 5,000 feet.

Along the northwest margin of the Uinta Basin the Navajo sandstone of Jurassic(?) and Jurassic age ranges in thickness from 1,000 to 1,200 feet and consists of relatively fine grained almost pure quartz sandstone. The thickness and lithology of this unit in the deeper part of the Uinta Basin are not known. Another sandstone unit, the Weber sandstone, lies about 4,000 feet below the top of the Navajo sandstone in the northwestern part of the basin and 2,000 feet below the top in the eastern part. It is 1,000 to 1,600 feet thick in the northern part of the Uinta Basin but nothing is known as to its thickness and lithology in the deep part of the basin. In outcrops and wells near the basin margin it consists of gray fine-grained pure quartz sandstone.

Limestone strata of Mississippian age have a combined thickness of 1,000 to 1,500 feet in the marginal parts of the Uinta Basin. Nothing is known of them in the central part. The limestone beds are hard and are partly dolomitic and partly cherty. The top of this carbonate sequence lies about 2,000 to 2,500 feet below the top of the Weber sandstone along the north margin of the basin.

Towns are sparse and small. Only Duchesne has a population that approaches 1,000 and the others have 200 or fewer. Throughout most of the basin the only industry is livestock raising. There are a few oil and gas fields and asphalt and gilsonite deposits.

North and Middle Parks, Colorado (29)

The downwarp area occupied by North and Middle Parks extends from the Colorado-Wyoming State line south-southeast for a distance of 60 miles. It is complicated by the North Park syncline, which cuts diagonally across the major synclinal axis. The deepest part of the area is thought to be near the intersection of these two synclines. A test well on the east side of this intersection was drilled to a total depth of 10,264 feet. Some geologists think the oldest rock penetrated is a black shale of Triassic age, whereas others interpret this rock as being a part of the Pierre shale of Late Cretaceous age.

In southwestern Middle Park, there is 4,900 feet of Pierre shale, almost all of which is black to gray, soft, and marine, with a few thin partings of sandstone and limestone. In parts of North Park the formation is somewhat thinner because the upper part has been removed by erosion, but nevertheless it is 3,000 feet or more thick in most subsurface sections. The lower half is exceptionally homogeneous, whereas the upper half contains some sandstone.

It is likely that in an area of 150 square miles near the intersection of the North Park syncline and the major North Park-Middle Park downwarp axis the Pierre shale may be more than 1,000 feet thick and buried at a depth of 10,000 feet or more. This area probably is a closed syncline.

Laramie Basin, Wyoming (30)

The Laramie Basin in southern Wyoming is about 60 miles long by 40 miles wide and reaches a depth of about 15,000 feet. It is underlain by predominantly clastic rocks of Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, and Tertiary ages, with some surficial glacial deposits. The rocks generally consist of thick shale units alternating with thin sandstone beds. The basin is deepest in its northwest part. The slope into the basin from the south and east is gentle but on the north it is steep. The strata on the west side are upturned and overridden by Precambrian granite along a series of thrust faults. Except for the city of Laramie with a population of more than 20,000 in the southeastern part, the area is sparsely settled and the principal industry is ranching.

Hanna Basin, Wyoming (31)

The Hanna Basin, in southeastern Wyoming, is one of the most remarkable structural basins in North America. It is cup shaped and is extremely deep with respect to its lateral extent. Uppermost Cretaceous, Paleocene, and lower Eocene rocks are unusually thick. A partial section of these rocks on the northeast flank of the basin is more than 20,000 feet thick. It is estimated that the top of the Steele shale, of Late Cretaceous age, is at a depth of approximately 29,000 feet about 10 miles northeast of the town of Hanna.

The Carbon Basin lies directly southeast of the Hanna Basin and is part of the general downwarp but is not as deep as the Hanna Basin. The top of the Steele shale is estimated to be at depths between 12,000 and 20,000 feet.

The Steele shale, about 4,500 feet thick, is gray, soft, homogeneous, and slightly calcareous. Some sandstone and sandy siltstone beds are present in the upper part of the section. Higher in the section is the Lewis shale with a similar lithology but lesser thickness (2,000 to 3,000 feet).

The Hanna Basin is sparsely populated. One town, Hanna, with about 1,300 people, is on the Union Pacific Railroad. This railroad and U. S. Highway 30 traverse the southern, more shallow part of the Hanna Basin. There are no oil or gas fields or industries other than livestock raising and some coal mining. The Union Pacific Railroad owns nearly every alternate square mile for 20 miles on each side of the track. The Seminole Reservoir is along the northwest margin of the area.

Washakie Basin-Sand Wash Basin area, Colorado-Wyoming (32)

The Washakie Basin is in southwestern Wyoming and the Sand Wash Basin is in northwestern Colorado. These two names apply to parts of a major downwarp area that is divided approximately along the State line by a zone of east-trending normal faults and by the Powder Wash anticline. As only a few deep wells have been drilled in the center of the basin both structural and stratigraphic control in the deepest parts of the downwarp are almost completely lacking. Probably as much as 30,000 feet of sedimentary rocks are present in parts of the basins. Most of this thickness is composed of beds of Cretaceous and Tertiary age.

Subsurface data indicate that the Green River formation (Eocene) is about 6,000 feet thick in the central part of the Washakie Basin. The oil-shale beds in this formation are much thinner than those in the Uinta Basin. The Wasatch formation, also of Eocene age, is reported to be 5,000 feet thick in the Vermillion Creek area of Colorado and 3,100 feet thick in the Powder Wash area. Paleocene rocks are reported to be 4,500 to 7,000 feet thick along the east margin of the Washakie Basin.

Uppermost Cretaceous rocks in the Washakie Basin-Sand Wash Basin area have a variable thickness, partly because of erosion and partly because of intertonguing of sandstone with the upper part of the shale sequence.

Along the southeast margin of the Washakie Basin the Lewis shale consists of 1,000 feet of extremely homogeneous gray marine shale overlain by several hundred feet of sandy shale and thin beds of sandstone. About 25 miles north-northwest, the Lewis shale thins to 700 feet. The formation seems to thin and lose its identity in a sandstone and shale sequence to the west across the Washakie Basin. In the Sand Wash Basin, the Lewis shale is said to range between 1,600 and 2,000 feet in thickness but to thin rapidly southward.

The depth of burial of the Lewis shale in the deepest part of the Washakie Basin-Sand Wash Basin is not known because there are few control points. However, the depth must be considerably more than 10,000 feet in an area of 500 square miles in the Washakie Basin. Except in the northwest corner, there is no information as to the depth of the Lewis shale in the Sand Wash Basin. In the Powder Wash oil field, the top of the Lewis shale is at about 9,100 feet. It is believed that the Sand Wash Basin becomes much deeper to the south and somewhat deeper to the southeast.

Another formation of interest is the Mancos shale, which is about 4,600 feet thick on the east side of the Washakie Basin. On the west side of the basin the formation is slightly thicker. The lower 2,000 to 3,000 feet of the Mancos shale in the Washakie Basin consists of gray, soft, homogeneous, slightly calcareous marine shale with a few thin limestone partings. The upper part contains more silt and sandstone. Control on the thickness and character of the Mancos shale in the Sand Wash Basin is sparse. Near the northwest corner of the basin, the Mancos shale is 5,200 feet thick. About 12 miles to the south it is 5,370 feet thick, and it is reported to be 4,900 feet thick in the southeastern part of the basin. The unit is essentially all shale except for a few sandstone beds in the upper part and at the base.

There are very few permanent inhabitants in the entire Washakie Basin. The Sand Wash Basin contains more residents but is still very sparsely populated. The only industry in both areas is livestock raising, except for the Powder Wash oil and gas field along the west-central margin of the downwarp and some uranium mining along the south and east-central margins. Nearly every alternate square mile for 20 miles south of the Union Pacific Railroad along the north margin of the Washakie Basin is owned by the Union Pacific Railroad. Much of the remaining land in both the Washakie and Sand Wash Basins is federally owned or State owned.

Red Desert Basin, Wyoming (33)

The Red Desert Basin, called the Great Divide Basin in many reports, lies directly north of the Washakie Basin and east of the Green River Basin in south-central Wyoming. It is separated from the Washakie Basin

by the Wamsutter arch and from the Green River Basin by the Rock Springs uplift. The basin is broad and asymmetric, with the trough line near the north and northeast margins.

The Lewis shale (Late Cretaceous) is about 1,100 feet thick along the south margin of the basin and 2,000 feet thick along the east side. Along the north margin the shale thins as a result of post-Lewis beveling. The lower part of the formation is consistently homogeneous shale, whereas the upper part contains some relatively thin sandstone and sandy shale beds.

The Cody shale, another unit of Late Cretaceous age, ranges in thickness from 3,000 to 5,000 feet, with the thicker and more homogeneous section in the eastern part of the area and the thinner and more sandy section in the western part. The upper 1,000 feet contains some sandstone lenses and sandy shale beds, whereas the lower 2,000 to 4,000 feet is gray soft homogeneous marine slightly calcareous shale.

Subsurface control is completely lacking throughout most of the basin, but interpretations of data around the margins, supplemented by geophysical information, suggest that within an area of about 2,000 square miles the Cody shale lies at depths greater than 10,000 feet. In the northern and eastern parts of the basin the shale may be at a depth of 17,000 feet or more. The area within which the Lewis shale is at a depth of 10,000 feet is not known but is considerably less than 2,000 square miles.

The Red Desert Basin is essentially uninhabited except along the south margin where the Union Pacific Railroad has maintenance stations. Nearly every alternate square mile for 20 miles north of the railroad is

owned by the company. Most of the remaining land is either federally owned or State owned. The only industries are livestock raising and natural gas.

Green River Basin, Wyoming (34)

The Green River Basin, in southwestern Wyoming, is one of the largest structural basins in the State. The basin is bordered on the south by the Uinta Mountains, on the west by the Wyoming Range and Hoback Range, on the north by the Gros Ventre Range, and on the northeast by the Wind River Range. Few wells have been drilled in the deepest part of the basin, which is thought to be adjacent to the northeast and north margins.

More than 5,000 feet of Eocene and younger Tertiary rocks is present in the Green River Basin. This sequence includes the Wasatch, Green River, and Bridger formations. A distinct unconformity separates the post-Paleocene sediments from the underlying older rocks.

A thick shale sequence (known variously as the Cody, Hillcaid, or Baxter shale) forms a prominent part of the Cretaceous section. The thickness of this unit, which is composed of soft gray calcareous shale, seems to range from 2,000 to 3,500 feet. It is difficult to say at what depth this shale sequence will be found in the basin. Data are so sparse that the best estimate is little more than a guess. In the area directly west of the Wind River Mountains, it is at depths of perhaps 15,000 to 20,000 feet. In the Hoback Basin area, directly south of the Gros Ventre Mountains, the depth may be between 20,000 and 30,000 feet. The shale is at a much shallower depth in the southern half of the basin. A median anticline extending north through the Church Buttes gas field bisects this

part of the basin, and along it the shale is at depths ranging from 7,500 feet to 9,955 feet. On both sides of this anticline the shale is probably at depths considerably greater than 10,000 feet.

Triassic rocks are more than 1,000 feet thick throughout the Green River Basin and consist chiefly of red siltstone with lesser amounts of gray dolomitic siltstone, fine-grained sandstone, and limestone. Limestone is more abundant in the western part of the area.

Pennsylvanian rocks are more than 1,000 feet thick in the eastern part of the Green River Basin. They consist of sandstone with some limestone, dolomite, and shale in the lower part. The maximum known thickness of continuous sandstone is less than 1,500 feet but it may be greater in the southwest corner of the basin.

The Madison limestone of Mississippian age is exposed or has been drilled only around the margins of the Green River Basin. Perhaps 9,700 square miles of the Green River Basin is underlain by more than 1,000 feet of this limestone at depths greater than 10,000 feet, and the formation probably is at depths greater than 35,000 feet in the northern part of the basin and 20,000 to 25,000 feet throughout much of the remainder. The limestone is relatively homogeneous, dolomitic in the lower part, and moderately cherty in the upper part. The maximum thickness of the Madison limestone is probably not much more than 1,400 feet.

Cambrian rocks are more than 1,000 feet thick throughout most of the Green River Basin except perhaps along the south margin. The basal part of this sequence consists of sandstone and the remainder of shale and limestone.

The density of population is very low throughout the Green River Basin. For example, the population of Sublette County, which encompasses the northern part of the basin, is only about 2,500 for an area of nearly 4,900 square miles. The Union Pacific Railroad owns every alternate square mile in a 40-mile strip across the southern part of the basin. Much of the remaining land is federally owned or State owned. The only industries within the basin proper are oil, gas, trona mining, and livestock raising. All but two of the oil and gas fields are along the west margin of the basin. The Church Buttes gas field is in the south-central part and the Pinedale gas field is near the northeast margin.

Jackson Hole, Wyoming (35)

The Jackson Hole area is in northwestern Wyoming. Parts of the basin are very deep. It is still seismically active and there has been considerable tilting during the last 7,000 years. The Cody shale of Late Cretaceous age lies at depths of 10,000 to 15,000 feet or more in some places. The Cody shale is about 2,000 feet thick in this area and is relatively homogeneous gray soft marine shale with two thin sandstone beds in the upper half. Pennsylvanian rocks are 1,000 feet thick in the southwestern part of the area and consist of sandstone, red shale, limestone, and dolomite. Mississippian carbonate rocks are 1,000 feet thick in the southwest part of Jackson Hole but are not deeply buried. Cambrian rocks, 900 to 1,000 feet thick, comprise a heterogeneous sequence of sandstone, shale, and limestone.

Most of the land in the Jackson Hole area is federally owned. Part is in the Teton National Forest and part in Grand Teton National Park. The area lies directly south of Yellowstone National Park.

Wind River Basin, Wyoming (36)

The Wind River Basin in central Wyoming contains more than 30 oil and gas fields and the largest uranium deposits known in the State. The basin is elongated along its east-west axis and is asymmetric, with the trough line near the north margin. The Owl Creek Mountains have been shoved southward over much of the northern flank of the syncline.

The Upper Cretaceous Cody shale ranges in thickness from 3,600 feet in the northwestern part of the basin to 5,000 feet in the southeastern part. The upper 500 to 2,000 feet of the formation contains thin interbedded sandstone, especially in the western part of the basin. The lower 2,000 to 4,000 feet is soft gray marine homogeneous shale throughout, except for thin calcareous partings. Thin beds of bentonite are present.

Within an area of more than 1,000 square miles the Cody shale is buried to a depth greater than 10,000 feet. In the northern part of the basin geophysical and drilling data suggest that the top of the shale is at a depth in excess of 20,000 feet.

The only town of consequence within the deepest part of the Wind River Basin is Shoshoni, which has a population of less than 1,000. Except for a Bureau of Reclamation irrigation project in the northwestern part, the area is very sparsely populated. Two gas fields are present in the deep part of the basin. All other oil and gas fields, and coal and uranium mines are marginal to the basin. The only other industries are livestock and farming. Much of the land is federally owned.

Bighorn Basin, Wyoming (37)

The Bighorn Basin is a long northwestward-trending basin in northwestern Wyoming. The basin is ringed with numerous major oil fields. Because of the abundant drilling and geophysical data, the stratigraphy and structure of the flanks of the basin are moderately well known.

The Cody shale (Late Cretaceous) is a relatively homogeneous sequence more than 1,000 feet thick and at a depth of more than 10,000 feet in the Bighorn Basin. Structural control along the trough line is poor, so even the approximate area in which the top of the Cody shale is at a depth of 10,000 feet is subject to considerable interpretation. This area may include about 400 square miles, beginning about 12 miles north of Cody and extending southeast to a point about 20 miles west of Worland. It has a maximum width of about 12 miles and a length of 60 miles.

At the northwest end of the deep part of the basin the Cody shale is about 1,800 feet thick and at the southeast end it is about 2,700 feet thick. The upper part of the Cody shale contains fine sand and silty gray marine shale with some lenticular sandstone. The lower 1,000 feet or more is relatively homogeneous gray marine shale.

None of the older Mesozoic or Paleozoic stratigraphic sequences contain as much as 1,000 feet of homogeneous silicate or carbonate rocks in the deepest part of the basin. The Madison limestone (Mississippian) underlies a large part of the basin at depths of 10,000 to 15,000 feet, but it is only 700 to 800 feet thick. If the Devonian dolomite and Ordovician dolomite are added, the total thickness of carbonate rocks is about 1,400 feet in the northern part of the area. However, this combined

sequence is somewhat heterogeneous, with rather pure limestone in the upper part, shaly dolomite and limestone in the lower middle, and siliceous dolomite near the base. Cambrian rocks are 1,200 feet or more in thickness but consist of a heterogeneous sequence of sandstone, shale, and limestone.

There are no towns or oil and gas fields in the deepest part of the basin. However, several major oil fields are within 10 miles to the west.

Crazy Mountains syncline, Montana (38)

The Crazy Mountains syncline is one of the deepest sedimentary basins in Montana. About 18,000 feet of sedimentary rocks underlie an area of more than 500 square miles. There is little structural control within the syncline. At the center of the downwarp the Crazy Mountains intrusive rocks are emplaced in an area of at least 50 square miles. The effect of these intrusives on the structure is not known but is probably considerable.

The Cody shale, of Late Cretaceous age, is thought to be 1,200 to 2,400 feet thick in the Crazy Mountains syncline. This unit consists of relatively homogeneous gray shale with a few beds of sandstone. It may underlie as much as 300 square miles. A carbonate sequence of Mississippian age is said to be 1,200 to 2,400 feet thick. The lower unit consists of 600 to 800 feet of limestone with only minor amounts of dolomite, sandstone, and shale. The middle unit is about 500 feet thick, of which the lower half is interbedded limestone and dolomite and the upper half is anhydrite with a minor amount of dolomite. The topmost unit consists of about 400 feet of marine limestone and dolomite with a middle zone of anhydrite.

The area is sparsely populated and has no large-investment industries.

Western Montana (39)

Intermontane valleys and faulted troughs filled with unknown thicknesses of Tertiary rocks are numerous in western Montana. In the Philipsburg area there is said to be 21,500 feet of Belt strata of Precambrian age and about 8,000 feet of Paleozoic and Mesozoic rocks. In places the Precambrian rocks are thrust over rocks of Mississippian age so that there is a 10,000-foot-thick thrust sheet above the normal position of the Paleozoic and Precambrian rocks. More than 7,000 feet of Belt rocks in the Whitehall area, southeast of Philipsburg, has been described. These rocks are involved in very complex structure.

The most extensive intermontane valleys are the valley near Flathead Lake, several basins in the vicinity of Dillon, and several basins in the vicinity of Bozeman. Neither the stratigraphy nor the structure of these basin areas has been worked out in detail.

Snake River downwarp, Idaho-Oregon (40)

The Snake River downwarp is an arcuate area about 300 miles long and 50 miles wide extending westward across the southern part of Idaho and into eastern Oregon. The surface and near-surface rocks consist of several thousand feet of upper Tertiary and Quaternary tuff, ash, silt, sand, flows (chiefly basalt), and local intrusives. The thickness of the Tertiary rocks in the deepest part of the downwarp is not known. A maximum possible thickness of 18,000 feet of upper Cenozoic rocks is in the western part of the downwarp, but the thickness in the eastern part is completely unknown.

The structure of the pre-Tertiary rocks that underlie at least the east half of the downwarp is not known. Thick sequences of carbonate and silicate rocks of Paleozoic and Mesozoic ages are present on both sides of the downwarp and presumably extend beneath the Tertiary deposits. No wells have penetrated the Paleozoic rocks in the downwarp.

Many of the Paleozoic and Mesozoic rock units that crop out adjacent to the downwarp are 1,000 feet or more thick and are relatively homogeneous. Some of these rocks have been drilled in areas south of the downwarp.

The Snake River downwarp includes many thousands of square miles. Some parts are uninhabited and some, particularly along the Snake River, are thickly populated. A large area in the vicinity of Arco is used by the Atomic Energy Commission.

Salt Lake-Utah Lake area, Utah (41)

The Salt Lake-Utah Lake Basin is about 65 miles long and 10 to 15 miles wide. The surface strata, which are chiefly Cenozoic in age, fill fault valleys underlain and surrounded by Paleozoic rocks. The thickness of the Cenozoic deposits is not known, but on the basis of geophysical studies, they are probably less than 10,000 feet thick. Rocks underlying this area include units of Pennsylvanian and Permian age. The overriding northeastward-shoved block of a very large thrust fault contains one sequence of quartzite and sandstone that is as much as 15,000 feet thick, with only very sparse thin limestone beds. A succession of sandstone, quartzite, and limestone is 20,000 to 30,000 feet thick in the Wasatch Mountains on the east side of the valley.

The structure under the Salt Lake-Utah Lake valley has not been determined, but presumably some or all of the sedimentary section was downdropped along the Wasatch normal fault. The depth to the major thrust plane under the Cenozoic deposits is not known.

West-central Utah (42)

The western part of the Basin and Range area in Utah consists of 20 or more large and small north-trending ranges of Paleozoic rocks separated by valleys filled with Cenozoic strata. The mountains in the eastern part of the area are intricately faulted, whereas those in the western part have less complex structure. The Cenozoic strata comprising the valley fill are much less disturbed than are the older rocks. About 40,000 feet of Paleozoic limestone and dolomite with relatively minor thickness of sandstone and shale are present.

In the Confusion Range, near the Utah-Nevada boundary, the stratigraphic succession consists of 16,000 to 24,000 feet of rocks ranging in age from Ordovician to Triassic. Several thousand feet of Cambrian rocks, predominantly limestone, are present in the House Range to the east. To the north, in the Gold Hill area, there is about 11,500 feet of Cambrian rocks, including more than 4,700 feet of quartzite and about 1,000 feet of sandy and shaly dolomite.

More than 1,500 feet of limestone of Early Ordovician age is reported in the area of the Confusion Range, and a maximum of 1,000 feet of dolomite in the Gold Hill area. About 1,600 feet of dolomite of Late Ordovician and Silurian age has been measured in the Ibex Hills, just east of the Confusion Range. The same general sequence is about 1,200 feet thick in the Gold Hill area.

Rocks of Devonian age in the Confusion Range are chiefly carbonate and are more than 4,000 feet thick in the Gold Hill area. They are about 2,500 feet thick and consist predominantly of limestone and dolomite, with some sandstone.

Mississippian rocks in the Confusion Range vary in lithology. In the Gold Hill area they include an estimated 4,500 feet of limestone.

About 1,600 feet of Pennsylvanian cherty limestone is reported from the Confusion Range, but another report shows a thickness of approximately 3,700 feet, with the lower part more clastic and the upper part more calcareous. In the Gold Hill area, the Pennsylvanian system is represented in part by nearly 3,000 feet of limestone with thin beds of sandstone.

Permian rocks are reported to be 9,000 to 10,000 feet thick in the Confusion Range. However, these figures may be in error because of duplications in the section. Another source gives a thickness of about 6,500 feet. At the base is 3,000 feet of sandstone with thin limy and dolomitic partings. This is overlain by 1,000 feet of gray massive homogeneous limestone, and then by at least 2,000 feet of limestone and limy shale.

The Cenozoic strata in the valleys between the mountains of Paleozoic and older rocks range in age from Oligocene to Recent. These deposits have not been studied in detail except in the corner common to Utah, Idaho, and Nevada. In that area, there is 800 feet of shale, tuff, sandstone, and conglomerate of Miocene or Pliocene age. This is overlain by at least 2,300 feet of beds of early or middle Pliocene age. These rocks consist of shale, sandstone, tuff, conglomerate, and limestone. They are folded into

gentle anticlines and synclines and are cut by many normal faults. In other parts of the Basin and Range area in Utah there are likewise many Cenozoic normal faults.

The stratigraphy and structure of the ranges are now being studied in some detail but the area is so vast that it will be many years before adequate structure maps will be completed and the geologic history worked out. The structure beneath the Cenozoic valley fill is almost completely unknown. There has been little drilling in the basin areas and most of the reflection seismograph information is not available.

Southwestern Utah (43)

In the southwest corner of Utah there are several areas where rocks are buried to depths of more than 10,000 feet. In the northern part of the Pine Valley syncline, in central Washington County, Cretaceous and older strata have an aggregate thickness between 15,000 and 20,000 feet. This sequence includes 1,500 to 1,800 feet of relatively pure white sandstone of Pennsylvanian and Permian age, 1,500 feet of Pennsylvanian limestone interbedded with quartzite, sandstone, and dolomite, 1,100 feet of cherty gray limestone with Mississippian fossils, and an undifferentiated sequence, 2,200 feet thick, containing more than 1,000 feet of dolomite, probably of Cambrian or Ordovician age.

In northwestern Kane County and adjacent parts of Washington and Iron Counties, Utah, the stratigraphic section of Paleozoic and Mesozoic rocks thins to between 10,000 to 15,000 feet. As this area has not been drilled, the stratigraphic section can only be inferred from data in adjacent areas. The area is sparsely inhabited and has no major industrial development.

Elko-Humboldt area, Nevada (44)

The geology of the Elko-Humboldt area, a large irregular area in northeastern Nevada, is poorly known. The following summary pertains not only to the area but to much of eastern Nevada. Although many quadrangles and mining areas in this part of the State have been mapped in excellent detail, only recently has there been an attempt to compile county geologic maps and other types of regional maps. Relatively little subsurface information is available in eastern Nevada.

The Elko-Humboldt area contains a series of northward-trending basins separated by mountain ranges of Paleozoic and volcanic rocks. Many of these basins are bounded by faults. There may be places where Paleozoic strata have been thrust over the surficial rocks of Tertiary age.

As much as 6,000 feet of Miocene and younger rocks is present just west of the Ruby Range. These rocks are chiefly tuff, limestone, shale, and conglomerate. Near the city of Elko a test well bottomed in Miocene rocks at a depth of 3,200 feet. In the northeast corner of Nevada there is 3,000 feet of Miocene and Pliocene rocks. In Nye County the Tertiary sedimentary and volcanic sequence is about 10,000 feet thick.

A section of 16,450 feet of rocks ranging in age from Cambrian to Mississippian has been described from the Ruby Mountains in Elko County. Mississippian, Pennsylvanian, and Permian rocks occur in northeastern Nevada. In the upper part of the section there is 1,100 to 1,400 feet of carbonate rocks of Pennsylvanian age, consisting of cherty limestone with some sand and silt. In the lower part of the Paleozoic section, 1,900 feet of dolomite of Devonian age is underlain by 1,350 feet of dolomite of Silurian age.

In the vicinity of Eureka there are several Paleozoic formations composed of limestone and dolomite, each more than 1,000 feet thick. The structure of the Eureka area is very complex and is essentially unknown under the Cenozoic deposits in the large basin areas to the west, north, and southeast.

The stratigraphy and structure of the Tertiary and pre-Tertiary rocks in the vicinity of the Eagle Springs oil field, northeastern Nye County, has been studied but almost nothing is known of the thickness, character, and structure of the pre-Tertiary rocks in the adjacent areas. To the southeast, in the Pioche district, there are 17,000 feet or more of Paleozoic rocks, predominantly carbonate. The Paleozoic rocks in this area are intricately folded and faulted.

Carson-Black Rock area, Nevada (45)

A series of relatively flat-floored structurally simple basins filled with Cenozoic deposits are present in the Carson-Black Rock area, northwestern Nevada. These basins are separated by mountains of complexly folded and faulted older rocks. Very little geologic information is available on the northwestern part of this area, which lies in Washoe County, western Humboldt County, and western Pershing County.

The southern part of the area is somewhat better known, but most of the available information is 50 years old. No oil and gas tests have been drilled in this area, except for an 800-foot test in southwestern Humboldt County. Therefore, virtually nothing is known about the thickness, lithology, and structure of the Tertiary rocks in the subsurface or what is buried beneath them.

Muddy Creek area, Nevada (46)

The Muddy Creek area consists of a series of northward-trending valleys filled with Cenozoic deposits. Most of the area is within Clark County. The deepest well in Clark County is 8,508 feet deep. It penetrated a sequence of sedimentary rocks composed of sandstone, shale, limestone, and dolomite. Paleozoic strata were topped at 4,475 feet.

In the western part of Nevada some areas, such as the Mina, Round Mountain, and Coaldale quadrangles, have been mapped in detail, and there are some maps of small mining districts. The Paleozoic and Mesozoic rocks in this part of the State are involved in extremely complex folds and faults. No wells have been drilled through the Tertiary strata. The thickest Tertiary sections probably are west of Tonopah and in the Walker River area, near the west border of Nevada. The thickness of the Tertiary strata is unknown but may be on the order of 10,000 feet or more.

East-central California (47)

The area included in east-central California lies east of the Sierra Nevada fault zone and north of the Garlock fault. Within this area, considerable thicknesses of Precambrian, Paleozoic, and Mesozoic strata accumulated. They are somewhat metamorphosed in the western part of the area but are essentially unaltered in the eastern part. Pre-Mississippian rocks have a maximum thickness of about 19,000 feet; Mississippian and Pennsylvanian rocks, 12,500 feet; and Mesozoic rocks, 8,100 feet. Cenozoic strata are present only locally and have no significant thickness. Almost all of the Paleozoic rocks are marine.

The area is sparsely populated and has few industrial establishments.

Mojave Desert, California (48)

The Mojave Desert region is generally considered to be part of the Basin and Range structural province. In general, the area is one of northward or northwestward-trending mountain ranges composed of igneous and sedimentary rocks. Between these ranges are broad flat valleys filled with alluvium or Tertiary strata.

Enormous thicknesses of Paleozoic rocks are present in scattered outcrops, but continuous sections are rare. Cambrian, Ordovician, and Silurian rocks are thought to have a total thickness of at least 20,000 feet in places, and the Pennsylvanian and Permian rocks may likewise be 20,000 feet thick. The Triassic and Jurassic rocks may be several thousand feet thick, as may the Tertiary strata.

Within the Mojave Desert region there is scarcely an area of 100 square miles in which the visible structure is not complex. What lies below the Cenozoic deposits in most places is not known because drilling data are inadequate. The area is very sparsely populated.

San Joaquin Valley, California (49)

The San Joaquin Valley, which is the southern half of the Great Valley of California, lies between the Sierra Nevada on the east and the Coast Ranges on the west. It is a large downwarp approximately 250 miles long and 50 to 60 miles wide. The north end is continuous with the Sacramento Valley. The major synclinal axis trends northwesterly and is close to the west side of the valley. The maximum thickness of sedimentary rocks is about 30,000 feet. Most of these rocks are of Cretaceous, Tertiary, and Quaternary ages. Because of the oil and gas development within the San Joaquin Valley, the geology has been studied in considerable detail.

Oil fields are abundant in the southern part of the San Joaquin Valley and gas fields are more common in the central and northern parts. Some of the largest oil reserves in California are in this valley. There are several cities with populations ranging from 20,000 to more than 100,000, and the industrial investment is considerable.

Because of the density of population, investment in industry and real estate, abundance of oil and gas fields, poorly consolidated nature of the upper Cenozoic rocks, abundance of underground water, and the crustal instability of adjacent areas, the San Joaquin Valley is not considered especially attractive for the purpose of waste disposal.

Several areas lying southeast, south, and southwest of the San Joaquin Valley warrant a brief note. These are the Los Angeles, Ventura, Santa Maria, and Central Coast Range Basins. Each contains more than 10,000 feet of sedimentary rocks, and the Ventura Basin contains more than 30,000 feet. Their structure is complex, they contain numerous oil fields and have a high density of population, and they are adjacent to the active San Andreas fault.

Sacramento Valley, California (50)

The Sacramento Valley, the northern part of the Great Valley of California, is both a topographic and structural valley. It contains a sedimentary sequence, composed chiefly of sandstone and shale ranging in age from Early Cretaceous to Pliocene, with a composite maximum thickness of about 50,000 feet. Gas fields are numerous throughout all but the extreme northern part of the valley.

There are many sandstone and shale sequences more than 1,000 feet thick at depths greater than 10,000 feet. The structure in the deepest part of the basin is relatively simple.

The population of the area is moderately dense, there is a large investment in industry and real estate, gas fields are abundant, the upper Cenozoic rocks are poorly consolidated, underground water is very important to the economy of the region, and areas adjacent to the Sacramento Valley are crustally unstable.

Harney Basin, Oregon (51)

The Harney Basin, in southeastern Oregon, includes an area of about 5,300 square miles and is the northwesternmost part of the Basin and Range province. Low-dipping Tertiary lavas and tuffs slope into the basin from the south and north. The east edge is complicated by block faulting and the west edge is covered by Tertiary or Quaternary lavas.

The deepest hole in the basin was drilled to 6,480 feet. The upper 4,000 feet was varicolored tuffaceous claystone and shale with minor amounts of tuff. The lower 2,480 feet was black volcanic rock with a few beds of altered claystone. There is no information as to what lies below a depth of 10,000 feet.

Central Oregon (52)

Throughout an area of 6,000 to 8,000 square miles in central Oregon are sporadic exposures of rocks ranging in age from Mississippian to Cretaceous. The total thickness of these rocks is unknown, but it is estimated that in one area the Paleozoic strata are as much as 3,500 feet thick and the Jurassic 15,000 feet. The rocks are somewhat folded and

faulted and are overlapped unconformably by Tertiary strata and volcanic rocks. Subsurface data are absent and the area as a whole has not been mapped or studied in detail. There is considerable variation regarding both stratigraphy and structural interpretations

Western Oregon (53)

A Tertiary marine basin 200 miles long and 500 miles wide is present in Oregon west of the Cascade Mountains. Within this basin Eocene and Oligocene rocks predominate, but Miocene and Pliocene rocks are exposed along the west and north margins of the basin. The total thickness of the Tertiary section is not known. In some places as much as 5,000 to 10,000 feet of volcanic rocks is interbedded with 15,000 to 20,000 feet of sedimentary rocks. The deepest well in the area drilled 2,500 feet of interbedded sandstone and siltstone and then 150 feet of transition sandstone and conglomerate. The remainder of the hole to 12,880 feet (total depth) was in middle or lower Eocene siltstone with interbedded basalt flows and basaltic sandstone.

The structure of the Tertiary marine basin is relatively simple. The regional dip is westward, but it is interrupted by elongate northward-trending anticlines and some faults.

Central Washington (54)

In central Washington there are several basin areas with unknown thicknesses of sedimentary rocks. These are, from north to south, the Quincy Basin, Pasco Basin, and Yakima Basin. A few outcrops are of Oligocene and Miocene age and the remainder is volcanic rock and Quaternary deposits. The structure of the basins is thought to be relatively simple

but the details have not been worked out. There are a number of broad gentle northwestward- or southwestward-trending anticlines and some faults.

The Rattlesnake Hills anticline, along the west side of the Pasco Basin, has been drilled to a depth of 8,400 feet. This test encountered volcanic rocks with a lesser amount of sedimentary rocks.

Western Washington (55)

The west coast of Washington is a northern continuation of the Tertiary marine basin of western Oregon. The area has a composite section of perhaps 40,000 to 50,000 feet of sedimentary and volcanic rocks that range in age from Cretaceous to Recent. A deep well near the coast bottomed in Eocene rocks at a depth of 11,002 feet. The rocks of this area have been folded into anticlines and synclines; there are some faults.

The areas that might be most promising for waste disposal if more subsurface information could be obtained are 50 to 75 miles west of the cities of Seattle, Tacoma, and Portland.

SELECTED REFERENCES

- 1 Abbott, W. O., 1957, Tertiary of the Uinta Basin, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf. 1957: p. 102-109.
- 2 Agocs, W. B., and Hartman, R. R., 1956, Airborne magnetometer profile from Olympia, Washington, to Laramie, Wyoming: Mining Eng., v. 8, p. 1210-1215.
- 3 Alexander, R. G., Jr., 1955, Geology of the Whitehall area, Montana: Yellowstone-Bighorn Research Proj. Contr. 195, 111 p.
- 4 Alexander, R. G., Jr. and Clark, E. W., 1954, Drilling of the Johns Valley, Upper Valley, and Muley Creek structures (Utah), in Intermountain Assoc. Petroleum Geologists, 5th Ann. Field Conf. 1954: p. 103-109.
- 5 Anderman, G. G., 1955, Tertiary deformational history of a portion of the north flank of the Uinta Mountains in the vicinity of Manila, Utah, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf. 1955: p. 130-134.
- 6 Anderson, J. L., 1951, Northeastern United States, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 421-437.
- 7 Andrichuk, J. M., 1955, Mississippian Madison group stratigraphy and sedimentation in Wyoming and southern Montana: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2170-2210.
- 8 _____ 1957, Mississippian strata in the Crazy Mountain Basin and adjacent areas, in Billings Geol. Soc. Guidebook 8th Ann. Field Conf.: p. 63-68.

- 9 Applin, P. L., 1951, Florida, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 404-408.
- 10 Arbenz, J. K., 1956, Tectonic map of Oklahoma: Oklahoma Geol. Survey.
- 11 Ardmore Geological Society, 1956a, South-north cross section, N. E., corner Montague County, Tex. to Springer, Carter County, Okla.: Ardmore, Okla.
- 12 _____ 1956b, South-north cross section, sec. 3, T. 2 S., R. 8 W., Stephens Co. to sec. 20, T. 8 N., R. 7 W., Grady Co., Okla.: Ardmore, Okla.
- 13 _____ 1956c, South-north cross section, sec. 23, T. 6 S., R. 6 W., Jefferson Co. to sec. 2, T. 2 N., R. 4 W., Garvin Co., Okla.: Ardmore, Okla.
- 14 _____ 1956d, West-east cross section, sec. 26, T. 2 N., R. 8 W., Stephens Co. to sec. 19, T. 3 S., R. 1 E., Carter Co., Okla.: Ardmore, Okla.
- 15 Bacon, C. S., Jr., 1948, Geology of the Confusion Range, west-central Utah: Geol. Soc. America Bull., v. 59, p. 1027-1052.
- 16 Baker, A. A., 1946, Geology of the Green River Desert-Cataract Canyon region, Emery, Wayne, and Garfield Counties, Utah: U. S. Geol. Survey Bull. 951, 122 p.
- 17 _____ 1947, Stratigraphy of the Wasatch Mountains in the vicinity of Provo, Utah: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 30.
- 18 Baldwin, E. M., 1955, Geology of the Marys Peak and Alsea quadrangles, Oregon: U. S. Geol. Survey Oil and Gas Inv. Map OM-162.

- 19 _____ 1956, Geologic map of the lower Siuslaw River area, Oregon:
U. S. Geol. Survey Oil and Gas Inv. Map OM-186.
- 20 Barnes, C. E., and Caldwell, E. W., Jr., 1957, Delaware Basin--the next
big boom?: World Oil, Aug. 1, 1957, p. 68-75.
- 21 Barton, J. M., 1945, Pre-Permian axes of maximum deposition in West Texas:
Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1336-1348.
- 22 Bartram, J. G., Imbt, W. C., and Shea, E. F., 1950, Oil and gas in
Arbuckle and Ellenburger formations, Mid-Continent region: Am. Assoc.
Petroleum Geologists Bull., v. 34, p. 682-700.
- 23 Bass, N. W., Eby, J. B., and Campbell, M. R., 1955, Geology and mineral
fuels of parts of Routt and Moffat Counties, Colorado: U. S. Geol.
Survey Bull. 1027-D, p. 143-250.
- 24 Bateman, A. F., 1957, Structure contour map of Nesson anticline, North
Dakota: U. S. Geol. Survey open-file report.
- 25 Bateman, P. C., and Merriam, C. W., 1954, Geologic map of the Owens Valley
region, California, in Jahns, R. H., ed., Geology of southern
California: California Div. Mines Bull. 170, Map Sheet 11.
- 26 Beikman, H. M., and Drakoulis, Sophie, 1958a, Records of unsuccessful test
wells drilled for oil and gas in Mississippi as of July 1, 1956:
U. S. Geol. Survey Bull. 1072-A, 66 p.
- 27 _____ 1958b, Map of Mississippi showing oil and gas fields,
unsuccessful test wells, salt domes, and pipelines: U. S. Geol.
Survey Oil and Gas Inv. Map OM-200.
- 28 Berry, E. W., 1951, North Carolina, in Ball, M. W., ed., Possible future
petroleum provinces of North America: Am. Assoc. Petroleum
Geologists Bull., v. 34, p. 412-415.

- 29 Billings Geological Society, 1957, Crazy Mountain Basin in Billings Geol. Soc. Guidebook 8th Ann. Field Conf., Sept. 6-7, 1957: 160 p.
- 30 Blackstone, D. L., Jr., 1955, Notes on a tectonic map of parts of southwestern Wyoming and adjoining States, in Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf. 1955: p. 122-124.
- 31 _____ 1956, Introduction to the tectonics of the Rocky Mountains, in Am. Assoc. Petroleum Geologists, Geol. Rec., 6th Ann. Mtg., Rocky Mtn. Sec.: p. 3-19.
- 32 Bonini, W. E., and Lavin, P. M., 1957, Gravity anomalies in southern Idaho and southwestern Montana: Geol. Soc. America Bull., v. 68, p. 1702.
- 33 Bornhauser, Max, 1947, Marine sedimentary cycles of Tertiary in Mississippi embayment and central Gulf Coast area: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 698-712.
- 34 Boucher, A. R., Moritz, C. A., and Swearingen, W. E., 1957, Oil possibilities seen in Williston Basin's southwest flank: World Oil, June 1957, p. 184-190.
- 35 Bowyer, Ben, Pampeyan, E. H., and Longwell, C. R., 1958, Geologic map of Clark County, Nevada: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-138.
- 36 Bradley, W. H., 1926, Shore phases of the Green River formation in northern Sweetwater County, Wyoming: U. S. Geol. Survey Prof. Paper 140, p. 121-131.
- 37 _____ 1931, Origin and microfossils of the oil shale of the Green River formation of Colorado and Utah: U. S. Geol. Survey Prof. Paper 168, 58 p.

- 38 _____ 1936, Geomorphology of the north flank of the Uinta Mountains (Utah): U. S. Geol. Survey Prof. Paper 185-I, p. 163-199.
- 39 _____ 1945, Geology of the Washakie Basin, Sweetwater and Carbon Counties, Wyoming, and Moffat County, Colorado: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 32.
- 40 Buddenhagen, H. J., 1951, Oregon, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geol. Bull., v. 35, p. 193-199.
- 41 California Department of Natural Resources, Division of Mines, 1943, Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, 773 p.
- 42 Calkins, F. C., and Butler, B. S., 1943, Geology and ore deposits of the Cottonwood-American Fork area, Utah: U. S. Geol. Survey Prof. Paper 201, 152 p.
- 43 Calkins, F. C., and Emmons, W. H., 1915, Description of the Philipsburg quadrangle, Montana: U. S. Geol. Survey Geol. Atlas, Folio 196.
- 44 Campbell, G. S., 1951, Permian system of Millard County, Utah, in Utah Geol. Soc. Guidebook no. 6: p. 63-65.
- 45 Cashion, W. B., 1957, Stratigraphic relations and oil shale of the Green River formation in the eastern Uinta Basin, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin 1957: p. 131-135.
- 46 Christiansen, F. W., 1952, Structure and stratigraphy of the Canyon Range, central Utah: Geol. Soc. America Bull., v. 63, p. 717-740.

- 47 Chuman, R. W., 1955, Electric log correlation of the Mesaverde group in southwestern Wyoming, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf., 1955: p. 95.
- 48 Coe, A. C., Conant, L. C., and Drakoulis, Sophie, 1955, Oil and gas fields of the United States (map): U. S. Geol. Survey.
- 49 Colle, J. O., Cooke, W. F., Jr., Denham, R. L., Ferguson, H. C., McGuirt, J. H., Reedy, Frank, Jr., and Weaver, Paul, 1952, Volume of Mesozoic and Cenozoic sediments in Western Gulf Coastal Plain of United States, Pt. 4 of Murray, G. E., Sedimentary volumes in Gulf Coastal Plain of United States and Mexico: Geol. Soc. America Bull., v. 63, p. 1193-1199.
- 50 Collins, J. B., 1952, Subsurface cross section of pre-Pennsylvanian rocks from Morton County, Kansas, to Gray County, Texas: U. S. Geol. Survey Oil and Gas Inv. Chart OC-47.
- 51 Coon, L. A., 1957, East Texas Basin hides deep prospects: Oil and Gas Jour., v. 55, no. 3, p. 92-96.
- 52 Corcoran, R. E., 1956, Sedimentary basins in Oregon: World Oil, October 1952, p. 140-142.
- 53 Dane, C. H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, 184 p. (1936).
- 54 _____ 1955, Stratigraphic and facies relationships of the upper part of the Green River formation and the lower part of the Uinta formation in Duchesne, Uintah, and Wasatch Counties, Utah: U. S. Geol. Survey Oil and Gas Inv. Chart OC-52.
- 55 Dane, C. H., and Bachman, G. O., 1957, Preliminary geologic map of the northwestern part of New Mexico: U. S. Geol. Survey Map I-224.

- 56 DeFord, R. K., 1951, Trans-Pecos province, west Texas and southeastern New Mexico, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 347-352.
- 57 Dobbin, C. E., 1939, Geologic structure of St. George district, Washington County, Utah: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 121-144.
- 58 Dobbin, C. E., Bowen, C. F., and Hoots, H. W., 1929, Geology and coal and oil resources of the Hanna and Carbon Basins, Carbon County, Wyoming: U. S. Geol. Survey Bull. 804, 88 p.
- 59 Dobbin, C. E., and Erdmann, C. E., 1955, Structure contour map of the Montana plains: U. S. Geol. Survey Oil and Gas Inv. Map OM-178.
- 60 Dole, H. M., and Corcoran, R. E., 1954, Reconnaissance geology along U. S. Highway 20 between Vale and Buchanan, Malheur and Harney Counties, Oregon: Oregon Dept. Geol. and Mineral Industries, The Ore Bin, v. 16, no. 6.
- 61 Donnell, J. R., 1957, 1,000-foot tests show new 30-gallon oil shale: Oil and Gas Jour., v. 55, no. 29, p. 162.
- 62 Dorr, J. A., Jr., 1952, Early Cenozoic stratigraphy and vertebrate paleontology of the Hoback Basin, Wyoming: Geol. Soc. America Bull., v. 63, p. 59-93.
- 63 _____ 1956, Post-Cretaceous geologic history of the Hoback Basin area, central western Wyoming, in Wyoming Geol. Assoc. Guidebook 11th Ann. Field Conf. 1956, Jackson Hole, Wyoming: p. 99-108.

- 64 Bott, R. H., and Murray, G. E., eds., 1954, Geologic cross section of Paleozoic rocks--central Mississippi to northern Michigan: Tulsa, Am. Assoc. Petroleum Geologists, 32 p.
- 65 Bott, R. H., Jr., 1955, Pennsylvanian stratigraphy of Elko and northern Diamond Ranges, northeastern Nevada: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2211-2305.
- 66 Duncan, D. C., and Belser, Carl, 1950, Geology and oil-shale resources of the eastern part of the Piceance Creek Basin, Rio Blanco and Garfield Counties, Colorado: U. S. Geol. Survey Oil and Gas Inv. Map OM-119.
- 67 Hardley, A. J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 55, p. 819-894.
- 68 _____ 1949, Structural evolution of Utah, in Hansen and Bell, the oil and gas possibilities of Utah: Utah Geol. Mineralog. Survey, p. 10-23.
- 69 _____ 1951, Structural geology of North America: New York, Harper and Brothers, 624 p.
- 70 Easton, W. H., 1951, Eastern desert and mountain region, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 264-269.
- 71 _____ chm., 1953, Revision of stratigraphic units in Great Basin: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 143-151.
- 72 Eby, J. B., 1956, Salt dome interest centers on Gulf Coast: World Oil, Oct. 1956, p. 143-152.

- 73 Eckel, E. B., and others, 1949, Geology and ore deposits of the La Plata district, Colorado: U. S. Geol. Survey Prof. Paper 219, 179 p. (1950)
- 74 Elias, G. K., 1956, Tectonics of the Paradox Basin and its relation to oil occurrence, in Am. Assoc. Petroleum Geologists, Geol. Rec., 6th Ann. Mtg., Rocky Mtn. Sec.: p. 21-27.
- 75 Etherington, T. J., 1951, Washington, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 189-192.
- 76 Felts, W. M., 1954, Occurrence of oil and gas and its relation to possible source beds in continental Tertiary of Intermountain region: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1661-1670.
- 77 Ferguson, H. C., chm., 1951, Western Gulf Coast, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 385-392.
- 78 Ferguson, H. G., Muller, S. W., and Roberts, R. J., 1951a, Geology of the Winnemucca quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map GQ-11.
- 79 _____ 1951b, Geology of the Mount Moses quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map GQ-12.
- 80 _____ 1952, Geology of the Golconda quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map GQ-15.
- 81 Finley, E. A., Dobbin, C. E., and Richardson, E. E., 1955, Preliminary structure contour map of the Colorado plains: U. S. Geol. Survey Oil and Gas Inv. Map OM-176.
- 82 Flawn, P. T., 1954, Summary of southeast New Mexico basement rocks, in New Mexico Geol. Soc., Guidebook 5th Field Conf., Oct. 1954: p. 114-116.

- 83 _____ 1956, Basement rocks of Texas and southeast New Mexico: Texas Univ. Pub. 5605, 261 p.
- 84 Folsom, L. W., 1955, Powder Wash-Ace field, Moffat County, Colorado, in Intermountain Assoc. Petroleum Geologists, Guidebook 6th Ann. Field Conf. 1955: p. 95-98.
- 85 Gill, J. R., and Denson, N. M., 1957, Regional synthesis-eastern Montana and the Dakotas, in Geologic investigations of radioactive deposits, semi-annual progress report, June 1 to Nov. 30, 1957: U. S. Geol. Survey TEI-700, p. 160-171, issued by U. S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge, Tenn.
- 86 Gilluly, James, 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, 171 p.
- 87 Goodhue, Betty, 1957, Geologic map of the Uinta Basin, Utah, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin: pl. 1.
- 88 Granger, A. E., 1953, Stratigraphy of the Wasatch Range near Salt Lake City, Utah: U. S. Geol. Survey Circ. 296, 14 p.
- 89 Granger, A. E., Bell, M. M., Simmons, G. C., and Lee Florence, 1954, Reconnaissance geologic map of Elko County, Nevada: Nevada Bur. Mines Bull. 54, pl. 1.
- 90 Gras, V. B., 1955, Vermilion Creek Basin area, Sweetwater County, Wyoming and Moffat County, Colorado, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf. 1955: p. 177-181.

- 91 Gregory, H. E., 1950, Geology and geography of the Zion Park region, Utah and Arizona: U. S. Geol. Survey Prof. Paper 220, 200 p. (1952).
- 92 Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U. S. Geol. Prof. Paper 164, 161 p.
- 93 Griffiths, M. L. O., 1949, Zones of Pierre formation of Colorado: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 2011-2028.
- 94 Guzman Jimenez, E. J., 1952, Volumes of Mesozoic and Cenozoic sediments in Mexican Gulf Coastal Plain, Pt. 5 of Murray, G. E., sedimentary volumes in Gulf Coastal Plain of the United States and Mexico: Geol. Soc. America Bull., v. 63, p. 1201-1220
- 95 Hale, L. A., 1955, Stratigraphy and facies relationship of the Montanan group in south-central Wyoming, northeastern Utah and northwestern Colorado, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf., 1955, p. 89-94.
- 96 Hammer, A. A., 1934, Rattlesnake Hills gas field, Benton County, Washington: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 847-859.
- 97 Hancock, E. T., 1925, Geology and coal resources of the Axial and Monument Butte quadrangles, Moffat County, Colorado: U. S. Geol. Survey Bull. 757, 134 p.
- 98 Hansen, W. R., 1955, Geology of the Flaming Gorge quadrangle, Utah-Wyoming: U. S. Geol. Survey Geol. Quad. Map GQ-75.
- 99 _____ 1957a, Geology of the Clay Basin quadrangle, Utah: U. S. Geol. Survey Geol. Quad. Map GQ-101.
- 100 _____ 1957b, Structural features of the Uinta arch, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann Field Conf., Guidebook to the geology of the Uinta Basin: p. 35-39.

- 101 Hansen, W. R., and Bonilla, M. G., 1954, Laramide faulting and orogeny on the north flank of the Uinta Mountains in eastern Daggett County, Utah: Colorado Sci. Soc. Proc., v. 17, 29 p.
- 102 _____ 1956, Geology of the Manila quadrangle, Utah-Wyoming: U. S. Geol. Survey Misc. Geol. Inv. Map I-156.
- 103 Hazzard, J. C., 1938, Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, California: California Jour. Mines and Geology, v. 33, p. 273-339.
- 104 Hazzard, J. C., and Moran, W. R., 1952, Reported late Tertiary thrusting in northeastern Nevada: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 844-856.
- 105 Heikkila, H. H., 1953, Horseshoe Creek area, Teton County, Idaho, in Intermountain Assoc. Petroleum Geologists 4th Ann. Field Conf., 1953: p. 93-94.
- 106 Herald, F. A., ed. 1951, Occurrence of oil and gas in northeast Texas: Texas Univ. Pub. 5116, 449 p.
- 107 _____ 1957, Occurrence of oil and gas in west Texas: Texas. Univ. Pub. 5716.
- 108 Herman, George, and Barkell, C. A., 1957, Pennsylvanian stratigraphy and productive zones, Paradox salt basin: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 861-881.
- 109 Herman, George, and Sharps, S. L., 1956, Pennsylvanian and Permian stratigraphy of the Paradox salt embayment, in Intermountain Assoc. Petroleum Geologists Guidebook 7th Ann. Field Conf., Geology and economic deposits of east-central Utah: p. 77-84.

- 110 Hewett, D. F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 162, 172 p.
- 111 _____ 1954a, A fault map of the Mojave Desert region, in Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull., 170, p. 15-18.
- 112 _____ 1954b, General geology of the Mojave Desert region, California, in Chap. 2 of Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull. 170, p. 5-20.
- 113 _____ 1956, Geology and mineral resources of the Ivanpah quadrangle, California and Nevada: U. S. Geol. Survey Prof. Paper 275, 172 p.
- 114 Hintze, L. F., 1951, Ordovician stratigraphy of central Utah, in Utah Geol. Soc. Guidebook no. 6: p. 38-43.
- 115 Hobson, H. D., 1951, Sacramento Valley, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 209-214.
- 116 Hoffman, F. H., 1957, Possibilities of Weber stratigraphic traps, Rangely area, northwest Colorado: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 894-905.
- 117 Hoots, H. W., 1930, Geology and oil resources along the southern border of San Joaquin Valley: U. S. Geol. Survey Bull. 812, p. 243-332.
- 118 Hoots, H. W., and Bear, T. L., 1954, History of oil exploration and discovery in California, in Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull. 170, p. 5-9.
- 119 Hoots, H. W., Bear, T. L., and Kleinpell, W. D., 1954a, Geological summary of the San Joaquin Valley, California, in Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull. 170, p. 113-129.

- 120 _____ 1954b, Stratigraphic traps for oil and gas in the San Joaquin Valley, California, in Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull. 170, p. 29-32.
- 121 Hopper, R. H., 1947, Geologic section from the Sierra Nevada to Death Valley, California: Geol. Soc. America Bull., v. 58, p. 393-432.
- 122 Howe, R. A., 1955, Tip Top field, Wyoming: Am. Assoc. Petroleum Geologists Rocky Mtn. Sec., Geol. Rec., Feb. 1955, p. 187-194.
- 123 Hughes, P. W., 1954, New Mexico's deepest oil test, in New Mexico Geol. Soc., Guidebook 5th Field Conf., Oct. 1954, p. 124-130.
- 124 Hunt, C. B., 1946, Guidebook to the geology and geography of the Henry Mountain region: Utah Geol. Soc. Guidebook no. 1, 51 p.
- 125 Hunt, C. B., 1956, Cenozoic geology of the Colorado Plateau: U. S. Geol. Survey Prof. Paper 279, 99 p.
- 126 Hunt, C. B., Averitt, Paul, and Miller, R. L., 1953, Geology and geography of the Henry Mountains region, Utah: U. S. Geol. Survey Prof. Paper 228, 234 p.
- 127 Inlay, R. W., 1943, Jurassic formations of Gulf region (of North America including United States, Mexico and Cuba): Am. Assoc. Petroleum Geologists Bull., v. 27, p. 1407-1533.
- 128 Jahns, R. H., ed., 1954, Geology of southern California: California Div. Mines Bull. 170.
- 129 Jenkins, O. P., 1938, Geologic map of California: California Div. Mines.
- 130 Joesting, H. R., and Byerly, P. E., 1956, Aeromagnetic and gravity profiles across the Uravan area, Colorado, in Intermountain Assoc. Petroleum Geologists Guidebook 7th Ann. Field Conf., Geology and economic deposits of east-central Utah: p. 38-41.

- 131 Johnson, M. S., and Hibbard, D. E., 1957, Geology of the Atomic Energy Commission Nevada Proving Grounds Area, Nevada: U. S. Geol. Survey Bull. 1021-K, p. 333-384.
- 132 Jones, D. J., Picard, M. D., and Wyeth, J. C., 1954, Correlation of nonmarine Cenozoic of Utah: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2219-2222.
- 133 Jones, W. B., and McGlamery, Winnie, 1957, Major oil field is seen in Citronelle structure: World Oil, March 1957, p. 99-102.
- 134 Kay, G. M., 1951, North American geosynclines: Geol. Soc. America Mem. 48, 143 p.
- 135 Keefer, W. R., and Rich, E. I., 1957, Stratigraphy of the Cody shale and younger Cretaceous and Paleocene rocks, in the western and southern parts of the Wind River Basin, Wyoming, in Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf., Southwest Wind River Basin, 1957: p. 71-78.
- 136 Kelley, V. C., 1954, Tectonic map of a part of the Upper Rio Grande area, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM-157.
- 137 _____ 1955, Regional tectonics of the Colorado Plateau and relationship to the origin and distribution of uranium: New Mexico Univ. Pub. Geology, no. 5, 120 p.
- 138 _____ 1956, Tectonics of the Colorado Plateau: Am. Assoc. Petroleum Geologists Rocky Mtn. sec., Geol. Rec. Feb. 1956, p. 99-108.
- 139 Kilkenny, J. E., 1951, San Joaquin Valley, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 215-218.

- 140 King, P. B., and others, 1944, Tectonic map of the United States: Am. Assoc. Petroleum Geologists.
- 141 Kinney, D. M., 1955, Geology of the Uinta River-Brush Creek area, Duchesne and Uintah Counties, Utah: U. S. Geol. Survey Bull. 1007, 185 p.
- 142 Kirk, Edwin, 1918, Stratigraphy of the Inyo Range (southern California): U. S. Geol. Survey Prof. Paper 110, p. 19-48.
- 143 Kirkham, V. R. D., 1931, Snake River downwarp: Jour. Geology, v. 39, p. 456-482.
- 144 _____ 1935, Natural gas in Washington, Idaho, eastern Oregon, and northern Utah, in Ley, H. A., Geology of natural gas: Am. Assoc. Petroleum Geologists, p. 221-244.
- 145 Knight, S. H., 1951, The late Cretaceous-Tertiary history of the northern portion of the Hanna Basin, Carbon County, Wyoming, in Wyoming Geol. Assoc. Guidebook 6th Ann. Field Conf., 1951: p. 45-53.
- 146 Kunkel, R. P., 1954, Structure contour map of the base of Mississippian rocks in the Williston Basin and adjoining areas of Montana, North Dakota, South Dakota, and Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-165.
- 147 Kupfer, D. H., and Bassett, A. M., 1956, Preliminary geologic map of part of southeastern Mojave Desert, California: U. S. Geol. Survey open file map.
- 148 Lafferty, R. C., 1951, Appalachian region, in Ball, M. W., ed. Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 438-457.
- 149 Lasky, S. G., 1947, Geology and ore deposits of the Little Hatchet Mountains Hidalgo and Grant Counties, New Mexico: U. S. Geol. Survey Prof. Paper 208, 101 p.

- 150 Lavin, P. M., and Bonini, W. E., 1957, Detailed gravity measurements in the Teton Range and Jackson Hole, Wyoming [abs.]: Geol. Soc. America Bull., v. 68, p. 1760.
- 151 Linn, E. H., 1956, Sedimentation--key to Appalachian production: Oil and Gas Jour., v. 54, no. 52, p. 165-173.
- 152 Lintz, Joseph, Jr., 1957a, What does Nevada's oil promise for the future?: Oil and Gas Jour., v. 55, no. 13, p. 243-251.
- 153 _____ 1957b, Nevada oil and gas drilling data, 1906-1953: Nevada Bur. Mines Bull. 52.
- 154 Lloyd, S. J., 1956, Prospects for deep drilling in Alabama: World Oil, March 1956, p. 102-106.
- 155 Longwell, C. R., 1949, Structure of the northern Muddy Mountain area, Nevada: Geol. Soc. America Bull., v. 60, p. 923-967.
- 156 Love, J. D., 1952, Chart showing correlation of Upper Cretaceous and Paleocene rocks in the southern part of the Bighorn Basin and adjacent areas, in Wyoming Geol. Assoc. Guidebook 7th Ann. Field Conf., Southern Big Horn Basin, Wyoming, 1952: facing p. 88.
- 157 _____ 1956a, Cretaceous and Tertiary stratigraphy of the Jackson Hole area, northwestern Wyoming, in Wyoming Geol. Assoc. Guidebook 11th Ann. Field Conf., Jackson Hole, Wyoming, 1956: p. 76-94.
- 158 _____ 1956b, Summary of geologic history of Teton County, Wyoming, during Late Cretaceous, Tertiary, and Quaternary times, in Wyoming Geol. Assoc. Guidebook 11th Ann. Field Conf., Jackson Hole, Wyoming, 1956: p. 140-150.
- 159 Love, J. D., Weitz, J. L., and Hose, R. K., 1955, Geologic map of Wyoming: U. S. Geol. Survey.

- 160 Lapher, R. L., 1941, Jurassic stratigraphy of central Oregon: Geol. Soc. America Bull., v. 52, p. 219-269.
- 161 Mabey, D. R., 1957, Gravity studies of Basin and Range geology [abs.]: Oil and Gas Jour., v. 55, no. 13, p. 188.
- 162 Maher, J. C., 1955, Geologic cross sections sponsored by geological societies affiliated or cooperating with the American Association of Petroleum Geologists, 1931-1955: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1405-1416.
- 163 Maher, J. C., and Lantz, R. J., 1953, Correlation of pre-Atoka rocks in the Arkansas Valley, Arkansas: U. S. Geol. Survey Oil and Gas Inv. Chart OC-51.
- 164 Mallory, W. W., 1956, Tectonic development of the Cordilleran region: Am. Assoc. Petroleum Geologists Rocky Mtn. Sec. Geol. Rec., Feb. 1956, p. 37-47.
- 165 Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 1-409.
- 166 Mapel, W. J., and Hail, W. J., 1956, Tertiary stratigraphy of the Goose Creek district, Cassia County, Idaho, and adjacent parts of Utah and Nevada, in Guidebook to the geology of Utah, no. 11, Geology of parts of northwestern Utah: p. 1-16.
- 167 Marsell, R. D., ed., 1952, Geology of the central Wasatch Mountains, Utah: Utah Geol. Soc. Guidebook no. 8, 71 p.
- 168 Mason, J. F., 1948, Geology of the Tecopa Area, southeastern California: Geol. Soc. America Bull., v. 59, p. 333-352.
- 169 McCabe, W. S., 1954, Williston Basin Paleozoic unconformities: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1997-2010.

- 170 McCaslin, J. C., 1957, Sooner Wildcatters sight Anadarko's deep sands:
Oil and Gas Jour., v. 55, no. 20, p. 250-251.
- 171 McGlothlin, Tom, 1944, General geology of Mississippi: Am. Assoc.
Petroleum Geologists Bull., v. 28, p. 29-62.
- 172 _____ chm., 1951, Southeastern United States, in Ball, M. W., ed.,
Possible future petroleum provinces of North America: Am. Assoc.
Petroleum Geologists Bull., v. 35, p. 399-402.
- 173 McGrew, L. W., 1955, Map of Wyoming showing test wells for oil and gas,
anticlines, oil and gas fields, and pipelines: U. S. Geol. Survey
Oil and Gas Inv. Map OM-175.
- 174 McIntyre, L. B., 1955, Correlation chart, Shell Creek-Pine Butte areas,
Washakie Basin, Wyoming, in Wyo. Geol. Assoc. Guidebook 10th Ann.
Field Conf., Green River Basin, 1955: facing p. 176.
- 175 McKee, E. D., 1951, Sedimentary Basins of Arizona and adjoining areas:
Geol. Soc. America Bull., v. 62, p. 481-505.
- 176 McKee, E. D., and others, 1956, Paleotectonic maps of the Jurassic system:
U. S. Geol. Survey Misc. Geol. Inv. Map I-175, 6 p.
- 177 Meholin, G. L., chm., 1952, North-south cross section, Seward County,
Kansas to Floyd County, Texas: Panhandle Geol. Soc., chart.
- 178 Merriam, C. W., and Berthiaume, S. A., 1943, Late Paleozoic formations
of central Oregon: Geol. Soc. America Bull., v. 54, p. 145-171.
- 179 Miller, C. F., 1957, Combined geologic and physiographic map of North
and Middle Parks, Colorado, in Rocky Mtn. Assoc. Petroleum
Geologists Guidebook 9th Ann. Field Conf., North and Middle Park
Basin, Colorado, 1957: Map (in pocket).

- 180 Miller, R. L., 1948, Rose Hill oil field, Lee County, Virginia, in Howell, J. V., ed., Structure of typical American oil fields: Am. Assoc. Petroleum Geologists, v. 3, p. 452-479.
- 181 Miller, R. L., and Brosge, W. P., 1950, Geology of the Jonesville district, Lee County, Virginia: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 104.
- 182 Milton, Charles, 1957, Authigenic minerals of the Green River formation of the Uinta Basin, Utah, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin, 1957, p. 136-143.
- 183 Miser, H. D., 1954, Geologic map of Oklahoma: U. S. Geol. Survey.
- 184 Morrissey, N. S., 1956, Deep south ready for deep payoff: Oil and Gas Jour., v. 54, no. 52, p. 156-163.
- 185 Muller, S. W., Ferguson, H. G., and Roberts, R. J., 1951, Geology of the Mount Tobin quadrangle, Nevada: U. S. Geol. Survey Geol. Quad. Map GQ-7.
- 186 Murray, G. E., Jr., 1947, Cenozoic deposits of central Gulf Coastal Plain (U. S.): Am. Assoc. Petroleum Geol. Bull., v. 31, p. 1825-1850.
- 187 _____ 1952, Volume of Mesozoic and Cenozoic sediments in Central Gulf Coastal Plain of United States, Pt. 3 of Sedimentary volumes in Gulf Coastal Plain of the United States and Mexico: Geol. Soc. America Bull., v. 63, p. 1177-1192.
- 188 _____ 1957, The Gulf Coastal province: Oil and Gas Jour., v. 55, no. 44, p. 109-116.

- 189 Neighbor, Frank, 1953, Big Elk Mountain anticline, Bonneville County, Idaho, in Intermountain Assoc. Petroleum Geologists 4th Ann. Field Conf., 1953: p. 88-92.
- 190 Nettleton, L. L., 1952, Geophysical aspects, Pt. 6, of Murray, G. E., Sedimentary volumes in Gulf Coastal Plains of the United States and Mexico: Geol. Soc. America Bull., v. 63, p. 1221-1228.
- 191 Newell, N. D., 1948, Key Permian section, Consufion Range, western Utah: Geol. Soc. America Bull., v. 59, p. 1053-1058.
- 192 New Mexico Geological Society, 1951, Rio Grand Basins, New Mexico and Colorado, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 308-311.
- 193 _____ 1954, Guidebook of southeastern New Mexico, 5th Field Cong., Oct. 21-24, 1954: 209 p.
- 194 Noble, L. F., 1941, Structural features of the Virgin Spring area, Death Valley, California: Geol. Soc. America Bull., v. 52, p. 941-999.
- 195 Noble, L. F., and Wright, L. A., 1954, Geology of the central and southern Death Valley region, California, in Jahns, R. H., ed., Geology of southern California: California Div. Mines Bull. 170, p. 143-160.
- 196 Nolan, T. B., 1935, The Gold Hill mining district, Utah: U. S. Geol. Survey Prof. Paper 177, 172 p.
- 197 _____ 1943, The Basin and Range province in Utah, Nevada, and California: U. S. Geol. Survey Prof. Paper 197-D, p. 141-196.

- 198 Nolan, T. B., Merriam, C. W., and Williams, J. S., 1956, The stratigraphic section in the vicinity of Eureka, Nevada: U. S. Geol. Survey Prof. Paper 276, p. 1-77.
- 199 North Dakota and Saskatchewan Geological Society, 1956, Williston Basin--a symposium: 202 p.
- 200 Oakeshott, G. B., Braun, L. T., Jennings, C. W., and Wells, Ruth, 1952, Exploratory wells drilled outside of oil and gas fields in California to Dec. 31, 1950: California Div. Mines Spec. Rpt. 23, 77 p.
- 201 O'Boyle, C. C., 1955, The Cretaceous rocks of northwest Colorado, in Intermountain Assoc. Petroleum Geologists, Guidebook 6th Ann. Field Conf., 1955: p. 32-35.
- 202 Ogden, Lawrence, 1951, Mississippian and Pennsylvanian stratigraphy, Confusion Range, west-central Utah: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 62-82.
- 203 Oil and Gas Journal, 1957a, Escambia County test given up as failure; Tulsa, Okla., The Petroleum Publishing Co., v. 55, no. 1, p. 182.
- 204 _____ 1957b, South Louisiana deep drilling--1956: T, O, TPPCo., v. 55, no. 4, p. 217.
- 205 _____ 1957c, Southeast New Mexico--1956: T, O, TPPCo., v. 55, no. 4, p. 218.
- 206 _____ 1957d, Depth records fall in nine States: T, O, TPPCo., v. 55, no. 4, p. 147-149.
- 207 _____ 1957e, West-Texas--1956: T, O, TPPCo., v. 55, no. 4, p. 219.
- 208 Oriel, S. S., 1954, Major tectonic elements of Colorado--a review, in Jensen, F. S., chm., The oil and gas fields of Colorado--a symposium: Rocky Mtn. Assoc. Geologists, p. 41-48.

- 209 Osmond, J. C., Jr., 1954, Dolomites in Silurian and Devonian of east-central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1911-1956.
- 210 Osterwald, F. W., and Dean, B. G., 1957, Tectonics of north-central Colorado, in Rocky Mountain Assoc. Petroleum Geologists Guidebook 9th Ann. Field Conf., North and Middle Parks Basin, Colorado, 1957: p. 13-17.
- 211 O'Sullivan, R. B., and Beaumont, E. D., 1957, Preliminary geologic map of western San Juan Basin, San Juan and McKinley Counties, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Map OM-190.
- 212 Panhandle Geological Society, 1953, West-east cross section, Union County, New Mexico, to Ellis County, Oklahoma: Panhandle Geol. Soc. chart.
- 213 Peace, F. S., 1956, History of exploration for oil and gas in Box Elder County, Utah, and vicinity, in Guidebook to the geology of Utah, no. 11, Geology of parts of northwestern Utah: p. 17-31.
- 214 Pedry, J. J., 1957, Cottonwood Creek field, Washakie County, Wyoming, carbonate stratigraphic trap: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 823-838.
- 215 Philpott, T. H., and Hazzard, R. T., 1949, Preliminary correlation chart--Upper Gulf Coast, in Shreveport, Geol. Soc. Guidebook 17 Ann. Field Trip, Cretaceous of Austin, Texas area, 1949, fig. 5.
- 216 Picard, M. D., 1955a, Subsurface stratigraphy and lithology of Green River formation in Uinta Basin, Utah: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 75-102.
- 217 _____ 1955b, Oil and gas developments in Utah and Nevada in 1954: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1035-1045.

- 218 _____ 1957, Green River and lower Uinta formations--subsurface stratigraphic changes in central and eastern Uinta Basin, Utah, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin, 1957: p. 116-130.
- 219 Pierce, W. G., Andrews, D. A., and Kerher, J. K., 1947, Structure contour map of the Big Horn Basin, Wyoming and Montana: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 74.
- 220 Piper, A. M., Robinson, T. W., Jr., and Park, C. F., Jr., 1939, Geology and ground-water resources of the Harney Basin, Oregon: U. S. Geol. Survey Water-Supply Paper 841, 189 p.
- 221 Post, J. D., 1955, Geology of the east Washakie Basin, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf., 1955: p. 182-185.
- 222 Pray, L. C., 1954, Outline of the stratigraphy and structure of the Sacramento Mountain escarpment, in New Mexico Geol. Soc., Guidebook 5th Field Conf., Oct. 1954: p. 92-107.
- 223 Pressler, E. D., 1947, Geology and occurrence of oil in Florida: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1851-1862.
- 224 Read, C. B., Wilpolt, R. H., Andrews, D. A., Summerson, C. H., and Wood, G. H., Jr., 1944, Geologic map and stratigraphic sections of San Miguel, Santa Fe, Sandoval, Bernalillo, Tarrant, and Valencia Counties, north-central New Mexico: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 21.
- 225 Read, C. B., and Wood, G. H., Jr., 1947, Distribution and correlation of Pennsylvanian rocks in late Paleozoic sedimentary basins of northern New Mexico: Jour. Geology, v. 55, p. 220-236.

- 226 Reber, S. J., 1952, Stratigraphy and structure of the south-central and northern Beaver Dam Mountains, Utah, in Thune, H. W., ed., Utah Geol. Soc. Guidebook, no. 7: p. 101-108.
- 227 Reed, R. D., and Hollister, J. S., 1936, Structural evolution of southern California: Am. Assoc. Petroleum Geologists Bull., v. 20, p. 1529-1704.
- 228 Reeside, J. B., Jr., 1944, Map showing thickness and general character of the Cretaceous deposits in the western interior of the United States: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 10.
- 229 _____ 1955, Revised interpretation of the Cretaceous section on Vermilion Creek, Moffat County, Colorado, in Wyoming Geol. Assoc., Guidebook 10th Ann. Field Conf. 1955: p. 85-88.
- 230 Reid, J. W., 1954, The structural and stratigraphic history of the Carboniferous (Mississippian and Pennsylvanian) of the Wasatch Plateau and environs (Utah), in Intermountain Assoc. Petroleum Geologists, 5th Ann. Field Conf., 1954: p. 18-20.
- 231 Richards, H. G., 1945, Subsurface stratigraphy of Atlantic Coastal Plain between New Jersey and Georgia: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 885-955.
- 232 _____ 1956, Don't write off the Atlantic Coastal Plain: Oil and Gas Jour., v. 54, no. 52, p. 182-191.
- 233 Ritzma, H. R., 1955, Early Cenozoic history of the Sand Wash Basin, north-west Colorado, in Intermountain Assoc. Petroleum Geologists, Guidebook 6th Ann. Field Conf., 1955: p. 36-40.
- 234 _____ 1956, Structural development of the eastern Uinta Mountains and vicinity, Colorado, Utah, and Wyoming: Am. Assoc. Petroleum Geologists Rocky Mtn. Sec., Geol. Rec., Feb. 1956, p. 119-128.

- 235 Robinson, T. W., 1953, Big Smoky Valley, Nevada, Chap. 8 of U. S. Cong.,
House Comm. Interior and Insular Affairs, Subsurface facilities of
water management and patterns of supply--type area studies: p. 130-146.
- 236 Ross, C. P., Andrews, D. A., and Witkind, I. J., 1955, Geologic map of
Montana: U. S. Geol. Survey.
- 237 Ross, C. P., and Forrester, J. D., 1947, Geologic map of the State of
Idaho: U. S. Geol. Survey.
- 238 Roth, R. I., 1934, Type section of Hermosa formation, Colorado: Am. Assoc.
Petroleum Geologists Bull., v. 18, p. 944-947.
- 239 Rush, R. W., 1951, Stratigraphy of the Burbank Hills, western Millard
County, Utah: Utah Geol. Mineralog. Survey Bull. 38, 24 p.
- 240 Sadlick, Walter, 1957, Regional relations of Carboniferous rocks of north-
eastern Utah, in Intermountain Assoc. Petroleum Geologists Guidebook
8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin,
1957: p. 56-77.
- 241 Sandeen, W. M., 1954, Geology of the Tularosa Basin, New Mexico, in New Mexico
Geol. Soc., Guidebook 5th Field Conf., Oct. 1954: p. 81-88.
- 242 Schultz, A. R., 1914, Geology and geography of a portion of Lincoln
County, Wyoming: U. S. Geol. Survey Bull. 543, 141 p.
- 243 _____ 1920, Oil possibilities in and around Baxter Basin, in the Rock
Springs uplift, Sweetwater County, Wyoming: U. S. Geol. Survey Bull.
702, 107 p.
- 244 Seal, O. G., ed., 1957, Guidebook to the geology of the Uinta Basin,
Intermountain Assoc. Petroleum Geologists, 8th Ann. Field Conf., 224 p.

- 245 **Sears, J. D., 1924, Geology and oil and gas prospects of part of Moffat County, Colorado, and southern Sweetwater County, Wyoming: U. S. Geol. Survey Bull. 751, p. 269-319.**
- 246 **Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The geology of Texas, v. 1, Stratigraphy: Texas Univ. Bull. 3232, 1007 p. (1933).**
- 247 **Sellards, E. H., and Baker, C. L., 1934, The geology of Texas, v. 2, Structural and economic geology: Texas Univ. Bull. 3401, 884 p. (1935).**
- 248 **Sharp, R. P., 1939, The Miocene Humboldt formation in northeastern Nevada: Jour. Geology, v. 47, p. 133-160.**
- 249 **_____ 1942, Stratigraphy and structure of the southern Ruby Mountains, Nevada: Geol. Soc. America Bull., v. 53, p. 647-690.**
- 250 **Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U. S. Geol. Survey Prof. Paper 205-D, p. 117-161.**
- 251 **_____ 1949, The transition between the Colorado plateaus and the great basin in central Utah: Utah Geol. Soc. Guidebook, no. 4, 106 p.**
- 252 **Stipp, T. F., and Haigler, L. B., 1956, Preliminary structure contour map of a part of southeastern New Mexico showing oil and gas development: U. S. Geol. Survey Oil and Gas Inv. Map OM-177 (1957).**
- 253 **Storm, L. W., 1945, Resume of facts and opinions on sedimentation in Gulf Coast region of Texas and Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1304-1335.**
- 254 **Stuffield, H. F., 1956, Anadarko Basin yields deep production: Oil and Gas Jour., v. 54, no. 83, p. 172-182.**

- 255 Swain, B. W., 1957, Fort Union formation, west flank of Sierra Madre, Carbon County, Wyoming [abs.]: Geol. Soc. America Bull., v. 68, p. 1874.
- 256 Swain, F. M., 1944, Stratigraphy of Cotton Valley beds of northern Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 577-614.
- 257 _____ 1949, Upper Jurassic of northeastern Texas: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1206-1250.
- 258 Swann, D. H., compiler, and others, 1951, Eastern Interior Basin, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 486-498.
- 259 Ten Eyck, R. G., 1951, Nevada, in Ball, M. W., ed., Possible future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 270-273.
- 260 Thompson, D. G., 1929, The Mojave Desert region, California, a geographic, geologic, and hydrologic reconnaissance: U. S. Geol. Survey Water-Supply Paper 578, 759 p.
- 261 Thune, H. W., ed., 1952, Cedar City, Utah, to Las Vegas, Nevada: Utah Geol. Soc. Guidebook No. 7, 165 p.
- 262 Totten, R. B., 1956, General geology and historical development, Texas and Oklahoma Panhandles: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 1945-1967.
- 263 Toulmin, L. D., Jr., 1952, Volume of Cenozoic sediments in Florida and Georgia, Pt. 2 of Murray, G. D., Sedimentary volumes in Gulf Coastal Plain of the United States and Mexico: Geol. Soc. America Bull., v. 63, p. 1165-1176.

- 264 _____ 1955, Cenozoic geology of southeastern Alabama, Florida and Georgia: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 207-235.
- 265 Tulsa Geological Society, 1951, in Ball, M. W., ed., Possible future petroleum provinces of North America, Midcontinent region: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 316-343.
- 266 Utah Geological Society, 1951, Geology of the Canyon, House, and Confusion Ranges, Millard County, Utah: Utah Geol. Soc. Guidebook no. 6, 113 p.
- 267 Van Houten, F. B., 1956, Reconnaissance of Cenozoic sedimentary rocks of Nevada: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2801-2825.
- 268 Veatch, A. C., 1907, Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, 178 p.
- 269 Wallace, R. E., and Calkins, J. A., 1956, Reconnaissance geologic map of the Izee and Logdell quadrangles, Oregon: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-82.
- 270 Walton, P. T., 1957, Cretaceous stratigraphy of the Uinta Basin, in Intermountain Assoc. Petroleum Geologists Guidebook 8th Ann. Field Conf., Guidebook to the geology of the Uinta Basin, 1957: p. 97-101.
- 271 Wanless, H. R., and Patterson, J., 1952, Cyclic sedimentation in the marine Pennsylvanian of the southwestern United States: Cong. Av. Etudes de Stratigraphie et de Geologie du Carbonifere, 3 e, Heerlen, juin 25-30, 1951, Compte rendu, tome 2, p. 655-664.
- 272 Warren, W. C., Norbistrath, Hans, Grivetti, R. M., and Brown, S. P., 1945, Preliminary geologic map and brief description of the coal fields of King County, Washington: U. S. Geol. Survey.

- 273 Washington Department of Conservation and Development, 1936, Preliminary geologic map of the State of Washington: Washington Dept. Conserv. and Devel., Div. Geology.
- 274 Waters, J. A., McFarland, P. W., and Lea, J. W., 1955, Geologic framework of Gulf Coastal Plain of Texas: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1821-1850.
- 275 Weaver, C. E., 1945, Geology of Oregon and Washington and its relation to occurrence of oil and gas: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1377-1415.
- 276 Weaver, Paul, 1955, Gulf of Mexico, in Poldervaart, A., ed., Crust of the earth--a symposium: Geol. Soc. America Spec. Paper 62, p. 269-278.
- 277 Weitz, J. L., and Love, J. D., 1952, Geologic map of Carbon County, Wyoming: Wyoming Geol. Survey and Wyoming Univ. Dept. Geology.
- 278 Wells, L. F., 1951, Summary of previous geologic work in the Confusion Range, Utah, in Utah Geol. Soc. Guidebook no. 6: p. 26-28.
- 279 Wengerd, S. A., 1956, Paradox oil in the Four Corners region: Oil and Gas Jour., v. 54, no. 73, p. 106-111.
- 280 Wengerd, S. A., and Strickland, J. W., 1954, Pennsylvanian stratigraphy of Paradox salt basin, Four Corners region, Colorado and Utah: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2157-2199.
- 281 Westgate, L. G., and Knopf, Adolph, 1932, Geology and ore deposits of the Pioche district, Nevada: U. S. Geol. Survey Prof. Paper 171, 79 p.
- 282 Wheeler, H. E., and McNair, A. H., 1950, Late Tertiary thrusting in northeastern Nevada [abs.]: Geol. Soc. America Bull., v. 61, p. 1513-1514.

- 283 Wheeler, H. E., and Steele, Grant, 1951, Cambrian sequence of the House Range, Utah, in Utah Geol. Soc. Guidebook no. 6: p. 29-37.
- 284 Williams, Neil, 1957, Lower Cretaceous score in Mississippi: Oil and Gas Jour., v. 55, no. 34, p. 167-168.
- 285 Wilson, J. B., 1951, Stratigraphy of the Sussex sandstone, Powder River Basin, Wyoming: Wyoming Geol. Survey Rept. Inv. 3, 11 p.
- 286 World Oil, 1956, Drilling depth record: Houston, Texas, The Gulf Publishing Co., v. 142, no. 3, p. 142-146.
- 287 Wyoming Geological Association, 1950, Fifth Annual Field Conf. Guidebook, Southwest Wyoming, August 8-11, 1950: 196 p.
- 288 _____ 1955, Guidebook, 10th Ann. Field Conf., 1955, Green River Basin [Colo.--Utah--Wyo.]: 243 p.
- 289 Yenne, K. A., and Pipiringos, G. N., 1954, Stratigraphic sections of Cody shale and younger Cretaceous and Paleocene rocks in the Wind River Basin, Fremont County, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Chart OC-49.
- 290 Young, R. G., 1955, Sedimentary facies and intertonguing in the Upper Cretaceous of the Book Cliffs, Utah-Colorado: Geol. Soc. America Bull., v. 66, p. 177-201.
- 291 _____ 1957, Late Cretaceous cyclic deposits, Book Cliffs, eastern Utah: Am. Assoc. Petroleum Geologists Bull., v. 41, p. 1760-1774.
- 292 Youngquist, Walter, and Killsgaard, T. H., 1951, Recent test drilling, Snake River Plains, southwestern Idaho: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 90-96.

- 293 Zapp, A. D., 1952, Structure contour map of the Powder River Basin,
Wyoming and Montana: U. S. Geol. Survey Oil and Gas Inv. Map OM-133.
- 294 _____ 1956, Structure contour map of the Tensleep sandstone in the
Big Horn Basin, Wyoming and Montana: U. S. Geol. Survey Oil and Gas
Inv. Map OM-182.

Index to references*

1. Atlantic Coastal Plain -- 6, 28, 231, 232
2. Eastern Triassic Basins -- See United States, General
3. Appalachian Basin -- 134, 148, 151, 180, 181
4. Gulf Coastal Plain
 - 4a. Florida -- 9, 203, 223, 263, 264
 - 4b. Alabama -- 154, 172, 187, 188, 263, 264
 - 4c. Mississippi -- 26, 27, 33, 64, 171, 172, 184,
187, 188, 284
 - 4d. Desha Basin, Arkansas-Mississippi -- 27, 33, 64,
171, 188
 - 4e. Louisiana -- 162, 186, 187, 188, 190, 204, 215,
253, 256
 - 4f. Tyler Basin, Texas -- 48, 72, 106, 127, 257, 274
 - 4g. Texas Gulf Coast -- 49, 72, 77, 107, 162, 188,
190, 246, 247, 274, 276
5. Michigan Basin -- 64
6. Illinois Basin -- 258
7. Forest City Basin, Iowa-Missouri -- See United States, General
8. Salina Basin, Kansas-Nebraska -- See United States, General
9. McAlester-Arkansas Basin, Arkansas-Oklahoma -- 22, 134, 163
10. Anadarko Basin, Oklahoma -- 10, 11, 12, 13, 14, 22, 50,
170, 177, 183, 212, 254, 262, 265
11. Ft. Worth Basin, Texas -- See United States, General
12. Val Verde Basin, Texas -- See United States, General
13. Midland Basin, Texas -- 56, 83, 123
14. Delaware Basin, New Mexico-Texas -- 20, 21, 56, 82, 83, 193,
205, 206, 207, 222, 252

15. Palo Duro Basin, Texas -- 262
16. Dalhart Basin, Texas -- 262
17. Denver Basin, Colorado -- 81
18. Powder River Basin, Wyoming -- 285, 293
19. Williston Basin, North Dakota -- 24, 34, 85, 146, 169, 199
20. Rio Grande Basins, New Mexico -- 136, 149, 192, 224, 225,
228, 241
21. Southwestern New Mexico -- 149
22. San Juan Basin, Colorado-New Mexico -- 55, 73, 137, 176, 211,
225, 238, 271, 286
23. Black Mesa Basin, Arizona -- 125, 137, 176, 192
24. Kaiparowits Basin, Utah -- 4, 16, 92, 125, 126, 137, 176,
261, 266
25. San Luis Basin, Colorado-New Mexico -- 192
26. Paradox Basin, Utah-Colorado -- 16, 53, 74, 108, 109, 130,
137, 138, 279, 280
27. Piceance Basin, Colorado -- 61, 66, 116, 137, 208
28. Uinta Basin, Utah -- 1, 5, 37, 45, 54, 87, 100, 116, 125,
137, 141, 175, 182, 216, 218
29. North and Middle Parks, Colorado -- 61, 93, 179, 210
30. Laramie Basin, Wyoming -- See United States, General
31. Hanna Basin, Wyoming -- 58, 145
32. Washakie Basin-SandWash Basin area, Colorado-Wyoming -- 23,
39, 47, 84, 90, 95, 159, 174, 201, 208,
214, 221, 229, 233, 234, 245, 255, 277
33. Red Desert Basin, Wyoming -- See United States, General
34. Green River Basin, Wyoming -- 16, 30, 36, 38, 62, 63, 98, 99, 101,
102, 122, 242, 243, 268, 287, 288

35. Jackson Hole, Wyoming -- 150, 157, 158
36. Wind River Basin, Wyoming -- 135, 159, 289
37. Bighorn Basin, Montana -- 3, 7, 156, 173, 214, 219, 294
38. Crazy Mountain Syncline, Montana -- 7, 8, 29, 59
39. Western Montana -- 43, 236
40. Snake River Downwarp, Idaho-Oregon -- 2, 32, 76, 105, 143, 144,
165, 166, 189, 213, 236,
237, 292
41. Salt Lake-Utah Lake area, Utah -- 17, 42, 67, 86, 88, 161,
167, 250, 251
42. West-central Utah -- 15, 44, 46, 68, 76, 114, 124, 132, 166,
176, 191, 196, 202, 230, 239, 248, 266,
278, 283
43. Southwestern Utah -- 57, 76, 91, 175, 176, 226, 261
44. Elko-Humboldt area, Nevada -- 35, 65, 78, 79, 80, 89, 104,
132, 166, 176, 185, 197, 198,
209, 217, 235, 248, 249, 259,
261, 267, 281, 282
45. Carson-Black Rock area, Nevada -- 152, 153
46. Muddy Creek Mountains, Nevada -- 35, 113, 131, 155, 261
47. East-central California -- 25, 70, 103, 110, 121, 129,
142, 194, 195
48. Mojave Desert, California -- 111, 112, 113, 128, 129, 147,
168, 194, 260
49. San Joaquin Valley, California -- 41, 117, 118, 119, 120,
129, 139, 200, 227
50. Sacramento Valley, California -- 115, 129
51. Harney Basin, Oregon -- 52, 60, 220, 275
52. Central Oregon -- 52, 160, 178, 275
53. Western Oregon -- 18, 19, 40, 52, 269, 275
54. Central Washington -- 96, 75, 273, 275

55. Western Washington -- 69, 75, 272, 273, 275

United States, General -- 48, 69, 134, 140

United States, Regional -- 7, 31, 37, 64, 68, 70, 71, 75,
76, 94, 114, 118, 128, 129, 132,
137, 138, 144, 159, 164, 173, 175,
176, 183, 184, 206, 207, 208, 217,
228, 236, 237, 246, 247, 273, 275

Map Index

1. Atlantic Coastal Plain
2. Eastern Triassic Basins
3. Appalachian Basin
- 4a. Florida
- 4b. Alabama
- 4c. Mississippi
- 4d. Desha Basin, Arkansas-Mississippi
- 4e. Louisiana
- 4f. Tyler Basin, Texas
- 4g. Texas Gulf Coast
5. Michigan Basin
6. Illinois Basin
7. Forest City Basin, Iowa-Missouri
8. Salina Basin, Kansas-Nebraska
9. McAlester-Arkansas Basin, Arkansas-Oklahoma
10. Anadarko Basin, Oklahoma
11. Ft. Worth Basin, Texas
12. Val Verde Basin, Texas
13. Midland Basin, Texas
14. Delaware Basin, New Mexico-Texas
15. Palo Duro Basin, Texas
16. Dalhart Basin, Texas
17. Denver Basin, Colorado
18. Powder River Basin, Wyoming

19. Williston Basin, North Dakota
20. Rio Grande Basins, New Mexico
21. Southwestern New Mexico
22. San Juan Basin, Colorado-New Mexico
23. Black Mesa Basin, Arizona
24. Kaiparowits Basin, Utah
25. San Luis Basin, Colorado-New Mexico
26. Paradox Basin, Utah-Colorado
27. Piceance Basin, Colorado
28. Uinta Basin, Utah
29. North and Middle Parks, Colorado
30. Laramie Basin, Wyoming
31. Hanna Basin, Wyoming
32. Washakie Basin-Sand Wash Basin area, Colorado-Wyoming
33. Red Desert Basin, Wyoming
34. Green River Basin, Wyoming
35. Jackson Hole, Wyoming
36. Wind River Basin, Wyoming
37. Bighorn Basin, Montana
38. Crazy Mountain Syncline, Montana
39. Western Montana
40. Snake River Downwarp, Idaho-Oregon
41. Salt Lake-Utah Lake area, Utah
42. West-central Utah
43. Southwestern Utah

44. Elko-Humboldt area, Nevada
45. Carson-Black Rock area, Nevada
46. Muddy Creek Mountains, Nevada
47. East-central California
48. Mojave Desert, California
49. San Joaquin Valley, California
50. Sacramento Valley, California
51. Harney Basin, Oregon
52. Central Oregon
53. Western Oregon
54. Central Washington
55. Western Washington

FIGURE 1. SEDIMENTARY BASINS OF THE UNITED STATES

...the ...
...the ...
...the ...
...the ...
...the ...

...the ...
...the ...
...the ...
...the ...
...the ...