STRUCTURAL AND STRATIGRAPHIC OIL TRAPS

Allison Lynn Hornbaker

STRUCTURAL AND STRATIGRAPHIC OIL TRAPS

Allison Lynn Hornbaker

Thesis

Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Geology,
University of Michigan, June 1947

CONTENTS

ILLUSTRATIONS

ABSTRACT

Oil and gas traps may be divided into two major groups, (1) structural traps in which closure is produced by structure; and (2) stratigraphic traps in which closure is produced by variations in porosity and permeability in the reservoir rock.

A census obtained from papers in the bulletins and symposiums of the American Association of Petroleum Geologists and World Petroleum indicates that 56.8% of oil traps are structural. A further breakdown shows that 30.4% of structural traps are anticlines, 20.8% domes, 19.8% faults, 10.7% elongate anticlines, and 10.4% super salt plug strata. Of the stratigraphic traps, 29.1% are lensing sandstones, 16% carbonate rock porosity, 12.7% dolomitization porosity, 10.9% lensing sandstone due to sedimentation, 7.2% metamorphic rocks, 6.3% salt plug flank, and 4.6% sandstone overlap. These figures give the relative importance of traps only from the numerical standpoint.

Anticlines have been the major traps in the past. We are gradually running out of untested anticlinal structures; as a result the search will be more and more for stratigraphic traps for they are the keys to the oil fields of the future.

INTRODUCTION

This paper presents a classification of oil and gas traps and evaluates the relative importance of the traps. The writer has obtained his data from papers in the bulletins and symposia of the American Association of Petroleum Geologists, World Petroleum, United States Geological Survey, Emmon's "Geology of Petroleum", and Lilley's "Economic Geology of Mineral Deposits". Dr. Kenneth K. Landes gave many helpful suggestions, and contributed the basic classification of oil traps which the writer slightly modified. The census given is not complete, however it gives a fairly accurate relation of the importance and abundance of the various traps.

CLASSIFICATION OF TRAPS

The following classification of oil traps is used in this paper:

A. Structural traps
   1. Folds
      a. Elongate anticline
      b. Anticline
      c. Dome
         (1) Quaquaversal
         (2) Super salt plug strata
      d. Syncline
      e. Monocline and terrace
   2. Faults
   3. Fissures and fractures

B. Stratigraphic traps

1. Varying porosity caused by sedimentation
    a. Lensing sandstone
    b. Lensing sandstone porosity
2. Varying porosity caused by ground water activity
    a. Lensing sandstone porosity
    b. Carbonate rock porosity
    c. Salt plug cap rock
    d. Dolomitization porosity
3. Varying porosity caused by truncation and sealing
    a. Solid hydrocarbon sealing
    b. Angular unconformity
        (1) Sandstone
        (2) Carbonate rock
    c. Miscellaneous unconformities
        (1) Salt plug
        (2) Igneous plug
        (3) Buried hills
        (4) Igneous rocks
        (5) Metamorphic rocks

STRUCTURAL TRAPS

A structural trap is one in which oil is in a consistently permeable reservoir rock, and is confined by structural features such as folds, faults, and fissures.

In the early days shortly after the Drake well was drilled, it was recognized that oil accumulated in anticlines;

however it was believed that it occurred in fissures near the crest. Later it was recognized that many sandstones were sufficiently porous to hold enormous quantities of oil without fracturing. In 1885 I. C. White (1885, pp.521-522) published his paper on the anticlinal theory which brought him fame as the father of the theory. At this time the anticlinal theory was practically synonymous with the structural theory. In the period 1888 to 1891 Edward Orton (1888, pp. 307-308) explained the flank pools of Ohio as being localized at points of "arrested dip" or terraces. The importance Orton gave to such accumulation was picked up quickly by many other geologists and was subsequently introduced in many of the geology texts; even today many authors place great importance on the role played by terraces and monoclines in the accumulation of oil. Prior to 1917--an exact date is difficult to establish--the search was entirely for anticlines. Since then, however, the tendency has been to interpret closure more as it is known today and to apply the expanding knowledge of regional geology in the search for stratigraphic traps as well as for structural traps. As early as 1909 Munn (1909, pp. 141-147) attacked the term, "anticlinal theory", and gradually the term, "structural theory", replaced it. Anticlines make a major subdivision under it.

Folds

Elongate Anticline.--An elongate anticline is a fold four or more times longer than it is wide. A typical field with an elongate anticlinal trap is the Ventura Avenue oil field, Ventura County, California. This field is on the crest of the Ventura anticline which strikes east-west. Fig. 1 is a cross section and subsurface map of the field showing structure at the base of the Gosnell shale. Other fields which produce from elongate anticlines are:

Aquas Blancas, Argentina
W 12, 9, 72-79, 1941 [1]

*Bahrein Island
W 9, 7, 66-69, 1938

Big Sand Draw, Wyoming
A 12, 12, 1137-1146, 1928

*Blackwell, Oklahoma
AS 1, 158-175, 1929

Cedar Creek, Montana
W o, 8, 34-49, 1938

*Fairport, Kansas
AS 1, 35-48, 1929

Graham, Oklahoma
A 8, 5, 593-620, 1924

*Greendale, Michigan
W 6, 5, 309-324, 1935

*Hendricks, Texas
A 14, 7, 923-944, 1930

Kirkuk, Iraq
W 9, 7, 58-63;124,126, 1938

Lanywa Burma
W 7, 11, 580-592, 1936

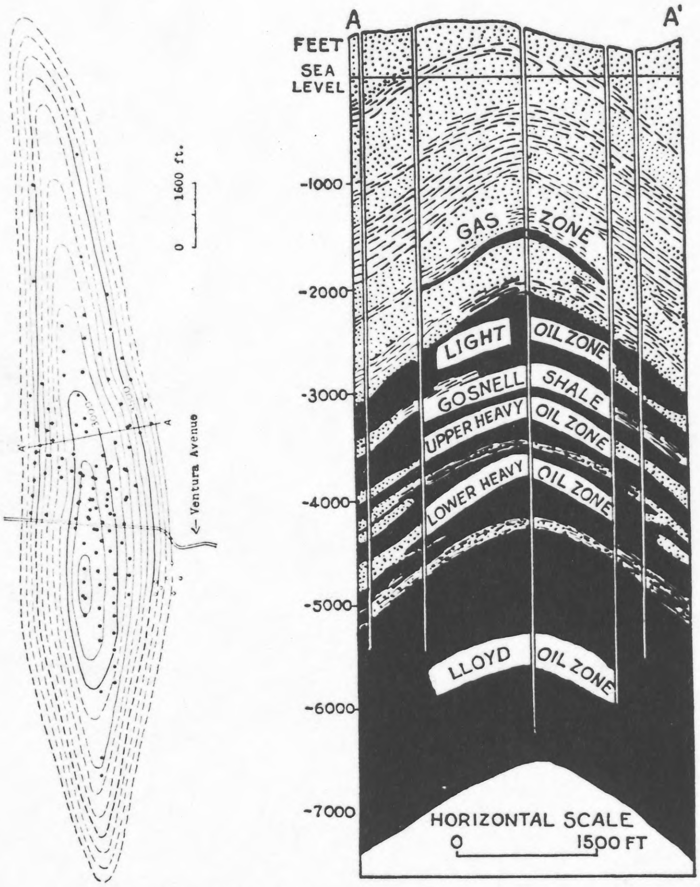
Lomitas-Tranquitas, Argentina
W 12, 9, 72-79, 1941

[1] Key for oil field references:

A---Bull. Amer. Assoc. Petrol. Geol.
AG--Symposium Amer. Assoc. Petrol. Geol. "Gulf Coast Oil Fields"
AP--Symposium Amer. Assoc. Petrol. Geol. "Problems of Petroleum Geology"
AS--Symposium Amer. Assoc. Petrol. Geol. "Structure of Typical American Oil Fields"
AST-Symposium Amer. Assoc. Petrol. Geol. "Stratigraphic Type Oil Fields"
C---Bull. Calif. Div. Mines
E---Emmons' "Geology of Petroleum"
VW--Ver Wiebe's "Oil Fields in the United States"
W---World Petroleum

Following the journal symbol are given, in the following order, the volume (if any), number (if any), pages, and year.

* Asterisks indicate a combination trap.



Ventura Avenue oil pool, California. Subsurface structure contour map and cross section along line A–A′ of contour map. Contours are given in depths below sea level. The section shows the thickness of the productive horizons admirably. Deeper horizons are now productive. *After L. C. Decius, A. I. M. M. E. Trans., General Volume for 1931, pp. 525 and 526.*

Figure 1.--(Emmons, Geol. of Petrol. 1931, p.296)

Lucien, Oklahoma
W 1, 11, 416-424, 1934

Lunlunta, Argentina
W 12, 9, 72-79, 1941

Minbu, Burma
W 7, 11, 580-592, 1936

Mosul Fields, Iraq
W 9, 7, 64-65, 1938

Olla Field, Louisiana
A 25, 4, 747-750, 1941

Palanyôn, Burma
W 7, 11, 580-592, 1936

*Panhandle, Texas
A 10, 8, 733-746, 1926

Rio Pescado, Argentina
W 12, 9, 72-79, 1941

Rock River, Wyoming
AS 2, 614-622, 1929

San Pedro, Argentina
W 12, 9, 72-79,1941

Singu & Yenangyat, Burma
W 7, 11, 580-592, 1936

Szechwan, China
A 8, 2, 162-177, 1924

Tartagal, Argentina
W 12, 9, 72-79, 1941

Tow Creek, Colorado
AS 2, 93-114, 1929

*Turner Valley, Alberta, Can.
W 11, 7, 68-71, 1940

Urania, Louisiana
AS 1, 91-104, 1929

Ventura Avenue, California
AS 2, 23044, 1929

*Vermilion Creek, Colo. & Wyo.
A 14, 8, 1013-1040, 1930

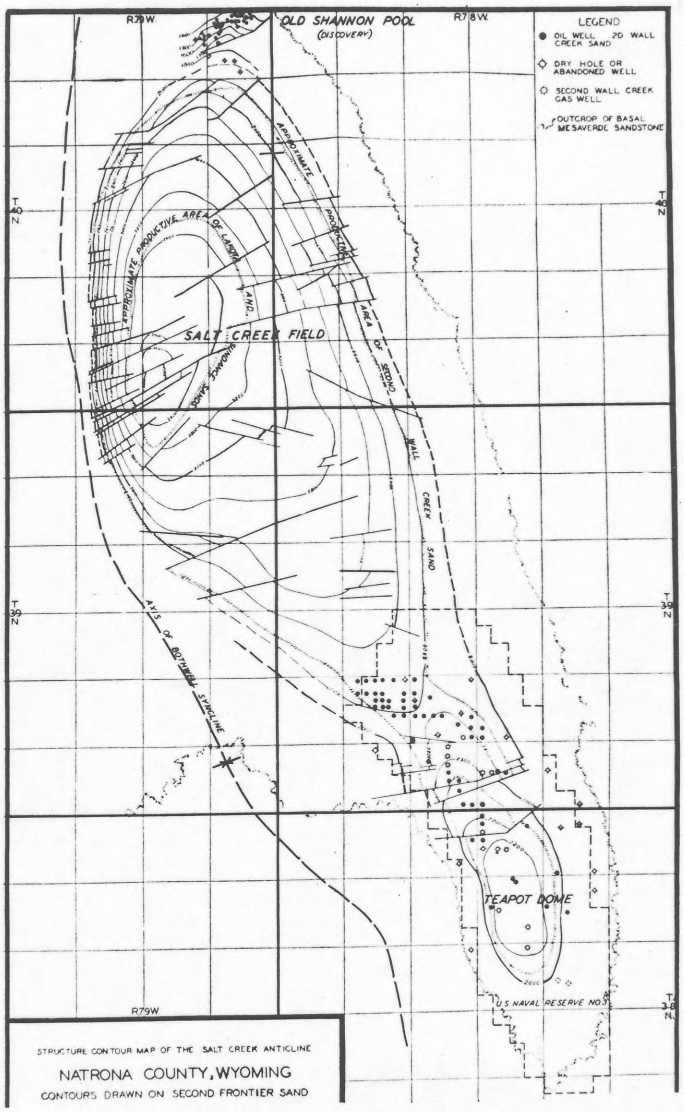
Volcano, West Virginia
VW 24, 51, 53, 67, 1930

*Westbrook, Texas
AS 1, 282-292, 1929

Yethaya, Burma
W 7, 11, 580-592, 1936

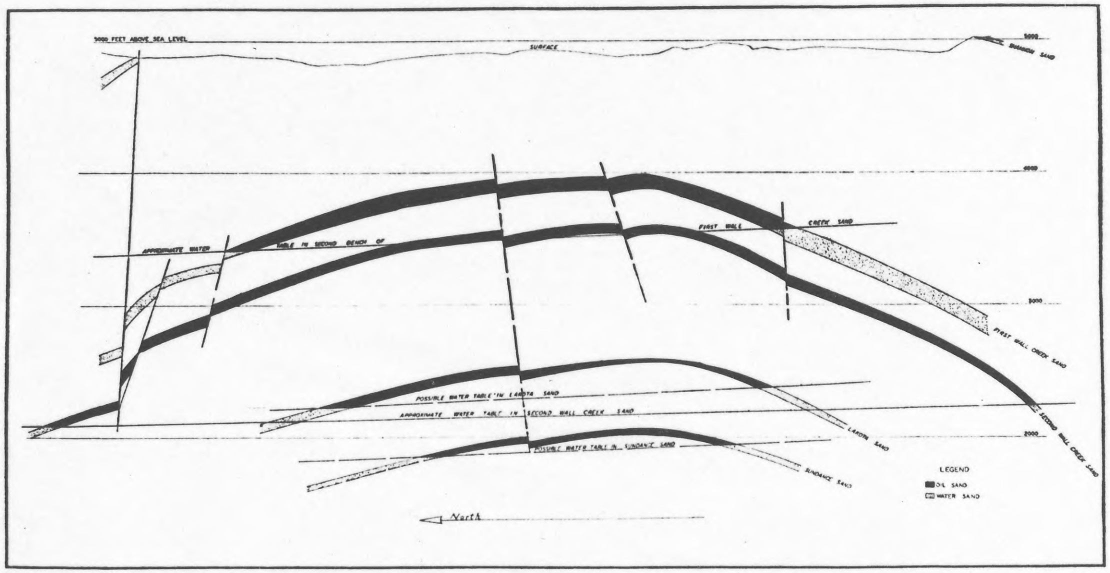
*Yost, Michigan
W 6, 5, 309-324, 1935

Anticline.--An anticline is a fold which is two to four times longer than it is wide. Salt Creek oil field in Wyoming has been taken for a typical example. This structure is 20 miles long and 5 miles wide. According to Wegemann (1917, p. 36) some oil has been found in fissures in the Cretaceous shale. Fig. 2 is the structural map of Salt Creek field contoured on the second Frontier sand. Fig. 3 is a cross section showing the relative position of water tables in the producing horizons. Below is a partial list of anticlinal fields:



Structure of Salt Creek field contoured on second Frontier sand. Contour interval, 200 feet. Datum, sea-level. Width of area mapped, 10 miles. Compiled by Elfred Beck. Drawn by E. W. Rumsey. Data from Producers and Refiners Corporation, U. S. Geological Survey, and F. G. Clapp.

Figure 2.--After Beck (AS 2, 589-603, 1929)



Cross section of Salt Creek field, Natrona County, Wyoming, showing relative position of water tables in producing horizons.

Figure 3.— After Beck (AS2, 589-603, 1929)

*Artesia, New Mexico
AS 1, 112-123, 1929

*Bradford, Pennsylvania
A 18, 2, 191-211, 1934

*Buckeye, Michigan
A 24, 11, 1950-1982, 1940

*Burbank, Oklahoma
AS 1, 220-229, 1929

Caddo, Louisiana
AS 2, 183-195, 1929

*Candeias, Brazil
W 16, 9, 74-75, 1945

*Carterville-Sarepta, Louisiana
A 22, 11, 1473-1503, 1938

Casabe, Colombia, S. America
A 29, 8, 1065-1142, 1943

Cat Canyon, California
AS 2, 18-22, 1929

Celina, Tennessee
A 11, 9, 905-918, 1927

*Comodora Rivadavia, Argentina
W 12, 9, 72-79, 1941

*Clay County, Kentucky
AS 1, 73-90, 1929

Coleman, Texas
A 25, 3, 428-429, 1941

Cooper Cove, Wyoming
A 29, 11, 1593-1604

*Crinerville, Oklahoma
AS 1; 192-210, 1929

Crooks Gap, Wyoming
A 29, 11, 1593-1604, 1945

Cunningham, Kansas
A 24, 10, 1779-1797, 1940

Cushing, Oklahoma
AS 2, 396-406, 1929

Depew, Oklahoma
AS 2, 365-377, 1929

*East Coalinga, California
A 29, 11, 1562, 1945

*East Tuskegee, Oklahoma
AST 436-455, 1941

ElDorado, Arkansas
A 7, 4, 350-361, 1923

*Elk Basin, Montana
AS 2, 577-588, 1929

*Elk Hills, California
AS 2, 44-61, 1929

Ferris, Wyoming
AS 2, 636-666, 1929

Francisco pool, Indiana
AS 2, 115-141, 1929

Ft. Collins, Colorado
E 505-507, 1931

*Garland, Wyoming
AP, 347-363, 1934

Gebel Zeit, Egypt
A 10, 4, 422-448, 1926

Gemsah, Egypt
A 10, 4, 422-448, 1926

*Glenmary, Tennessee
A 11, 9, 905-918, 1927

Goldsmith pool, West Texas
A 23, 10, 1525-1552, 1939

*Government Wells, Texas
A 19, 8, 1131-1147, 1935

*Greasewood, Colorado
AST, 19-42, 1941

*Greenwich, Kansas
A 23, 5, 643-662, 1939

Hewitt, Oklahoma
AS 2, 290-299, 1929

Hiawatha, Colorado
AS 2, 93-114, 1929

*Hobbs, New Mexico
W 6, 8, 458-472, 1935

*Hoffman, Texas
A 24, 12, 2126-2142, 1940

*Hull-Silk, Texas
AST, 661-679, 1941

Huntington Beach, California
A 8, 1, 41-46, 1924

Hurghada, Egypt
A 10, 4, 422-448, 1926

Indaw, Burma
W 7, 11, 580-592, 1936

*Infantas, Colombia, S. Am.
A 29, 8, 1065-1142, 1945

*Itaparica, Brazil
W 16, 9, 74-75, 1945

*Jesse pool, Oklahoma
A 22, 11, 1560-1578, 1938

Kettleman Hills, California
A 17, 10, 1161-1193, 1933

La Cira, Columbia, S. Am.
A 29, 8, 1065-1142, 1945

Lance Creek, Wyoming
AS 2, 604-613, 1929

*La Rosa, Texas
A 25, 2, 300-317, 1941

*Long Beach, California
C 118, 1943

Lyons, Kansas
A 24, 10, 1779-1797, 1940

*Martinsville pool, Illinois
AS 2, 115-141, 1929

Medicine Bow, Wyoming
W 9, 9, 5064, 1938

Mervine, Oklahoma
AS 1, 158-175, 1929

Mill Creek, Tennessee
A 11, 9, 905-918, 1927

*Montebello, California
C 118, 1943

*Monument-Eunice, New Mexico
W 9, 9, 50-64, 1938

Morrison, Oklahoma
AS 1, 148-157, 1929

*Muskegon, Michigan
A 16, 2, 153-168, 1932

North Cowden, Texas
A 25, 4, 593-629, 1941

Okha field, Sakhalin Island
W 2, 8, 492, 1931

Oregon Basin, Wyoming
W 9, 9, 50-64, 1938

Piqua pool, Kansas
A 24, 10, 1779-1797, 1940

Ponca City, Oklahoma
AS 1, 158-175, 1929

*Porter field, Michigan
W 6, 5, 309-324, 1935
A 28, 2, 173-196, 1944

Raisin City, California
W 12, 9, 72-79, 1941

Ranquil-County, Argentina
W 12, 9, 72-79, 1941

*Rattlesnake Hills, Washington
A 18, 7, 847-859, 1934

Rio Bravo, California
A 24, 7, 1330-1333, 1940

*Robberson, Oklahoma
A 7, 6, 625-644, 1923

*Saginaw, Michigan
AS 1, 105-111, 1929

*Saxet, Texas
A 24, 10, 1805-1835, 1940

*Shannon Pool, Wyoming
AS 2, 589-603, 1929

*South Cotton Lake, Texas
A 25, 10, 1898-1920, 1941

*South Mountain, California
A 8, 6, 789-829, 1924

Spence Dome, Wyoming
A 29, 11, 1593-1604, 1945

Spurrier-Riverton, Tennessee
A 11, 9, 905-918, 1927

Sumner County, Tennessee
A 11, 9, 905-918, 1927

Table Mesa, New Mexico
A 13, 2, 117-151, 1929

Tonkawa, Oklahoma
A 10, 885-891, 1926

*Tri County, Indiana
A 14, 4, 423-431, 1930

*Tupungato, Argentina
W 12, 9, 72-79, 1941

*Turkey Mt. Lime pools, Okla.
AS 1, 211-219, 1929

Virgil pool, Kansas
AS 2, 142-149, 1929

*Voshell, Kansas
A 17, 2, 169-191, 1933

Wagon Hound, Wyoming
A 29, 11, 1593-1604, 1945

*Walnut Bend, Texas
AST, 776-805, 1941

Wellington, Colorado
W 9, 9, 50-64, 1938

Wertz, Wyoming
AS 2, 636-666, 1929

West Ferris, Wyoming
AS 2, 636-666, 1929

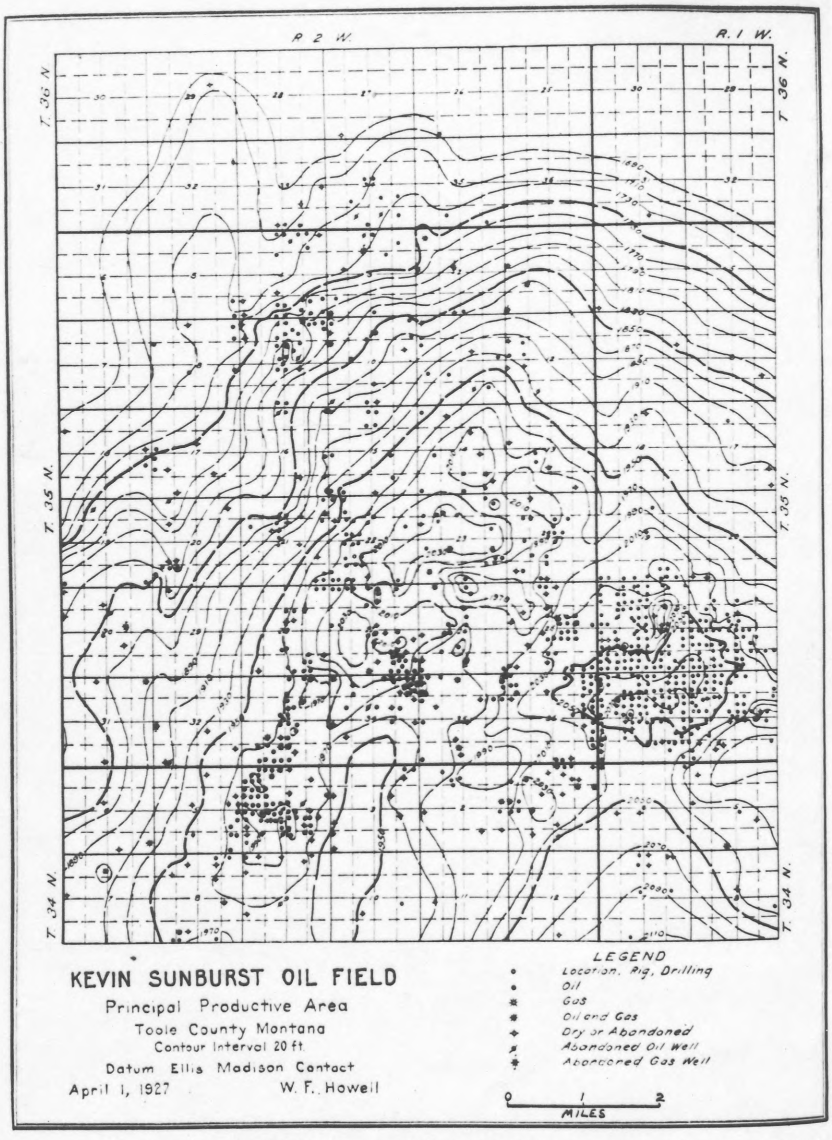
Wheeler Ridge, California
A 10, 5, 495-501, 1926

Willow Grove, Tennessee
A 11, 9, 905-918, 1927

Winkleman, Wyoming
A 29, 11, 1593-1604, 1945

Yenangyaung, Burma
W 7, 11, 580-592, 1936

Quaquaversal Dome.--A quaquaversal structure is a fold less than twice as long as wide. The Kevin-Sunburst field, fig. 4, is a broad flat dome. Most of the oil is from the Madison limestone. The upper 150 feet is dolomitic and porous, a result of weathering. Many of the wells appear to be independent of the small domes suggesting that the localization of the oil pools is controlled very largely by the porosity of the top of the Madison limestone. A list of



Structure of principal productive area, Kevin-Sunburst field, contoured on Ellis-Madison contact. Contour interval, 20 feet.

Figure 4.--After Howell (AS 2, 254-268, 1929)

fields with domal trapping is given below:

*Aratu, Brazil
W 16, 9, 74-75, 1945

Bailey Dome, Wyoming
A 29, 11, 1593-1604, 1945

Baxter Basin, Wyoming
W 9, 9, 50-64, 1938

*Bellevue, Louisiana
AS 2, 229-253, 1929

*Big Lake, Texas
AS 2, 500-541, 1929

Bowlegs, Oklahoma
AS 2, 315-361, 1929

*Breckenridge, Texas
AS 2, 470-479, 1929

Buckeye, Texas
A 19, 3, 378-400, 1935

*Carolina, Texas
E 110, 1931

Cat Creek, Montana
W 9, 8, 34-49, 1938

*Centralia-Sandoval, Illinois
AS 2, 115-141, 1929

Central Wilbarger Co., Texas
AS 1, 293-303, 1929

Coffeeville, Kansas
AS 1, 49-51, 1929

Cotton Valley, Louisiana
A 9, 5, 875-885, 1925

*Cromwell, Oklahoma
AS 2, 300-314, 1929

Cunningham, Kansas
A 21, 4, 500-524, 1937

Damman field, Saudi Arabia
W 10, 1, 31, 1939

*Dry Creek, Montana
W 9, 8, 34-49, 1938

Earlsboro, Oklahoma
AS 2, 315-361, 1929

Edna gas field, Texas
A 25, 1, 104-119, 1941

*ElDorado, Kansas
AS 2, 150-167, 1929

*Eola field, Louisiana
A 25, 7, 1363-1395, 1941

*Garber, Oklahoma
AS 1, 176-191, 1929

Grass Creek, Wyoming
AS 2, 623-635, 1929

*Greta, Texas
A 19, 4, 544-559, 1935

Hawkins, Texas
A 25, 5, 898-899, 1941

*Hitchcock, Texas
AST, 641-660, 1941

*Hogback, New Mexico
W 9, 9, 50-64, 1938

*Homer, Louisiana
AS 2, 196-228, 1929

*Iles, Colorado
AS 2, 93-114, 1929

*Katy gas field, Texas
W 17, 12, 64-67, 1946

*Kevin-Sunburst, Montana
AS 2, 254-268, 1929

Little Buck Creek, Wyoming
A 29, 11, 1593-1604, 1945

*Little Lost Soldier, Wyoming
AS 2, 636-666, 1929

Little River, Oklahoma
AS 2, 315-361, 1929

Moffat (Hamilton), Colorado
AS 2, 93-114, 1929

Osage County, Oklahoma
AS 2, 378-395, 1929

Padaukpin, Burma
W 7, 11, 580-592, 1936

Pearson Switch, Oklahoma
AS 2, 315-361, 1929

*Petrolia, Texas
AS 2, 542-555, 1929

Pine Island, Louisiana
AS 2, 168-182, 1929

*Powder Wash, Colorado
A 22, 8, 1020-1047, 1938

*Ramsey, Oklahoma
A 24, 11, 1995-2005, 1940

*Rangely, Colorado
W 9, 9, 50-64, 1938

*Rattlesnake, New Mexico
A 13, 2, 117-151, 1929

*Richland Parish, Louisiana
A 12, 10, 985-993, 1928

Santa Fe Springs, California
C 118, 1943
A 8, 178-194, 1924

Scenery Hill, Pennsylvania
AS 2, 443-450, 1929

*Searight, Oklahoma
AS 2, 315-361, 1929

*Seminole City, Oklahoma
AS 2, 315-361, 1929

*Smackover, Arkansas
A 7, 6, 672-683, 1923

South Blackwell, Oklahoma
AS 1, 158-175, 1929

South Elk Basin, Wyoming
A 29, 11, 1593-1604, 1945

St. Louis, Oklahoma
AS 2, 315-361, 1929

Strand, California
A 24, 7, 1333-1338, 1940

*Sugar Creek, Louisiana
A 22, 11, 1504-1518, 1938

Sweetgrass Arch, Montana
A 13, 7, 779-797, 1929

*Thomas, Oklahoma
A 10, 7, 643-655, 1926

Thornburg, Colorado
AS 2, 93-114, 1929

*Tinsley's Bottom, Tennessee
AS 1, 247-248, 1929

*Tri-State Dist., Okla., Ks., Missouri
A 14, 12, 1436-1445, 1933

*University field, Louisiana
AST, 208-236, 1941

Welsh, Louisiana
A 9, 3, 464-477, 1925

White River, Colorado
AS 2, 93-114, 1929

*Wilmington, California
A 22, 8, 1048-1079, 1938

Yates oil pool, Texas
A 13, 12, 1509-1556, 1929
AS 2, 480-499, 1929

<u>Super Salt Plug Strata</u>.--Super salt plug strata are

similar to ordinary domes except that a salt plug underlies them and was without doubt responsible for their formation. The reservoirs are chiefly in sandstones, however, brecciated shales and limestones produce some oil. A sharp distinction between super salt plug reservoir and cap rock reservoir is sometimes difficult to make due to gradational calcareous cement. There are a number of fields in which salt has not been found, but is believed to be present at greater depths than the drill has penetrated. If such salt is present, these fields should be classified as super salt plug traps. As a rule these reservoirs are gently arched, however a few, such as Goose Creek and Sugarland, have been arched as much as 2000 feet. A deep seated super salt plug trap is illustrated in the cross section, fig. 5, through the Conroe field. The structure is a slightly elongate dome. Three major faults break the regularity of the dome. There is free communication and equalization of fluid across the fault planes so that a unit reservoir exists in which the fluids segregate at uniform levels throughout the field. Fields classified as having super cap production are:

*Anahuac, Texas
W 9, 6, 27-39, 1938

*Anse La Butte, Louisiana
A 27, 8, 1123-1156, 1943

Barataria, Louisiana
A 25, 2, 322-323, 1941

*Barbers Hill, Texas
A 9, 6, 958-973, 1925

*Bellevue, Louisiana
A 22, 12, 1658-1681, 1938

*Clay Creek, Texas
AG, 757-779, 1936

*Conroe, Texas
A 20, 6, 736-779, 1936

Cow Bayou, Texas
AP, 629-677, 1934

*Darrow Dome, Louisiana
A 22, 10, 1412-1422, 1938

East Hackberry, Louisiana
AP, 629-677, 1934

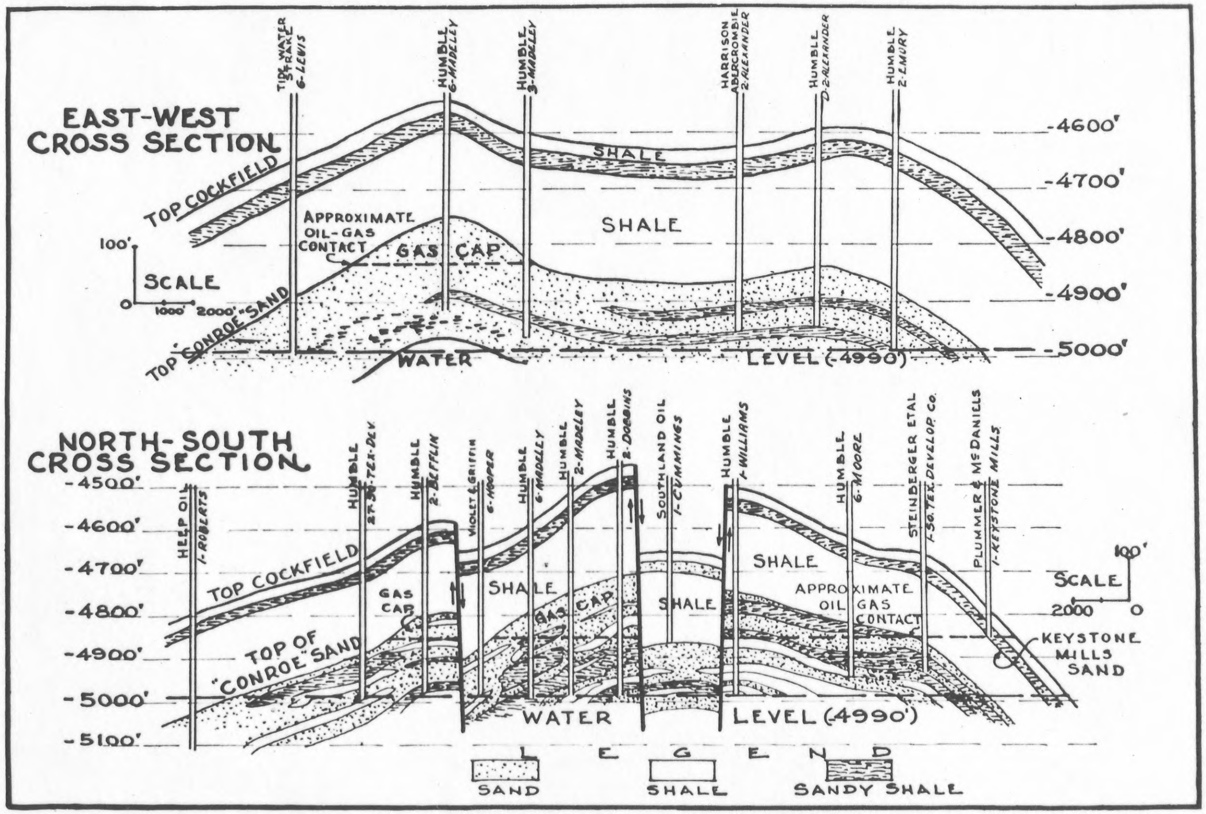


FIG. 10.—Cross sections of Conroe field. (After Michaux.)

Figure 5.– (A 20, 6, 736-779, 1936)

Edgerly, Louisiana
A 9, 3, 497-504, 1925

Esperson, Texas
A 18, 4, 500-518, 1934

*Goose Creek, Texas
A 18, 4, 500-518, 1934

*Hastings, Texas
W 9, 6, 27-39, 1938

Hoskins, Texas
AG, 833-856, 1936

Humble, Texas
A 18, 4, 500-518, 1934

Iowa Junction, Louisiana
AP, 629-677, 1934

Ives Creek, Texas
AP, 629-677, 1934

*Jennings, Louisiana
A 27, 8, 1102-1122, 1943

Lockport, Louisiana
A 18, 4, 500-518, 1934

*Mansfield Ferry, Texas
AP, 629-677, 1934

*Orange, Texas
A 18, 4, 500-518, 1934

*Raccoon Bend, Texas
A 17, 12, 1459-1491, 1933

*Refugio, Texas
A 22, 9, 1184-1216, 1938

Saratoga, Texas
A 9, 2, 263-285, 1925

Shongaloo, Louisiana
A 22, 11, 1473-1503, 1938

*Sour Lake, Texas
A 18, 4, 500-518, 1934

*Spindletop, Texas
A 18, 4, 500-518, 1934
A 21, 4, 475-490, 1937

Starks Dome, Louisiana
AP, 629-677, 1934

Sugarland, Texas
A 17, 11, 1362-1386, 1933
A 18, 4, 500-518, 1934

Thompson, Texas
AP, 629-677, 1934

Syncline.--Oil is trapped in synclines in several fields in the Appalachian area, especially in West Virginia. The main producing sands in synclines are the Mississippian Maxon, Keener, Big Injun, Weir, and Berea, and the Gordon of upper Devonian age. None of these sands carry enough water to influence the movement of oil or gas to any extent. Usually the gas is high and the oil is well down the flanks of the anticlines with some extending to the bottom of the synclines. Ordinarily the flat bottoms of the synclines are barren or yield only small amounts of oil.

The Griffithsville pool in Lincoln County, West Virginia, figure 6, is distinctly synclinal with the most prolific production at the bottom of the fold. The pool lies in a pocket on the slope of a larger syncline. The Berea sandstone, fine grained, hard, closely cemented, and free of water, is the main oil producing stratum. The wells are relatively small with initial productions ranging from 20 to 75 barrels per day; however, they maintained a settled rate of production for many years. Fields with synclinal trapping are:

Big Creek, West Virginia
AS 2, 571-576, 1929

Copley, West Virginia
AS 1, 440-461, 1929

Granny's Creek, West Virginia
AS 2, 571-576, 1929

Griffithsville, West Virginia
AS 2, 571-576, 1929

McKittrick, California
A 17, 1, 1-15, 1933

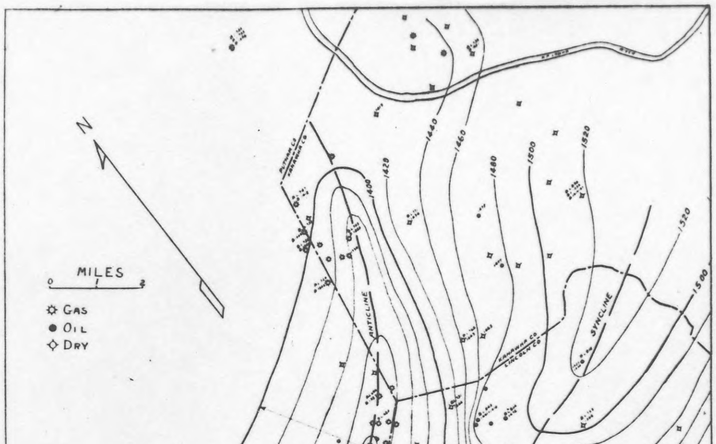
*Richburg pool, New York
AS 2, 269-289, 1929

Rouzer pool, West Virginia
AS 2, 571-576, 1929

Tanner Creek, West Virginia
AS 2, 571-576, 1929

Wolf Summit, West Virginia
AS 2, 571-576, 1929

Monocline and Terrace.--The controlling factor in trapping of oil in monoclines and terraces has long been a subject of much discussion. Many large and highly prolific oil fields occur on flanks of large anticlines or on monoclines, terraces, and noses. Many writers emphasize the importance of terrace production. Among them are Bosworth (1920, p. 225), Ziegler (1920, 87-116), Emmons (1931, p. 87), Van Tuyl (1924, p. 58), Thompson (1925, p. 162), and Lilley (1936, pp. 295, 296). In 1934 W. B. Wilson (1934, p. 437)

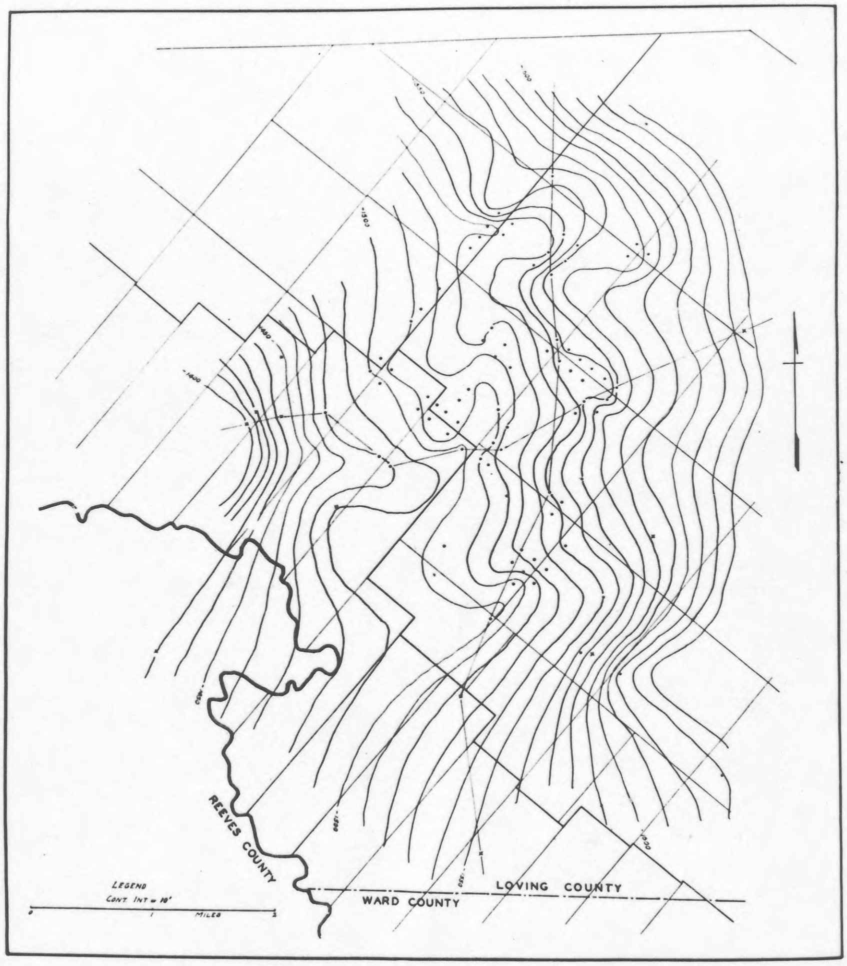


—Map showing subsurface structure of Big Creek, or Griffithsville, pool, Lincoln County, West Virginia. Contours drawn on top of the Berea sandstone. Contour interval, 20 feet. All contours below sea-level.

Figure 6.--After Davis and Stephenson (AS 2, 571-576, 1929)

vigorously attacked the concept of monocline and terrace trap. He argues that such trapping does not exist for commercial production of oil. He admits that it is theoretically possible, but maintains that the accumulation would be due to very low dips in the beds which would prevent the movement of oil, and it would thus be trapped. Present terraces may have been tilted back and forth enough, regionally, to dislodge terrace oil and to prevent its accumulation in other than closed traps. Production occurs beneath surface terraces and monoclines, but wherever there is good dependable subsurface evidence, variations in porosity and permeability are found to control accumulation.

According to J. E. Adams (1936, pp. 780-796), the Wheat pool in Loving County, Texas, fig. 7, is an excellent example of an open terrace trap. The oil occurs in the Delaware Mountain sand which is microscopically uniform in texture and cementation, and judging from the flow of oil and water, uniformly permeable. Water is present both up and down dip from the oil. Accumulation is believed to be due to a physical change involving a loss of the gas vehicle that assisted in the original accumulation which may have hampered further migration, or to the theory that for every size grade of pore space there is a critical angle of dip up which oil can migrate. Until this critical angle is reached no migration will occur. The critical dip for the Delaware Mountain sand is about 60 feet per mile or about 10 feet per mile steeper than the average dip from one edge of production



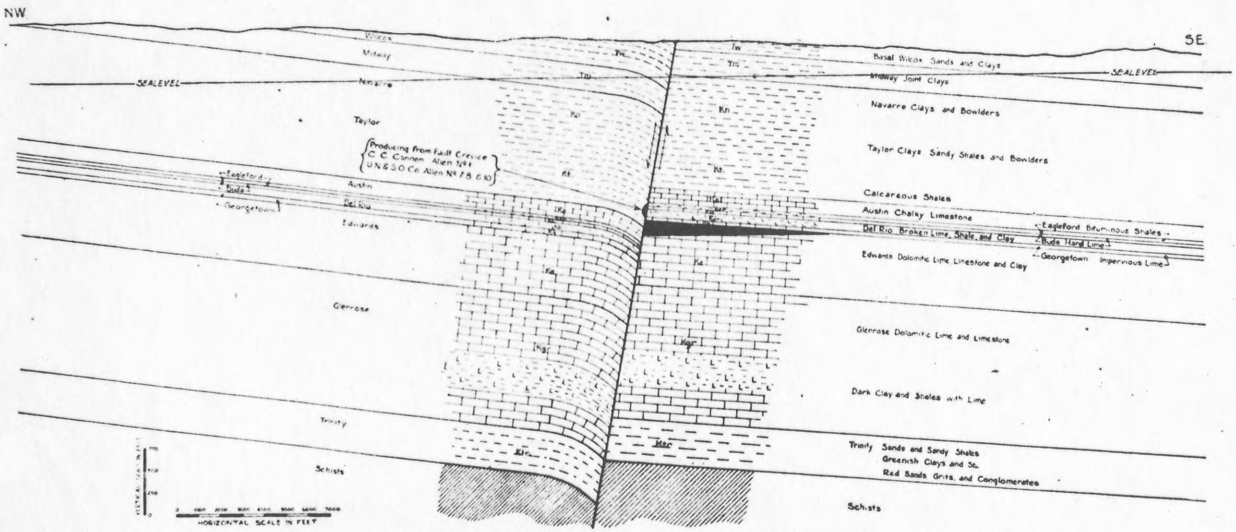
Structure of Wheat pool contoured on "Frijole."

Figure 7.--After Adams (A 20, 6, 780-796, 1936)

to the other. There are two other fields for which the writer could find no other cause for accumulation other than a monoclinal structure. These are the Minerva oil field in Texas (A 8, 5, 632-640, 1924) and the Shensi oil field in China (A 8, 2, 169-177, 1924). It is believed, however, that with sufficient subsurface evidence accumulation would be due to either structural or stratigraphic closure.

Faults

Some faults act as channelways through which fluids can escape. Others are accompanied by fault gouge, a finely ground clay material which seals the opening, making the fault impervious. Fault traps may occur in monoclines which are sealed up dip by an impervious fault. Fault traps are common in any formation which has sheet porosity and in which faults occur, such as along the Mexia fault zone in Texas. Such trapping is very frequently associated with domes and anticlines and may have no effect, a modifying effect, or may control the accumulation of oil. Examples are the Shannon pool north of Salt Creek, Whittier field in California, and the Binigadi field, Baku Peninsula, Russia. The Luling field, Caldwell and Guadalupe counties, Texas, is considered a typical example of a fault trap. The structure, fig. 8, is a faulted monocline limited on the northwest, northeast, and southwest by faults of about 450 feet displacement. The fault trends N 35° E. According to Brucks (1929, p. 266), closure in the Luling



Generalized northwest-southeast section, showing the structure and stratigraphy of the Luling fault.

Figure 8.- After Brucks (AS 1, 256-281, 1929)

field is produced on the northwest by the main fault and the accompanying downthrow on that side; on the southeast by the normal basinward depression occasioned by the regional southeast dip; on the northeast by a northeast dip and the Joliet east-west cross-fault and a marked stratigraphic depression. Oil accumulation is controlled or partially controlled by faulting in the fields listed below:

Amelia, Texas
W 9, 6, 27-39, 1938

*Anahuac, Texas
W 9, 6, 27-39, 1938

*Anse La Butte, Louisiana
A 27, 8, 1123-1156, 1943

*Aratu Field, Brazil
W 16, 9, 74-75, 1945

*Bellevue, Louisiana
AS 2, 229-253, 1929

*Carolina Field, Texas
E, 110, 1931

*Casmalia, California
AS 2, 18-22, 1929

Cedar Creek, Texas
AS 1, 304-388, 1929

*Clay Creek, Texas
AG, 757-779, 1936

*Comodoro Rivadavia, Argentina
W 12, 9, 72-79, 1941

*Conroe, Texas
A 20, 6, 736-779, 1936

Cotton Lake, Texas
W 9, 6, 27-39, 1938

*Cromwell, Oklahoma
AS 2, 300-314, 1929

Currie, Texas
AS 1, 304-388, 1929

*Darst Creek, Texas
A 17, 1, 16-37, 1933

*Edison, California
AST, 1-8, 1941

*Elk Basin, Montana
AS 2, 577-588, 1929

*Eola, Louisiana
A 25, 7, 1363-1395, 1941

*Glenmary, Tennessee
A 11, 9, 905-918, 1927

*Government Wells, Texas
A 19, 8, 1131-1147, 1935

*Greasewood, Colorado
AST, 19-42, 1941

*Greta, Texas
A 19, 4, 544-559, 1935

Half Moon,
A 29, 11, 1593-1604, 1945

*Hastings, Texas
W 9, 6, 27-39, 1938

*Hitchcock, Texas
AST, 641-660, 1941

Irma Oil Field, Arkansas
AS 1, 1-17, 1929

*Jesse Pool, Oklahoma
A 22, 11, 1560-1578, 1938

*Kern Front, California
AST, 9-18, 1941

*Laredo District, Texas
A 21, 11, 1422-1438, 1937

Larremore, Texas
A 29, 11, 1733-1737, 1945

*Little Lost Soldier, Wyoming
AS 2, 636-666, 1929

Lobato field, Brazil
W 16, 9, 74-75, 1945

Lompoc, California
AS 2, 18-22, 1929

*Long Beach, California
C, 118, 1943

Luling, Texas
AS 1, 256-281, 1929

*McKittrick, California
A 17, 1, 1-15, 1933

Mexia, Texas
AS 1, 304-388, 1929

*Moreni field, Roumania
A 29, 11, 1578, 1945

Nigger Creek, Texas
AS 1, 304-388, 1929

North Currie, Texas
AS 1, 304-388, 1929

North Groesbeck, Texas
AS 1, 304-388, 1929

*O'Hern field, Texas
AST, 722-749, 1941

Olinda, California
E, 562, 1931

*Orange, Texas
A 18, 4, 500-518, 1934
A 20, 5, 531-559, 1936

*Panuco, Mexico
A 12, 4, 395-442, 1928

Powell, Texas
AS 1, 304-388, 1929

*Ramsey, Oklahoma
A 24, 11, 1995-2005, 1940

*Rattlesnake Hills, Washington
A 18, 7, 847-859, 1934

Richland, Texas
AS 1, 304-388, 1929

Salt Flat, Texas
A 14, 11, 1401-1423, 1930

*Santa Maria, California
AS 2, 18-22, 1929

Sargent, California
C, 118, 1943

Sheridan, Texas
A 25, 6, 1008, 1941

*Shannon, Wyoming
AS 2, 589-603, 1929

*South Groesbeck, Texas
AS 1, 304-388, 1929

*Thomas, Oklahoma
A 10, 7, 6430655, 1926

*Vermilion Creek, Wyo. & Colo.
A 14, 8, 1013-1040, 1930

*Voshell, Kansas
A 17, 2, 169-191, 1933

West Beaumont, Texas
W 9, 6, 27-39, 1938

Whittier, California
E, 562, 1931

*Wilmington, California
A 22, 8, 1048-1079, 1938

Wortham, Texas
AS 1, 304-388, 1929

Fissures and Fractures

That oil has long been known to accumulate in fractures and fissures is indicated by an article by Professor E. B. Andrews (1863, pp. 259-264) of Marietta, Ohio, in 1863. His idea of accumulation was stated as follows: "In the broken rocks along the central lines of a great uplift, we meet with the largest quantity of oil. It would appear to be a law, that the quantity of oil is in a direct ratio to the amount of fissures." In 1866 Charles H. Hitchcock (1866, pp. 55-57) listed fissures or cavities, either in synclinal basins or on anticlinal slopes, as one condition for the occurrence of oil. The outstanding example of production from fissures is the Florence oil field in Fremont County, Colorado. The oil occurs in fissures in the Pierre shale and is in a belt three miles wide on the eastern limb of a geosyncline, fig. 9. Removal of the overburden is believed to permit fissures to open in the Pierre shale, and the oil accumulates in these fissures. Fields in which accumulation is controlled or partially controlled by fissures are:

Canon City, Colorado
AS 2, 75-92, 1929

*Casmalia, California
AS 2, 18-22, 1929

Florence, Colorado
AS 2, 75-92, 1929

*Iles field, Colorado
AS 2, 93-114, 1929

*Midway, California
C, 118, 1943

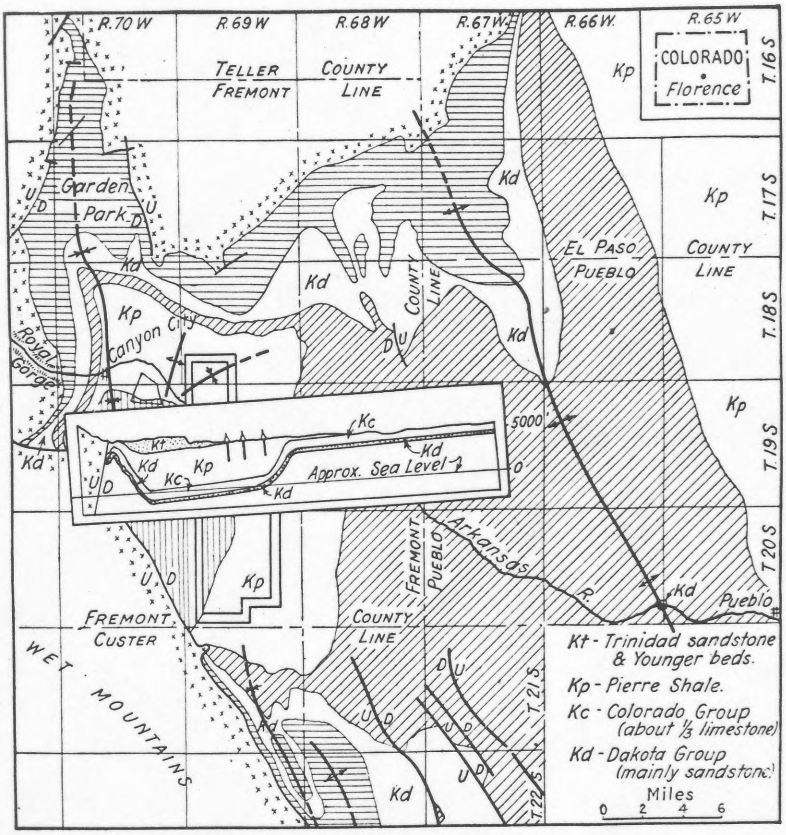
*Northern Tampico Region, Mex.
AP, 377-398, 1934

*Osage, Wyoming
AST, 847-857, 1941

*Panuco, Mexico
A 12, 4, 395-442, 1928

*Rangely, Colorado
W 9, 9, 50-64, 1938

*Salt Creek, Wyoming
AS 2, 589-603, 1929



Generalized map and section through Florence oil field, Colorado. (*After de Ford.*)

Figure 9.--After DeFord (AS 2, 75-92, 1929)

*Santa Maria, California
AS 2, 18-22, 1929

Spring Creek, Tennessee
A 11, 9, 905-918, 1927

*Tow Creek, Colorado
AS 2, 93-114, 1929

*Tupungato, Argentina
W 12, 9, 72-79, 1941

STRATIGRAPHIC TRAPS

A stratigraphic trap is one in which oil is confined by a change in the permeability of the reservoir rock. Such a field as Salt Creek as already described is typically structural; on the other hand, a field such as one of the shoestring gas fields of Michigan has a typical stratigraphic trap, the accumulation being entirely a function of the sand distribution. Structure plays little or no part in the localization of the gas. Between these two extremes of 100 percent pure structural trap and 100 percent pure stratigraphic trap is found every gradation. When combinations of structural and stratigraphic traps approach equal importance, it is difficult to determine which is the dominant type. A stratigraphic trap is bounded at least on one side by non-permeability. Lateral changes in permeability caused by ground water activity, or changes in porosity and permeability caused by sedimentation may form stratigraphic traps. Truncation and sealing by solid hydrocarbons, overlap, or various types of unconformities may also form such traps.

Varying Porosity Caused by Sedimentation

Lensing Sandstone.--The best examples of lensing sandstones are those which represent old stream channels or offshore bars. Typical fields of this group are the shoestring sands of Kansas and Michigan. The shoestring sands of Michigan are chosen for illustration because of their excellent cross sections, figures 10 and 11, clearly indicating that they are sand bars formed on offshore shoals in a shallow sea. Many of the traps creating the fields listed below are stratigraphic pinch-outs of the sand bodies, or lateral variations in their thickness.

Archer County, Texas
AS 1, 421-439, 1929

Berea sand trend, W. Virginia
AST, 806-829, 1941

Border-Red Coulee, Mont.& Alb.
AST, 267-326, 1941

*Bradford, Pennsylvania
A 18, 2, 191-211, 1934

Bryson, Texas
A 16, 2, 179-188, 1932

Bush City, Kansas
AST, 43-56, 1941

Cabin Creek, West Virginia
AS 1, 462-475, 1929

*Candeias, Brazil
W 16, 9, 74-75, 1945

Campton, Kentucky
AS 1, 73-90, 1929

Chanute, Kansas
AST, 57-77, 1941

*Clay County, Kentucky
AS 1, 73-90, 1929

*Comodoro Rivadavia, Argentina
W 12, 9, 72-79, 1941

*Conroe, Texas
A 20, 6, 736-779, 1936

*Crinerville, Oklahoma
AS 1, 192-210, 1929

Cross Cut-Blake, Texas
AST, 548-563, 1941

Davenport, Oklahoma
AST, 386-407, 1941

*Cut Bank, Montana
AST, 327-381,1941

Delaware extension pool, Okla.
AS 2, 362-364, 1929

Dixie oil pool, Louisiana
A 14, 6, 743-763, 1930

Dora, Oklahoma
AST, 408-435, 1941

Driscoll pool, Texas
A 17, 7, 816-826, 1933

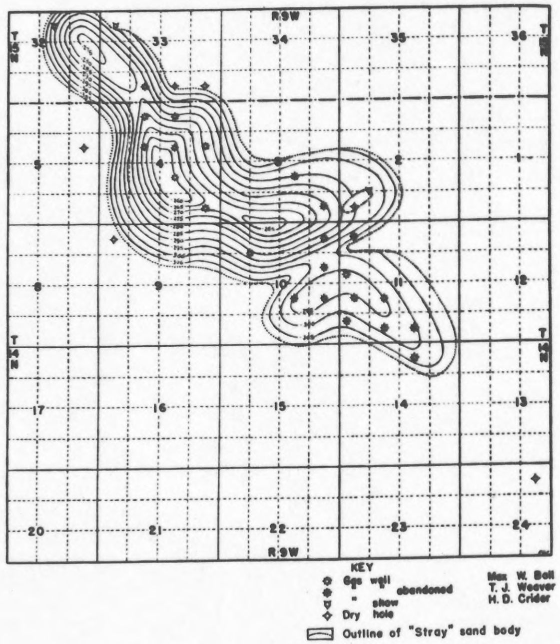
*Earlsboro, Oklahoma
AS 2, 315-361, 1929

*Elk Hills, California
AS 2, 44-61, 1929

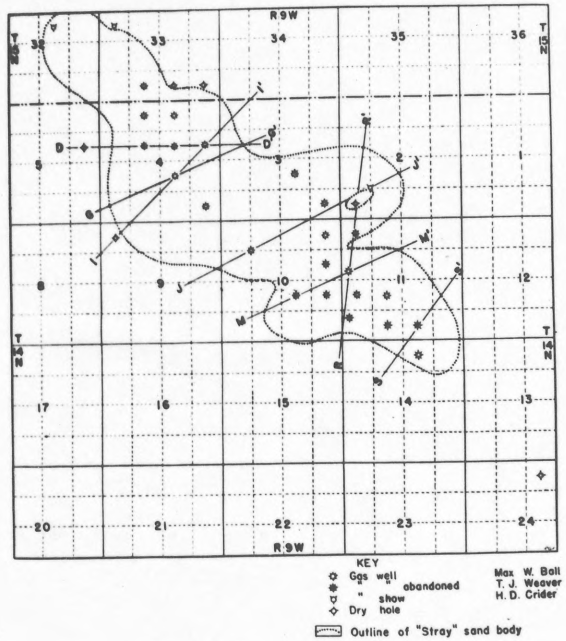
Elliot County, Kentucky
AS 1, 73-90, 1929

*Garber, Oklahoma
AS 1, 176-191, 1929

*General Petroleum field, Wyo.
AS 2, 636-666, 1929

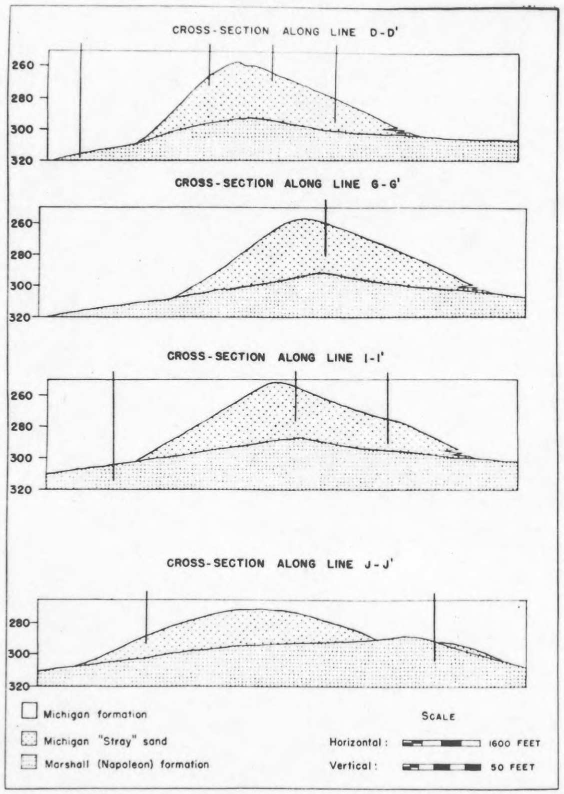


Structure-contour map of Austin gas field, drawn on top of Michigan Stray sand. July, 1940. Contour interval, 5 feet.

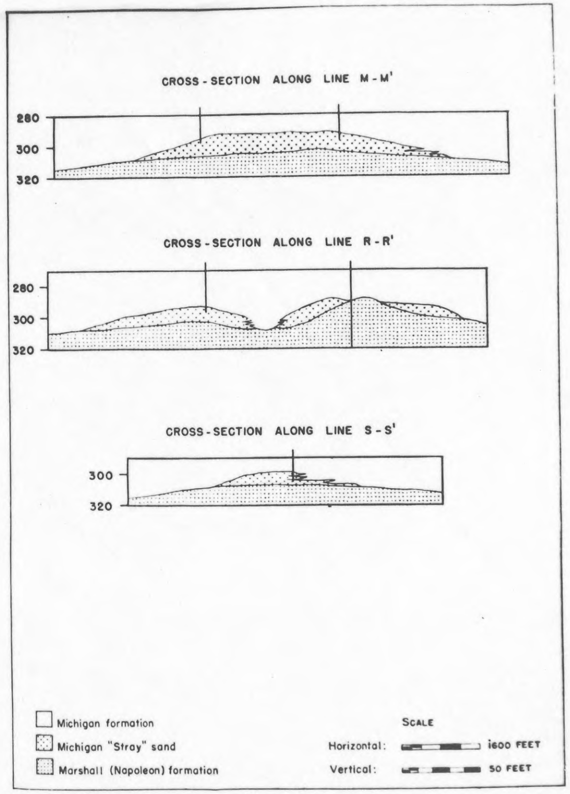


Austin gas field, showing location of cross sections. July, 1940.

Figure 10.- After Ball (AST, 237-266, 1941)



Cross sections DD', GG', II', and JJ', Austin gas field.



Cross sections MM', RR', and SS', Austin gas field.

Figure 11.— After Ball (AST, 237-266, 1941)

*Stephens, Arkansas
AS 2, 1-17, 1929

*Sugar Creek, Louisiana
A 22, 11, 1504-1518, 1938

*TriCounty, Indiana
A 14, 4, 423-431, 1930

*Tri-State, Okla., Kans, Mo.
A 17, 12, 1436-1445, 1933

*University field, Louisiana
AST, 208-236, 1941

Venango sands, Pennsylvania
AST, 507-538, 1941

Wherry pool, Kansas
AST, 118-138, 1941

Yenanna, Burma
W 7, 11, 580-592, 1936

Lensing Sandstone Porosity.--A sandstone which grades laterally into poorly sorted silty or shaly sand may cause effective closure and thus form a good trap for oil. There are undoubtedly many fields in which this type of trap plays an important role, but due to insufficient data it is difficult to prove such a condition. Much of the literature makes no distinction between lensing sandstone porosity due to poor sorting with increase in shaly matter and lensing sandstone porosity due to cementation. Clear-cut examples of the latter are extremely difficult to find, however it is the writer's opinion that they are relatively abundant and play an important role in the accumulation of oil.

The type field for lensing sandstone porosity due to poor sorting and increase in shale content is the Bryson oil field, Jack County, Texas, fig. 12. The structure is a simple monocline. It is interesting to note that the several members of the Bryson sand zone lose their porosity and permeability in the same general area which is near the dotted line A-B, where they grade into shale and siltstone.

Fields in which lateral gradation into shale plays an important part in oil trapping are:

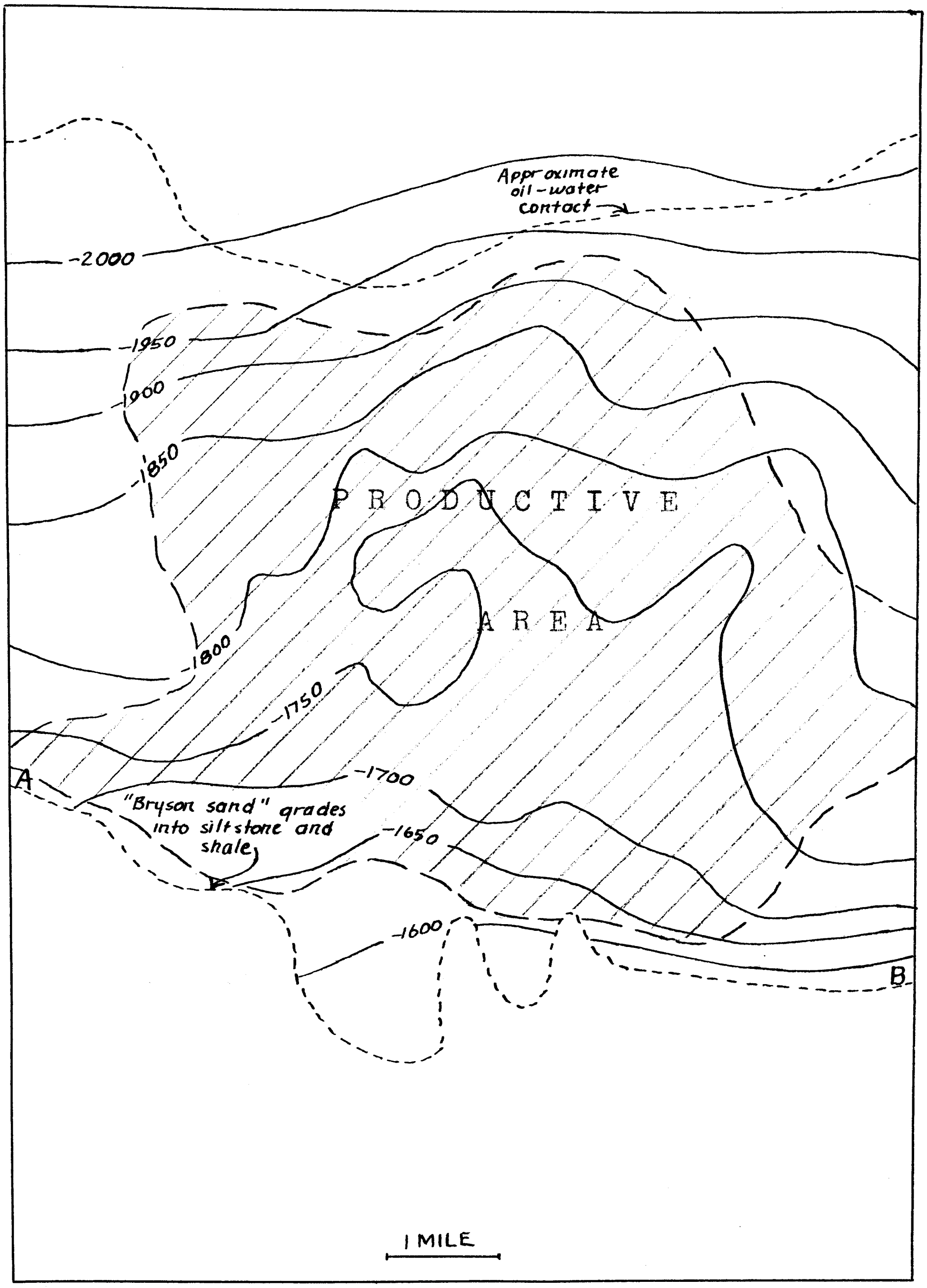


Figure 12.--Subsurface structure map of Bryson oil field. Contours drawn on top of Mary Bryson sand have interval of 50 feet. After Hiestand (AST 539-547, 1941)

Bryson, Texas
AST, 539-547, 1941

*Burbank, Oklahoma
AS 1, 220-229, 1929

*Carterville-Sarepta, Louisiana
A 22, 11, 1473-1503, 1938

*Cromwell, Oklahoma
AS 2, 300-314, 1929

*Cut Bank, Montana
AST, 327-381, 1941

*Edison, California
AST, 1-8, 1941

*General Petroleum, Wyoming
AS 2, 636-666, 1929

*Greasewood, Colorado
AST 19-22, 1941

*Greta, Texas
A 19, 4, 544-559, 1935

*Hoffman, Texas
A 24, 12, 2126-2142, 1940

*Hugoton, Kansas
AST, 78-104, 1941

*Hull-Silk, Texas
AST, 661-679, 1941

*Infantas, Colombia, S. America
A 29, 8, 1065-1142, 1945

*Kern Front, California
AST, 9-18, 1941

*Minbu, Burma
W 7, 11, 580-592, 1936

*Montebello, California
C, 118, 1943

*O'Hern, Texas
AST, 722-749, 1941

Palanyôn, Burma
W 7, 11, 580-592, 1936

*Refugio, Texas
A 22, 9, 1184-1216, 1938

Shinnston, West Virginia
AST, 830-846, 1941

*Smackover, Arkansas
A 7, 6, 672-683, 1923

*Smith-Ellis, Texas
AS 2, 556-570, 1929

*Stephens, Arkansas
AS 2, 1-17, 1929

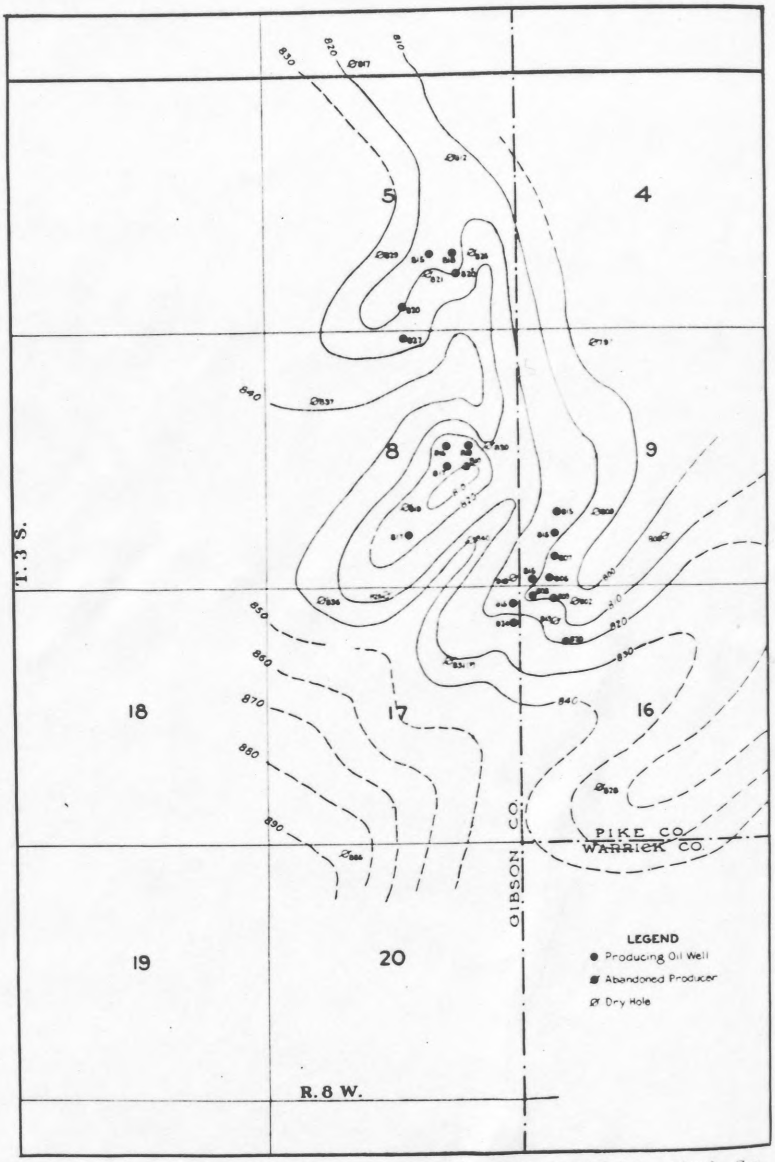
*University field, Louisiana
AST, 208-236, 1941

*Walnut Bend, Texas
AST, 776-805, 1941

Yethaya, Burma
W 7, 11, 580-592, 1936

Varying Porosity Caused by Ground Water Activity

Sandstone Cementation.--The Tri-County oil field, fig. 13, produces from the Oakland City sand. Sand lenses form the dominant traps but differential cementation has been effective in limiting the distribution of oil. Other fields in which accumulation is controlled or at least influenced by cementation are:



The key horizon is the Oakland City sand. Figures show depth below sea-level. Contour interval, 10 feet.

Figure 13.--After Wanenmacher and Gealy (A 14, 4, 423-431, 1930)

*East Tuskegee pool, Oklahoma
AST, 436-455, 1941

*Greasewood, Colorado
AST, 19-42, 1941

*Stephens, Arkansas
AS 2, 1-17, 1929

*Tri-County field, Indiana
A 14, 4, 423-431, 1930

Carbonate Rock Porosity.--Limestone porosity may be of two types; primary, originating at the time of the limestone deposition; or secondary, due to fracturing, solution or re-crystallization. Primary porosity and permeability have been increased by solution or by recrystallization in most major oil fields. Solution is caused by the action of circulating, unsaturated ground waters and may take place at any depth within the circulation range. In the Kevin-Sunburst field, fig. 4, there is no oil production on top of the structure. The porosity of the limestone is the dominant factor in the trapping of the oil, although local structure in areas of porosity has a decided effect on accumulation. Fig. 14 shows secondary porosity in the Dundee limestone from the Porter oil field, Midland County, Michigan. Carbonate rock porosity plays an important role in oil accumulation in the following fields:

*Bahrein Island, Gulf of Persia
W 9, 7, 66-69, 1938

*Blackwell, Oklahoma
AS 1, 158-175, 1929

*Buckeye, Michigan
A 24, 11, 1950-1982, 1940

*Breckenridge, Texas
AP, 347-363, 1934

Cacalilao, Mexico
AP, 377-398, 1934

Covert-Sellers, Kansas
AP, 309-345, 1934

Ebano, Mexico
AP, 377-398, 1934

Elbing, Kansas
AP, 309-345, 1934

*Fairport, Kansas
AS 1, 35-48, 1929

Florence, Kansas
AP, 309-345, 1934

*Greendale, Michigan
W 6, 5, 309-324, 1935

Golden Lane, Mexico
AP, 377-398, 1934

Figure 14.--Photomicrograph of Dundee limestone, showing secondary porosity. Magnification about 20 X. After Landes (A 28, 2, 173-196, 1944)

*Greenwich pool, Kansas
A 23, 5, 643-662, 1939

*Hendrick, Texas
A 14, 7, 923-944, 1930

*Hugoton, Kansas
AST, 78-104, 1941

*Kentucky, western fields
A 16, 3, 231-254, 1932

Kevin-Sunburst, Montana
AS 2, 251-268, 1929

Lisbon, Louisiana
A 23, 3, 281-324, 1939

*Martinsville, Illinois
AS 2, 115-141, 1929

Medicine Lodge, Kansas
A 24, 10, 1779-1797, 1940

*Muskegon, Michigan
A 16, 2, 153-168, 1932

Noodle Creek, Texas
AST, 698-721, 1941

*Oklahoma City, Oklahoma
A 14, 12, 1515-1533, 1930

Page, Texas
A 25, 4, 630-636, 1941

*Panuco, Mexico
AP, 377-398, 1934

Peabody, Kansas
AP, 309-345, 1934

*Porter field, Michigan
W 6, 5, 309-324, 1935
A 28, 2, 173-196, 1944

*Saginaw, Michigan
AS 1, 105-111, 1929

*Searight, Oklahoma
AS 2, 315-361, 1929

*Seminole City, Oklahoma
AS 2, 315-361,1929

Seymour, Texas
AST, 760-775, 1941

*Sugar Creek, Louisiana
A 22, 11, 1504-1518, 1938

*Tinsley's Bottom, Tennessee
AS 1, 247-248, 1929

Topila, Mexico
AP, 377-398, 1934

*Turner Valley, Alberta, Can.
A 29, 8, 1156-1168, 1945

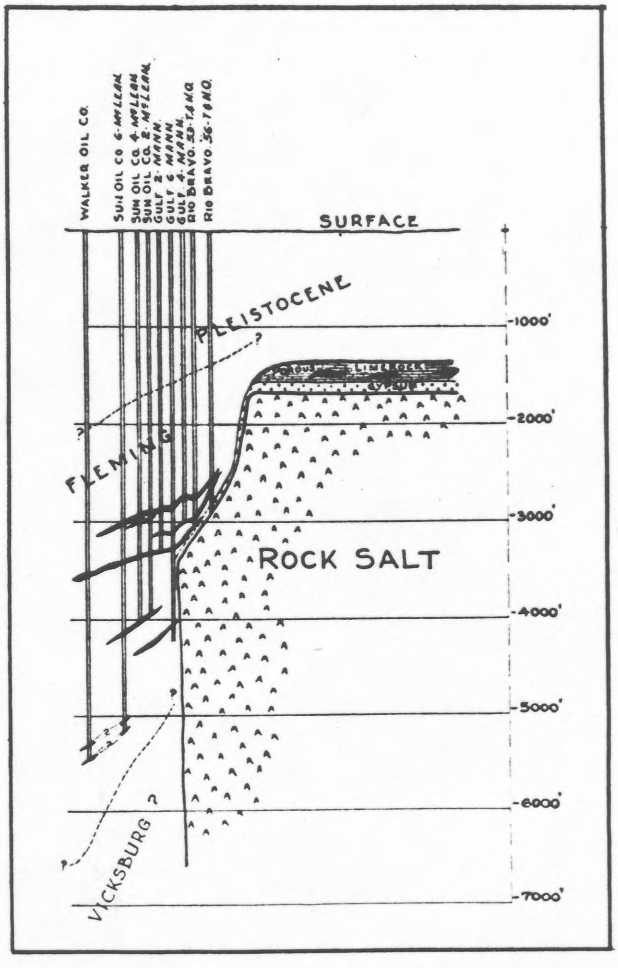
*Yates Pool, Texas
A 14, 6, 705-717, 1930

*Yost Field, Michigan
W 6, 5, 309-324, 1935
A 28, 2, 173-196, 1944

<u>Salt Plug Cap Rock</u>.--Traps in the limestone caprocks of salt domes are formed by the same kind of porosity as described above in carbonate rock porosity. Spindletop, fig. 15, is an excellent example of such a trap. Other fields with such traps are:

*Barbers Hill, Texas
A 9, 6, 958-973, 1925

Batson, Texas
A 18, 4, 500-518, 1934



Cross section of southwest flank of Spindletop.

Figure 15.--After Deussen (A 18, 4, 500-518, 1934)

*High Island Dome, Texas
AG, 909-960, 1936

*Humble, Texas
A 18, 4, 500-518, 1934

*Jennings dome, Louisiana
AG, 961-982, 1936

*Sour Lake, Texas
A 18, 4, 500-518, 1934

*Spindletop, Texas
A 18, 4, 500-518, 1934

Dolomitization Porosity.--Dolomitization porosity is formed during the process of dolomitization. According to K. K. Landes (1946, 315-318) such porosity results from an excess of solution over precipitation during the process of local replacement of limestone by circulating ground waters. He believes that local diastrophism produced master fissures in the limestone and that artesian waters circulating in a deeper zone of dolomite rise into the limestone where they replace some of the limestone by dolomite. Where porosity exists, the amount of solution was in excess over precipitation during the replacement process. From the structure contour map of the Deep River pool, figure 16, it appears likely that a fissure existed with a northwest-southeast trend, and that local dolomitization in which there was excess solution occurred along this fissure. The Lima-Indiana field has long been famous for its dolomite porosity type of accumulation. Other fields in which this type of trap plays an important role are:

Adams, Michigan
A 30, 3, 305-318, 1946

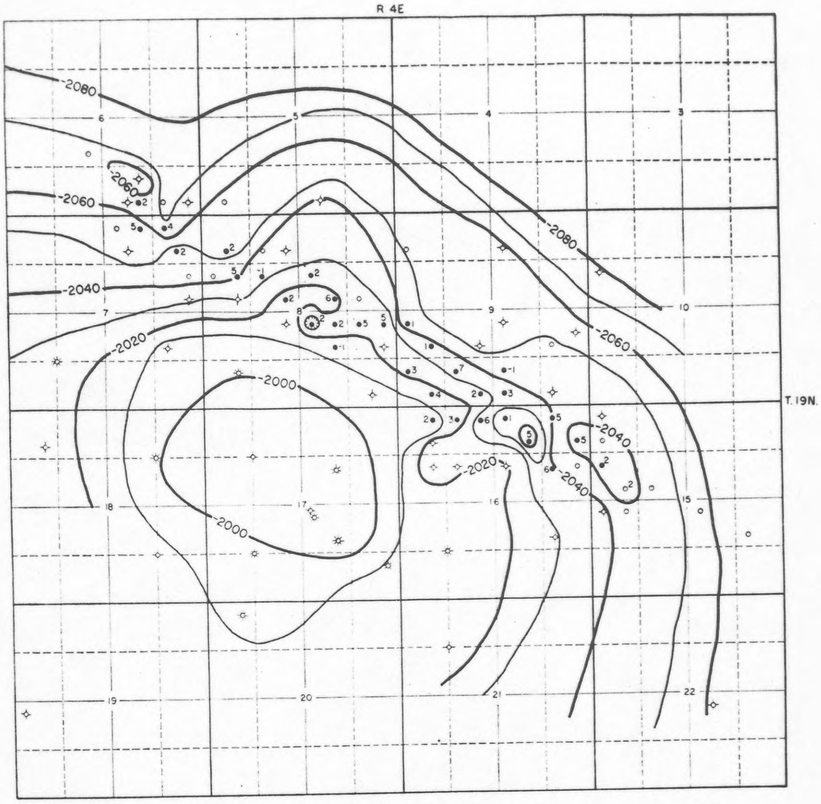
*Artesia, New Mexico
AS 1, 112-123, 1929

*Big Lake, Texas
AS 2, 500-541, 1929

*Big Sinking field, Kentucky
AST, 166-207, 1941

Coldwater, Michigan
A 30, 3, 305-318, 1946

Cooper, New Mexico
W 6, 8, 458-472, 1935



STRUCTURE CONTOUR MAP OF THE DEEP RIVER OIL POOL,
ARENAC COUNTY, MICHIGAN

DATUM IS BASE OF TRAVERSE
CONTOUR INTERVAL 10 FEET
SCALE
0 1 MILE

EXPLANATION

2 OIL WELL. FIGURE DESIGNATES NUMBER OF THOUSAND BARRELS (TO NEAREST THOUSAND) INITIAL PRODUCTION. FIGURE -1 DENOTES PRODUCTION OF LESS THAN 500 BARRELS, 1 AN INITIAL PRODUCTION BETWEEN 500 AND 1500 BARRELS, ETC.

GAS WELL

DRY HOLE

DRILLING WELL (JUNE 20, 1945)

MOST WELLS IN AND AROUND THE GAS FIELD STOPPED IN THE BEREA SANDSTONE. CONTROL POINTS FOR CONTOURING WERE OBTAINED BY ADDING 1314 FEET TO THE NEGATIVE ELEVATION OF THE TOP OF THE BEREA

Figure 16.--After Landes (A 30, 3, 305-318, 1946)

*Darst Creek, Texas
A 17, 1, 16-37, 1933

Deep River, Michigan
A 30, 3, 305-318, 1946

Evart, Michigan
A 30, 3, 305-318, 1946

Fort, Michigan
A 30, 3, 305-318, 1946

*Garber, Oklahoma
AS 1, 176-191, 1929

*Garland, Wyoming
AP, 347-363, 1934

Grass Creek, Wyoming
A 16, 9, 670-673, 1932

*Greenwich, Kansas
A 23, 5, 643-662, 1939

*Hobbs, New Mexico
W 6, 8, 458-472, 1935

*Hugoton, Kansas
AST, 78-104, 1941

Jal, New Mexico
W 6, 8, 458-472, 1935

Lima-Indiana
E, 205-210, 1931

Lynn, New Mexico
W 6, 8, 458-472, 1935

*Monument-Eunice, New Mexico
W 9, 9, 50-64, 1938

Nikkel pool, Kansas
AST, 105-117, 1941

*Salt Flat, Texas
A 14, 11, 1401-1423, 1930

*Seminole City, Oklahoma
AS 2, 315-361, 1929

Sherman, Michigan
A 30, 3, 305-318, 1946

Temple field, Michigan
A 24, 6, 980-981, 1940

*Turkey Mt. Lime pools, Okla.
AS 1, 211-219, 1929

*Turner Valley, Alberta, Can.
W 11, 7, 68-71, 1940

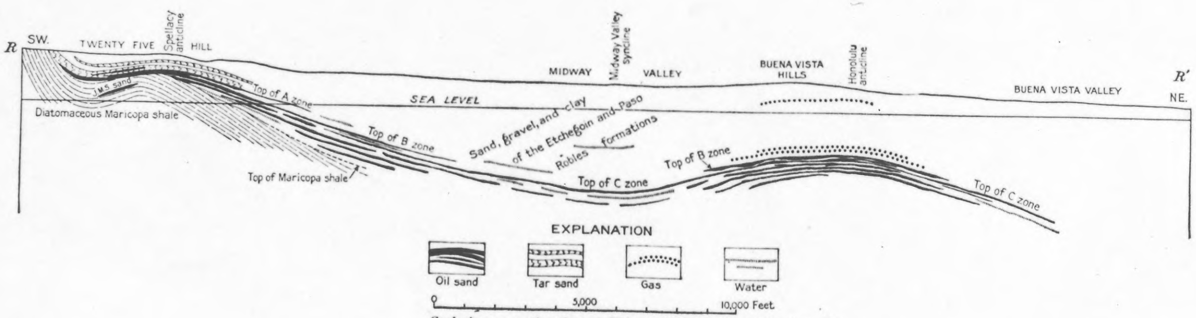
*Westbrook, Texas
AS 1, 282-292, 1929

Winterfield, Michigan
A 30, 3, 305-318, 1946

*Zenith, Kansas
AST, 139-163, 1941

Varying Porosity Caused by Truncation and Sealing

Solid Hydrocarbon Sealing.--Certain reservoirs on monoclines, terraces, or flanks of anticlines are sealed above by tarry products that have resulted from hardening of the oils. As a rule such traps occur in reservoirs in which the oil is of the heavier asphaltic type rather than the light paraffine type. The Sunset-Midway field of California, fig.17, is a notable example of such sealing. The tar is formed by the



Geologic cross section through Midway field along line R-R′, Plate III.

Figure 17.— After Pack (USGS Prof. Paper #116 p. 78)

interaction of the mineralized waters and the hydrocarbons that compose the oil--a reaction which results in the reduction of sulphate water to form sulphides and the addition of the sulphur or sulphides to the oil. Solid hydrocarbon seals occur in the following fields:

Cacheuta field, Argentina
W 12, 9, 72-79, 1941

*East Coalinga, California
A 29, 11, 1562, 1945

*McKittrick, California
A 14, 1, 1-15, 1933

*Oklahoma City, Oklahoma
A 14, 12, 1515-1533, 1930

*Sunset Midway, California
USGS Prof. Paper, #116,p.78

<u>Angular Unconformity</u>.--Some of the major oil fields of the world are located on angular unconformities. This paper divides them into two kinds--those in which the oil occurs in the sandstones and those in which the oil occurs in carbonate rocks. The Oklahoma City field, Oklahoma, fig. 18, is one of the outstanding fields in this category and production comes from both sandstones and carbonate rocks. The producing sandstones are in the Simpson group and the detrital sandy beds above the unconformity. The Arbuckle limestone is highly porous and contained enormous amounts of oil. Fields with sandstone overlap sealing are:

*Blackwell, Oklahoma
AS 1, 158-175, 1929

East Texas field
AST, 600-640, 1941

*Edison, California
AST, 1-8, 1941

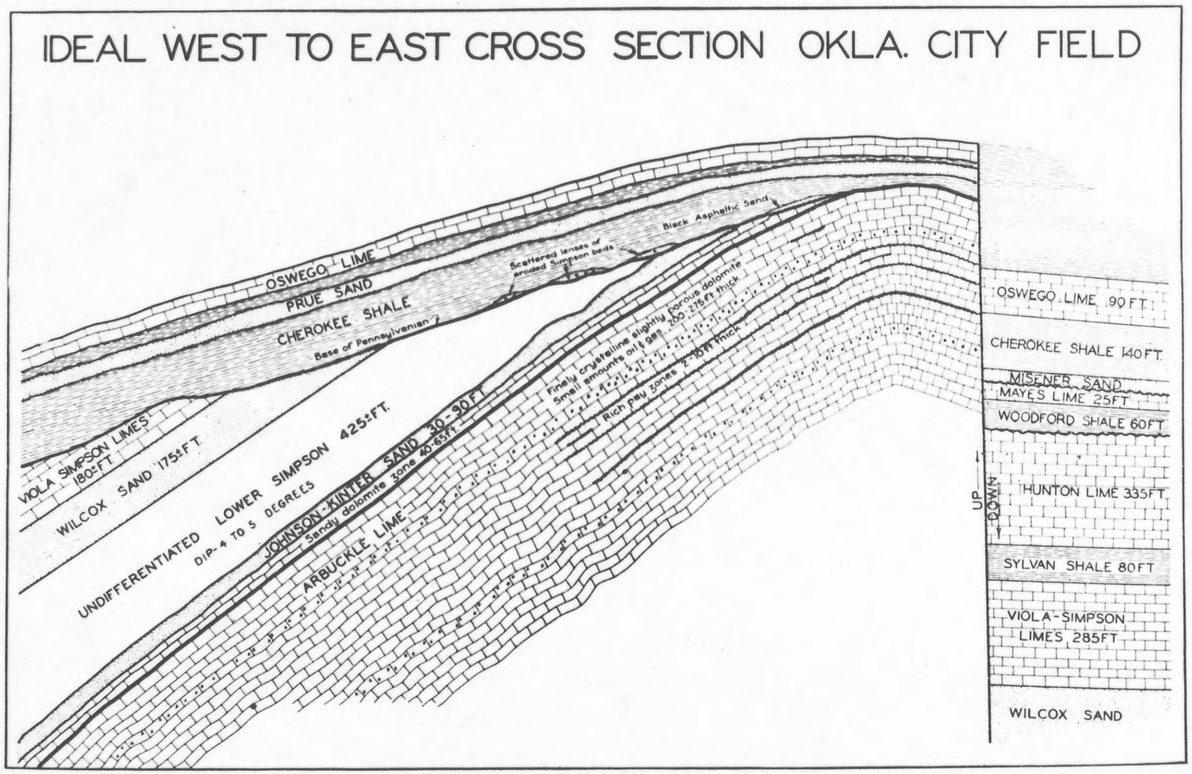
*ElDorado, Kansas
AS 2, 160-167, 1929

*Garber, Oklahoma
AS 1, 176-191, 1929

*Jennings, Louisiana
A 27, 8, 1102-1122, 1943

*Oklahoma City, Oklahoma
A 14, 12, 1515-1533, 1930

Playa del Rey, California
C, 118, 1943



Type section showing relation of subsurface formations in Oklahoma City field. The section on the downthrown side of the fault was taken from the log of a well on the east side of the field. (Length of section about 3 miles.)

Figure 18.- After Charles (A 14, 12, 1515-1533, 1930)

Tatums, Oklahoma
A 19, 3, 401-411, 1935

*Thomas, Oklahoma
A 10, 7, 643-655, 1926

*Zenith, Kansas
AST, 139-163, 1941

Fields with carbonate rock overlap sealing are:

*Big Sinking field, Kentucky
AST, 166-207, 1941

*Eldorado, Kansas
AS 2, 16--167, 1929

*Garber, Oklahoma
AS 1, 176-191, 1929

*Nikkel Pool, Kansas
AST, 105-117, 1941

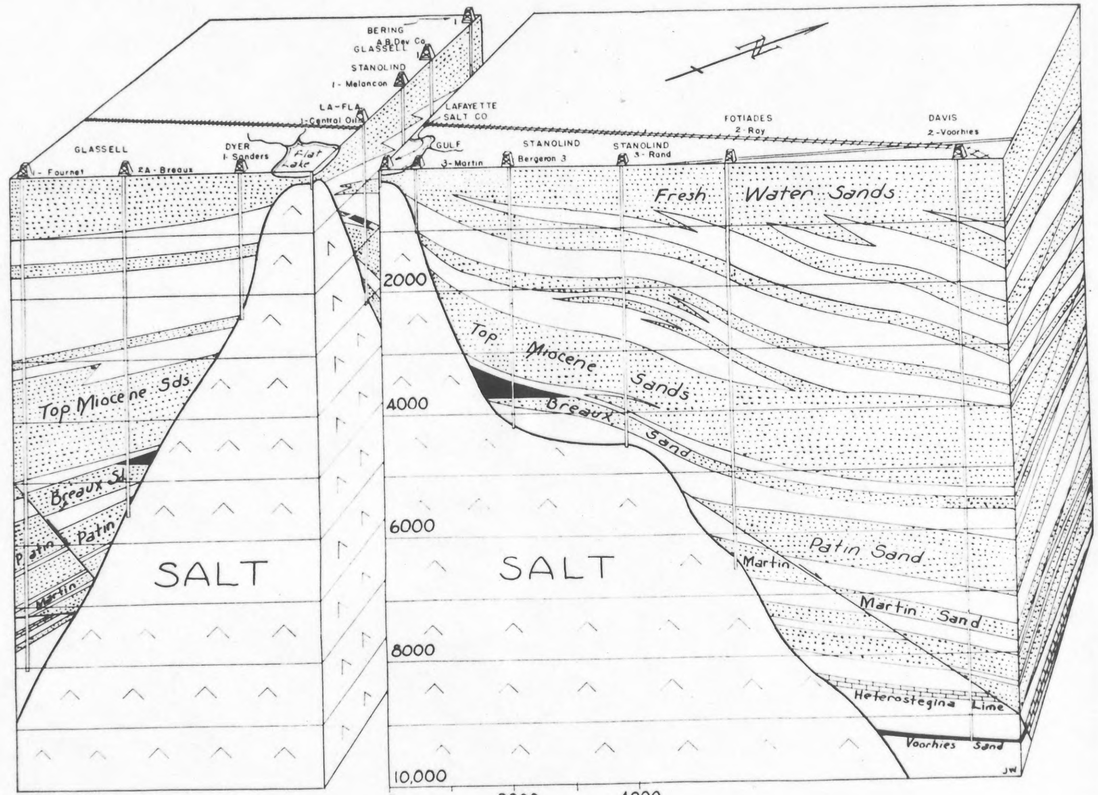
*Zenith, Kansas
AST, 139-163, 1941

Miscellaneous Unconformities

Miscellaneous unconformity traps include the piercement type salt plug, igneous plugs, buried hills, igneous rock traps, and metamorphic rocks. The trapping in the first three is restricted to the flanks or is what might be called off-lap production.

Salt Plug Type.--Flank production from salt plugs came into its own after cap rock production had for the most part ceased and most of the fields were considered depleted. This type of trap brought a new boom to the salt dome area and accounted for millions of barrels of oil. Spindletop was among the first prolific flank producers, fig. 15. The greatest production was from the southwest flank of the dome.

In recent years deep flank production was found at Anse La Butte, Louisiana, fig. 19. Accumulation is controlled to a considerable extent by radial faulting, certain blocks being more productive than others. Salt plug flank production is found in the following fields:



Block diagram of Anse la Butte dome looking northwest.

Figure 19.- After Bates (A27, 8, 1123-1156, 1943)

*Anse La Butte, Louisiana
A 27, 8, 1123-1156, 1943

Barbers Hill, Texas
A 18, 4, 500-518, 1934

Damon Mound, Texas
A 9, 3, 505-535, 1925

*Darrow salt dome, Louisiana
A 22, 10, 1412-1422, 1938

East Hackberry, Louisiana
A 18, 4, 500-518, 1934

*High Island, Texas
AG, 909-960, 1936

Hull, Texas
A 18, 4, 500-518, 1934

*Humble, Texas
A 18, 4, 500-518, 1934

*Jennings Dome, Louisiana
AG, 961-982, 1936

*Moreni, Roumania
A 29, 11, 1578, 1945

Pierce Junction, Texas
A 18, 4, 500-518, 1934

*Sour Lake, Texas
A 18, 4, 500-518, 1934

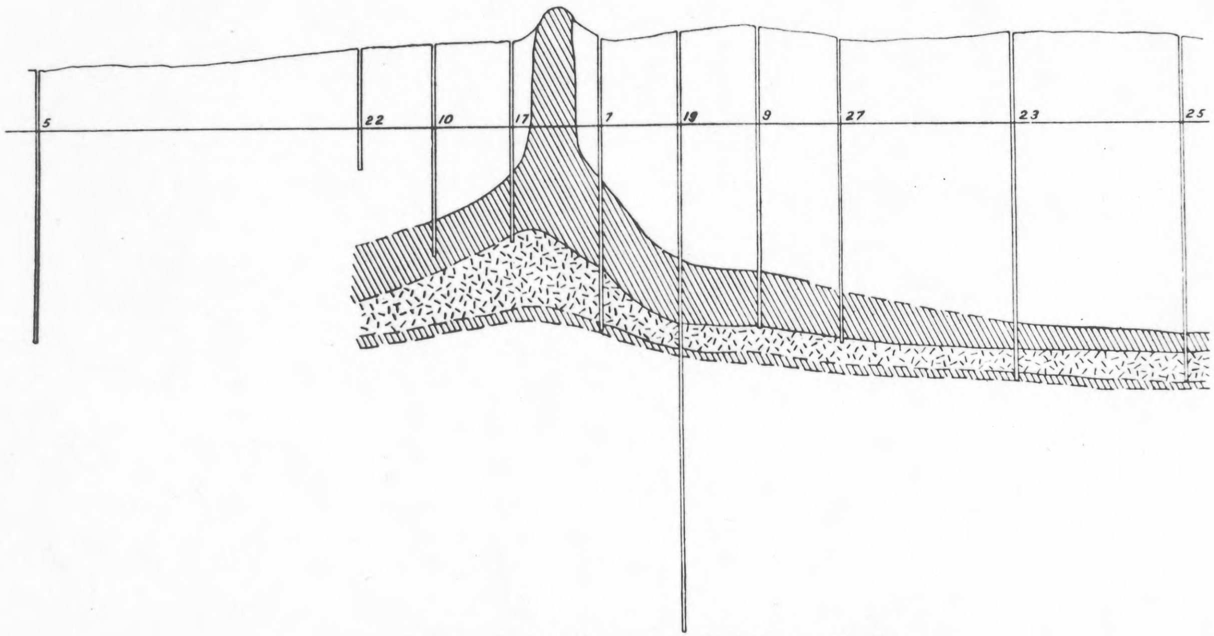
South Liberty, Texas
A 18, 4, 500-518, 1934

*Spindletop, Texas
A 18, 4, 500-518, 1934

West Columbia, Texas
AS 2, 451-469, 1929

Igneous Plug Production.--Igneous plug production is extremely rare and is important mostly from its unusual accumulation. The writer searched the literature for illustrative examples of such a field in which the trapping was of this type. Furbero, Mexico, figures 20 and 21, seems to be the best available. The oil occurs in commercial quantities both in the igneous and metamorphosed rocks. The determining factor in the accumulation of oil in this field is the highly variable porosity of the rocks rather than the structure.

Buried Hills Flank Production.--Unconformities play a very important role in the accumulation of oil. Much of the mid-continent oil production comes from anticlines over buried hills. In the trap under discussion, off-lap or



Geological Section of the Furbero Oil Field.

Figure 20.- After DeGolyer (AIME Trans. 52, 268-280, 1915)

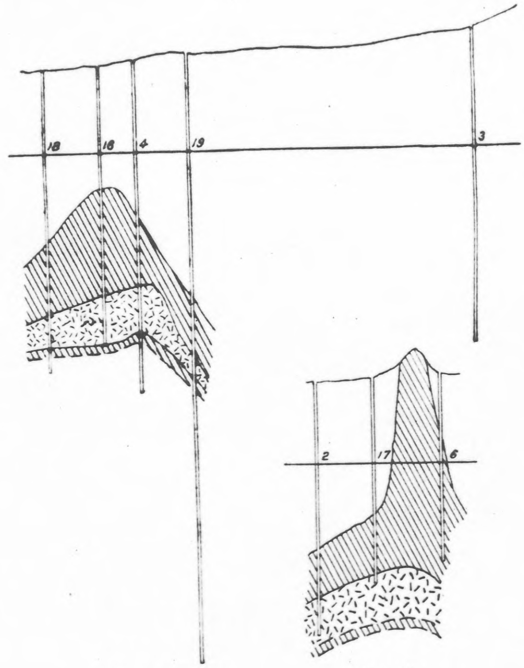


FIG. 3. FIG. 4.

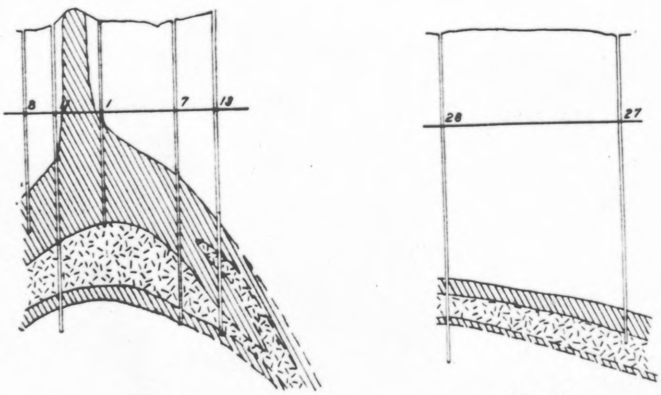


FIG. 5. FIG. 6.

FIGS. 3 TO 6.—GEOLOGICAL SECTIONS OF THE FURBERO OIL FIELD.

Figure 21.--After DeGolyer (AIME Trans. 52, 268-280, 1915)

flank production against a buried hill is the dominant factor in accumulation of oil. This type production is of less importance than the overlap type. One of the best examples of off-lap production is in the Texas Panhandle field, fig. 22, where a thick series of granitic sands, unassorted gravels, and conglomerates are laid down against the hill and later buried. This rock is locally called "granite wash" and produces large amounts of oil and gas, the gas from the higher parts and the oil from the down-dip portions of the "wash". Fields which produce from off-lap reservoirs are:

Page, Texas
A 25, 4, 630-636, 1941

Texas Panhandle
A 19, 8, 1089-1109, 1935

Petrolia, Texas
AS 2, 542-555, 1929

Igneous Rock Traps.--Igneous traps are rare. Production usually comes from fissures or vesicles in lavas, tuffs, or crushed granitic rocks. The Rattlesnake Hills gas field in Washington, fig. 23, is an excellent example of production from porous basalt. The gas is thought to have m grated from the interbedded shales. Other fields producing from igneous rocks are:

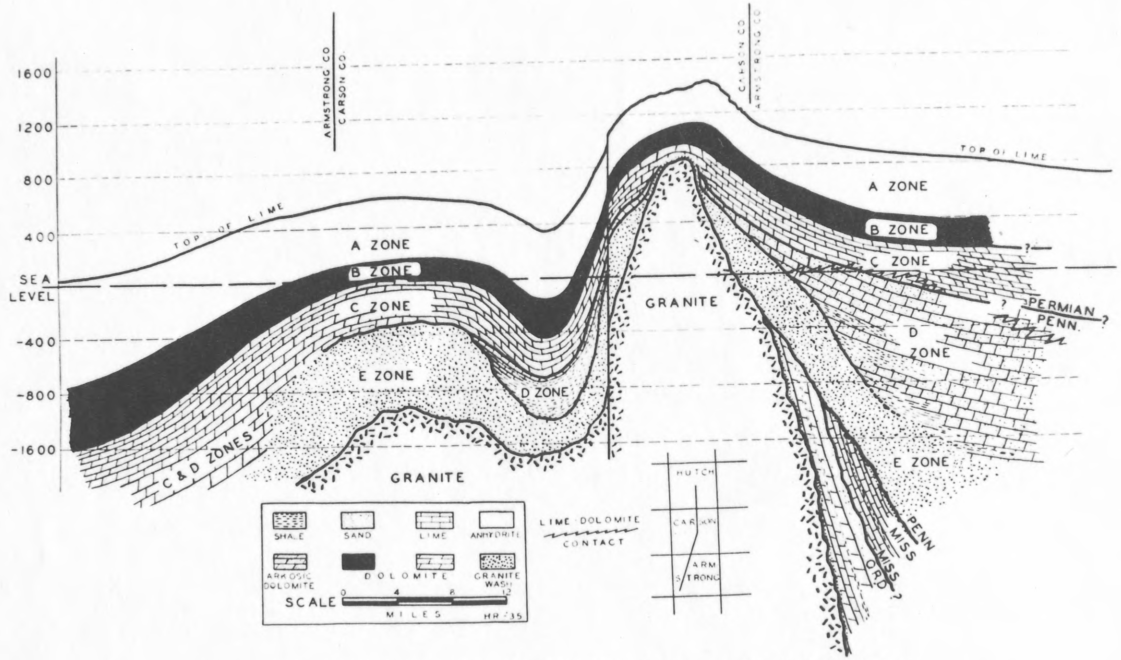
*Mendoza Province, Argentina
A 16, 8, 819-824, 1933

*Richland Parish, Louisiana
A 12, 10, 985-993, 1928

*Rattlesnake Hills, Wash.
A 18, 7, 847-859, 1934

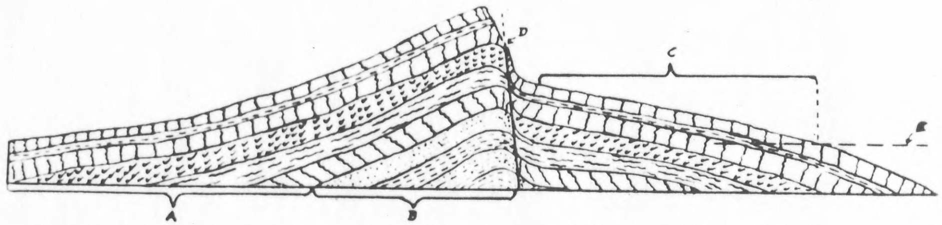
Taranaki, New Zealand
A 16, 8, 833-836, 1932

Metamorphic Rock Traps.--In recent years metamorphic rock production has increased tremendously. Lytton Springs,



Transverse section of Granite ridge, Texas Panhandle. Vertical scale in feet.
(Permian Red-beds not shown.)

Figure 22.– After Rogatz (A 19, 8, 1089-1109, 1935)



Ideal cross section of Rattlesnake Hills gas field. *A*, basaltic flows. *B*, probable Eocene and early Miocene sediments. Likely source of gas in this area. *C*, position of present productive area. *D*, point of gas escape along fracture zones. *E*, approximate position of water table in principal producing horizon.

Figure 23.– After Hammer (A 18, 7, 847-859, 1934)

fig. 24, is the classic locality for serpentine production. A mass of serpentine over a mile in diameter lies at a depth of 1200-1500 feet. The serpentine is altered intrusive, and in part extrusive, basalt with lava and ash phases. It is fractured and brecciated and in part vesicular. Prior to June 1945 all possible productive horizons in the Edison field, California were considered to be tested since most of the wells had penetrated the entire sedimentary section. In June, however, a well was drilled 83 feet into schist and was completed for an initial potential of 528 barrels per day. By January 1947, 106 wells were completed with an estimated productive capacity of 41,300 barrels per day. The productive area covers 1600 acres which includes most of that part of the field producing from sediments. The production is governed by the amount of interconnected voids present in the fractured metamorphic rock located in a favorable structural position on the Edison uplift. Ver Wiebe (1938, p. 108) describes production from pre-Cambrian quartzites in the Orth pool, Rice County, Kansas. The oil occurs in a structural high where porosity and permeability was formed during a pre-Pennsylvanian erosional period. Below is a partial list of fields producing from metamorphic rocks.

Bacuranao, Cuba
A 16, 8, 809-818, 1933

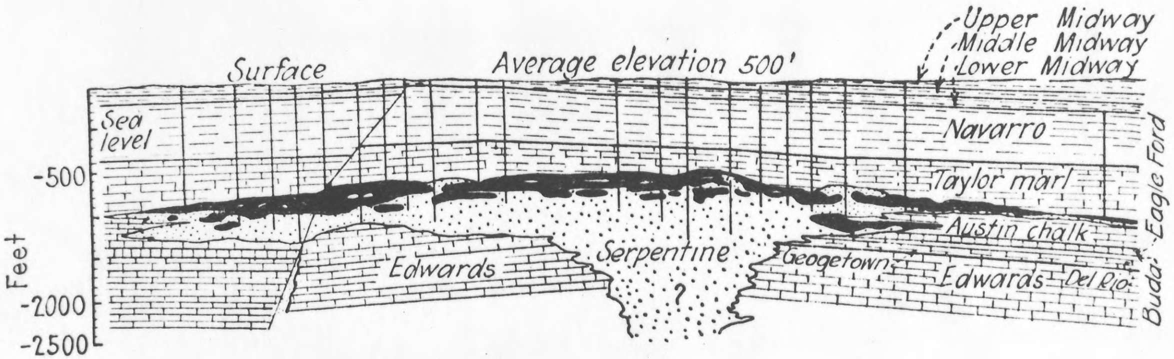
Buchanan, Texas
A 16, 8, 741-768, 1933

Chapman, Texas
A 16, 8, 741-768, 1933

Dale, Texas
A 16, 8, 741-768, 1933

*Darst Creek, Texas
A 17, 1, 16-37, 1933

Del Rey, California
A 20, 2, 150-154, 1936



Cross section of Lytton Springs oil field, Texas. The oil (black) is concentrated in fractured and porous serpentine. (*After Collingswood and Rettger.*)

Figure 24.- (A 10, 10, 953-975, 1926)

*Edison, California
AST, 1-8, 1941

Hilbig, Texas
A 19, 7, 1023-1037, 1935

Lytton Springs Townsite, Tex.
A 16, 8, 741-768, 1933
A 10, 10, 953-975, 1926

Motembo, Cuba
A 16, 8, 809-818, 1933

Placerita Canyon, California
A 16, 8, 777-785, 1933

Schimmel-Batts, Texas
A 16, 8, 741-768, 1933

Thrall, Texas
A 16, 8, 741-768, 1933

Venice field, California
A 20, 2, 150-154, 1936

Yost, Texas
A 14, 9, 1191-1197, 1930

SUMMARY AND CONCLUSIONS

The census given in the preceding pages brings out several interesting facts. Structural traps constitute 57% of the total traps. Of these, slightly over 60% are anticlines and domes, and 20% are faults.

Lensing sandstones are the most important of the stratigraphic traps, making up nearly 30% of the total. Lensing sandstone, lensing sandstone due to sedimentation, carbonate rock porosity, and dolomitization account for nearly 70% of the stratigraphic traps. The chart below gives the relative importance of the various traps.

Structural Traps	Percent of Structural Traps	Percent of Total Traps
Elongate anticlines	10.7	6.1
Anticlines	30.4	17.3
Quaquaversal domes	20.8	11.9
Super salt plug strata	10.4	6.0
Synclines	2.5	1.4
Monoclines & terraces	1.0	.6

Faults	19.8	11.4
Fissures & fractures	4.4	2.5
Stratigraphic Traps	Percent of Stratigraphic Traps	
Lensing sandstone	29.1	12.4
Lens. sandstone sed.	10.9	4.7
Lens. sandstone cem.	2.1	.9
Carbonate rock porosity	16.0	6.9
Salt plug cap	3.0	1.3
Dolomitization	12.7	5.4
Solid hydrocarbon seal	2.1	.9
Sandstone overlap	4.6	2.0
Carbonate rock overlap	2.5	1.1
Salt plug	6.3	2.7
Igneous plug	.5	.2
Buried hills	1.3	.6
Igneous rock	1.7	.7
Metamorphic rock	7.2	3.0

Because of the intensive search for structural traps, we are gradually running out of untested anticlines. As a result, stratigraphic traps are producing a progressively greater percentage of the oil.

The importance of stratigraphic traps has been recognized only in the last few years. As the search is directed more to stratigraphic traps, many new oil fields will be discovered. The writer believes that they are the keys to the oil fields of the future.

BIBLIOGRAPHY

Adams, J. E. (1920) Oil Pool of the Open Reservoir Type, AAPG Bull., vol. 20, no. 6, pp. 780-796.

Bosworth, T. O. (1920) Geology of Mid-Continent Oil Fields, (The Macmillan Company, New York), p. 225.

Brucks, E. W. (1929) Luling Oil Field, Texas, AAPG Symposium, Structure of Typical American Oil Fields, vol. 1, pp. 256-281.

Coal and Petroleum (1863) Harper's New Monthly Mag., vol. 27, pp. 259-264.

Emmons, W. H. (1931) Geology of Petroleum, (McGraw-Hill Book Company, New York), 736 pages.

Hitchcock, Charles (1866) The Geological Distribution of Petroleum in North America, Rept. Brit. Assoc., pp. 55-57.

Landes, K. K. (1946) Porosity Through Dolomitization, AAPG Bull., vol. 30, no. 3, pp. 305-318.

Lilley, E. R. (1936) Economic Geology of Mineral Deposits, (Henry Holt & Company, New York), 811 pages.

Munn, M. J. (1909) Studies in the Application of the Anticlinal Theory of Oil and Gas Accumulation, Econ. Geol., vol. 4, pp. 141-147.

Orton, Edward (1888) The Geology of Ohio, Considered in its Relation to Petroleum and Natural Gas, Geol. Survey of Ohio, vol. 6, pp. 307-308.

Thompson, A. B. (1925) Oil Field Exploration, vol. 1, (D. Van Nostrand Co., New York), p. 162.

Van Tuyl, F. M. (1924) Elements of Petroleum Geology, (Denver Publishing Company, Denver Colorado), p. 58.

Ver Wiebe, W. A. (1936) Oil and Gas Reserves of Western Kansas, State Geological Survey of Kansas, Mineral Resources Circ. 10, April 1, 179 pages.

Wegeman, C. H. (1917) The Salt Creek Oil Field, Wyoming, USGS Bull. 670, p. 36.

White, I. C. (1885) The Geology of Natural Gas, Science, vol. 5, pp. 521-522.

Wilson, W. B. (1934) Proposed Classification of Oil and Gas Reservoirs, AAPG Symposium, Problems of Petroleum Geology, pp. 433-445.

Ziegler, Victor (1920) Popular Oil Geology, (John Wiley and Sons, New York), pp. 87-116.