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HABITAT OF SOME OIL[1]

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ABSTRACT

Detailed statistics have been prepared and studied for 236 or all of the major oil fields of the free world. They represent 217 billion barrels, which is 82.5 per cent of the free-world's ultimate reserves discovered to date. The study shows the bulk of this oil occurs: (1) on the stable side of basins, (2) in anticlines, (3) in sandstone and carbonate reservoirs, (4) from formations of Mesozoic age or younger, and (5) from a depth range of 2,000–8,000 feet.

Most of the discovered free-world's ultimate oil is 30° API gravity or lighter, with mixed- asphaltic-base oils predominating. The discovery of the free-world's major oil fields has been cyclic, with 10-year intervals beginning in 1917.

INTRODUCTION

"The Habitat of Oil in the Sedimentary Basin" was the central theme of the annual meeting of the American Association of Petroleum Geologists held in New York in March, 1955. At that meeting, numerous excellent papers were presented covering many of the producing basins of the world. As a follow-up to those presentations, this paper offers a statistical study of the habitat of most of the world's ultimate oil discovered to date outside Soviet Russia and its affiliated countries.

For practical reasons, this study deals only with the so-called major fields, those fields having an ultimate recovery exceeding 100 million barrels. Ultimate recovery, as used in this paper, means total oil discovered to date, that is, present remaining reserves plus past production. During the study, it was found that 236 fields qualified as major oil fields. These fields are located in 42 basins and to-

[1] Manuscript received, December 10, 1955.

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The petroleum reserves data which are the basis of this study were gathered by geologists working for Standard Oil Company (N. J.) and its affiliates. The writers are responsible for the compilation of the data and for the conclusions derived. Thanks are due to Mrs. Pearle Blackman for reading the manuscript and to S. W. Reims for drafting suggestions.

gether account for 217 billion barrels of oil. This represents 82.5 per cent of the known ultimate recovery of the free world of approximately 263 billion barrels. The remaining 17.5 per cent, or 46 billion barrels, is scattered in thousands of smaller fields whose individual recoveries will not reach 100 million barrels.

From these figures, it is apparent that any study involving the world's major oil fields carries considerable weight in view of the impressive aggregate ultimate recovery that these fields have. Consequently, these major accumulations provide the geologist with the easiest accessible means of studying the bulk of the world's oil found to date.

The world's habitat of oil picture can be viewed from as many angles as there are relevant controlling geologic factors. In this statistical study, the information relating to the habitat of oil in the free-world's major oil fields is presented on the basis of the following criteria.

1. Geographical Location

2. Basin Position

Depositional Basin	*Present (Structural) Basin*
a. Mobile rim	a. Mobile rim
b. Deep basin	b. Deep basin
c. Hingeline (cerniera)	c. Hingeline
d. Shelf	d. Shelf
	e. Other

3. Type of Trap

a. Anticline	d. Reef
b. Fault	e. Other stratigraphic
c. Unconformity	f. Combination

4. Lithology of Reservoir

a. Sand	b. Carbonates	c. Other fracture

5. Geologic Age of Reservoir

a. Pleistocene-Pliocene	d. Mesozoic
b. Miocene-Oligocene	e. Paleozoic
c. Eocene-Paleocene	

6. Gravity of Crude

a. Light (above 30° API)	b. Medium (22°–30° API)	c. Heavy (below 22° API)

7. Chemical Base of Crude

a. Paraffinic	b. Mixed	c. Asphaltic

8. Subsurface Depth of Occurrence

(Feet)	*(Feet)*
a. 0 –1,000	h. 7,000– 8,000
b. 1,000–2,000	i. 8,000– 9,000
c. 2,000–3,000	j. 9,000–10,000
d. 3,000–4,000	k. 10,000–11,000
e. 4,000–5,000	l. 11,000–12,000
f. 5,000–6,000	m. Over 12,000
g. 6,000–7,000	

9. Time of Discovery

Once a field was properly classified according to the subdivisions of this scheme, the next step consisted in assigning ultimate reserves to every one of the classifications pertaining to each field. Finally, the allocated reserves figures of

Billion per americani = 1000 milioni = 1 miliardo
per inglesi = 1 milione di milioni = 1000 miliardi

1 bbl = 159 litri —— $1 m^3$ = 6,3 barili

the individual fields were totaled for each basin in order to arrive at totals for each continent and for the free world as a whole. In addition, under each classification, the number of fields was also totaled in order to gain an idea of how many individual occurrences were responsible for the reserves calculated in the previous step.

GEOGRAPHICAL LOCATION

Preceding the geologic details of the study a few generalities on the geographical location of these giant fields and the basins in which they occur are shown in the following tables.

North America leads the way in total number of major fields, and the Middle East shows the highest average ultimate yield per field. Table I also indicates

TABLE I. DISTRIBUTION OF MAJOR FIELDS BY AREA AND SIZE

Area	*Number of Major Fields*					*Average Ultimate**
	Total	*Class I*	*Class II*	*Class III*	*Class IV*	
North America	177	153	19	5	0	300
South America	28	22	5	0	1	730
Europe	1	1	0	0	0	120
Africa	1	1	0	0	0	200
Middle East	21	2	6	8	5	6,700
Far East	8	6	1	1	0	520
Free World	236	185	31	14	6	920

Class I—Fields with 100–500 million barrels ultimate.
Class II—Fields with 500–1,000 million barrels ultimate.
Class III—Fields with 1,000–10,000 million barrels ultimate.
Class IV—Fields with more than 10,000 million barrels ultimate.
* Millions of barrels.

that 185 fields, or 82 per cent, are in Class I, the smallest bracket, of the breakdown having ultimate reserves of less than 500 million barrels each. The true giants with reserves of more than 10 billion barrels each are confined to the Middle East with the exception of one located in Western Venezuela. In the Middle East, 13 fields, or 56 per cent of the total of 21 fields, have ultimates exceeding one billion barrels each, and of these, five fields, or 38 per cent, have an ultimate yield in excess of 10 billion barrels.

The world-wide distribution and relative importance of the privileged basins having major oil fields are shown by Table II.

Table II shows that only eight basins in the world have more than 10 major fields each. It should be noted that 31 basins, or 74 per cent of the total, belong to Class I having five or less major fields. Of the total of 42 basins having major oil fields, only two, the Persian Gulf and the Gulf Coast, have more than 20 major fields among their petroleum accumulations.

POSITION IN DEPOSITIONAL BASIN

Figure 1 shows schematically the four simplified parts of a basin which were used in this work, namely, the shelf, hingeline, deep basin, and mobile rim. If a

Valore di un campo da 1 miliardo di bbls × $ 1,4 =
$ 1,4 miliardi =~ 870 miliardi di lire

TABLE II. DISTRIBUTION OF BASINS WITH MAJOR OIL FIELDS BY AREA AND NUMBER OF FIELDS PRESENT

Areas	Number of Basins				
	Total	Class I 0–5 Major Fields	Class II 5–10 Major Fields	Class III 10–20 Major Fields	Class IV Over 20 Major Fields
North America	28	20	2	5	1
South America	6	4	1	1	0
Europe	1	1	0	0	0
Africa	1	1	0	0	0
Middle East	1	0	0	0	1
Far East	5	5	0	0	0
Free World	42	31	3	6	2

more elaborate breakdown had been used, the results would be more difficult to interpret even though they might more nearly conform with the architecture of basins as understood to-day.

There may be some question about the basin position assigned to some of the fields. The writers believe that the selections made are reasonably correct and should be accepted until a more exhaustive study is made. It should be emphasized, however, that there is usually less room for argument regarding the basin position of the fields in the present or structural basin. Therefore, the position in

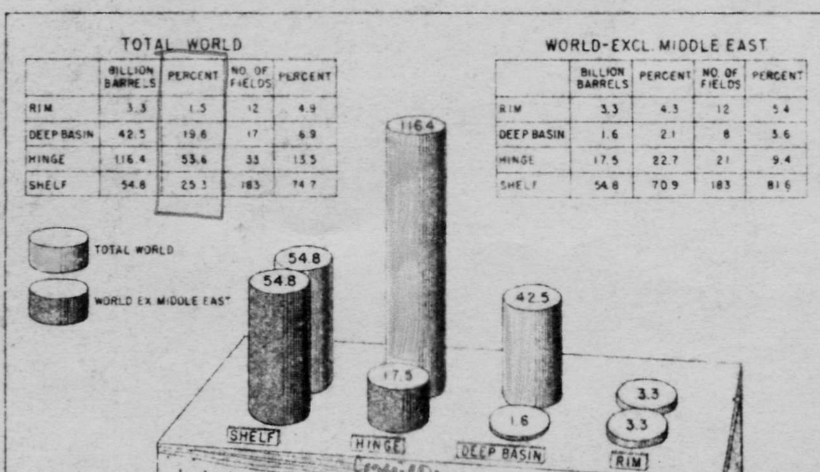

FIG. 1.—Habitat of oil in free-world's major oil fields according to basin position in depositional basin.

Kuwait. Small amounts of oil were discovered during the economic depression of the early thirties following the discovery of the East Texas field and again during the relative inactive period of World War II. The figures for the years since 1950 will probably move upward as those new fields become properly evaluated.

CONCLUSIONS

Statistics can be dull and meaningless unless they carry a message. It is hoped that the statistics presented in this study will at least serve the following purposes.

1. Make petroleum geologists more familiar with the location and distribution of the bulk of the free-world's oil.

2. Present an over-all picture of the preferred localization of this oil from as many points of view, geologically or otherwise, as a general study of this kind will permit.

3. Stimulate work and research seeking rational geological explanation for the patterns of distribution shown.

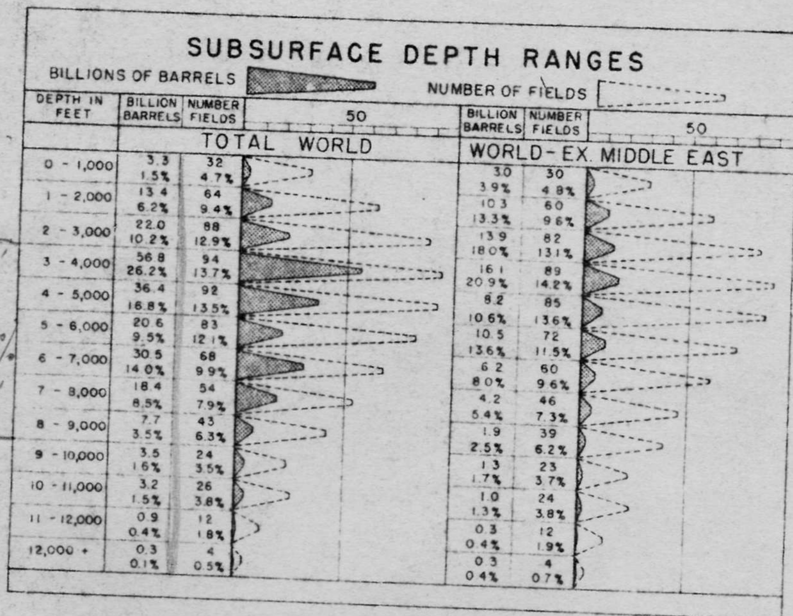

FIG. 9.—Habitat of oil in free-world's major oil fields according to subsurface depth of occurrence.

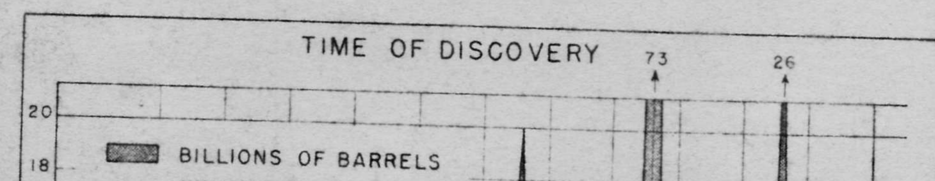

FIG. 10.—Chronological record of discovery of free-world's major oil fields.

1917 Venezuela Ovest

1938 Burgan Kuwait

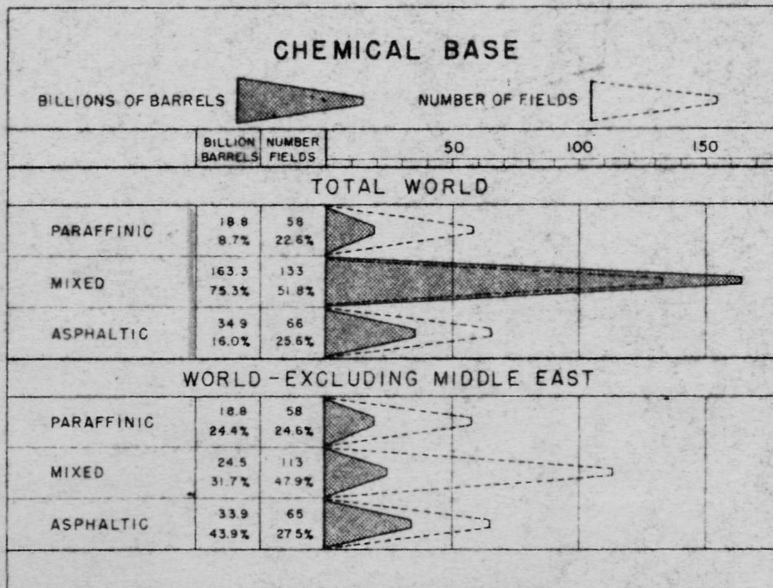

FIG. 8.—Habitat of oil in free-world's major oil fields according to chemical base of crude.

SUBSURFACE DEPTH OF OCCURRENCE

Figure 9 presents the subsurface depth distribution of oil, by 1,000 foot-increments, in the free-world's major oil fields. The richest subsurface depth interval is the 3,000–4,000-foot range which holds 26 per cent of the total oil discovered in the free-world's major oil fields. From this peak the values decrease in both directions, the decrease being more gradual toward the greater depths.

Of necessity, some of the figures that went into these depth computations must be considered as approximates only, since in some areas the geological details were not available.

It is to be expected that the deeper picture will probably improve with time as more and deeper wildcats are drilled. However, this is the depth habitat of oil as it is known to-day. There must be some reason for the occurrence of the bulk of our oil, 85 per cent, at depths between 2,000 and 8,000 feet. Any answer about the underlying cause for such distribution would be a contribution toward a better understanding of the processes of oil generation and accumulation.

TIME OF DISCOVERY

Figure 10 shows the number of major fields and the amount of oil discovered on a yearly basis since 1900. The 10-year cycle of major discoveries began with the Bolivar coastal fields of Western Venezuela in 1917. The peak discovery year, with 73 billion barrels, was in 1938 with the discovery of the Burgan field of

API GRAVITY

As shown by the data in Figure 7, light oil predominates over medium and heavy reserves by a substantial margin. It should be emphasized that 91.2 per cent of the total oil discovered in the world's major oil fields is lighter than 22° API gravity. Of the 42 basins having major oil fields, only four (Magdalena, Mississippi Salt Dome, Salinas Valley, and Santa Maria) show no light-oil reserves. Medium-oil major fields are located chiefly in California, Gulf Coast,

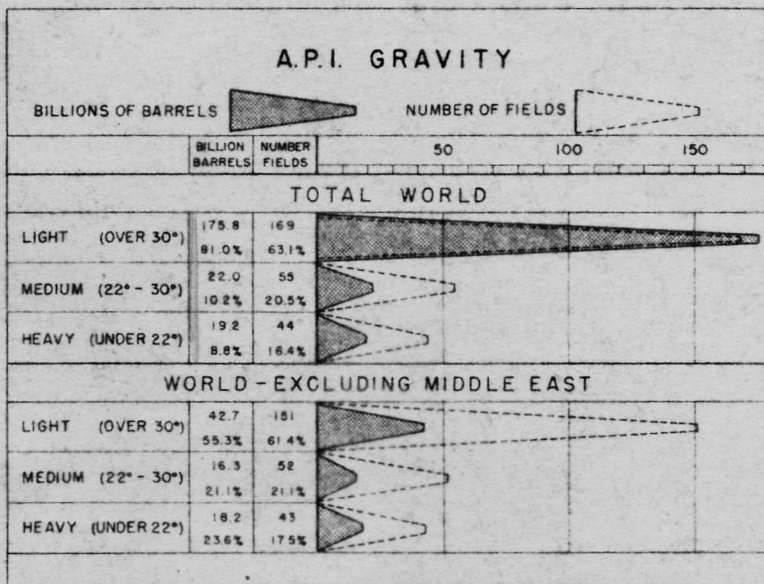

FIG. 7.—Habitat of oil in free-world's major oil fields according to API gravity of crude.

Venezuela, and the Middle East. Important heavy oil regions include Venezuela, California, and Mexico. Large reserves of the so-called tar oils were not included in the study inasmuch as these are considered non-commercial at present, and reliable estimates as to their amount are largely lacking.

CHEMICAL BASE

The marked preponderance of mixed crudes shown in Figure 8 is due mainly to the Middle East reserves which almost exclusively belong to the mixed-base category. If the Middle East is excluded, the picture changes noticeably, with asphaltic crudes leading the way, followed by the mixed and paraffinic oils. The largest asphaltic reserves are located in the Maracaibo basin. The Gulf Coast and West Texas areas hold the largest reserves of paraffin-base oils.

The source data available on crude oil base for various areas are limited, and the results shown may vary somewhat should more reliable data become available.

passing one billion barrels, in their order of importance, are: Central Basin platform and Midland and Delaware basins of West Texas, Alberta basin, the Nemaha ridge of Kansas and Oklahoma, the Seminole uplift and Ardmore basin of Oklahoma, and the Eastern Interior basin of Illinois, Indiana, and Kentucky.

A general idea about the relative richness of the individual fields of the various age groups considered can be gained by comparing percentage-wise the number of fields and the corresponding reserves of each particular age. For the world as a whole, the picture is as follows. Mesozoic fields lead with 19.5 per cent of the

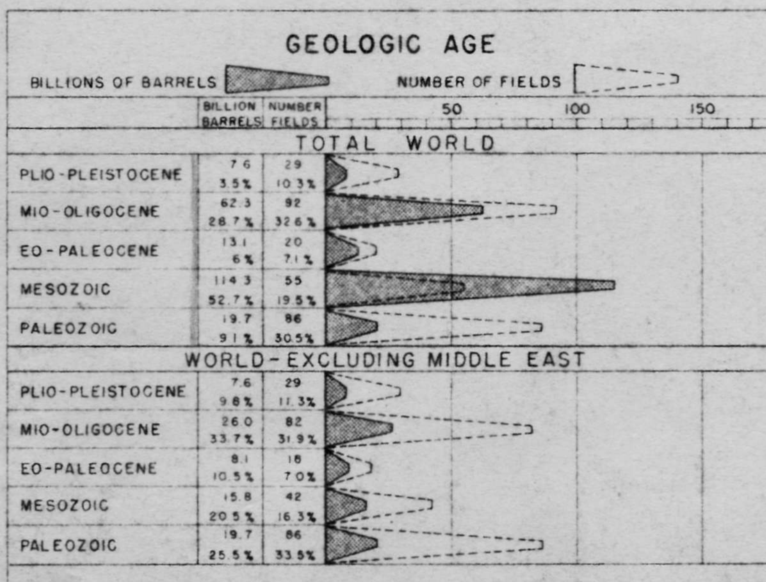

FIG. 6.—Habitat of oil in free-world's major oil fields according to geologic age of producing formation.

total fields accounting for an overwhelming 52.7 per cent of the total reserves. The Tertiary fields with 50 per cent of the total are responsible for 38.2 per cent of the total reserves. Paleozoic fields, although accounting for 30.5 per cent of the total number of fields, contain only 9.1 per cent of the total reserves. If the sizeable Middle East fields are excluded, the Mesozoic fields still maintain the lead with 16.3 per cent of the fields containing 20.5 per cent of the reserves; the Tertiary fields greatly improve their position now, with 50.2 per cent of the fields credited with 54 per cent of the reserves; the Paleozoic fields show some improvement, with 33.5 per cent of the fields containing 25.5 per cent of the total reserves. These comparisons conclusively show that world-wide, on an average individual field basis, Mesozoic major fields are richer than either Paleozoic or Tertiary fields.

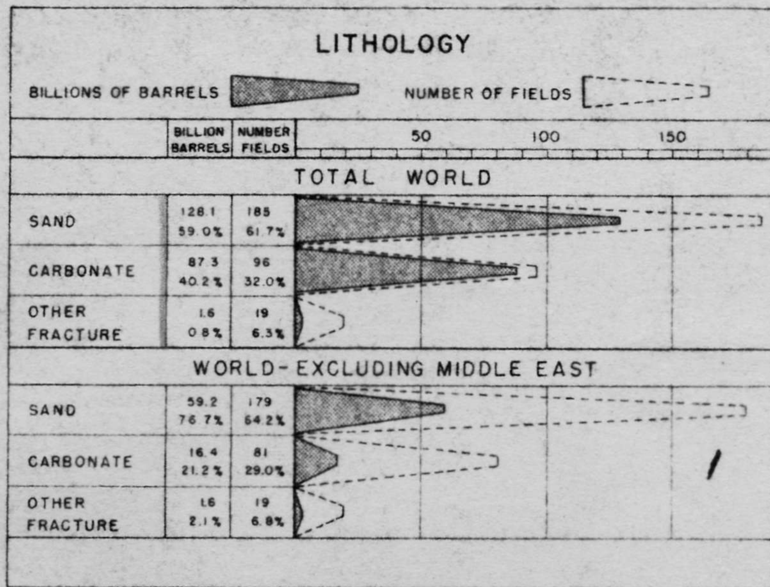

FIG. 5.—Habitat of oil in free-world's major oil fields according to lithologic character of reservoir rock.

GEOLOGIC AGE OF RESERVOIR

The reserves breakdown based on age of producing formation is presented in Figure 6. The figures clearly indicate the predominant position of Mesozoic and Mio-Oligocene rocks as oil producers. Sediments belonging to these ages account together for more than 80 per cent of the total oil of the free-world's major oil fields. Exclusive of the Middle East, the Mio-Oligocene becomes the leader, followed by the Paleozoic and Mesozoic, with the Eocene-Paleocene and Plio-Pleistocene being virtually tied at the fourth place.

Major Plio-Pleistocene fields are restricted to California, the Gulf Coast, Eastern Venezuela, and one field in the Far East. Mio-Oligocene major fields are present in all these areas, plus the Middle East, Western Venezuela, and Colombia. Eocene-Paleocene fields are more restricted in occurrence, the more important accumulations being located in the Maracaibo basin, Middle East, Magdalena and Talara basins of Colombia and Peru, and the San Joaquin Valley and Gulf Coast of the United States.

Mesozoic major fields are concentrated in the Middle East, Rocky Mountain province, Upper Gulf Coast, Mexico, Western Venezuela, and Argentina. Out of the 114 billion barrels of Mesozoic oil in the major fields, 98 billion, or 86 per cent, occurs in the Middle East producing countries.

Paleozoic production from major fields comes almost exclusively from the United States and Canada. The seven most prolific areas having ultimates surgenerally considered as unconformity accumulations really belong to the combination type of trap. The leader among the unconformity fields is the East Texas field, with more than 5 billion barrels ultimate.

An attempt was made to gain reliable information on the amount of oil occurring within 300 feet of an unconformity. Unfortunately, the figures obtained are not conclusive, as data on the oil located within 300 feet of an unconformity were not available for many fields. The incomplete information at hand on 130 fields indicates that 23.5 billion barrels are found within 300 feet of an unconformity. This amount, 10.8 per cent of the total, is surprisingly low and could no doubt be raised to at least 30 billion barrels should more information become available. This shows the importance of unconformities as places near which sizeable oil reserves are likely to occur.

Reef fields hold 2.4 per cent of the oil of major fields. The three more important areas producing from purely reef traps are the Devonian fields of the Alberta basin of Canada, the Permian and Pennsylvanian reefs of West Texas and New Mexico, and the Golden Lane fields of Mexico.

Other stratigraphic traps, such as pinchouts, shaleouts, and asphalt seals, are responsible for 7.3 per cent of the 217 billion barrels of ultimate oil from the free-world's major oil fields. The most important fields of this type are located in the Alberta basin, San Joaquin Valley, McAlester basin, Midland and Delaware basins, and the Maracaibo and Orinoco basins.

Combination traps in which two or more trapping elements combine to form an effective barrier contain 6.3 per cent of the total reserves of the free-world's major oil fields. Three major areas are responsible for more than half of the reserves held in this type of trap. These areas in order of importance are: the Maracaibo basin, the San Joaquin Valley, and the fields associated with the Nemaha ridge of Kansas and Oklahoma.

LITHOLOGIC CHARACTER OF RESERVOIR

The free-world picture of the lithologic character of the reservoir rock is shown in Figure 5. These data are judged particularly significant in that they disprove the commonly held belief that most of the oil found to date is reservoired in limestones and dolomites. The results show that sand reservoirs hold 59 per cent of the oil found in major fields, with carbonates holding almost the entire remaining 41 per cent. Other fractured rocks such as shales and igneous or metamorphic rocks contain only 0.8 per cent of the oil in major fields.

Major fields with sand reservoirs are found in all but two of the 42 basins of this study, the exception being the Williston basin and the Cincinnati arch. Carbonate reservoirs of major fields are found in 20 of the basins. Basins having more than one billion barrels of reserves in major carbonate fields are listed in order of importance: Persian Gulf, West Texas, Northeast Mexico, Alberta, and Maracaibo.

in a mere "handful" of anticlines, many of which were detected by simple "old fashioned" surface geology observations. It is to be emphasized that anticlines still account for more than 40 per cent of the oil of the major fields if the astronomical Middle East reserves are excluded. It is a moot question whether or not anticlines will be able to maintain their leadership in the years to come. It may well happen that the more advanced exploration techniques now available will eventually shift the balance, and the reserves that will be discovered in the more

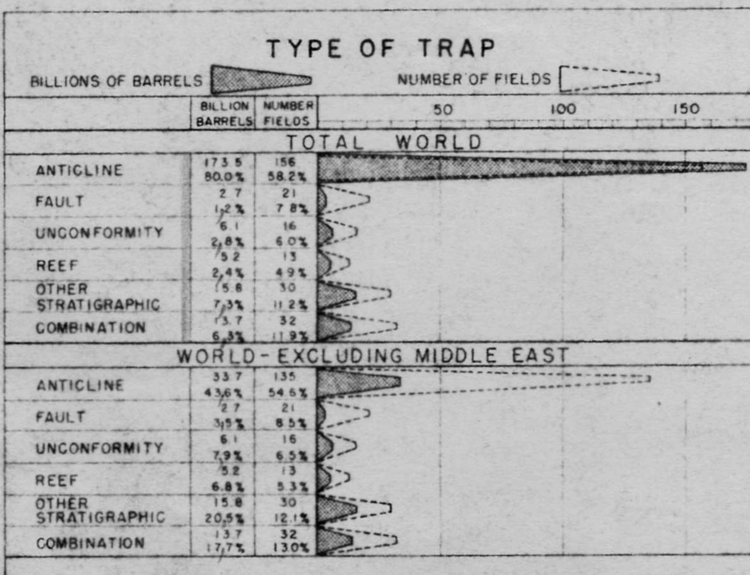

FIG. 4.—Habitat of oil in free-world's major oil fields according to type of trap responsible for accumulation.

elusive stratigraphic traps might go beyond the amount now credited to anticlinal traps.

In addition to the Middle East, other anticlinal areas of importance are the California basins, the Central Basin platform of West Texas, the Western Maracaibo basin, and the basins of the Far East (Burma, Sumatra, and Borneo).

It is somewhat surprising that strictly fault traps account only for 1.2 per cent of the total oil of the major oil fields of the world. The explanation probably is that many of the so-called fault traps are really combination traps, the fault being only one of the trapping elements. Major fault-trap fields are limited to the Gulf Coast and Ardmore basins in North America and to the Orinoco, Magdalena, and Talara basins of South America.

True unconformity fields account for a disappointingly low percentage of the total oil found in the major oil fields. Here again, it may be that most of the fields of this breakdown the shelf and hingeline occurrences are grouped together, and a total for the stable side of the basin is obtained. In the same manner, the deep-basin reserves are added to those belonging to the rim in order to get a total for the more mobile side of the basin.

This figure clearly shows that the stable side of the basins holds most of the oil. The data indicate that in the depositional basins, discovered reserves to date in the stable side are nearly four times those of the mobile side. In the present-day basins the mobile side has an improved position, but still the stable side leads the way by an approximate two to one margin. It is significant that this pattern of distribution holds true for both the depositional and structural basins.

TOTAL WORLD

DEPOSITIONAL BASIN

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE SIDE	45.8	21.1	29	11.8
STABLE SIDE	171.2	78.9	216	88.2

PRESENT STRUCTURAL BASIN

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE SIDE	71.1	32.8	90	37.8
STABLE SIDE	138.2	63.7	114	47.9
OTHER	7.7	3.5	34	14.3

WORLD-EXCL. MIDDLE EAST

DEPOSITIONAL BASIN

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE SIDE	4.9	6.3	20	8.9
STABLE SIDE	72.3	93.7	204	91.1

PRESENT STRUCTURAL BASIN

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE SIDE	30.3	39.2	81	37.3
STABLE SIDE	39.2	50.8	102	47.0
OTHER	7.7	10.0	34	15.7

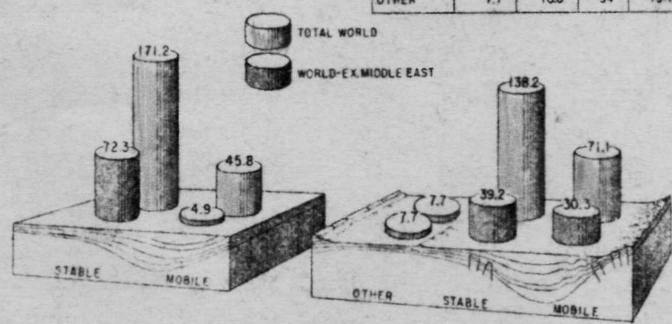

FIG. 3.—Habitat of oil in free-world's major oil fields according to position in stable or mobile side of basins.

TYPE OF TRAP

Figure 4 is a breakdown in billions of barrels and number of fields according to the type of trap responsible for the oil accumulations in the fields included in the study. Anticlinal traps are a clear leader, accounting for 80 per cent of the total oil found to date in the free-world's major oil fields. Many of these anticlines are faulted, but in all cases listed under "anticline"; the primary element causing the accumulation is the structural folding. The greatest anticlinal province is the Middle East where close to 140 billion barrels of oil have been found the structural basin is considered more reliable, and should be the criterion used to indicate the basin habitat of oil.

In the figures and tabulations that follow, two sets of figures are shown. One set applies to the free world as a whole, and the second gives the free-world's picture, excluding the Middle East. This is necessary because the tremendous reserves of the Middle East often distort the picture of the habitat of oil in the other areas.

Figure 1 presents, numerically and graphically, the distribution in the depositional basin of the ultimate oil discovered to date in the free-world's major oil fields. This figure shows that more than 50 per cent of the ultimate reserves of the major fields studied are located along the hingelines of the depositional basins. However, if the prolific Middle East fields are excluded, the shelf becomes the leader in both ultimate oil and number of fields.

Fields located along rims of depositional basins are present in the Rocky Mountains and the Mid-Continent region of the United States and in the Orinoco basin of Eastern Venezuela and Trinidad.

Deep-basin fields are more widespread than rim fields and occur in the Ardmore basin of southern Oklahoma, some of the California basins, West Texas, and the Middle East.

Hingeline fields in North America are limited to the Alberta, Ardmore, Gulf Coast, and Appalachian basins. In South America, important hingeline fields are found in the Maracaibo basin of Western Venezuela and the Comodoro Rivadavia basin of Southern Argentina. The greatest bulk of the Middle East oil is localized along the hingeline of the Persian Gulf basin. All of the known producing fields of southern Iraq, Kuwait, Saudi Arabia, Bahrain, and Qatar lie along the basin's hingeline, with an estimated ultimate of nearly 100 billion barrels.

Of the 42 basins having major fields, all but seven have fields along the shelf of the depositional basin. The three most important domestic areas from the standpoint of ultimate reserves from the shelf are the Gulf Coast, California, and West Texas. Elsewhere, important shelf reserves are found in the Alberta, Northeast Mexico, Maracaibo, Orinoco, and Central Sumatra basins.

POSITION IN PRESENT (STRUCTURAL) BASIN

Figure 2 shows the basin habitat in the present or structural basin of the free-world's major oil fields. A fifth category has been added to the basin subdivisions. Under this "other" category are classified those fields which can not be associated with any present-day structural basin. All the fields included here are located in the United States and all are closely related to large tectonic features such as the Central Kansas uplift, Nemaha ridge, and Cincinnati arch.

The figures show that the hingeline still accounts for roughly 50 per cent of the producible oil of the fields being considered. The mobile rim province has increased to 21 per cent of the total at the expense of the reserves of both the deep basin and the shelf. Again, if the Middle East is excluded, the shelf occurrence would predominate in both reserves and number of fields. However, the commanding position of the shelf province is not as marked here as it was in the case of the depositional basin. The difficulty of recognizing a hingeline in many present-day basins may account for the relatively small number of fields under the hinge.

Fields located on the mobile rim side of the present-day structural basins are found chiefly in the Rocky Mountains, California, Venezuela, and Middle East.

TOTAL WORLD

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE RIM	46.3	21.3	32	13.4
DEEP BASIN	24.8	11.4	58	24.4
HINGE	109.0	50.3	39	16.4
SHELF	29.2	13.5	75	31.5
OTHER	7.7	3.5	34	14.3

WORLD-EXCL. MIDDLE EAST

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE RIM	16.9	21.9	26	12.0
DEEP BASIN	13.4	17.4	55	25.3
HINGE	10.0	12.9	27	12.4
SHELF	29.2	37.8	75	34.6
OTHER	7.7	10.0	34	15.7

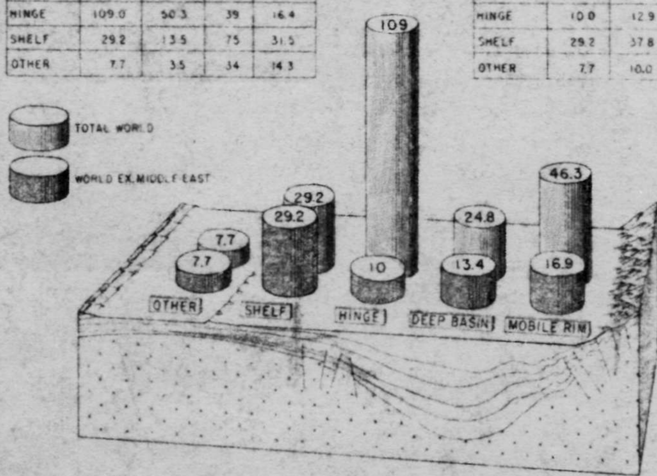

FIG. 2.—Habitat of oil in free-world's major oil fields according to basin position in present (structural) basin.

Deep-basin fields occur mostly in Canada, the Mid-Continent area, California, and the Gulf Coast. Substantial reserves are also found in the deeper parts of the Persian Gulf basin.

Hingeline fields in the United States are found mainly in the Gulf Coast and California. In South America both Venezuela and Argentina have important hingeline accumulations. The Middle East contains close to 100 billion barrels of ultimate reserves in fields located along the hingeline of the Persian Gulf basin.

Major-shelf fields are reported in 21 basins, of which those having in excess of one billion barrels ultimate are listed in diminishing order: Gulf Coast, West Texas (Midland and Delaware basins), Northeast Mexico (Tampico Embayment), Alberta, Central Sumatra, Maracaibo, Los Angeles, and Orinoco.

In an attempt to summarize the previously discussed basin habitat of oil, Figure 3 presents the same data in a more simplified manner. In the preparation