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GEOLOGICAL SURVEY

Distribution and quantitative assessment of world crude-oil

reserves and resources

By

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This report is preliminary and has not been reviewed for conformity with
U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

World Demonstrated Reserves of crude oil are approximately 723 billion barrels of oil (BBO). Cumulative production is 445 BBO and annual production is 20 BBO. Demonstrated Reserves of crude-oil have declined over the past 10 years consistent with discoveries lagging production over the same period. The assessment of Undiscovered Resources shows a 90 percent probability that the amount discoverable lies between 321 and 1,417 BBO, 550 BBO being the most likely value. The most likely value for Ultimate recoverable resources is 1,718 BBO. The distribution of Ultimate Resources of crude oil will remain highly skewed toward the Middle East; no frontier areas that have potentials large enough to significantly affect present distribution are recognized. Rates of discovery have continued to decline over the past 20 years even though exploration activity has increased in recent years. Prudence dictates, therefore, that the low side of the assessment of Undiscovered Resources be responsibly considered and that alternate energy sources be a part of future planning.

Extra-heavy oil and bitumen are assessed separately, with Reserves being figured as the annual productive capacity of installed facilities times 25 years. The annual production of extra-heavy oil is about 8 million barrels and of bitumen about 60 million barrels.

INTRODUCTION AND DEFINITIONS

The enumeration of world crude-oil reserves and resources is a difficult undertaking. One must rely on data gathered by others and, through various spot-check and cross-check mechanisms, distinguish the reasonable from the unreasonable. Estimating techniques vary; standards of measurement vary; classification of the reported elements differ; and, in some cases, even the recognition of what is being reported is obfuscated by language and nomenclatural ambiguities. Therefore, to improve world petroleum resource understanding, it is prudent to describe the methodologies and measurement standards explicitly, to disaggregate the data as much as possible to gain insight into the source of the differences, and to standardize the classification and nomenclature scheme to establish unambiguous communication.

The purpose of this report is to give an estimate of world crude-oil resources, their distribution, and their API gravity. The resource classification diagram of the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (U.S. Geological Survey Circ. 831, 1980) allows for the reporting of both reserves and resources with the degree of geologic certainty of the data expressed on the horizontal axis and the degree of economic potential expressed on the vertical axis. Utilizing this classification format, figure 1 shows the estimate for world Resources of conventional crude oil. By conventional oil, we mean the oil greater than 10° API gravity (excluding natural gas liquids) which is broadly considered to be economically recoverable by conventional primary, water-flood, and pressure-maintenance techniques; the extra-heavy oil (less than 10° API and greater than 10,000 centipoise) of the Orinoco Petroleum Belt of Venezuela and the bitumen of the Athabasca tar sands of Canada, for examples, are not included with conventional crude oil but are listed separately. The resources of crude oil are classified as being Identified or Undiscovered.

The left-half of figure 1 shows Identified (or "Discovered") Resources. Economically recoverable Identified Resources are called Reserves and classified in three subdivisions: Measured Reserves (or Proved, of the U.S. Energy Information Administration (EIA) (DOE/EIA-0216(81), 1982) are defined as the expected recovery, by conventional techniques, considering the full extent of each recognized reservoir; Indicated Reserves (or Indicated Additional as defined by American Petroleum Institute (API, 1980)) are defined as the additional amount of oil that could be recovered given installation of conventional water-flood facilities; and Inferred Reserves are defined as the amount of oil derived from the expected growth in the reported size of fields, given the addition of new pools or reservoir extensions not envisioned in the Measured Reserve calculation. The combination of the Measured and Indicated Reserve is a Demonstrated Reserve. Industry custom prior to 1970 was to report Measured (or Proved) Reserves in the restricted sense of only what had actually received sufficient development drilling to permit reliable flow testing. Since then, however, it has become customary to report an estimate of the maximum expectable conventional recovery from the recognized reservoirs, whether or not they have been completely developed by drilling and whether or not they have been completely fitted for optimum water-flood

RESOURCES OF CRUDE OIL

AREA: WORLD   UNITS: BILLIONS BARRELS

CUMULATIVE PRODUCTION 445	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES
	DEMONSTRATED		INFERRED	PROBABILITY RANGE
	MEASURED	INDICATED		95% MODE 5%
ECONOMIC	RESERVES 723		INFERRED RESERVES	321 550 1,417
MARGINALLY ECONOMIC	MARGINAL RESERVES EACH 1% WORLD AVERAGE RECOVERY INCREASE EQUALS 34		INFERRED MARGINAL RESERVES	—
SUB-ECONOMIC	DEMONSTRATED SUBECONOMIC RESOURCES 2,267		INFERRED SUBECONOMIC RESOURCES	623 1,068 2,750

(diagonal text across INFERRED column: NOT ASSESSED)

| OTHER OCCUR-RENCES | EXTRA-HEAVY OIL AND BITUMEN |

Authors: Masters, Root, Dietzman   Date: Identified Resources and production as of 1/1/81
Undiscovered Resources: 3/83

Figure 1.--Shows classification of world ultimate crude oil resources. Subeconomic quantity based on world average conventional recovery of 34%.

recovery. Our definitions and estimates are consistent with current custom and are reported as Demonstrated Reserves. The remainder of the in-place crude oil may be defined as Subeconomic Resources, or if some portion of the remainder is judged to be economic under a specified set of conditions, it can be reported as Marginal Reserves. In effect, when we gain the capability to assess oil deriving from enhanced oil recovery (EOR)--i.e., recovery techniques other than those herein defined as conventional--, the quantities likely will be identified initially as Marginal Reserves; even though there is limited production from EOR, its low level of 81 million barrels of oil per year in the United States and 18 million barrels per year in the rest of the world (Meyer and others, in press) suggests that the activity is still in the pilot-plant stage, so any estimates of potential reserves are premature.

The right side of the classification diagram (fig. 1) shows subdivisions of the Undiscovered Resources based on the same principles as those considered in classifying Identified Resources. The estimate of the economically recoverable Undiscovered Resources is based, broadly, on existing price-cost relationships, and their quantity may be expressed graphically through a full range of probabilities; commonly we report two points on the range encompassing a 90 percent probability of occurrence, as well as the mode or most likely occurrence.

Other Occurrences of oil, which are defined as including both extra-heavy oil and tar sand (bitumen), are referred to at the bottom of figure 1. These resources are set apart from conventional oil at least in part because of their vastly different, technically achievable reserve-to-annual production ratios (R/P). The estimate for Other Occurrences of oil is discussed in a later section.

METHODOLOGY FOR ASSESSMENT OF CRUDE-OIL RESERVES AND THEIR API GRAVITIES

Reserves were estimated by field and aggregated by country and by region (table I). Prime sources of data were the well and field files of Petroconsultants S.A., scientific and trade literature, and government publications. Approximately 80 percent of world reserves, field-by-field, have been specifically examined by W. D. Dietzman and his colleagues with the EIA; they have estimated for each field the Demonstrated oil in place and the Original Reserves. (For an example of one of several publications, see Dietzman and others, 1981.) The weighted-average recovery factor from these studies is 34 percent; this recovery factor includes only the conventional (primary plus water-flood and pressure-maintenance) oil recovery. Approximately 20 percent of the world's known oil is in countries for which adequate field data were not available. In those countries reserves are estimated from available production data and from published national estimates. It is possible that the published estimates of national reserves correspond to a definition of reserves more strict than that used here. We have not compensated for this by adding an extra quantity of oil to these countries but remain mindful of its possible existence.

Table I also shows the distribution of crude oil by API gravity. Data are derived from Meyer (in press), from Petroconsultants S.A., and from personal communication with many interested persons. The aggregate data base is almost complete for most countries, and at the regional level, the data are entirely credible. As shown in figure 2 and table I, 89 percent of conventional world oil is lighter than 25° API gravity: 57 percent lies between 25° and 35° API, and 32 percent is lighter than 35° API. Actually, we have no basis for the specific subdivisions shown; needed is a technical rationale for classification —the data apparently are available.

Table 1.—World Estimate of Original Recoverable Resources of Conventional Crude Oil in Billions of Barrels

	Production Cumulative	Reserves Demonstrated	Reserves Original	Undiscovered recoverable resources Probability range 95%	Mode	5%	Ultimate recoverable resources (Mode)
North America	142.2	62.7	205.6	104	163	322	369
U.S.A.	124.0	29.8	153.8	64	80	105	
Canada	10.1	6.4	16.5	19	26	48	
Mexico	8.1	26.5	34.6	26	50	170	
Other			.7	1	2	8	
Cuba							
Guatemala							
Greenland				1	2	8	

% Original Reserves by avg API gravity:	10-20° 11	20-25° 16	25-35° 37	>35° 36

	Production Cumulative	Reserves Demonstrated	Reserves Original	Undiscovered recoverable resources Probability range 95%	Mode	5%	Ultimate recoverable resources (Mode)
South America	47.2	34.2	81.5	20	33	69	115
Venezuela	36.1	25.5	61.6	12	17	38	
Other	11.2	8.7	19.9	10	14	28	
Argentina	3.5	2.5	5.9				
Bolivia	.2	<.1	.3				
Brazil	1.2	1.6	2.8				
Chile	.3	.1	.4	8	12	26	
Columbia	2.2	.8	2.9				
Ecuador	.7	2.3	3.0				
Peru	1.2	.9	2.1				
Trinidad	2.0	.5	2.5	1	2	4	

% Original Reserves by avg API gravity:	10-20° 8	20-25° 15	25-35° 63	>35° 14

	Production Cumulative	Reserves Demonstrated	Reserves Original	Undiscovered recoverable resources Probability range 95%	Mode	5%	Ultimate recoverable resources (Mode)
Europe (less USSR)	11.2	26.5	37.7	13	20	49	58
Western	5.7	24.9	30.6	12	17	40	
U.K.	1.9	14.0	15.9	9	15	34	
Norway	.8	8.8	9.6				
Other(inc.Med)	3.0	2.1	5.2	1	2	10	
Austria	.6	.1	.8				
Denmark	<.1	.3	.3				
Ireland	-	.1	.1				
France	.4	<.1	.5				
W. Germany	1.3	.4	1.7				
Greece	-	.2	.2				
Italy	.3	.4	.6				
Netherlands	.4	.3	.7				
Spain	.1	.1	.2				
Eastern	5.5	1.6	7.1	1	2	4	
Romania	3.9	.9	4.8				
Other	1.6	.7	2.3				
Albania	.2	.2	.4				
Bulgaria	<.1	<.1	.1				
Czechslov.	<.1	<.1	.1				
E. Germany	<.1	<.1	.1				
Hungary	.4	.2	.6				
Poland	.4	<.1	.4				
Yugoslavia	.5	.3	.7				

% Original Reserves by avg API gravity:	10-20° 2	20-25° 7	25-35° 18	>35° 73

Table 1. (continued)

	Production	Reserves		Undiscovered recoverable resources			Ultimate recoverable resources (Mode)
					Probability range		
	Cumulative	Demonstrated	Original	95%	Mode	5%	
U.S.S.R.	67.8	69.8	137.6	59	107	343	245
% Original Reserves by avg API gravity:	10-20°	20-25°	25-35°	>35°			
Africa	32.1	52.9	85.0	28	46	105	131
Libya)	12.8	24.3	37.1	4	7	25	
Algeria) North	6.4	11.7	18.0	3	5	17	
Egypt) Africa	2.4	4.0	6.3	1	2	12	
Tunisia)	.4	.7	1.1	1	2	9	
Nigeria	8.4	7.9	16.3	2	6	23	
Other	1.7	4.3	6.1	10	21	45	
Angola	.6	.7	1.3				
Cameroon	<.1	.4	.4				
Gabon	.9	.6	1.5	1	3	11	
Ghana	—	<.1	<.1				
Ivory Coast	—	.8	.9				
Congo	.1	.4	.5				
West Sahara				0	0	—	
Morocco	.04	.02	.1	0.1	0.2	2	
Benin	—	<.1	<.1				
Chad	—	1.0	1.0	0.8	2	8	
Sudan	—	2.0	.4	1.6	3	15	
Zaire	<.1	.1	.1				
Niger				0	1	2	
Mali				0.0	tr	0.1	
Mauritania				0.0	tr	0.5	
Ethiopia				0.1	0.2	2	
Somalia				0.1	0.2	6	
% Original Reserves by avg API gravity:	10-20° / 2	20-25° / 3	25-35° / 29	>35° / 66			
Middle East	123.6	441.7	565.3	72	125	337	690
Saudi Arabia	40.8	170.5	211.3	23	40	109	
Kuwait	20.3	88.6	108.9	1	2	7	
Neutral Zone	3.3	12.6	15.9	1	2	4	
Iran	30.0	63.8	93.8	11	19	51	
Iraq	15.8	50.8	66.6	32	56	150	
Abu Dhabi) Dubai)	7.1	46.5	53.6	3	5	13	
Other	6.3	8.9	15.2	<1	1	4	
Bahrain	.7	.3	1.0	0	0		
Oman	1.5	3.5	5.0	<1	1	4	
Qatar	3.2	3.6	6.8	0	0		
Syria	.6	1.2	1.8				
Israel	<.1	<.1	<.1				
Turkey	.4	.2	.6				
% Original Reserves by avg API gravity:	10-20° / 5	20-25° / 3	25-35° / 68	>35° / 24			

Table 1. (concluded)

| | Production | Reserves | | Undiscovered recoverable resources | | | Ultimate recoverable resources (Mode) |
	Cumulative	Demonstrated	Original	95%	Probability range Mode	5%	
Asia/Oceania	21.0	34.6	55.6	33	58	176	114
China	6.1	16.3	22.4	14	34	90	
Indonesia	9.4	10.5	19.9	5	9	35	
Other	5.6	7.7	13.3	12	21	34	
Australia⎬ N.Zealand⎠	1.6	2.1	3.7	4 .05	6 .15	11 .5	
Malaysia⎬ Brunei ⎠	2.2	2.4	4.6				
Thailand		<.1	<.1	tr	1		
Vietnam	–			1	3	8	
Philippines		.2	.2				
Papua N.G.							
Afghanistan							
Pakistan	.1	.5	.6	⎫			
India	1.0	2.4	3.4	⎬ 3	5	9	
Bangladesh				⎬			
Burma	.4	.1	.6	⎭			
Japan	.2	<.1	.3				

| % Original Reserves by avg API gravity: | 10-20°
2 | 20-25°
12 | 25-35°
45 | >35°
41 | | | |

	Production	Reserves		Undiscovered recoverable resources			Ultimate
Antarctica	0	0	0	0	0	19	0

	Cumulative	Demonstrated	Original	95%	Mode	5%	(Mode)
WORLD	445.1	723	1,168	321	550	1,417	1,718

| % Original Reserves by avg API gravity: | 10-20°
5 | 20-25°
6 | 25-35°
57 | >35°
32 | | | |

Authors: Masters, C. D., Root, D. H., Dietzman, W. D.

Date: Reserves and production as of 1/1/81
Resources as of 3/83

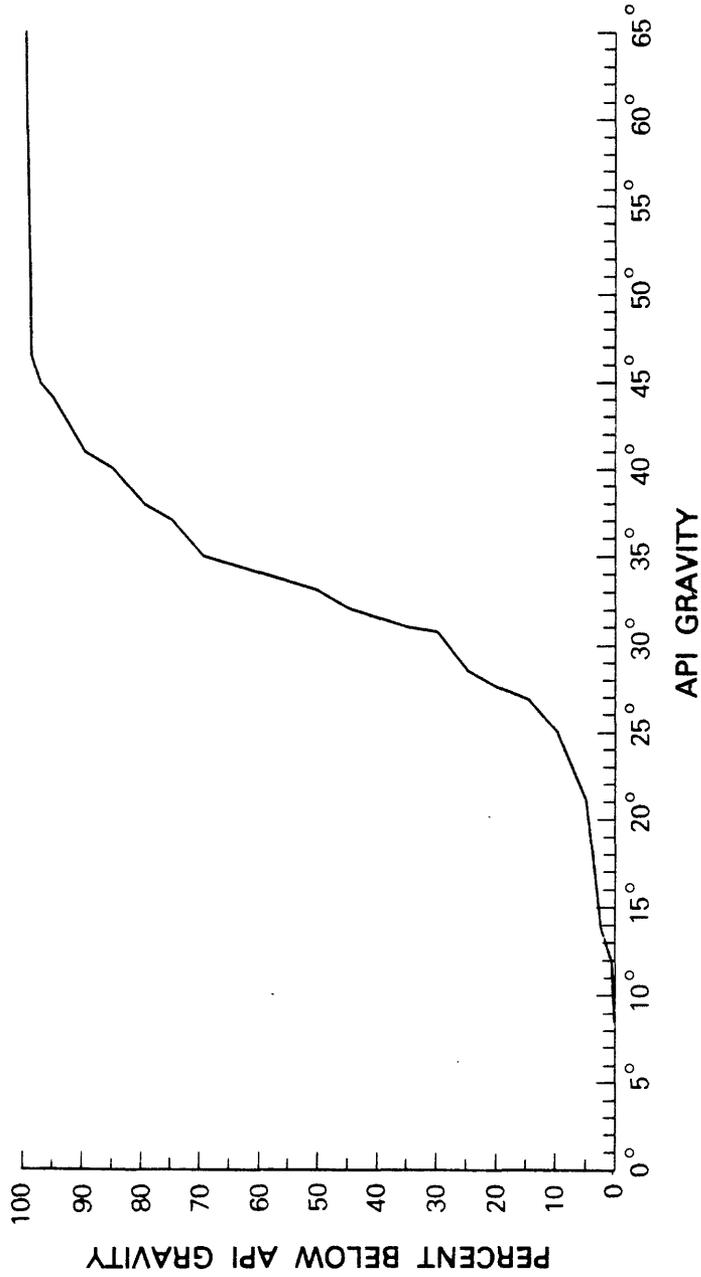DISTRIBUTION BY API GRAVITY OF
WORLD'S ORIGINAL RESERVES OF CRUDE OIL

Figure 2.--Distribution by API gravity of world's Original Reserves of crude oil. (API gravity = 141.5/specific gravity - 131.5).

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METHODOLOGY FOR ASSESSMENT OF UNDISCOVERED RESOURCES OF CRUDE OIL

Undiscovered economically recoverable resources of crude oil (table I) were assessed for this study by utilizing the techniques employed by the USGS for domestic petroleum assessment (Dolton and others, 1981). In general, the intent is to estimate economically recoverable resources, but in the case of very deep water and of Arctic/Antarctic ice conditions, we have assumed eventual economic recovery for large-field occurrence, even though technical capability may not yet be demonstrated.

The assessment technique requires study of a given area, paying particular attention to the geologic factors controlling the occurrence, quality, and quantity of the petroleum resource. Standardization of critical elements of the investigations is achieved by the preparation of data forms for each basin that call for specific volumetric, areal, and rock-quality measurements, as well as the determination of basin analogues for comparison. In addition, finding-rate histories and projections are constructed whenever possible. The absence in some areas of reliable dry-hole data is a problem that unquestionably weakens the assessment process and may result in a high-side bias to the assessment. From these data and analyses, a set of resource numbers is calculated by making volumetric comparisons with different analogue basins, by projecting discovery and production curves, and/or by play analysis.

The assessment process itself is subjective; the results of the geological investigation and of the resource calculations are presented to a team of USGS assessment specialists (in this case, a team of 10 to 12 scientists, each on average having about 20 years of petroleum studies experience), each of whom makes his personal estimates conditional upon economically recoverable resources being present. Initial assessments are made for each of the assessed provinces as follows:

(a) A low-resource estimate corresponding to a 95 percent probability of more than that amount

(b) A high-resource estimate corresponding to a 5 percent probability of more than that amount

(c) A modal (most likely) estimate of the quantity of the resource associated with the greatest likelihood of occurrence

The individual estimates are then posted and averaged and the results debated from the perspectives of the personal experiences of the individual assessors. A second and third iteration of the procedure may follow depending on consensus. If no commercial oil has yet been discovered in the basin, a marginal probability is subjectively assessed to record the probability of any commercial oil being present. The results of the final estimates are averaged, and the numbers are computer-processed using probabilistic methodology (Crovelli, 1983) to show graphically the range of the economically recoverable resource values.

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Approximately 90 percent of the world's undiscovered resources of crude oil were assessed in this way over a period of about 3 years utilizing approximately 18 man-years. (For an example of one of several publications, see Masters and others, 1982.) Many small basins, or those considered after preliminary examination to have limited petroleum potential, were assessed on the basis of exploration or production projections or by cursory volumetric and analogue determinations. In our judgment, no area having significant crude-oil potential remains unassessed at this stage of data development and availability.

ANALYSIS OF ESTIMATES OF RESERVES OF CONVENTIONAL CRUDE OIL AND THEIR DISCOVERY RATES

Because reserves by definition are economic and because economics varies with the perspective of the operator, unavoidable inconsistencies exist in reserves reporting. Some world reserves estimates, however, appear to be clearly too low and others arguably too high. That the series of numbers reported, for example, in the API Basic Petroleum Data Book (API, 1981) is likely too low is evidenced by the following analysis: 1) The amounts of oil discovered over the past 10 years, as reported for this study (fig. 3) or by Exxon (1982), are considerably less than the amounts of oil produced over the same period. We show the differential to be about 80 BBO over the 10-year period, whereas Exxon shows it to be about 60 BBO. Whichever data set proves to be most nearly correct, there would seem to have been a deficit for the 10-year period of about 70 BBO. 2) During this same period, the reserves reported in the API Basic Petroleum Data Book did not decline but rather increased by about 41 BBO. 3) Reserves, therefore, must have been larger than stated or they grew, through additions from the Inferred Reserves, by at least 111 BBO. The conundrum is how much longer we will be able to reevaluate upwards because of improved recovery practices or because of new pools and unpredicted field extensions (Inferred Reserves) enlarging the Demonstrated Reserve. On a smaller scale, in the United States during the last 10 years, production exceeded discoveries by more than 22 BBO, yet reported reserves declined by only about 12 BBO. A possible explanation for this lies in the USGS estimate of 23 BBO of Inferred Reserves (Dolton and others, 1981). The United States clearly is the most extensively explored and developed region in the world, yet the data show the need for revisions of the reserves reporting, year-by-year, on the order of 1 BBO, or one-third of our annual production. It is important for us to learn where that oil is coming from because some day that cushion is going to be exhausted; it is equally important, for the same reasons, that we establish, on the world scale, a known relationship between discovery, production, and reserves.

Contrariwise, some reserve numbers appear to us, definitionally, to be too high, because the authors assumed 40 percent average conventional recovery (Halbouty and Moody, 1979). When account is taken of the higher assumed recovery factors, however, the estimates of these particular authors are approximately consistent overall with those in table I.

Figure 3. WORLD CRUDE-OIL DISCOVERY RATE
AVERAGED OVER FIVE YEAR PERIODS

MIDDLE EAST

EASTERN EUROPE,
U.S.S.R., ASIA, OCEANIA

WESTERN EUROPE, AFRICA,
WESTERN HEMISPHERE
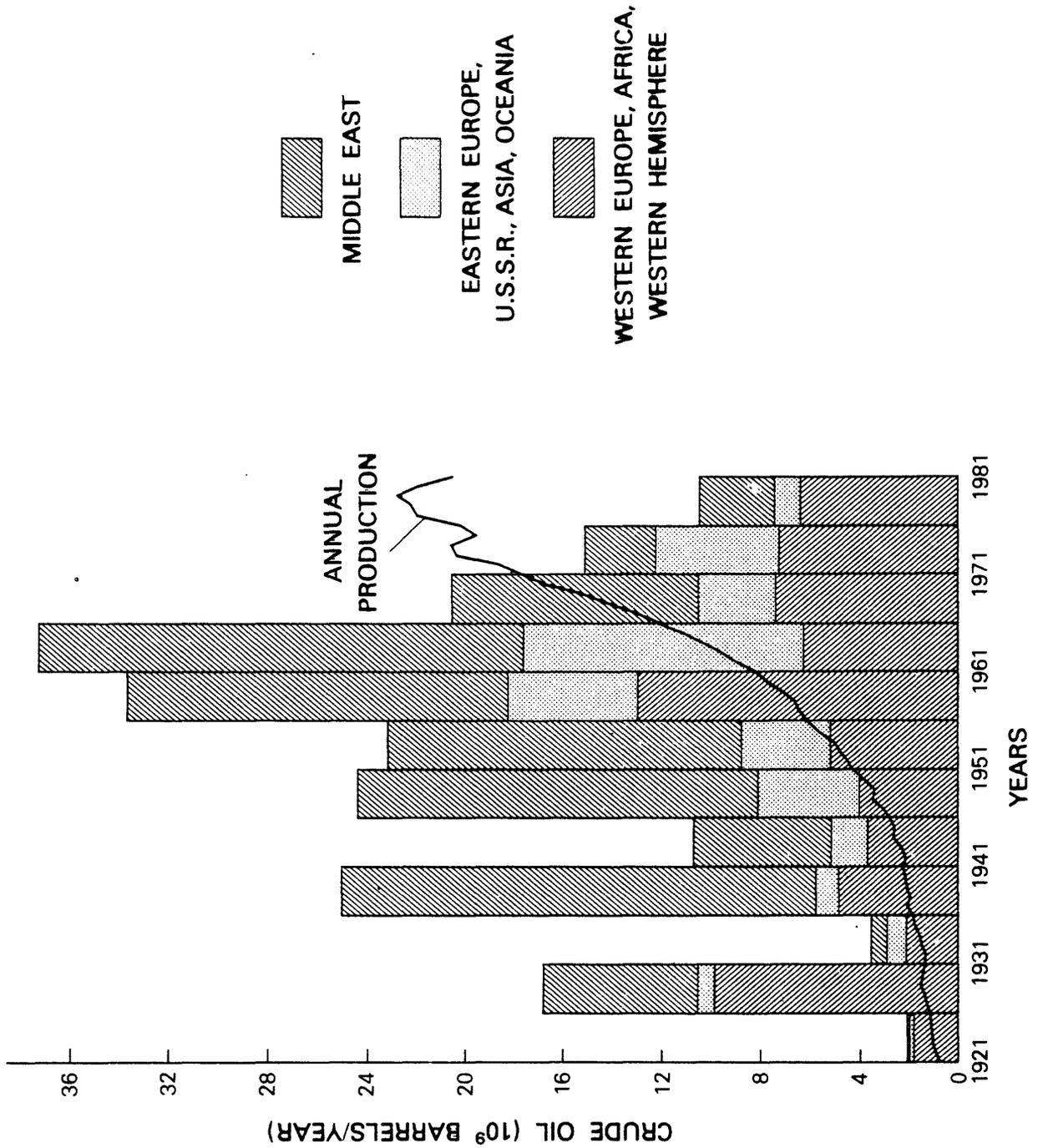
Four years ago, Halbouty and Moody (1979) reported a modest decline in reserves over the previous decade; we concur with their findings and with the continuation of that trend (fig. 4). We also concur with their findings, and those of Exxon (1982), of a declining discovery rate now extending over 2 decades. Our data, however, show an even sharper decline (fig. 3); we are conscious of the possibility that additions from Inferred Reserves might enlarge the reserves estimates of the discoveries of the past 5 or 10 years but would suggest that, for reasons described above, those additions may be modest.

The elements of accurate reserves reporting appear to be within our grasp. In a few countries, understanding of definitions and availability of public data for independent analysis are still lacking, but overall we are confident that these estimates are proportionally and geographically satisfactory. Specifically unaccounted for is an unassessed quantity of Indicated Reserves, as described above, along with some Inferred Reserves in the form of new pools and unpredicted extensions of known reservoirs; we believe the quantities unaccounted for can be no more than a few percent of the total and likely could be assessed statistically, given greater certainty in production and discovery data.

ANALYSIS OF THE UNDISCOVERED RESOURCES OF CONVENTIONALLY RECOVERABLE
CRUDE OIL

Our assessment of the world potential for Undiscovered Resources of conventionally recoverable crude oil indicates a 90 percent probability that the value lies between 321 and 1,417 BBO, with a most likely (modal) value being 550 BBO (table I). Our assessment (95 percent to 5 percent probability range) falls inside the range (90 percent to 10 percent probability range) assessed by Halbouty and Moody (1979) for the Tenth World Petroleum Congress of 280 to 2,415 BBO, and our modal value is significantly less than their expected value of 987 BBO. Whereas comparison of the estimates by region (fig. 5 of this paper and table 4 of Halbouty and Moody, 1979) discloses remarkable similarities in the modal assessments of the United States and of the Middle East, the other world subdivisions show considerable differences. Because the areas corresponding to the assessments are not the same, however, it is not possible to be precise about where all the differences lie. Nehring (1982) has recently published a disaggregated reserve and resource analysis with which we find we are in substantial agreement, both with respect to total numbers and to regional distribution of crude oil. Because of reporting differences, however, a dialogue is nonetheless required to ascertain the conceptual differences between oil additions deriving from discovery as opposed to oil additions deriving from increased recovery.

A further difference between the assessment provided to the Tenth World Petroleum Congress and this assessment lies in the high-side values which differ by a factor of almost two. Our view at this point is that world data are fully adequate to support a relatively narrower range of resource

Figure 4.--DEMONSTRATED RESERVES OF
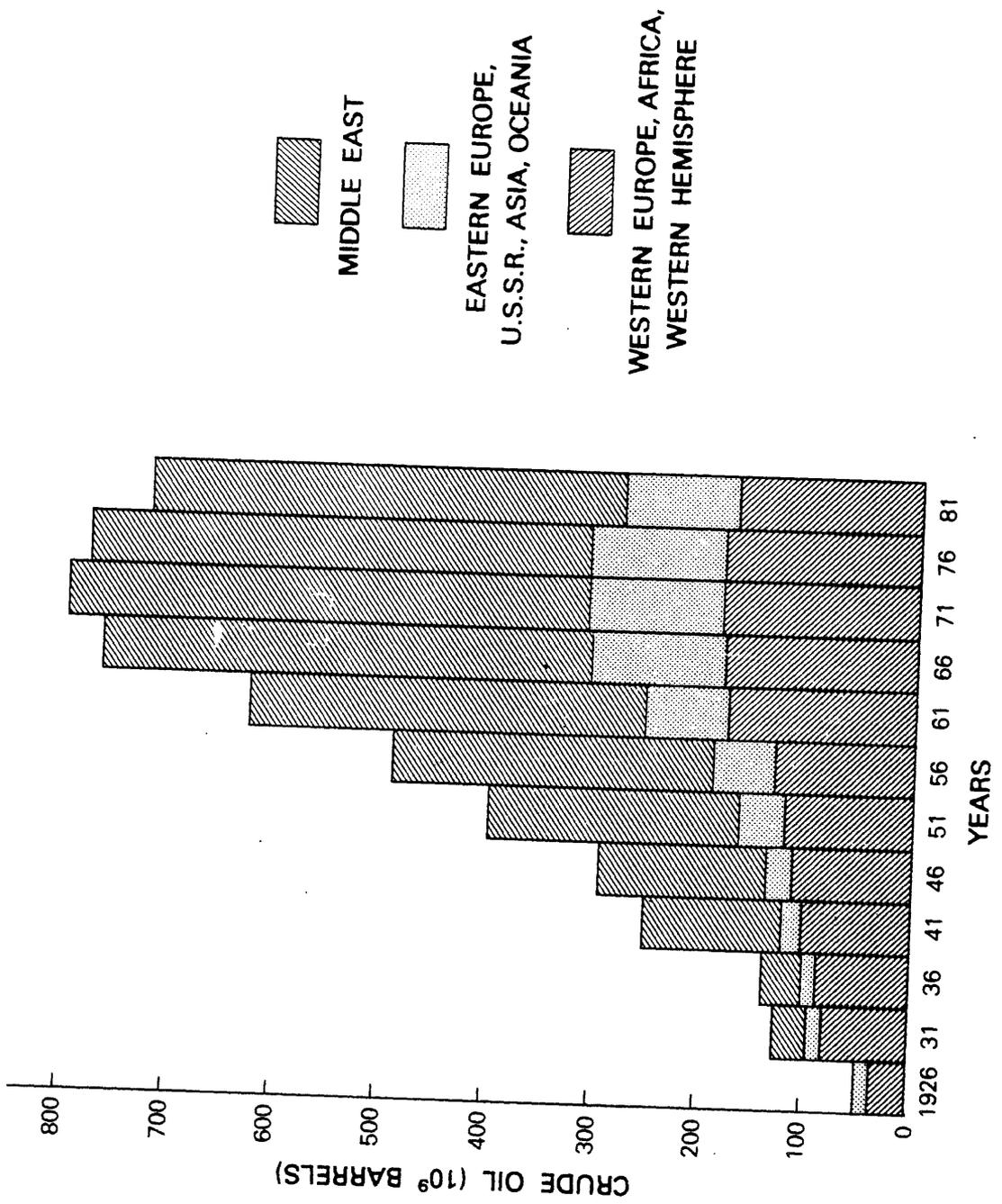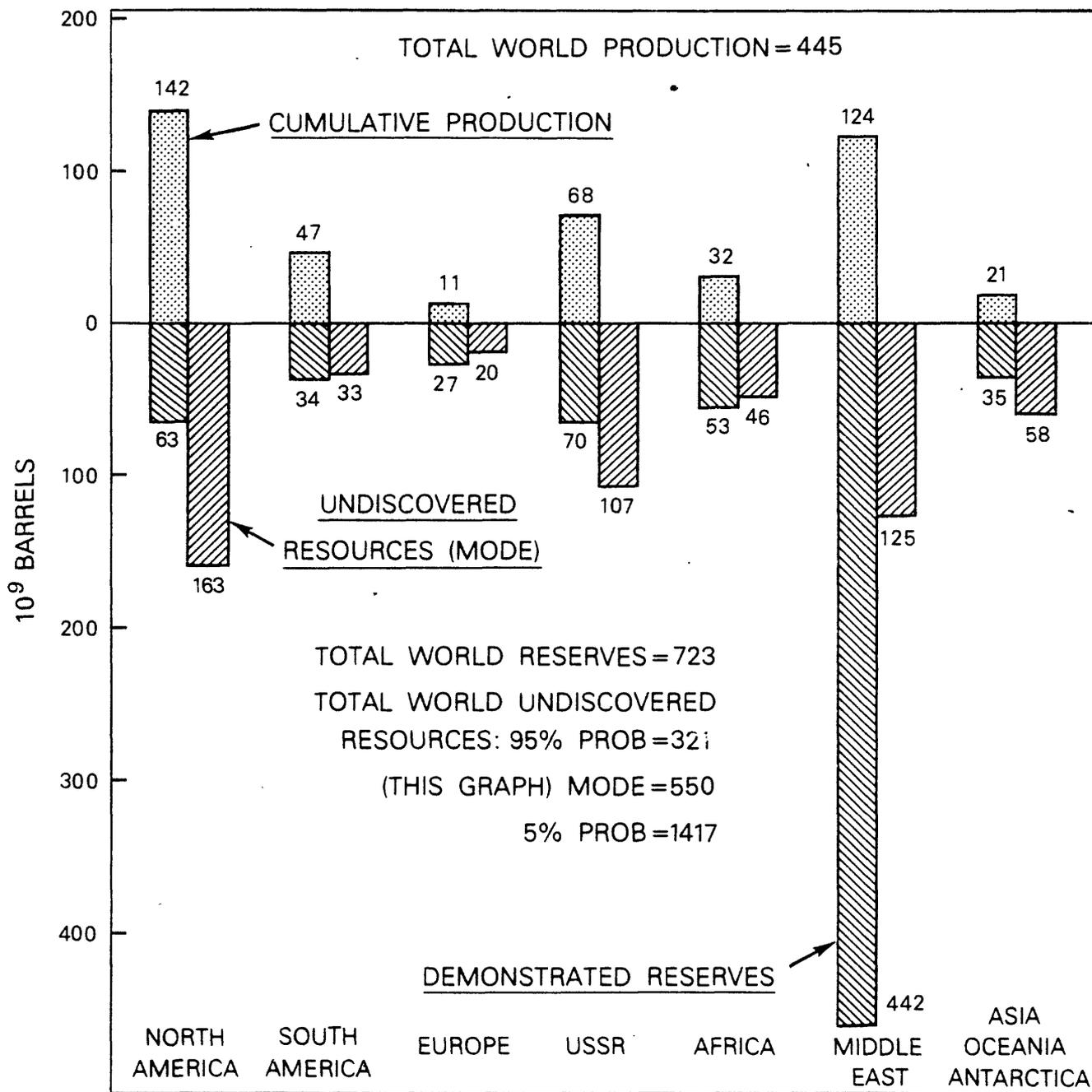CRUDE OIL IN 5-YEAR INTERVALS

MIDDLE EAST

EASTERN EUROPE,
U.S.S.R., ASIA, OCEANIA

WESTERN EUROPE, AFRICA,
WESTERN HEMISPHERE

CRUDE OIL (10^9 BARRELS)

YEARS

Figure 5.-- REGIONAL DISTRIBUTION OF WORLD CRUDE OIL

TOTAL WORLD PRODUCTION = 445

CUMULATIVE PRODUCTION

UNDISCOVERED
RESOURCES (MODE)

TOTAL WORLD RESERVES = 723

TOTAL WORLD UNDISCOVERED
RESOURCES: 95% PROB = 32i

(THIS GRAPH) MODE = 550

5% PROB = 1417

DEMONSTRATED RESERVES

North America: 142, 63, 163
South America: 47, 34, 33
Europe: 11, 27, 20
USSR: 68, 70, 107
Africa: 32, 53, 46
Middle East: 124, 442, 125
Asia Oceania Antarctica: 21, 35, 58

10⁹ BARRELS

NORTH AMERICA   SOUTH AMERICA   EUROPE   USSR   AFRICA   MIDDLE EAST   ASIA OCEANIA ANTARCTICA

estimates. To achieve the higher of the two assessments, a discovery of the dimensions of another Middle East province clearly must be considered, and our studies indicate no possibility for such an occurrence.

The low-side assessments, on the other hand, remain essentially identical. They, of course, reflect the potential of relatively well known provinces, and the assessment process has, in this case, the advantage of more complete information.

For our modal assessment of 550 BBO of Undiscovered Resources to be sustained, a massive amount of exploration is still required. We have not completed the studies of trends of finding-rate efficiencies, but our general perception is that numbers of exploratory wells are increasing yet discoveries are declining; hence exploration efficiency is also declining. Needed to reverse that decline is the discovery of new major provinces (ultimate resources in excess of 20 BBO or 1-year's production for the world), or significant discovery increases in the giant Middle East province or in others of the identified petroleum-favorable regions of the world. Our analysis suggests the likelihood that most of the new oil will come from the established provinces, but the unknown of the Arctic, deep water, and other frontier areas always must remain a consideration.

In attempting to address the issue of contributions of frontier basins to new oil discovery, we tried to analyze the often repeated notion that there are a certain significant number of still untested basins. We have not yet completed the work to permit a comprehensive statement, but we can note that most of these basins are untested for good geologic or economic reasons. In particular, we examined the Arctic region for clues to the prediction of undiscovered major provinces. The region is so big that it is awkward to downgrade almost any part for lack of favorable oil characteristics. However, we do not think that the evidence is encouraging, for example, for any significant extension under the Barents Sea of the highly favorable Devonian source rock of the Volga Urals basin or the mature Jurassic source rock of the North Sea basin; in all other areas of the Arctic, likewise, there does not appear to be that combination of geologic factors necessary for truly large oil occurrence. On the basis of area and volume alone, a significant amount of oil must be assessed for the Arctic, but we see little possibility there for the discovery of a major province. In addition, the Arctic poses logistic and environmental problems that necessarily will deter commercial development.

The deep-water areas remain poorly known. Although an attempt was made to extend geologic understanding of coastal regions out to a water depth of 2,500 m, we must acknowledge inconsistency in this effort. Certainly, data become sparse in deep-water regions, but in most areas we also judge that the merit of the petroleum geology declines as well.

Our still limited understanding of China reflects, in part, only the time constraints for preparation of this paper. There is much published literature to be digested and vast minimally drilled areas to be tested. Nonetheless, it has been possible to develop a broad, general understanding of China's

petroleum geology sufficient to render a credible assessment (table I).
Published regional analyses are excellent, and sufficient quantitative data
are available to begin to get an idea of their reserves, the dimension of
their basins, and various other specific petroleum geology parameters. The
most critical data still missing are drilling results to permit exploration-
maturity analysis.

OTHER OCCURRENCES OF OIL RESOURCES - EXTRA-HEAVY CRUDE OIL
AND BITUMEN

Though large quantities of extra-heavy crude oil and bitumen are known
in various parts of the world (Meyer and others, in press), these commodities
are not at present serious economic contenders in the market. We suggest,
therefore, that the issue is not how much is in the ground but rather how
much can be produced. Considering that production facilities have a finite
service life, we define reserves as the amount of oil that can be produced
over a 25-year period given installed production facilities; the otherwise
recoverable resources are classified as Marginal Reserves; the remainder of
the in-place resources, considering approximately a 10-percent recovery factor,
is shown as Subeconomic Resources (fig. 6). Though considerable quantities
of bitumen are available in different parts of the world, only in Canada,
from the Athabasca tar sands, is a major extraction effort underway--now
producing approximately 60 million barrels/yr. The overwhelmingly dominant
resource of extra-heavy oil is in the Orinoco heavy-oil belt of Venezuela;
on a pilot-plant basis, some 3 million barrels are being produced. Elsewhere
in the world, annual production of 3 million barrels is also being achieved
in Italy and 1 million barrels/yr is being produced in both the United States
and in Mexico, for a total extra-heavy-oil production of 8 million barrels/yr.
Extra-heavy oil and bitumen cannot contend economically with conventional
crude oil, but their presence in large quantities in various parts of the
world assures mankind of the essentially limitless availability of naturally
occurring oil.

9

ORIGINAL MEASURED RESOURCES OF EXTRA-HEAVY OIL AND BITUMEN

AREA: WORLD   UNITS: Billions Barrels

CUMULATIVE PRODUCTION	EXTRA-HEAVY OIL	0.227
	BITUMEN	0.427
RESERVES	EXTRA-HEAVY OIL	0.2
	BITUMEN	1.5
MARGINAL RESERVES	EXTRA-HEAVY OIL	59
	BITUMEN	172
SUBECONOMIC RESOURCES	EXTRA-HEAVY OIL	500
	BITUMEN	1,500

AUTHOR: Meyer, R. F.   DATE: 1983

Figure 6.--Classification of Original Measured Resources of
          extra-heavy oil and bitumen.

CONCLUSIONS

There is an immense quantity of conventional crude oil in the world; our capacity for consumption, however, is perfectly capable of challenging that immensity. Though there is much yet to be discovered and produced, there is no room for complacency. The slack is coming out of reserves estimates, and to the extent that discoveries remain less than production, world Demonstrated Reserves, as defined herein, will continue to decline. Even if EOR and the production of extra-heavy oil and bitumen become ubiquitous reality, they are unlikely to achieve rates of production even close to matching those of primary and secondary recovery in the past; the resulting patterns of consumption of crude oil in the decades ahead, then, will be quite different.

The distribution of crude oil remains restricted, and there is little chance that that condition will change (fig. 5). The Middle East region dominates known world petroleum occurrence, and we judge it still to be the richest hunting ground. Even though most of the world's oil will continue to be supplied from traditional areas, exciting discoveries of great local significance will be made in many other areas of the world. However, one should not anticipate riches from so-called untested areas just because exploration activity has not been obvious.

A further concern about estimates of world petroleum availability is the present limited discovery rate relative to production. Without evaluating in detail the geology of all exploration activity, the general level of exploration, as measured by numbers of wells, has increased over time, yet annual discoveries are declining, suggesting the possible reality of low-side assessments. If the low side be reality, the need for alternate energy sources becomes increasingly critical for most of the world's countries.

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