UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Global oil assessments and the search for non-OPEC oil

by

Charles D. Masters[1]

Open-File Report 86-373

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

[1] Reston, Virginia

1986

CONTENTS

ILLUSTRATIONS

TABLES

Global oil assessments and the search for non-OPEC oil

by

Charles D. Masters

Abstract

Over the last 10 years several individuals and groups have attempted to estimate the ultimate quantities of conventional crude oil. The estimates of several groups have now settled on the range of 1,500 to 2,000 billion barrels of oil (BBO) with some 1,100 or 1,200 BBO having already been discovered. These various assessors all agree broadly on the regional location of this oil, but still there are notable differences at the province level of assessment, reflecting variations in available data and in interpretation. Focusing on the non-Opec province assessments outside the United States and Canada, we compare USGS assessments with Ivanhoe's province-by-province analysis and offer further an additional 14 provinces including several frontier areas. Where assessments differ significantly in either OPEC or non-OPEC areas, we offer brief explanations of the possible differences in interpretations that may have led to the discrepancy. In particular, the addition of the Barents Sea and Western China record the two areas with the greatest chance to add significantly to world oil reserves.

Introduction

The search for oil is a highly personal endeavour that involves a good deal more effort than assessors expend in analyzing the global oil scene. It is relatively easy to determine that a certain basin has a good chance for big oil or it does not. Such determinations are useful for long-term policy planning at either a government or company level. To actually search for oil, to spend money, to take risks, are other matters entirely. The explorer can begin by analyzing overall basin potentials of interest as expressed by global oil assessors, and, if it is oil of a dimension to affect world markets that one seeks, good information can derive from that study; if, on the other hand, one's view is that of an entrepreneur searching for a modest profit center, the approach must be entirely different and likely more detailed than global assessors of whatever stripe will present.

There are many opportunities around the world for this latter approach. A prime example might be the Hunt Oil Company discovery in North Yemen. That local area would never appear very high on any assessor's priority list, but if you are looking for investment opportunity and are not afraid of risk and expenditure, any small graben (a few 100 sq mi) with a thick sedimentary section (>20,000 ft) is worth investigating. Apparently Hunt made it work, but at what reserves level is not yet understood. The Jean d'Arc basin on the Grand Banks is another such small, isolated basin that would not likely appear on most world assessors' charts, but there lies profit and glory for the courageous. On the other hand, the Llanos-Oriente of Colombia and Peru is a regional geologic phenomenon of such a dimension that the global assessor would readily highlight it for interest (even before Cano Limon). The Gulf of Alaska, offshore Chile, and the offshore area south of Java likewise can be evaluated by the global assessor, but those places would be of minimal interest based on regional geologic factors. Once again, however, the entrepreneur, even in the areas of minimal world interest, may find anomalies of personal interest. So what do we mean by the global search for non-OPEC oil? Do we want, by clever exploration, to undo the present imbalance of supply or do we want just to broaden supply opportunities and thereby serve world security needs (as derived from dispersed supply) as long as possible?

World Assessments

The broad global answer that most assessors present is that a quick fix of the OPEC and non-OPEC imbalance is not likely. In other words, they cannot identify any major new provinces that might serve to tilt the balance. This certainly is the view of Ivanhoe (1985), of Nehring (1982), and of the U.S. Geological Survey (USGS) (Masters and others, 1983), all three of whom assess ultimate oil occurrence to be in the range of 1,500 to 2,000 billions of barrels. Other assessment groups in the Soviet Union, such as those headed by Kalinin (1983) and by Modelevskiy (reported on by Odell and Rosing in Petroleum Economist, September 1985, from a paper presented to the International Institute for Applied Systems Analysis (IIASA) Conference in 1985), report assessments of Undiscovered Resources approximately 20 to 50 percent higher than does the USGS (Masters and others, 1984) (table 1), but they very clearly assign the resources to broad regions ranked in the same order of quantitative merit as in the assessments by the USGS, by Ivanhoe, and by

Table 1--Initial recoverable resources[1] of oil and condensate of the world minus socialistic countries, billion barrels.

Region	Kalinin, and others 1974	Kalinin, ed. 1983	Modelevskiy and others unpublished article	Masters and others 1984
Africa	495.8	200.5	281.2	131.0
Asia[2]	218.3	159.0	131.0	60.2
Middle East	825.1	740.0	823.6	690.3
Australia and Oceania	59.2	34.8	62.2	9.9
West Europe	60.7	60.7	65.1	47.6
North America[3]	540.2	340.4	526.9	278.3
Latin America	473.6	304.9	385.5	201.8
TOTAL	2,672.9	1,840.3[4]	2,275.5	1,419.1

[1] At 0.33 recovery ratio and including cumulative production, proved reserves, and undiscovered recoverable resources (excludes EOR). Masters and others use the modal value of undiscovered resources, which value is lower than the commonly reported mean.

[2] Minus China and Vietnam.

[3] Mexico is included in Latin America.

[4] In the book by Kalinin, this number is supplemented by an additional 51 tonnes of undiscovered oil from unconventional sources (deep sea, Antarctica, etc.).

Nehring. In effect, then, present analyses by various professionals and groups suggest no great differences in quantity or distribution of world oil resources.

But we can all know that is not the whole story. There are professionals who have made estimates far in excess of those of the above mentioned groups. Most commonly, however, the very high assessments are predicated on a presumption of substantially increased recovery factors for conventional oil and hoped-for significant extraction of unconventional oils. Further, it is fair to be reminded that some professionals (e.g., Grossling, 1985) see the potential for large amounts of undiscovered oil in poorly explored regions under the assumption, presumably, that oil is an expected event in sedimentary basins, and nobody knows enough to say it is not there.

With respect to improved recovery factors deriving from Enhanced Oil Recovery (EOR), the United States now has considerable experience that has been reported in two National Petroleum Council reports (1976 and 1984). Broadly, their judgment is that the procedures are difficult and costs are high; for the United States, the 1984 report estimates the possible recovery of 14 billion barrels of oil (BBO), given a $30 price with a maximum short-term production capacity of 2 million barrels of oil per day. The point of raising this issue is to emphasize that EOR and recovery cannot be calculated as being directly proportional to price increases. Further, we note that rates of production will be relatively low and capital costs high, acting as further deterrents to EOR oil. The same is true of unconventional oils, i.e., extra heavy oil or bitumens. We know they can be produced but at significant expense, both in terms of dollars and of men and equipment. It is my view at this time that one should not count the chickens before they are hatched. We must remain aware of the potential of unconventional resources, but I believe we should judge their reserves dimension as a function of installed production capacity multiplied by 25 years of service life of the facility; thereby, we take advantage of the wisdom and experience of the people actually trying to produce the reserves. In 1983 (Masters and others), we judged annual production of extra heavy oil and bitumens to be about 68 million barrels of oil per year, yielding a reserve calculation of 1.7 BBO. Certainly, those production and reserves numbers are larger today but probably not significantly.

The other source of higher potential-oil numbers derives from assumptions that oil and gas are found by exploratory effort, and in the absence of that effort, one must rationally assume significant undiscovered resources. It was to challenge those conclusions, in part, that we established the program in world energy resources studies. Our objective was to build a framework of geologic understanding basin-by-basin so that we could present a responsible assessment of world crude oil occurrence. In varying degrees of detail, we have accomplished that exercise for the world, and our results are published in various places, but broadly summarized in Masters and others (1983) and in Masters (1985).

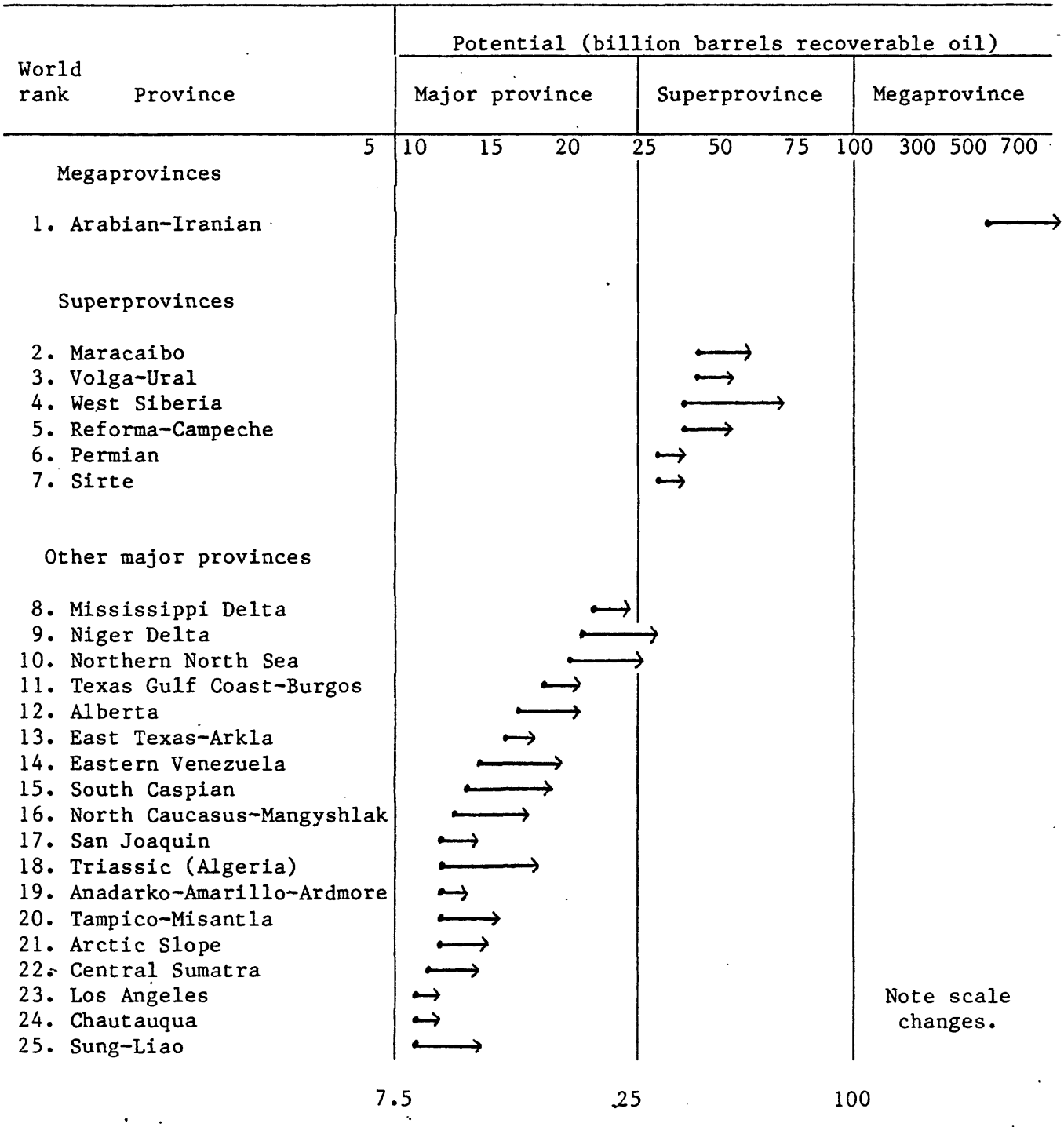
But assessing world oil is only the beginning of the search for non-OPEC oil. An assessment means nothing more than a judgment on its occurrence. Whether or not it will be discovered depends on the discovery activity. In

that sense, Ivanhoe's method of Drilling Index Analysis, or finding rate, comes closest to predicting exploration success, given that the wells are drilled. Normally we consider a finding-rate type of study to reflect a generally pessimistic view of resources, because it can only project a trend of exploration success and can hardly be expected to recognize a major new play. Indeed, Ivanhoe (1985, p. 167) acknowledges that frontier provinces are not included in his assessment projection. In spite of this acknowledged omission, his assessment for ultimate world oil resources of 1,700 billion barrels (Ivanhoe, 1985) is the same as that of the USGS - 1,718 billion barrels (Masters and others, 1983), which assessment encompasses the entire world including Antarctica. Presumably, the reason for this unusual expression of optimism by Ivanhoe can be attributed to methodology. Because he does not have access to field data, his annual reserves-increase data include growth in old fields as well as new discoveries. Were he able to attribute growth back to the year of discovery, there would not be the appearance of such a high recent discovery rate, and the projection would decline more rapidly. In any event, the ultimate assessments are all in the same range, and for the non-OPEC oil explorer the issue remains of what is left to find and where.

Province Assessments

The most convenient source of province-level data for undiscovered resources is found in Ivanhoe (1985) where he also reports a personal communication from Nehring. Masters and others (1983) showed estimates at a country level, which is a more detailed presentation than commonly available, and in Masters' (1985) later publication, he presented world maps (Appendix) showing the location of crude oil futures (Demonstrated Reserves plus a modal value of Undiscovered Resources); in addition, one can find numerous detailed basin-level assessments in separate publications of the USGS' World Energy Resources Program. The essence of all of these numbers is that none of the investigators recognizes the possible existence of a new, large province of perhaps 20 BBO, but all recognize, in general, the same localities around the world where important occurrences of petroleum may lie--big enough to serve local or regional needs and providing, thereby, a brief holding action while, hopefully, others (possibly just the action of markets) are negotiating the future of world energy.

These sources of non-OPEC oil are many and carry quite varying risks. Some will involve massive infrastructure development but others have established logistical support. Because Ivanhoe (1985b) has done such a lucid job of presenting the world areas of significant oil potential, I have modified his figures 2 and 3 (figs. 1 and 2) and will comment on the basin petroleum potential in the light of our assessments as expressed in the various publications and as approximated on the three maps in the Appendix. Because the search is for non-OPEC oil, I will focus attention on the Ivanhoe-listed basins in non-OPEC countries but exclusive of the United States and Canada which are relatively well known and published; where of general interest, I will also comment on the dimension of assessments in certain of the OPEC countries. Other than the foregoing limitations, an absence of comment may be interpreted as a general agreement in the assessments between the USGS and Ivanhoe. Further, I have prepared an additional listing of provinces (fig. 3) that includes frontiers not considered by Ivanhoe and



Note: Dots show the known oil production (production + reserves) in each province as of Jan. 1, 1979. Arrows indicate the probable volume of oil still to be discovered in each province, restricted by an estimated ultimate recovery (EUR) of 1,700 BBO for the world's producing basins.

Modified from Ivanhoe, Oil and Gas Journal, Nov. 18, 1985.

Figure 1.--Potential of known, possible major oil provinces.

some basins perhaps just ignored. These additional provinces are lettered for identification, because they have not been incorporated into the ranked sequence presented by Ivanhoe.

A discussion of some world petroleum basins, ranked according to Ivanhoe, follows (see figs. 1 and 2 for number sequence and the three Appendix maps of World Crude Oil Futures for geographic location):

1. Arabian Iranian (see fig. 1).--Certainly this is the dominating mega-province, but we would not accord it such a rich future (300 BBO) by one-half. A strong limiting factor is the paleo arch across the southern Persian Gulf that limits oil migration from the Persian Gulf area into southern Saudi Arabia. Though the Middle East receives a range of assessments from various workers, all rank Iraq as having the greatest potential. The USGS accords Iraq 45 percent of the assessed oil for the region.

2. Maracaibo (Venezuela).--We would reduce this assessment from Ivanhoe's 21 BBO to 4 BBO on the basis of basin development history, which likely did not evolve traps on the Andes side until long after oil migration.
3. Volga Ural (USSR).--One of the most maturely explored provinces in the Soviet Union can hardly sustain discovery of 15 to 20 BBO; however, we have suggested about 5 BBO.

4. West Siberia (USSR).--This is one of the premier exploration provinces in the world. We agree that it has a rich exploration future.

5. Reforma Campeche (Mexico).--Insufficient development drilling in this basin has taken place to limit growth to only 24 BBO (Ivanhoe); we believe it could be twice that much.

10. Northern North Sea.--Presuming the area of reference to be south of 62°N lat, we would judge the assessment of between 5 to 10 BBO to be low by at least one-half.

15,16. South Caspian, North Caucasus-Mangyshlak (or Middle Caspian) (USSR).--The petroleum geology is excellent in these areas, and continuing significant discoveries can be expected. The assessment of several billions of barrels is entirely appropriate.

18. Triassic (Algeria, Tunisia).--This is another OPEC area that we agree has excellent potential in the amount of a few billions of barrels of oil.

20. Tampico-Misantla (Mexico).--While we believe Mexico as a whole has excellent potential for continued discoveries, we do not consider the Tampico area to be a major contributor and suggest that the assessment of 5 BBO should be reduced to no more than 1 BBO. Chicontopec, a heavy oil area, may have been included in Ivanhoe's estimate, but great uncertainty still obtains as to its viability--and certainly for the near future in terms of any significant rate of production.

25. Songliao (China).--The Chinese have apparently made a major effort to add reserves in this area as an encore to Daqing. Various plays have been tested, in particular the search for another delta sequence, with minimal results. We do not anticipate that additional discoveries will total as much as 6 BBO--perhaps 1 to 3 BBO is more expectable.

26. North China Basin (see fig. 2).--This is one of the premier exploration areas in China, but the tendency is toward relatively small field sizes with irregular reservoir distribution. Our assessment is twice as high as Ivanhoe's value of 3 BBO.

27. Gulf of Suez (Egypt).--This small, rich petroleum province is difficult to assess because of the possibility of large fields, owing to exceptionally thick pays, in small areas. Further, if geothermal gradients abate to the north, deeper pays may eventually prove to be oil productive. A few billions of barrels is an appropriate assessment level.

28. Sarawak (Malaysia).--This large basin just north of the island of Borneo has several play types ranging from delta (Brunei) to carbonate platform (Malaysia) to turbidite sands in a tectonized zone (Sabah, Malaysia). Significant discoveries have already been achieved, and exploration will continue. Possibly new discoveries will begin to bias toward gas, rendering Ivanhoe's judgment of 2.5 BBO very reasonable.

31. Peri Carpathian (Romania).--This is a very maturely explored area. We judge there to be a potential of less than 1 BBO.

32. Timan Pechora (USSR).--North of the Volga Urals basin, this well explored region certainly has at least 2 BBO remaining.

34. Gippsland (Australia).--This basin accounts for 95 percent of Australian production. It has been maturely and effectively explored and, we would judge, not likely to have additional potential of as much as 1 BBO.

35. Cambay-Gujarat (India).--Cambay is a graben basin extending off of the general area of the Bombay High. If we assume Gujarat includes the Bombay Shelf, then the combination surely has the potential for 1 BB of additional oil.

39. Neuquen (Argentina).--We have not made a specific assessment of this basin, but its maturity of exploration rather suggests to us that as much as an additional 1.6 BBO is not likely, but one-half of that seems reasonable. Deeper drilling may result in substantial gas discoveries--a local salt seal enhances gas potential.

43. Cabinda-Cuanga (Congo, Zaire, Angola).--The geology is complex in this area, leading to intricate trapping conditions that are difficult to map. Ivanhoe's estimate of 1.8 BBO undiscovered seems conservative; we believe it is reasonable to consider the possibility of additional discoveries of 3 to 5 BBO.

World rank	Petroleum province (nations)	Nehring-80 Known oil resources 1/1/79-BBO	Ivanhoe-85 Estimated ult. recov. EUR-BBO	Potential billions barrels recoverable oil (BBO) 0 1 2 3 4 5 6 7 8
Large petroleum provinces (2-7 BBO)		BBO (%)	BBO (%)	Large=2-7 BBO Major
26.	North China (China)	6.0	9	
27.	Gulf of Suez (Egypt)	4.9	8	
28.	Sarawak (Brunei-Malaysia)	4.5	7	
29.	Illinois (United States)	4.1	5	
30.	Appalachian (United States)	4.0	5	
31.	Pre-Carpathian (Romania-USSR)	4.0	5	
32.	Timan-Pechora (U.S.S.R.)	4.0	6	
33.	Ghadames-Illizi (Algeria-Libya)	3.5	5	
34.	Gippsland (Australia)	3.2	5	
35.	Cambay-Gujarat (India)	3.0	4	
36.	Eastern Gulf (United States)	2.8	4	
37.	Ventura-S. Maria (United States)	2.8	5	
38.	Williston (Canada-USA)	2.7	4	
39.	Neuquen (Argentina)	2.4	4	
40.	Big Horn (United States)	2.3	3	
41.	Central Kansas (United States)	2.3	3	
42.	Kutei-Mahakan (Indonesia)	2.3	4	
43.	Cabinda (Angola-Congo-Zaire)	2.2	4	
44.	Powder River (United States)	2.2	3	
45.	Bend (United States)	2.1	3	
46.	Isthmus-Saline (Mexico)	2.1	3	
47.	Oriente-Llanos (Peru-Colombia)	2.1	6	
48.	Dneiper-Pripyat (U.S.S.R.)	2.0	4	
49.	Netherlands-NW Germany (NW Germany)	2.0	3	
50.	San Jorge (Argentina)	2.0	3	
	Subtotal - Large provinces (2-7 BBO)	75.5 (7)	115 (7)	
	Subtotal - All major provinces (+7)	973.4 (88)	1500 (88)	
	Subtotal - All significant prov.	1048.9 (95)	1615 (95)	
	All other provinces	52.1 (5)	85 (5)	
	Total - World	1101.0 (100)	1700 (100)	
		BBO (%) Known: 1/79 Nehring-80	BBO (%) EUR:1/85 Ivanhoe-85	

Modified from Ivanhoe, Oil and Gas Journal, Nov. 18, 1985

Figure 2.--Potential of the known large oil provinces.

46. Isthmus Saline (Mexico).--This is a maturely explored and highly productive basin just to the west of Reforma-Chiapas. Trapping conditions, created by salt diapirs, are complicated and have resulted in large fields. Probably future discoveries will be more moderate in size; an assessment of <1 BBO seems appropriate.

47. Llanos-Oriente (Colombia, Peru).--This area has recently enjoyed a significant new field discovery, Cano Limon, located along the Venezuelan border. Excessive depth of burial of the source rocks to the south may restrict the play to the northern part of the basin, but the basin is regionally favorable for the occurrence of oil and gas, and Ivanhoe's assessment of almost 4 BBO is reasonable.

48. Dneiper-Pripyat (USSR).--This is a well explored graben in western USSR that surely has a limited future.

49. Netherlands-Northwest Germany.--This area is well explored, has thin pays and small structures but a good exploration climate.

50. San Jorge (Argentina).--This is a basin that geologically has a lot of negative features, but geologists continue to discover small pools and seemingly will do so forever; however certainly, overall, reserves will remain modest.

Though, as noted, we concur with Ivanhoe's general view of world oil occurrence and its future potential, we would also add some additional areas for consideration (see fig. 3):

A. Western China basins (Zhungaer, Tarim, Chaidamu). The three basin areas in question are larger than the state of Texas and have known oil occurrences and favorable geological conditions sufficient to suggest recovery potentials of two or three 10's of billions of barrels. Initially, giant field discoveries will be required to establish necessary infrastructure (Ulmishek, 1984b).

B. Barents Sea (USSR, Norway). This is a very large area with exciting prospects for large oil occurrences but mostly in formations that do not have a performance history; a few tens of billions of barrels would not be surprising. Important wells are planned on the Norwegian side for the summer of 1986. Little is known of USSR activity, but many seismic lines have been logged and several wells drilled (Ulmishek, 1985).

C. East Siberia.--A very large area with mediocre petroleum geology but nonetheless substantial potential. The Precambrian gas reserves are unique in the world. Oil and gas from this region likely will be transported to western markets of the Pacific.

D. Norwegian Coastal.--A narrow zone of oil-mature Jurassic source rock extends up to the Barents Sea. A parallel and much larger zone of gas-mature rocks follows along in the adjoining deep water. Early

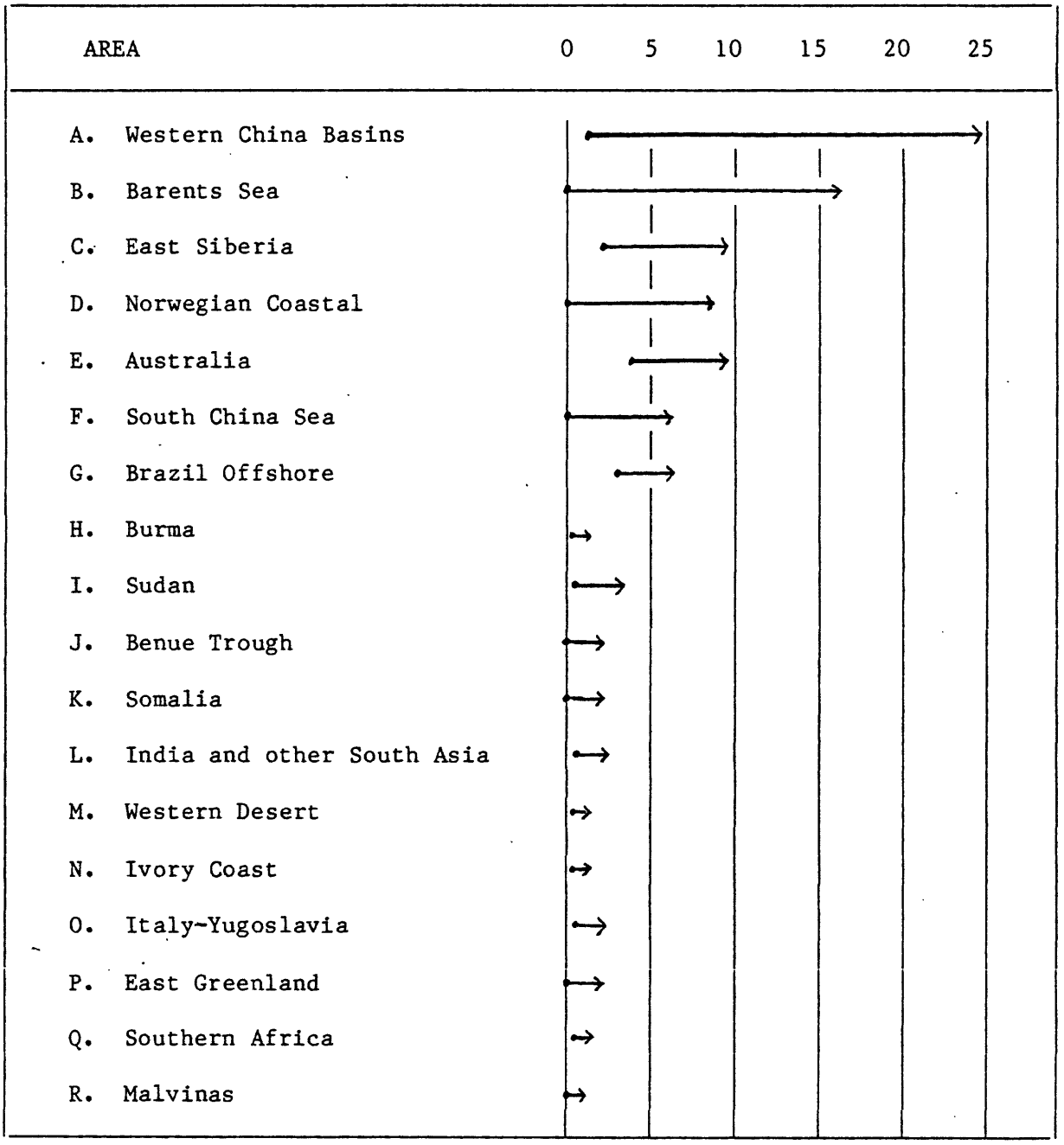


Figure 3.--Approximate ultimate resource occurrence in frontier areas and in smaller provinces.

tests have recovered mostly gas, but an oil discovery on Haltenbanken, with an astounding 1,000 ft of pay, was reported last year attesting to the potential oil richness of the province.

E. Australia.--Exploration will continue apace in the Great Artesian basins in eastern Australia; only small fields can be expected of the size of a few 10's of millions at most. On the northwest coast, the Browse, Canning, and Carnarvan basins have recorded oil discoveries and are producing, but pay thicknesses are limited and structures are not large. There remains, however, the tantalizing occurrence of Upper Jurassic rifts, which may yet provide a habitat for giant field occurrence. For the entire continent, we estimate an occurrence of some 6 BBO of undiscovered resources.

F. South China Sea.--The geology is very similar to that found in the North China basin onshore, resulting generally in the discovery of only modest sized fields on small fault blocks. So far, no large discoveries have been reported other than ARCO's gas discovery, totalling several Tcf, south of Hainan Island.

G. Brazil Offhore.--Exploration to date would not appear to have been as successful as in the analogue basins of west Africa. For reasons not fully known to us, most exploration effort has focused on the small Campos basin at the southern end of the chain of offshore basins. Much remains to be done. Ultimate targets are probably in the range of a few BBO; field sizes likely will be in the range of a few 10's to a few 100 millions of barrels of oil, but recent deep water discoveries in the offshore Campos basin may prove to be the first giant discoveries, possibly in the range of 1 to 2 BBO each.

H. Burma.--An old producing area with still interesting potential but likely less than 1 BBO. Drilling is commonly deep and some plays are in remote areas (Kingston, 1986).

I. Sudan.--Over the past 10 years, Chevron drilled more than 80 wells and shot thousands of miles of seismic lines to discover two fields of a combined dimension of some 500 million barrels of oil. Source and reservoir rocks are good; structures so far are not large; seals may be a problem.

J. Benue Trough (Nigeria).--A graben with a thick sedimentary section is of interest anywhere in the world. Exploration has been limited to date; the potential for hundreds of millions of barrels of oil to a few billion barrels is clearly there (Peterson, 1985a).

K. Somalia.--The geology is very similar to the Middle East, but for some reason exploration has been unsuccessful. Possibly the reason has to do with known difficult seismic problems that eventually might be solved. Given that possibility, the potential could be of the order of a few BBO (Peterson, 1985a).

L. India, Pakistan, Bangladesh.--Many small basins exist around the periphery of India, but low temperature gradients and poor reservoir rocks combine to suggest only limited petroleum potential. The massive Bengal basin reasonably should provide source rock; however, the overpressured environment theoretically constrains oil migration, so the foreland shelf of eastern India, presumably, has received no oil. Or maybe it did and exploration has been insufficient. Even modest amounts of oil in this part of the world would find a ready market (Kingston, 1986).

M. Western Desert (Egypt).--Early in its development, the Western Desert was considered highly favorable because of its proximity to Libya. We now know the geology to be quite different and not as favorable for petroleum. Nonetheless, attractive plays are being processed and small discoveries are reported in the northern part of the area. We assess a potential of a few 100 million barrels of oil (Peterson, 1985b).

N. Ivory Coast.--A discovery was posted by Phillips a few years ago but development has weakened. The reservoirs are irregular turbidite sands, but possibly problems could be solved. Oil has been generated and has migrated; that is an excellent starting point.

O. Italy/Yugoslavia/Adriatic.--Exploration activity is highly variable in the area. Discoveries so far are modest and regional geology does not support potential for giants, but overthrust faulting, especially on the Yugoslavia side, may be obscuring significant potential.

P. East Greenland Shelf.--The split-up of the Atlantic Ocean left the North Sea on the east side and the East Greenland Shelf on the west. Regional studies, however, suggest that the Greenland Shelf area was insufficiently buried by Tertiary sediments to mature the potential Jurassic source rocks, so no oil migrated (Ulmishek, 1984a). But maybe that is not true; somebody has to find out. We understand that Arco conducted seismic operations there in the summer of 1985.

Q. Southern Africa.--A lot of controversy exists about the basins through southern Africa. On the one hand, there is the general perception of their being gas prone, but scattered data available to us do not necessarily support that conclusion. Exploration success to date has been minimal, but solid reasons for lack of success have not yet become clear. The Orange River Delta off of Namibia should have potential. More work is necessary.

R. Malvinas.--As a most likely event, only little oil can be accorded Malvinas because of the history of discovery in the adjoining onshore analogue basin of Magallanes, wherein field sizes of less than 50 million barrels of oil predominate. A major new play with possibly a Lake Maracaibo analogue should be tested.

Oil is where you find it, and certainly it has not been possible to present all petroleum-potential areas in the world, but this discussion,

including comparisons with Nehring and Ivanhoe in some detail and with Soviet authors in lesser detail, is the most exhaustive presentation we are aware of. For additional non-OPEC discovery potential expected in the United States and in Canada, one should refer respectively to Dolton and others (1981) and to Procter and others (1984). In addition, one cannot forget the potential provided by that small graben in North Yemen, or Northwest Australia, or Antarctica. A rich field may well be hidden there, but we can be almost sure that the overall dimension of discovery will be small--unless, of course, it is a Los Angeles basin. No one can ever know, but good judgments can be made to reduce the odds.

References

Dolton, G. L., Carlson, K. H., Charpentier, R. R., Coury, A. B., Crovelli, R. A., Frezon, S. E., Khan, A. S., Lister, J. H., McMullin, R. H., Pike, R. S., Powers, R. B., Scott, E. W., and Varnes, K. L., 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: U.S. Geological Survey Circular 860, 87 p.

Grossling, B. F., and Nielsen, D. T., 1985, In search of oil: London, Financial Times Business Information, v. 2.

Ivanhoe, L. F., 1985a, Oil discovery index rates and projected discoveries of the Free World, in Moss, J. R., ed., Exploration and Economics of the Petroleum Industry: New York, Matthew Bender, p. 421-461.

_____ 1985b, Potential of world's significant oil provinces: Oil and Gas Journal, November 18, p. 164-168.

Kalinin, N. A., and others, 1974, "Resursy Nefti i Gaza Kapitalisticheskikh i Razvivayushchikhsya Stran" (Oil and Gas Resources of Capitalistic and Developing Countries), v. 1 and 2, Transactions of the Scientific Research Laboratory on the Geology of Foreign Countries: Leningrad, v. 30 and 34, Nedra.

Kalinin, N. A., ed., 1983, "Kadastr Zarubezhnykh Stran Obladayushchikh Prirodnymi Resursami Nefti i Gaza," (Cadastre of Foreign Countries Possessing Natural Oil and Gas Resources): All-Union Scientific Research Institute on the Geology of Foreign Countries, v. 1 and 2, Leningrad, v. 40 and 41, Nedra.

Kingston, John, 1986, Undiscovered petroleum resources of South Asia: U.S. Geological Survey Open-File Report 86-80, 173 p.

Masters, C. D., 1985, World petroleum resources - a perspective: U.S. Geological Survey Open-File Report 85-248, 25 p.

Masters, C. D., Root, D. H., and Dietzman, W. D., 1983, Distribution and quantitative assessment of world crude-oil reserves and resources: U.S. Geological Survey Open-File Report 83-728, 11 p.

Modelevskiy, M. S., Gurevich, G. S., and Khartukov, E. M., "World Cheap Crude Oil and Natural Gas Resources." Announced and made available in an unpublished form by Academician Styrikovich at the June 1985 meeting of the International Institute for Applied Systems Analysis Energy Workshop in Laxenburg, Austria.

National Petroleum Council, 1976, Enhanced oil recovery, Enhanced Oil Recovery Committee: Washington, D.C., 231 p.

_____ 1984, Enhanced oil recovery, Enhanced Oil Recovery Committee: Washington, D.C., 94 p. with appendices.

Nehring, Richard, 1982, Prospects for conventional world oil resources, in Annual Review of Energy 1982: Palo Alto, CA, Annual Reviews, Inc., v. 7, p. 175-200.

Odell, P. R., and Rosing, K. E., 1985, East West differ on estimates: Petroleum Economist, v. 52, no. 9, p. 329-331.

Peterson, J. A., 1985a, Geology and petroleum resources of central and east-central Africa, U.S. Geological Survey Open-File Report 85-589, 48 p.

Peterson, J. A., 1985b, Geology and petroleum resources of north-central and northeastern Africa, U.S. Geological Survey Open-File Report 85-709, 54 p.

Procter, R. M., Taylor, G. C., and Wade, J. A., 1984, Oil and natural gas resources of Canada: Geological Survey of Canada Paper 83-31, 59 p.

Ulmishek, Gregory, 1984a, The geology and petroleum resources of basins in the Asian Arctic and offshore East Greenland: Argonne National Laboratory, ANL/EES-TM-247, 104 p.

_____1984b, Geology and petroleum resources of basins in Western China: Argonne National Laboratory, ANL/ES-146, 131 p.

_____1985, Geology and petroleum resources of the Barents-Northern Kara Shelf in light of new geologic data, unpublished report: Argonne National Laboratory, ANL/EES-TM-xxx, 139 p.

Figure 1.--World crude oil futures, North and South America.

Possible petroleum basins are patterned to show the future potential (measured as an aggregate of present reserves plus assessed undiscovered recoverable resources) for conventional crude-oil recovery within a given outlined assessment area.

Figure 2.--World crude oil futures, Europe, West Asia, and Africa.

Possible petroleum basins are patterned to show the future potential (measured as an aggregate of present reserves plus assessed undiscovered recoverable resources) for conventional crude-oil recovery within a given outlined assessment area.

Figure 3.--World crude oil futures, East Asia, Australia, and the Pacific.

Possible petroleum basins are patterned to show the future potential (measured as an aggregate of present reserves plus assessed undiscovered recoverable resources) for conventional crude-oil recovery within a given outlined assessment area.

WORLD CRUDE OIL FUTURES

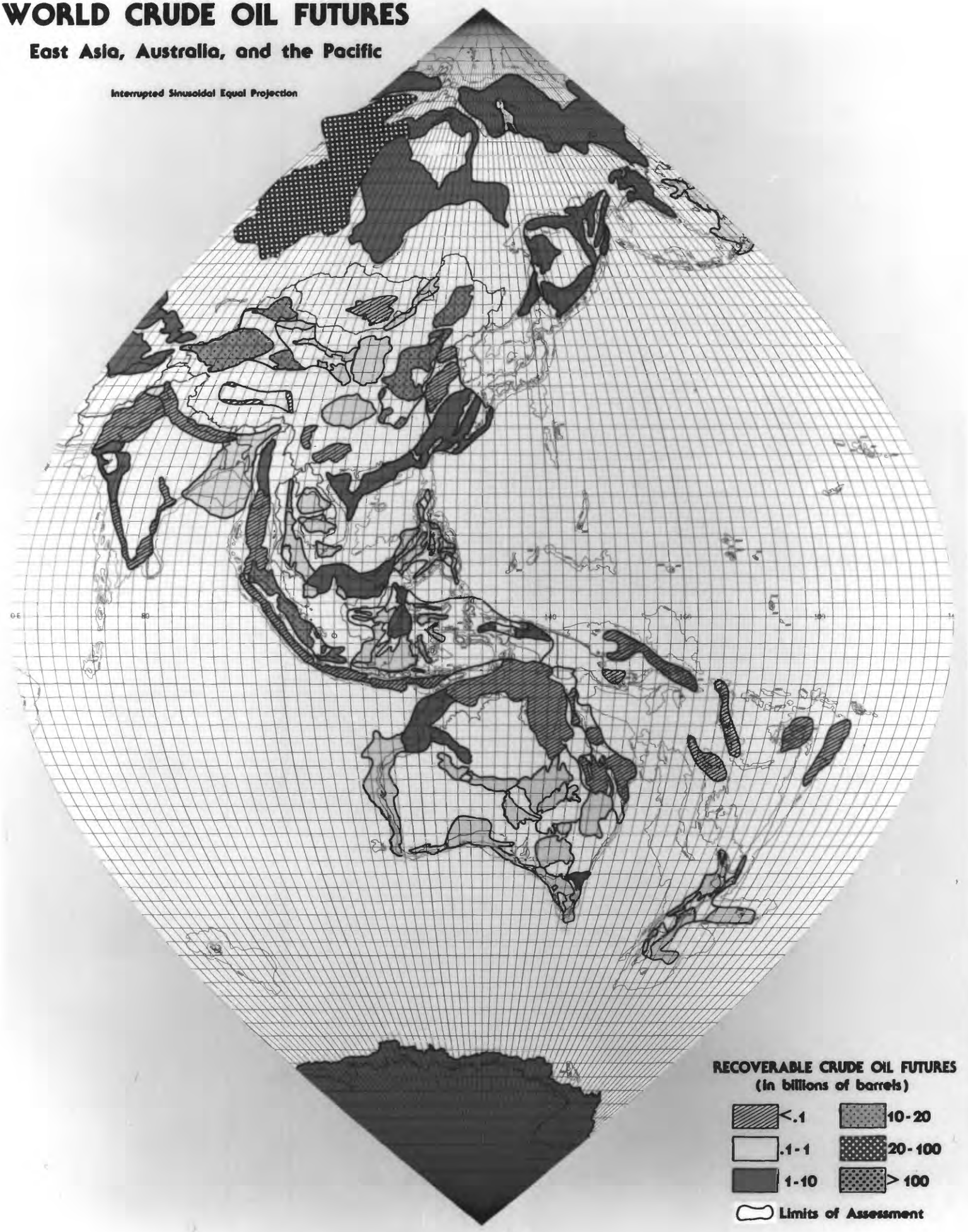
North and South America

Interrupted Sinusoidal Equal Projection

WORLD CRUDE OIL FUTURES

East Asia, Australia, and the Pacific

Interrupted Sinusoidal Equal Projection



WORLD CRUDE OIL FUTURES

Europe, West Asia, and Africa

Interrupted Sinusoidal Equal Projection