

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Assessment of undiscovered conventionally recoverable petroleum resources
of South Asia

by

John Kingston¹

Open-File Report 84-852

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

1. Santa Barbara, California

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ASSESSMENT OF ENERGY RESOURCES

This report was prepared as part of The World Energy Resources Program of the U.S. Geological Survey (USGS). The objective of the study is to assess the undiscovered conventionally recoverable resources remaining within the petroleum producing provinces. The study utilizes geological and petroleum engineering data, in conjunction with statistical techniques, to estimate undiscovered resources by a process involving a team of geologists and statisticians. The estimates represent the views of the U.S. Geological Survey estimation team and should not be regarded as an official position of the Department of the Interior.

Other U.S. Geological Survey reports relating to the assessment of undiscovered conventionally recoverable petroleum resources include the following:

- Open File Reports 81-0986 - Persian Gulf Basin and Zagros fold belt
(Arabian-Iranian Basin)
- 81-1027 - Volga Ural Basin
 - 81-1142 - Indonesia
 - 81-1143 - Northeastern Mexico
 - 81-1144 - Southeastern Mexico, northern Guatemala, and Belize
 - 81-1145 - Trinidad
 - 81-1146 - Venezuela
 - 81-1147 - West Siberian and Kara Sea Basins
 - 82-0296 - Middle Caspian Basin
 - 82-1027 - East Siberian Basin, U.S.S.R.
 - 82-1056 - North Africa
 - 82-1057 - Timan-Pechora Basin, U.S.S.R.; Barents-northern
Kara shelf
 - 83-0598 - Northwestern, Central, and Northeastern Africa
 - 83-0801 - Onshore China
 - 84-0094 - Northwest European region
 - 84-0158 - New Zealand
 - 84-0214 - Australia
 - 84-0328 - Malaysia and Brunei
 - 84-0329 - China
 - 84-0330 - Thailand

INTRODUCTION

The location of the main South Asia basins is shown in figure 1. Table 1 is a summary of the estimates of undiscovered petroleum resources of these basins. Table 2 combines the estimated undiscovered petroleum resources (in modal quantities) and estimated petroleum reserves to show the estimated total recoverable petroleum content of individual basins of South Asia.

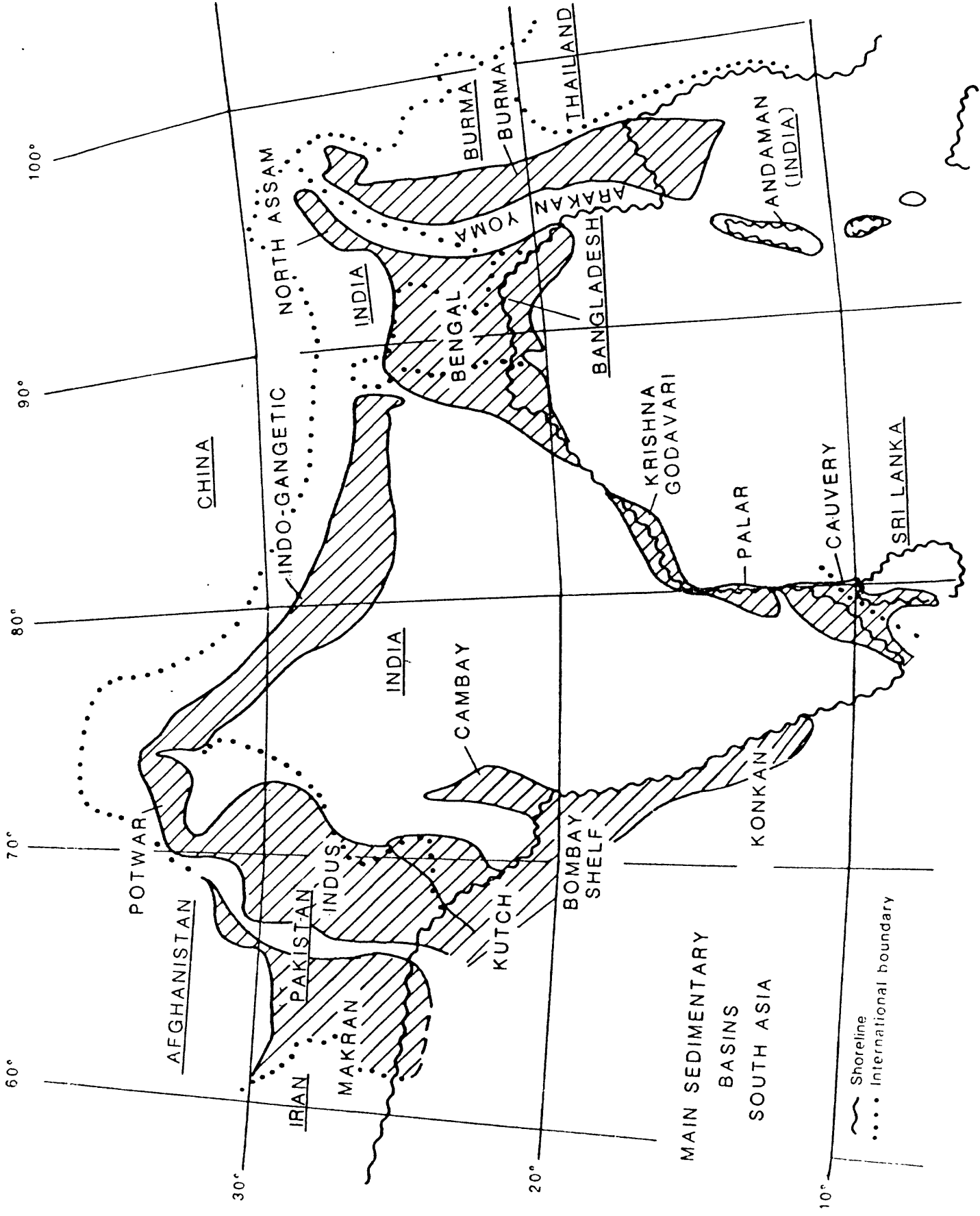
The cumulative probability curves for the undiscovered petroleum resources of individual basins are shown in figures 2 through 31. The objective of the cumulative probability curve construction is to derive the mean quantity of undiscovered recoverable petroleum in each basin from three consensus estimates made by a group of U.S.G.S. geologists. The three estimates are: (1) an estimate of the most likely quantity, (2) an estimate of which there appears to be a 95-percent chance the quantity exceeds, and (3) an estimate of which there appears to be only a 5-percent chance the quantity exceeds. Accordingly, the mean quantity embodies estimates of the most likely quantity together with less certain probabilities for more. Of significant effect on the mean is the substantially larger, but less likely, estimated quantities of undiscovered recoverable petroleum.

The mean quantities of undiscovered petroleum resources for each basin are listed in table 1 and aggregated for each country. The aggregated results of this study are as follows:

	<u>Oil</u> (billions of barrels)	<u>Gas</u> (trillions of cubic feet)
Pakistan	.35	34.74
India	2.91	27.83
Bangladesh	.09	18.91
Burma	1.43	8.44

ACKNOWLEDGMENTS

The resource assessment for this report was prepared in collaboration with the Resource Appraisal Group of the Branch of Oil and Gas Resources.



MAIN SEDIMENTARY BASINS, SOUTH ASIA

FIGURE 1

Table 1.--Assessment of undiscovered recoverable petroleum resources of South Asia. Unconditional resource assessment by USGS as of 4/20/83; see also figures 1 through 32.

Province	Probability	OIL in billions of barrels (BBb)				GAS in trillions of cubic feet (Tcf)			
		Low (>95%)	High (>5%)	Mean	Mode	Low (>95%)	High (>5%)	Mean	Mode
PAKISTAN									
Indus, Potwar, and Makran		0.05	0.70	0.35	0.30	15.00	60.00	34.74	30.00
INDIA									
Bombay		0.30	2.50	1.25	1.00	2.00	10.00	5.25	4.00
Cambay		0.05	0.50	0.23	0.15	0.25	3.00	1.16	0.50
Konkan		0.00	0.21	0.04	0.15	0.00	0.66	0.10	0.40
Kutch		0.00	1.73	0.54	0.70	0.00	10.31	3.19	4.00
Cauvery (+ Palar ¹)		0.00	0.95	0.36	0.30	0.00	2.82	1.08	0.80
Krishna-Godavari		0.00	0.48	0.21	0.20	0.00	1.93	0.93	1.00
North Assam (+ Indo-Gangetic ¹)		0.05	0.50	0.16	0.10	0.50	2.00	1.16	1.00
Bengal (38%) ²		0.00	0.31	0.08	0.15	3.80	30.40	14.97	11.40
India aggregate		0.73	7.14	2.91	1.41	8.87	61.66	27.83	16.53
BANGLADESH									
Bengal (48%) ²		0.00	0.39	0.09	0.19	4.80	38.40	18.91	14.40
BURMA									
Burma (+ Andaman ¹)		0.30	3.00	1.41	1.00	1.00	6.00	2.92	2.00
Bengal (14%) ²		0.00	0.11	0.03	0.06	1.40	11.20	5.52	4.20
Burma aggregate		0.47	3.13	1.43	0.87	3.14	17.33	8.44	5.63

¹ Basins of minor potential grouped with adjoining basins.

² Bengal Basin aggregate: 0.00, 0.82, 0.20, 0.40 for oil; 10.00, 80.00, 39.41, 30.00 for gas.

Table 2.--Estimated ultimate petroleum resources of South Asia sedimentary basins (in billion barrels of oil and trillions of cubic feet of gas).

Province	Estimated Original Reserves ¹		Estimated undiscovered petroleum ² (mode)		Estimated ultimate resources	
	OIL	GAS	OIL	GAS	OIL	GAS
PAKISTAN³						
Indus	<0.1	22.0	(0.2) ⁴	(30.0)	0.2	52.0
Potwar	0.1	<0.1	(0.1)	(0.1)	0.2	0.1
Makran			(0.0)	(0.0)	0.0	0.0
Aggregate ⁵	<u>0.1</u>	<u>22.0</u>	<u>0.3</u>	<u>30.0</u>	<u>0.4</u>	<u>52.0</u>
INDIA						
Bombay	3.3	9.6	1.0	4.0	4.3	13.6
Cambay	0.8	0.8	0.2	0.5	1.0	1.3
Konkan			0.2	0.4	0.2	0.4
Kutch			0.7	4.0	0.7	4.0
Cauvery			0.3	0.8	0.3	0.8
Palar ⁶			<0.1	<0.1	<0.1	<0.1
Krishna-Godavari			0.2	1.0	0.2	1.0
North Assam	0.9	8.0	0.1	1.0	1.0	9.0
Indo-Gangetic ⁶			<0.1	<0.1	<0.1	<0.1
Andaman ⁶			(<u><0.1</u>) ⁴	(<u><0.1</u>)	<0.1	<0.1
Bengal (38%)			<u>0.2</u>	<u>11.4</u>	<u>0.1</u>	<u>11.4</u>
Aggregate ⁵	<u>5.0</u>	<u>18.4</u>	<u>1.4</u>	<u>16.5</u>	<u>6.4</u>	<u>34.9</u>
BANGLADESH						
Bengal (48%)	0.0	11.0	0.2	14.4	0.2	25.2
BURMA						
Bengal (14%)	<0.1	0.0	0.1	4.2	0.1	4.2
Burma (minus Bengal)	<u>0.9</u>	<u><0.1</u>	(<u>1.0</u>) ⁴	(<u>2.0</u>)	<u>1.9</u>	<u>2.0</u>
Aggregate ⁵	1.0	<0.1	0.9	5.6	1.9	5.7

1. Original reserves include present reserves, plus cumulative production, plus an estimate of undeveloped discoveries.
2. Most likely (modal) values within a range of probabilities (figs. 2 through 31).
3. Pakistan basins grouped into a single assessment.
4. Bracketed values show estimated splits for particular basins grouped into a single assessment.
5. An aggregate of most likely (modal) values for estimated undiscovered petroleum is not a summation of the values for the basins but a somewhat lesser number depending on the individual probability curves.
6. Minor basins grouped with related adjacent basins (see figures 12, 13, 16, 17, 26, and 27).

Figure 2.--Pakistan-Indus, Potwar, and Makran Basins, undiscovered recoverable oil. Assessment date: May 20, 1983

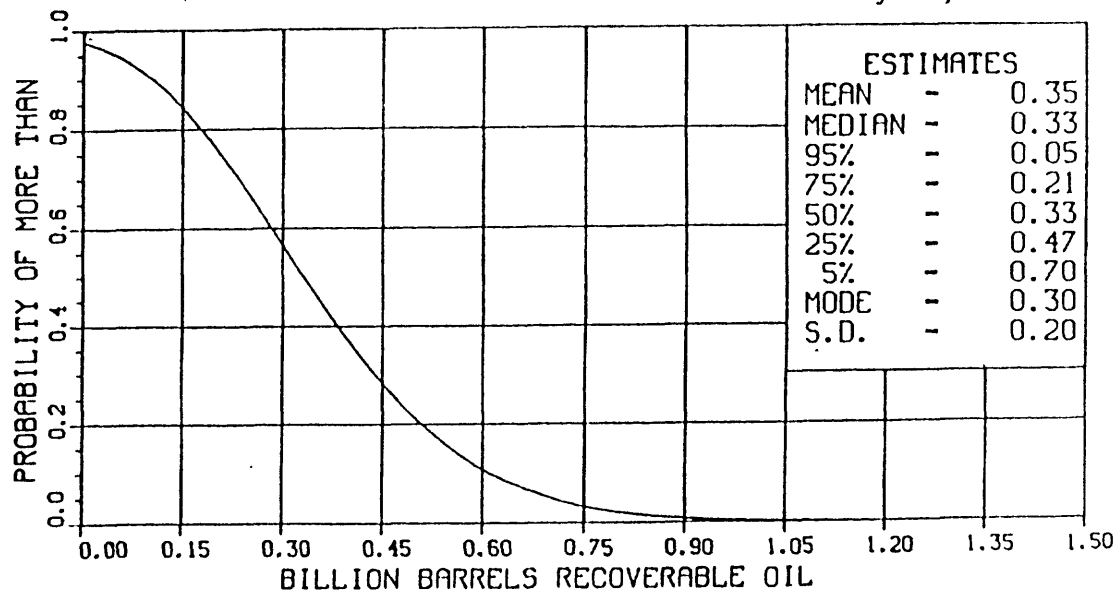


Figure 3.--Pakistan-Indus, Potwar, and Makran Basins, undiscovered recoverable total gas. Assessment date: May 20, 1983

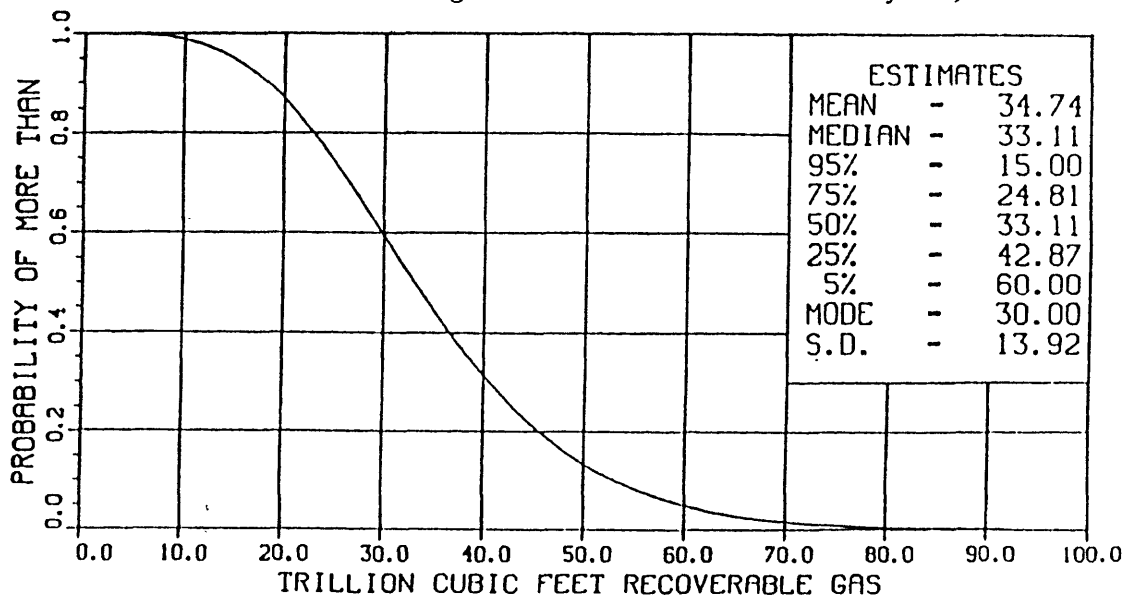


Figure 4.--India, Bombay Shelf, undiscovered recoverable oil.
 Assessment date: May 20, 1983

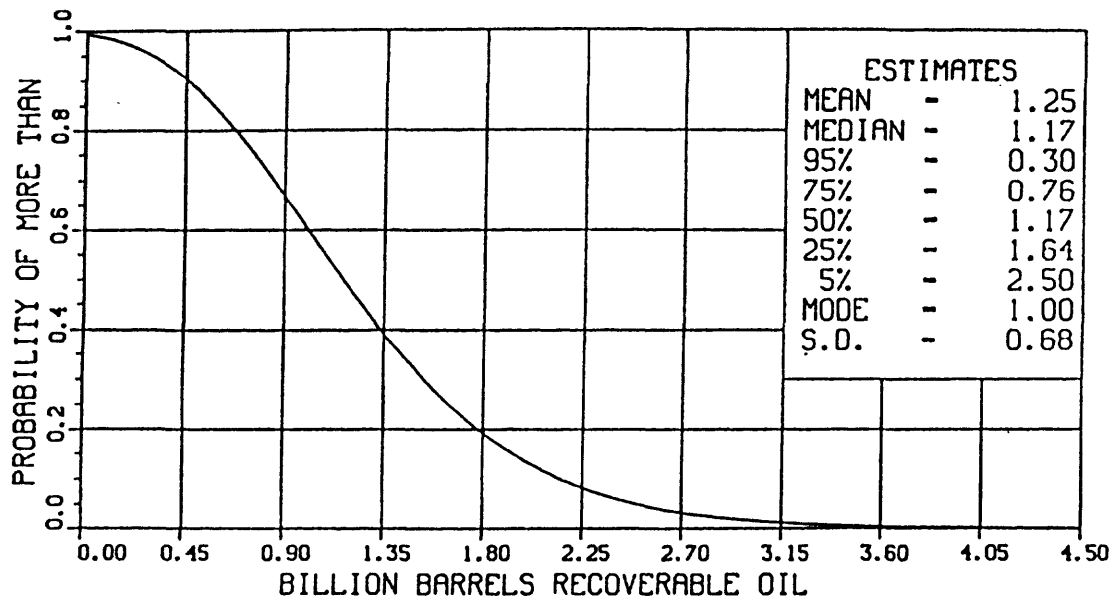


Figure 5.--India, Bombay Shelf, undiscovered recoverable total gas
 Assessment date: May 20, 1983

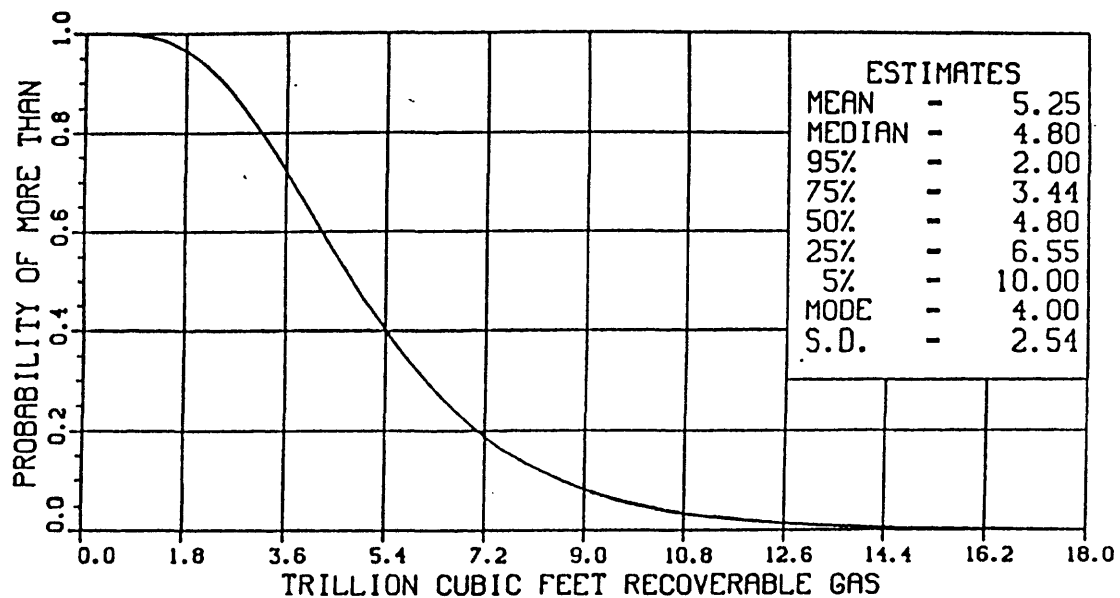


Figure 6.--India, Cambay Graben, undiscovered recoverable oil.
 Assessment date: May 20, 1983

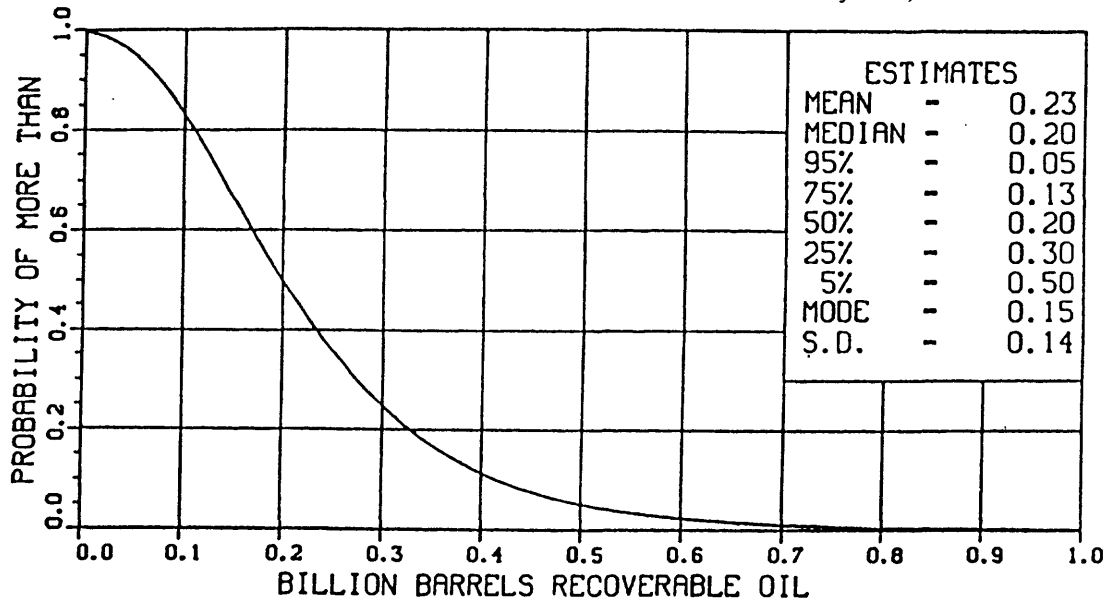


Figure 7.--India, Cambay Graben, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

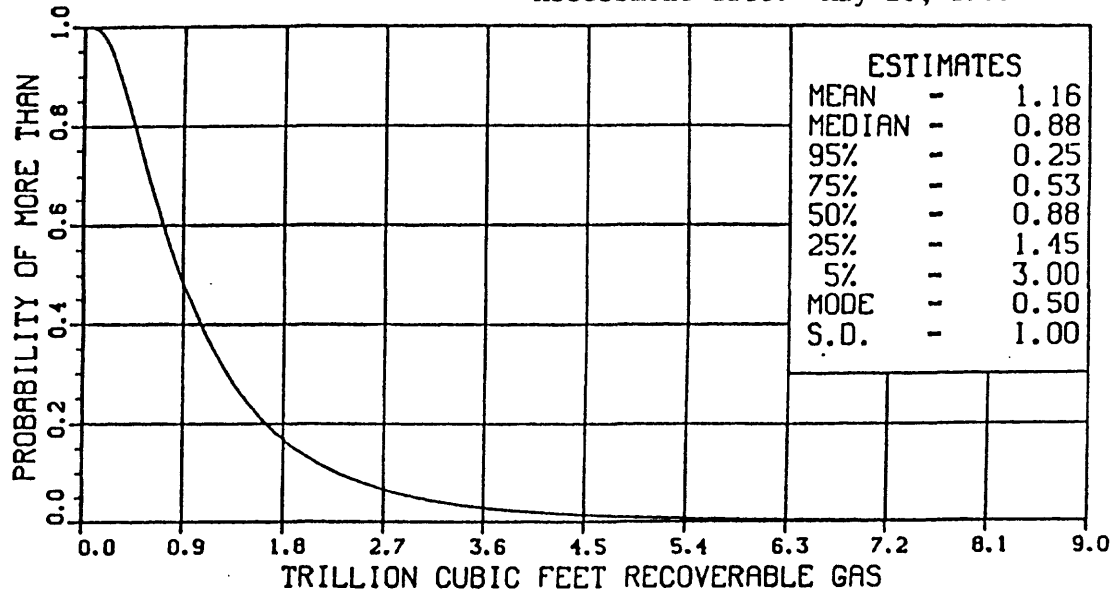


Figure 8.--India, Konkan Shelf, undiscovered recoverable oil.
 Assessment date: May 20, 1983

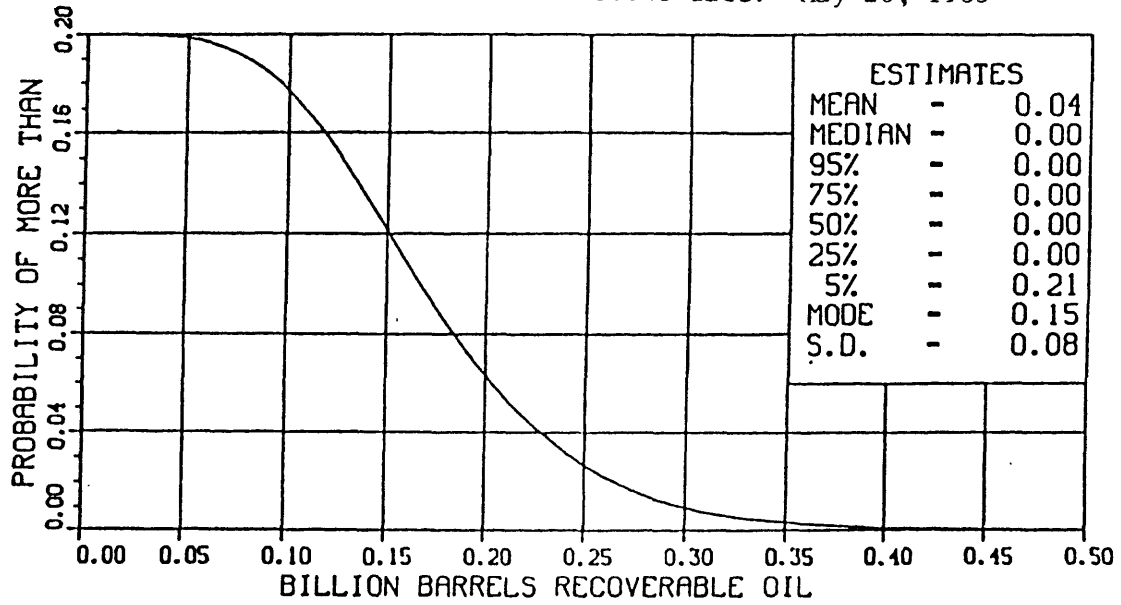


Figure 9.--India, Konkan Shelf, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

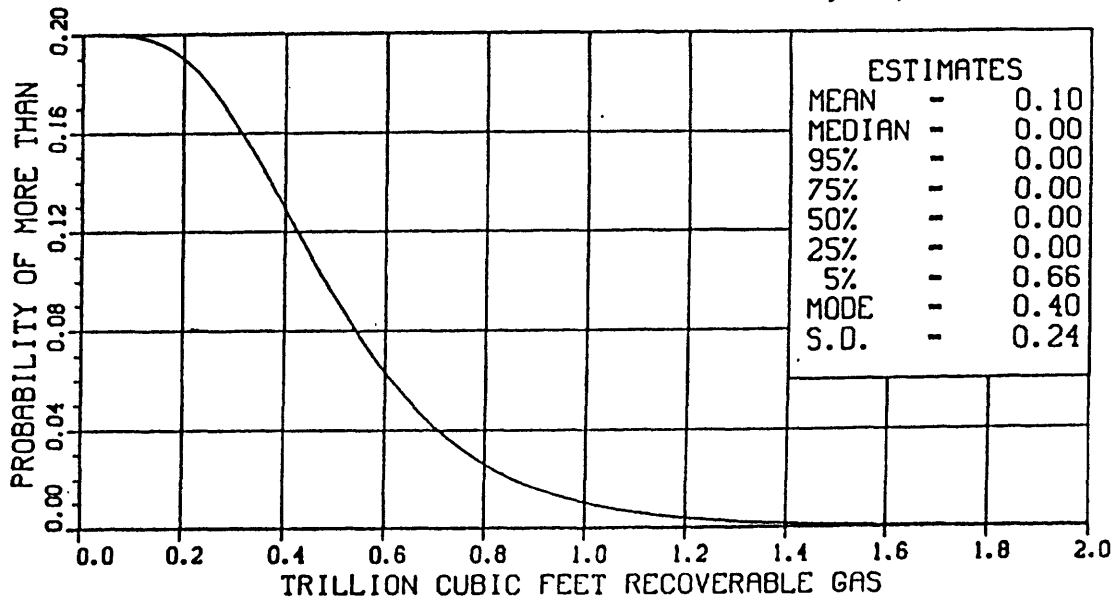


Figure 10.--India, Kutch Shelf, undiscovered recoverable oil.
 Assessment date: May 20, 1983

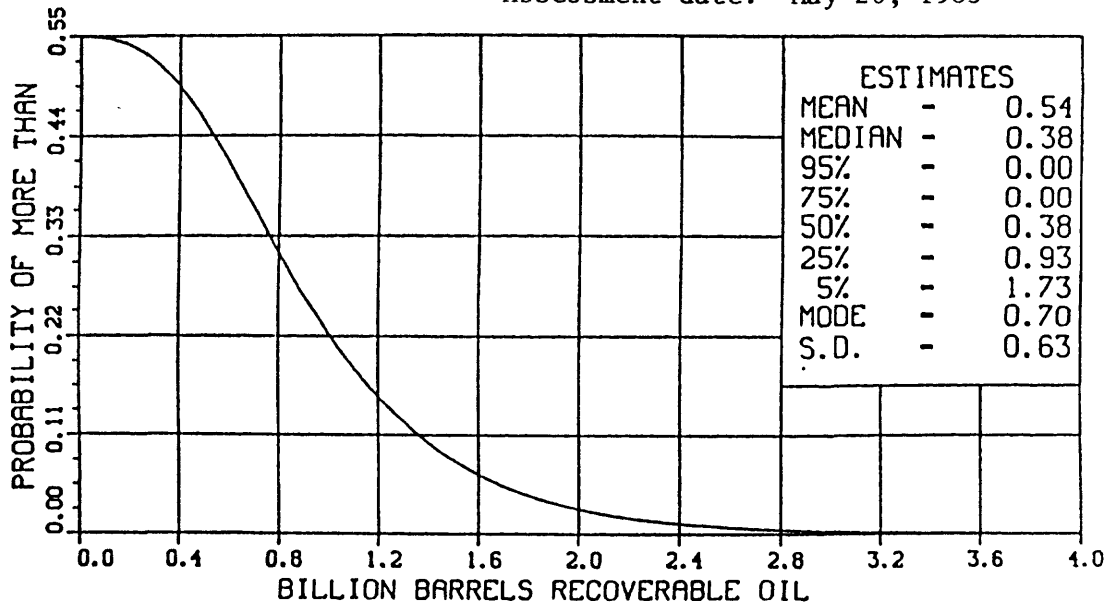


Figure 11.--India, Kutch Shelf, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

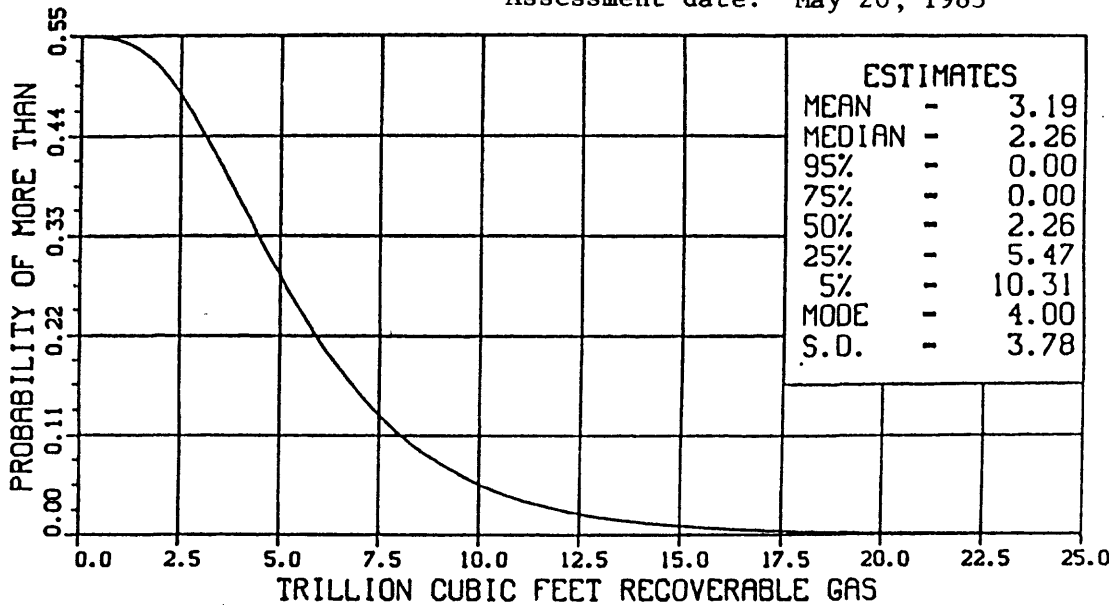


Figure 12.--India, Cauvery and Palar Basins, undiscovered recoverable oil.
Assessment date: May 20, 1983

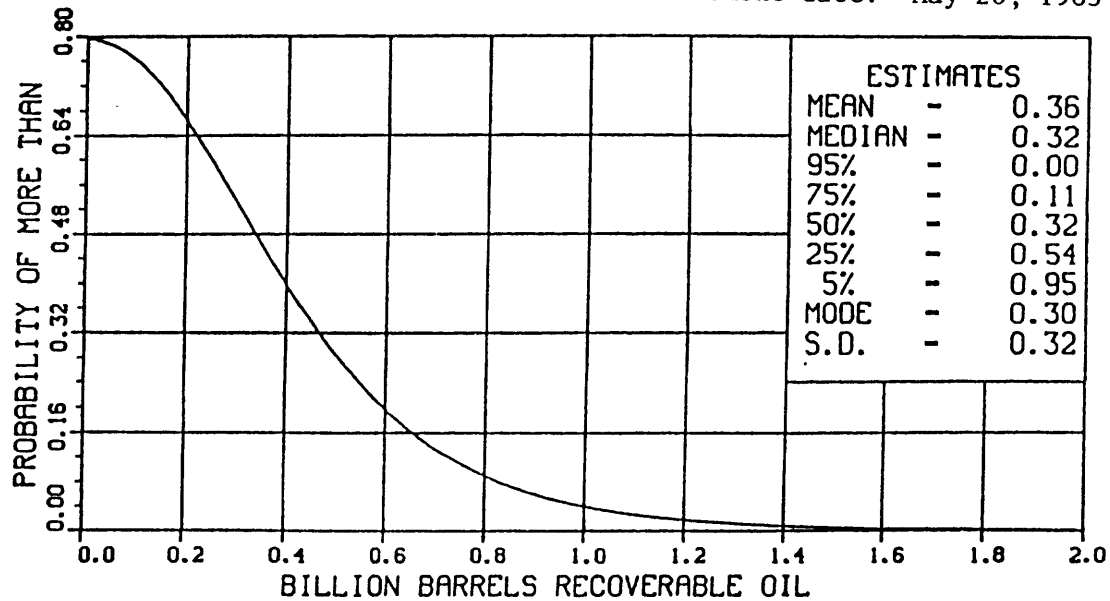


Figure 13.--India, Cauvery and Palar Basins, undiscovered recoverable total gas.
Assessment date: May 20, 1983

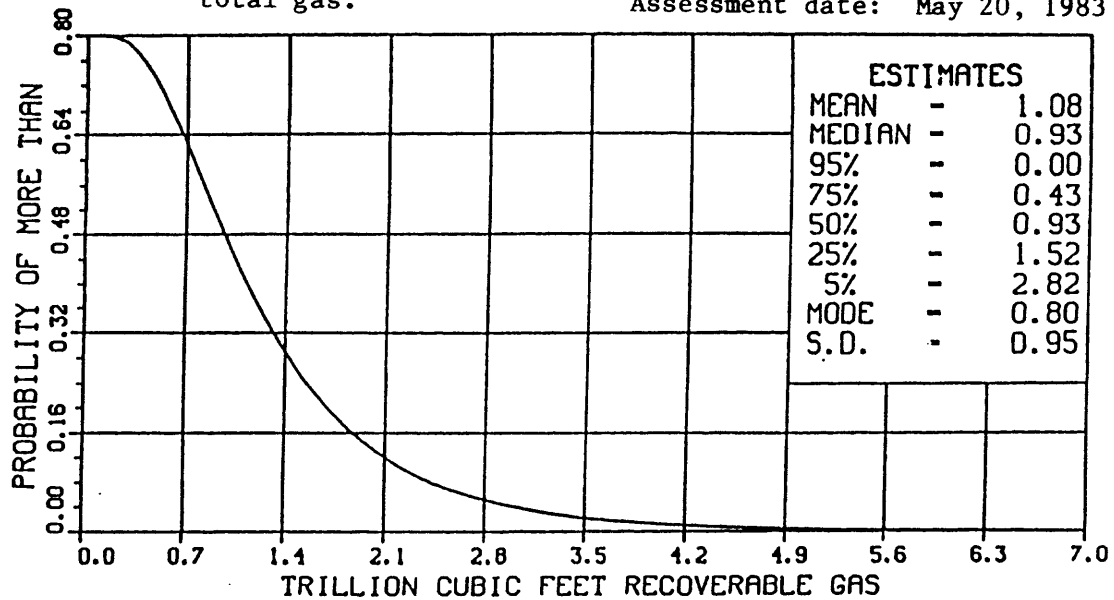


Figure 14.--India, Krishna-Godavari Basin, undiscovered recoverable oil.

Assessment date: May 20, 1983

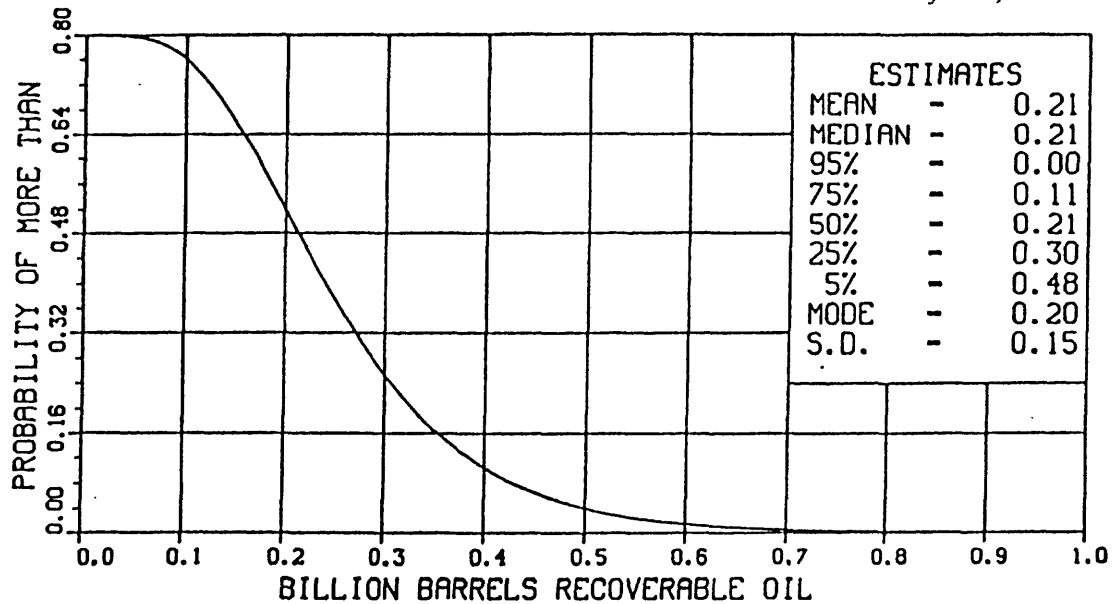


Figure 15.--India, Krishna-Godavari Basin, undiscovered recoverable total gas.

Assessment date: May 20, 1983

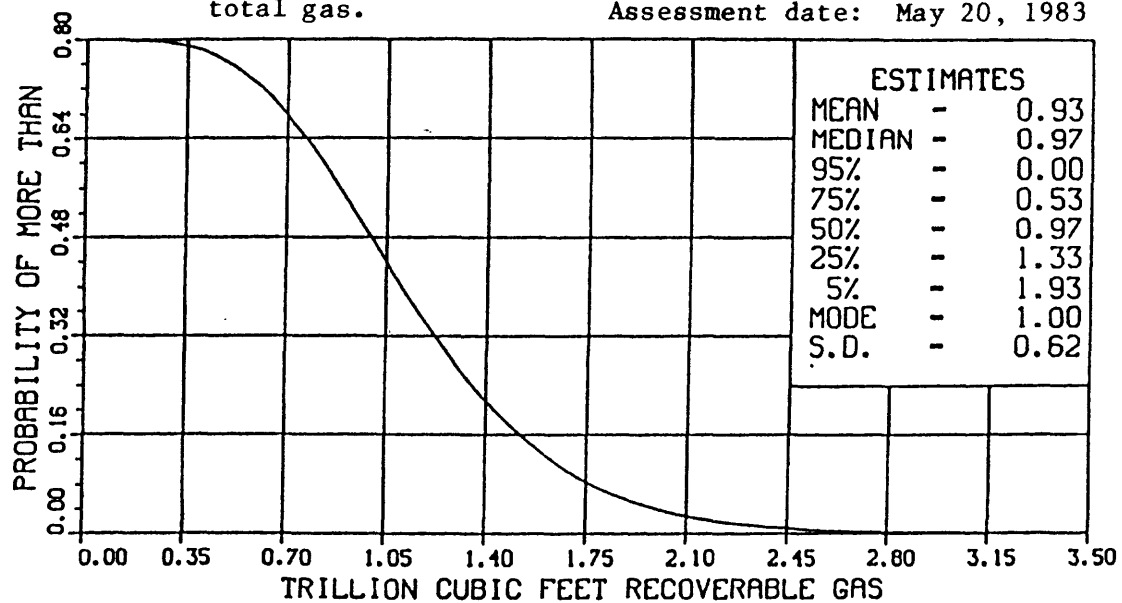


Figure 16.--India, North Assam and Indo-Gangetic Basins, undiscovered recoverable oil. Assessment date: May 20, 1983

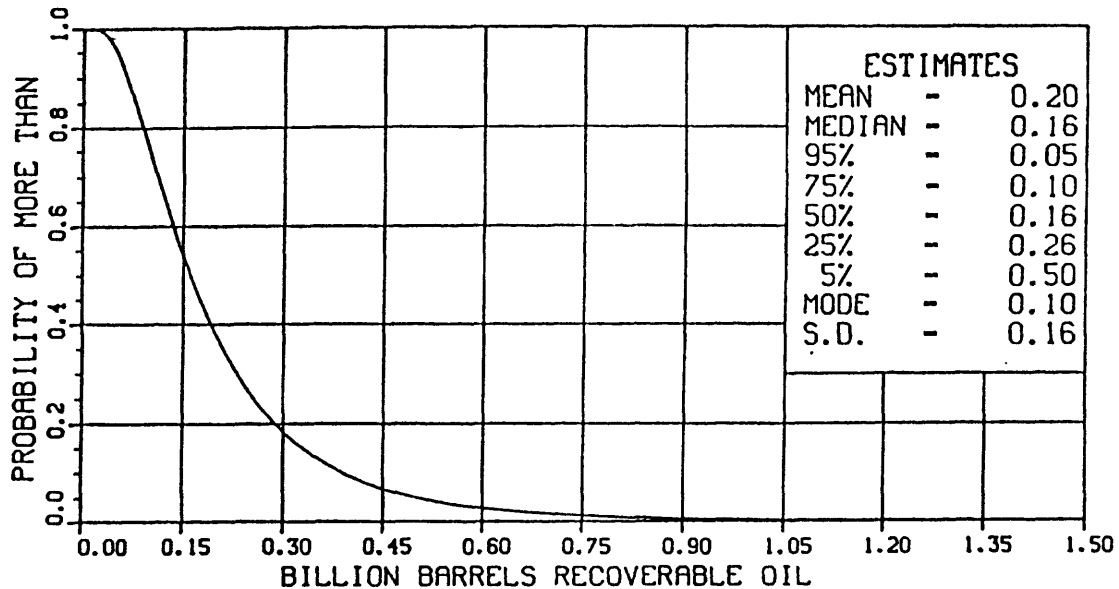


Figure 17.--India, North Assam and Indo-Gangetic Basins, undiscovered recoverable total gas. Assessment date: May 20, 1983

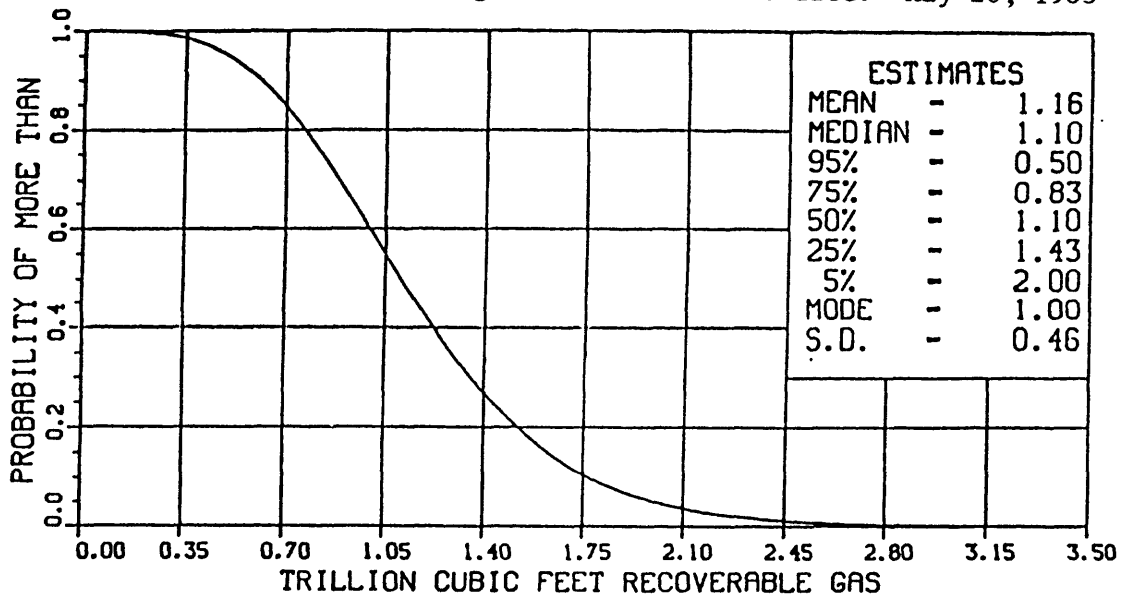


Figure 18.--India, Bengal Basin, undiscovered recoverable oil.
 Assessment date: May 20, 1983

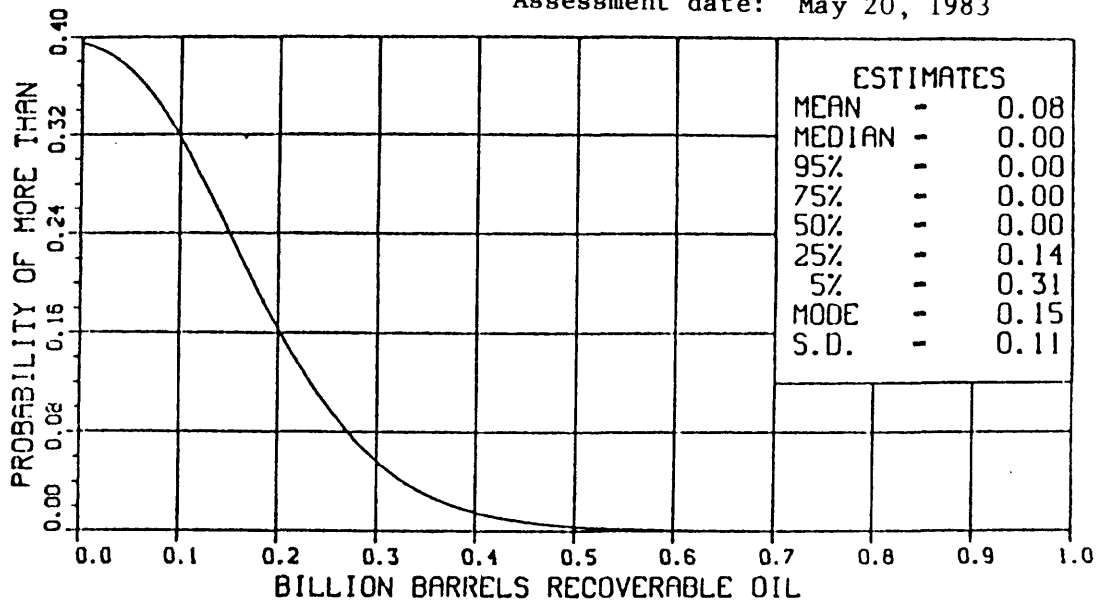


Figure 19.--India, Bengal Basin, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

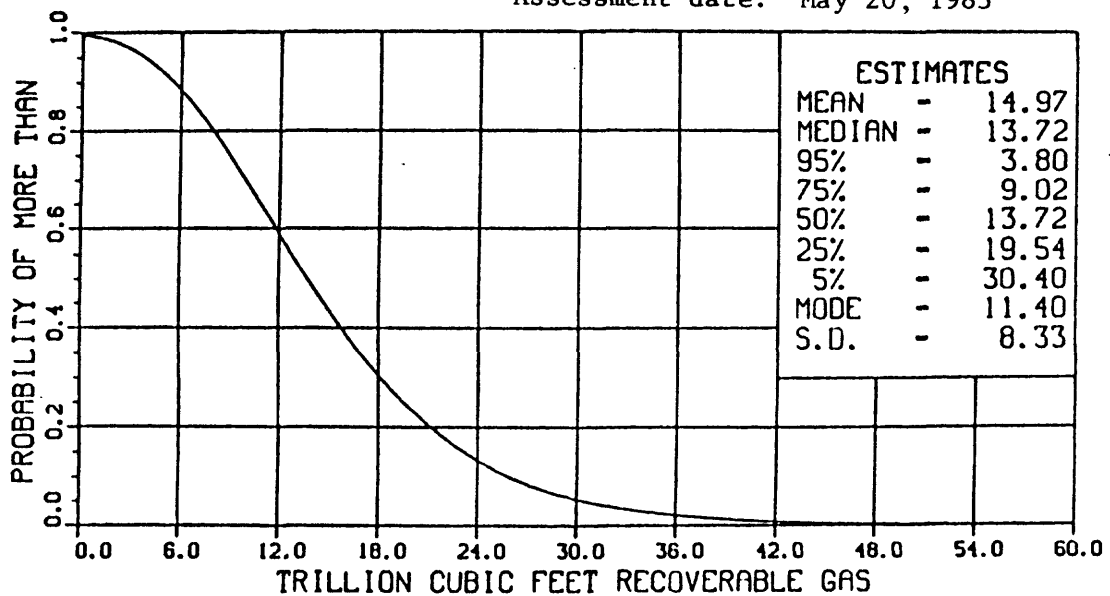


Figure 20.--India, aggregate undiscovered recoverable oil.
 Assessment date: May 20, 1983

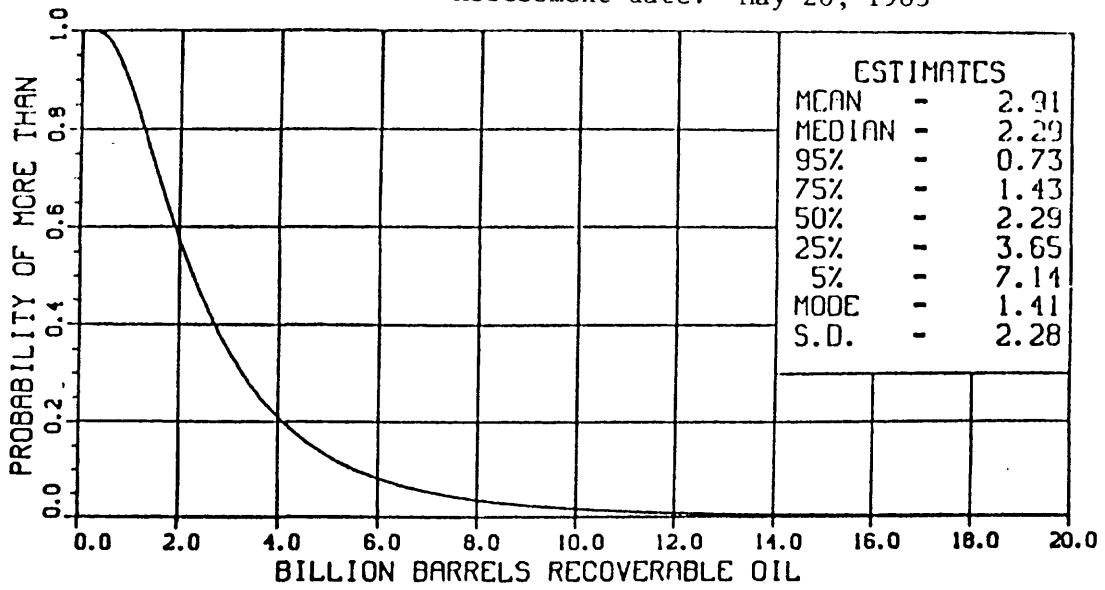


Figure 21.--India, aggregate undiscovered recoverable total gas.
 Assessment date: May 20, 1983

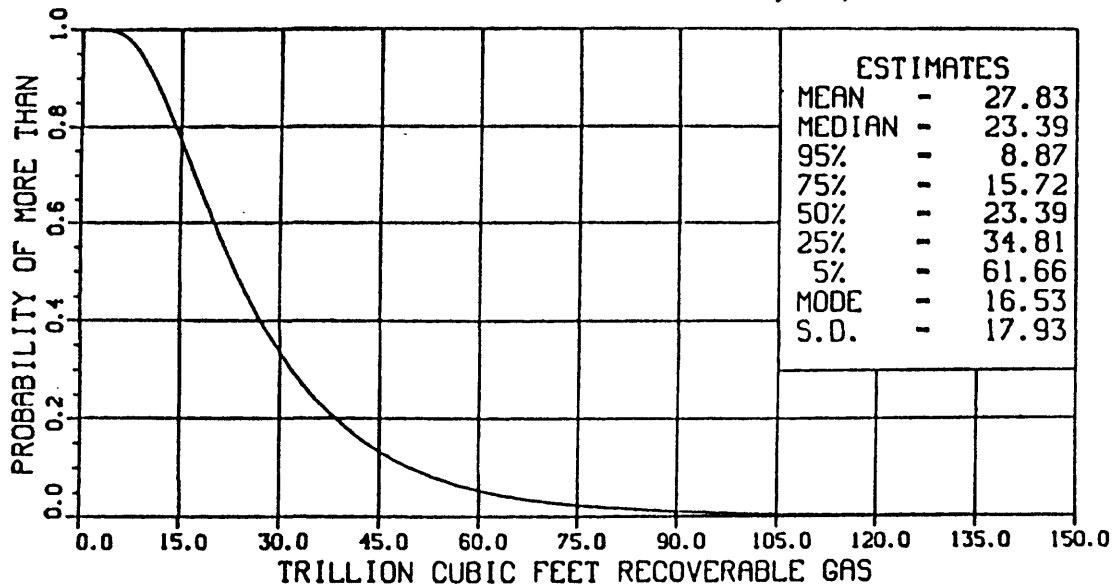


Figure 22.--Bangladesh, Bengal Basin, undiscovered recoverable oil.
 Assessment date: May 20, 1983

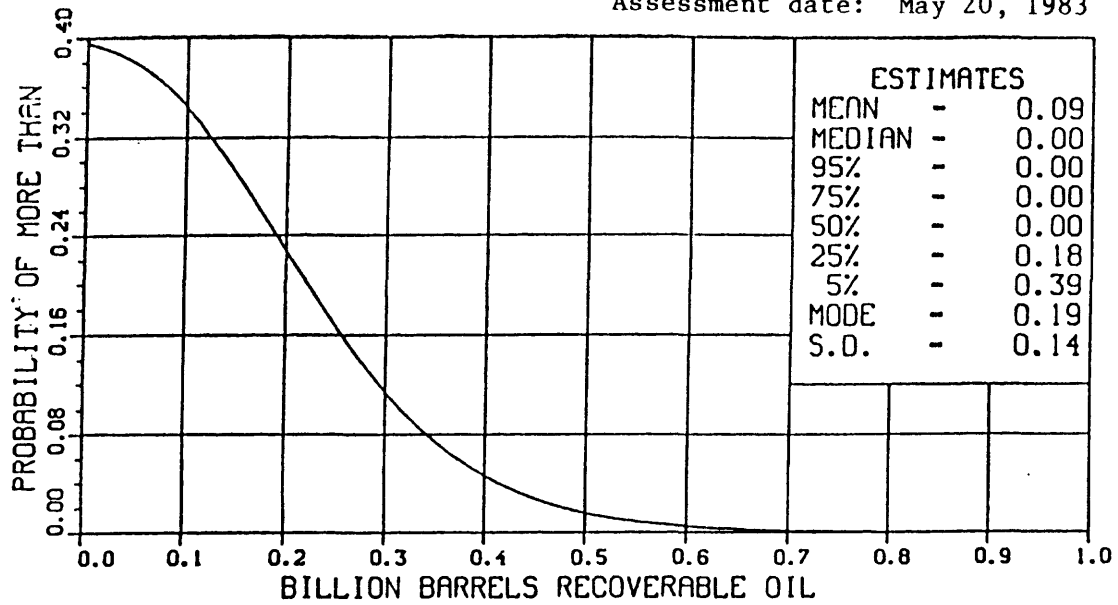


Figure 23.--Bangladesh, Bengal Basin, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

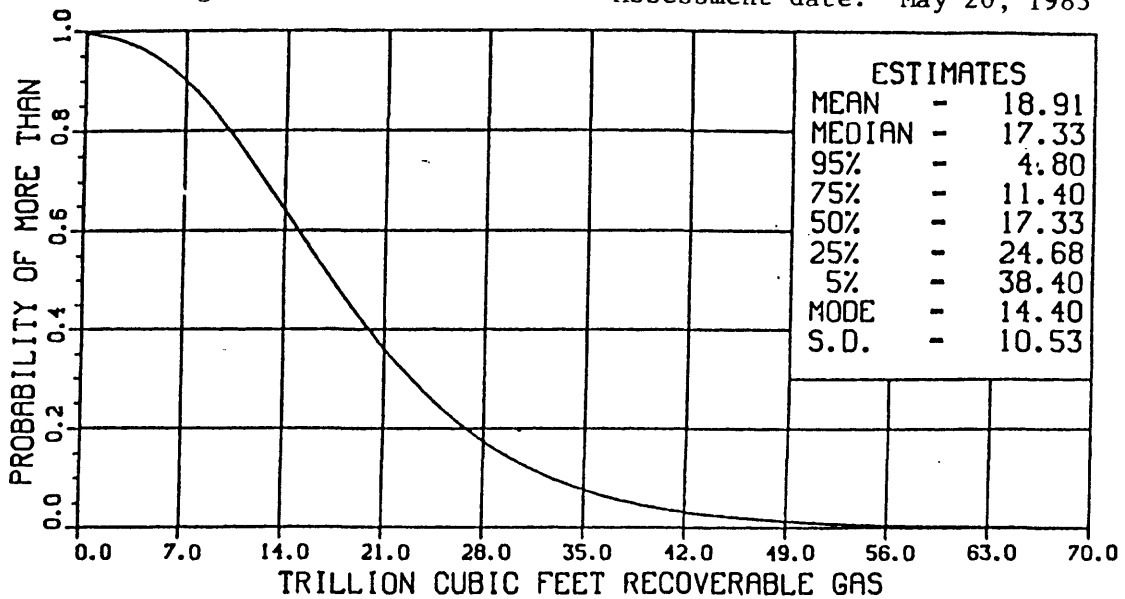


Figure 24.--Burma, Bengal Basin, undiscovered recoverable oil.
 Assessment date: May 20, 1983

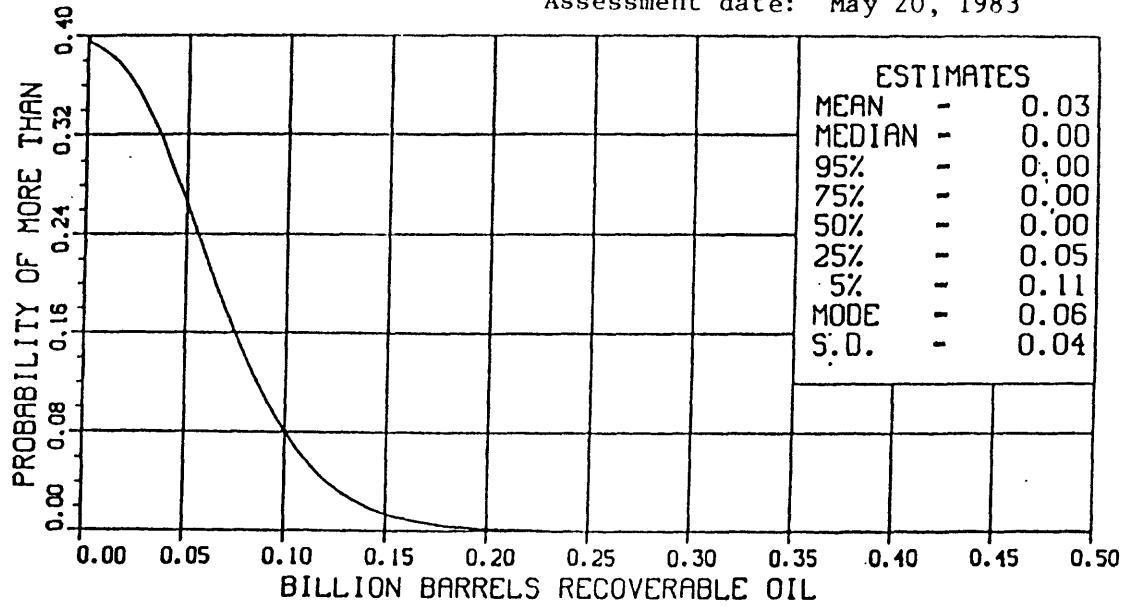


Figure 25.--Burma, Bengal Basin, undiscovered recoverable total gas.
 Assessment date: May 20, 1983

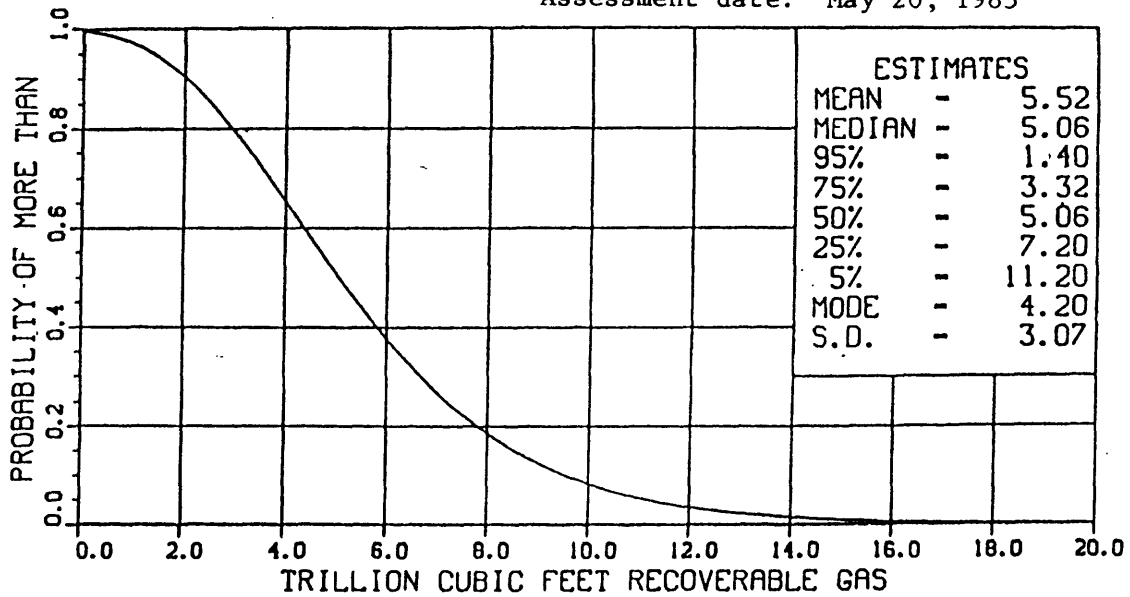


Figure 26.--Burma (4 plays) and Andaman (India) Basins, undiscovered recoverable oil. Assessment date: May 20, 1983

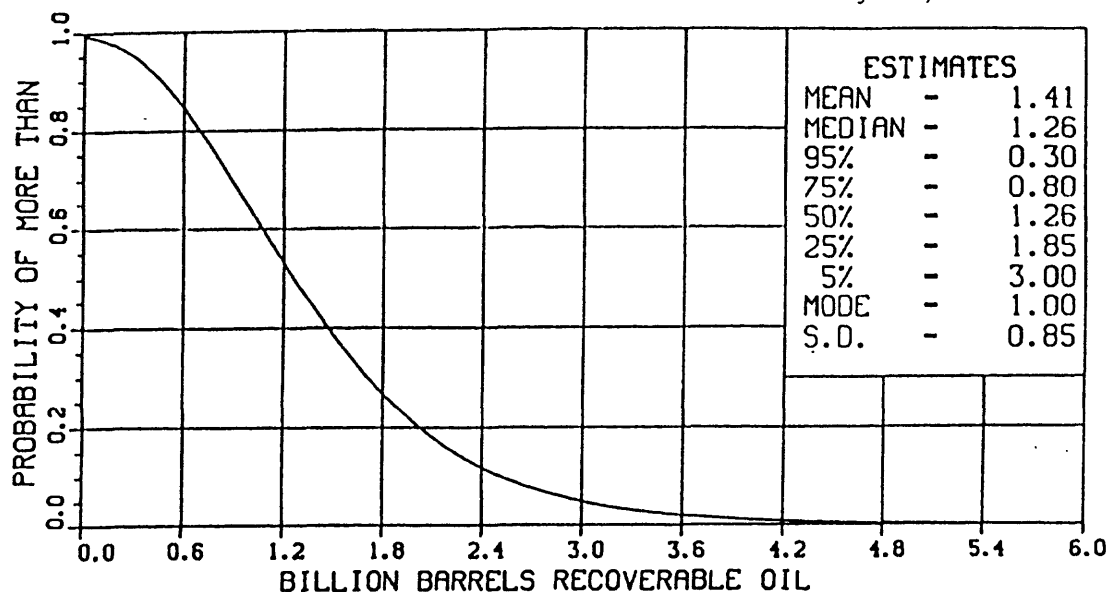


Figure 27.--Burma (4 plays) and Andaman (India) Basins, undiscovered recoverable total gas. Assessment date: May 20, 1983

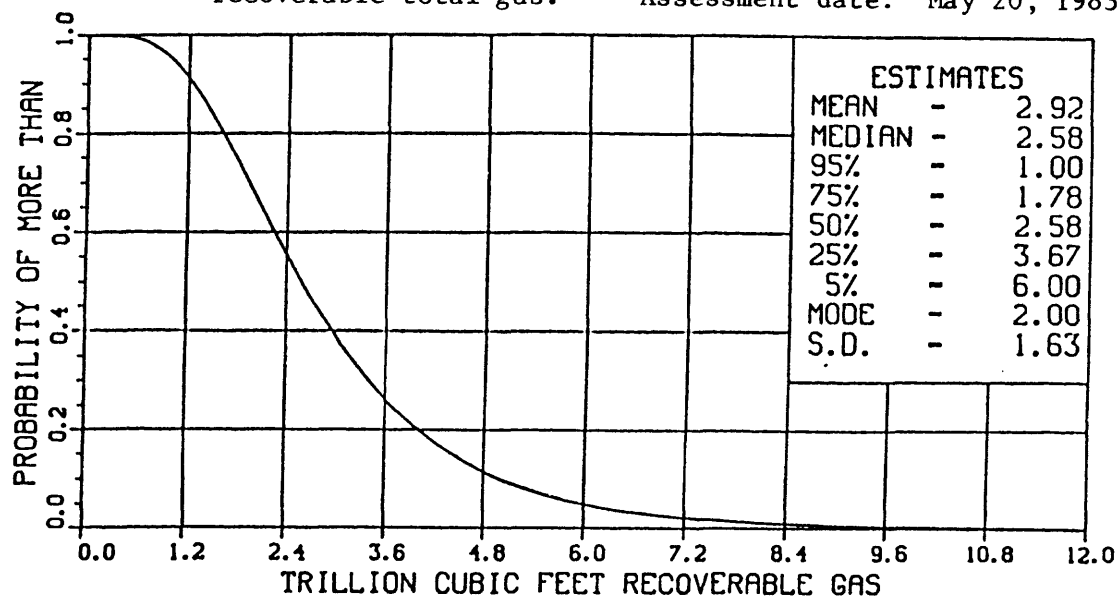


Figure 28.--Burma, aggregate undiscovered recoverable oil.

Assessment date: May 20, 1983

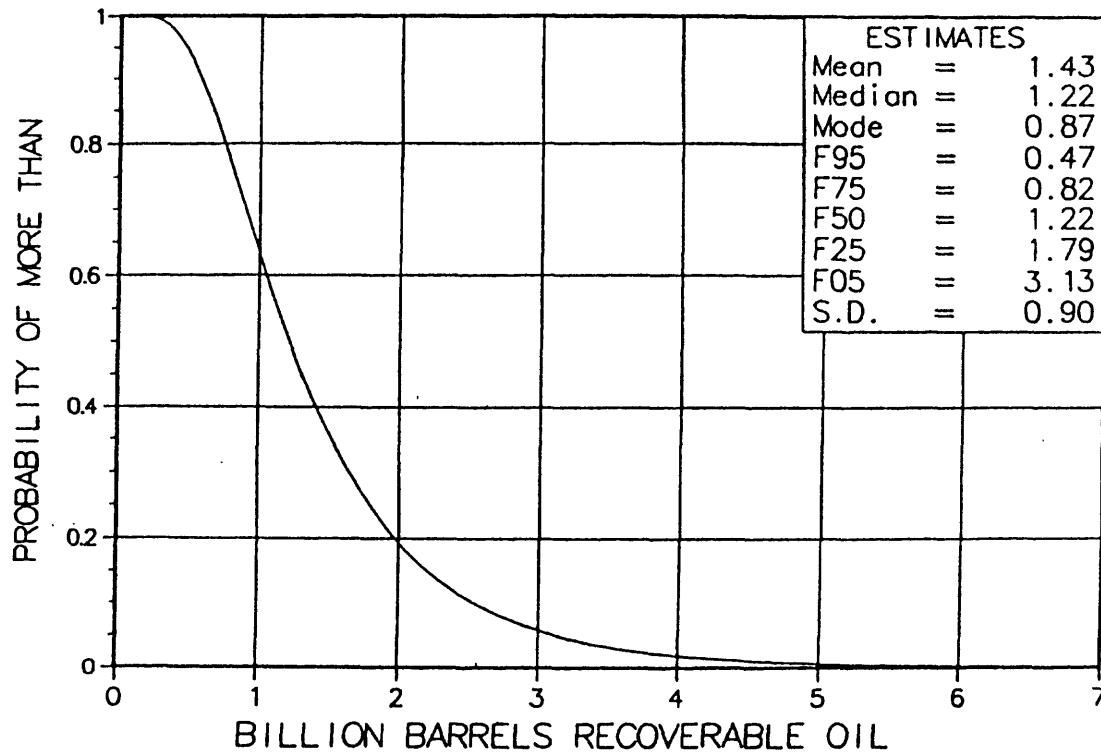


Figure 29.--Burma, aggregate undiscovered recoverable total gas.

Assessment date: May 20, 1983

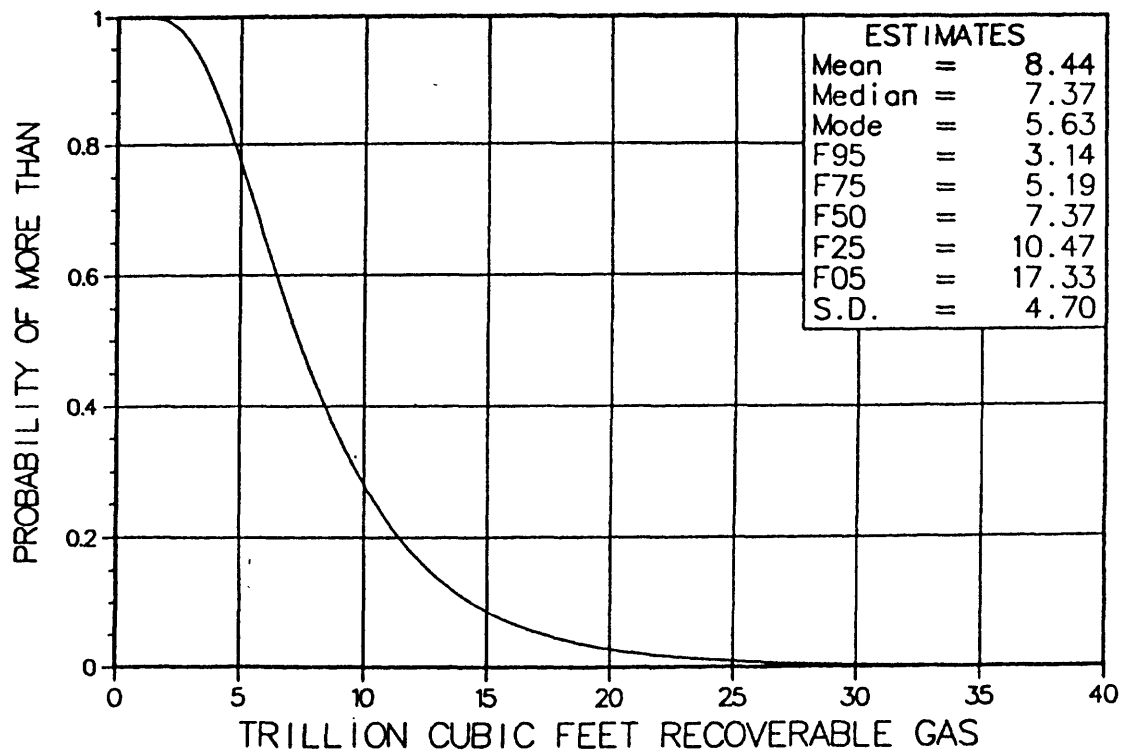


Figure 30.--Bengal Basin, aggregate undiscovered recoverable oil, Burma, India, Bangladesh. Assessment date: May 20, 1983

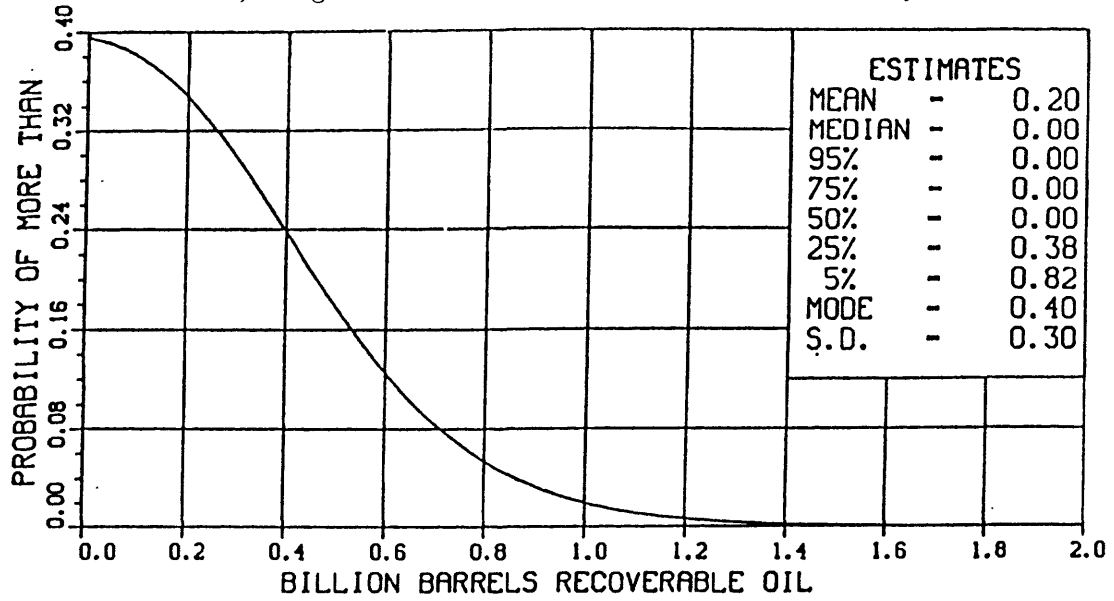
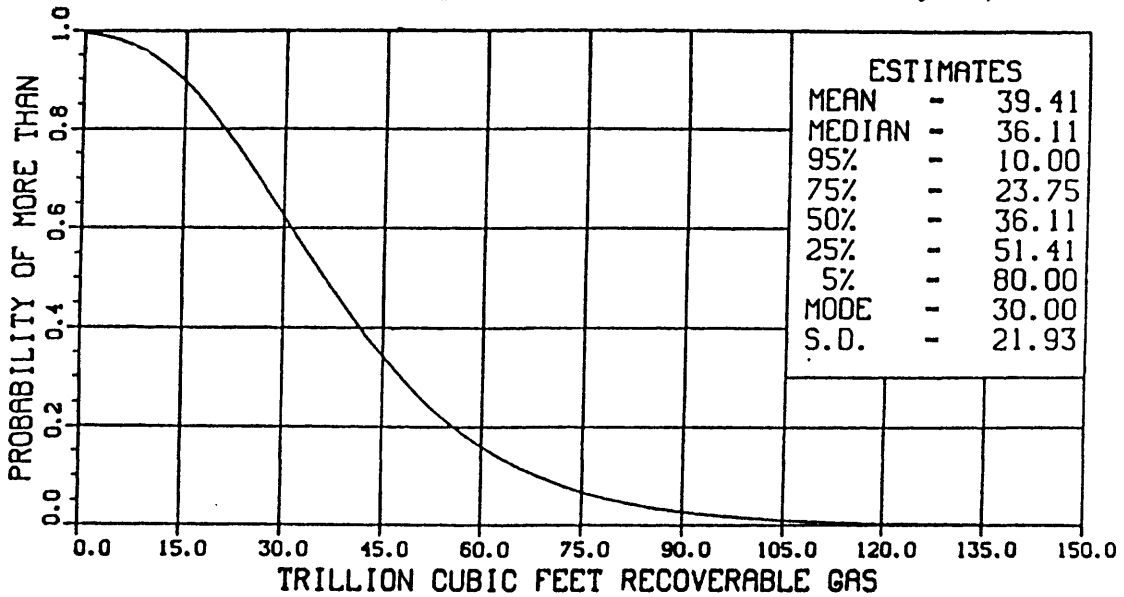


Figure 31.--Bengal Basin, aggregate undiscovered recoverable total gas, Burma, India, Bangladesh. Assessment date: May 20, 1983



COMMENTS

- Assessments are based on incomplete information, i.e., available published data.
- Our reserve figures are very approximate estimates and in general appear larger than the few available official figures. Uncertainty exists as to the handling of potential reserves indicated by discoveries but apparently not yet established by development drilling. The total petroleum content of a basin, however, should not be affected by this (see table 2).
- Pakistan has three basins, the Indus of some 125 thousand square miles (324 thousand square kilometers), the Potwar of 8.5 thousand square miles (22 thousand square kilometers), and the Makran of 60 thousand square miles (155 thousand square kilometers). The large Indus Basin is gas prone. Indus source rocks apparently are largely of pre-Tertiary age and are now thermally overmature; during the Tertiary when they were mature, uplift and erosion may have allowed the generating and migrating petroleum to escape. Present petroleum is mainly gas, which may be principally from the largely overmature remnant organic material in pre-Tertiary source rock. Some oil may have been, and is still being, sourced from the basin's perimeter where pre-Tertiary source rocks were, and are, shallower (and therefore less heated, i.e., less mature). The Potwar Basin is oil-bearing but limited by small size and poor reservoir development. The Makran area has been designated a basin but is largely an accretionary wedge of sediments and appears to have little petroleum potential.
- India has ten (and part of an eleventh) major sedimentary basins totalling some 575 thousand square miles (1490 thousand square kilometers). Three of these basins, Bombay, Cambay, and North Assam, produce oil and gas. Except for two relatively unimportant basins (Indo-Gangetic and Andaman), these basins are of (or closely related to) one tectonic type, i.e., the rifted continental margin basin. Characteristically, the trap configuration and source environment are directly or indirectly controlled by horst and graben structure. The source rocks are generally Paleogene and the reservoirs Paleogene and Neogene. The thermal gradients are relatively low except in the area of the Bombay and Cambay Basins where they are high and where most of the oil reserves of India (and South Asia) are centered. It is judged that about two-thirds of the undiscovered oil and one-fourth of the undiscovered gas is in the Bombay Shelf, the remainder being in the rifted marginal basins or shelves on the eastern and western sides of the India Continental Block.
- Bangladesh lies within and occupies half of one basin, the Bengal Basin. This basin is gas prone; the lack of oil is attributed to the inability of the larger petroleum (oil) molecules to migrate through the massive, thick, over-pressured, dominantly shale section between the source and the shallower reservoirs. Further gas discoveries, more than doubling the present reserves, are expected, but oil prospects are limited to the western shelf area where the effects of the over-pressured shale may not be a factor.

- Burma has four basins with an area of 120 thousand square miles (310 thousand square kilometers). Except for a small eastern back-arc basin, the north-trending string of Burma basins are dextrally wrenched fore-arc basins on-trend with the fore-arc basins of Indonesia. Like fore-arc basins in general, the thermal gradient is low, but owing to their relatively great depth, the deepest parts of the basins have reached thermal maturity. This may restrict the petroleum prospects of these basins to their central, deepest portions. Although it has a long exploration history, the petroleum potential of Burma may not yet be realized owing to rather limited modern exploration. It is estimated that less than one-half the petroleum has been discovered.