Historical Changes in Oil-Field Populations as a Method of Forecasting Field Sizes of Undiscovered Populations:

A Comparison of Kansas, Wyoming, and California

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Kansas Geological Survey

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ABSTRACT

This study involves analysis of historical changes in oil-field sizes in Kansas, Wyoming, and California. It is common knowledge that large oil or gas fields tend to be found early in the sequence of discoveries in a region, and that the sizes of fields tend to diminish progressively as exploration proceeds. This study has found that populations of oil fields (or oil and gas fields combined) tend to be more or less lognormally distributed; but in some regions or districts, the populations of fields discovered early tend to depart more severely from an ideal lognormal distribution than do populations discovered later. Comparisons between populations of fields discovered early, intermediately, and late were made by segregating the presently known fields in each of the three states into intervals representing the first 20 percent to be discovered, the second 20 percent to be discovered, and so on. This method of segregating by discovery sequence also was employed for individual districts within each state.

The results are presented graphically and in tables, and may be used to predict the population parameters of fields to be discovered in the future. In most of the districts, as well as for each state, the forecasts of new-field discoveries are pessimistic. This pessimism stems from the rapid decline in population parameters (median, geometric mean, and total volume) with the progression of discoveries. It is to be emphasized that these predictions pertain to the discovery of new fields, and exclude increases in oil and gas that may result from extensions of known fields, or from enhanced oil and gas recovery in existing fields. Furthermore, the forecasts pertain to general regions of already-discovered fields and exclude provinces (such as offshore central and northern California) that have been relatively little explored.

In California, it is estimated that, of the next 81 fields to be discovered (within the established oil- or gas-bearing regions of California), the total volume of oil and gas (expressed as barrels of oil equivalent, or BOE) will be about 0.6 percent of the total hydrocarbons that ultimately will be extracted from California's total of 404 fields discovered from 1861 through 1974. Furthermore, this forecast population is estimated to be approximately lognormally distributed, with a median size of only 125,000 BOE. Given the graph of this forecast distribution, probabilities attached to individual field-size ranges (in BOE) can be estimated. Within the forecast population of 81 fields, for example, the probability is only nine percent that any particular field discovered will be between 10 and 100 million BOE. The probability of finding a field greater than 100 million BOE is only a small fraction of one percent.

In Wyoming, the forecast of the next 151 fields to be discovered is only slightly less pessimistic. It is forecast that this population of new fields will contribute only about 1.6 percent additional BOE relative to the total BOE extractable from the 754 fields discovered in Wyoming from 1884 through 1977.

The data for Kansas exclude gas and are based on cumulative production of oil through the end of 1978 for all fields discovered through the end of 1973. Thus, the oil-field size distributions for Kansas (in contrast to Wyoming and California) are somewhat inadequate measures for forecasting purposes because they exclude estimates of remaining reserves. Thus, because many Kansas fields are still producing, the population parameters must be revised upward. Nevertheless, the forecast for new-field discoveries in Kansas is pessimistic. By comparison with the total of 2,992 oil fields discovered in Kansas from 1890 through 1973, if 598 new fields are discovered (20 percent more) they probably will contribute only two or three percent more to the oil discovered in Kansas through 1973.

INTRODUCTION

This study involves changes in the characteristics of oil-field populations with their sequence of discovery. It is common knowledge that large oil and gas fields tend to be discovered early, and that the sizes of fields tend to diminish progressively as exploration proceeds in a region. If these changes are sufficiently regular, they should permit the characteristics of future oil-field populations to be predicted, based on the historical shifts observed to date.

One of the most important aspects of any mineral-resource assessment is an understanding of the statistical properties of the deposits that have been discovered. Unfortunately, inadequate effort has been expended in preparing an inventory of United States oil and gas fields and, paradoxically, almost no effort has been spent in statistically analyzing the data that do exist.

This study involves a comparison of oil fields in California, Wyoming, and Kansas. The data have been derived from publicly accessible sources. We have analyzed the oil-field populations for each of these three states, as well as for individual geographic districts or sedimentary basins within each state. The population of oil fields within each of these states or subdivisions has been segregated into five subpopulations according to sequence of discovery. The first 20 percent of fields to be discovered defines the first subpopulation, the second 20 percent discovered defines the second subpopulation, and so on. Comparison of the differences between these subpopulations provides a basis for prediction.

In California and Wyoming, data from both oil and gas fields have been used, and the field sizes have been expressed in barrels of oil equivalent (BOE). The field sizes in these two states involve the cumulative production for each field at the end of 1977 in Wyoming, and the end of 1978 in California. The cumulative production figure for each field is then combined with the estimated remaining reserves to yield an estimate of the total recoverable BOE for each field.

In Kansas, only oil-production data have been used, and the oil-field sizes are expresssed solely as the cumulative production (to the end of 1978). Data on reserves remaining the Kansas oil fields are not available.

It is important to realize that the predictions in this study are derived almost solely from historical changes and, with one exception, do not incorporate geological data other than the field volumes. The predictions apply to new fields to be discovered and do not pertain to increases in estimates that may arise from extension of existing oil fields or from enhanced oil recovery. Furthermore, the predictions apply, more or less, to established provinces that have undergone exploration. The area offshore central and northern California, for example, is not included in the prediction for California because this area generally has not been explored and has not contributed to the existing resource base of proven oil and gas fields in California.

PROCEDURES

The procedures employed involved transforming the estimates of oil- and gas-field sizes to barrels of oil equivalent (BOE) for fields in California and Wyoming. A conversion factor--5.7 thousand cubic feet of gas equals one barrel of oil--was used. In California, the size tabulated for each field represents the cumulative production through the end of 1978 plus the estimated reserves at the end of 1978. In Wyoming, the cumulative production was tabulated through the end of 1977 and added to estimated reserves remaining as of that date. In Kansas, only oil production data were used (production from gas fields and production of gas associated with oil are not included). In Kansas, the cumulative production for each field through the end of 1978 was employed.

The oil- and gas-field volumes, expressed as the total producible hydrocarbons in BOE in California and in Wyoming, and cumulative oil production in Kansas, were segregated chronologically according to year of discovery for each field. Then, for each state, as well as for selected geographic districts or basins within each state, the fields were segregated into five classes according to discovery sequence. These classes are (A) the first 20 percent of the fields that were discovered relative to the total population of fields that had been discovered by a specific date (end of 1973 for Kansas, end of 1974 for California, end of 1977 for Wyoming), (B) the next 20 percent of fields discovered, (C) the third 20 percent discovered, (D) the fourth 20 percent discovered, and (E) the fifth 20 percent discovered.

The frequency distributions for each of these five intervals were plotted, and certain population parameters were computed, namely the median, geometric mean, and either the BOE discovered through 1978 (for California) and 1977 (for Wyoming) or the cumulative production through 1978 (for Kansas).

The frequency distributions have been plotted on log-probability paper, a form particularly convenient because a perfect lognormal distribution appears as a straight line. Figure 1 provides a comparison between a lognormal distribution plotted in conventional form and the same distribution plotted on log-probability paper. Part a of Figure 1 shows the lognormal distribution plotted as a histogram, to which a bell-shaped curve (s) has been fitted. The same distribution plotted in cumulative form (c) has been superimposed. The cumulative curve is sigmoidal; the cumulative percentage scale is linear and ranges from 0 to 100 percent.

If we distort the cumulative percentage scale so those parts of the scale that lie toward both the zero-percent and 100-percent ends are progressively stretched (log-probability scale), the cumulative percentage scale can be made to compensate for differences in the height of the normal curve. The normal curve is, of course, asymptotic toward its two ends, but if the cumulative percentage scale is stretched to compensate for this, the sigmoidal curve is transformed to a straight line (Fig. 1-b). Under these circumstances, 0 and 100 percent lie at an infinite distance because the normal curve is asymptotic. If an actual distribution deviates from a straight line when plotted on log-probability paper, the deviation provides a graphic measure of the degree to which the actual distribution differs from an ideal lognormal distribution.

The procedure for plotting a population on log-probability paper is simple. The objects (fields in our examples) are ranked in ascending order. A fractile percentage is assigned to each field and the percentages are progressively accumulated. The fractile percentage is obtained by dividing 100 percent by the number of fields plus one. Thus, if there are 24 fields, the individual fractile percentage is 100/(24 + 1) = 4 percent, and the sequence of cumulative percentage values is 4, 8, 12, 16, ... , 92, and 96. Thus 0 and 100 percent are not represented because they cannot be accommodated on log-probability plots. By convention, the lower end of the cumulative percentage scale is plotted so that it corresponds with the lower end of the sequence of fields as ranked by size. The resulting plot thus extends from lower left to upper right, provided that the cumulative percentage scale is plotted horizontally.

GRAPHIC PRESENTATION OF THE DATA

Most of the illustrations in this report, with the exception of index maps and several other figures, involve use of a standardized graphic format. A single explanation will suffice for Figures 3 through 6, 8 through 17, and 19 through 26, all of which employ this standard format. Each of these figures contains four boxes, labeled a, b, c, and d, which contain graphs. Box a in the upper left is a log-probability plot of the total population of fields within the area represented. For convenience, individual points at 2, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 85, 90, 95, and 98 cumulative percent have been plotted, and a curve then fitted manually. The degree to which the plot approaches a straight line is a measure of the degree to which the overall population approaches an ideal lognormal distribution.

Box b, in the upper right, is also a log-probability plot, but pertains to subpopulations that have been segregated according to discovery sequence. There are five such subpopulations, labeled A, B, C, D, and E, which represent the first 20 percent of fields discovered, the second 20 percent discovered, and so on. These curves are based on points plotted in a manner identical to that used in box a, but the individual points are omitted for simplicity.

Curves F and G in box b are shown with dashed lines. F represents the forecast populations for the next 20 percent of fields to be discovered, and G the 20 percent of fields to be discovered after that. The letters used to label these populations have been used consistently throughout. If we define the "present" total, consisting of fields that had been discovered at the end of 1973 in

Kansas, the end of 1974 in California, and the end of 1977 in Wyoming, as 100 percent, then the percentage ranges and identifying letters are as follows.

Identifying letter	Percentage range of total fields presently discovered
Subpopulations of fields that have been discovered:	
A	0-20
B	20-40
C	40-60
D	60-80
E	80-100
Subpopulations of fields forecast to be discovered in the future:	
F	100-120
G	120-140

In fitting curves F and G, the medians for these subpopulations were employed in manually fitting smoothed curves that conform, more or less, with the general trends in the progression of changes from curves A through F. The method used is shown in box c in the lower left. Shown is a plot of the medians of the subpopulations versus discovery sequence. The same letters are employed to label the subpopulations, A being the oldest subpopulation (the first 20 percent) and E the youngest (the last 20 percent). A curve has been manually fitted to the five points and, in some plots, two or even three curves have been fitted, representing "optimistic" versus "realistic" projections. The extension of the fitted curve (the dashed portion) yields the projected medians for subsequent subpopulations F and G.

Box d, in the lower right, presents the cumulative volumes in the subpopulations and, as in box c, involves a projection (dashed part of the fitted curve) for the subsequent populations F and G. Both boxes c and d use a log scale along the vertical axis because of the very large ranges of volumes involved. The volumes may exhibit a range of as much as two orders of magnitude, making use of a linear scale impractical.

TABULAR PRESENTATION

Standardized sets of tables have also been employed. Tables 1, 3, and 5 contain data that pertain to the standardized graphs described above as well as other information. The subpopulation percentage ranges are arranged in rows and labeled A through G. By columns, information is provided, including the range of years, number of fields, median, geometric mean, total quantity discovered, and percentage of present total.

The geometric mean is computed by finding the average of the logarithms of the individual field volumes in a specific population, and then taking the antilog of this value.

Tables 2, 4, and 6 contain probabilities estimated for fields that remain to be discovered (subpopulations F and G). The number of fields in each forecast population is presented, as well as the probabilities attached to different field-size ranges expressed as a progression of powers of 10. Seven columns of field-size ranges are provided, from $<10^3$ (less than 1000 barrels or BOE), to 10^8 to 10^9 BOE or barrels. These probability estimates are read from the curves F and G in box b for each population. They represent probabilities attached to the discovery of new fields within the specified area, district, or basin. Table 7 provides a summary comparison of the three states.

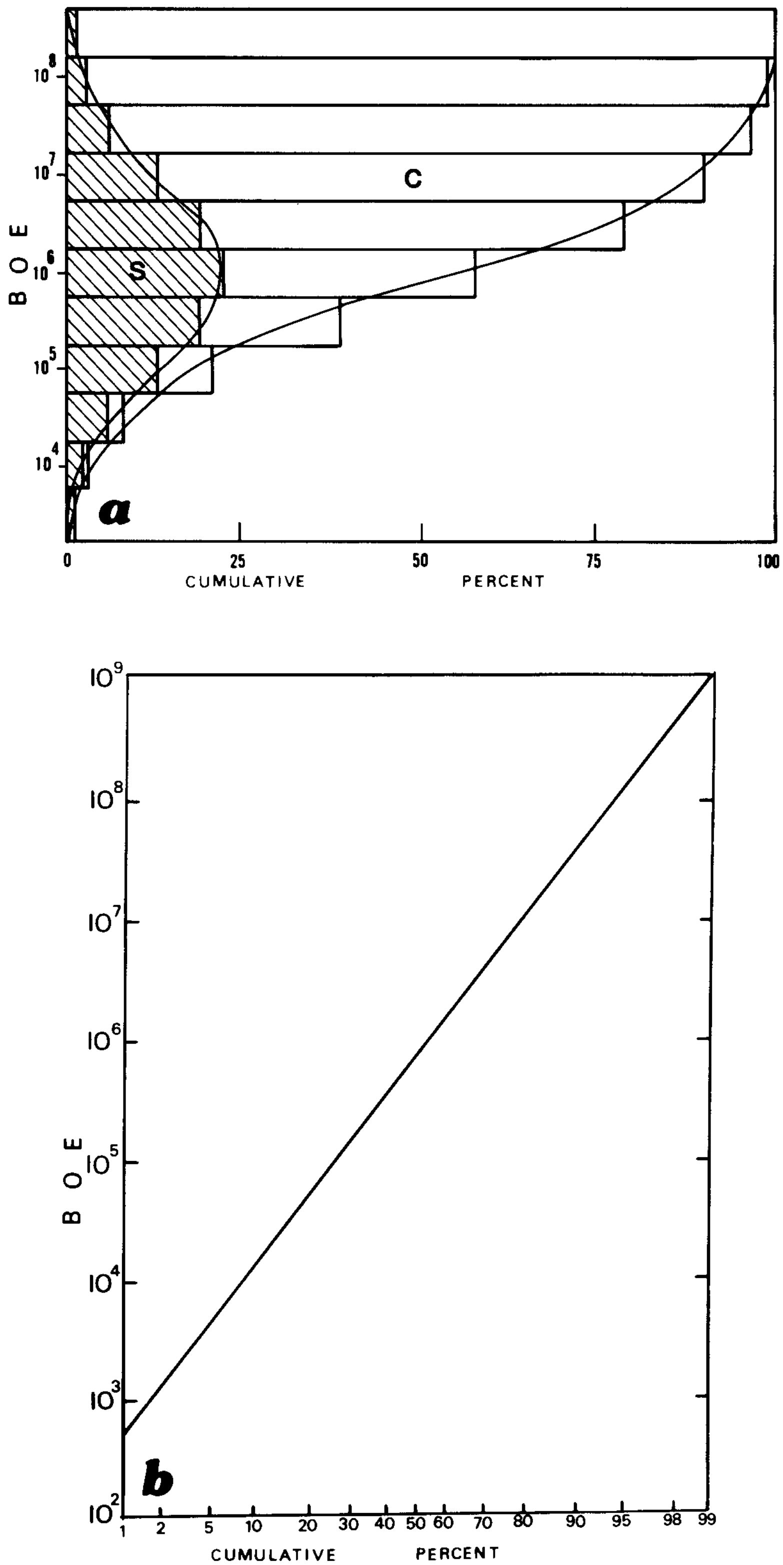

Figure 1. Diagrams illustrating forms in which a lognormal distribution may be plotted: (a) Histograms and fitted curves representing perfect lognormal distribution plotted in standard form (s), and same distribution plotted in cumulative form (c). (b) When same distribution is plotted on log-probability paper incorporating distorted cumulative percentage scale, distribution plots as a straight line.

CALIFORNIA

The data for California used in this study were taken largely from a report by the California Division of Oil and Gas (1979). This report contains information on a field-by-field basis for all fields in the State, and provides cumulative production and estimated reserves of oil and gas through the end of 1978. By combining the cumulative production figures with the reserves and transforming gas to its equivalent in oil (BOE), a single figure was obtained representing the estimated size (in recoverable oil and gas) for each field.

The California Division of Oil and Gas has established six administrative districts in California (Fig. 2). These districts do not necessarily coincide with geologic province boundaries. District 6 essentially encompasses both the Sacramento Valley and the northern part of the San Joaquin Valley, which is a gas-producing province. Districts 4 and 5 combined include the central and southern San Joaquin Valley, which is both an oil- and gas-producing province. District 1 includes the Los Angeles basin as a producing province, but also includes part of the eastern extension of the Ventura basin (Newhall area). For simplicity, we segregated the fields into only four geographic areas, namely District 1, Districts 2 and 3 combined, Districts 4 and 5 combined, and District 6.

Frequency distributions for these four areas, as well as for all of California, were tabulated and plotted in Tables 1 and 2 and Figures 3 through 8. With the exception of Figure 7, the results have been plotted with an identical format for each area and for the entire State, using the graphic format described in the section entitled Graphic Presentation of the Data. The preparation of the tables is discussed in the section entitled Tabular Presentation.

ENTIRE STATE

California's overall population (Fig. 3) of 404 fields approximates a lognormal distribution, although there is some skewness. The subpopulations, segregated by discovery sequence, reveal a drastic decrease in general sizes of the fields in the progression involving the first four discovery intervals (A, B, C, and D). As Table 1-A indicates, the median size decreased by a factor of almost 300 between subpopulation A and subpopulation D, with corresponding large decreases in the geometric means (over 100-fold) and in the aggregate quantity of hydrocarbons discovered (over 50-fold). These large decreases are reversed, however, in the last 20-percent interval (E), which involves a dramatic rise in the median, geometric mean, and total quantity as compared with interval D. The explanation lies partially in a succession of discoveries of large gas fields in the Sacramento Valley, in District 6.

Projections for California as a whole are pessimistic. Of the population of the next 81 fields to be found in the State as a whole (this projection excludes areas that are not part of the area of California that had been explored as of the end of 1974), the population is forecast to have a median size of only about 125,000 BOE and to yield roughly 185 million BOE, or about 0.6 percent of the BOE contained in fields discovered through the end of 1974 in the State. Probabilities attached to individual field-size ranges for this forecast population are shown in the first row in the body of Table 2.

It is probably of marginal value to consider California as a whole from an exploration forecasting standpoint, although the State's total outlook for new-field discoveries has strong relevance to the nation's energy policy. Analyses of the individual districts are, however, more revealing from an exploration standpoint.

DISTRICT 1

District 1 embraces fields of the Los Angeles basin and the eastern end of the Ventura basin (Newhall area). The plots (Fig. 4) reveal an extremely large decline in the medians and geometric means following interval B (which ended in 1940). As Table 1-B details,the medians and geometric means declined on the order of 100-fold. Such a decline reflects the early discovery of very large fields, including Wilmington, Santa Fe Springs, Huntington Beach, and Long Beach, discoveries that were not duplicated in size in later intervals.

The forecast for District 1 for new-field discoveries is a guarded one. A "realistic" versus a "pessimistic" forecast is provided in Figure 4-b and c, Table 1-A, and Table 2. Two sets of curves, labeled F and G and F' and G' in Figure 4-b, represent the "realistic" versus "pessimistic" forecasts. The "realistic" forecast distribution, however, will yield only about 0.5 percent of the present aggregate BOE if 36 new fields are actually discovered.

As Table 2 reveals, the probability of finding a field greater than 100 million BOE is only about 1½ percent for any particular field among the next 18 fields to be discovered in District 1 (assuming 18 fields are to be discovered and using the "realistic" curves for forecasting). On the other hand a probability of about 10 percent is attached to a discovery of less than 10,000 BOE for each field to be discovered among these next 18 fields using the "realistic" curve. Such small sizes are absurdly uneconomic for most of District 1 and may be discounted in advance as "non-discoveries." If we use the "pessimistic" curves of Figure 4, the forecast distributions of field sizes are even less encouraging.

DISTRICTS 2 AND 3

Districts 2 and 3 combined are paradoxical in that the initial interval A has a substantially smaller median (and geometric mean) than intervals B and C (Table 1-C). Thus, the usual sequence has been reversed (Fig. 5). This is explainable, in part, by the large geographic expanse of the combined districts and their geologic diversity. Major discoveries, such as the Ventura field, occurred in interval 1, accounting for its large median and geometric mean. Interval C, too, included large discoveries (Santa Maria and San

Ardo fields, for example), accounting for its intermediate median and geometric mean.

Curves F and G of Figure 5-b represent the "realistic" forecast, and seem to be in accord with overall trends.

DISTRICTS 4 AND 5

Districts 4 and 5 embrace the central and southern San Joaquin Valley, which forms a large and diverse petroleum-producing province. As Table 1-D reveals, the discoveries during interval A yield a population with an exceedingly large median and geometric mean. This is readily explainable by the early discoveries of a number of giant fields (Buena Vista, Coalinga, Elk Hills, Kern River, Kettleman Hils, Midway-Sunset, and South Belridge). Although some major discoveries were made in the next interval (East Coalinga Extension, for example), these subsequent discoveries did not keep pace in size. The decrease in field-size medians (Table 1-D) from interval A to E is impressive (more than an 1100-fold decrease). The declines in geometric means and in gross BOE discovered, though less dramatic, are still very large. Based on these trends, the forecast for Districts 4 and 5 is not encouraging. Population F, consisting of the next 24 fields to be discovered, has a forecast median of only 52,000 BOE, with only an seven percent probability that any field will be larger than 10 million BOE, and only about a one percent probability that any field will be larger than 100 million BOE.

The population of 24 fields discovered during the initial interval (A) is strongly skewed, with a predominance of large fields. This is demonstrated by the extreme departure of the graph of this population (Fig. 6-b) from a straight line. A smoothed curve fitted to a histogram of field sizes and plotted in conventional form (Fig. 7) emphasizes this departure from the lognormal. Populations of fields discovered in later intervals, D and E, more closely approach the lognormal ideal.

DISTRICT 6

District 6 embraces the Sacramento Valley and the central part of the Great Valley (that is, the northern part of the San Joaquin Valley). Virtually all of the production is gas. The overall population of 102 fields departs moderately from the lognormal (Fig. 8-a), but the subpopulations defined by the succession of discoveries do not reveal the abrupt decline in medians (or geometric means) observed in the other districts. Indeed, both the medians and the geometric means decline from A to C (Fig. 8-c and Table 1-E), but they rise again in the succession from C to E. If we were to take a very optimistic view of the future, we might envision a progressive rise in the field-size parameters, as represented by the curve labeled "very optimistic" on Figure 8-c. However, a more realistic view is that the populations of fields to be discovered in the future will progressively decline. An estimated median of 900,000 BOE for the next 20 fields to be discovered (F) seems reasonable. Given the uncertainties in projection, however, we can take a view that an optimistic forecast also may be justified. Table 2 provides probabilities attached to different field sizes that accord with an "optimistic" projection (which coincides, more or less, with the curve labeled B in Figure 8-b), as well as with the "realistic" projection, which yields the curves labeled F and G in Figure 8-b.

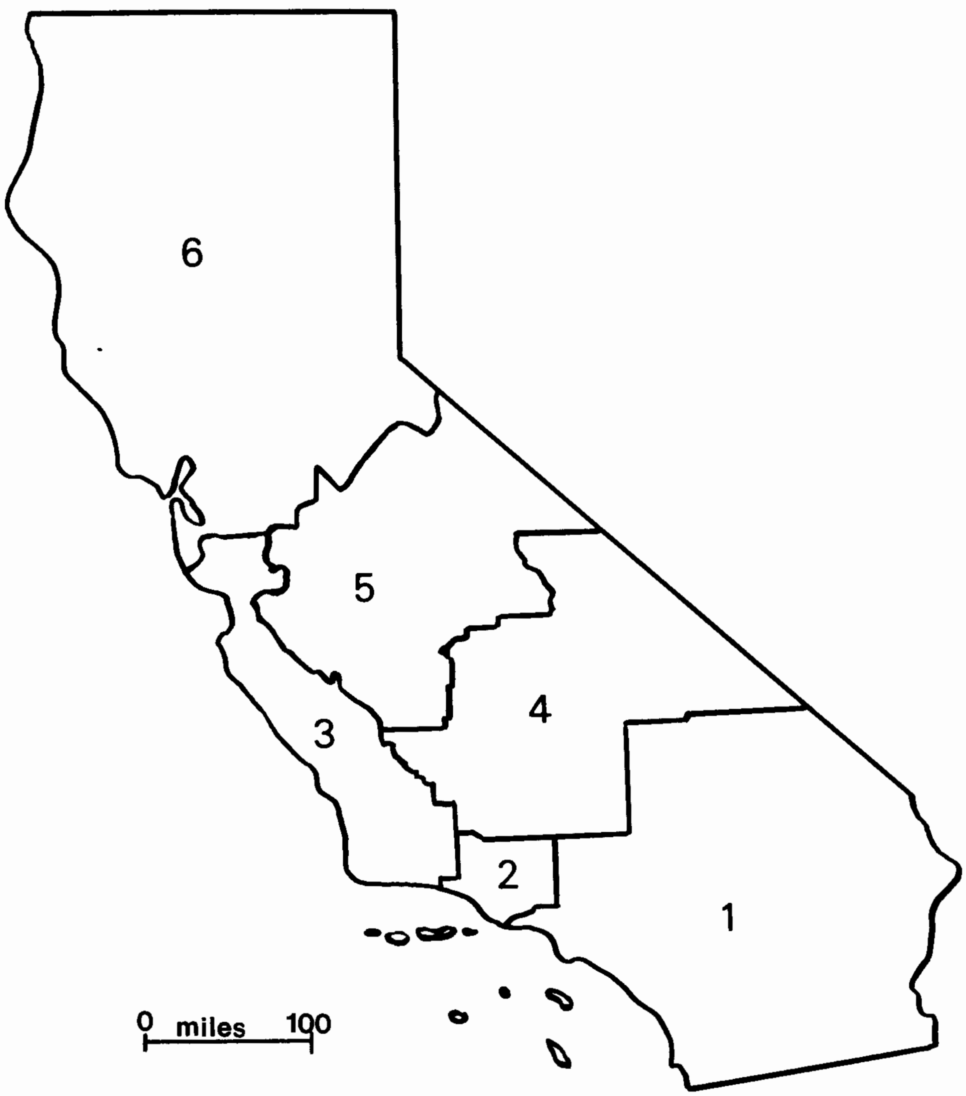

Figure 2. Index map of California showing six districts established by California Division of Oil and Gas for oil-field classification purposes.

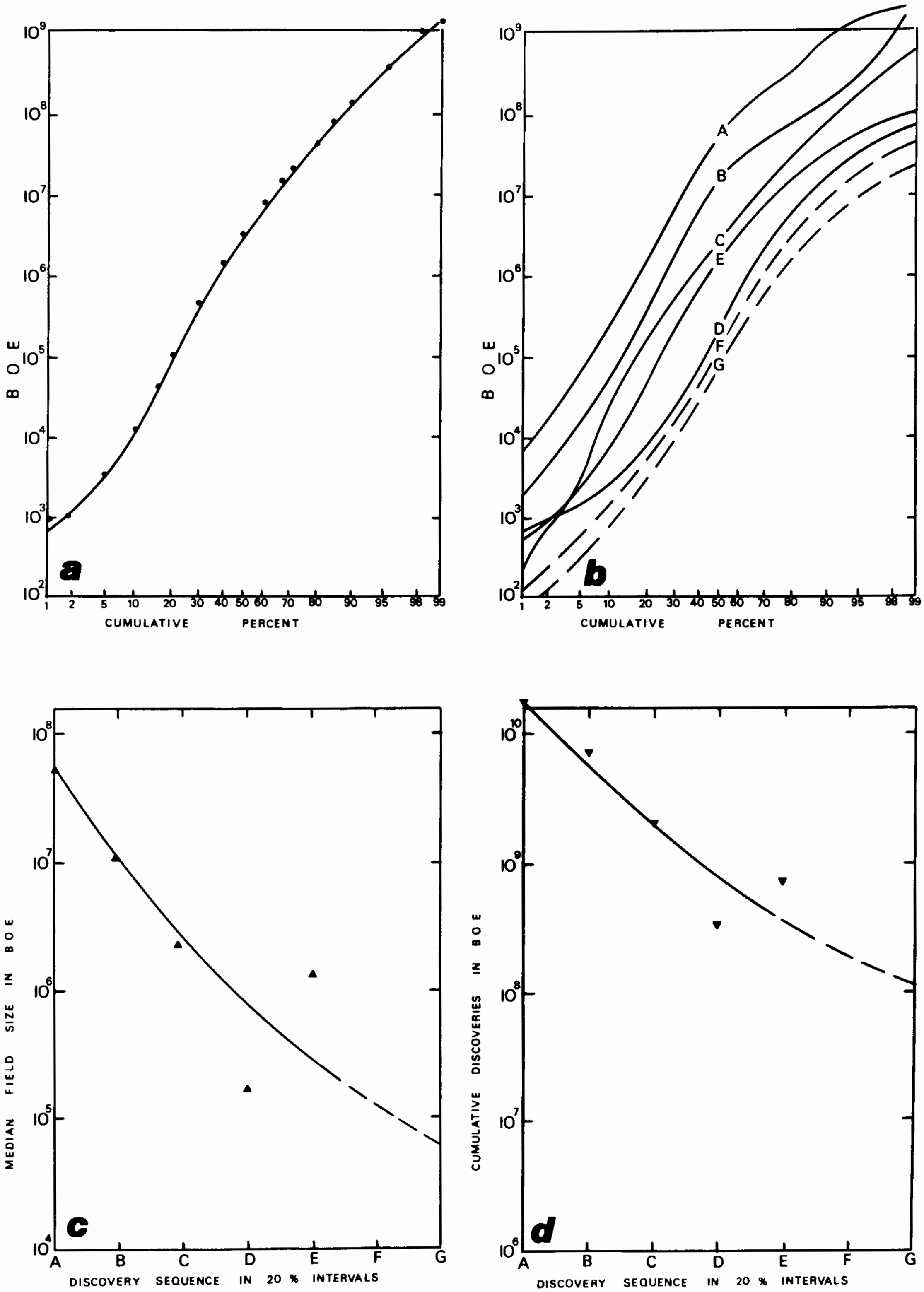

Figure 3. Combined oil and gas field distributions for all of California. See section entitled Graphic Presentation of the Data for explanation.

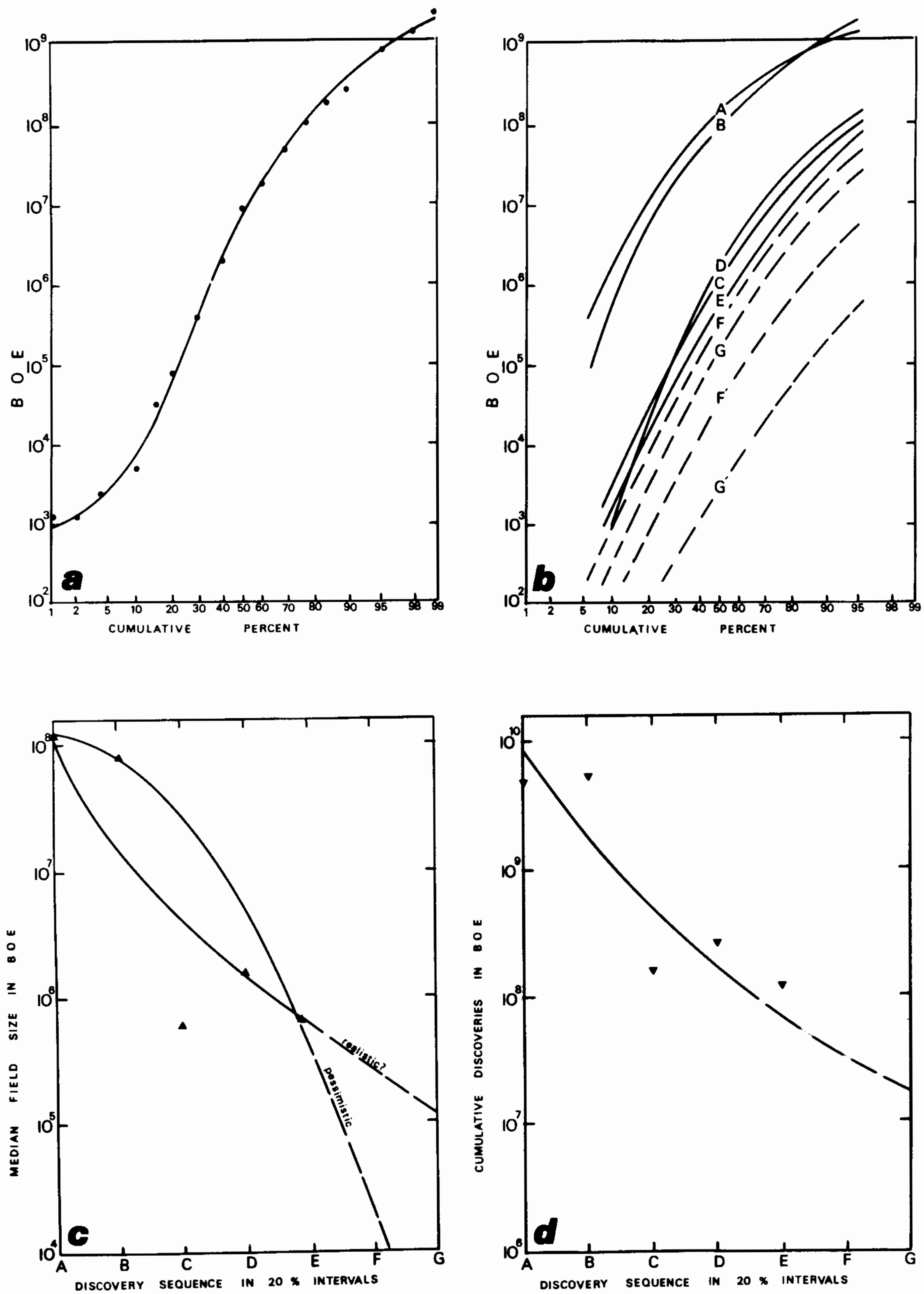

Figure 4. District 1, California.

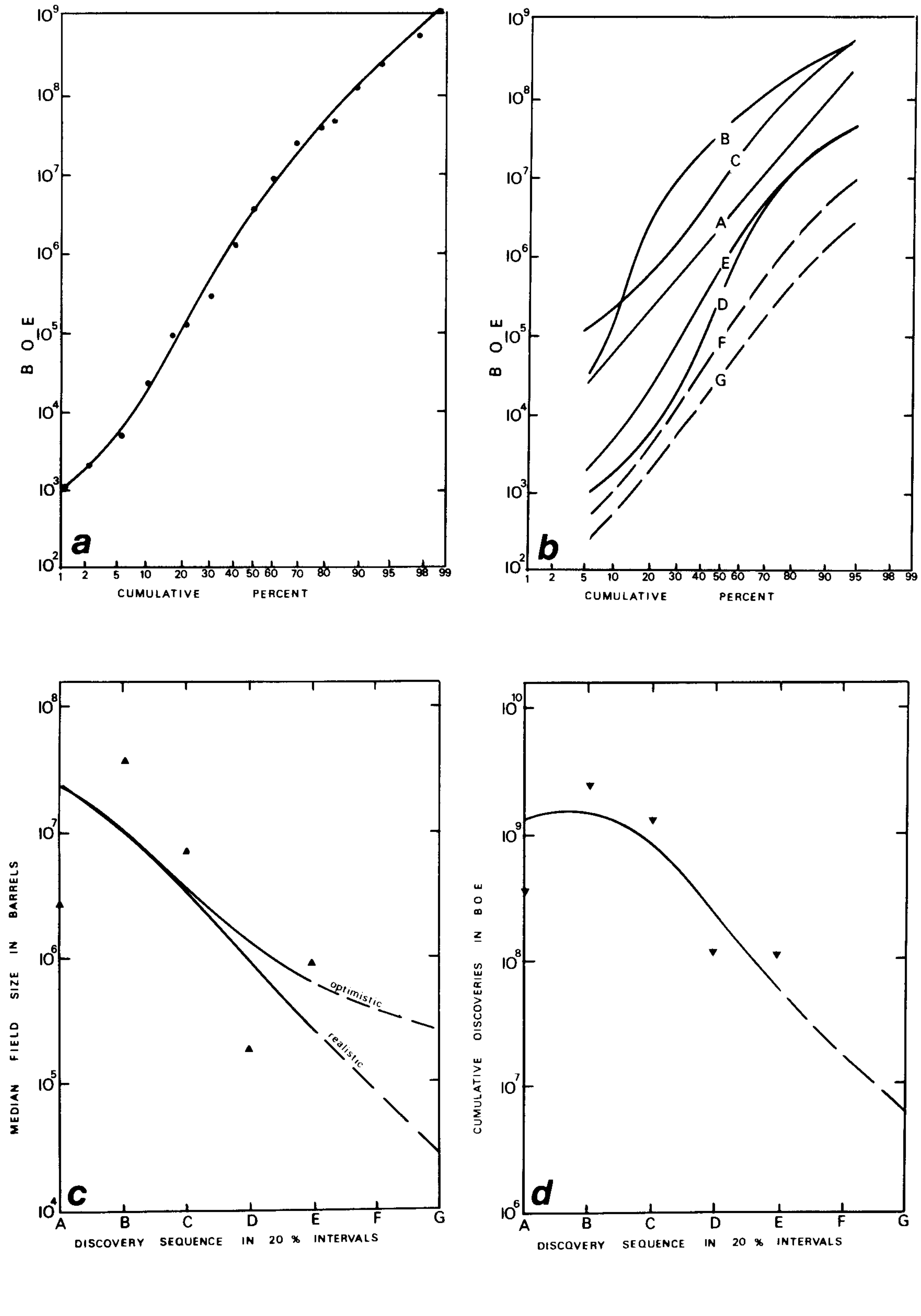

Figure 5. Districts 2 and 3 combined, California.

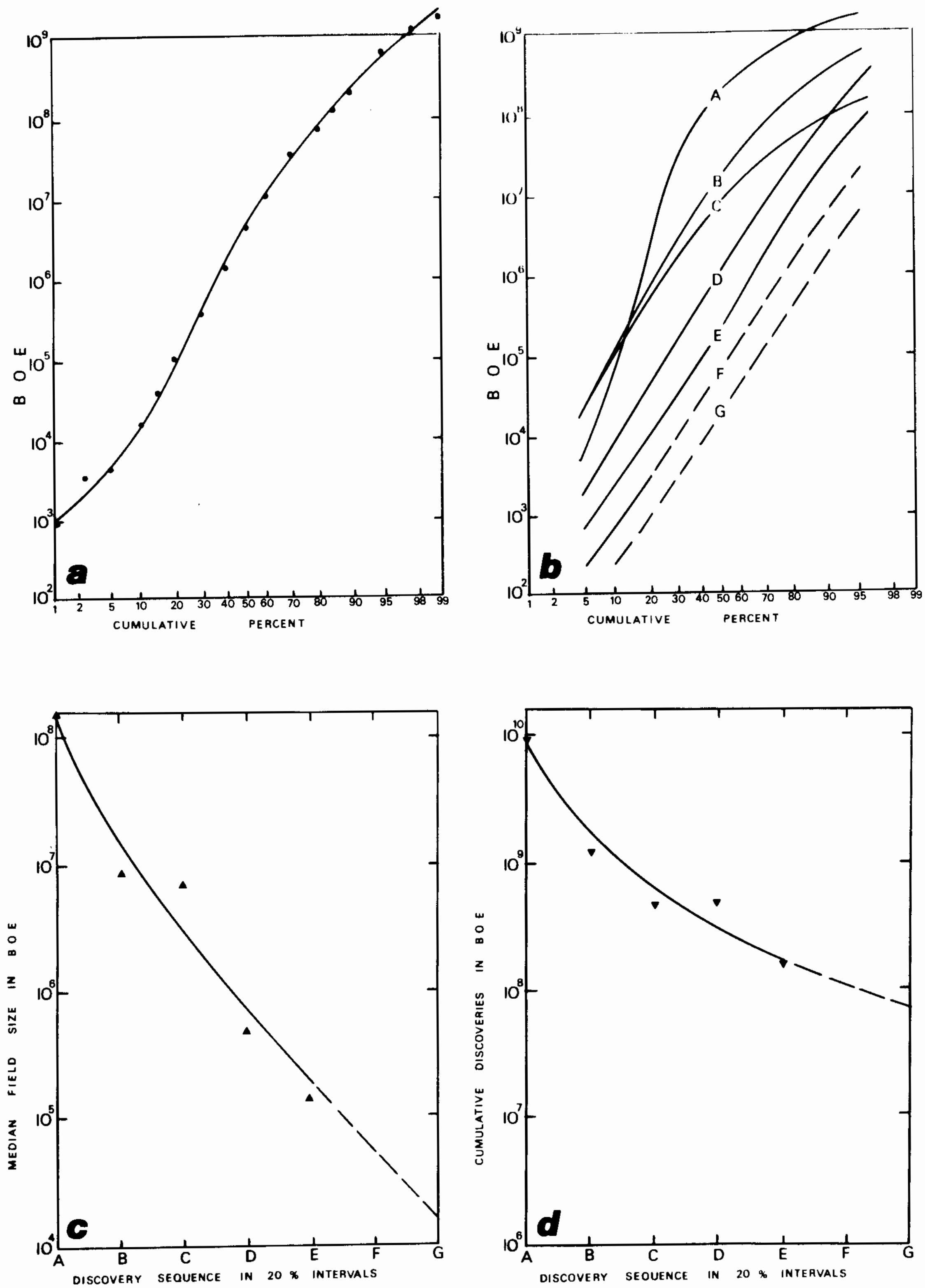

Figure 6. Districts 4 and 5 combined, California.

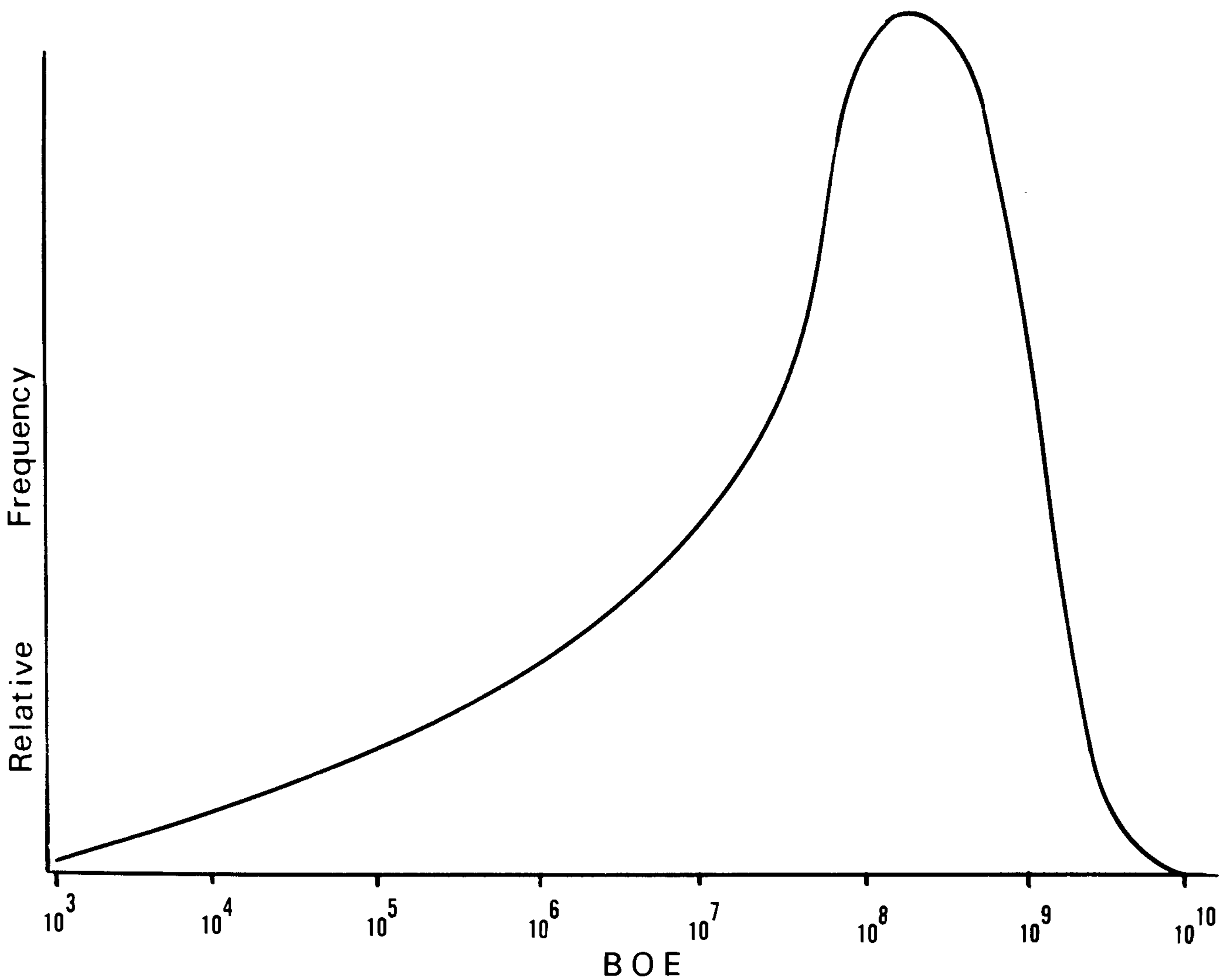

Figure 7. Plot of frequency distribution in standard form of curve A shown in Figure 6-b, representing first 20 percent of fields discovered in Districts 4 and 5 combined, emphasizing strong skewness of the distribution.

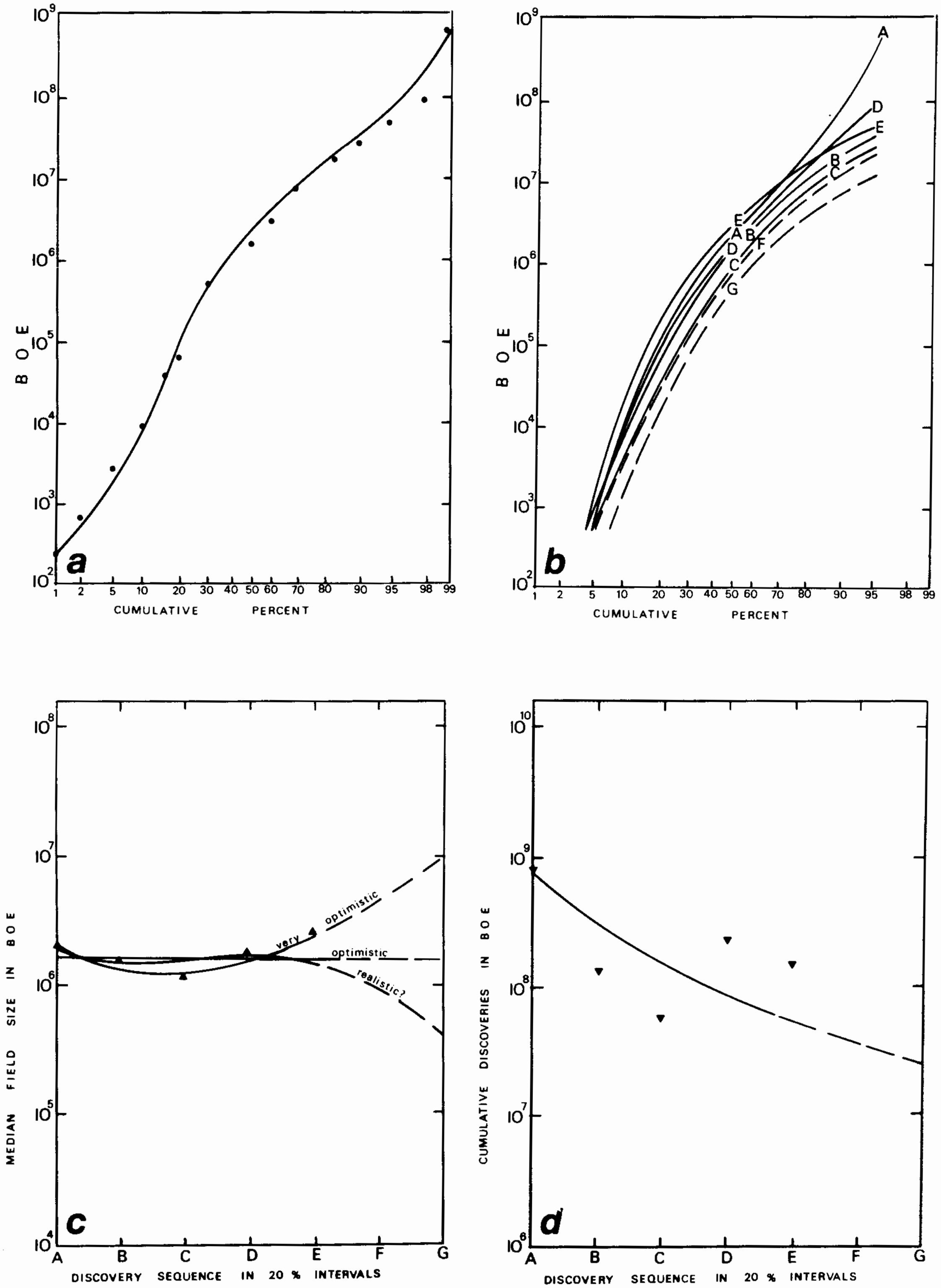

Figure 8. District 6, California.

Table 1. California Production Statistics and Forecasts

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	A:	Entire State						
Entire District		0-100	1861-1974	404	3,040	2,032	28,643	100.0
	A	0-20	1861-1928	81	55,320	23,032	18,008	62.9
Progressive	B	20-40	1928-1943	81	12,460	6,066	7,460	26.0
Discoveries	C	40-60	1943-1952	81	1,980	1,519	2,113	7.4
Through	D	60-80	1952-1959	80	190	204	342	1.2
1974	E	80-100	1959-1974	81	1,410	784	720	2.5
Forecast Future	F	100-200		81	125		185	0.6
Discoveries	G	120-140		81	70		118	0.4
	B:	District 1						
Entire District		0-100	1875-1967	89	8,320	2,919	10,940	100.0
	A	0-20	1875-1921	17	106,000	75,494	4,901	44.8
Progressive	B	20-40	1921-1940	18	94,570	42,618	5,501	50.3
Discoveries	C	40-60	1940-1947	18	640	488	157	1.4
Through	D	60-80	1947-1955	18	1,550	482	265	2.4
1974	E	80-100	1955-1967	18	670	284	116	1.1
Forecast Future	F	100-120		18	260		32	0.3
Discoveries	G	120-140		18	108		17	1.1

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	C:	Districts 2 and 3						
Entire District		0-100	1861-1967	91	3,498	2,074	4,626	100.0
	A	0-20	1861-1902	18	2,760	2,172	371	8.0
Progressive	B	20-40	1902-1932	18	38,423	19,962	2,659	57.5
Discoveries	C	40-60	1932-1950	19	7,095	7,693	1,366	29.5
Through	D	60-80	1950-1958	18	190	213	119	2.6
1974	E	80-100	1958-1967	18	933	486	111	2.4
Forecast Future	F	100-200		18	75		18	0.4
Discoveries	G	120-140		18	15		6	0.1
	D:	Districts 4 and 5						
Entire District		0-100	1891-1974	122	4,210	2,822	11,686	100.0
	A	0-20	1890-1929	24	158,500	42,682	9,147	78.3
Progressive	B	20-40	1929-1940	25	8,600	7,255	1,410	12.1
Discoveries	C	40-60	1940-1946	24	7,140	4,186	482	4.1
Through	D	60-80	1946-1956	24	490	549	490	4.2
1974	E	80-100	1956-1974	25	140	186	157	1.3
Forecast Future	F	100-120		24	52		100	0.9
Discoveries	G	120-140		24	15		70	0.6

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	E:	District 6						
Entire District		0-100	1890-1973	102	1,550	953	1,391	100.0
	A	0-20	1890-1944	20	1,950	1,528	800	57.5
Progressive	B	20-40	1944-1953	21	1,560	711	136	9.8
Discoveries	C	40-60	1953-1960	20	1,130	386	61	4.4
Through	D	60-80	1960-1962	21	1,840	950	242	17.4
1974	E	80-100	1962-1973	20	2,640	1,185	152	10.9
Forecast Future	F	100-120		20	900		35	2.5
Discoveries	G	120-140		20	400		25	1.8

Table 2. Probabilities attached to field-size ranges for the next 20 percent (F) of fields to be discovered, and for the next 20 percent (G) to be discovered after that, in California.

Area	Label on Curve	Number of Fields	Probabilities (in percent) attached to field-size ranges in BOE						
			$<10^3$	10^3-10^4	10^4-10^5	10^5-10^6	10^6-10^7	10^7-10^8	10^8-10^9
Entire State	F	81	7	19	22	21	22	9	
	G	81	12	19	21	24	19	5	
District 1 (realistic)	F	18	10	11	18	23	21	15-1/2	1-1/2
	G	18	14	8	23	24	21	9	1
District 1 (pessimistic)	F'	18	21	17	23	22	14-1/2	2-1/2	
	G'	18	39	24	21	13	3		
Districts 2 & 3 combined (realistic)	F	18	9	19	23	24	20	5	
	G	18	14	22	27	25	11-1/2	1/2	
Districts 4 & 5 combined	F	24	12	18	23	25	14	7	1
	G	24	20	22	26	19	10	2-1/2	1/2
District 6 (optimistic)	B	20	6	5	11	20	36	21-1/2	1/2
District 6 (realistic)	F	20	6	8	14	25	32	15	
	G	20	9	9	14	27	34	7	

WYOMING

The six principal sedimentary basins in Wyoming are outlined in Figure 9. Four of the basins (Green River, Big Horn, Wind River, and Powder River) have been analyzed in a fashion similar to that employed in California. In addition, fields in the Powder River basin also have been segregated according to whether they are associated with structural traps or with stratigraphic traps. The other two basins (the Hanna-Laramie basin and the Denver basin) contain an insufficient number of fields to be analyzed in the same manner as the other basins, although a frequency distribution for each basin overall has been plotted. The Denver basin is a very large basin, but only a small fraction of its total area lies within Wyoming. The Colorado and Nebraska portions of the Denver basin are not considered here.

Because the individual basins in Wyoming are geographically separated from each other, segregation of the oil-field data by basins seems more desirable than by arbitrary districts. Our objective in this portion of the study has been to determine whether the field-size statistics differ from basin to basin, perhaps reflecting underlying geological controls on petroleum occurrence within individual basins. The data for Wyoming were obtained from an unpublished report prepared by the firm of Barlow and Haun (1978).

ENTIRE STATE

Statistics for all of Wyoming are presented in Figure 10, Table 3-A, and Table 4. The distribution of field sizes, expressed in BOE, closely approximates an ideal lognormal distribution. When the 754 fields incorporated in this study are segregated by discovery sequence into 20 percent intervals, there is a general progressive decrease in medians, geometric means, and total BOE discovered. Although there is some overlapping of the distributions (curves A through E in Figure 10-b), the shifts are sufficiently regular to allow forecast of future discoveries by projection. The "realistic" projection of the medians (Fig. 10-c) accords with the curves representing forecast populations F and G.

GREEN RIVER BASIN

The distribution of fields as a whole for the Green River basin approximates the lognormal (Fig. 11-a) but the subpopulations, A through E, deviate considerably from the lognormal ideal (Fig.11-b). The subpopulation medians, geometric means, and total BOE (Fig. 11-c and d, and Table 3-B) shift in a somewhat erratic fashion. Curves F and G (Fig. 11-b), representing the populations of fields to be discovered, are based on the "realistic" projections of the medians. The probabilities attached to size ranges of fields to be discovered (Table 4) surpass those of the other basins in Wyoming, making the Green River basin relatively attactive from a statistical standpoint.

BIG HORN BASIN

The Big Horn basin (Fig. 12, Table 3-C, and Table 4) has an overall population that is virtually perfect in its lognormal distribution. There is a very sharp decrease in field-size parameters between intervals C and D, with some improvement from D to E. The overall field-size population trends are not encouraging, and populations F and G are forecast to have small total volumes.

WIND RIVER BASIN

The populations of fields in the Wind River basin display a somewhat erratic pattern. The overall population (Fig. 13-a) significantly departs from the lognormal ideal. Subpopulations A, B, D, and E also depart from the ideal lognormal, although subpopulation C is essentially lognormal (Fig. 13-b). The populations to be discovered (F and G) offer some encouragement, particularly in view of their projected total volumes (Table 3-D and Fig. 13-d), although the probabilities attached to the discovery of large fields are small (Table 4).

HANNA-LARAMIE AND DENVER BASINS

Frequency distributions for the overall populations in each of these basins (Wyoming portion only of the Denver basin) are shown in Figure 14. Both depart from the lognormal ideal, particularly those in the Denver basin. Because of the small overall population (33 fields with recorded production in Hanna-Laramie basin and 15 in the Denver basin), it is impractical to divide the overall populations into subpopulations.

POWDER RIVER BASIN

Fields in the Powder River basin were placed in three classes, namely all fields (380 fields, Fig. 15), fields that are structurally controlled (134 fields, Fig. 16), and fields that are stratigraphically controlled (246 fields Fig. 17). The structural field subpopulations (except for the last interval, E) depart substantially from the lognormal ideal, with a pronounced tendency toward early discovery of medium-large fields (Fig.16-b). The stratigraphic fields, on the other hand, depart less from the lognormal ideal (Fig. 17-b).

Forecasts for populations of fields to be discovered in the future differ markedly for structural versus stratigraphic fields. The decline in field-size parameters is much less for stratigraphic fields than for structural fields. This relationship is not surprising, and probably reflects the fact that stratigraphic traps are much less obvious to explorationists than structural traps and therefore the bias toward early discovery of large fields is less for stratigraphic fields than for structural fields.

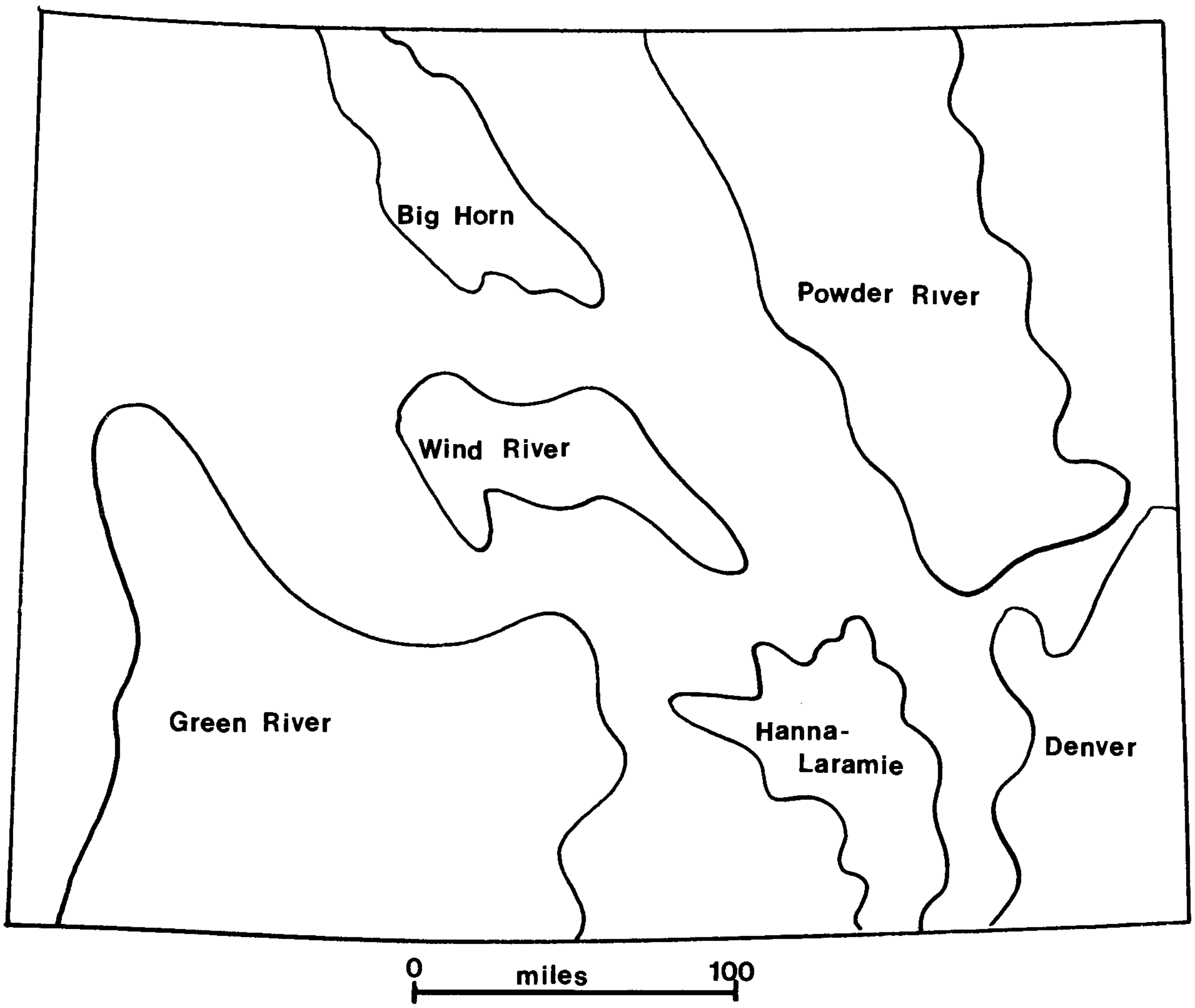

Figure 9. Index map of Wyoming showing principal sedimentary basins.

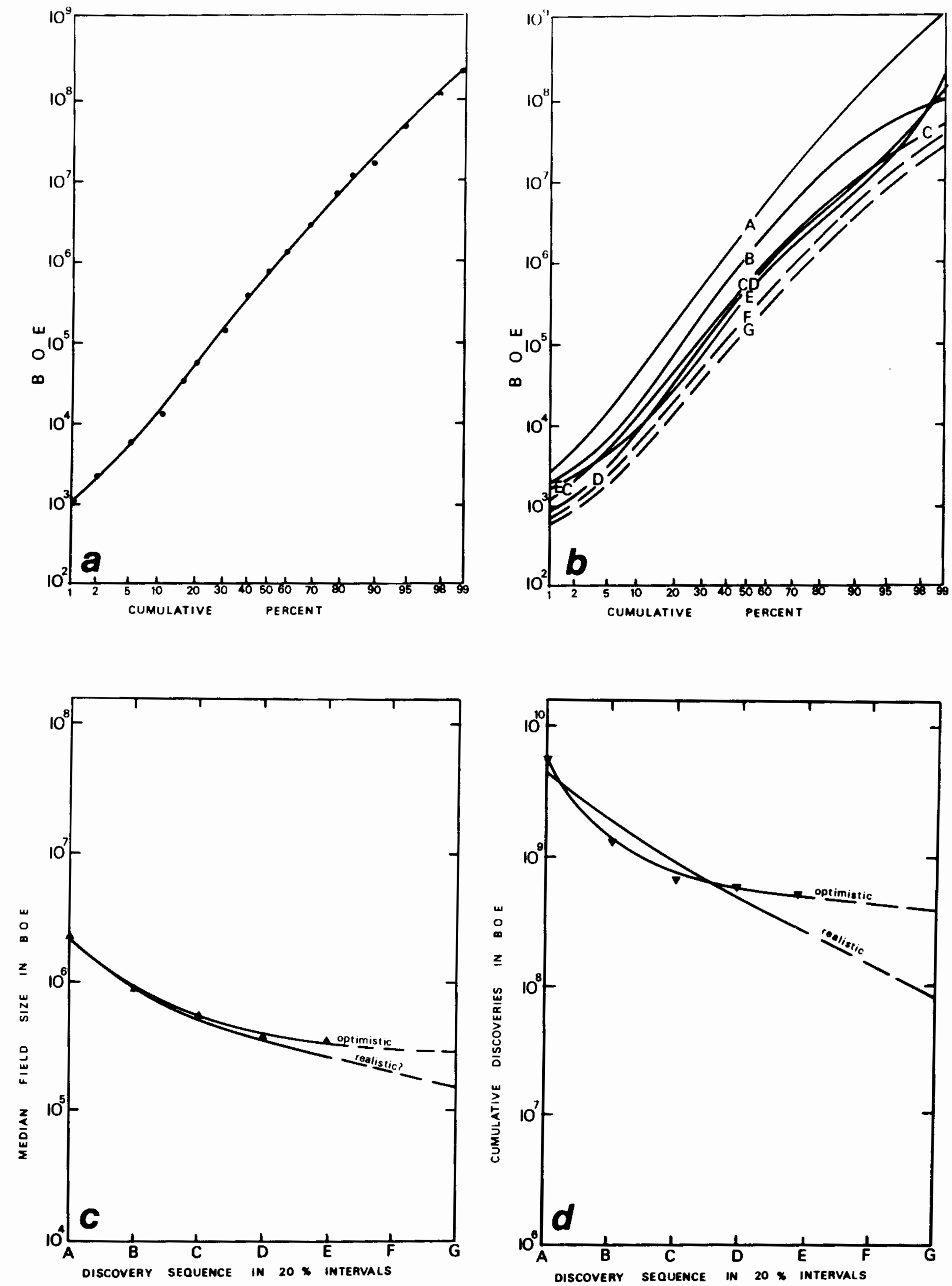

Figure 10. All of Wyoming. See section entitled Graphic Presentation of the Data for explanation.

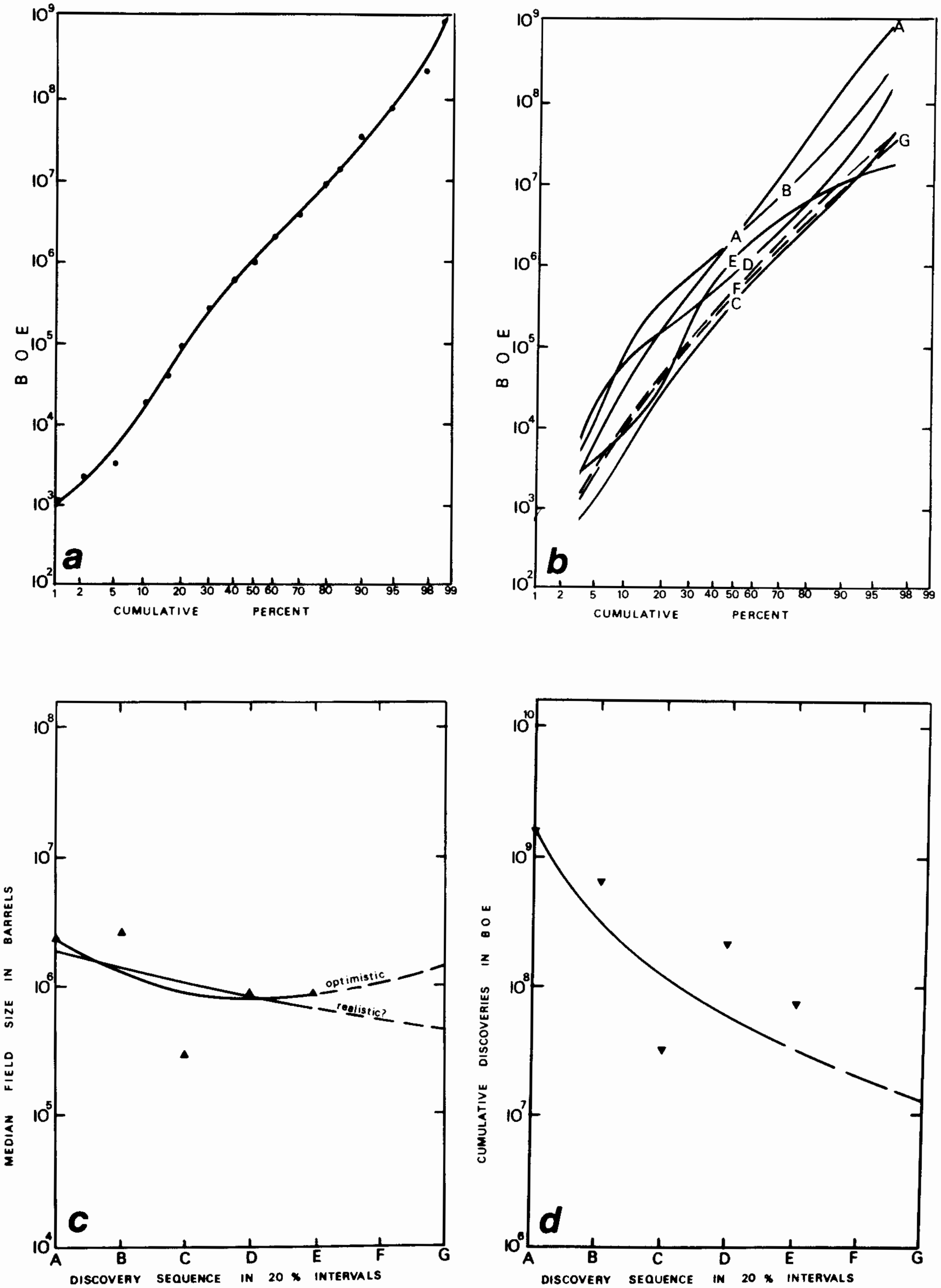

Figure 11. Green River basin of Wyoming.

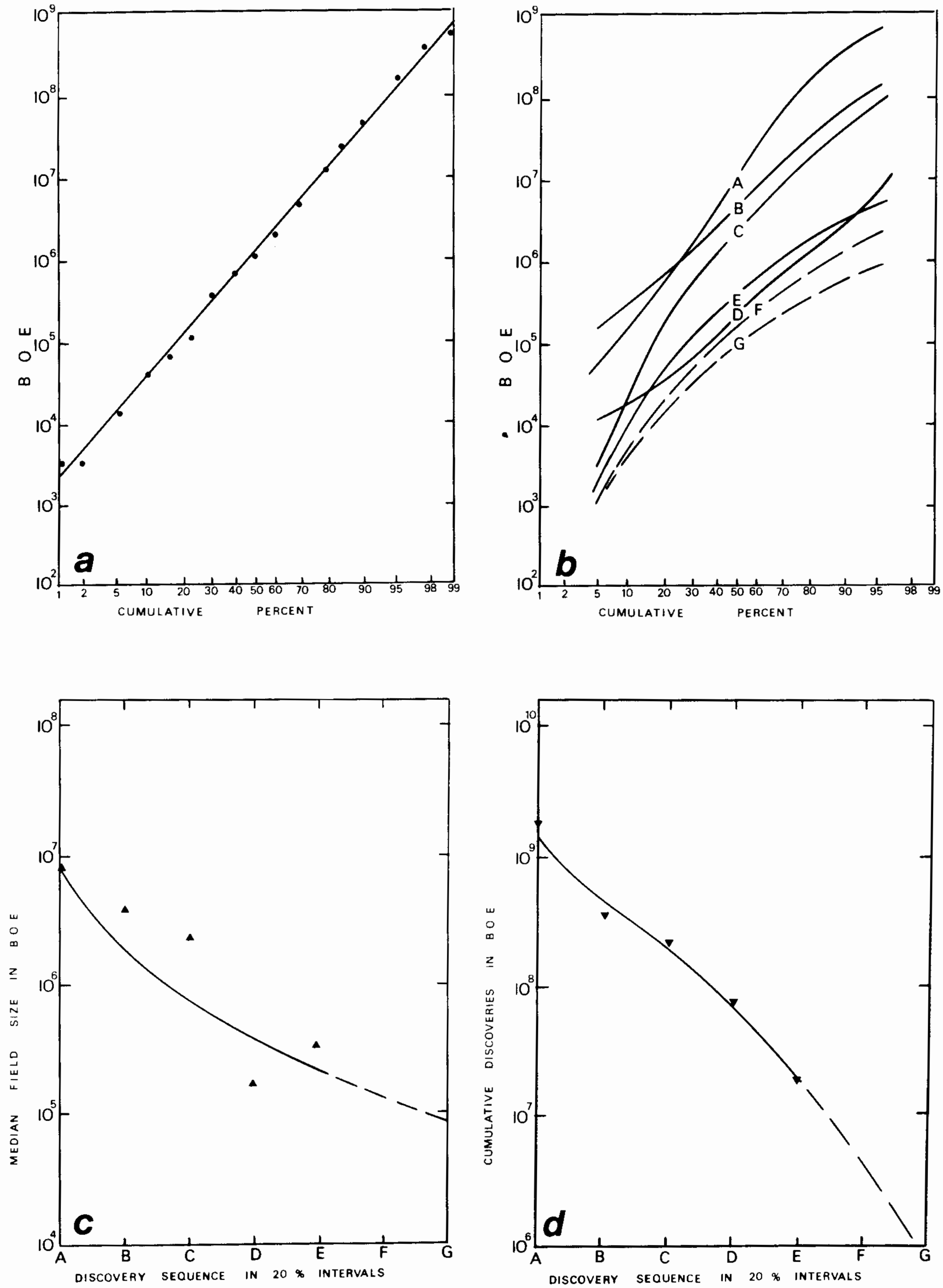

Figure 12. Big Horn basin of Wyoming.

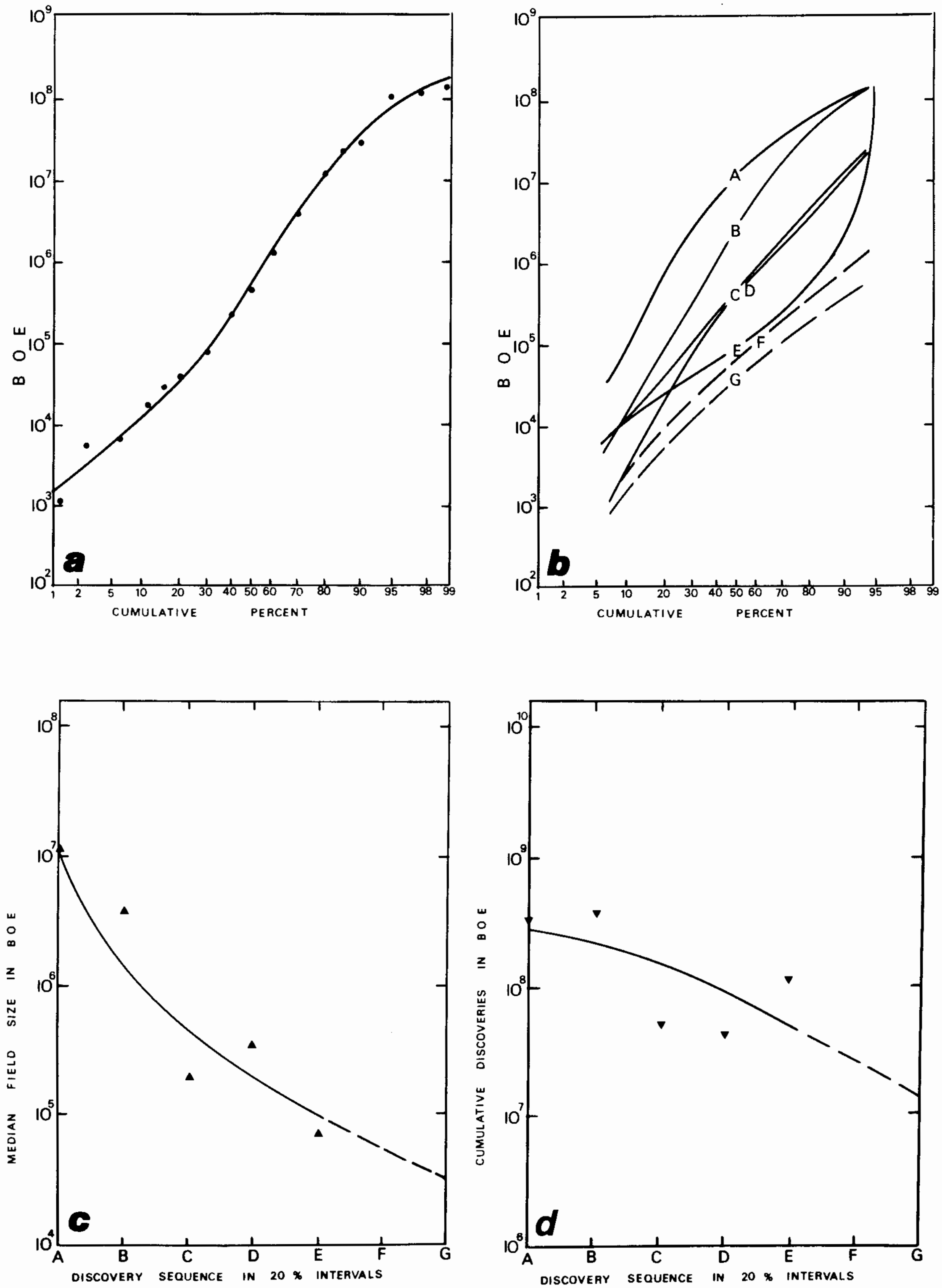

Figure 13. Wind River basin of Wyoming.

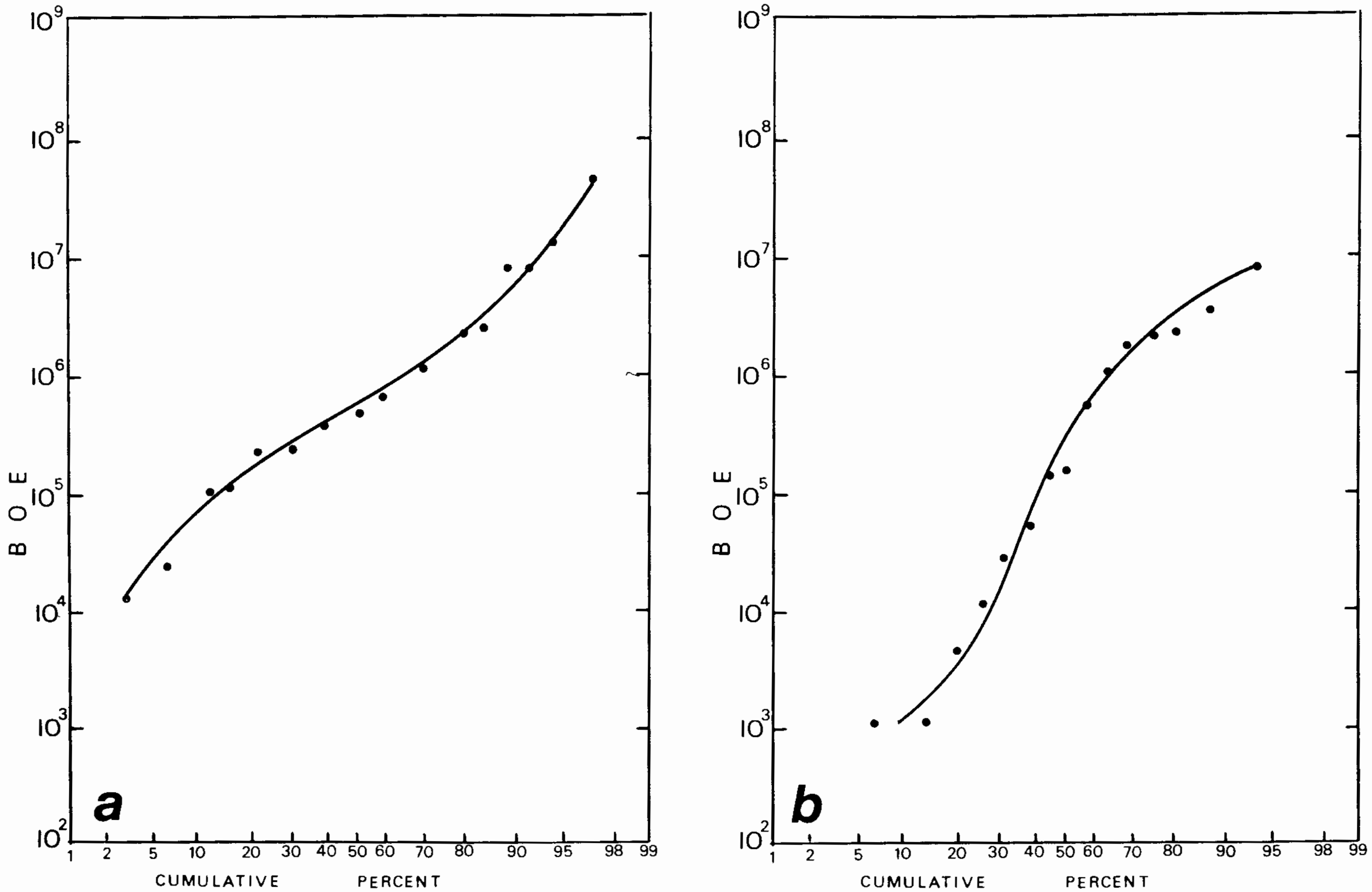

Figure 14. Distributions for all fields in (a) Hanna-Laramie basin, and (b) Denver basin, in Wyoming.

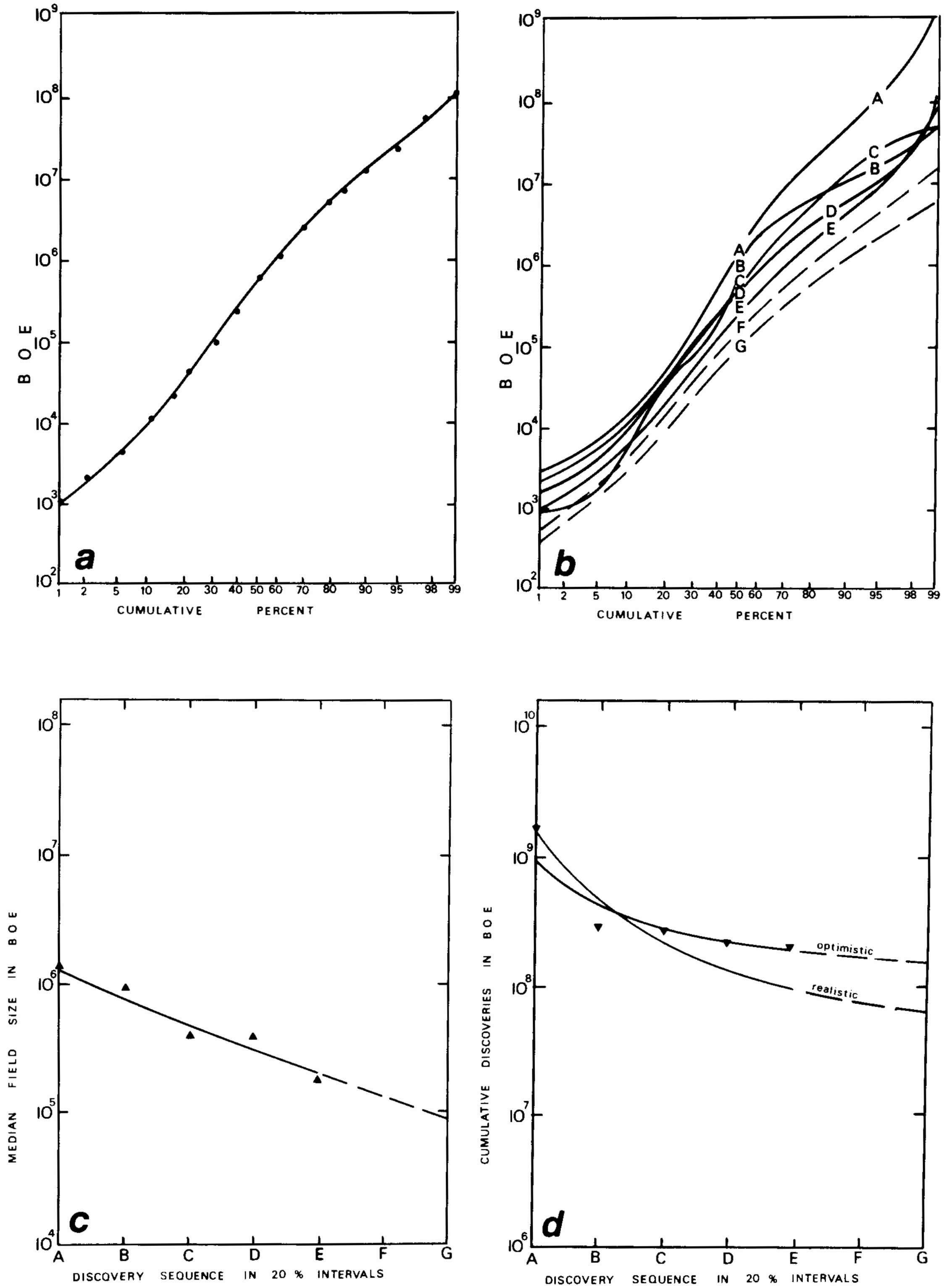

Figure 15. Powder River basin of Wyoming, all fields.

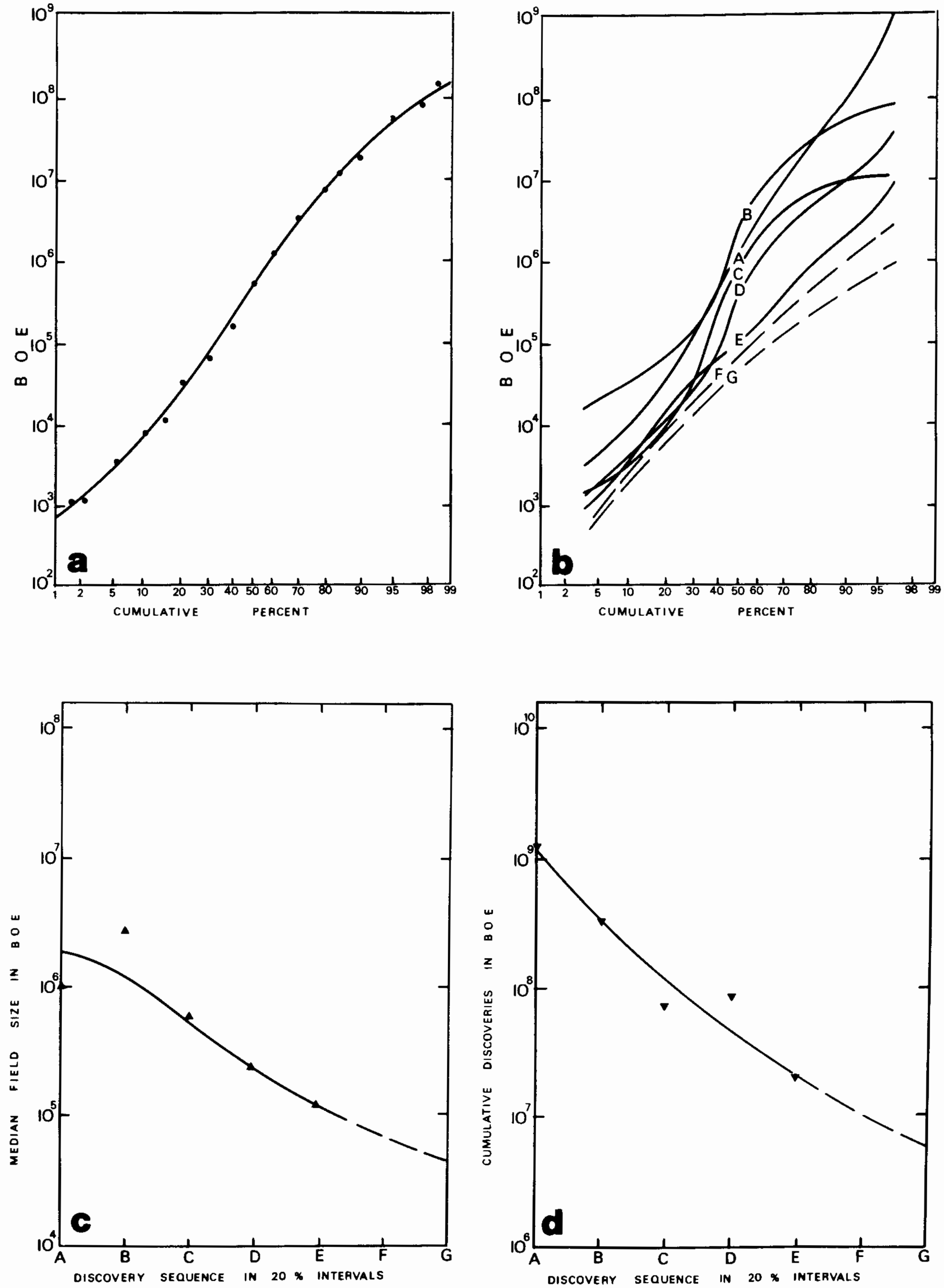

Figure 16. Powder River basin of Wyoming, structural fields only.

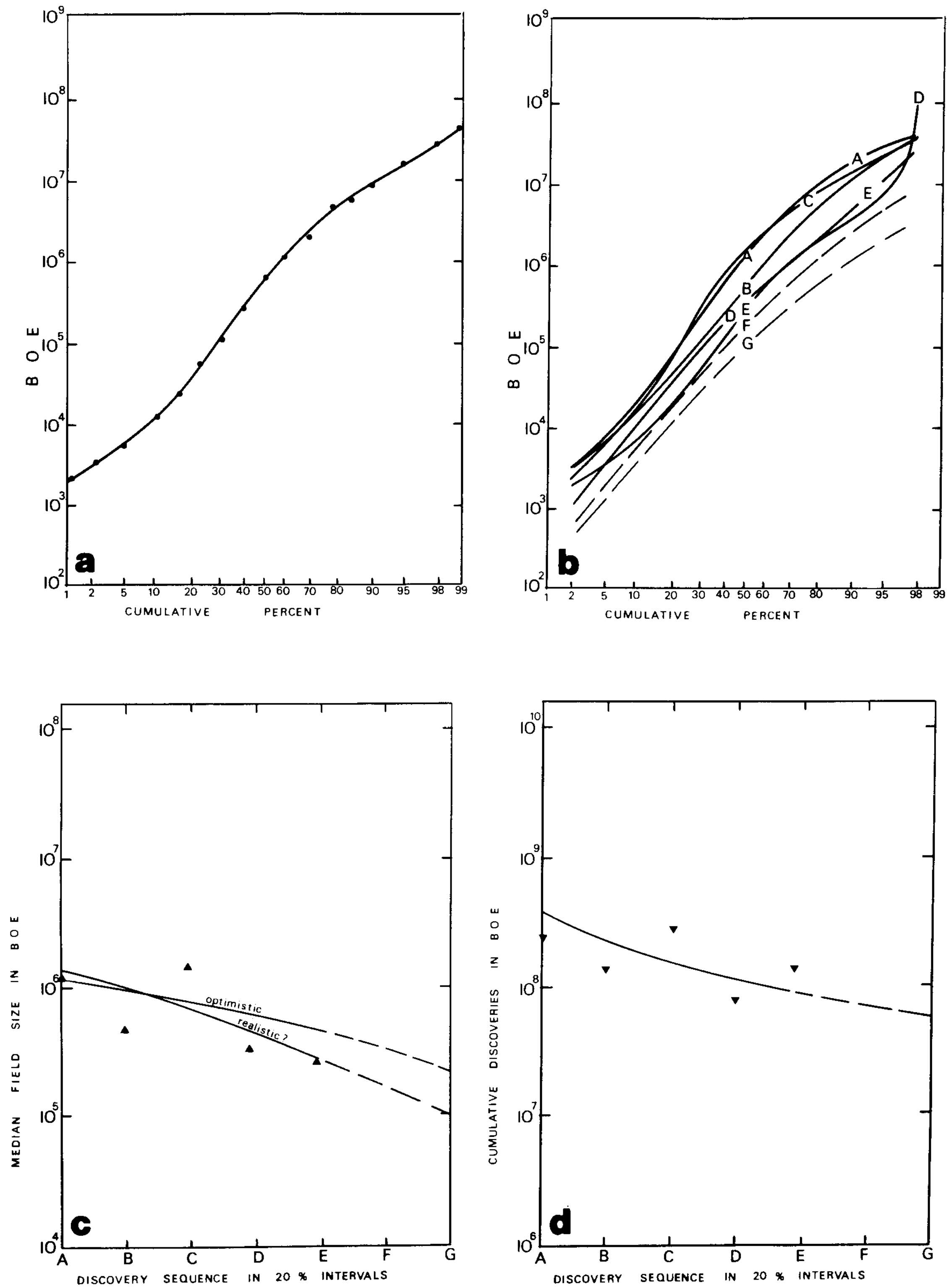

Figure 17. Powder River basin of Wyoming, stratigraphic fields only.

Table 3. Wyoming Production Statistics and Forecast

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	A:	Entire State						
Entire District		0-100	1884-1977	754	696	578	8,771	100.0
	A	0-20	1884-1948	151	2,259	2,320	5,698	65.0
Progressive	B	20-40	1948-1959	151	942	814	1,294	14.8
Discoveries	C	40-60	1959-1966	150	551	417	670	7.6
Through	D	60-80	1966-1972	151	378	306	596	6.8
1977	E	80-100	1972-1977	151	358	279	513	5.8
Forecast Future	F	100-120		151	200		140	1.6
Discoveries	G	120-140		151	150		90	1.0
	B:	Green River Basin						
Entire District		0-100	1900-1977	139	902	835	2,582	100.0
	A	0-20	1900-1956	28	2,236	2,050	1,565	60.0
Progressive	B	20-40	1956-1961	28	2,632	2,022	677	26.3
Discoveries	C	40-60	1961-1969	27	292	245	32	1.2
Through	D	60-80	1969-1974	28	877	958	230	8.9
1977	E	80-100	1974-1977	28	887	434	78	3.0
Forecast Future	F	100-120		28	500		20	0.8
Discoveries	G	120-140		28	450		11	0.4

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	C:	Big Horn Basin						
Entire District		0-100	1906-1977	108	1,008	1,170	2,457	100.0
	A	0-20	1906-1926	22	8,617	7,210	1,787	72.7
Progressive	B	20-40	1926-1947	21	4,125	4,109	357	14.5
Discoveries	C	40-60	1947-1953	22	2,527	1,494	221	9.0
Through	D	60-80	1953-1964	21	186	236	74	3.0
1977	E	80-100	1964-1977	22	340	233	18	0.7
Forecast Future	F	100-120		21	125		5	0.2
Discoveries	G	120-140		21	85		1	0.04
	D:	Wind River Basin						
Entire District		0-100	1884-1974	76	405	604	904	100.0
	A	0-20	1884-1925	15	11,860	4,133	331	36.6
Progressive	B	20-40	1925-1954	15	4,314	2,007	374	41.4
Discoveries	C	40-60	1954-1960	16	211	353	49	5.4
Through	D	60-80	1960-1966	15	388	265	41	4.5
1977	E	80-100	1966-1974	15	78	135	109	12.1
Forecast Future	F	100-120		15	50		25	2.8
Discoveries	G	120-140		15	30		11	1.2

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	E:	Powder River Basin (all fields)						
Entire District		0-100	1887-1977	380	589	426	2,643	100.0
	A	0-20	1887-1954	76	1,414	973	1,649	62.4
Progressive	B	20-40	1954-1963	76	993	634	285	10.8
Discoveries	C	40-60	1963-1968	76	423	356	277	10.5
Through	D	60-80	1968-1973	76	435	303	224	8.5
1977	E	80-100	1973-1977	76	185	211	208	7.9
Forecast Future	F	100-120		76	125		80	3.0
Discoveries	G	120-140		76	90		65	2.5
	F:	Powder River Basin (structural fields)						
Entire District		0-100	1887-1977	134	500	412	1,734	100.0
	A	0-20	1887-1941	27	1,000	895	1,220	70.4
Progressive	B	20-40	1941-1952	27	2,655	1,314	337	19.4
Discoveries	C	40-60	1952-1960	26	587	347	72	4.2
Through	D	60-80	1960-1968	27	220	206	85	4.9
1977	E	80-100	1968-1977	27	112	116	20	1.3
Forecast Future	F	100-120		27	65		10	0.8
Discoveries	G	120-140		27	42		7	0.6

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	G:	Powder River Basin (stratigraphic fields)						
Entire District		0-100	1943-1977	246	607	431	905	100.0
	A	0-20	1943-1962	49	1,294	841	247	27.3
Progressive	B	20-40	1962-1966	49	501	417	139	15.4
Discoveries	C	40-60	1966-1969	50	1,612	863	294	32.5
Through	D	60-80	1969-1974	49	377	245	78	8.6
1977	E	80-100	1974-1977	49	275	207	147	16.2
Forecast Future	F	100-120		49	150		70	7.7
Discoveries	G	120-140		49	100		58	6.4

Table 4. Probabilities attached to field-size ranges for the next 20 percent (F) of fields to be discovered, and for the next 20 percent (G) to be discovered after that, in Wyoming.

Area	Label on Curve	Number of Fields	Probabilities (in percent) attached to field-size ranges in BOE						
			$<10^3$	10^3-10^4	10^4-10^5	10^5-10^6	10^6-10^7	10^7-10^8	10^8-10^9
Whole State	F	151	2	12	24	32	24	5	1
	G	151	3	14	25	33	21	3	1
Green River Basin	F	29	3	7	15	35	29	10	1
	G	29	3	7	19	34	28	8	1
Big Horn Basin	F	22	4	8	26	45	17		
	G	22	4	12	35	45	4		
Wind River Basin	F	16	6	14	39	32	9		
	G	16	7	19	41	31	2		
Powder River Basin (structural fields)	F	27	6	17	35	33	8-1/2	1/2	
	G	27	6	30	42	19	3		
Powder River Basin (stratigraphic fields)	F	50	3	10	26	37	23	1	
	G	50	4	14	32	38	12		
Powder River Basin (all fields)	F	77	2	14	27	36	19	1-1/2	
	G	77	7	20	36	24	12-1/2	1/2	

KANSAS

Kansas has been arbitrarily divided into seven districts (Fig. 18) for this study. The districts do not coincide with officially defined districts, as in California. Districts 1 and 2 embrace much of western and northwestern Kansas. District 3 includes part of the Hugoton embayment. Districts 5 and 6 incorporate much of relatively maturely explored south-central Kansas. District 7 incorporates the remainder of the State, and embraces many older producing areas in southeastern Kansas, as well as the Salina and Forest City basins, which are relatively unexplored.

The districts are defined in terms of aggregates of rectangles defined by the following township and range limits:

District 1	T.1S-6S and R.16W-42W
District 2	T.7S-15S and R.22W-42W, plus T.16S-20S and R.19W-43W, plus T.21S-22S and R.19W-24W
District 3	T.7S-15S and R.5W-21W, plus T.16S-22S and R.5W-18W
District 4	T.21S-35S and R.25W-43W
District 5	T.23S-35S and R.5W-24W
District 6	T.14S-35S and R.5E-4W
District 7	T.1S-6S and R.21E-15W, plus T.7S-13S and R.25E-4W, plus T.14S-35S and R.25E-6E.

The data presented for Kansas are based on cumulative production of oil (gas production is not incorporated, and the production statistics are in barrels and not BOE). The cumulative production data extend through the end of 1978 and include all fields discovered before the end of 1973. Reserve estimates are not included, so that the total field sizes (in barrels of producible oil) are necessarily less than if presented as an estimate of total recoverable oil. Thus, the data for Kansas are not directly comparable with those for California and Wyoming.

The data for Kansas were supplied in magnetic-tape form by the Kansas Geological Survey, which has published an equivalent compilation (Beene, 1979).

ENTIRE STATE

The oil-field size distribution for Kansas as a whole closely approximates an ideal lognormal distribution (Fig. 19), and the subpopulation parameters decline consistently when the chronologically segregated subpopulations, A through E, are compared (Tables 5 and 6). The more recently discovered fields have had less time to produce, and therefore the population statistics reflect this influence as well as the bias toward early discovery of large fields. The last 20 percent of Kansas fields included in this study (the 598 fields that define subpopulation E as segregated from the overall population of 2992 fields) were discovered from 1967 to the end of 1973, and it is obvious that they have had much less opportunity to produce than fields discovered earlier as, for example, those in subpopulation A (1890-1947), many of which have benefited from enhanced oil-recovery operations.

DISTRICTS 1, 2, AND 3

Districts 1, 2, and 3 are somewhat similar in their statistics (Figs. 20 to 22). Because these districts have undergone extensive exploration in recent years, the rapid drop in median, geometric mean, and aggregate cumulative production for the subpopulations (Table 5-B, C, and D) may be somewhat misleading, since these statistics will necessarily increase as existing fields continue to produce. Nevertheless, it is instructive to compare the percentages of the total production (the last column of Table 5) with similar statistics for California and Wyoming (where reserves remaining are incorporated). As a percentage of the total for each district, those for subpopulations D and E in Kansas, although varying from district to district, do occur in the same general range as in California and Wyoming. This may imply that the bias toward early discovery of large fields is less in Kansas than in California or Wyoming, but this possibility cannot be convincingly determined unless reserve estimates are incorporated in the Kansas field-size data.

DISTRICTS 4, 5, 6, AND 7

Districts 4 through 7 do not display orderly reductions in population parameters with discovery sequence. While the overall populations of each district are essentially lognormal (Figs. 23 to 26), the graphs of the chronologically segregated subpopulations cross each other in an unpredictable manner. The medians and geometric means, however, exhibit somewhat more orderly arrangement (Table 5-E, F, G, and H) and seem to permit the extrapolation of future populations (Table 6) with some consistency.

Analysis of the Kansas data makes clear that we are dealing with populations of fields that have much smaller parameters than those of California or Wyoming. Table 7 presents a summary forecast of new-field discoveries for all three states, with the caveat that the estimates for Kansas exclude gas (thus are not on a BOE basis) and must be adjusted upward to accommodate continuing production.

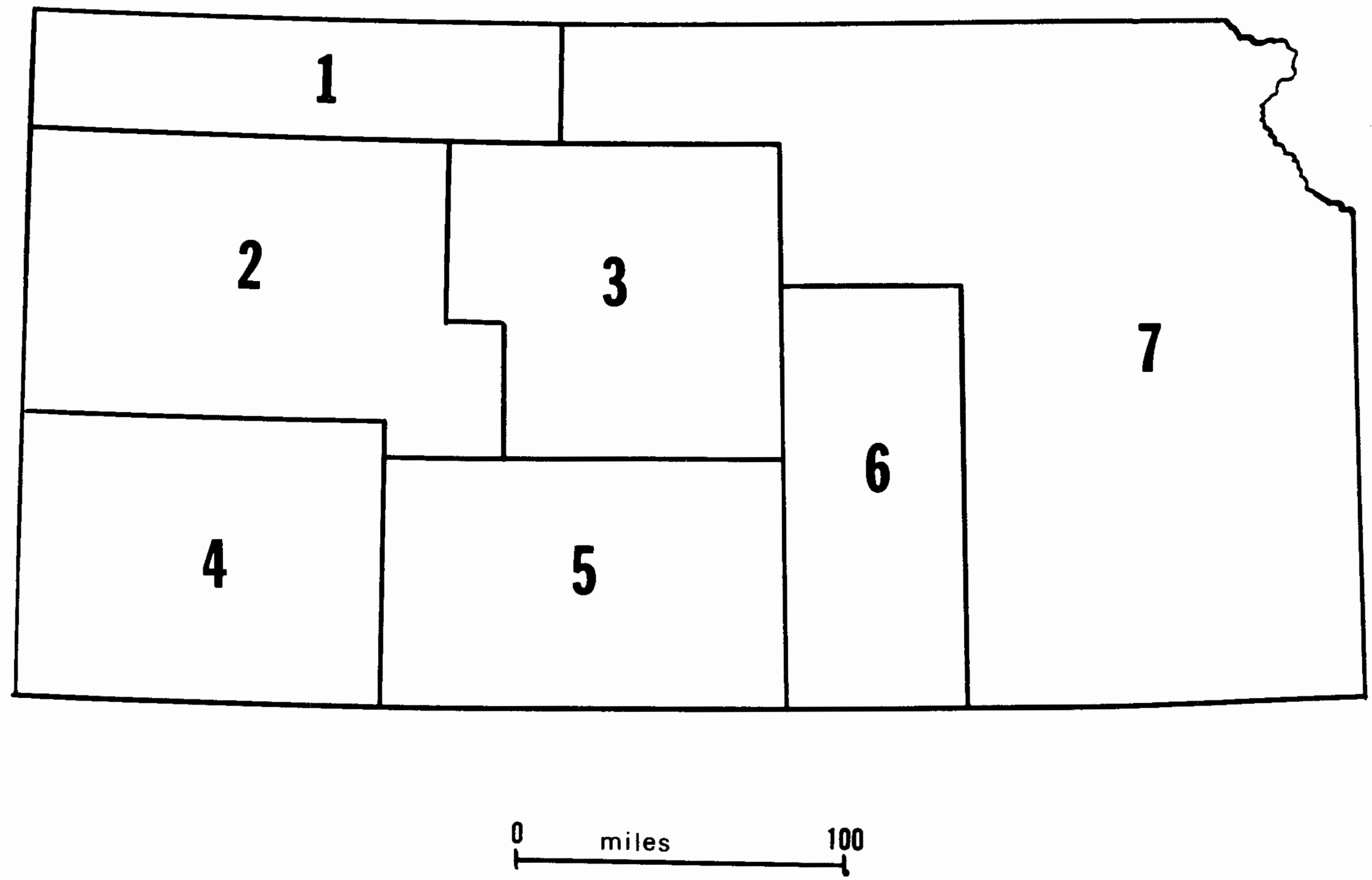

Figure 18. Index map of Kansas showing seven districts that have been established for this study.

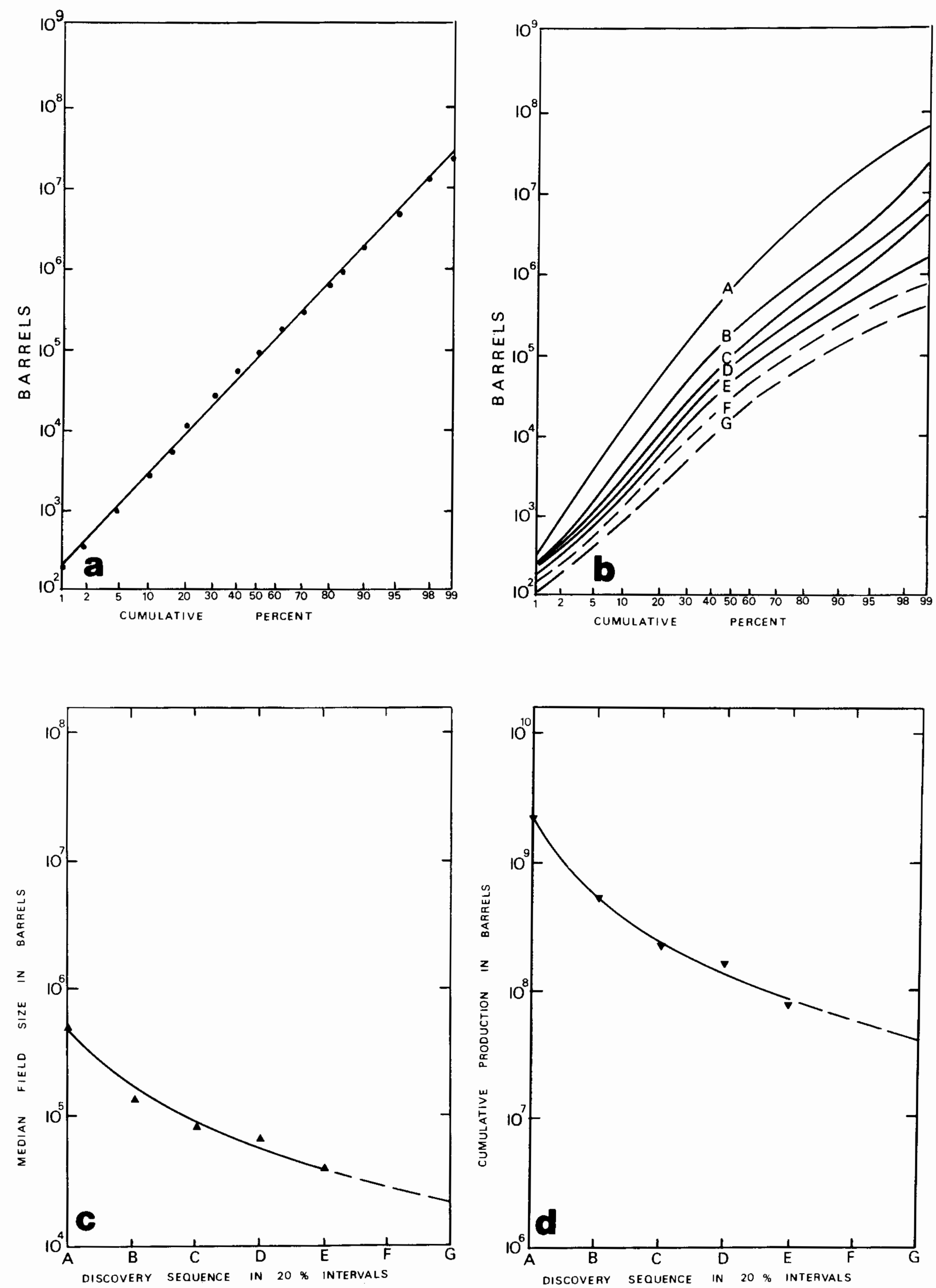

Figure 19. All of Kansas. Oil-field volumes are expressed in barrels and represent cumulative production through 1978, and exclude reserves. See section entitled Graphic Presentation of the Data for explanation.

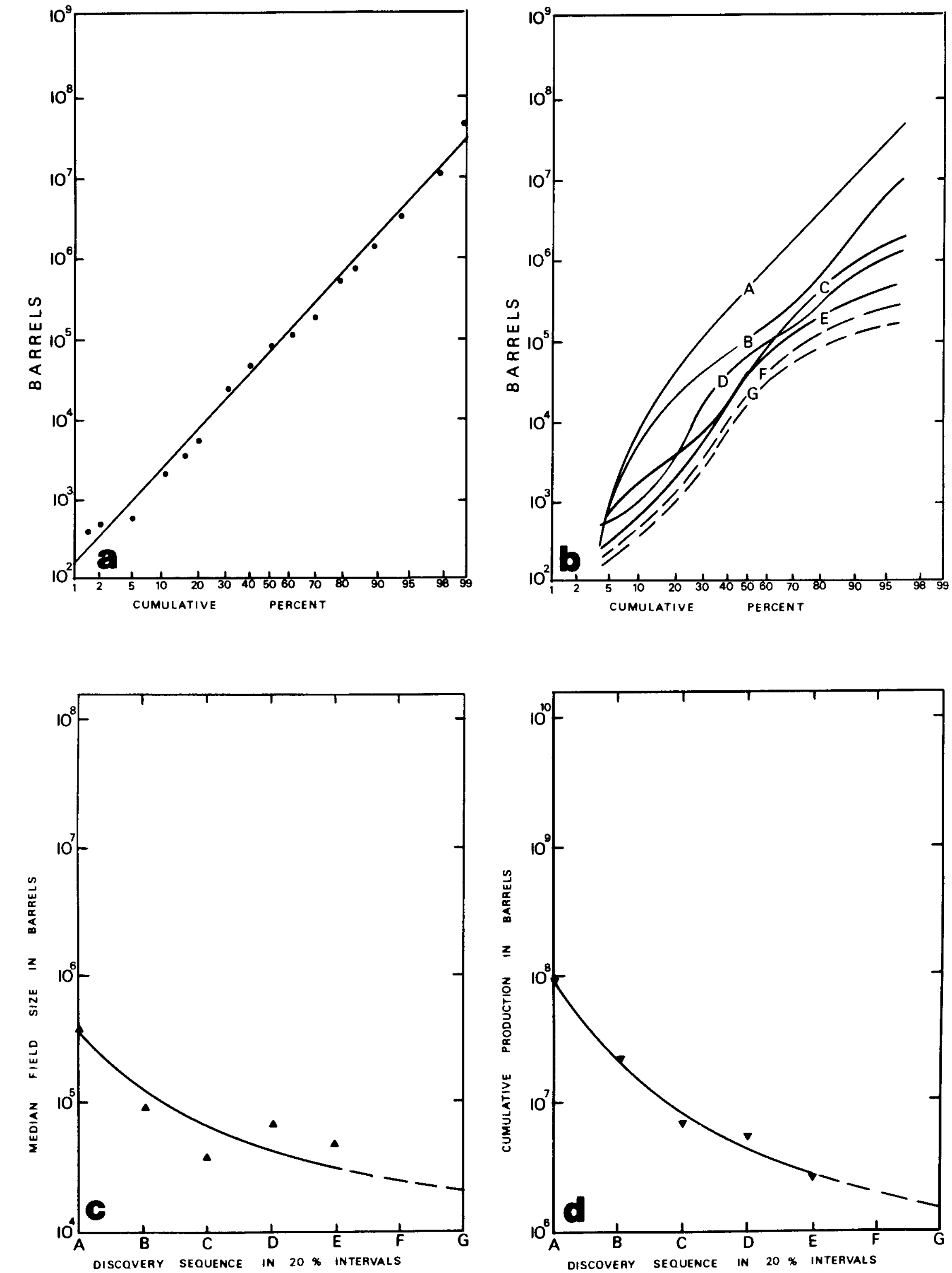

Figure 20. District 1, Kansas.

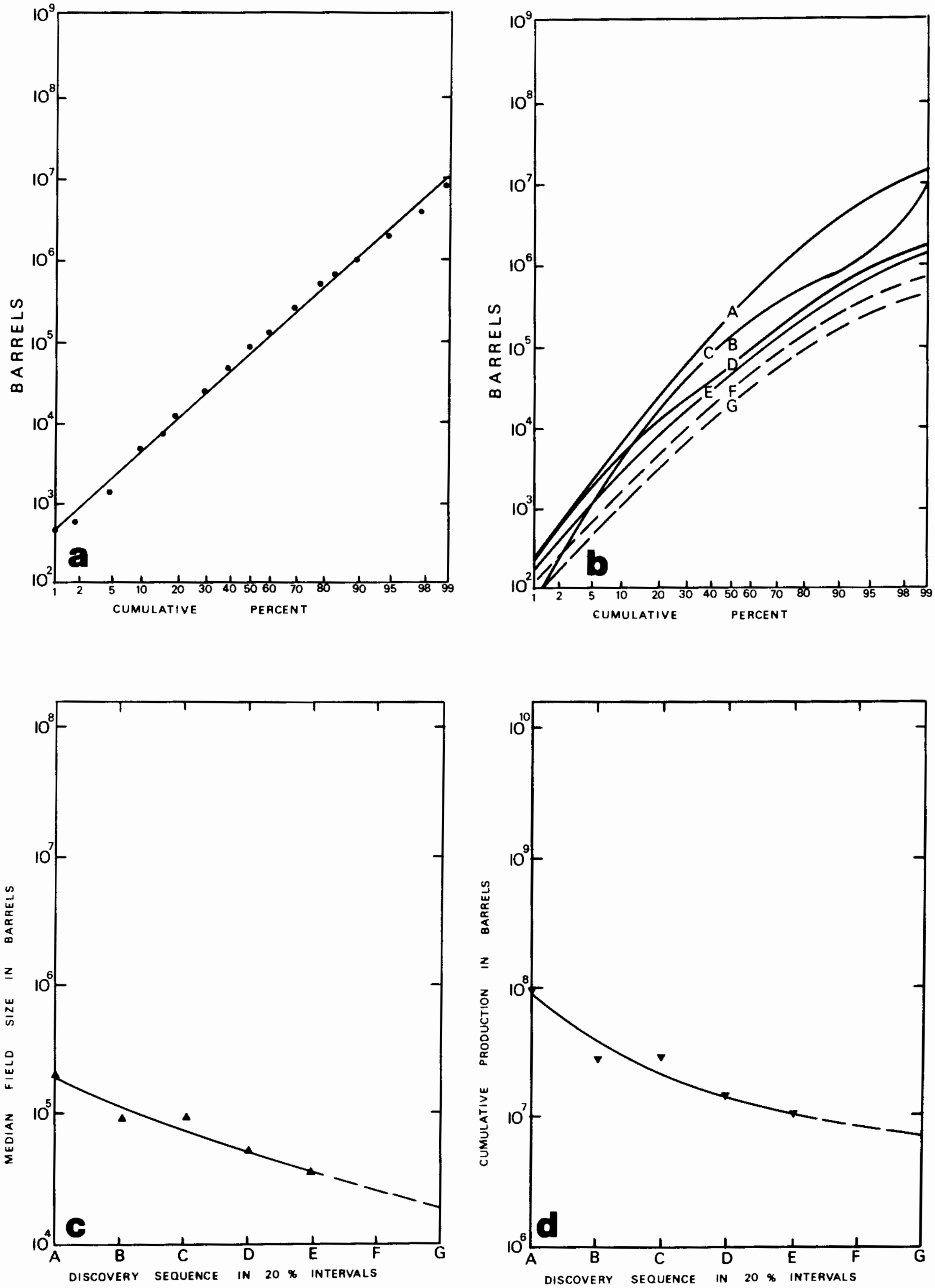

Figure 21. District 2, Kansas.

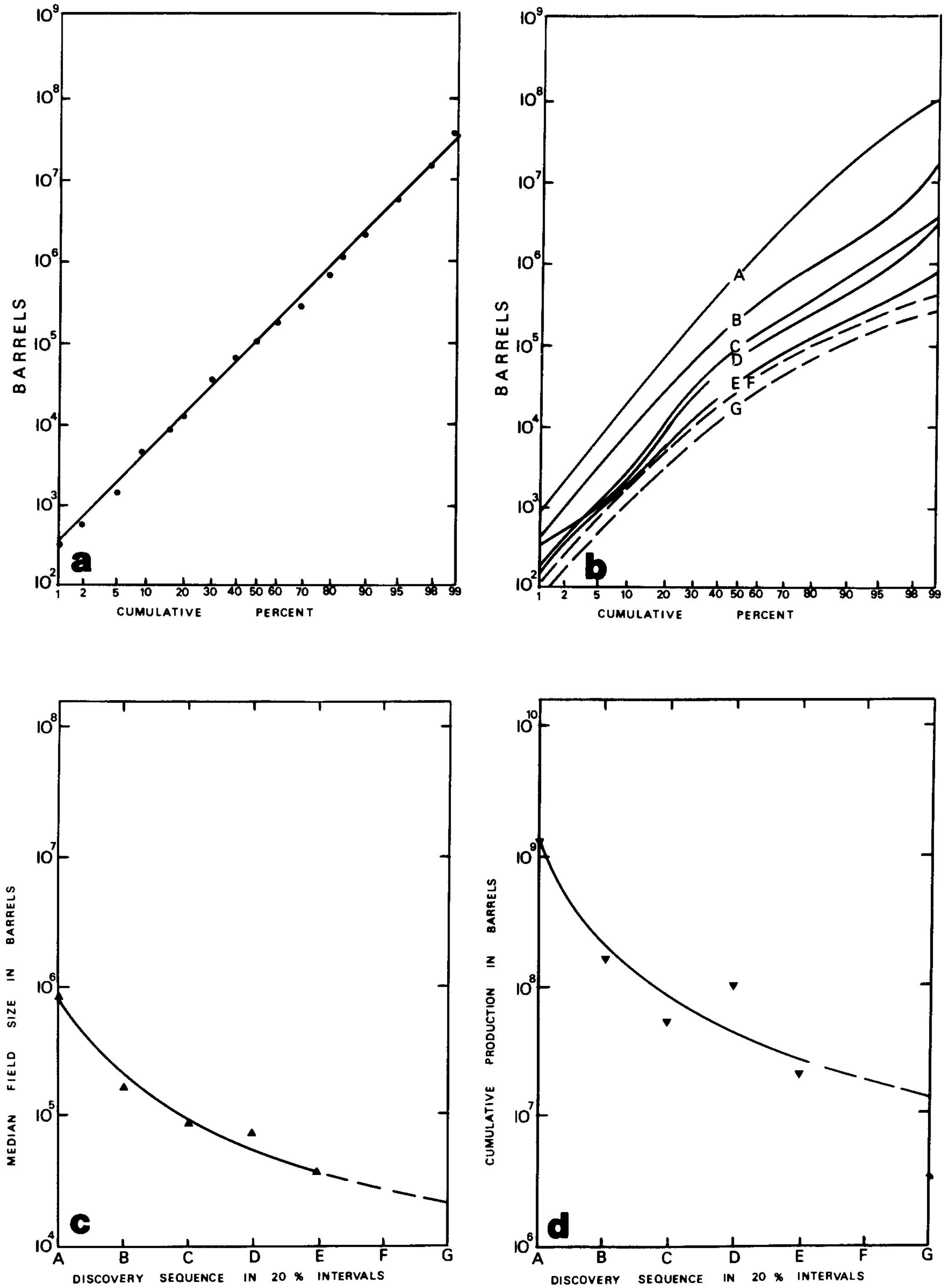

Figure 22. District 3, Kansas.

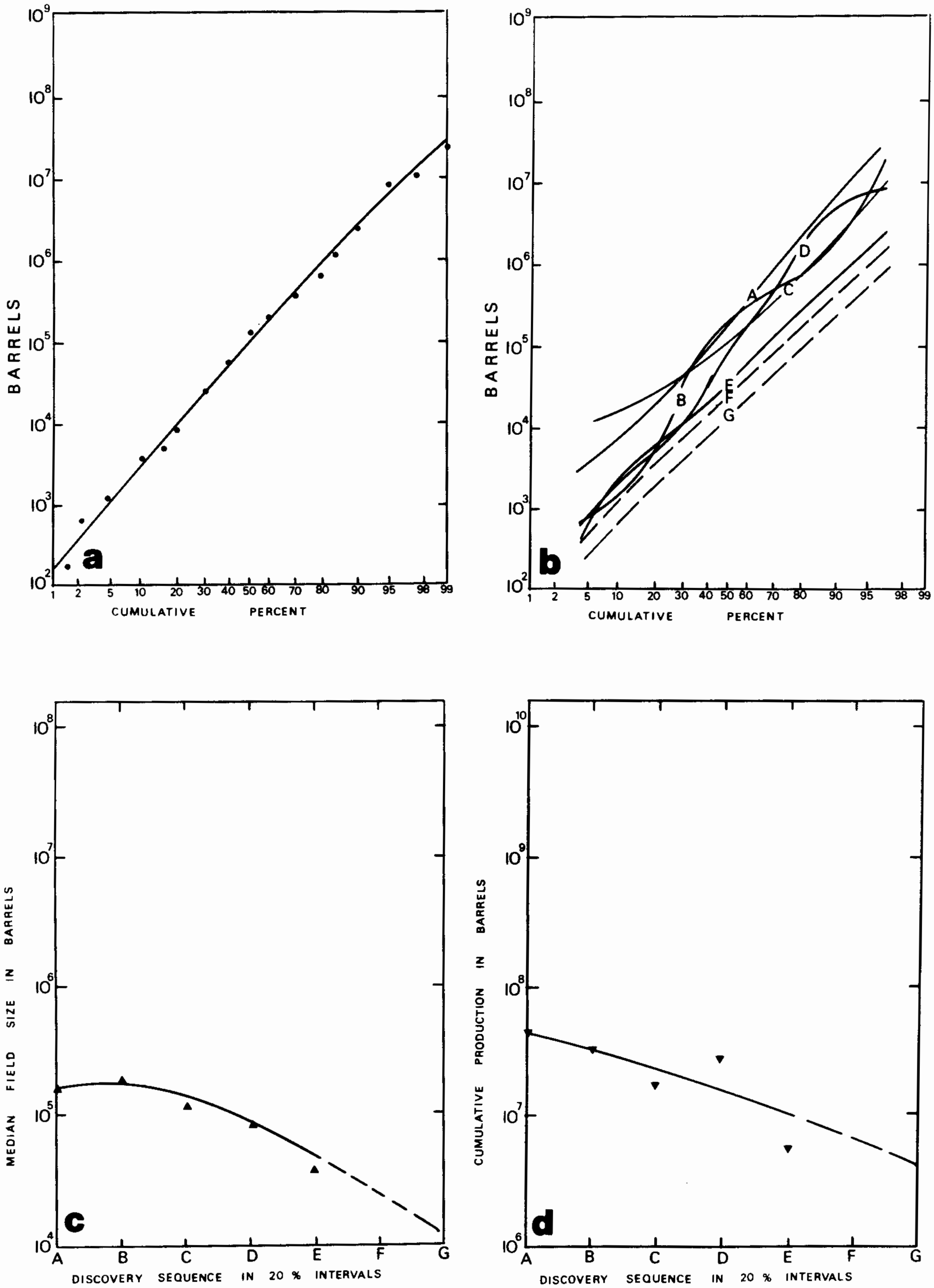

Figure 23. District 4, Kansas.

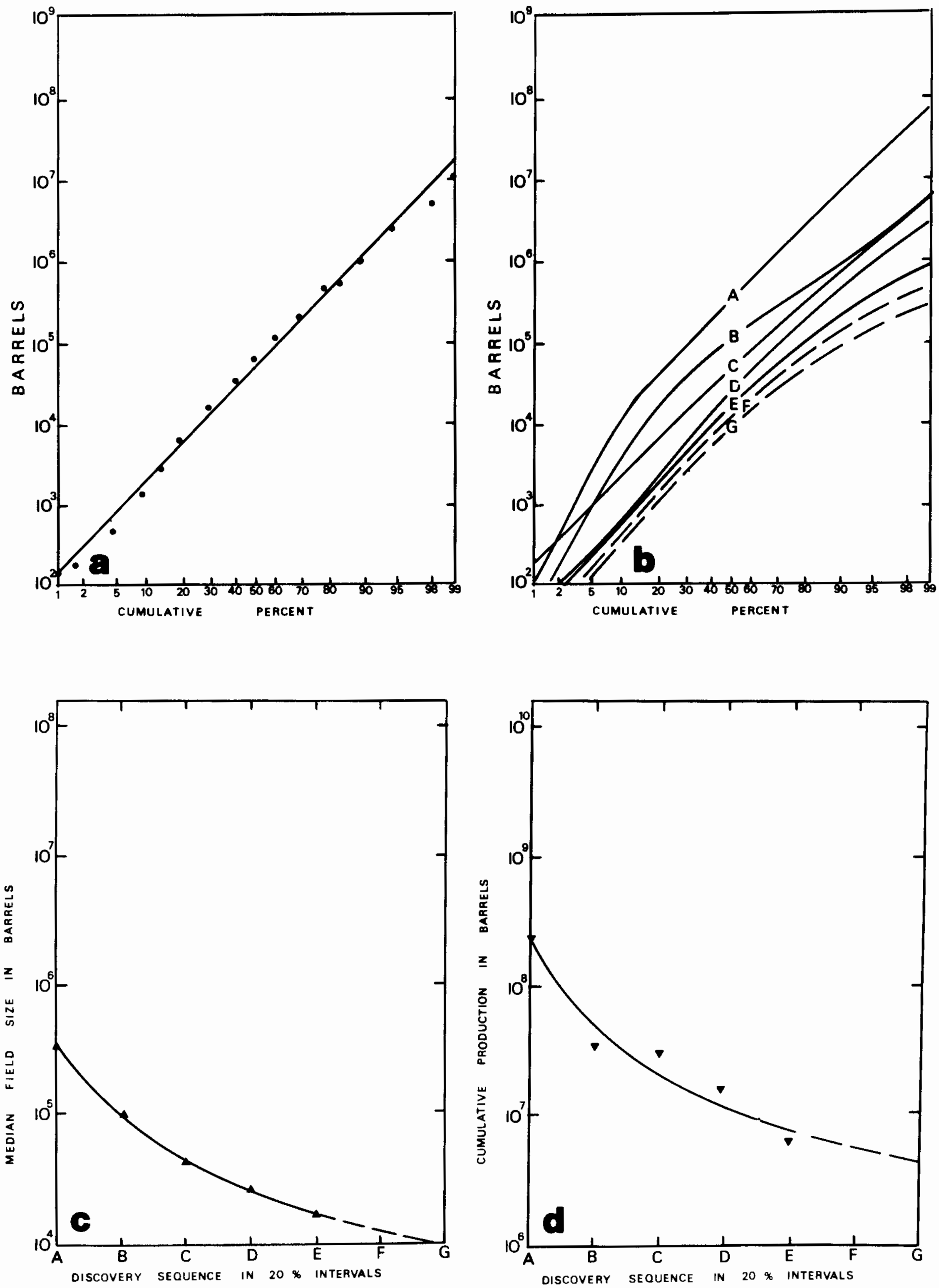

Figure 24. District 5, Kansas.

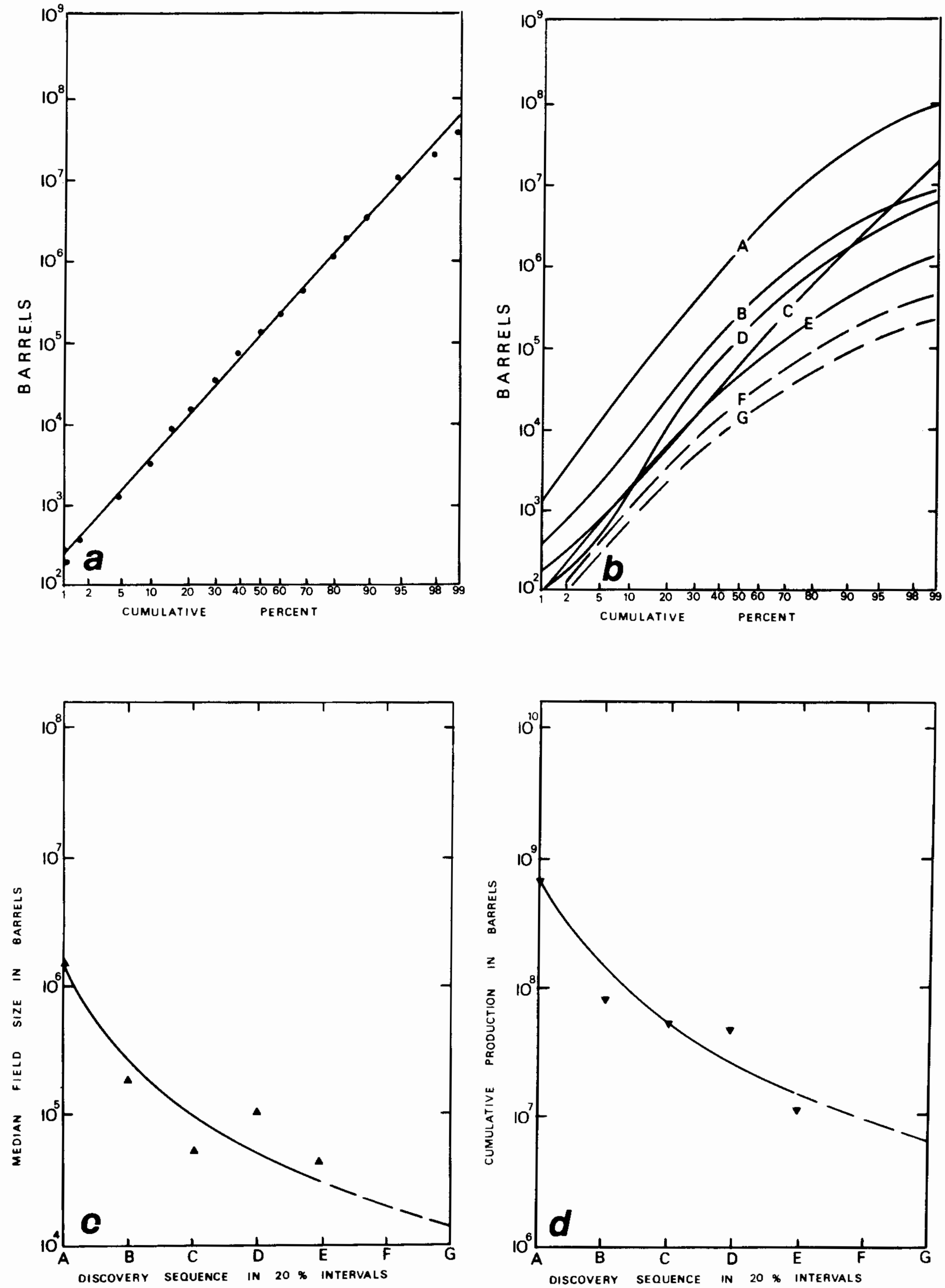

Figure 25. District 6, Kansas.

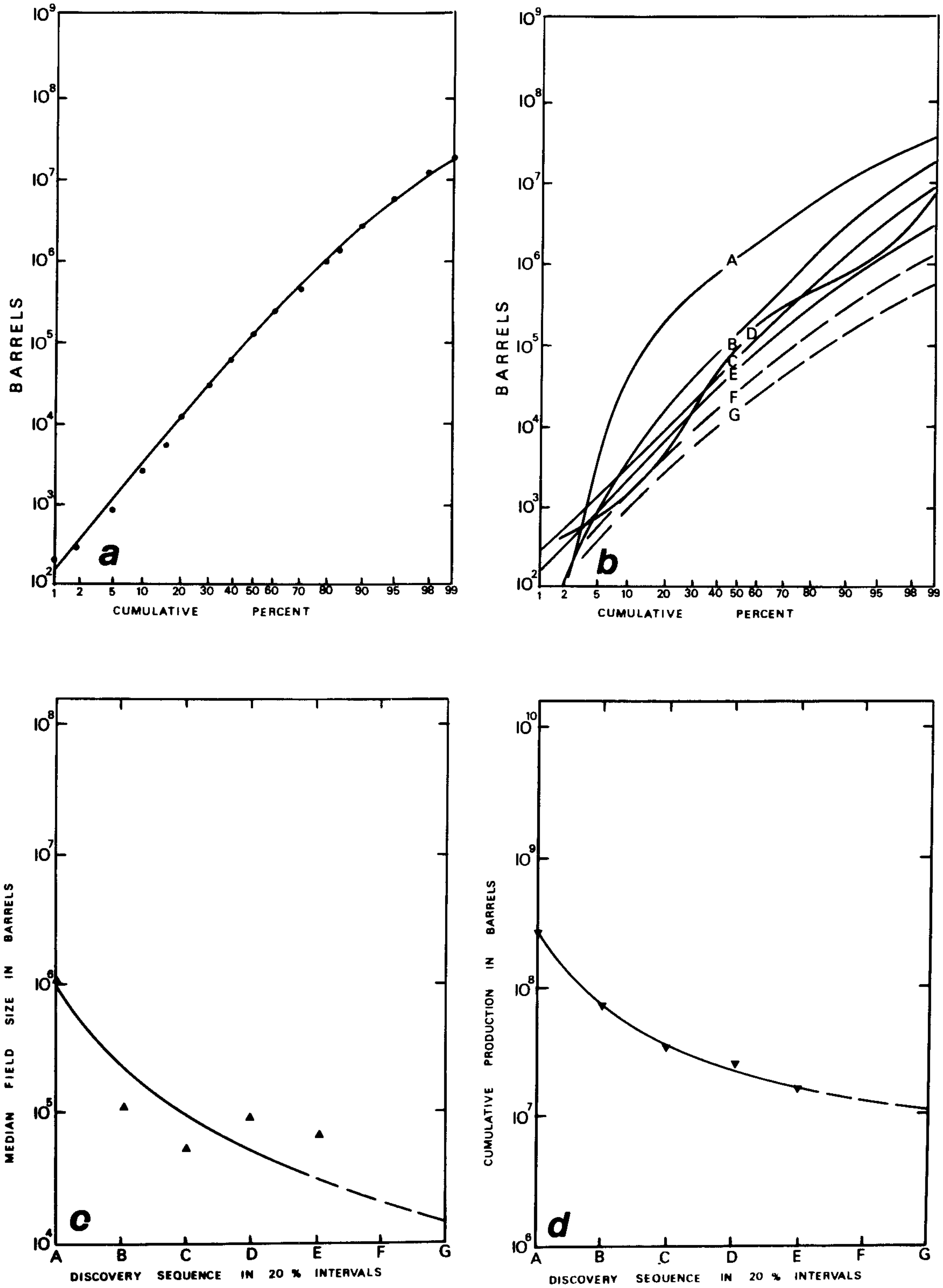

Figure 26. District 7, Kansas.

Table 5. Kansas Production Statistics and Forecasts

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of Barrels	Geometric Mean in Thousands of Barrels	Total for Interval in Millions of Barrels	Percentage of Present Total for Entire District
	A:	Entire State						
Entire District		0-100	1890-1973	2,992	96	82	3,605	100.0
	A	0-20	1890-1947	598	533	436	2,503	69.4
Progressive	B	20-40	1947-1955	599	143	112	581	16.1
Discoveries	C	40-60	1955-1960	598	87	64	261	7.2
Through	D	60-80	1960-1967	599	68	43	178	4.9
1973	E	80-100	1967-1973	598	39	28	83	2.3
Forecast Future	F	100-120		598	26		55	1.5
Discoveries	G	120-140		598	20		48	1.3
	B:	District 1						
Entire District		0-100	1936-1973	131	71	57	121	100.0
	A	0-20	1936-1952	26	395	322	86	71.1
Progressive	B	20-40	1952-1959	26	95	88	22	18.2
Discoveries	C	40-60	1959-1965	27	38	27	6	5.0
Through	D	60-80	1965-1969	26	72	63	5	4.1
1973	E	80-100	1969-1973	26	50	26	2	1.7
Forecast Future	F	100-120		26	23		1.8	1.5
Discoveries	G	120-140		26	19		1.4	1.2

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	C:	District 2						
Entire District		0-100	1929-1973	401	83	70	177	100.0
	A	0-20	1929-1956	80	220	176	92	52.0
Progressive	B	20-40	1956-1961	80	102	69	30	16.9
Discoveries	C	40-60	1961-1966	81	105	73	30	16.9
Through	D	60-80	1966-1971	80	56	51	15	8.5
1973	E	80-100	1971-1973	80	40	34	10	5.6
Forecast Future	F	100-120		80	25		8	4.5
Discoveries	G	120-140		80	17		7	4.0
	D:	District 3						
Entire District		0-100	1922-1973	999	104	96	1,560	100.0
	A	0-20	1922-1949	198	865	659	1,235	79.2
Progressive	B	20-40	1949-1953	198	175	148	155	9.9
Discoveries	C	40-60	1953-1959	198	88	62	51	3.3
Through	D	60-80	1959-1966	198	77	50	99	6.3
1973	E	80-100	1966-1973	198	37	20	20	1.3
Forecast Future	F	100-120		198	25		19	1.2
Discoveries	G	120-140		198	20		14	0.9

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	E:	District 4						
Entire District		0-100	1922-1973	124	120	86	131	100.0
	A	0-20	1922-1954	25	170	167	45	34.4
Progressive	B	20-40	1954-1957	25	203	101	33	25.2
Discoveries	C	40-60	1957-1959	24	128	111	18	13.7
Through	D	60-80	1959-1965	25	87	73	29	22.1
1973	E	80-100	1965-1973	25	40	35	6	4.6
Forecast Future	F	100-120		25	25		7	5.3
Discoveries	G	120-140		25	12		4	3.1
	F:	District 5						
Entire District		0-100	1926-1973	491	58	46	324	100.0
	A	0-20	1926-1952	98	345	265	236	72.8
Progressive	B	20-40	1952-1955	98	102	74	35	10.8
Discoveries	C	40-60	1955-1960	99	43	62	32	9.9
Through	D	60-80	1960-1965	98	27	21	15	4.6
1973	E	80-100	1965-1973	98	17	12	6	1.9
Forecast Future	F	100-120		98	13		5	1.5
Discoveries	G	120-140		98	9		4	1.2

	Label	Percentage Ranges	Range of Years	Number of Fields	Median in Thousands of BOE	Geometric Mean in Thousands of BOE	Total for Interval in Millions of BOE	Percentage of Present Total for Entire District
	G:	District 6						
Entire District		0-100	1900-1973	446	128	119	872	100.0
	A	0-20	1900-1938	89	1,658	1,084	681	78.1
Progressive	B	20-40	1938-1951	89	199	166	81	9.3
Discoveries	C	40-60	1951-1957	90	54	53	54	6.2
Through	D	60-80	1957-1962	89	117	86	45	5.2
1973	E	80-100	1962-1973	89	45	32	11	1.3
Forecast Future	F	100-120		89	20		9	1.0
Discoveries	G	120-140		89	14		7	0.8
	H:	District 7						
Entire District		0-100	1890-1973	409	126	96	420	100.0
	A	0-20	1890-1925	82	1,090	649	265	63.1
Progressive	B	20-40	1925-1938	82	118	106	74	17.6
Discoveries	C	40-60	1938-1956	81	55	61	39	9.3
Through	D	60-80	1956-1965	82	99	51	25	6.0
1973	E	80-100	1965-1973	82	69	60	17	4.0
Forecast Future	F	100-120		82	20		13	3.1
Discoveries	G	120-140		82	15		11	2.6

Table 6. Probabilities attached to field-size ranges for the next 20 percent (F) of fields to be discovered, and for the next 20 percent (G) to be discovered after that, in Kansas.

Area	Label on Curve	Number of Fields	Probabilities (in percent) attached to field-size ranges in BOE						
			$<10^3$	10^3-10^4	10^4-10^5	10^5-10^6	10^6-10^7	10^7-10^8	10^8-10^9
Entire State	F	598	8	23	43	25-½	½		
	G	598	12	29	44	15			
District 1	F	26	17	23	34	26			
	G	26	19	23	42	16			
District 2	F	80	7	23	44	25	1		
	G	80	9	29	44	18			
District 3	F	198	6	24	50	20			
	G	198	9	29	50	12			
District 4	F	25	9	25	38	23	4-½	½	
	G	25	13	32	36	16	3		
District 5	F	98	17	29	40	14			
	G	98	19	31	41	9			
District 6	F	89	9	25	48	18			
	G	89	12	31	49	8			
District 7	F	82	7	24	42	25	2		
	G	82	10	30	44	15-½	½		

CONCLUSIONS AND RECOMMENDATIONS

This study was undertaken to achieve an understanding of the most elementary of petroleum resource-base considerations, namely, the frequency distributions of oil-field volumes. Some generalized conclusions may be drawn as follows.

(1) The lognormal distribution is a very useful general model in dealing with populations of oil and gas fields. Unless refuted by studies in other regions, it seems appropriate to assume that the populations of undiscovered oil and gas fields in frontier regions that have undergone little or no exploration will be essentially lognormal, assuming that such populations exist at all.

(2) The bias toward early discovery of large fields is a major influence and statistically seems to be greater than many explorationists realize. A decrease in population parameters (median and geometric mean) of from one to as much as three orders of magnitude (powers of ten) appears to be common as a district or basin approaches maturity.

(3) Subpopulations of fields discovered early tend to depart more from the lognormal ideal than later subpopulations. However, these shifts in population characteristics vary widely from district to district, and generalized statements about these changes must await additional study.

(4) The "actual" distribution of oil and gas field sizes may not be lognormal and instead may have the general form suggested in Figure 27. The lower size limits of fields that have actually yielded oil or gas are generally set by either economic factors, or the ability to detect small accumulations, or both. It is possible, and even probable, that there is no definable lower field-size limit and that the form of the distribution is exponential with regard to very small accumulations. Thus, the actual distribution may be bimodal in the sense that there are two peaks, one of which represents the producing fields and the other (the exponential extension) a virtual infinity of accumulations, some of infinitesimal size. Obviously, the definition of an "oil field" becomes meaningless when extended to this extreme. It will suffice to say that we have almost no knowledge of the lower limit of field-size distributions. This shortcoming may be of minor practical consequence, however, since extremely small fields are of negligible economic importance.

(5) Studies of oil-field populations should be conducted regionally. Furthermore, populations should be segregated geologically. The data from the Powder River basin suggest that the population parameters for structural versus stratigraphic fields may differ significantly in other regions.

(6) Extrapolation of parameters of chronologically segregated oil-field populations is a useful predictive tool.

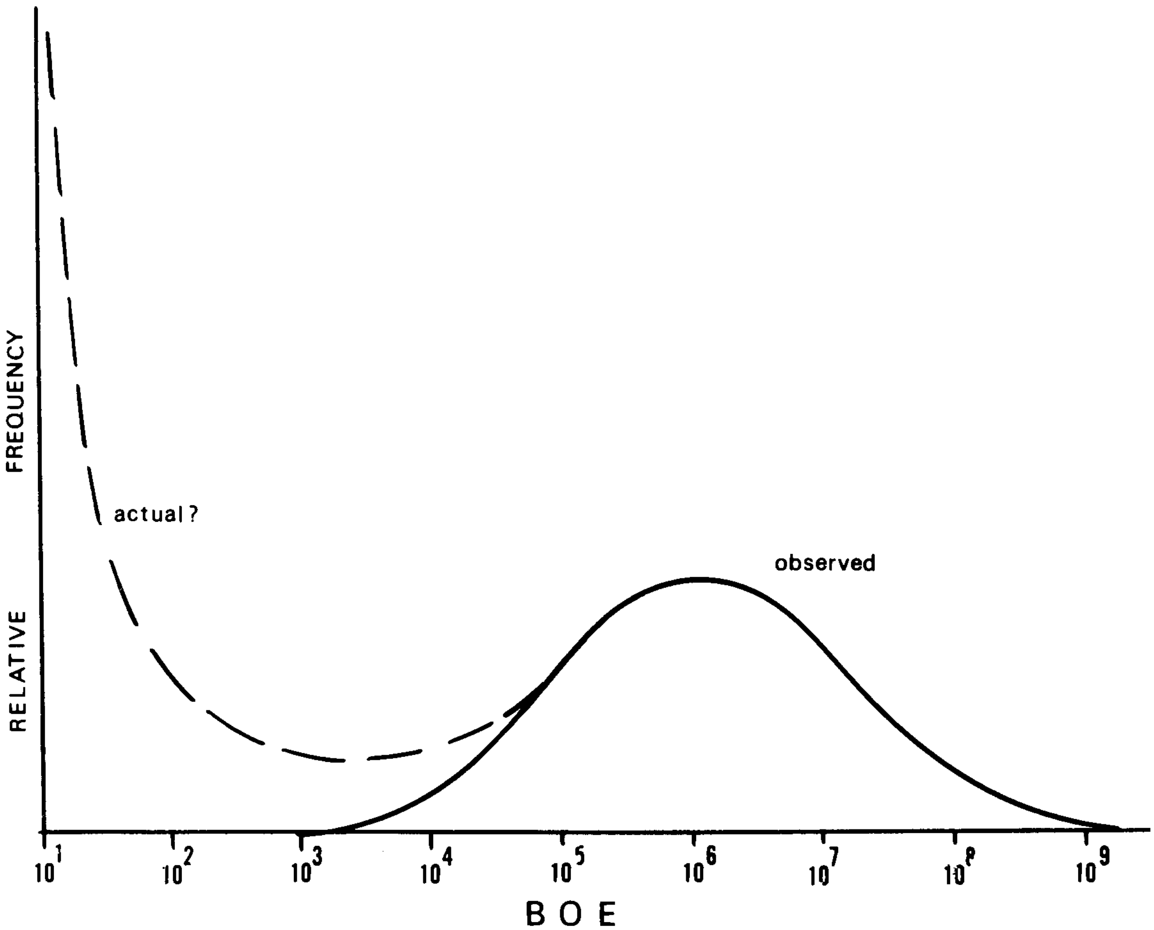

Figure 27. Possible alternative forms of distribution of oil-field volumes. Observed distribution is lognormal, but actual distribution may be bimodal with long exponential tail toward lower end of individual volumes.

Table 7. Summary comparison of forecasts for the three states for the next 20 percent of fields to be discovered, and the 20 percent after that.

	Next 20%		20% after that	
	Number of Fields	Millions of BOE[1]	Number of Fields	Millions of BOE[1]
California	81	185	81	118
Wyoming	151	140	151	90
Kansas	598	55	598	48

[1]Volumetric estimates for Kansas exclude gas and involve predictions based on cumulative oil production through 1978, exclude reserves, and must necessarily be revised upwards as production continues.

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