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Helium—Its Relationship to Geologic Systems and Its Occurrence With the Natural Gases, Nitrogen, Carbon Dioxide, and Argon

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HELIUM-ITS RELATIONSHIP TO GEOLOGIC SYSTEMS AND ITS OCCURRENCE WITH THE NATURAL GASES, NITROGEN, CARBON DIOXIDE, AND ARGON

by

Claude A. Tongish¹

ABSTRACT

This Federal Bureau of Mines report presents information on the accumulation and distribution of helium in U.S. natural gas reservoirs. The investigation concerns the relationship or association of helium with geographic location, geologic age, reservoir depth, nitrogen, carbon dioxide, and argon. Although helium is a minor constituent in natural gas, these data show that certain conditions make some reservoirs statistically more favorable than others for the accumulation of helium.

The report is based on gas analysis information collected by the Bureau from 1917 to 1974 from 10,086 gas samples, representing 6,455 reservoirs in 35 States. The occurrence of helium in the reservoirs was 11.5 percent with less than 0.005 percent of helium, 70.9 percent with 0.005 through 0.29 percent of helium, and 17.6 percent with 0.30 percent or more of helium in the gas. Results of the various correlations are presented in tables and charts. Relationships have also been determined quantitatively by measures of correlation. The statistical data can be used to determine the environment under which reservoirs with high-helium contents are most likely to occur. These data can be used with other information for predicting the future helium resources of the United States.

INTRODUCTION

The investigation was conducted to furnish information regarding the accumulation and distribution of helium in natural gas reservoirs of the United States and to determine if a definitive relationship existed between helium concentrations and geographic location, geologic age, reservoir depth, nitrogen, carbon dioxide and argon. This report is concerned with the helium found in natural gas, although helium has also been found in minerals and rocks (34,36),² in mineral springs (14), in mine gases (4), in volcanic gases (31), in the atmosphere (37), and has been observed in celestial bodies (18).

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²Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Helium has been known to be a component in natural gas since 1905 (3) when it was discovered in a gas sample from Dexter, Kans. The Federal Bureau of Mines helium resources evaluation program, in operation since 1917, was developed to evaluate the helium resources of the United States in the interest of Federal needs, including aeronautic and national defense, and to conserve this unique elemental gas for future generations. The chemical inertness of helium, low cross-section capture coefficient, its simple molecular structure and low density make it particularly suitable for space flight and related uses, nuclear energy research and development, cryogenics research, medical application, shielded-arc welding, lighter-than-air craft flights, and numerous applications.

Data for this study are based on gas analyses performed by the Bureau of Mines from 1917 to 1974 and reservoir data furnished by well operators. Methods and procedures of analyzing the gas samples are explained by Boone (2). Gas analyses and well data have been published (1-2, 5-9, 19-29) and compiled on the Bureau of Mines helium survey computer tape file³ which includes gas analyses from 37 States and 23 foreign countries. Only gas analyses from natural gas wells located in the United States and for which the geologic system were known are included in this study.

In 1921, Rogers (38) reported "that noteworthy proportions of helium have been found only in natural gases of the nitrogen type (low heating values due to high concentrations of nitrogen)." He also concluded that high concentrations of helium would probably not be found below 2,000 to 2,500 feet. In 1963, Jodry and Henneman (12) indicated that if there was a critical depth below which high helium contents would not be found, it would be below 7,000 feet, rather than the 2,000 to 2,500 feet suggested by Rogers (38).

The present investigation has revealed significant statistical relationships between helium content and geologic system, reservoir depth, nitrogen, carbon dioxide, and argon contents of natural gas from a particular reservoir. Generally, natural gas reservoirs containing the highest concentrations of helium are found in Paleozoic-age rocks at depths above 9,000 feet. These natural gas reservoirs also contain more than 30 percent of nitrogen, less than 30 percent of carbon dioxide, and more than 0.3 percent of argon.

Results are presented in tables and figures that show the number and percentage of reservoirs in different ranges of helium content for geologic system and depths and for the component gases, nitrogen, carbon dioxide, and argon. Well potentials and gas reserves are not included because inconsistencies in reporting rates and because some well owners did not give that information on the well survey forms. The results can be used to determine, with some certainty, the environment under which high-helium-content reservoirs are most likely to be found and to predict future helium resources of the United States.

³Bureau of Mines Computer Tape File, Analyses of Natural Gases, PB-267-696, National Technical Information Service, Springfield, Va. 22161.

PROPERTIES OF HELIUM AND COMPOSITION OF THE ATMOSPHERE

Helium is an odorless, colorless, and tasteless inert elemental gas having an atomic and molecular weight of 4. Helium has next to the lowest specific gravity known, its specific gravity being 0.1381 (air is 1, whereas hydrogen has a known specific gravity of 0.0695). Helium weighs 0.0112 pounds per cubic foot, and hydrogen weighs 0.0056 pounds per cubic foot; however, the buoyancy of helium in air is about 93 percent that of hydrogen.

Helium was first liquefied by H. K. Onnes (30) in 1908, at a temperature of -450.2° F and a pressure of 33 pounds per square inch, absolute. The density of the liquid was found to be 0.122. W. H. Keesom (15) first solidified helium in 1926 at temperatures ranging from -452.2° F and 141 atmospheres down to -457.6° F and 25 atmospheres. The substance he obtained was homogeneous crystalline solid so tough that it could be hammered.

Helium is a higher conductor of heat, has a higher diffusivity, and a higher velocity of sound than all other gases except hydrogen. It is less soluble in water than any gas and liquefies at the lowest temperature of any gas. Neon is the only gas that conducts electricity better than helium(39,42).

The composition of the earth's atmosphere, listed in table 1, shows the variations with elevation. Of particular interest are the helium, nitrogen, carbon dioxide, and argon gases used as comparison values for similar components found in natural gas.

TABLE 1. - Variations in composition of the atmosphere with elevation

Component	Percentage distribution by volume				
	Sea level ¹	6.8 miles	12 miles	31 miles	62 miles
Helium.....	0.0004	NA	NA	0.07	1.31
Nitrogen.....	78.03	78.02	81.24	86.78	2.95
Carbon dioxide..	.03	.03	.01	NA	NA
Argon.....	.94	.94	.59	.12	NA
Hydrogen.....	.01	.01	.04	2.76	95.58
Oxygen.....	20.99	20.99	18.10	10.17	.11
Water.....	0	.01	.02	.10	.05

¹Dry.

Source: Handbook of Chemistry and Physics 30th ed., 1947.

ORIGIN OF HELIUM

The origin of helium has been the subject of many reports, investigations, and studies since it was discovered in 1868 in the atmosphere surrounding the sun (17). Hypotheses concerning the celestial origin of helium and its subsequent accumulation in geologic traps have been reported by many investigators (10, 12-13, 32, 43, 46) and others since its discovery on earth in 1895 (34).

Two of the more prominent theories on the origin of helium are: (1) helium in natural gas emanated from deposits of uranium or thorium and spread through the earth not far beneath the zones in which the high-helium-content gas now occurs and (2) helium is primordial, derived from deep-seated sources within the earth's crust, and has had no connection with generally depressed, low-level radioactivity of dispersed radioactive minerals. Another theory often mentioned is that because there is a large volume of helium contained in the atmosphere (38), helium in natural gas reservoirs may have in some way been derived from the atmosphere. However, the discovery by Ramsay and Soddy (35) in 1903 that helium was a product of decay of the radioactive elements and that the alpha-particles are helium atoms convinced many observers that the occurrence of helium is a product of radioactivity. Katz (13) presented a paper at the helium centennial in 1968 in which he stated:

Uranium and thorium are everywhere present in concentrations at the ppm (parts per million) level in sedimentary rocks. The shales (and limestones) often pointed to as a source beds for natural gas, contain these generators of helium in low concentrations. Material balances can be made to show that the uranium and thorium are of the right order of magnitude of concentration to generate in the source beds the amount of helium found in such fields as Hugoton.

DISCOVERY OF HELIUM AND DEVELOPMENT IN NATURAL GAS RESERVOIRS

In 1868, while studying an eclipse of the sun, J. N. Lockyer (17) discovered an unknown spectral line in the sun's atmosphere. When he could not reproduce this line, he concluded that it came from a substance in the sun, but was unknown on earth. Lockyer named this substance helium from the Greek word "helios" meaning sun. Twenty-seven years later in 1895, William Ramsay (34) discovered helium on earth. While looking for new sources of argon, he discovered helium in the gases evolved from cleveite, a uranium-bearing mineral. In 1905, H. P. Cady and D. F. McFarland (3) found 1.84 percent of helium in a natural gas sample from a well drilled in 1903 to 400 feet at Dexter, Kans. The natural gas contained a high percentage of nitrogen and was not combustible (11). Further work with other gases showed helium to be a minor component in several natural gases from Kansas and in gases from other States.

The discovery of helium in natural gas provided a potential source from which helium could be extracted in quantities. However, helium was not utilized in large quantities until World War I when it was used for airships, because of its lifting force and nonflammable properties.

Helium Survey

World War I caused considerable activity and interest in helium production for airships, resulting in the construction of the first helium plant in the United States. In 1917, the Navy Department built a plant at Fort Worth, Tex., to process gas from the Petrolia field in Clay County, Tex. The helium resources evaluation program was also started at that time when an independent contractor made a preliminary helium survey investigation for the Bureau. This

preliminary investigation showed that a comprehensive and far-reaching helium resources evaluation program was needed. G. Sherburne Rogers (38) of the U.S. Geological Survey was assigned to the Bureau in 1918 and given the task of searching for additional helium supplies. His 1921 report on helium in natural gas was considered the most authoritative source on helium resources for many years.

During 1919 to 1933, the helium resources evaluation program resulted in the discovery of a gas containing 1.8 percent helium at Cliffside field in Potter County, Tex. The Government acquired the gas rights and built a helium plant, in 1929, near Amarillo, Tex., to process the Cliffside gas. The program was relatively inactive from July 1933 to April 1941 until World War II when the program was intensified and resulted in the location of gas supplies for an additional four helium plants. After the war ended, production capacity of the five plants was greater than postwar demand, and only one plant operated continuously from 1945 to 1959. Production from this plant after 1945 in excess of the Federal demand was stored underground in the Bureau's Cliffside field.

The program resulted in the discovery of a gas containing 2.1 percent helium in the Keyes field in Oklahoma. In 1959, the Bureau built a plant near Keyes, Okla., to process the gas produced from the field. By 1968, three of the plants built during World War II were permanently shut down owing to depleting gas supplies. In 1970 and 1971, two plants stopped purification operations, and only the Keyes plant continued to produce helium for Federal use.

Conservation Programs

Congress passed legislation in 1960 implementing a helium conservation program. Long-term contracts with four private firms were negotiated by the Government to purchase helium that would have been otherwise lost. Five extraction plants were built adjacent to large natural gas transmission lines in Texas and Kansas. Most of the gas processed was produced from the West Panhandle field of Texas and the Hugoton field in Texas, Oklahoma, and Kansas, which contain the largest known helium reserves in the world. The extracted helium was stored in the Government-owned Bush Dome storage reservoir of Cliffside field in Potter County, Tex. When this helium is needed, it will be withdrawn, purified, and sold.

As of October 1, 1978, helium stored in Bush Dome totaled 39.7 billion cubic feet measured at a pressure and temperature base of 14.7 pounds per square inch, absolute, and 70° F. This volume consisted of 37.8 billion cubic feet of helium purchased and/or accepted for storage and 1.9 billion cubic feet stored under separate contracts for private companies.

Thus, approximately 60 years after the discovery of helium in natural gas, the program has resulted in the conservation of about 40 billion cubic feet of helium stored in the Bureau underground storage reservoir near Amarillo, Tex., and the 340 gas analyses from 14 States reported by Rogers (38) in 1921 have been expanded to include over 15,000 gas analyses from 37 States and 23 foreign countries.

DATA BASE

The information used in this investigation is based on the helium resources evaluation data collected by the Bureau from 1917 to 1974. Some analyses were excluded from the investigation because they were pipeline samples, foreign samples, air-contaminated, or incomplete analyses.

A reservoir tape file was prepared from the computer tape file,⁴ using only analyses from gas wells located in the United States with known geologic systems. Analyses from the same well were grouped together to obtain an average analysis and to reduce the effect that several individual analyses from the same reservoir might have on the distribution. The resultant reservoir tape file utilized as the data base for the investigation is made up of 10,086 analyses and represents 6,455 natural gas reservoirs in 35 States.

In this report, a natural gas reservoir is defined as a porous rock that has produced some volume of gas. Each reservoir considered is a computer match of geologic system, State, county, field, and formation made from the reservoir tape file. A reservoir may have been penetrated by one or more wells that may or may not be productive.

Some of the reservoirs may be represented more than once owing to the computer procedure of matching the analyses data. This additional representation may occur, for example, when a gas sample is obtained from a well while it is in wildcat status. Changes in the field name or well status may also result in additional samples being obtained from the same well or field, but under different names or status. It would be a monumental task to eliminate this type of error because of the computer matching procedure. Although this problem tends to increase the total number of reservoirs and could increase the number of reservoirs containing the higher concentrations of helium, duplications do not materially affect the results of this investigation.

DEVELOPMENT OF RELATIONSHIPS

This investigation was carried out to evaluate the relationship or association, if any, of helium with geographic location, geologic age, reservoir depth, and the inert gases, nitrogen, carbon dioxide, and argon. Although helium has been known as a minor constituent of natural gas since 1905 and its association with nitrogen was discussed by Rogers in 1921, no other publication has developed statistical relationships with helium found in natural gas and geographic location, geologic system, reservoir depth, or gas composition over a wide range of geographic locations.

The gas samples on which this study is based are considered a fair and representative sampling of the natural gas-producing areas of the United States. Therefore, the gas analysis data are statistical data, and information that can be used for predicting or estimating maximum expectations of helium in natural gas areas, reservoirs, or wells in the United States.

⁴Work cited in footnote 3.

The information can be evaluated statistically in terms of the limits of relative frequencies. The number of reservoirs that fall within a particular group, divided by the total number of reservoirs of all groups, is the relative frequency and generally expresses as a percentage. The relative frequency with which an event occurs in the long run is its probability. The proportion in which reservoirs appear in the various percentage ranges shown in the tables can be expressed as probabilities or probability percentages.

The investigation is concerned with measures to predict the helium content in natural gas in terms of geologic factors and gas composition; however, this was not possible to achieve and, at best, only averages or expected values can be predicted. Predictions that describe the relationship between helium found in natural gas and these variables can be made in a qualitative manner by directly observing the scatter diagrams shown in the figures. However, to determine the degree of scattering of the data about a line, quantitatively, it is necessary to use measures of correlation for describing the relationship. The correlation coefficient is a measure of the departure or scatter of the data about a line, and it is used in this report to determine how well a linear equation describes or explains the relationship between the particular variables. Therefore, it is of interest to know the degree of relationship between two variables to help describe or explain any relationships that might exist.

When the number of observations or groups is small, the rank correlation test is a measure for determining the relationship between variables.⁵ In this test, one group of paired variables is ranked in some order and numbered in series. The other variable is also ranked for each variable in the first group. Instead of using the actual values of the variables, the data are ranked in order of size, importance, or other criteria using numbers 1, 2, 3, . . . , N. When two variables are ranked in this manner, the "rank correlation coefficient" is given by

$$R = 1 - \frac{6\sum D^2}{N(N^2-1)}$$

where D = differences between ranks of corresponding variables,

N = number of pairs of variables.

This is Spearman's formula for rank correlation, and it is a linear measure of the degree of scattering of the data (40-41, 44). Nonlinear correlation measures were not used. Values of the rank correlation coefficient, R, range between -1 and +1. The $\pm$ signs are used to indicate a positive or

⁵Because 81 percent of the reservoirs contained less than 10 percent nitrogen, a correlation coefficient calculated from the percent nitrogen and percent helium of the 6,445 reservoirs (with nitrogen) would be dominated by the reservoirs with low nitrogen. For this reason, the rank correlation coefficient was used to show the relationships over the full range of nitrogen percentages. A similar situation exists for carbon dioxide and argon.

negative slope trend (positive or negative correlation). A value of zero is equivalent to no correlation, whereas a value of ± 1 would indicate perfect correlation. The computed value, R , measures the degree of relationship relative to a linear equation. Therefore, if the computed value of R is near zero, it means that there is almost no linear relationship between the variables although there may actually be a high nonlinear relationship between the variables. The correlation coefficient, therefore, measures the goodness of fit of the type equation assumed for the data.

The rank correlation coefficient, R , is computed after all the data have been arranged and ranked. The customary practice is to then compare the computed R with tabulated values (41, 44) at the 5-percent and 1-percent probability levels. If the computed value is equal to or greater than the table value at the 5-percent probability level, but less than the table value at the 1-percent probability level, the rank correlation coefficient is considered significant. This indicates that the chances are 5 or less in 100 of being wrong, that there is a linear relationship between the variables. If the computed R is equal to or greater than the table value at the 1-percent probability level, the rank correlation coefficient is considered highly significant and indicates a 1-percent or less probability of error that there is a linear relationship between the variables. Values of the computed correlation coefficient smaller than the values tabulated at the 5-percent probability level are considered not significant.

The rank correlation coefficient and the significance levels have been determined to test or establish relationships with helium content and geologic factors, and with the component gases, nitrogen, carbon dioxide and argon, found in natural gas.

GEOLOGIC SYSTEMS

Two parallel classifications are usually used to identify the time necessary to form the rock and the rock units of the earth. These have been termed geologic-time units and time-stratigraphic units, respectively (16). The time-stratigraphic units differ from the descriptive classifications of the time necessary to form the rock in that the rock boundaries are based on geologic time units and are a subdivision of rocks considered solely as the record of a specific interval of geologic time. The *erathem*⁶ is a time-stratigraphic unit composed of a chronological sequence of systems. The system is a fundamental unit of worldwide time stratigraphic classification of rocks. The reservoir rocks range in age from about 1 million years for the younger Cenozoic rocks to about 600 million years for the older Paleozoic rocks. The age of the reservoir rock, however, does not necessarily indicate the time at which natural gas accumulated in it. Also, the depth of a reservoir is not necessarily an indication of its age.

⁶American Commission on Stratigraphic Nomenclature. Code of Stratigraphic Nomenclature, 1970. The American Association of Petroleum Geologists, Inc., Tulsa, Okla.

The geologic time scale shown in table 2 lists the chronological arrangement of the units used to measure the age of reservoir rocks. The Cenozoic (two systems) and Mesozoic (three systems) Erathems each have about 17 percent of the 6,455 reservoirs investigated, while the Paleozoic Erathem (eight systems)⁷ accounts for 66 percent of the reservoirs. Thirty percent of the reservoirs and 31 percent of the samples were obtained from the Pennsylvanian System of Paleozoic age. Table 3 summarizes the reservoir gases for four selected reservoir depths found in each reservoir system. Methane is included for identification and comparative purposes only and is not discussed further.

TABLE 2. - Geologic time scale with depth and reservoir information for U.S. natural gas reservoirs

Geologic time scale, erathem and system	Age, million years	Depth, feet			Reservoirs ¹		Analyses	
		Minimum	Maximum	Average	No.	Pct of total	No.	Pct of total
Cenozoic:	1-60	120	20,440	6,690	1,104	17.1	1,271	12.6
Quaternary.....		187	8,350	3,701	46	.7	55	.5
Tertiary.....		120	20,440	6,820	1,058	16.4	1,216	12.1
Mesozoic:	60-200	200	18,207	5,309	1,089	16.8	1,431	14.2
Cretaceous.....		301	14,124	5,177	910	14.1	1,194	11.8
Jurassic.....		210	18,207	6,714	151	2.3	192	1.9
Triassic.....		200	10,819	2,008	28	.4	45	.5
Paleozoic:	200-600	118	22,566	4,937	4,252	66.0	7,384	73.2
Permian.....		190	15,257	3,259	468	7.3	1,738	17.2
Pennsylvanian.....		118	21,604	5,350	1,945	30.1	3,087	30.6
Mississippian.....		205	18,431	3,936	748	11.6	1,053	10.4
Devonian.....		309	22,566	5,427	519	8.0	612	6.1
Silurian.....		720	18,988	4,569	261	4.0	312	3.1
Ordovician.....		280	21,630	7,724	228	3.5	333	3.3
Cambrian and Ordovician...		1,350	11,440	4,037	63	1.0	159	1.6
Cambrian.....		1,476	10,086	4,004	30	.5	90	.9
All systems.....		118	22,566	5,301	6,455	100	10,086	100

¹These numbers represent the reservoirs determined from gas well samples analyzed for helium with known geologic systems. The number of reservoirs used in the depth, nitrogen, carbon dioxide, and argon studies differ from those shown here because of incomplete gas analyses and/or insufficient information accompanying the gas sample.

⁷The Paleozoic Erathem contains seven systems. However, because some geologists question whether certain reservoir rocks belong in the Ordovician System or the Cambrian System, an additional system (Cambrian and Ordovician) has been included in this erathem to indicate this uncertainty.

TABLE 3. - Selected reservoir depths and mole-percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon, for each geologic system

Geologic system	Reservoir depth, feet	Component gases, mole-percent				
		Helium	Methane	Nitrogen	Carbon dioxide	Argon
Quaternary.....	¹ 4,315	0.15	99.3	0.0	0.0	0.0
	² 3,701	.01	91.4	3.0	.8	(⁶)
	³ 187	.12	90.6	5.8	.4	.0
	⁴ 8,350	(⁵)	93.9	.5	.2	(⁷)
Tertiary.....	¹ 2,450	.45	73.6	11.3	.1	.0
	² 6,820	.01	89.5	1.7	.7	(⁶)
	³ 120	(⁵)	13.3	85.8	.5	.0
	⁴ 20,440	(⁵)	92.7	.6	1.4	.0
Cretaceous.....	¹ 453	1.04	78.4	19.8	.2	(⁷)
	² 5,177	.05	84.1	3.6	1.8	(⁶)
	³ 301	(⁵)	76.4	5.7	8.1	(⁷)
	⁴ 14,124	(⁵)	89.2	.2	8.0	.0
Jurassic.....	¹ 959	7.51	.1	75.6	14.1	(⁷)
	² 6,714	.29	70.2	10.4	7.6	.01
	³ 210	(⁵)	.0	.6	99.4	(⁷)
	⁴ 18,207	.01	69.4	2.6	2.5	.0
Triassic.....	¹ 1,196	9.23	.0	89.5	.7	.8
	² 2,008	2.53	19.4	45.0	29.2	.17
	³ 200	5.13	.3	93.5	.2	.4
	⁴ 10,819	.05	1.3	3.7	94.4	.1
Permian.....	¹ 1,354	9.74	.1	88.9	.7	.7
	² 3,259	.51	62.0	21.1	2.8	.03
	³ 190	.52	.1	97.9	1.3	.0
	⁴ 15,257	.01	94.4	.7	.6	.0
Pennsylvanian.....	¹ 6,514	8.00	12.8	70.1	.9	.7
	² 5,350	.32	77.4	8.5	1.0	.01
	³ 118	.01	35.8	61.3	1.9	.7
	⁴ 21,604	.02	94.8	.3	4.6	.0
Mississippian.....	¹ 6,950	8.01	9.8	75.4	.5	(⁷)
	² 3,936	.42	74.6	8.7	3.4	.02
	³ 205	(⁵)	97.0	.4	2.6	.0
	⁴ 18,431	.26	6.1	6.4	86.6	.1
Devonian.....	¹ 6,020	7.80	.6	90.5	.1	1.0
	² 5,427	.25	79.7	5.9	2.3	.02
	³ 309	(⁵)	45.6	3.5	.6	(⁷)
	⁴ 22,566	.06	91.6	3.5	4.7	.0

See footnotes at end of table.

TABLE 3. - Selected reservoir depths and mole-percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon, for each geologic system--Continued

Geologic system	Reservoir depth, feet	Component gases, mole-percent				
		Helium	Methane	Nitrogen	Carbon dioxide	Argon
Silurian.....	¹ 4,180	0.90	67.3	29.5	0.1	0.1
	² 4,569	.15	82.1	5.2	.8	(⁶)
	³ 720	.22	84.6	3.2	.0	.0
	⁴ 18,988	.03	96.3	1.0	1.7	.0
Ordovician.....	¹ 4,026	2.72	46.9	41.6	.1	.2
	² 7,724	.24	72.6	6.7	2.2	.01
	³ 280	.10	80.2	9.4	.4	(⁷)
	⁴ 21,630	.02	98.0	.3	1.5	.0
Cambrian and Ordovician.	¹ 3,556	6.50	12.0	77.2	.4	.2
	² 4,037	1.80	66.6	20.0	.4	.05
	³ 1,350	1.22	64.3	15.1	.2	(⁷)
	⁴ 11,440	.07	85.9	2.1	.2	.0
Cambrian.....	¹ 3,902	5.50	.6	92.9	.3	.7
	² 4,004	.99	56.0	27.0	5.8	.07
	³ 1,476	.05	.3	95.1	1.8	1.4
	⁴ 10,086	.40	7.5	89.3	.7	.2
All systems ⁸	5,301	0.27	78.6	7.6	1.9	.01

¹Depth and mole-percentages of selected gas components of the reservoir with the maximum observed system helium content.

²Depth and mole-percentages of selected gas components of the average reservoir in the system.

³Depth and mole-percentages of selected gas components of the shallowest reservoir in the system.

⁴Depth and mole-percentages of selected gas components of the deepest reservoir in the system.

⁵Less than 0.005 mole-percent.

⁶Less than 0.01 mole-percent.

⁷Unknown percentage.

⁸Composite average of all systems.

GEOGRAPHIC DISTRIBUTION OF HELIUM AND GEOLOGIC SYSTEM RESERVOIRS

Helium content is divided into 11 helium content ranges, ranging from less than 0.005 percent to greater than 10 percent of helium. None of the reservoirs, however, contained 10 percent or more of helium in the gas. Only 11.5 percent of the reservoirs contained gas with less than 0.005 percent of helium, indicating that most reservoirs contain some helium. Essentially, all of the gas samples of recent years contained at least a trace (0.005 percent) of helium. Some of the older analyses showed no helium present; however, it is believed that the more precise analytical equipment available

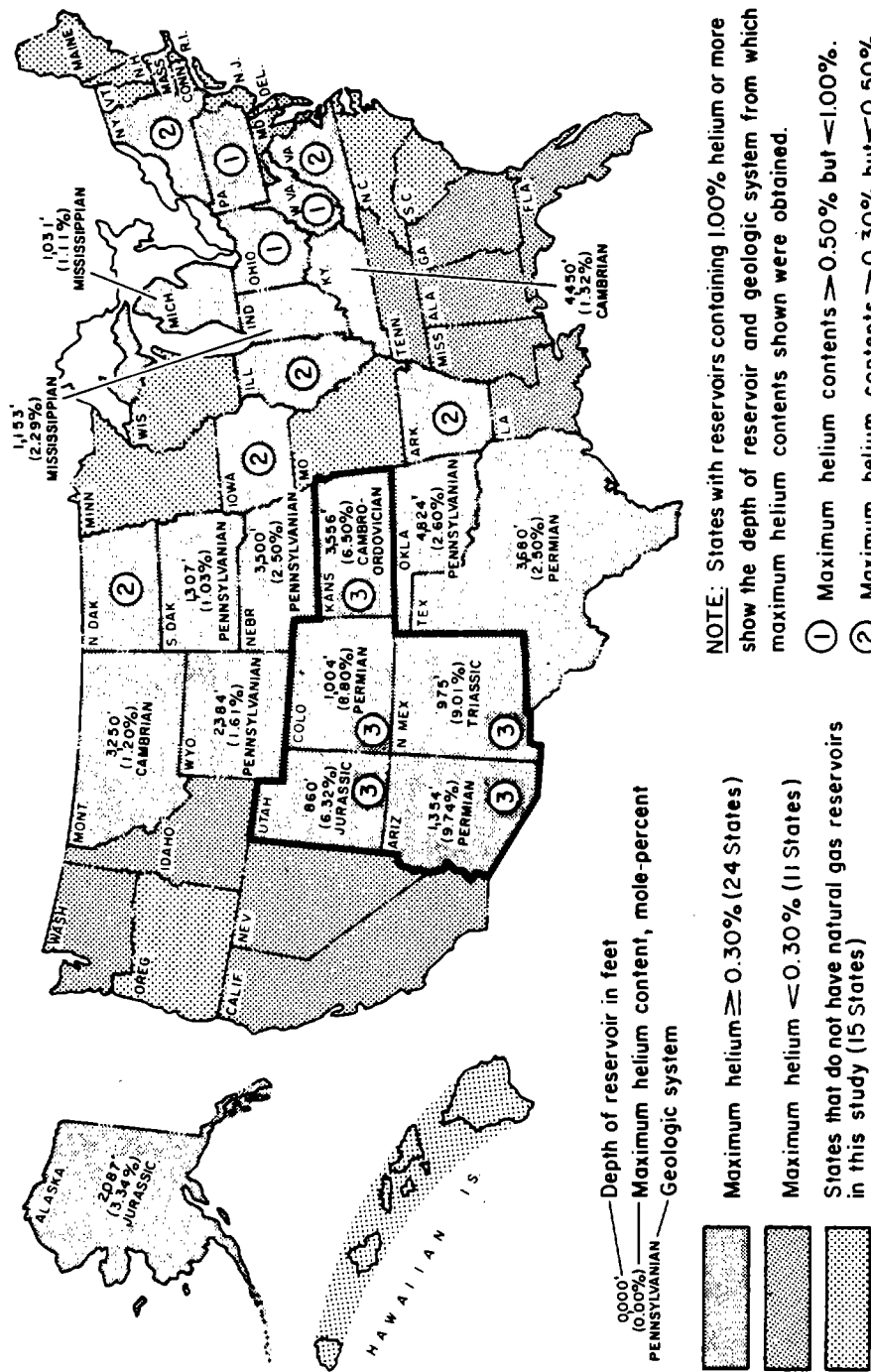


FIGURE 1. - Geographic distribution of maximum observed helium contents in U.S. natural gas reservoirs.

today would confirm that all natural gas contains some helium. When a gas is analyzed for helium in the conventional manner, the mole-percentage is not determined beyond the nearest 0.005 of 1 percent. (Other components in the sample are not determined beyond the nearest 0.05 of 1 percent.)

Reservoirs in 24 States contained gas with 0.30 percent⁸ or more of helium. Eleven States had no reservoirs that contained over 0.29 percent of helium in the gas, and 15 States had no natural gas production. Figure 1 shows the distribution of helium in natural gas reservoirs of the United States. Reservoirs in States containing 1 percent or more of helium show the highest helium content observed and the geologic system and reservoir depth from which the gas was obtained. All of the reservoirs with 5 percent or more of helium are found in the five States (Arizona, Colorado, Kansas, New Mexico, and Utah) outlined in the figure. Table A-1 lists the geologic system, reservoir depth, and gas analysis data for all of the reservoirs that contained 1 percent or more of helium. Information is listed from the shallowest through the deepest reservoir for each State. Ninety percent of the helium reserves of the United States, containing 0.30 percent or more of helium in the natural gas (24), are in Texas, Oklahoma, and Kansas. These States also account for about 43 percent of the estimated proved natural gas reserves of the United States. Table 4 lists the States with the number of reservoirs in each and the distribution of these reservoirs in various helium content ranges.

Five geologic systems (Pennsylvanian, Tertiary, Cretaceous, Mississippian, and Devonian) account for over 80 percent of the reservoirs studied. Sixty-one percent of the gas samples are from Texas, Oklahoma, and Kansas, and these States represent 55 percent of the reservoirs studied. Table 5 shows the distribution of reservoirs by geologic system⁹ for each of the 35 States from which gas samples were obtained.

⁸A value of 0.30 percent was arbitrarily selected for this report and has no other particular significance.

⁹Geologic systems are abbreviated in some tables. These abbreviations and the words they represent are as follows: QUAT--Quaternary, TERT--Tertiary, CRET--Cretaceous, JURA--Jurassic, TRIA--Triassic, PERM--Permian, PENN--Pennsylvanian, MISS--Mississippian, DEVO--Devonian, SILU--Silurian, ORDO--Ordovician, CAMO--Cambrian and Ordovician, and CAMB, Cambrian.

TABLE 4. - Distribution of helium in U.S. natural gas reservoirs for 35 States

STATE	HELIUM CONTENT IN PERCENTAGE												GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES
	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99					
ALABAMA	0	1	1	0	0	0	0	0	0	0	0	0	2	2	
ALASKA	7	8	0	0	0	0	0	0	0	0	0	0	16	25	
ARIZONA	2	2	2	1	8	4	0	5	12	11	0	0	47	102	
ARKANSAS	7	56	69	2	0	0	0	0	0	0	0	0	134	150	
CALIFORNIA	71	43	1	0	0	0	0	0	0	0	0	0	115	136	
COLORADO	34	154	47	17	28	6	3	4	0	5	0	0	298	403	
FLORIDA	0	3	0	0	0	0	0	0	0	0	0	0	3	3	
GEORGIA	0	0	1	0	0	0	0	0	0	0	0	0	1	1	
IDAHO	4	1	0	0	0	0	0	0	0	0	0	0	5	8	
ILLINOIS	2	3	14	1	0	0	0	0	0	0	0	0	20	24	
INDIANA	1	5	18	9	4	0	1	0	0	0	0	0	38	48	
IOWA	1	0	0	1	0	0	0	0	0	0	0	0	2	4	
KANSAS	3	17	191	121	167	138	34	11	4	0	0	0	686	1290	
KENTUCKY	2	31	52	9	0	1	0	0	0	0	0	0	95	107	
LOUISIANA	132	107	12	0	0	0	0	0	0	0	0	0	251	283	
MARYLAND	0	8	0	0	0	0	0	0	0	0	0	0	8	8	
MICHIGAN	2	21	43	24	26	2	0	0	0	0	0	0	118	145	
MISSISSIPPI	1	34	6	0	0	0	0	0	0	0	0	0	41	45	
MONTANA	6	59	41	6	6	4	0	0	0	0	0	0	122	164	
NEBRASKA	0	4	10	1	0	1	1	0	0	0	0	0	17	21	
NEVADA	0	2	0	0	0	0	0	0	0	0	0	0	2	2	
NEW MEXICO	14	193	52	8	2	7	7	11	15	10	0	0	319	606	
NEW YORK	5	23	26	1	0	0	0	0	0	0	0	0	55	69	
NORTH DAKOTA	1	16	4	1	0	0	0	0	0	0	0	0	22	26	
OHIO	7	20	133	18	5	0	0	0	0	0	0	0	183	213	
OKLAHOMA	36	500	401	41	35	19	8	0	0	0	0	0	1040	1752	
PENNSYLVANIA	5	79	66	1	1	0	0	0	0	0	0	0	152	169	
SOUTH DAKOTA	0	2	0	0	0	1	0	0	0	0	0	0	3	3	
TENNESSEE	0	2	1	0	0	0	0	0	0	0	0	0	3	5	
TEXAS	335	969	346	77	84	17	3	0	0	0	0	0	1831	3154	
UTAH	8	68	24	12	27	13	2	0	1	0	0	0	155	302	
VIRGINIA	1	5	7	1	0	0	0	0	0	0	0	0	14	17	
WASHINGTON	2	0	0	0	0	0	0	0	0	0	0	0	2	6	
WEST VIRGINIA	5	184	129	8	3	0	0	0	0	0	0	0	329	376	
WYOMING	47	229	34	2	10	4	0	0	0	0	0	0	326	418	
TOTAL	741	2849	1731	362	406	217	59	32	32	26	0	0	6455	10086	

TABLE 5. - State distribution of U.S. natural gas reservoirs according to geologic system

STATE	GEOLOGIC SYSTEM													NUMBER OF RESERVOIRS	NUMBER OF SAMPLES
	QUAT	TERT	CRET	JUKA	THIA	PERM	PENN	MISS	DEVO	SILU	OKDO	CAMO	CAMB		
ALABAMA	0	0	0	1	0	0	0	1	0	0	0	0	0	2	2
ALASKA	0	9	3	3	0	1	0	0	0	0	0	0	0	16	25
ARIZONA	0	0	1	0	8	12	14	6	6	0	0	0	0	47	102
ARKANSAS	22	60	31	14	0	3	108	1	1	0	1	0	0	134	150
CALIFORNIA	0	23	175	21	4	9	51	14	1	0	0	0	0	115	136
COLORADO	0	0	0	3	0	0	0	0	0	0	0	0	0	298	403
FLORIDA	0	0	1	0	0	0	0	0	0	0	0	0	0	3	3
GEORGIA	0	4	0	0	0	0	0	1	0	0	0	0	0	1	1
IDAHO	0	0	0	0	0	0	0	0	0	0	0	0	0	5	8
ILLINOIS	0	0	0	0	0	0	0	15	1	1	0	0	0	20	24
INDIANA	0	0	0	0	0	0	2	16	4	1	15	0	0	38	48
IOWA	0	0	0	0	0	0	0	0	0	0	2	0	0	2	4
KANSAS	0	0	1	0	0	71	330	171	2	0	42	58	11	686	1290
KENTUCKY	0	0	0	0	0	0	5	47	31	9	1	1	1	95	107
LOUISIANA	20	156	60	15	0	0	0	0	0	0	0	0	0	251	283
MARYLAND	0	0	0	0	0	0	0	0	8	0	0	0	0	8	8
MICHIGAN	1	0	0	1	0	0	0	56	17	38	5	0	0	118	145
MISSISSIPPI	0	6	26	5	0	0	0	4	0	0	0	0	0	41	45
MONTANA	0	0	74	12	0	1	3	14	9	1	5	0	3	122	164
NEBRASKA	0	0	15	0	0	0	1	0	0	0	0	0	1	17	21
NEVADA	1	0	0	0	0	0	0	0	0	0	0	0	1	2	2
NEW MEXICO	0	0	82	0	6	78	108	18	21	3	1	0	2	319	606
NEW YORK	0	0	0	0	0	0	0	0	26	23	6	0	0	55	69
NORTH DAKOTA	0	0	2	0	1	0	2	7	5	2	3	0	0	22	26
OHIO	1	0	0	0	0	0	7	15	6	136	8	0	10	183	213
OKLAHOMA	0	5	1	0	0	49	736	117	61	1	67	3	0	1040	1752
PENNSYLVANIA	0	0	0	0	0	1	7	10	125	8	1	0	0	152	169
SOUTH DAKOTA	0	0	2	0	0	0	1	0	0	0	0	0	0	3	3
TENNESSEE	0	0	0	0	0	0	0	2	0	0	1	0	0	3	3
TEXAS	1	732	183	36	2	216	493	27	55	17	68	1	0	1831	3154
UTAH	0	24	34	20	4	11	35	20	7	0	0	0	0	155	302
VIRGINIA	0	0	0	0	0	0	1	10	3	0	0	0	0	14	17
WASHINGTON	0	2	0	0	0	0	0	0	0	0	0	0	0	2	6
WEST VIRGINIA	0	0	0	0	0	0	12	167	129	21	0	0	0	329	375
WYOMING	0	36	214	19	3	16	25	9	1	0	2	0	1	326	418
TOTAL	46	1058	910	151	28	468	1945	748	519	261	228	63	30	6455	10086

HELIUM CONTENT OF RESERVOIRS BY GEOLOGIC SYSTEM

For convenience, the 11 helium content ranges have been summarized into the following five groups for comparative and evaluation purposes: (1) reservoirs containing less than 0.10 percent of helium, (2) reservoirs containing 0.10 percent through 0.29 percent of helium, (3) reservoirs containing 0.30 percent or more of helium, (4) reservoirs containing 1 percent or more of helium, and (5) reservoirs containing 5 percent or more of helium in the gas. These five percentage groups were selected for purposes of this report and have no other particular significance.

The helium-geologic system study includes 6,455 reservoirs, represented by 10,086 gas samples with 1,134 reservoirs containing 0.30 percent or more of helium. Three hundred sixty-six of these reservoirs contained 1 percent or more of helium, and 58 contained 5 percent or more of helium. Gases with the highest helium contents were found in the reservoir rocks of Jurassic age or older with the Silurian rocks being the exception. Quaternary age rocks do not contain any reservoirs with helium contents over 0.15 percent. Reservoirs with the highest helium contents found in each of the geologic systems do not necessarily occur at a particular stratigraphic position within the system.

Table 6 shows the distribution of natural gas reservoirs according to geologic erathem for reservoirs containing less than 0.10 percent of helium, 0.10 percent through 0.29 percent of helium, and 0.30 percent or more of helium. This table was prepared to show helium distribution according to erathem (Cenozoic, Mesozoic, and Paleozoic) for comparison with previously published material (32). Reservoirs with less than 0.10 percent of helium account for about 55.6 percent of all reservoirs studied, reservoirs containing 0.10 percent through 0.29 percent of helium account for 26.8 percent, and reservoirs with 0.30 percent or more of helium account for 17.6 percent of the total. The information in table 6 is summarized in figure 2.

TABLE 6. - Distribution of U.S. helium-bearing natural gas reservoirs by geologic erathem

Erathem	(He <0.1%)		(0.1% ≤He <0.3%)		(He ≥0.3%)		Total	
	No.	Pct	No.	Pct ¹	No.	Pct ¹	No.	Pct ²
Cenozoic.....	1,082	98.0	14	1.3	8	0.7	1,104	17.1
Mesozoic.....	877	80.5	150	13.8	62	5.7	1,089	16.9
Paleozoic.....	1,631	38.2	1,567	36.8	1,064	25.0	4,262	66.0
Total.....	3,590	55.6	1,731	26.8	1,134	17.6	6,455	100.0

¹Percent of reservoirs in age group.

²Percent of all reservoirs.

Table 7 shows that the percentage of reservoirs with less than 0.10 percent of helium in the gas decreases as the geologic age increases and that reservoirs with 0.10 percent or more of helium in the gas increases as the geologic age increases. One-fourth of the reservoirs of Paleozoic age contained 0.30 percent or more helium. The average helium contents are 0.01 percent for Cenozoic reservoirs, 0.15 percent for Mesozoic reservoirs, and 0.36 percent for Paleozoic reservoirs. The average helium content of the gas from all 6,455 natural gas reservoirs is 0.27 percent.

TABLE 7. - Distribution of 6,455 U.S. natural gas reservoirs according to helium content by geologic system

Geologic system	Reservoirs and helium content ¹														Total	Helium content, mole-percent	
	(He <0.10)			(0.10≤He<0.30)			(He ≥0.30)			(He ≥1.00)			(He ≥5.00)				
	No.	Pct2		No.	Pct2		No.	Pct2		No.	Pct2		No.	Pct2			
Quaternary.....	44	95.7	2	4.3	0	0	0	0	0	0	0	0	46	0.15	0.01		
Tertiary.....	1,038	98.1	12	1.1	8	.8	0	0	0	0	0	0	1,058	.85	.01		
Cretaceous.....	769	84.5	119	13.1	22	2.4	1	.1	0	0	0	0	910	1.04	.05		
Jurassic.....	98	64.9	27	17.9	26	17.2	5	3.3	2	1.3	2	1.3	151	7.51	.28		
Triassic.....	10	35.7	4	14.3	14	50.0	13	46.4	8	28.6	8	28.6	28	9.23	2.53		
Permian.....	197	42.1	84	17.9	187	40.0	46	9.8	10	2.1	10	2.1	468	9.74	.51		
Pennsylvanian.	671	34.5	803	41.3	471	24.2	142	7.3	11	.6	11	.6	1,945	8.00	.32		
Mississippian.	238	31.8	283	37.8	227	30.3	65	8.7	12	1.6	12	1.6	748	8.01	.42		
Devonian.....	332	64.0	153	29.4	34	6.6	20	3.9	10	1.9	10	1.9	519	8.11	.25		
Silurian.....	60	23.0	180	69.0	21	8.0	0	0	0	0	0	0	261	.90	.15		
Ordovician....	124	54.4	57	25.0	47	20.6	17	7.5	0	0	0	0	228	2.72	.24		
Cambrian and Ordovician ³ ..	3	4.7	2	3.2	58	92.1	43	78.3	4	6.3	4	6.3	63	6.50	1.80		
Cambrian.....	6	20.0	5	16.7	19	63.3	14	46.7	1	3.3	1	3.3	30	5.50	.99		
All systems...	3,590	55.6	1,731	26.8	1,134	17.6	366	5.7	58	0.9	58	0.9	6,455	9.74	0.27		

¹Helium content in mole-percent.

²Percent of total system reservoirs.

³See footnote 7 of text.

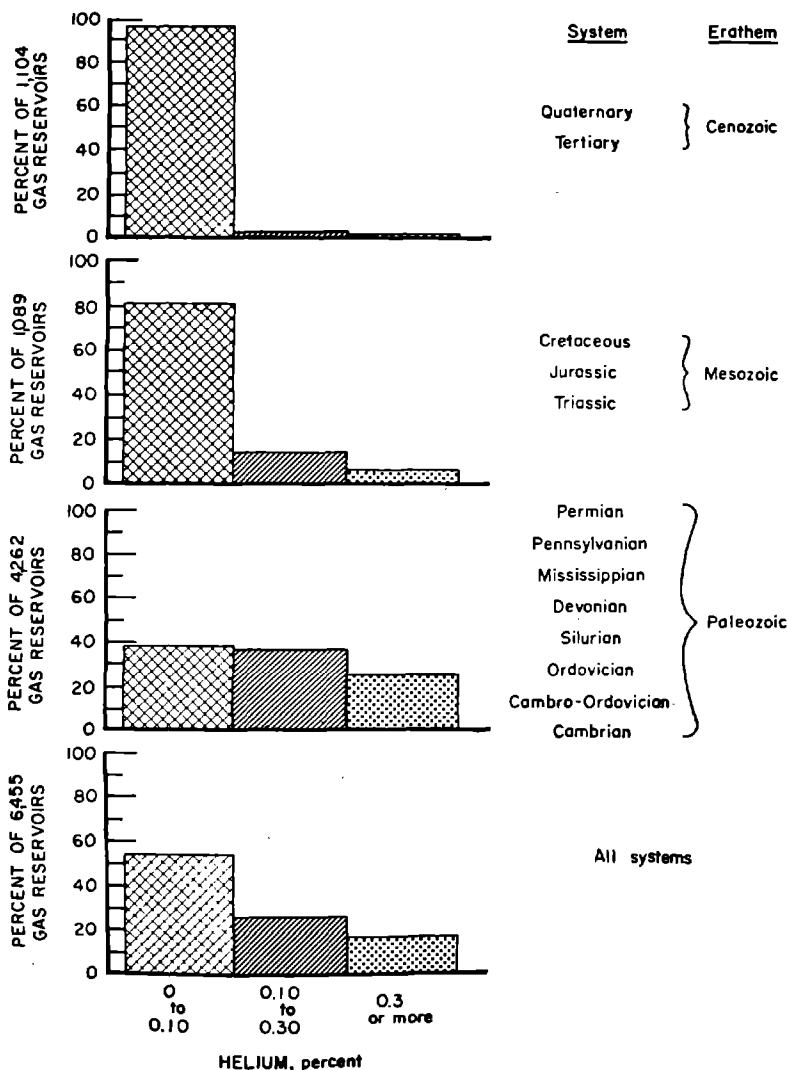


FIGURE 2. - Distribution of U.S. helium in three percentage groups according to age of the reservoir rock.

containing 0.30 percent or more of helium tends to increase with age through the five systems of the Cenozoic and Mesozoic, but the trend is reversed through the first four systems of the Paleozoic.

Table 8 lists the number of reservoirs in 11 different helium content ranges for each of the geologic systems investigated, from the youngest (Quaternary) through the oldest (Cambrian). Figure 3 shows the percentage of system reservoirs in each of the helium content groups versus geologic system, and it also shows the maximum and average helium contents of each system.

Figure 2 shows that when helium distribution is compared with geologic age, the older erathems contain a larger percentage of reservoirs with 0.30 percent or more of helium. Pierce (32) published a paper in 1960 showing a plot (his figure 37.1) of helium content versus geologic erathem (Cenozoic, Mesozoic, Paleozoic) for gasfields of the United States. That figure is comparable to figure 2 of this investigation. In his paper, Pierce states that "the helium content in gas fields tends to increase systematically with the geologic age of the reservoir rock as would be expected if the helium were derived from slow decay of uranium and thorium in rocks."

When the geologic age is divided into the individual geologic systems and accumulated as shown in table 7, the increase in helium content with age of system is not so apparent or systematic as it appears to be in figure 2. The percentage of reservoirs

TABLE 8. - Distribution of U.S. natural gas reservoirs in geologic systems

GEOLOGIC SYSTEM RESERVOIR	LESS THAN .005 .09	.10 TO .29	.30 TO .49	HELIUM CONTENT IN PERCENTAGE												GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
				.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99										
QUATERNARY	37	7	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES					
TERTIARY	463	579	12	4	0	0	0	0	0	0	0	1058	1211	12					
CRETACEOUS	102	667	119	9	12	1	0	0	0	0	0	910	1194	18					
JURASSIC	15	83	27	7	14	1	1	1	1	1	0	151	192	13					
TRIASSIC	4	6	4	1	0	4	0	1	2	6	0	28	45	7					
PERMIAN	20	177	84	50	91	30	6	0	1	9	0	468	1738	12					
PENNSYLVANIAN	44	627	803	158	171	93	25	13	9	2	0	1945	3087	21					
MISSISSIPPIAN	12	226	283	89	73	31	15	7	8	4	0	748	1053	23					
DEVONIAN	19	313	153	8	6	3	3	4	6	4	0	519	612	21					
SILURIAN	10	50	180	19	2	0	0	0	0	0	0	261	312	13					
ORDOVICIAN	14	106	57	11	23	16	1	0	0	0	0	228	338	16					
CAMBRO-ORDOVICIAN	1	2	2	1	14	27	6	6	4	0	0	63	159	4					
CAMBRIAN	0	6	5	5	0	11	2	0	1	0	0	30	90	8					
TOTAL	741	2849	1731	362	406	217	59	32	32	26	0	6455	10086						

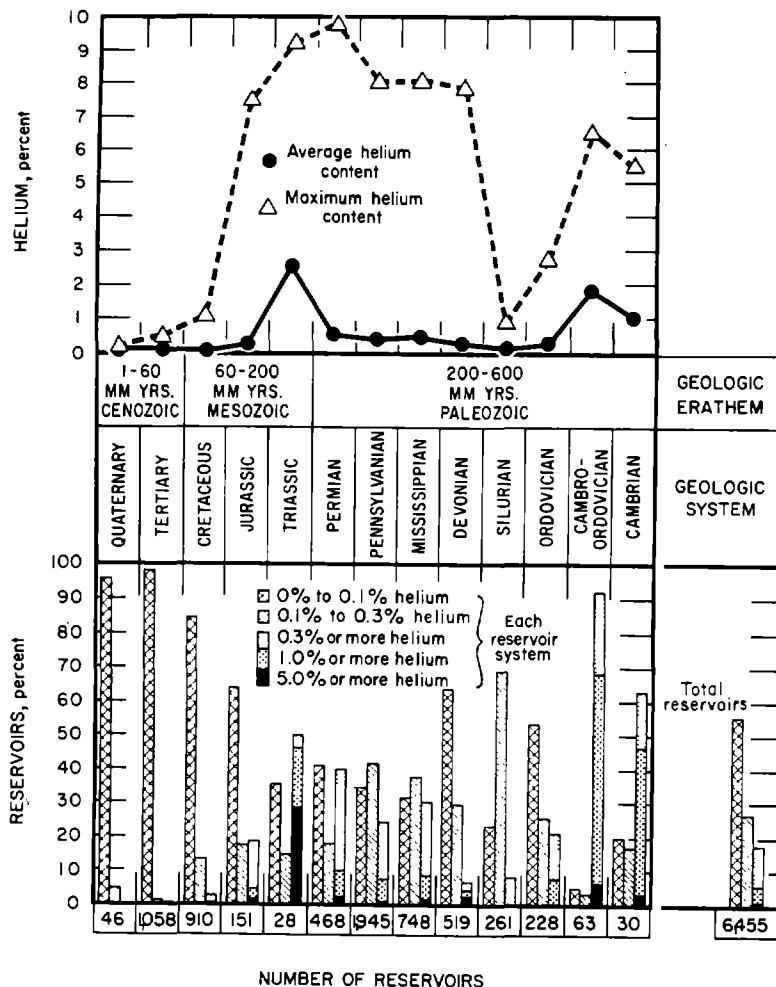


FIGURE 3. - Maximum and average helium contents of 6,455 U.S. natural gas reservoirs and percentage of these reservoirs containing various concentrations of helium by geologic system.

in which maximum system helium contents were found.

Maximum Helium Content of Reservoirs by Geologic System

The maximum helium contents for reservoirs in the two systems of the Cenozoic are 0.15 and 0.45 percent, with the highest percentage found in the Tertiary System, the oldest of the Cenozoic. The maximum helium contents in reservoirs of the three systems of the Mesozoic range from 1.04 to 9.23 percent. In these reservoirs the highest helium content is found in the Triassic, which is the oldest system of the Mesozoic Erathem. The Paleozoic Erathem includes eight geologic systems, and a trend is found opposite to those observed in reservoirs of the Cenozoic and Mesozoic. The maximum helium contents of reservoirs in these eight systems range from 0.90 to 9.74 percent, with the highest helium found in a Permian reservoir, the youngest system of the Paleozoic. Table 9 lists information concerning the geologic systems, depths, and the States

The lowest maximum-system-helium content for a reservoir of Paleozoic age was 0.90 percent, found in the Silurian System. This was followed by a maximum helium content of 2.72 percent for the Ordovician System. Maximum helium contents tend to be lower in the reservoirs of the older systems of the Paleozoic. However, the lowest maximum helium content found in any system of the Paleozoic was higher than the maximum helium content found in any system of the Cenozoic. All three systems of Mesozoic age have higher maximums than the Silurian System of the Paleozoic. The highest helium contents found by this study are in the six systems, from youngest to oldest, beginning with the middle of the Mesozoic (Jurassic System) through the middle of the Paleozoic (Devonian System). The helium contents range from 7.51 (Jurassic System) through 9.74 percent (Permian System).

TABLE 9. - Minimum, maximum, and average depths of U.S. reservoirs and their associated helium content by geologic system

Geologic system	Depth ¹						Maximum helium content of each geologic system ²		
	Minimum		Maximum		Average				State ²
	Depth, feet	Helium, pct	Depth, feet	Helium, pct	Depth, feet	Helium, pct	Depth, feet	Helium, pct	
Quaternary....	187	0.12	8,350	(³)	3,701	0.01	4,315	0.15	Calif.
Tertiary.....	120	(³)	20,440	(³)	6,820	.01	2,450	.45	Tex.
Cretaceous....	301	(³)	14,124	(³)	5,177	.05	453	1.04	Colo.
Jurassic.....	200	(³)	18,207	0.01	6,714	.28	959	7.51	Do.
Triassic.....	200	5.13	10,819	.05	2,008	2.53	1,196	9.23	Ariz.
Permian.....	190	.52	15,257	.01	3,259	.51	1,354	9.74	Do.
Pennsylvanian.	118	.01	21,604	.02	5,350	.32	6,514	8.00	N. Mex.
Mississippian.	205	(³)	18,431	.26	3,936	.42	6,950	8.01	Do.
Devonian.....	309	(³)	22,566	.06	5,427	.25	6,020	⁴ 7.80	Do.
Silurian.....	720	.22	18,988	.03	4,569	.15	4,180	.90	W. Va.
Ordovician....	280	.10	21,630	.02	7,724	.24	4,026	2.72	Kans.
Cambrian and Ordovician ⁵ ..	1,350	1.22	11,440	.07	4,037	1.80	3,556	6.50	Do.
Cambrian.....	1,476	.05	10,086	.40	4,004	.99	3,902	5.50	N. Mex.
All systems...	118	0.01	22,566	0.06	5,301	0.27	Nap	5.20	

Nap Not applicable.

¹Averages obtained from all reservoirs in each system and for all 6,455 reservoirs, helium in mole-percent.

²Depth of reservoir where maximum helium content was found and the State in which reservoir is located.

³Less than 0.005 mole-percent helium.

⁴The highest helium content observed in a Devonian reservoir was 8.11 percent, but the reservoir depth was not given. See Table A-1 for analysis data for reservoirs containing 1 percent or more of helium.

⁵See footnote 7 of text.

The Quaternary System did not have any reservoirs that contained 0.30 percent or more of helium. The trend of an increasing percentage of reservoirs containing 0.30 percent or more of helium goes from the Tertiary System through the Triassic System where the percentage reaches 50 (table 7). The trend then reverses from the Permian System through the Devonian System where the percentage is 6.6. The trend reverses again and reaches a high of 92 percent for the Cambrian and Ordovician System reservoirs, followed by 63 percent for reservoirs in the Cambrian System. The increase in the percentage of reservoirs containing 0.30 percent or more of helium with the age of the geologic system is not as systematic as implied by figure 2 for the geologic age groups shown.

Helium and Geologic System Correlation

Spearman's' formula (40-41, 44), after arranging and ranking the geologic systems from the youngest through the oldest and the maximum system helium contents from the lowest through the highest, respectively, gives a value of 0.214 for the coefficient of rank correlation. This value is not significant and an indication that there is no meaningful linear relationship between geologic system and maximum-system-helium content. The maximum-system-helium content does not tend to increase or decrease linearly with age of the reservoir rock.

The average helium content of all reservoirs in each geologic system is included on figure 3. The three geologic systems with the highest average helium contents are the Triassic with 2.53 percent, the Cambrian and Ordovician with 1.80 percent, and the Cambrian with 0.99 percent. The remaining 10 geologic systems have average helium contents ranging from about 0.01 to 0.51 percent. The coefficient of rank correlation yields a value of 0.512, indicating that the linear relationship between geologic system and average helium content is not significant.

There is a total of 1,134 reservoirs containing 0.30 percent or more of helium, and 1,064, or 93.8 percent, are found in the Paleozoic. The coefficient of rank correlation yields a value of 0.654, indicating a significant linear relationship between geologic system and reservoirs containing 0.30 percent or more of helium. The positive value indicates that, as the age of systems increase, the percent of reservoirs containing 0.30 percent or more of helium tends to increase linearly. Analyzing the reservoirs containing 0.10 through 0.29 percent of helium in a similar manner yields a coefficient of rank correlation of 0.402, which indicates that there is no significant linear relationship with geologic system age. The coefficient of rank correlation for the reservoirs containing less than 0.10 percent of helium is -0.824, which is highly significant and indicates a remarkable linear relationship between geologic system age and this group of reservoirs. The data assume a negative linear slope trend, indicating that the youngest systems have the largest percentages of reservoirs containing less than 0.10 percent of helium. The chances of finding reservoirs containing 0.30 percent or more of helium in the older geologic systems is more favorable than in the younger geologic system reservoirs. A tabulation of the rank correlation coefficients for the relationship between the various helium content groups and geologic systems is included in the Summary and conclusions.

Information presented in figure 3 illustrates that the relationships obtained from the correlation tests agree with the graphical results.

HELIUM CONTENT AND DEPTH OF RESERVOIR

The helium depth study included 6,270 reservoirs represented by 9,878 gas samples, with 1,089 reservoirs containing 0.30 percent or more of helium. Three hundred forty-five reservoirs contained 1 percent or more of helium, and 54 reservoirs contained 5 percent or more of helium in the gas. The deep natural gas reservoirs (below 9,000 feet) contained less helium than the shallow reservoirs (above 9,000 feet). There were 861 reservoirs at depths greater than 9,000 feet, and only 15 of these reservoirs contained 0.30 percent or more of helium. None of the 15 reservoirs contained 1 percent or more of helium in the gas. Each depth interval (1,000 feet) from 9 to 23,000 feet included reservoirs with some helium. The shallowest reservoir was found at 118 feet in the Pennsylvanian System and contained 0.01 percent of helium. The deepest reservoir was found at 22,566 feet in the Devonian System and contained 0.06 percent of helium. The highest helium content of 9.74 percent was found in a Permian System reservoir at a depth of 1,354 feet. Table 10 shows the number of reservoirs in the various depth intervals for each of the 16 geologic systems. The Cenozoic (two youngest systems) accounts for 17.5 percent of the reservoirs, the Mesozoic (three systems) accounts for 16.9 percent, and the Paleozoic (eight oldest systems) accounts for 65.6 percent of the reservoirs.

TABLE 10. - Depth distribution of U.S. natural gas reservoirs according to geologic system

GEOLOGIC SYSTEM																
DEPTH IN FEET	QUAT	TERT	CRET	JURA	TRIA	PERM	PENN	MISS	DEVO	SILU	ORDO	CAMO	CAMB	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
0 - 999	3	16	43	9	10	25	78	34	20	1	16	0	0	255	387	24
1000 - 1999	7	39	76	13	9	83	142	188	37	15	14	1	2	626	1126	30
2000 - 2999	8	111	124	17	1	155	177	122	91	67	11	1	0	885	1840	23
3000 - 3999	7	94	82	13	5	95	290	68	89	62	15	39	18	877	1408	25
4000 - 4999	13	111	114	8	0	32	287	126	70	39	37	16	3	856	1352	22
5000 - 5999	2	94	118	6	1	18	250	36	31	25	15	0	3	599	865	21
6000 - 6999	3	95	93	7	0	8	205	54	32	12	5	0	1	515	793	18
7000 - 7999	2	110	93	10	0	11	121	40	32	6	13	0	0	438	596	16
8000 - 8999	1	106	64	11	0	6	83	37	31	4	15	0	0	358	494	17
9000 - 9999	0	78	35	13	0	4	76	12	4	1	12	2	0	237	285	14
10000 - 10999	0	67	14	12	1	5	61	6	8	1	8	0	1	184	226	10
11000 - 11999	0	51	14	8	0	3	33	3	17	3	8	1	0	141	162	11
12000 - 12999	0	28	7	9	0	1	28	1	12	3	9	0	0	98	113	8
13000 - 13999	0	21	7	3	0	1	15	2	8	0	8	0	0	65	71	8
14000 - 14999	0	11	1	1	0	0	12	1	7	0	5	0	0	38	39	5
15000 - 15999	0	12	0	4	0	1	8	2	5	2	6	0	0	40	46	7
16000 - 16999	0	3	0	1	0	0	3	0	4	4	4	0	0	19	24	5
17000 - 17999	0	2	0	0	0	0	2	1	2	3	1	0	0	11	17	3
18000 - 18999	0	3	0	1	0	0	2	1	0	1	3	0	0	11	13	4
19000 - 19999	0	0	0	0	0	0	0	0	2	0	2	0	0	4	5	1
20000 - 20999	0	1	0	0	0	0	0	0	1	0	5	0	0	7	9	2
21000 - 21999	0	0	0	0	0	0	1	0	0	0	4	0	0	5	6	2
22000 - 22999	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1
TOTAL	46	1053	885	146	27	448	1874	734	504	249	216	60	28	6270	9878	

At least 1,089 reservoirs, or about 17.4 percent, contained 0.30 percent or more of helium, with 1,030 of these located above a depth of 7,000 feet, 54 reservoirs in the 7,000- to 11,000-foot depth range, and only 5 in the 11,000- to 18,000-foot depth range. None of the reservoirs below 18,000 feet contained 0.30 percent or more of helium. Table 11 shows the distribution of reservoirs for 11 helium content ranges at 1,000-foot depth intervals down to 23,000 feet. (Similar tables for each individual geologic system are included in the appendix.)

Only 722 reservoirs, or 11.5 percent, contained less than 0.005 percent helium, indicating that most natural gas reservoirs contained some helium regardless of reservoir depth. This is the same observation as noted in previous sections but with regard to the geologic systems. Helium is found to occur in most reservoirs, regardless of their depth or geologic age.

Variations in Helium With Depth

Reservoirs in the 0- to 5,000-foot depth range accounted for 3,499, or 55.8 percent, of the 6,270 reservoirs investigated. This interval contained 915 reservoirs, with 0.30 percent or more of helium. There were 2,331 reservoirs, or 37.2 percent of the total reservoirs, in the 5,000- to 10,000-foot range, and 169 of these reservoirs contained 0.30 percent or more of helium. The 11,000- to 18,000-foot depth range includes 412 reservoirs, or 6.6 percent of the total reservoirs, and only 5 reservoirs contained 0.30 percent or more of helium. Below depths of 18,000 feet, there were 28 reservoirs representing 0.4 percent of the total reservoirs, and none of these contained 0.30 percent or more of helium. Table 12 lists the number and percentage of reservoirs in the different helium content groups for various depth intervals. The highest percentage of reservoirs containing 0.30 percent or more of helium is found at depths above 8,000 feet, and all of the reservoirs that contained 1 percent or more helium were found at depths above 9,000 feet. Below 9,000 feet, the percentage of reservoirs containing 0.30 percent or more helium decreases rapidly.

Rogers (38) emphasized that natural gas with high helium contents was most likely to be found at shallow depths and that reservoirs found at depths greater than approximately 2,500 feet were not favorable for gases rich in helium. He also stated that in most fields in which there are two or more gas sands, the gases richest in helium are at the shallowest depth. Other authors (12) have indicated that there might be a critical depth below which high-helium-content gases do not occur, and that if there is such a depth it would probably be at depths below 7,000 feet, rather than the 2,500 feet indicated by Rogers in 1921.

TABLE 11. - Depth distribution of U.S. natural gas reservoirs according to helium content/

GEOLOGIC SYSTEM:ALL AGES		MINIMUM DEPTH:			118			MAXIMUM DEPTH:122,566			RESERVOIRS: 6270			SAMPLES: 9,878			STATES: 35		
AVERAGE DEPTH, FEET		HELIUM CONTENT IN PERCENTAGE																	
		LESS THAN .005		.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES			
0 - 999	37	63	80	18	29	12	2	2	4	4	8	0	255	387	24				
1000 - 1999	47	181	233	71	62	21	3	0	0	0	8	0	626	1126	30				
2000 - 2999	66	325	260	87	103	18	4	1	1	1	0	0	885	1840	23				
3000 - 3999	53	300	277	56	83	77	18	7	5	1	0	0	877	1408	25				
4000 - 4999	65	302	275	68	63	49	23	7	4	0	0	0	856	1352	22				
5000 - 5999	41	281	214	19	27	11	1	4	1	1	0	0	599	865	21				
6000 - 6999	54	241	168	15	9	3	5	5	8	7	0	0	515	793	18				
7000 - 7999	59	268	86	6	1	6	1	4	7	0	0	0	438	596	16				
8000 - 8999	63	236	40	3	10	5	1	0	0	0	0	0	358	494	17				
9000 - 9999	56	159	17	3	2	0	0	0	0	0	0	0	237	285	14				
10000 - 10999	55	120	4	5	0	0	0	0	0	0	0	0	184	226	10				
11000 - 11999	38	99	4	0	0	0	0	0	0	0	0	0	141	162	11				
12000 - 12999	22	70	5	0	1	0	0	0	0	0	0	0	98	113	8				
13000 - 13999	18	42	5	0	0	0	0	0	0	0	0	0	65	71	8				
14000 - 14999	8	28	1	0	1	0	0	0	0	0	0	0	38	39	5				
15000 - 15999	10	28	0	0	2	0	0	0	0	0	0	0	40	46	7				
16000 - 16999	4	15	0	0	0	0	0	0	0	0	0	0	19	24	5				
17000 - 17999	1	7	2	0	1	0	0	0	0	0	0	0	11	17	3				
18000 - 18999	4	5	2	0	0	0	0	0	0	0	0	0	11	13	4				
19000 - 19999	0	4	0	0	0	0	0	0	0	0	0	0	4	5	1				
20000 - 20999	1	6	0	0	0	0	0	0	0	0	0	0	7	9	2				
21000 - 21999	0	5	0	0	0	0	0	0	0	0	0	0	5	6	2				
22000 - 22999	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1				
RESERVOIRS	722	2786	1673	351	394	202	58	30	30	24	0	0	6270	9878	1				

TABLE 12. - Distribution of 6,270 U.S. natural gas reservoirs according to helium content for various depth ranges

Depth ranges	Reservoirs and helium content ¹												Total	Helium content, mole-percent	
	(He <0.10)			(0.10≤He<0.30)			(He ≥0.30)			(He ≥5.00)				Maximum	Average
	No.	Pct2	No.	Pct2	No.	Pct2	No.	Pct2	No.	Pct2	No.	Pct2			
0-999.....	100	39.2	80	31.4	75	29.4	28	11.0	12	4.7	255	9.01	0.62		
1,000-1,999..	228	36.4	233	37.2	165	26.4	33	5.3	8	1.3	626	9.74	.35		
2,000-2,900..	411	46.4	260	29.4	214	24.2	23	2.6	1	.1	885	5.01	.22		
3,000-3,999..	353	40.3	277	31.6	247	28.2	108	12.3	6	.7	877	7.43	.40		
4,000-4,999..	367	42.9	275	32.1	214	25.0	83	9.7	4	.5	856	5.29	.34		
5,000-5,999..	322	53.8	214	35.7	63	10.5	17	2.8	1	.2	599	5.10	.17		
6,000-6,999..	295	57.3	168	32.6	52	10.1	28	5.4	15	2.9	515	8.01	.36		
7,000-7,999..	327	74.7	86	19.6	25	5.7	18	4.1	7	1.6	438	5.66	.20		
8,000-8,999..	299	83.5	40	11.2	19	5.3	7	2.0	0	0	358	2.77	.08		
9,000-9,999..	215	90.7	17	7.2	5	2.1	0	0	0	0	237	.68	.04		
10,000-10,999	175	95.1	4	2.2	5	2.7	0	0	0	0	184	.45	.03		
11,000-17,999	390	94.7	17	4.1	5	1.2	0	0	0	0	412	.89	.03		
18,000-22,999	26	92.9	2	7.1	0	0	0	0	0	0	28	.26	.03		
All depths...	3,508	55.9	1,673	26.7	1,089	17.4	345	5.5	54	0.9	6,270	9.74	0.26		

¹Helium content classification in mole-percent.

²Percent of total reservoirs in depth range.

Table 12 shows that five reservoirs in the 11,000- to 18,000-foot depth range contained 0.30 percent or more of helium, but less than 1 percent. The following information concerns these five reservoirs: (1) a Pennsylvanian System reservoir in Wyoming contained 0.75 percent of helium at 12,878 feet, (2) an Ordovician System reservoir in Texas contained 0.39 percent of helium at 14,166 feet, (3) a reservoir in the Ordovician System of Wyoming contained 0.80 percent of helium at 15,095 feet, (4) a Mississippian System reservoir in Wyoming contained 0.64 percent of helium at 15,750 feet, and (5) another Mississippian System reservoir in Wyoming contained 0.90 percent of helium at 17,783 feet. The fifth reservoir is an average helium content of gas samples obtained from two different depths, although in the same formation, while drilling the well. The gas from the shallower zone was obtained at 17,562 feet and contained 0.27 percent of helium, while the second sample was from a deeper zone at 18,004 feet and contained 1.52 percent of helium (22).

These samples were analyzed by the Bureau during 1961 to 1973 and represent the deepest zones from which high-helium-content gas has been observed in reservoirs through 1974. The information from the well in the fifth reservoir, obtained in 1973, establishes that helium contents greater than 1 percent occur in natural gas reservoirs at depths below 18,000 feet. If there is such a critical depth below which high-helium-content gas does not occur, it is at depths below 18,000 feet. This is of considerable interest because the current trend is to deeper drilling in the search for additional gas reserves. Prior to 1961, none of the samples from reservoirs below a depth of 9,000 feet contained 0.50 percent or more of helium in the gas.

The information obtained from the reservoirs previously discussed, and particularly (5), are in conflict with two important conclusions developed in 1921 by Rogers (38). These are: (1) that high-helium-content gas would not be found at great depths (below 2,500 feet) and (2) that in fields in which there are two or more zones, the shallower gas is richer in helium. Rogers' conclusions, however, were based on a limited number of gas analysis data collected by Cady and McFarland (38) during 1906 and 1907 and on data obtained from gas samples Rogers collected in 1918. Only three of the wells in his study were drilled deeper than 4,000 feet, with the deepest being 4,384 feet in the Tertiary System of California. A large percentage of his gas analysis data was obtained from wells in Kansas, where this investigation shows that about 69 percent of the reservoirs sampled contained 0.30 percent or more of helium.

Another example of richer helium being found in the deeper zones, compared with shallower zones, was observed in gas analyses from a well in Alaska that had been completed above 2,500 feet. The shallower gas, at a depth of 1,960 feet, contained 1.97 percent of helium, while the deeper gas from 2,087 feet contained 3.17 percent of helium (22). Jodry and Henneman (12) also noted a similar occurrence in Pinta Dome, Ariz., with the deeper zone, at 1,032 feet, containing 8.09 percent of helium, and the shallower zone, at 780 feet, contained 6.98 percent of helium. Other examples similar to these are found in New Mexico gas wells and have been published (22), along with those analyses previously cited.

The most favorable reservoir depths for high-helium-content gases are those of less than 5,000 feet. About 26 percent of these reservoirs contained 0.30 percent or more of helium, and about the same percentage of reservoirs (containing 0.30 percent or more of helium) is found in each 1,000-foot interval down to 5,000 feet. Below 5,000 feet, the percentage of these reservoirs drops off rapidly, as shown in table 12. Figure 4 shows a scatter diagram of helium content versus depth for natural gas reservoirs containing 1 percent or more of helium. The scatter diagram emphasizes that no apparent functional relationship exists between gas containing 1 percent or more of helium and reservoir depth, at least above about 9,000. Figure 5 shows the number and the percentage of reservoirs in the various depth ranges, indicating the intervals where reservoirs with the different helium contents were found. Also included are the depth ranges at which the reservoirs with the highest helium contents occurred and the average helium contents of each depth range. The highest helium contents were found in reservoirs of the Permian System with 9.74 percent at a depth of 1,354 feet, and in the Triassic System with 9.23 percent at 1,196 feet. A reservoir in the Mississippian System contained gas with 8.01 percent helium at a depth of 6,960 feet. This is the highest helium content observed for a reservoir in the Mississippian System, and it also represents the greatest depth at which a maximum-system-helium content has been found in any of the geologic systems. Gases containing 5 percent or more of helium have not been found below 8,000 feet.

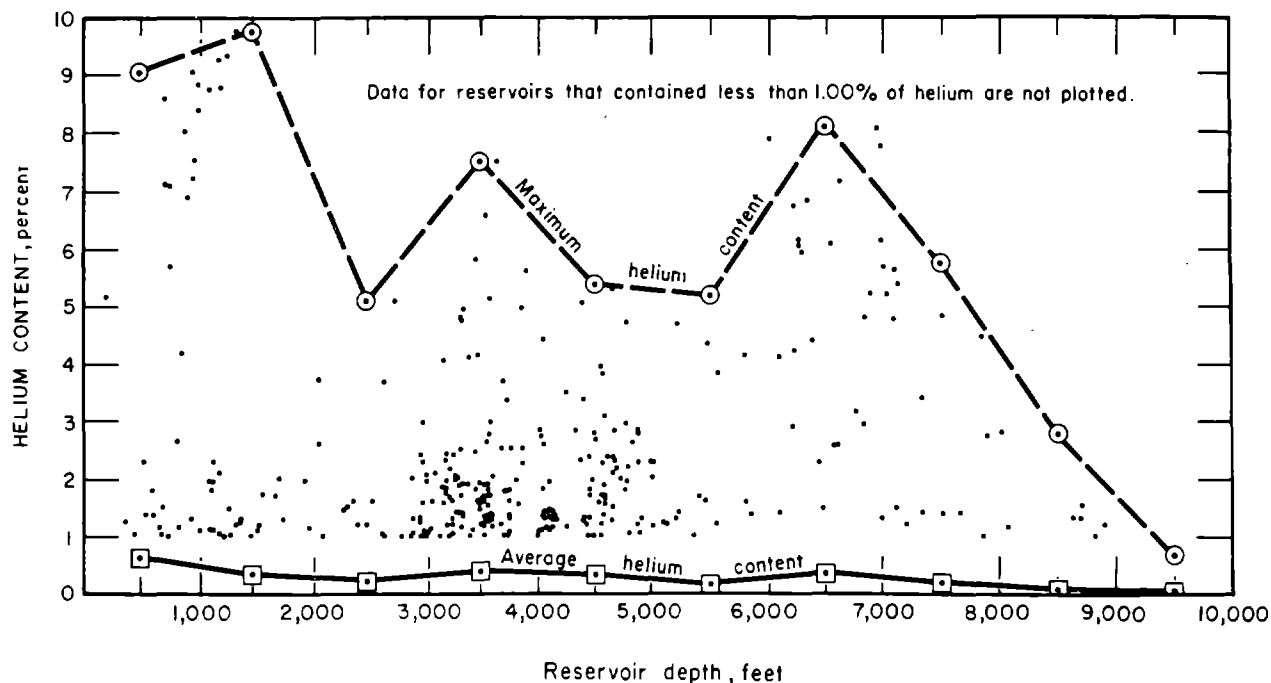


FIGURE 4. - Scatter diagram of helium content versus depth of reservoir for U.S. natural gas reservoirs containing 1 percent or more of helium gas. Maximum and average helium content curves obtained from all samples in each depth range.

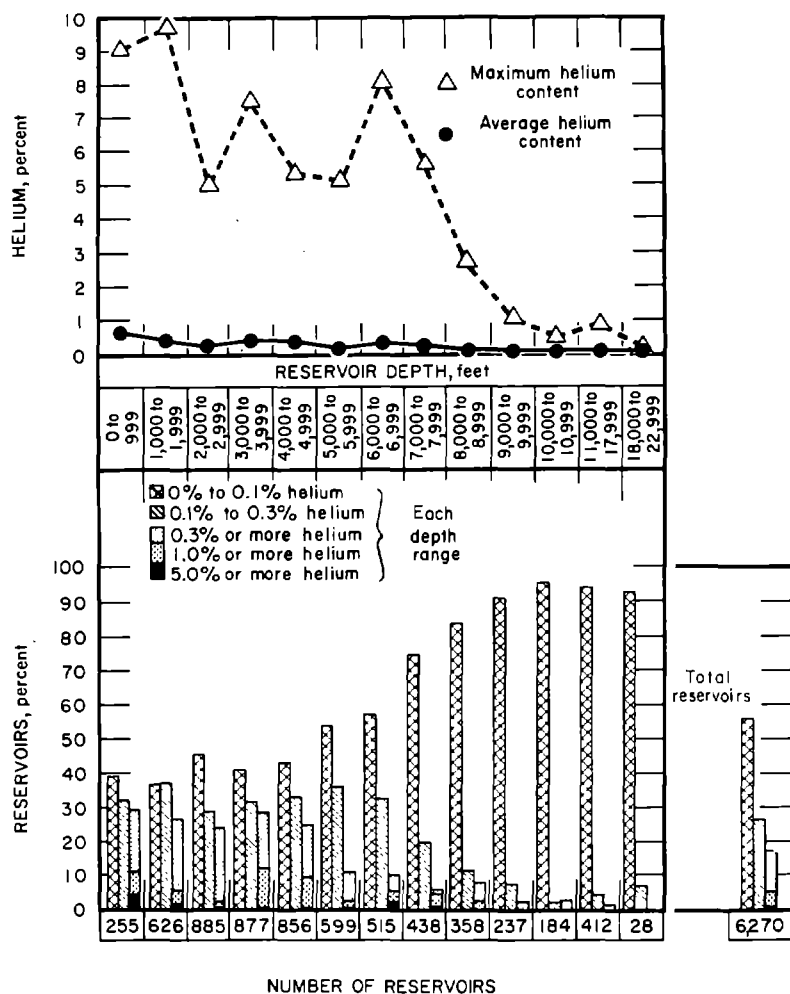


FIGURE 5. - Maximum and average helium contents of 6,270 U.S. natural gas reservoirs and percentage of these reservoirs containing various concentrations of helium at different reservoir depths.

between average and maximum helium contents and reservoir depth. The average helium content and maximum helium content tend to decrease as the depth of the reservoirs increase. A tabulation of the rank correlation coefficients for the relationship between the various helium-content groups and reservoir depth is included in the Summary and conclusions.

When the maximum and average reservoir depths are ranked from the shallowest to the deepest and the geologic systems are ranked from the youngest to the oldest, the rank correlation coefficients are found to be 0.176 and 0.055, respectively. These values are not significant and indicate that there is no linear relationship between reservoir depth and age of the reservoir rock. Although the geologically older reservoir rocks generally contain higher percentages of helium than the younger reservoir rocks, they are not necessarily the deeper reservoirs.

Helium and Depth Correlation

If the depth intervals are arranged from the shallowest through the deepest and the percentage of reservoirs containing 0.30 percent or more of helium are arranged from the lowest percentage through the highest percentage, the value of the rank correlation coefficient is found to be -0.967. This value is highly significant and indicates a marked linear relationship between reservoir depth and helium content. As the reservoir depth increases, the percentage of reservoirs containing 0.30 percent or more of helium decreases. Similar arrangement of depth intervals and average helium contents yields a rank correlation coefficient of -0.879. Also, if the maximum observed helium contents of each range are ranked as above, the correlation coefficient is -0.835. These values are both highly significant and indicate a reverse linear relationship

HELIUM-NITROGEN RELATIONSHIP

The helium-nitrogen study includes 6,445 reservoirs represented by 10,074 gas samples obtained from 35 States. Reservoirs with 0.30 percent or more of helium account for 1,132 reservoirs, with 364 of these containing 1 percent or more of helium, and 58 containing 5 percent or more of helium. Eight hundred sixty-six of the reservoirs that contained 0.30 percent or more of helium also contained less than 30 percent of nitrogen in the gas. (The 30-percent nitrogen value was arbitrarily selected for this report and has no other particular significance.) The 364 reservoirs with 1 percent or more of helium included 193 reservoirs with 30 percent or more of nitrogen. Fifty-seven of the 58 reservoirs that contained 5 percent or more of helium also contained 30 percent or more of nitrogen. It seems that gases with the highest helium contents are found in reservoirs that generally contain high concentrations of nitrogen in the gas. This association of helium and nitrogen was discussed by Rogers (38) who also stated that, "the general occurrence of helium in high-nitrogen gases also suggests that the origin of the nitrogen is in some way related to that of helium."

Table 13 lists the number of reservoirs containing nitrogen for all geologic systems combined and accumulated according to helium content. Nitrogen ranges from 0 to 10 percent in 1-percent increments and from 10 to 100 percent in 10-percent increments. (Similar tables for each individual geologic system are included in the Appendix.) Table 14 shows the distribution of nitrogen in 6,445 reservoirs, according to helium content. This table also shows the maximum helium and average helium contents found in each nitrogen range.

Natural gas containing 30 percent or more of nitrogen was found in 357 reservoirs, and over 94 percent of these reservoirs were located in eight States that include Kansas with 82, New Mexico with 73, Texas with 61, Arizona with 35, Oklahoma with 22, Utah with 20, Colorado with 19, and Montana with 19. In the helium-nitrogen study, these States also accounted for 88 percent of the 1,132 reservoirs that contained 0.30 percent or more of helium and 97 percent of the 364 reservoirs that contained 1 percent or more of helium in the gas. All 58 of the reservoirs containing 5 percent or more of helium were found in five of these States: Arizona, Colorado, Kansas, New Mexico, and Utah. One of the 58 reservoirs contained 27 percent of nitrogen. Geologic system, reservoir depth, and the components helium, nitrogen, carbon dioxide, and argon of all reservoirs containing 1 percent or more of helium are tabulated in table A-1.

Table 15 shows the nitrogen distribution of the 6,455 reservoirs in each of the 35 States included in the report. Reservoirs are accumulated according to nitrogen content of the gas. (Ten reservoirs with unknown nitrogen contents are included with those containing 0 to 1 percent nitrogen.

TABLE 11. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:ALL AGES		HELIUM CONTENT IN PERCENTAGE											GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99					
NITROGEN PERCENTAGE	0.0 - 0.9	482	1256	196	6	2	1	0	0	0	0	0	0	1943	2294	26
	1.0 - 1.9	105	718	311	6	1	1	0	0	0	0	0	0	1142	1507	24
	2.0 - 2.9	29	295	262	13	0	0	0	0	0	0	0	0	599	768	25
	3.0 - 3.9	32	158	197	16	2	0	0	0	0	0	0	0	405	580	25
	4.0 - 4.9	17	114	149	21	4	0	0	0	0	0	0	0	305	374	23
	5.0 - 5.9	10	70	137	34	8	0	0	0	0	0	0	0	259	370	22
	6.0 - 6.9	6	42	100	14	16	3	0	1	0	0	0	0	182	295	25
	7.0 - 7.9	3	25	84	24	13	1	0	0	0	0	0	0	150	385	19
	8.0 - 8.9	8	28	49	23	11	12	0	0	0	0	0	0	131	197	17
	9.0 - 9.9	4	14	55	16	20	1	0	0	0	0	0	0	110	153	15
0.0 - 9.9	696	2720	1540	173	77	19	0	1	0	0	0	0	5226	6923		
10.0 - 19.9	20	63	130	145	181	67	4	0	0	0	0	0	610	1694	26	
20.0 - 29.9	9	21	23	27	92	58	20	1	1	0	0	0	252	729	22	
30.0 - 39.9	1	9	8	8	34	31	11	4	0	0	0	0	106	256	14	
40.0 - 49.9	1	7	8	4	6	12	6	4	2	0	0	0	50	91	8	
50.0 - 59.9	1	5	0	0	5	1	4	4	5	0	0	0	25	43	8	
60.0 - 69.9	0	3	5	0	2	12	2	6	6	1	0	0	37	92	10	
70.0 - 79.9	1	1	4	0	5	11	5	4	6	11	0	0	48	93	11	
80.0 - 89.9	3	2	2	3	1	2	2	3	6	11	0	0	35	75	10	
90.0 - 100.0	6	14	10	2	3	3	4	5	6	3	0	0	56	78	14	
TOTAL	738	2845	1730	362	406	216	58	32	32	26	0	0	6445	10074		

TABLE 14. - Distribution of 6,445 U.S. natural gas reservoirs according to nitrogen content and accumulated into various helium content groups.

Nitrogen percentage, range	Reservoirs and helium content ¹												Total	Helium content, mole-percent	
	(He <0.10)		(0.10≤He<0.30)		(He ≥0.30)		(He ≥1.00)		(He ≥5.00)		Maximum	Average			
	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²					
0-9.9.....	3,416	65.3	1,540	29.5	270	5.2	20	0.4	0	0	5,226	3.25	0.09		
10-19.9.....	83	13.6	130	21.3	397	65.1	71	11.6	0	0	610	2.43	.51		
20-29.9.....	30	11.9	23	9.1	199	79.0	80	31.7	1	0.4	252	5.13	.87		
30-39.9.....	10	9.4	8	7.5	88	83.0	46	43.4	0	0	106	3.82	1.07		
40-49.9.....	8	16.0	8	16.0	34	68.0	24	48.0	2	4.0	50	6.04	1.35		
50-59.9.....	6	24.0	0	0	19	76.0	14	56.0	5	20.0	25	6.65	2.44		
60-69.9.....	3	8.1	5	13.5	29	78.4	27	73.0	7	18.9	37	7.50	2.39		
70-79.9.....	2	4.2	4	8.3	42	87.5	37	77.1	17	35.4	48	9.01	3.59		
80-89.9.....	5	14.3	2	5.7	28	80.0	24	68.6	17	48.6	35	9.74	4.27		
90-100.....	20	35.7	10	17.9	26	46.4	21	37.5	9	16.1	56	8.58	1.71		
All ranges..	3,583	55.6	1,730	26.8	1,132	17.6	364	5.6	58	0.9	6,445	9.74	0.27		

¹Helium content classification in mole-percent.

²Percent of total reservoirs in helium percentage range.

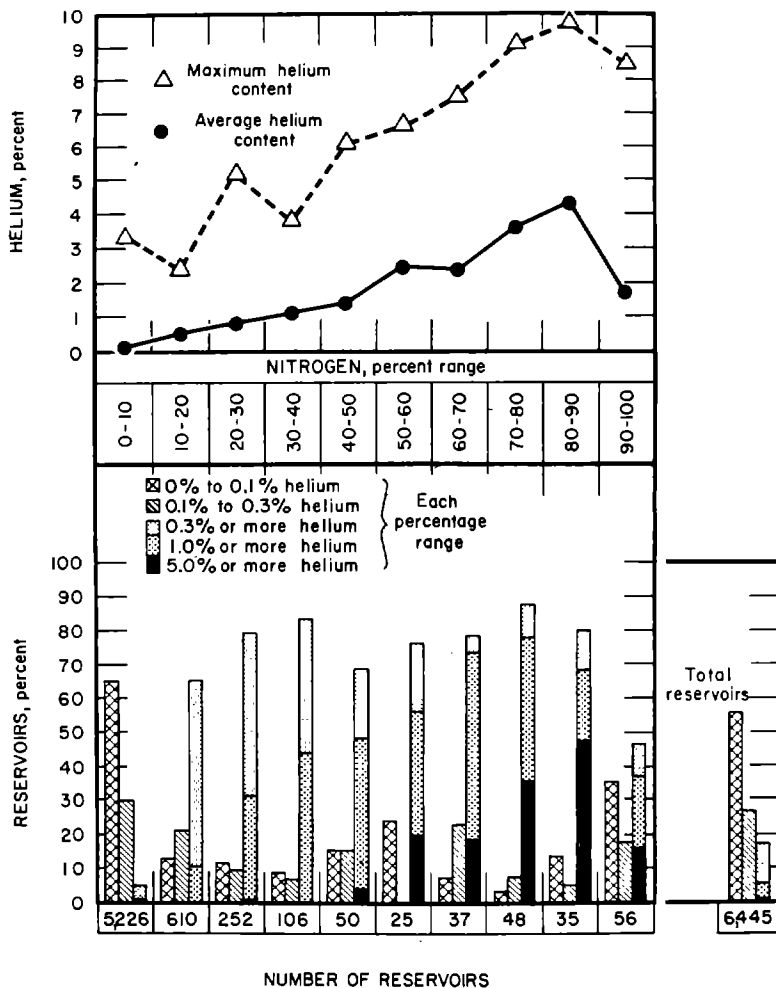


FIGURE 6. - Maximum and average helium contents of 6,445 U.S. natural gas reservoirs and percentage of these reservoirs containing various concentrations of helium for different nitrogen content ranges.

1 percent or more of helium. Figure 6 also shows that reservoirs containing 0.30 percent or more of helium are about equally distributed in all but the lowest and the highest nitrogen ranges. Katz (13) stated that

The organic debris which is closely associated with the uranium and thorium, sometimes in compound form, could well have caused nitrogen to be released because of the alpha particle bombardment. Thus, helium generation would have provided related argon-free nitrogen generation. The He (helium), N₂ (nitrogen) and hydrocarbon gases generated in a given cubic yard of sedimentary rock then would have started their journey together toward the trap which accumulated them.

Reservoir gases with high nitrogen contents do not necessarily have high-helium contents. Although most natural gases that contain helium also

Reservoirs containing less than 0.10 percent of helium account for 3,583, or 55.6 percent, of the total reservoirs; those containing 0.10 through 0.29 percent of helium account for 1,730, or 26.8 percent, reservoirs; and reservoirs containing 0.30 percent or more of helium account for 1,132, or 17.6 percent, reservoirs. Gas containing less than 30 percent of nitrogen is found in 6,088 of the 6,445 reservoirs and accounts for 94.5 percent of the reservoirs studied. Eight hundred sixty-six reservoirs that contained less than 30 percent of nitrogen also contained 0.30 percent or more of helium, which includes 171 reservoirs with 1 percent or more of helium and one reservoir with 5 percent or more of helium.

The percentage of reservoirs with high helium contents increases as the nitrogen content of the gas increases. This is apparent in figure 6, and it is particularly true with respect to reservoirs containing

contain some nitrogen, many of the gases that have large nitrogen contents do not contain enough helium to be detected by ordinary analysis methods.

Nitrogen and Depth of Reservoir

The relationship between depth and nitrogen content in natural gas reservoirs is similar to the relationship between depth and helium content (table 11). Reservoirs with the higher concentrations of nitrogen (30 percent or more) are found mostly above 9,000 feet. There were 344 reservoirs out of 6,291 in the depth-nitrogen study that contained 30 percent or more of nitrogen, and 333 of these reservoirs were above 9,000 feet. Only five reservoirs in the 10,000- to 14,000-foot depth range contained more than 30 percent of nitrogen in the gas. None of the reservoirs below 14,000 feet contained gas with over 30 percent of nitrogen. There were 54 reservoirs with 30 percent or more of nitrogen at depths of less than 1,000 feet; however, as the depth of the reservoir increases, the number of reservoirs containing high percentages of nitrogen decrease. The deepest reservoir containing a high concentration of nitrogen in the gas was found at 13,134 feet. This reservoir is located in the Jurassic System of Texas; the gas contained only 0.09 percent of helium, but it contained 62.5 percent of nitrogen. Table 16 shows the distribution of nitrogen in natural gas reservoirs compared with depth of the reservoir. (Similar tables for each individual geologic system are included in the Appendix.)

Nitrogen Content of Reservoirs by Geologic System

Table 17 shows the distribution of reservoirs containing various percentages of nitrogen accumulated according to geologic system. Reservoirs containing less than 5 percent of nitrogen in the gas represents 68.2 percent of the 6,445 reservoirs, and 94.5 percent of these reservoirs contained less than 30 percent nitrogen. Gas containing high concentrations of nitrogen (30 percent or more) was found in 12 of the 13 geologic systems. The Silurian System did not have any reservoirs with over 30 percent of nitrogen in the gas, and the highest helium content found in any reservoir of this system was 0.90 percent. The Triassic System includes only 28 reservoirs. However, 15 reservoirs, or 53.6 percent, contained 30 percent or more of nitrogen, and 13 of these reservoirs contained 60 percent or more of nitrogen. Generally, the reservoirs containing high percentages of nitrogen also contained the highest percentages of helium found in each geologic system. In the five States in which all of the reservoirs containing 5 percent or more of helium are located, high helium contents are found in 8 of the 13 geologic systems.

Figure 1 and tables 4 and 15 indicate that the higher concentrations of helium and nitrogen in natural gases seem to be related to the geographic location of the reservoir more so than on the depth of the reservoir and/or the geologic system in which the gas is found.

TABLE 17. - Nitrogen distribution of U.S. natural gas reservoirs according to geologic system

GEOLOGIC SYSTEM RESERVOIR	LESS THAN 5.0	NITROGEN CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		5.0 to 9.9	10.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40.0 to 49.9	50.0 to 59.9	60.0 to 69.9	70.0 to 79.9	80.0 to 89.9	90.0 to 100.0					
QUATERNARY	40	1	2	2	1	0	0	0	0	0	0	46	55	6		
TERTIARY	996	32	19	4	0	0	0	0	0	1	2	1054	1205	12		
CRETACEOUS	729	121	43	7	3	1	3	0	0	0	1	910	1194	18		
JURASSIC	88	21	17	10	4	6	0	3	1	1	0	151	192	13		
TRIASSIC	8	3	1	1	2	0	0	1	2	5	5	28	45	7		
PERMIAN	147	72	104	39	30	14	7	8	10	11	23	465	1735	12		
PENNSYLVANIAN	1161	291	251	134	43	17	6	13	14	3	8	1943	3085	21		
MISSISSIPPIAN	474	119	72	26	14	6	6	10	11	5	4	747	1052	23		
DEVONIAN	439	35	17	4	3	1	0	1	4	5	10	519	612	21		
SILURIAN	161	68	29	3	0	0	0	0	0	0	0	261	312	13		
OROVICIAN	139	43	27	14	2	1	0	0	0	1	1	228	338	16		
CAMPANIAN-OROVICIAN	3	23	19	7	2	3	1	1	3	1	0	63	159	4		
CAMPANIAN	9	3	9	1	0	1	0	0	3	2	2	30	90	8		
TOTAL	4394	832	610	252	106	50	25	37	48	35	56	6445	10074			

Helium and Nitrogen Correlation

The rank correlation coefficient for the relationship between maximum-system-helium content and nitrogen content yields a value of 0.939. This value is highly significant and indicates a strong positive linear relationship between the maximum helium content and the nitrogen present in the gas. As the nitrogen content of the gas increases, so does the helium content. If the average helium content is paired with its respective nitrogen range and the average helium content of each nitrogen range is ranked from the lowest to the highest, the correlation test then yields a rank correlation coefficient of 0.867. This value is also highly significant and indicates that there is a strong positive linear relationship between average helium content and the nitrogen content of natural gas. The relationship between nitrogen content and the percent of reservoirs, with helium concentrations of 1 percent or more, is found to be highly significant with a rank correlation coefficient of 0.709. This value indicates that a positive correlation exists between natural gas, with 1 percent or more of helium and the nitrogen present in the gas. The rank correlation coefficient between natural gases containing 5 percent or more of helium and its contained nitrogen is 0.830. This value indicates a highly significant positive linear correlation. However, when the percentage of reservoirs containing 0.30 percent or more of helium in each range is compared with the nitrogen content of the gas, the rank correlation coefficient is 0.309. This value is not significant and indicates that reservoirs containing 0.30 percent or more of helium occur with about the same percentage, regardless of nitrogen content. Reservoirs in the eight nitrogen ranges between 10 percent and 90 percent have nearly the same percentage of reservoirs, with 0.30 percent or more of helium. Similar correlation tests for the reservoirs with less than 0.10 percent of helium yields a value of -0.115 which is not significant. A tabulation of the rank correlation coefficients for the relationship between the various helium content groups and nitrogen content is included in the Summary and conclusions.

Figure 7, showing a scatter diagram of helium and nitrogen, indicates a wide variation in helium-to-nitrogen ratios for the different reservoirs containing 1 percent or more of helium. The diagram includes helium and nitrogen information for reservoirs containing less than 1 percent of helium and 50 percent or more of nitrogen. This diagram appears to indicate that an average curve would be of limited value for predicting helium contents from the percentage of nitrogen contained in the natural gas. However, the diagram does provide a method for predicting the range of helium contents that can be expected from a particular nitrogen content gas.

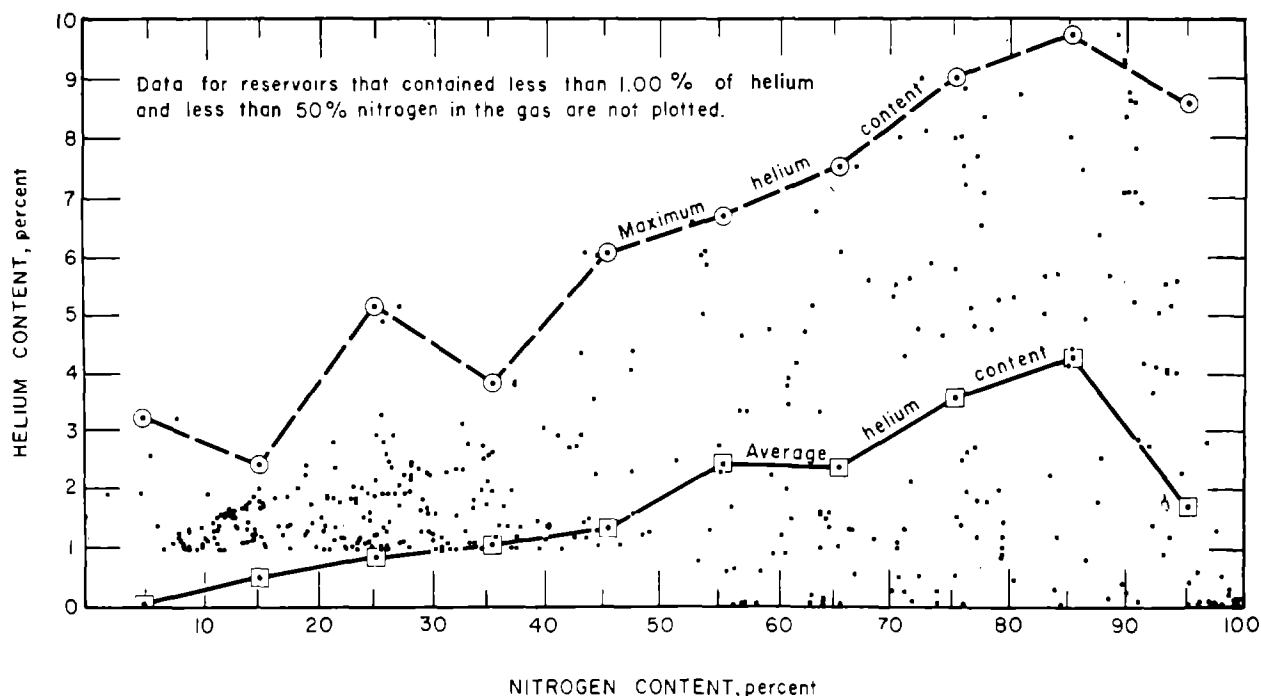


FIGURE 7. - Scatter diagram of helium versus nitrogen contents of U.S. natural gas reservoirs containing 1 percent or more of helium gas. Maximum and average helium content curves obtained from all samples in each nitrogen range.

HELIUM-CARBON DIOXIDE RELATIONSHIP

The helium-carbon dioxide study included 6,448 reservoirs represented by 10,079 gas samples that included 1,132 reservoirs, with 0.30 percent or more of helium. Only 36 reservoirs with 0.30 percent or more helium contained 30 percent (the 30-percent carbon dioxide value was arbitrarily selected for this report and has no other particular significance) or more of carbon dioxide. Three hundred sixty-four reservoirs contained 1 percent or more of helium, and only 26 of these reservoirs contained 10 percent (arbitrary value) or more of carbon dioxide. In the 5-percent or more helium range, there were 58 reservoirs with all 58 containing less than 30 percent of carbon dioxide, and 47 of these contained less than 10 percent of carbon dioxide in the gas. The highest helium contents were found in reservoirs with the lower concentrations of carbon dioxide. Table 18 shows the number of reservoirs for each of the 35 States, accumulated according to carbon dioxide content. (Six reservoirs with unknown carbon dioxide contents are included in table 18 under the carbon dioxide percentage column headed 0 to 1 percent.)

Eighteen States have all 171 reservoirs with 10 percent or more of carbon dioxide. Seven of these 18 States have 152 of the 171 reservoirs: Arizona has 10, Colorado, 39, Montana, 8, New Mexico, 27, Texas, 21, Utah, 32, and Wyoming, 15.

TABLE 18. - State distribution of U.S. natural gas reservoirs according to carbon dioxide content.

STATE	CARBON DIOXIDE CONTENT IN PERCENTAGE																NUMBER OF RESERVOIRS	NUMBER OF SAMPLES				
	LESS THAN 5.0		5.0 TO 9.0		10.0 TO 19.0		20.0 TO 29.0		30.0 TO 39.0		40.0 TO 49.0		50.0 TO 59.0		60.0 TO 69.0				70.0 TO 79.0		80.0 TO 89.0	
ALABAMA	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
ALASKA	15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
ARIZONA	29	0	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47
ARKANSAS	130	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	134
CALIFORNIA	111	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115
COLORADO	241	18	14	4	0	0	0	0	0	0	0	0	2	1	0	3	15	0	0	0	0	296
FLORIDA	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
GEORGIA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
IDAHO	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
ILLINOIS	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
INDIANA	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38
IOWA	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
KANSAS	684	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	685
KENTUCKY	92	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	95
LOUISIANA	249	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	251
MARYLAND	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
MICHIGAN	117	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	118
MISSISSIPPI	38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41
MONTANA	109	5	1	1	0	0	0	0	0	0	1	0	1	0	0	1	2	0	0	0	0	122
NEBRASKA	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
NEVADA	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
NEW MEXICO	282	10	7	0	0	0	0	0	0	0	0	0	1	0	0	1	15	0	0	0	0	319
NEW YORK	54	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
NORTH DAKOTA	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
OHIO	183	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183
OKLAHOMA	1034	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1040
PENNSYLVANIA	152	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	152
SOUTH DAKOTA	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TENNESSEE	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TEXAS	1765	45	7	3	2	3	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	5
UTAH	116	7	4	7	2	2	0	0	0	0	0	2	2	2	1	0	4	0	0	0	0	1831
VIRGINIA	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	155
WASHINGTON	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
WEST VIRGINIA	327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
WYOMING	302	9	2	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	329
TOTAL	6169	115	52	20	11	5	8	5	11	5	6	8	5	6	11	53	11	53	11	53	11	53

Table 19 shows the number and percent of reservoirs containing various concentrations of carbon dioxide accumulated according to helium content. Carbon dioxide ranges vary from 0 to 10 percent in 1-percent increments and from 10 to 100 percent in 10-percent increments. (Similar tables for each individual geologic system are included in the Appendix.) All of the carbon dioxide ranges included natural gas reservoirs with 0.30 percent or more of helium except for five reservoirs ranging from 40 to 50 percent, and all five of these reservoirs contained less than 0.10 percent of helium. There were only five reservoirs ranging from 60 to 70 percent carbon dioxide, and all of them contained gas with 0.30 percent or more of helium. None of the five reservoirs, however, contained natural gas with over 1 percent of helium. Gases with the highest helium contents contained less than 30 percent of carbon dioxide. Table 20 lists the maximum and average range of helium contents found in natural gas reservoirs containing various percentages of carbon dioxide and the number and percentage of reservoirs containing various helium contents.

Only 70 of the 1,132 reservoirs containing 0.30 percent or more of helium also contained 10 percent or more of carbon dioxide in the gas. Twenty-six of these reservoirs contained 1 percent or more of helium, and 11 contained 5 percent or more of helium in the gas. Reservoirs with 5 percent or more of helium were not found in natural gases containing over 23 percent of carbon dioxide. Table 20 shows that 6,284 of the 6,448 reservoirs contained less than 10 percent carbon dioxide. In this group, 1,062 reservoirs contained 0.30 percent or more of helium, 339 contained 1 percent or more, and 47 contained 5 percent or more of helium in the gas. Only 164 reservoirs, or 2.6 percent, of the total reservoirs investigated were found to contain 10 percent or more of carbon dioxide in the gas. Table 20 also shows that the number of reservoirs drops off rapidly as the carbon dioxide content of the natural gases increases.

Figure 8 is a plot of maximum helium and average helium contents compared with the carbon dioxide content of the natural gases. This figure shows that as the carbon dioxide content increases, the maximum helium content found in the gas decreases. The decrease is systematic until the carbon dioxide content of the gas reaches the 40- to 50-percent range where the maximum helium content reaches the lowest value of less than 0.09 percent. The maximum helium content then increases to a little above 1 percent where it tends to level off.

The presence of carbon dioxide does not seem to be of any significance in the occurrence of helium in natural gases. The highest concentrations of helium are found in natural gases containing less than 30 percent of carbon dioxide in the gas.

TABLE 19. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:ALL AGES			HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
CARBON DIOXIDE PERCENTAGE	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0						
0.0 - 0.9	521	2142	1579	324	346	182	47	20	15	16	0	5192	8247	34			
1.0 - 1.9	108	427	55	12	15	4	4	6	5	2	0	638	610	26			
2.0 - 2.9	49	129	20	1	5	4	0	2	1	2	0	213	336	18			
3.0 - 3.9	22	40	14	1	1	4	2	0	0	0	0	83	116	14			
4.0 - 4.9	9	19	7	1	1	2	0	0	4	0	0	43	55	13			
5.0 - 5.9	5	21	6	0	1	1	0	0	0	0	0	34	112	8			
6.0 - 6.9	4	10	7	3	5	2	0	0	0	0	0	31	51	10			
7.0 - 7.9	0	10	1	1	0	1	0	1	0	0	0	14	18	6			
8.0 - 8.9	4	5	2	0	5	0	0	0	0	0	0	14	18	7			
9.0 - 9.9	0	6	3	0	2	3	3	3	1	1	0	22	41	9			
0.0 - 9.9	722	2807	1693	343	381	203	56	32	26	21	0	6284	9804				
10.0 - 19.9	6	13	10	3	7	4	1	0	3	3	0	52	73	14			
20.0 - 29.9	1	3	5	0	7	1	0	0	3	0	0	20	72	6			
30.0 - 39.9	1	2	3	2	0	2	1	0	0	0	0	11	25	7			
40.0 - 49.9	1	4	0	0	0	0	0	0	0	0	0	5	5	3			
50.0 - 59.9	0	1	2	3	0	2	0	0	0	0	0	8	14	6			
60.0 - 69.9	0	0	0	2	3	0	0	0	0	0	0	5	5	3			
70.0 - 79.9	0	1	1	2	1	1	0	0	0	0	0	6	6	5			
80.0 - 89.9	0	1	1	1	2	3	0	0	0	0	0	11	13	5			
90.0 - 100.0	6	15	15	6	2	0	0	0	0	0	0	46	62	8			
TOTAL	739	2847	1730	362	406	216	58	32	32	26	0	6448	10079				

TABLE 20. - Distribution of 6,448 U.S. natural gas reservoirs according to carbon dioxide content and accumulated into various helium content groups

Carbon dioxide, percent	Reservoirs and helium content ¹												Total	Helium content, mole-percent	
	(He <0.10)		(0.10≤He<0.30)		(He ≥0.30)		(He ≥1.00)		(He ≥5.00)		Maximum	Average			
	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²					
0-9.9.....	3,529	56.1	1,693	26.9	1,062	16.9	339	5.4	47	0.7	6,284	9.74	0.25		
10-19.9....	19	36.5	10	19.2	23	44.2	13	25.0	8	15.4	52	8.80	1.38		
20-29.9....	4	20.0	5	25.0	11	55.0	4	20.0	3	15.0	20	6.08	1.25		
30-39.9....	3	27.3	3	27.3	5	45.4	3	27.3	0	0	11	2.77	.63		
40-49.9....	5	100.0	0	0	0	0	0	0	0	0	5	.03	.02		
50-59.9....	1	12.5	2	25.0	5	62.5	2	25.0	0	0	8	1.72	.62		
60-69.9....	0	0	0	0	5	100.0	0	0	0	0	5	.90	.58		
70-79.9....	1	16.7	1	16.7	4	66.6	1	16.7	0	0	6	1.37	.53		
80-89.9....	1	9.1	1	9.1	9	81.8	3	27.3	0	0	11	1.40	.72		
90-100.....	23	50.0	15	32.6	8	17.4	0	0	0	0	46	.76	.13		
All ranges.	3,586	55.6	1,730	26.8	1,132	17.6	365	5.7	58	0.9	6,448	9.74	0.27		

¹Helium content classification in mole-percent.

²Percent of total reservoirs in percentage range.

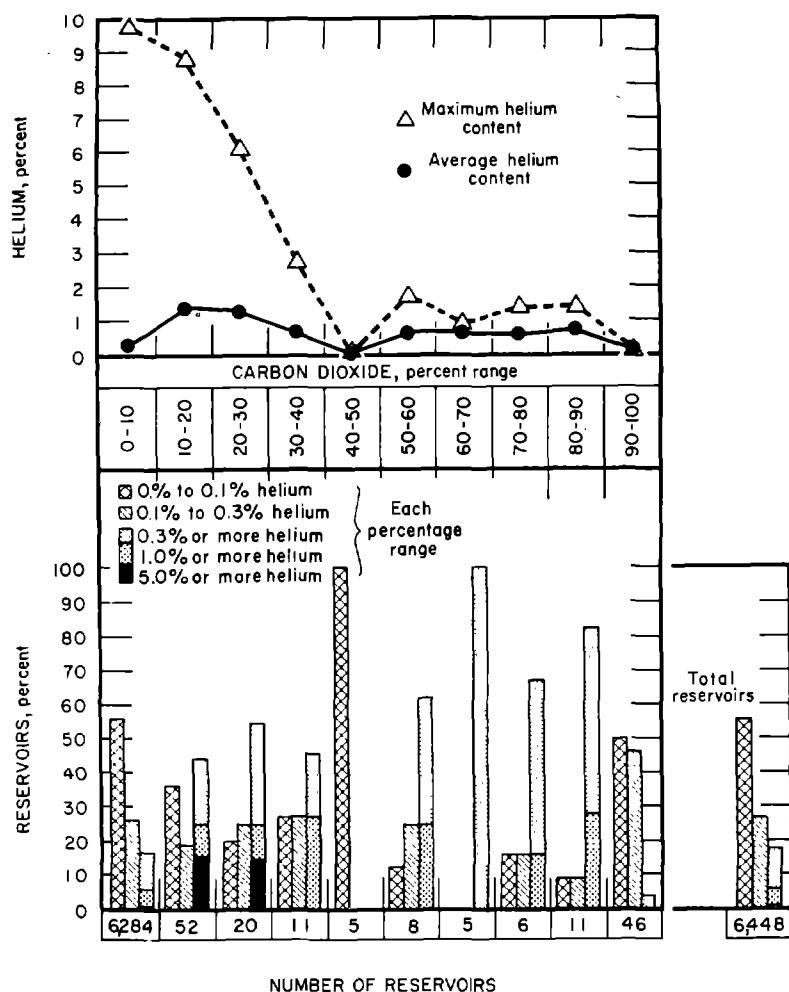


FIGURE 8. - Maximum and average helium contents of 6,448 U.S. natural gas reservoirs and percentage of these reservoirs containing various concentrations of helium for different carbon dioxide content ranges.

contained high carbon dioxide gas was found at a depth of 18,431 feet. The reservoir contained 86.6 percent of carbon dioxide, 6.4 percent of nitrogen, and 0.26 percent of helium in the gas. All of the reservoirs below 19,000 feet contained less than 10 percent of carbon dioxide.

Gases with the highest helium contents were found in reservoirs above 9,000 feet, with less than 30 percent of carbon dioxide. The carbon dioxide content of gases generally decreases as the depth of the reservoir increases.

Carbon Dioxide and Depth of Reservoir

Table 21 shows the number of reservoirs that contained carbon dioxide for various reservoir depths of all 13 geologic systems combined. (Similar tables for each individual geologic system are included in the Appendix.)

There were 6,264 reservoirs with known carbon dioxide contents, including 6,000 that contained less than 5 percent carbon dioxide. One hundred fifty-four reservoirs contained gas with 10 percent or more of carbon dioxide, of which 132 were found above 12,000 feet. These 132 reservoirs included 42 that contained 90 to 100 percent carbon dioxide. Twenty-two of the 154 reservoirs that contained 10 percent or more of carbon dioxide were found at depths ranging from 12,000 to 19,000 feet. In the 18,000- to 18,999-foot depth range, four reservoirs were found to contain 20 percent or more carbon dioxide in the gas. The deepest reservoir that

TABLE 21. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: ALL AGES		MINIMUM DEPTH:			11B			MAXIMUM DEPTH: 22,566			RESERVOIRS: 6264			SAMPLES: 9,872			STATES: 35		
AVERAGE DEPTH, FEET	LESS THAN 5.0	CARBON DIOXIDE CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES					
		10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0									
0 - 999	237	5	5	0	0	0	0	0	0	2	5	254	386	24					
1000 - 1999	403	5	7	0	0	0	1	0	1	0	7	624	1124	30					
2000 - 2999	865	10	6	2	0	0	0	0	0	0	2	885	1840	23					
3000 - 3999	830	5	3	3	2	1	0	1	0	1	6	876	1407	25					
4000 - 4999	830	17	6	0	0	0	1	0	1	0	1	856	1352	22					
5000 - 5999	576	7	5	3	0	0	1	0	1	0	5	598	864	21					
6000 - 6999	497	3	2	3	1	0	2	1	2	2	2	515	793	18					
7000 - 7999	422	8	2	0	1	0	0	0	0	2	2	437	595	16					
8000 - 8999	335	10	1	4	2	0	1	0	0	1	4	358	494	17					
9000 - 9999	223	4	5	0	2	0	0	0	0	0	3	237	285	14					
10000 - 10999	175	3	2	0	0	0	0	0	0	0	4	184	226	10					
11000 - 11999	131	3	1	0	0	0	0	0	0	0	1	141	162	11					
12000 - 12999	89	7	0	0	0	1	0	1	0	0	0	98	113	8					
13000 - 13999	57	2	2	2	1	1	0	0	0	0	0	65	71	8					
14000 - 14999	36	1	1	0	0	0	0	0	0	0	0	38	39	5					
15000 - 15999	33	1	1	1	1	1	0	1	0	1	0	40	46	7					
16000 - 16999	15	4	0	0	0	0	0	0	0	0	0	19	24	5					
17000 - 17999	7	1	1	1	0	0	0	0	0	1	0	11	17	3					
18000 - 18999	7	0	0	1	0	1	1	0	0	1	0	11	13	4					
19000 - 19999	2	2	0	0	0	0	0	0	0	0	0	4	5	1					
20000 - 20999	5	2	0	0	0	0	0	0	0	0	0	7	9	2					
21000 - 21999	4	1	0	0	0	0	0	0	0	0	0	5	6	2					
22000 - 22999	1	0	0	0	0	0	0	0	0	0	0	1	1	1					
RESERVOIRS	6000	110	50	20	10	5	7	4	5	11	42	6264	9872	35					

Carbon Dioxide Content of Reservoirs by Geologic System

Table 22 lists the distribution of reservoirs containing various amounts of carbon dioxide for each of the 13 geologic systems. More than 92 percent of each system's reservoirs contained gas with less than 5 percent of carbon dioxide, except the Jurassic System which had 78.8 percent and the Triassic which had 57.1 percent. Twenty-eight percent of the reservoirs found in the Triassic System contained gas with carbon dioxide contents ranging from 90 to 100 percent. None of the reservoirs in this range contained over 0.76 percent of helium in the gas.

Reservoirs containing 50 percent or more of carbon dioxide in the gas were found in 10 of the 13 geologic systems. All the reservoirs in the Quaternary and Tertiary Systems contained natural gas with less than 20 percent carbon dioxide. The Cambrian and Ordovician System did not have any reservoirs that contained over 5 percent of carbon dioxide in the gas. Eight geologic systems had reservoirs with carbon dioxide contents ranging from 90 to 100 percent. These systems and the number of reservoirs in this range included the Cretaceous, 6, Jurassic, 5, Triassic, 8, Permian, 8, Pennsylvanian, 4, Mississippian, 11, Devonian, 3, and Cambrian, 1.

Gas containing less than 10 percent of carbon dioxide was found in 6,284 reservoirs with helium contents ranging from 0.005 to 8.80 percent. Gases with the higher concentrations of helium were found mostly in reservoirs containing less than 30 percent carbon dioxide.

Helium and Carbon Dioxide Correlation

The rank correlation coefficient for the relationship between maximum helium content and carbon dioxide content is -0.770. This is a highly significant value, indicating a reverse linear relationship between the two. The maximum helium content tends to decrease as the carbon dioxide content increases. The correlation test using average helium contents and carbon dioxide contents yields a value of -0.297 for the rank correlation coefficient. This value is not significant and indicates that there is no meaningful linear relationship between the average helium content and the carbon dioxide content of natural gas. The rank correlation coefficient of reservoirs, containing 0.30 percent or more of helium and carbon dioxide, is 0.455 and not significant. The correlation test between carbon dioxide content and reservoirs containing 1 percent or more of helium gives a value of -0.139 which is also not significant. A tabulation of the rank correlation coefficients between the various helium content groups and carbon dioxide content is included in the Summary and conclusions.

Generally, the maximum helium content is inversely related to the carbon dioxide content of the gas. The helium content of natural gas does not seem to be related to the carbon dioxide content of the gas.

TABLE 22. - Carbon dioxide distribution in U.S. natural gas reservoirs according to geologic system

GEOLOGIC SYSTEM RESERVOIR	LESS THAN 5.0	5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
QUATERNARY	44	0	2	0	0	0	0	0	0	0	0	46	55	6
TERTIARY	1051	2	4	0	0	0	0	0	0	0	0	1057	1210	12
CRETACEOUS	874	21	4	4	0	0	0	0	1	0	6	910	1194	18
JURASSIC	119	16	4	1	1	1	1	1	0	2	5	151	192	13
TRIASSIC	16	3	1	0	0	0	0	0	0	0	8	28	45	7
PERMIAN	431	12	9	2	2	0	1	0	0	0	8	465	1735	12
PENNSYLVANIAN	1887	33	10	2	4	0	0	1	2	0	4	1943	3085	21
MISSISSIPPIAN	702	7	7	7	1	0	2	3	1	6	11	747	1052	23
DEVONIAN	488	11	6	1	0	3	1	0	2	2	3	519	612	21
SILURIAN	254	3	1	1	1	0	1	0	0	0	0	261	312	13
ORDOVICIAN	213	6	2	2	2	1	1	0	0	1	0	228	338	16
CAMBRO-ORDOVICIAN	63	0	0	0	0	0	0	0	0	0	0	63	159	4
CAMBRIAN	27	1	0	0	0	0	1	0	0	0	1	30	90	8
TOTAL	6169	115	52	20	11	5	8	5	6	11	46	6448	10079	

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HELIUM-ARGON RELATIONSHIP

The helium-argon study includes 5,004 reservoirs represented by 7,979 gas samples, with 821 of these reservoirs containing 0.30 percent or more of helium in the gas. None of the reservoirs was found to contain more than 1.4 percent of argon. Gas containing 0.5 percent or more of argon was produced from 83 reservoirs, or about 1.7 percent of the total reservoirs in this study. (Argon contents used in this study were arbitrarily selected for discussion purposes only and have no other particular significance.) Sixty-nine of these 83 reservoirs contained 0.30 percent or more of helium. Sixty-one reservoirs were found with argon contents ranging from 0.5 to 0.9 percent; 58 of these contained 1 percent or more helium and 36 contained 5 percent or more helium.

Table 23 is a distribution of natural gas reservoirs containing various percentages of argon for each of the 35 States studied. South Dakota and Washington do not have any reservoirs included in the helium-argon study because of incomplete gas analyses. About 87 percent of the reservoirs contained less than 0.1 percent of argon. The 117 natural gas reservoirs that contained 0.3 percent or more of argon were located in 17 States. Eighty-three of these 117 reservoirs contained 0.5 percent or more of argon, and 47 contained at least 5 percent of helium. The States in which the 47 reservoirs are located include Arizona, 23, Colorado, 2, Kansas, 1, and New Mexico, 21. Three reservoirs in Kansas contained 5 percent or more of helium in the gas, but contained only 0.1 to 0.2 percent of argon. The one reservoir in Utah with over 5 percent of helium was not analyzed for argon content. Fifty reservoirs with known argon contents contained 5 percent or more of helium. The average gas composition of these 50 reservoirs is 0.64 percent of argon, 6.61 percent of helium, 75.59 percent of nitrogen, 3.92 percent of carbon dioxide, and 13.24 percent of other components.

Most of the reservoirs contained less than 0.1 percent of argon. Only 648 reservoirs contained 0.1 to 1.4 percent of argon. Natural gas containing 0.30 percent or more of helium was found in 821 reservoirs, including 364 reservoirs with less than 0.1 percent of argon. Twenty-six of these 364 reservoirs contained 1 percent or more of helium, but none contained over 3.25 percent of helium. Reservoirs that contained argon ranging from 0.1 to 0.29 percent and contained 0.30 percent or more helium totaled 357. This number includes 168 reservoirs with at least 1 percent of helium. Only three reservoirs with argon contents ranging from 0 to 0.29 percent also contained 5 percent or more of helium. Reservoirs that contained 0.3 percent or more of argon in the gas and also contained 0.30 percent or more of helium numbered 100. These 100 reservoirs included 88 with at least 1 percent of helium and 47 reservoirs with 5 percent or more of helium. Fifty out of 5,004 reservoirs contained 5 percent or more of helium, and 43 of these also contained 0.5 percent or more of argon.

TABLE 23. - State distribution of U.S. natural gas reservoirs according to argon content

STATE	ARGON CONTENT IN PERCENTAGE										GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES
	LESS THAN 0.1	.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49					
ALABAMA	1	0	0	0	0	0	0	0	0	0	0	1	1
ALASKA	15	0	0	0	0	0	0	0	0	0	0	15	24
ARIZONA	3	14	4	6	16	2	0	1	0	0	0	46	101
ARKANSAS	110	5	0	0	0	0	0	0	0	0	0	115	129
CALIFORNIA	54	3	0	0	0	0	0	0	0	0	0	57	68
COLORADO	210	40	2	1	2	1	0	0	0	0	0	256	330
FLORIDA	5	0	0	0	0	0	0	0	0	0	0	3	3
GEORGIA	0	0	1	0	0	0	0	0	0	0	0	1	1
IDAH0	1	0	0	0	0	0	0	0	0	0	0	1	3
ILLINOIS	8	0	0	0	0	0	0	0	0	0	0	8	8
INDIANA	4	2	0	0	0	0	0	0	0	0	0	6	7
IOWA	0	1	1	0	0	0	0	0	0	0	0	2	4
KANSAS	344	165	5	1	1	0	0	0	0	0	0	521	964
KENTUCKY	43	0	0	1	0	1	0	0	0	0	0	45	48
LOUISIANA	174	7	0	0	0	0	0	0	0	0	0	186	194
MARYLAND	7	1	0	0	0	0	0	0	0	0	0	8	8
MICHIGAN	44	12	0	0	0	0	0	0	0	0	0	56	68
MISSISSIPPI	30	1	0	0	0	0	1	0	0	0	0	32	34
MISSOURI	55	15	1	1	0	0	0	1	0	0	0	73	102
NEBRASKA	13	2	1	1	0	0	0	0	0	0	0	17	21
NEVADA	0	0	0	0	0	0	0	0	0	1	0	1	1
NEW MEXICO	196	24	4	12	18	7	4	0	0	0	0	265	517
NEW YORK	57	2	0	0	0	0	0	0	0	0	0	39	41
NORTH DAKOTA	16	3	1	0	0	0	0	0	0	0	0	20	22
OHIO	109	3	0	0	1	1	0	0	0	0	0	114	135
OKLAHOMA	702	56	1	0	0	0	0	0	0	0	0	759	1373
PENNSYLVANIA	155	3	0	0	0	0	0	0	0	0	0	138	148
SOUTH DAKOTA	0	0	0	0	0	0	0	0	0	0	0	1	1
TENNESSEE	1	0	0	0	0	0	0	0	0	0	0	1	1
TEXAS	1441	95	2	0	0	1	1	0	0	0	0	1540	2710
UTAH	90	45	10	0	0	0	0	0	0	0	0	145	284
VIRGINIA	14	0	0	0	0	0	0	0	0	0	0	14	17
WASHINGTON	0	0	0	0	0	0	0	0	0	0	0	289	325
WEST VIRGINIA	203	6	0	0	0	0	0	0	0	0	0	230	287
WYOMING	203	26	1	0	0	0	0	0	0	0	0	5004	7979
TOTAL	4356	531	34	23	38	13	7	2	0	0	0	5004	7979



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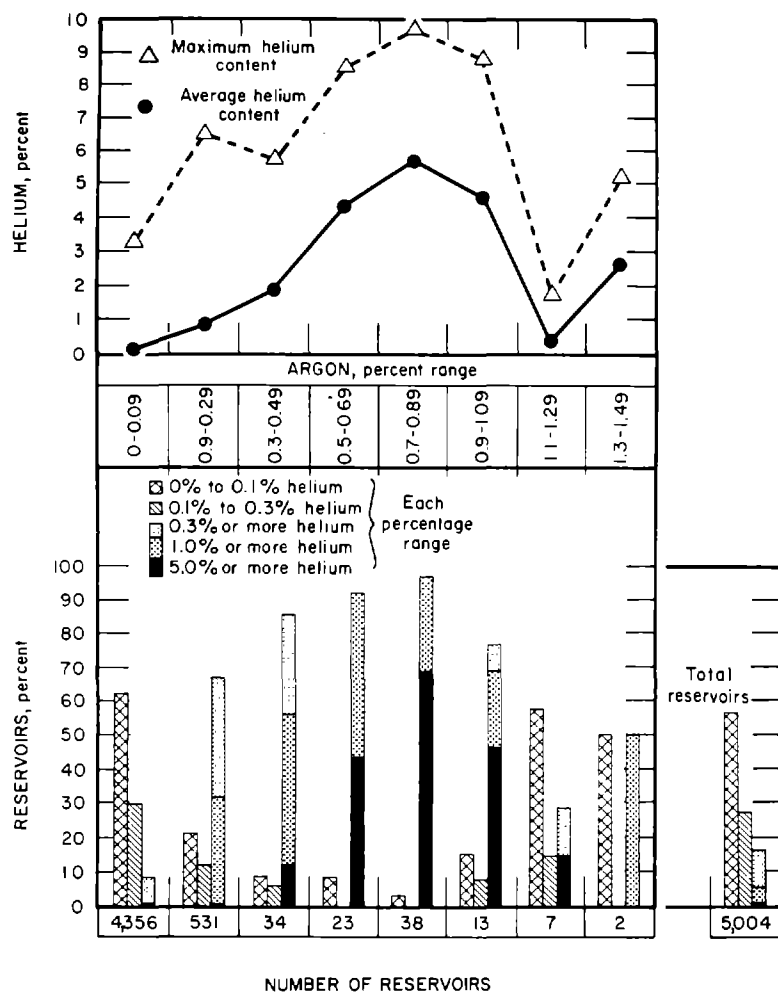


FIGURE 9. - Maximum and average helium contents of 5,004 U.S. natural gas reservoirs and percentage of these reservoirs containing various concentrations of helium for different argon content ranges.

Reservoirs containing less than 0.10 percent of helium account for 56.7 percent of the total; those containing 0.10 percent through 0.29 percent of helium account for 26.9 percent; and those reservoirs containing 0.30 percent or more of helium account for 16.4 percent of the 5,004 reservoirs in the helium-argon study. These percentages are nearly the same as those found in the previously discussed helium relationships even though the number of reservoirs included in this study is about 22.5 percent less reservoirs.

Table 24 lists the number of reservoirs in each helium content range, according to the argon content. (Similar tables for each individual geologic system are included in the Appendix.) Table 25 shows the distribution of argon, for the 5,004 reservoirs, grouped according to helium content. This table also shows the maximum and the average helium contents for each argon percentage range. Information from table 25 is shown graphically in figure 9, which also shows a plot of maximum and average helium contents for the eight argon ranges, varying from 0 to 1.49 percent. Also shown are the percentages of reservoirs containing various amounts of helium in each argon range. As the argon contents increase, the maximum and average helium contents also increase until the argon concentration reaches about 0.9 percent. Continued increases in argon generally result in lower helium contents.

TABLE 24. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM ALL AGES																	
ARGON PERCENTAGE		HELIUM CONTENT IN PERCENTAGE												GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99						
0.0 - 0.09	443	2268	1281	198	140	25	0	1	0	0	4356	6015	30				
0.1 - 0.29	7	106	61	46	143	116	40	9	3	0	531	1666	23				
0.3 - 0.49	1	2	2	4	6	6	4	5	4	0	34	69	13				
0.5 - 0.69	0	2	0	0	0	3	4	4	7	3	23	61	7				
0.7 - 0.89	0	1	0	0	0	1	2	8	16	10	38	120	5				
0.9 - 1.09	2	0	1	1	0	0	0	3	0	6	13	39	6				
1.1 - 1.29	2	2	1	0	1	1	0	0	0	0	7	7	4				
1.3 - 1.49	0	1	0	0	0	0	0	0	1	0	2	2	2				
> 1.49	0	0	0	0	0	0	0	0	0	0							
TOTAL	455	2382	1346	249	290	152	50	30	31	19	5004	7979					

TABLE 25. - Distribution of 5,004 U.S. natural gas reservoirs according to argon content and accumulated into various helium content groups

Argon, percent	Reservoirs and helium content ¹										Total	Helium content, mole-percent	
	(He <0.10)		(0.10≤He<0.30)		(He ≥0.30)		(He ≥1.00)		(He ≥5.00)			Maximum	Average
	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²	No.	Pct ²			
0.0-0.09.....	2,711	62.2	1,281	29.4	364	8.4	26	0.6	0	0	4,356	3.25	0.10
0.1-0.29.....	113	21.3	61	11.5	357	67.2	168	31.6	3	0.6	531	6.50	.85
0.3-0.49.....	3	8.8	2	5.9	29	85.3	19	55.9	4	11.8	34	5.75	1.91
0.5-0.69.....	2	8.7	0	0	21	91.3	21	91.3	10	43.5	23	8.60	4.28
0.7-0.89.....	1	2.6	0	0	37	97.4	37	97.4	26	68.4	38	9.74	5.68
0.9-1.09.....	2	15.4	1	7.7	10	76.9	9	69.2	6	46.2	13	8.80	4.58
1.1-1.29.....	4	57.1	1	14.3	2	28.6	1	14.3	0	0	7	1.80	.36
1.3-1.49.....	1	50.0	0	0	1	50.0	1	50.0	1	50.0	2	5.19	2.64
All ranges..	2,837	56.7	1,346	26.9	821	16.4	282	5.6	50	1.0	5,004	9.74	0.27

¹Helium content classification in mole-percent.

²Percent of total reservoirs in percentage range.

The argon contents of the reservoirs investigated vary from 0.0 to 1.4 percent, averaging 0.01 percent. The atmosphere contains 0.94 percent of argon, which is considerably higher than the average, although several reservoirs contained amounts equal to or greater than that percentage found in the atmosphere. The origin and accumulation of argon in natural gas reservoirs, like helium and nitrogen, has been the subject of many investigators (13, 33, 43). Wasserburg (45) has shown that the argon in gas from the western part of the Panhandle field of Texas consisted mainly of argon-40, the decay product of potassium-40. Pierce (33), however, indicated an apparent problem in explaining the radiogenic argon (0.10 percent) in the Panhandle field. He stated that: "Calculations show that the reservoir rock would have to be about 100 percent potassium to supply the argon present; the argon, therefore, ... must have been derived from an external source."

Katz (13) has indicated that the argon in natural gas reservoirs is believed to come primarily from the decay of potassium-40. He has also determined that the presence of high percentages of argon in New Mexico reservoirs containing high-helium-content gas could reflect large potassium deposits associated with the source beds.

Argon and Depth of Reservoir

Table 26 lists the number of reservoirs in various depth ranges accumulated according to the argon content of the gas for all 5,004 reservoirs. (Similar tables for each individual geologic system are included in the Appendix.) Only 4,875 of 5,004 reservoirs, represented by 7,841 gas analyses, had argon and depth information. There were 4,253 of these reservoirs that had argon contents of less than 0.1 percent. One hundred sixty-three reservoirs contained 0.3 percent or more of argon, and all of them were found above 11,000 feet. All reservoirs from 11,000 to 19,000 feet contained less than 0.3 percent of argon. Below 19,000 feet, all of the reservoirs contained less than 0.1 percent of argon. All but one of the reservoirs with 0.5 percent or more of argon were found above 9,000 feet. This reservoir was found at a depth of 9,843 feet and contained 1.1 percent of argon and only 0.01 percent of helium in the gas. The highest argon contents (also the highest helium and nitrogen contents) were generally found in the shallower reservoirs, above 9,000 feet, with the deeper reservoirs containing the lower concentrations.

TABLE 26. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM:ALL AGES		MINIMUM DEPTH:		110		MAXIMUM DEPTH:22,566		RESERVOIRS: 4875		SAMPLES: 7,841		STATES: 33											
AVERAGE DEPTH, FEET		ARGON CONTENT IN PERCENTAGE																					
		LESS THAN 0.1		.10 TO .29		.30 TO .49		.50 TO .69		.70 TO .89		.90 TO 1.09		1.10 TO 1.29		1.30 TO 1.49		GREATER THAN 1.49		NUMBER OF RESERVOIRS		NUMBER OF SAMPLES	
0 - 999		43	13	4	3	6	1	3	0	0	73	125	19										
1000 - 1999		258	49	0	2	6	2	2	1	0	320	627	24										
2000 - 2999		491	81	0	0	1	0	0	0	0	573	1394	23										
3000 - 3999		519	117	6	3	3	1	0	0	0	649	1071	25										
4000 - 4999		598	98	2	2	5	0	0	1	0	706	1122	22										
5000 - 5999		474	44	6	0	1	2	0	0	0	527	766	21										
6000 - 6999		420	29	3	8	6	6	0	0	0	472	746	17										
7000 - 7999		361	19	3	2	9	0	0	0	0	394	550	16										
8000 - 8999		309	20	5	1	0	0	0	0	0	335	468	17										
9000 - 9999		214	9	1	0	0	0	1	0	0	225	273	14										
10000 - 10999		162	10	1	0	0	0	0	0	0	173	207	10										
11000 - 11999		129	5	0	0	0	0	0	0	0	134	154	10										
12000 - 12999		90	6	0	0	0	0	0	0	0	96	111	8										
13000 - 13999		58	4	0	0	0	0	0	0	0	62	67	8										
14000 - 14999		36	2	0	0	0	0	0	0	0	38	39	5										
15000 - 15999		38	2	0	0	0	0	0	0	0	40	46	7										
16000 - 16999		18	1	0	0	0	0	0	0	0	19	24	5										
17000 - 17999		9	2	0	0	0	0	0	0	0	11	17	3										
18000 - 18999		9	2	0	0	0	0	0	0	0	11	13	4										
19000 - 19999		4	0	0	0	0	0	0	0	0	4	5	1										
20000 - 20999		7	0	0	0	0	0	0	0	0	7	9	2										
21000 - 21999		5	0	0	0	0	0	0	0	0	5	6	2										
22000 - 22999		1	0	0	0	0	0	0	0	0	1	1	1										
RESERVOIRS		4253	513	31	21	37	12	6	2	0	4875	7841											

Argon Content of Reservoirs by Geologic System

Table 27 lists the distribution of reservoirs that contained various concentrations of argon in each of the 13 geologic systems. Reservoirs with argon contents ranging from 0.3 to 1.4 percent account for 117 of the 5,004 reservoirs, and 99 of these reservoirs were found in the Triassic, Permian, Pennsylvanian, Mississippian, and Devonian Systems. Only nine reservoirs in these five systems with at least 0.3 percent of argon contained less than 0.30 percent helium. The Quaternary System did not have any reservoirs that contained natural gas with over 0.1 percent of argon. Five reservoirs were found in Tertiary and Cretaceous Systems with over 0.3 percent of argon. None of these five reservoirs, however, contained gas with 0.30 percent or more of helium. The Jurassic and Silurian Systems, like the two youngest systems, did not have any reservoirs that contained gas with 0.3 percent or more of argon. The oldest three systems, Ordovician, Cambrian and Ordovician, and Cambrian, had 13 reservoirs with argon contents ranging from 0.3 to 1.4 percent. Ten of these 13 reservoirs contained 0.30 percent or more of helium, 8 contained 1 percent or more, and 1 contained over 5 percent of helium. Argon concentrations of 0.3 percent or more are found mostly in geologic systems older than the Jurassic. These reservoirs also contained the highest concentrations of helium and nitrogen.

Helium and Argon Correlation

The rank correlation coefficient for the maximum helium and argon is -0.024 which is not significant, and this is an indication that there is no linear relationship between the two. The rank correlation coefficient for the average helium content is 0.405, which is also not significant. There does not seem to be any linear relationship between maximum and average helium contents when compared with the argon content of the natural gas. Figure 9, however, indicates an apparent relationship between maximum and average helium contents and the argon percentage ranges, although the relationship does not appear to be linear.

Correlation tests with various argon contents and reservoirs containing 0.30 percent or more of helium, 1 percent or more of helium, and 5 percent or more of helium yield correlation coefficients that are not significant. These correlation tests, therefore, indicate that there is no apparent linear relationship between these three helium content groups and the argon present in the natural gas. A tabulation of the rank correlation coefficients for the relationship between the various helium content groups and argon content is included in the Summary and conclusions.

Although the correlation tests with argon and helium are not significant with respect to linear relationships, there does seem to be a definite nonlinear association between them. The results obtained from the rank correlation tests are confirmed in figure 9, which also indicates a possible nonlinear relationship between the concentrations of helium and argon contained in natural.

TABLE 27. - Argon distribution in U.S. natural gas reservoirs according to geological system

GEOLOGICAL SYSTEM	LESS THAN 0.1	ARGON CONTENT IN PERCENTAGE								NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49			
QUATERNARY	28	0	0	0	0	0	0	0	0	28	34	3
TERTIARY	807	20	0	0	0	0	0	1	0	828	942	10
CRETACEOUS	644	50	2	1	0	0	0	1	0	698	918	15
JURASSIC	91	19	0	0	0	0	0	0	0	110	137	12
TRIASSIC	5	5	4	2	4	1	1	1	0	22	38	7
PERMIAN	211	97	1	2	6	1	3	0	0	321	1481	11
PENNSYLVANIAN	1368	184	9	9	10	2	1	0	0	1583	2511	18
MISSISSIPPIAN	469	62	9	6	8	4	0	0	0	558	819	22
DEVONIAN	391	26	2	1	8	4	0	1	0	433	499	20
SILURIAN	181	11	0	0	0	0	0	0	0	192	229	12
ORDOVICIAN	136	21	2	0	0	1	0	0	0	160	198	13
CAMBRO-ORDOVICIAN	13	30	4	1	1	0	0	0	0	49	131	4
CAMBRIAN	12	6	1	1	1	0	0	1	0	22	42	8
TOTAL	4356	531	34	23	38	13	7	2	0	5004	7979	

SUMMARY AND CONCLUSIONS

The statistical information revealed by this investigation indicates that certain relationships exist between helium found in natural gas reservoirs of the United States and geographic and geologic factors, reservoir depth, and between certain gas components--particularly nitrogen. As a result of these findings, tables and figures have been prepared that can be used, along with other data, for estimating or predicting maximum helium expectations from natural gas reservoirs of the United States. The information can be extended to potential or probable gas resources including helium, nitrogen, carbon dioxide, and argon gases.

In addition to tables and figures, rank correlation coefficients have been calculated to measure the strength of relationships between various helium content groups and geologic system, reservoir depth and the component gases nitrogen, carbon dioxide, and argon. A summary of findings follows, and the coefficients appear in table 28.

TABLE 28. - Rank correlation coefficient measurements

Helium group	Item correlated Pct	Rank correlation coefficients ¹				
		Geologic system ²	Reservoir depth ³	Nitrogen ⁴	Carbon dioxide ⁵	Argon ⁶
Helium <0.10		⁷ -0.824	⁷ 0.956	⁸ -0.115	⁸ -0.430	⁸ -0.024
0.10 ≤ Helium <0.30		⁸ .402	⁹ -.635	⁸ -.418	⁸ -.152	⁸ -.381
Helium ≥ 0.30		⁹ .654	⁷ -.967	⁸ .309	⁸ .455	⁸ .024
Helium ≥ 1.00		⁹ .615	⁷ -.788	⁷ .709	⁸ -.139	⁸ .238
Helium ≥ 5.00		⁸ .442	⁷ -.692	⁷ .830	⁸ -.455	⁸ .482
Maximum helium		⁸ .214	⁷ -.835	⁷ .939	⁷ -.770	⁸ -.024
Average helium		⁸ .512	⁷ -.879	⁷ .867	⁸ -.297	⁸ .405

¹Negative values denote inverse correlations.

²Data from table 7.

³Data from table 12.

⁴Data from table 14.

⁵Data from table 20.

⁶Data from table 25.

⁷Relationship highly significant.

⁸Relationship not significant.

⁹Relationship significant.

NOTE.--Geologic systems, reservoir depths, and nitrogen, carbon dioxide and argon contents were arranged and ranked 1, 2, 3,...N from the youngest or lowest values through the oldest or highest values, respectively. The percentage of reservoirs in each helium group, for each item above, were ranked 1, 2, 3,...N from the lowest percentage through the highest percentage. The differences between the two rankings were determined and used to calculate the rank correlation coefficients.

1. Geologic system correlation--Linear relationship between geologic system and natural gas containing less than 0.10 percent of helium is highly significant; natural gas containing 0.30 percent or more of helium and 1.00 percent or more of helium is significant; and the other relationships are not significant.

2. Reservoir depth correlation--Linear relationship between reservoir depth and helium content is highly significant for all helium groups except one, and its relationship is significant.

3. Nitrogen correlation--Linear relationships between nitrogen content and natural gas containing 1.00 percent or more of helium, 5.00 percent or more of helium, maximum helium content, and average helium content are all highly significant. Other relationships are not significant.

4. Carbon dioxide correlation--Linear relationship between carbon dioxide content and maximum helium content of natural gas is highly significant. Other relationships with helium are not significant.

5. Argon correlation--Linear relationships between argon content in natural gas and helium content are not significant.

6. Reservoir rocks of Paleozoic age are the most favorable for finding natural gas, with more than 0.30 percent of helium.

7. Cenozoic reservoir rocks are the least favorable for finding helium in the natural gas, and these reservoirs generally contain natural gas with less than 0.10 percent of helium.

8. The helium content of natural gas generally decreases as the depth of the reservoirs increases.

9. Natural gas reservoirs containing over 1 percent of helium are rarely found at depths below 9,000 feet.

10. Most natural gas reservoirs contain at least a trace (0.005 of 1 percent) of helium.

Fifteen States had reservoirs that contained gas with 1 percent or more of helium. The largest concentration of these reservoirs was found in 11 States in the west-central part of the United States. Other States outside the 11-State area with reservoirs that contained 1 percent or more of helium are Alaska, Indiana, Kentucky, and Michigan. All reservoirs that contained 5 percent or more of helium were found in the west-central United States and includes Arizona, Colorado, Kansas, New Mexico, and Utah.

Average helium contents and maximum helium contents progressively increase as the geologic age of the reservoir rocks increase from the youngest through the oldest erathems (Cenozoic, Mesozoic, and Paleozoic). However, when the erathems are subdivided into the 13 geologic systems, the average helium contents and the maximum helium contents do not progressively increase

as the ages of the reservoir rocks increase from the youngest through the oldest.

Natural gases with the highest helium contents are found in reservoirs of the Jurassic System, or older geologic systems. The two youngest systems (Quaternary and Tertiary) contain the lowest averages and the lowest maximum helium contents of any of the geologic systems. The highest helium content found in each geologic system does not follow any observable pattern with respect to depth below the surface, nor does it seem to be related to the stratigraphic position of the reservoir.

The most favorable reservoir depths for high-helium-content gas are those reservoirs less than 5,000 feet deep. In this interval, 26 percent of the reservoirs contained 0.30 percent or more of helium in the gas. Natural gas containing 1.52 percent of helium was found in a reservoir at a depth of 18,004 feet and by 1974, was the deepest reservoir found containing over 0.5 percent of helium. Prior to 1961, only a small number of gas samples were analyzed from reservoirs at depths below 11,000 feet, and all these reservoirs contained less than 0.5 percent of helium in the gas.

The maximum helium content and the average helium content of the reservoirs tend to decrease as the reservoir depth increases. Although the geologically older reservoirs generally contain higher helium contents than the geologically younger reservoirs, they are not necessarily the deeper reservoirs. There is no linear correlation between reservoir depth and geologic age.

Reservoirs that contained 0.30 percent or more of helium in the gas were found in about the same percentage in all but the lowest and highest nitrogen content ranges. The percentage of reservoirs with 1 percent or more of helium generally increases as the nitrogen content of the gas increases. Correlation tests indicate a strong relationship between nitrogen found in natural gas and contained helium.

Maximum helium contents tend to decrease as the carbon dioxide content of the gas increases. The carbon dioxide content found in the natural gas does not seem to be related to the helium found in the gas. High helium contents are generally found in natural gas containing less than 10 percent of carbon dioxide.

The argon content in natural gas increases with the maximum and average helium contents until the argon content reaches 0.9 percent. Continued increases in the argon content generally results in lower concentrations of helium in the natural gas. Correlation tests indicate that a linear relationship between argon and helium is not significant, although there appears to be a definite nonlinear relationship between the two.

The highest argon contents, and also the highest helium and nitrogen contents, were generally found in reservoirs above 9,000 feet. Argon concentrations of 0.3 percent or more were found mostly in geologic systems older than the Jurassic System. These systems also generally contained the highest concentrations of helium and nitrogen.

If a natural gas contains 0.3 percent or more of argon, the chances are approximately 90 in 100 that the gas contains 30 percent or more of nitrogen and about 86 in 100 that it also contains 0.30 percent or more of helium. Natural gas containing 30 percent or more of nitrogen will also contain 0.30 percent or more of helium 75 percent of the time. Similarly, the nitrogen, argon, and helium contents found in natural gas indicates the chances are about 88 in 100 that a gas containing 30 percent of nitrogen and 0.3 percent of argon will also contain 0.30 percent or more of helium.

The association of argon and nitrogen in natural gas suggests that the occurrence of these two gases may, in some way, be related and that this relationship may also be related to the occurrence of helium found in natural gas.

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APPENDIX A.--GEOLOGIC SYSTEM, RESERVOIR DEPTH, GAS COMPONENTS, AND
GAS-HELIUM RATIOS OF GASES CONTAINING 1 PERCENT OR MORE OF
HELIUM IN U.S. RESERVOIRS

Appendix A contains information on the 366 reservoirs from 15 States that contained 1 percent or more of helium in the gas. Kansas has the most reservoirs that contain 1 percent or more of helium and it includes 187 reservoirs, followed by New Mexico with 50 and Arizona with 32. The remaining 12 States each have 20 reservoirs or less with 1 percent or more of helium.

The table includes, in addition to the States, the geologic system in which the reservoirs are located, the reservoir depths, nitrogen contents, carbon dioxide contents, argon contents, and gas-helium ratios for each reservoir listed.

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	CO ₂ /HE
COLORADO	MISS	4665	2.29	0.2	54.7	1.8	0.0871	23.8344	0.7843
COLORADO	MISS	4774	4.63	0.7	56.6	7.1	0.1511	12.2246	1.5334
COLORADO	MISS	4760	2.94	0.6	42.7	14.2	0.2040	14.5238	4.8299
COLORADO	PENN	5477	4.28	0.3	70.6	0.8	0.0700	16.4953	0.1869
COLORADO	MISS	6822	1.00	0.1	11.5	9.5	0.1000	11.5000	9.3000
INDIANA	MISS	4153	2.29	0.2	94.4	0.2	0.0873	41.2227	0.0873
KANSAS	PENN	265	3.66	---	91.9	0.0	---	25.1092	0.0000
KANSAS	PENN	475	1.80	---	87.2	0.1	---	48.4444	0.0555
KANSAS	PENN	615	1.81	---	76.8	0.1	---	42.2674	0.0550
KANSAS	PENN	620	1.58	0.1	39.7	0.0	0.0724	28.7681	0.0000
KANSAS	PENN	677	1.16	---	14.5	0.0	---	12.4677	0.0000
KANSAS	PENN	758	1.00	---	39.1	0.0	---	39.1000	0.0000
KANSAS	PERM	630	2.64	---	76.0	0.4	---	28.7878	0.1515
KANSAS	PENN	960	1.31	---	66.2	0.1	---	50.5343	0.0763
KANSAS	PENN	1121	1.96	---	75.9	0.2	---	38.7244	0.1020
KANSAS	PENN	1136	1.13	---	24.3	0.1	---	21.5044	0.0884
KANSAS	PENN	1140	1.95	---	1.9	0.1	---	0.9743	0.0512
KANSAS	PENN	1151	1.12	---	15.3	0.0	---	13.5758	0.0000
KANSAS	PERM	1243	1.00	0.1	41.0	0.1	0.1000	41.0000	0.1000
KANSAS	CAMU	1350	1.22	---	15.1	0.2	---	12.3770	0.1639
KANSAS	PERM	1385	1.26	---	29.8	0.3	---	23.6507	0.2380
KANSAS	PERM	1398	1.31	---	28.8	0.2	---	21.9847	0.1526
KANSAS	PERM	1770	1.30	0.1	44.0	0.9	0.0769	33.8461	0.6923
KANSAS	PERM	2000	1.14	0.1	29.8	0.2	0.0877	26.1403	0.1754
KANSAS	PENN	2116	1.02	---	36.7	0.6	---	35.9803	0.5882
KANSAS	PENN	2304	1.45	0.1	42.9	0.2	0.0689	29.5862	0.1379
KANSAS	PENN	2430	1.20	0.1	37.1	0.1	0.0833	30.9166	0.0833
KANSAS	PENN	2501	1.20	0.1	35.3	0.1	0.0833	29.4166	0.0833
KANSAS	PENN	2550	1.60	0.1	47.2	0.1	0.0625	29.5000	0.0625
KANSAS	PERM	2663	1.00	0.0	34.0	0.1	0.0000	34.0000	0.1000
KANSAS	PERM	2884	1.00	0.1	37.1	0.2	0.1000	37.1000	0.2000
KANSAS	PENN	2897	2.00	0.1	78.7	0.3	0.0500	39.3500	0.1500
KANSAS	PENN	2915	1.05	0.1	25.4	0.2	0.0952	24.1904	0.1904
KANSAS	PENN	2967	2.40	0.1	26.3	0.2	0.0416	10.9583	0.0833
KANSAS	PENN	2970	1.52	---	32.6	0.1	---	24.6969	0.0757
KANSAS	PENN	2978	1.01	---	30.1	0.3	---	29.8019	0.2970
KANSAS	PERM	2990	1.59	---	12.1	0.2	---	7.6100	0.1257
KANSAS	PENN	2990	2.28	0.1	18.9	0.0	0.0438	8.2894	0.0000
KANSAS	CAMU	2999	2.95	0.1	26.5	0.3	0.0338	8.9830	0.1016
KANSAS	PENN	3009	1.03	0.0	27.8	0.1	0.0000	26.9902	0.0970
KANSAS	PENN	3011	1.11	---	27.1	0.2	---	24.4144	0.1801
KANSAS	PENN	3018	1.10	---	31.2	0.4	---	28.3636	0.3636
KANSAS	PENN	3022	1.00	0.0	20.5	0.3	0.0000	20.5000	0.3000
KANSAS	PENN	3028	1.95	0.1	26.1	0.1	0.0512	13.3846	0.0512
KANSAS	PENN	3029	2.06	0.1	23.8	0.2	0.0484	11.5565	0.0969
KANSAS	PENN	3042	1.05	0.0	24.7	1.9	0.0000	23.5238	1.8095

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	CO ₂ /HE
KANSAS	PENN	3065	1.15	---	27.5	0.1	---	24.1592	0.0884
KANSAS	MISS	3074	1.50	---	63.4	0.1	---	39.6250	0.0625
KANSAS	PENN	3097	2.09	0.1	23.2	0.1	0.0478	11.1004	0.0478
KANSAS	PENN	3139	1.01	0.0	26.1	0.2	0.0000	25.7650	0.1974
KANSAS	PENN	3153	1.00	0.1	25.3	0.1	0.1010	25.5555	0.1010
KANSAS	PENN	3161	1.85	0.1	29.0	0.0	0.0540	15.6756	0.0000
KANSAS	MISS	3172	1.58	---	63.4	0.2	---	40.1265	0.1265
KANSAS	PENN	3195	2.51	0.1	31.0	0.1	0.0432	13.4199	0.0432
KANSAS	PENN	3202	2.42	0.2	28.0	0.3	0.0826	11.5702	0.1239
KANSAS	CAP	3204	1.83	0.1	33.4	0.3	0.0546	18.2513	0.1639
KANSAS	PENN	3206	1.95	0.1	27.5	0.0	0.0512	14.1025	0.0000
KANSAS	MISS	3206	1.19	0.0	42.2	0.1	0.0000	35.4621	0.0840
KANSAS	PENN	3222	1.02	0.0	25.4	0.2	0.0000	24.9019	0.1960
KANSAS	PENN	3240	1.75	0.1	27.0	0.1	0.0569	15.3846	0.0569
KANSAS	PENN	3250	1.30	0.0	29.5	3.5	0.0000	22.6923	2.6923
KANSAS	PENN	3250	1.60	0.0	30.2	0.3	0.0000	18.8750	0.1875
KANSAS	PENN	3257	1.04	0.0	22.3	0.1	0.0000	21.4423	0.0961
KANSAS	PENN	3261	2.39	0.1	21.5	0.2	0.0418	8.9958	0.0836
KANSAS	PENN	3267	2.05	0.1	18.5	0.0	0.0487	8.9268	0.0000
KANSAS	MISS	3278	1.00	0.1	19.1	0.0	0.1010	19.2929	0.0000
KANSAS	DEVO	3280	1.41	0.1	39.9	0.2	0.0709	28.2978	0.1418
KANSAS	PENN	3309	1.88	---	23.3	0.4	---	12.3936	0.2127
KANSAS	PENN	3326	2.49	0.1	28.0	0.1	0.0401	11.2449	0.0401
KANSAS	MISS	3333	1.16	---	39.6	0.1	---	34.1379	0.0862
KANSAS	PENN	3334	1.91	0.1	20.8	0.1	0.0522	10.8729	0.0522
KANSAS	PENN	3342	1.41	0.1	16.6	0.4	0.0709	11.7730	0.2836
KANSAS	PENN	3385	1.89	0.1	20.9	0.1	0.0528	11.0465	0.0528
KANSAS	CAP	3403	4.07	0.1	47.0	0.2	0.0245	11.5479	0.0491
KANSAS	PENN	3416	1.00	0.0	23.4	0.1	0.0000	23.4000	0.1000
KANSAS	PENN	3422	1.11	0.0	24.1	0.1	0.0000	21.5563	0.0894
KANSAS	PENN	3451	1.81	0.1	21.9	0.1	0.0552	12.0994	0.0552
KANSAS	CAP	3457	2.43	0.1	19.0	0.3	0.0411	7.8189	0.1234
KANSAS	CAP	3460	5.75	0.3	74.9	0.5	0.0521	13.0260	0.0869
KANSAS	CAP	3467	5.87	0.2	72.9	0.4	0.0340	12.4190	0.0681
KANSAS	PENN	3468	1.61	---	11.7	0.2	---	7.2670	0.1242
KANSAS	CAP	3468	1.63	---	12.1	0.2	---	7.4233	0.1226
KANSAS	PENN	3473	1.54	---	11.3	0.3	---	7.3376	0.1948
KANSAS	CAP	3481	1.59	---	12.3	0.3	---	7.7261	0.1884
KANSAS	CAP	3490	1.57	---	12.0	0.3	---	7.6045	0.1901
KANSAS	CAP	3494	1.92	0.1	17.4	0.3	0.0519	9.0436	0.1559
KANSAS	CAP	3494	1.45	---	11.0	0.2	---	7.5705	0.1376
KANSAS	PENN	3504	1.62	---	12.8	0.1	---	7.9012	0.0617
KANSAS	CAP	3519	1.69	0.1	15.1	0.2	0.0591	8.9349	0.1183
KANSAS	CAP	3529	1.60	0.1	12.6	0.1	0.0625	7.8750	0.0625
KANSAS	CAP	3535	1.18	---	8.1	0.2	---	6.8354	0.1687
KANSAS	CAP	3537	1.89	0.1	16.3	0.2	0.0527	8.6061	0.1055
KANSAS	PENN	3557	1.00	0.0	25.4	0.1	0.0000	25.4000	0.1000
KANSAS	CAP	3559	1.74	0.1	15.3	0.2	0.0574	8.7931	0.1149



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TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N2/HE	C02/HE
KANSAS	PENN	3540	1.24	0.0	25.1	0.2	0.0000	20.2419	0.1612
KANSAS	CARD	3541	1.55	0.1	11.4	0.2	0.0750	8.5521	0.1500
KANSAS	PENN	3551	2.61	---	67.3	1.4	---	25.7854	0.5363
KANSAS	CARD	3556	6.50	0.2	77.2	0.4	0.0307	11.8769	0.0615
KANSAS	CARD	3561	1.34	---	8.9	0.4	---	6.6417	0.2985
KANSAS	PENN	3564	1.70	0.1	13.9	0.2	0.0588	8.1764	0.1176
KANSAS	CARD	3564	1.80	0.1	15.3	0.1	0.0555	8.5000	0.0555
KANSAS	CARD	3564	1.90	0.1	14.5	0.1	0.0526	7.6315	0.0526
KANSAS	CARD	3565	1.55	0.1	12.9	0.3	0.0651	8.4093	0.1955
KANSAS	PENN	3574	1.68	0.1	12.8	0.5	0.0595	7.6190	0.2976
KANSAS	CARD	3576	2.74	---	76.7	1.7	---	27.9927	0.6204
KANSAS	CARD	3587	1.38	0.1	10.0	0.3	0.0720	7.2098	0.2162
KANSAS	PENN	3588	1.70	0.1	13.5	0.1	0.0588	7.9411	0.0588
KANSAS	PENN	3591	2.96	0.1	25.1	0.1	0.0337	8.4797	0.0337
KANSAS	CARD	3591	5.04	0.1	53.2	0.6	0.0198	10.5409	0.1188
KANSAS	OROU	3596	1.28	---	8.2	0.3	---	6.4062	0.2343
KANSAS	OROU	3596	1.17	0.0	21.4	0.0	0.0000	18.2905	0.0000
KANSAS	CARD	3607	2.03	0.1	15.0	0.4	0.0492	7.3891	0.1970
KANSAS	CARD	3672	1.21	---	8.1	0.4	---	6.6942	0.3305
KANSAS	CARD	3700	3.65	0.2	43.8	0.6	0.0547	11.9835	0.1641
KANSAS	CARD	3704	1.02	0.1	6.7	0.4	0.0975	6.5365	0.3902
KANSAS	CARD	3718	1.77	0.5	13.8	0.5	0.2824	7.7966	0.2824
KANSAS	CARD	3730	3.33	0.4	63.3	0.4	0.1201	19.0090	0.1201
KANSAS	PENN	3741	1.02	0.1	8.6	0.3	0.0980	8.4313	0.2941
KANSAS	MISS	3745	1.07	---	46.1	0.2	---	43.0841	0.1869
KANSAS	CARD	3754	1.30	0.1	8.9	0.4	0.0769	6.8461	0.3076
KANSAS	CARD	3755	1.79	0.1	19.4	0.8	0.0558	10.8379	0.4469
KANSAS	CARD	3756	1.36	---	8.9	0.4	---	6.5441	0.2941
KANSAS	CARD	3760	2.51	0.2	26.1	0.6	0.0794	10.3736	0.2384
KANSAS	CARD	3762	1.00	---	6.3	0.3	---	6.3636	0.3030
KANSAS	CARD	3812	1.96	0.1	10.6	0.3	0.0510	5.4081	0.1530
KANSAS	PENN	3833	1.56	0.0	12.7	0.0	0.0000	8.1410	0.0000
KANSAS	CARD	3863	4.92	0.3	86.1	0.5	0.0609	17.5000	0.1016
KANSAS	CARD	3864	2.26	0.1	27.4	0.5	0.0441	12.0917	0.2206
KANSAS	OROU	4000	1.00	---	11.8	0.2	---	11.8000	0.2000
KANSAS	CARD	4016	1.09	0.1	8.4	0.5	0.0917	7.7064	0.4587
KANSAS	CARD	4021	2.82	---	25.7	0.6	---	9.1134	0.2127
KANSAS	OROU	4026	2.72	0.2	41.6	0.1	0.0735	15.2941	0.0367
KANSAS	CARD	4042	1.11	0.1	10.1	0.1	0.0900	9.0990	0.0900
KANSAS	MISS	4044	1.34	0.0	13.8	0.1	0.0000	10.2985	0.0746
KANSAS	CARD	4044	1.82	0.1	14.1	0.5	0.0547	7.7260	0.2739
KANSAS	CARD	4048	2.58	0.1	26.2	0.4	0.0387	10.1550	0.1550
KANSAS	CARD	4053	1.40	0.1	10.1	0.4	0.0714	7.2142	0.2857
KANSAS	CARD	4054	4.58	0.2	47.1	0.5	0.0456	10.7534	0.1141
KANSAS	CARD	4072	1.15	0.1	10.5	0.3	0.0866	9.0987	0.2599
KANSAS	CARD	4077	1.93	0.1	15.6	0.4	0.0517	8.0703	0.2069
KANSAS	CARD	4096	1.40	0.7	11.5	0.6	0.5000	8.2142	0.4285
KANSAS	PENN	4097	1.32	0.1	11.1	0.1	0.0757	8.4090	0.0757

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	CO ₂ /HE
KANSAS	OROU	4105	1.46	---	19.5	0.3	---	13.3561	0.2054
KANSAS	CARU	4111	1.10	0.0	7.5	0.5	0.0000	6.8181	0.4545
KANSAS	OROU	4123	1.42	---	17.7	0.2	---	12.4647	0.1408
KANSAS	PENN	4131	1.16	0.1	14.4	0.1	0.0862	12.4137	0.0862
KANSAS	MISS	4132	1.39	0.1	21.5	0.3	0.0719	15.4676	0.2158
KANSAS	OROU	4151	1.36	---	14.6	0.2	---	10.6959	0.1465
KANSAS	PENN	4250	3.46	0.2	60.7	0.3	0.0578	17.5433	0.0867
KANSAS	MISS	4257	1.16	0.1	11.0	0.1	0.0862	9.4827	0.0862
KANSAS	MISS	4329	2.80	0.1	52.8	0.2	0.0357	11.7142	0.0714
KANSAS	PENN	4407	3.34	0.2	57.1	0.1	0.0598	17.0958	0.0299
KANSAS	MISS	4444	2.37	0.1	28.7	0.2	0.0421	12.0842	0.0842
KANSAS	OROU	4448	1.70	0.2	29.4	0.3	0.1173	17.2434	0.1759
KANSAS	MISS	4450	1.80	0.1	14.2	0.2	0.0555	7.8888	0.1111
KANSAS	CARU	4475	1.97	---	24.3	0.4	---	12.3350	0.2030
KANSAS	PENN	4495	1.01	0.0	8.9	0.5	0.0000	8.8118	0.4950
KANSAS	MISS	4496	2.76	0.1	34.2	0.1	0.0362	12.3913	0.0362
KANSAS	MISS	4512	2.65	0.1	35.0	0.3	0.0377	13.2075	0.1132
KANSAS	MISS	4558	1.05	0.1	17.7	0.1	0.0970	17.1844	0.0970
KANSAS	PENN	4558	1.70	0.1	15.1	0.6	0.0588	8.8823	0.3529
KANSAS	PENN	4571	1.38	0.1	25.6	0.1	0.0724	18.5507	0.0724
KANSAS	OROU	4582	1.55	---	20.3	0.2	---	13.0967	0.1290
KANSAS	MISS	4583	3.07	0.2	39.4	0.3	0.0651	12.8338	0.0977
KANSAS	MISS	4592	1.64	0.1	24.5	0.2	0.0609	14.9390	0.1219
KANSAS	MISS	4617	2.38	0.1	41.7	0.1	0.0420	13.3193	0.0420
KANSAS	MISS	4645	1.27	0.1	14.6	0.3	0.0787	11.4960	0.2362
KANSAS	MISS	4654	2.36	0.1	32.4	0.1	0.0423	13.7288	0.0423
KANSAS	PENN	4660	2.82	0.1	21.3	3.4	0.0354	7.5531	1.2056
KANSAS	OROU	4864	1.21	0.1	22.0	0.1	0.0826	18.1818	0.0826
KANSAS	MISS	4868	2.77	0.2	42.3	0.0	0.0722	15.2707	0.0000
KANSAS	MISS	4986	2.27	0.2	43.9	0.1	0.0881	19.3392	0.0440
KANSAS	MISS	4994	2.00	0.4	36.7	9.8	0.2000	18.3500	4.9000
KANSAS	PENN	5008	2.26	0.1	59.2	0.5	0.0442	26.1946	0.2212
KANSAS	PENN	5234	1.40	0.1	12.9	0.4	0.0714	9.2142	0.2857
KANSAS	PENN	5362	1.01	0.0	9.6	0.2	0.0000	9.5049	0.1980
KANSAS	MISS	5460	1.60	0.1	30.0	0.2	0.0625	18.7500	0.1250
KANSAS	MISS	5556	1.20	0.0	10.3	0.3	0.0000	8.5833	0.2500
KANSAS	OROU	---	1.61	---	29.4	0.2	---	18.2156	0.1239
KANSAS	OROU	---	1.79	---	23.3	0.3	---	13.0167	0.1675
KANSAS	PERM	---	1.81	0.1	15.0	0.1	0.0552	8.2872	0.0552
KANSAS	PENN	---	3.82	0.2	35.8	0.4	0.0523	9.3717	0.1047
KANSAS	OROU	---	1.06	0.0	8.9	0.3	0.0000	8.3962	0.2830
KANSAS	OROU	---	1.15	---	13.6	0.0	---	11.8260	0.0000
KANSAS	MISS	---	1.46	0.1	14.0	0.1	0.0684	9.5890	0.0684
KANSAS	PENN	---	2.76	---	91.6	0.2	---	33.1884	0.0724
KANSAS	CARU	---	1.76	---	34.5	0.3	---	19.5689	0.1701
KANSAS	OROU	---	1.13	---	13.9	0.3	---	12.3008	0.2654
KANSAS	PENN	---	1.86	0.1	22.9	0.3	0.0531	12.1808	0.1595
KANSAS	PENN	---	1.90	0.1	24.8	0.4	0.0526	13.0526	0.2105

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	C ₀₂ /HE
KANSAS	ORDO	---	1.12	---	13.5	0.2	---	12.0535	0.1785
KANSAS	PENN	---	1.11	0.1	23.4	0.1	0.0900	21.0810	0.0900
KANSAS	CANU	---	5.30	---	25.5	2.4	---	7.7272	0.7272
KENTUCKY	CAMB	4450	1.52	0.5	70.7	1.8	0.3787	53.5606	1.3636
MICHIGAN	MISS	1031	1.11	---	11.3	0.4	---	10.1801	0.3603
MICHIGAN	MISS	1211	1.07	---	25.9	0.1	---	24.2056	0.0934
MONTANA	CAMB	5250	1.20	---	79.0	9.4	---	65.8333	7.8333
MONTANA	MISS	5000	1.16	---	68.0	23.5	---	58.6206	20.2586
MONTANA	ORDO	5203	1.30	0.5	97.5	0.0	0.2307	75.0000	0.0000
MONTANA	MISS	---	1.56	0.1	39.8	1.6	0.0724	28.8405	1.3043
NEBRASKA	CAMB	3500	1.20	0.4	63.7	0.4	0.3333	65.7500	0.3333
NEBRASKA	PENN	5862	2.50	0.5	75.5	9.8	0.2000	30.2000	3.9200
NEW MEXICO	INDIA	975	9.01	---	72.0	0.5	---	7.9911	0.0332
NEW MEXICO	MISS	990	7.50	0.7	66.4	0.1	0.0933	8.8533	0.0133
NEW MEXICO	INDIA	1137	1.80	1.2	77.7	18.8	0.6666	43.1666	10.4444
NEW MEXICO	PENN	1585	1.72	0.5	56.0	52.1	0.2898	20.8695	30.2028
NEW MEXICO	CAMB	5902	5.50	0.7	92.9	0.3	0.1272	16.8909	0.0545
NEW MEXICO	PENN	5212	4.62	0.7	73.8	0.0	0.1513	15.9567	0.0000
NEW MEXICO	MISS	5812	4.10	0.9	92.2	0.5	0.2195	22.4878	0.1219
NEW MEXICO	DEVO	6020	7.80	1.0	90.5	0.1	0.1282	11.6025	0.0128
NEW MEXICO	DEVO	6100	4.05	0.9	93.2	0.0	0.2222	23.0123	0.0000
NEW MEXICO	PENN	6100	1.40	0.1	17.4	0.1	0.0714	12.4285	0.0714
NEW MEXICO	DEVO	6220	2.87	0.7	90.7	0.0	0.2439	31.6027	0.0000
NEW MEXICO	DEVO	6230	4.16	0.9	91.1	0.0	0.2163	21.8990	0.0000
NEW MEXICO	PENN	6237	6.65	0.6	52.3	0.8	0.0902	7.8646	0.1203
NEW MEXICO	PENN	6350	6.74	0.7	63.0	1.9	0.1037	9.3416	0.2817
NEW MEXICO	PENN	6360	4.53	0.5	42.7	1.1	0.1154	9.8614	0.2540
NEW MEXICO	DEVO	6445	2.25	0.6	83.1	0.0	0.2666	36.9333	0.0000
NEW MEXICO	PENN	6514	8.00	0.7	70.1	0.9	0.0875	8.7625	0.1125
NEW MEXICO	PENN	6554	6.00	0.5	44.1	4.0	0.0833	7.5500	0.6666
NEW MEXICO	PENN	6577	2.54	0.3	34.3	0.4	0.1179	13.4827	0.1572
NEW MEXICO	MISS	6600	2.55	0.8	87.4	0.2	0.3137	34.2745	0.0784
NEW MEXICO	MISS	6634	7.07	0.9	77.4	0.5	0.1271	10.9368	0.0423
NEW MEXICO	DEVO	6640	7.07	---	90.4	0.2	---	12.7773	0.0282
NEW MEXICO	PENN	6767	3.13	0.4	32.4	2.5	0.1277	10.3448	0.7982
NEW MEXICO	PENN	6840	4.73	0.5	58.9	1.0	0.1057	12.4524	0.2114
NEW MEXICO	PENN	6841	2.91	0.4	40.7	9.5	0.1372	13.9622	3.2590
NEW MEXICO	PENN	6880	5.13	0.5	27.1	4.1	0.0973	5.2775	0.7984
NEW MEXICO	MISS	6950	8.01	---	75.4	0.5	---	9.4132	0.0624
NEW MEXICO	MISS	6950	7.97	1.0	74.8	2.2	0.1253	9.3746	0.2757
NEW MEXICO	DEVO	6980	7.68	0.9	76.8	1.1	0.1171	10.0000	0.1432
NEW MEXICO	DEVO	6995	6.04	0.8	65.1	4.4	0.1324	10.7781	0.7284
NEW MEXICO	PENN	7010	5.60	0.7	71.0	0.5	0.1250	12.6785	0.0535

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	CO ₂ /HE
NEW MEXICO	MISS	7034	5.15	0.6	62.7	16.1	0.1167	12.2031	3.1335
NEW MEXICO	PENN	7096	4.70	0.5	62.1	0.5	0.1063	13.2127	0.0638
NEW MEXICO	PENN	7106	5.56	0.7	67.5	0.4	0.1253	12.0837	0.0716
NEW MEXICO	PENN	7114	1.48	0.2	26.2	9.7	0.1345	17.6312	6.5275
NEW MEXICO	PENN	7131	5.50	0.7	69.6	0.4	0.1319	13.1147	0.0753
NEW MEXICO	PENN	7198	1.20	0.3	22.2	12.9	0.2500	18.5000	10.7500
NEW MEXICO	MISS	7340	1.40	0.1	6.2	88.5	0.0714	4.4285	63.2142
NEW MEXICO	PENN	7345	3.56	0.7	56.4	1.2	0.2080	16.7607	0.3566
NEW MEXICO	MISS	7445	5.63	0.7	82.6	1.4	0.1243	14.6714	0.2486
NEW MEXICO	MISS	7465	5.63	0.7	88.2	0.2	0.1241	15.6466	0.0354
NEW MEXICO	MISS	7500	5.66	0.7	83.7	1.4	0.1235	14.7697	0.2470
NEW MEXICO	MISS	7512	4.78	0.7	76.6	0.9	0.1461	15.9983	0.1879
NEW MEXICO	DEVO	7850	4.40	0.7	85.0	0.1	0.1590	19.3181	0.0227
NEW MEXICO	MISS	7895	2.71	---	---	---	---	---	---
NEW MEXICO	MISS	8020	2.77	0.6	54.7	35.6	0.2160	19.6975	12.0993
NEW MEXICO	MISS	8070	1.16	0.1	8.2	88.1	0.0862	7.0689	75.9482
NEW MEXICO	PENN	---	5.50	0.7	69.8	0.3	0.1272	12.6909	0.0545
NEW MEXICO	DEVO	---	8.11	---	72.3	2.7	---	8.9116	0.3327
NEW MEXICO	PENN	---	6.04	0.5	43.0	4.2	0.0827	7.1133	0.6947
OKLAHOMA	PENN	691	1.04	---	44.2	0.1	---	42.5000	0.0961
OKLAHOMA	PENN	845	1.19	---	43.1	0.4	---	36.2184	0.3361
OKLAHOMA	PENN	1260	1.00	0.0	31.5	0.1	0.0000	31.3000	0.1000
OKLAHOMA	PENN	1700	1.70	0.2	55.7	0.0	0.1176	32.7647	0.0000
OKLAHOMA	PENN	1738	2.00	0.2	60.5	0.0	0.1000	30.2500	0.0000
OKLAHOMA	PENN	4060	1.23	0.1	48.0	0.0	0.0813	39.0243	0.0000
OKLAHOMA	PENN	4112	1.40	0.1	35.6	0.4	0.0714	25.4285	0.2857
OKLAHOMA	PENN	4128	1.29	0.1	48.7	0.6	0.0775	37.7519	0.4651
OKLAHOMA	PENN	4161	1.29	0.1	48.7	0.1	0.0775	37.7519	0.0775
OKLAHOMA	PENN	4367	2.30	0.1	29.3	0.6	0.0434	12.7391	0.2608
OKLAHOMA	PENN	4392	1.27	0.1	17.0	0.4	0.0787	13.3858	0.3149
OKLAHOMA	PENN	4425	1.20	0.0	23.7	0.1	0.0000	19.7500	0.0833
OKLAHOMA	PENN	4470	1.00	0.2	31.8	0.1	0.2000	31.8000	0.1000
OKLAHOMA	PENN	4530	1.57	0.1	23.9	0.5	0.0636	15.2132	0.3182
OKLAHOMA	PENN	4560	1.21	0.1	50.7	0.1	0.0826	25.3719	0.0826
OKLAHOMA	PENN	4562	2.25	0.1	29.7	0.6	0.0444	13.2000	0.2666
OKLAHOMA	PENN	4571	1.68	0.1	21.3	0.8	0.0531	11.3177	0.4250
OKLAHOMA	PENN	4576	1.69	0.1	12.4	0.6	0.0589	7.3156	0.3539
OKLAHOMA	PENN	4651	2.09	0.1	27.1	0.7	0.0476	12.9170	0.3336
OKLAHOMA	PENN	4668	1.50	0.1	24.5	0.5	0.0666	16.3333	0.3333
OKLAHOMA	PENN	4684	2.18	---	25.0	0.6	---	11.4416	0.2745
OKLAHOMA	PENN	4727	1.98	0.1	27.9	0.4	0.0504	14.0695	0.2017
OKLAHOMA	PENN	4775	1.94	0.1	26.7	2.1	0.0514	13.7416	1.0808
OKLAHOMA	PENN	4787	2.19	0.1	28.0	0.9	0.0456	12.7853	0.4109
OKLAHOMA	PENN	4824	2.60	0.1	34.7	0.6	0.0384	13.3461	0.2307
OKLAHOMA	PENN	4871	2.26	---	28.0	1.4	---	12.3893	0.6194
OKLAHOMA	PENN	4899	1.30	0.0	20.5	0.2	0.0000	15.7692	0.1538
SOUTH DAKOTA	PENN	1307	1.05	---	79.0	3.2	---	76.6990	3.1067

TABLE A-1. - Geologic system, reservoir depth, gas components, and gas-helium ratios of gases containing 1 percent or more of helium in U.S. reservoirs--Continued

STATE	GEOLOGICAL SYSTEM	DEPTH	HELIUM	ARGON	NITROGEN	CARBON DIOXIDE	A/HE	N ₂ /HE	CO ₂ /HE
TEXAS	PENN	549	1.39	---	36.3	0.4	---	26.1151	0.2877
TEXAS	PENN	700	1.51	0.1	43.3	0.2	0.0660	28.5808	0.1320
TEXAS	PENN	1291	1.48	0.1	38.9	0.1	0.0675	26.2837	0.0675
TEXAS	PENN	1490	1.01	---	22.4	0.2	---	22.1782	0.1980
TEXAS	PENN	2633	1.04	0.1	15.5	0.2	0.0961	14.9038	0.1923
TEXAS	PENN	2810	1.00	---	21.0	0.2	---	21.0000	0.2000
TEXAS	PENN	2912	1.30	0.1	25.9	0.0	0.0769	19.9230	0.0000
TEXAS	PENN	2966	1.26	0.1	18.8	0.5	0.0793	14.9206	0.3968
TEXAS	PENN	3222	1.68	0.1	28.8	0.7	0.0594	17.1224	0.4161
TEXAS	PENN	3235	2.15	0.1	34.7	0.5	0.0465	16.1395	0.2325
TEXAS	PENN	3273	1.98	0.2	35.0	0.1	0.1007	17.6322	0.0503
TEXAS	PENN	3306	2.00	0.1	34.1	3.4	0.0500	17.0500	1.7000
TEXAS	PENN	3310	1.40	0.1	20.6	4.9	0.0714	14.7142	3.5000
TEXAS	PENN	3323	1.70	0.1	33.3	5.3	0.0586	19.5307	3.1085
TEXAS	PENN	3354	1.85	0.1	24.1	0.6	0.0538	12.9779	0.3231
TEXAS	PENN	3578	1.24	0.1	24.8	0.4	0.0806	20.0000	0.3225
TEXAS	PENN	3606	1.36	0.1	37.4	6.1	0.0730	27.3192	4.4558
TEXAS	PENN	3680	2.50	0.2	50.8	0.5	0.0800	20.3200	0.2000
TEXAS	PENN	---	1.09	---	---	---	---	---	---
TEXAS	PENN	---	1.56	---	0.0	0.0	---	0.0000	0.0000
UTAH	JUNA	539	2.31	---	47.2	0.3	---	20.4063	0.1297
UTAH	JUNA	860	6.32	---	87.3	0.8	---	13.8001	0.1264
UTAH	PENN	3341	1.36	0.2	64.2	33.2	0.1470	47.2058	24.4117
UTAH	PENN	4490	1.03	0.2	64.9	0.1	0.1941	63.0097	0.0970
UTAH	DEVO	4670	2.80	0.3	96.6	0.3	0.1071	34.5000	0.1071
UTAH	PENN	4791	1.04	0.1	30.6	7.9	0.0961	29.4230	7.5961
UTAH	IRIA	5092	1.22	0.4	60.1	6.0	0.3278	49.2622	4.9180
UTAH	DEVO	5807	1.58	0.2	31.9	56.8	0.1265	20.1898	35.9493
UTAH	DEVO	5855	1.37	0.1	13.1	77.5	0.0729	9.5620	56.5693
UTAH	MISS	6270	1.47	0.2	79.1	2.7	0.1360	53.8095	1.8367
UTAH	MISS	7512	1.39	0.2	75.5	4.2	0.1431	54.0443	3.0064
UTAH	MISS	7663	1.40	0.2	91.9	0.6	0.1421	65.3162	0.4264
UTAH	MISS	7861	1.00	0.2	63.4	3.9	0.2000	63.4000	3.9000
UTAH	MISS	8637	1.32	0.2	65.8	3.5	0.1507	49.5855	2.6375
UTAH	MISS	8710	1.53	0.3	75.2	2.5	0.1956	49.0541	1.6307
UTAH	MISS	8900	1.20	0.4	76.8	2.1	0.3333	64.0000	1.7500
WYOMING	PENN	2332	1.50	0.1	60.9	0.7	0.0666	40.6000	0.4666
WYOMING	PENN	2384	1.61	---	64.2	0.1	---	39.8757	0.0621
WYOMING	PENN	4435	1.01	---	70.0	0.8	---	69.3069	0.7920
WYOMING	PENN	6990	1.30	0.2	19.1	31.7	0.1538	14.6923	24.3846

0366 NUMBER RECORDS READ
0366 NUMBER RECORDS WRITTEN

APPENDIX B.--QUATERNARY SYSTEM

The Quaternary System is the only one of the 13 geologic systems investigated that had no natural gas reservoirs with 0.30 percent or more of helium. The deeper reservoirs contained the least helium, and over 80 percent of the reservoirs contained less than 0.005 percent of helium. This system included 46 reservoirs and accounts for 0.7 percent of the reservoirs studied. The reservoir with the highest helium content, 0.15 percent, was found in California at a depth of 4,315 feet. The gas contained 99.3 percent of methane, 0.0 percent of nitrogen, 0.0 percent of carbon dioxide, and 0.0 percent of argon. The shallowest reservoir in this system was found in Ohio at a depth of 187 feet, and it contained 0.12 percent of helium, 90.6 percent of methane, 5.8 percent of nitrogen, 0.4 percent of carbon dioxide, and 0.0 percent of argon. The deepest reservoir was found in Louisiana at a depth of 8,350 feet, and it contained less than 0.005 percent of helium, 93.9 percent of methane, 0.5 percent of nitrogen, 0.2 percent of carbon dioxide, and an unknown percent of argon. The average reservoir depth for this system is 3,701 feet; the average percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon are 0.01 percent, 91.4 percent, 3.0 percent, 0.8 percent, and less than 0.01 percent, respectively.

Appendix B contains the following seven tables concerning the Quaternary System:

TABLE B-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: QUATERNARY		HELIUM CONTENT IN PERCENTAGE										RESERVOIRS: 46		SAMPLES: 55		STATES: 6	
AVERAGE DEPTH, FEET	LESS THAN .005	MINIMUM DEPTH: 187										7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		.005 TO .01	.01 TO .02	.02 TO .04	.04 TO .05	.05 TO .10	.10 TO .19	.19 TO .29	.29 TO .49	.49 TO .79	.79 TO 1.00						
0 - 999	0	2	1	0	0	0	0	0	0	0	0	0	0	3	3	3	
1000 - 1999	4	5	0	0	0	0	0	0	0	0	0	0	0	7	13	2	
2000 - 2999	6	0	0	0	0	0	0	0	0	0	0	0	0	8	8	2	
3000 - 3999	7	0	0	0	0	0	0	0	0	0	0	0	0	7	8	2	
4000 - 4999	11	1	1	0	0	0	0	0	0	0	0	0	0	13	15	2	
5000 - 5999	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	
6000 - 6999	2	1	0	0	0	0	0	0	0	0	0	0	0	3	3	3	
7000 - 7999	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	
8000 - 8999	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	
9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1		
10000 - 10999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
RESERVOIRS	57	7	2	0	0	0	0	0	0	0	0	0	0	46	55		

TABLE B-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:QUATERNARY		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE																
0.0 - 0.9	27	2	1	0	0	0	0	0	0	0	0	0	30	30	3	3
1.0 - 1.9	7	1	0	0	0	0	0	0	0	0	0	0	8	11	2	2
2.0 - 2.9	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
3.0 - 3.9	0	0	0	0	0	0	0	0	0	0	0	0				
4.0 - 4.9	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
5.0 - 5.9	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1
6.0 - 6.9	0	0	0	0	0	0	0	0	0	0	0	0				
7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0	0				
8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0	0				
9.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0	0				
0.0 - 9.9	35	4	2	0	0	0	0	0	0	0	0	0	41	44		
10.0 - 19.9	1	1	0	0	0	0	0	0	0	0	0	0	2	2	1	1
20.0 - 29.9	1	1	0	0	0	0	0	0	0	0	0	0	2	6	1	1
30.0 - 39.9	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0	0				
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0	0				
TOTAL	37	7	2	0	0	0	0	0	0	0	0	0	46	55		

TABLE B-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM BOUNDARY		MINIMUM DEPTH:				NITROGEN CONTENT IN PERCENTAGE				RESERVOIRS:		46 SAMPLES:	55 STATES:	6
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0			
AVERAGE DEPTH, FEET	CLASS THICK- NESS	1	1	0	1	0	0	0	0	0	0	3	3	3
		5	0	1	0	0	0	0	0	0	0	7	13	2
1000 - 1999	7	0	1	0	0	0	0	0	0	0	0	8	8	2
2000 - 2999	7	0	0	0	0	0	0	0	0	0	0	7	8	2
3000 - 3999	12	0	0	1	0	0	0	0	0	0	0	13	15	2
4000 - 4999	2	0	0	0	0	0	0	0	0	0	0	2	2	1
5000 - 5999	5	0	0	0	0	0	0	0	0	0	0	3	3	3
6000 - 6999	2	0	0	0	0	0	0	0	0	0	0	2	2	2
7000 - 7999	1	0	0	0	0	0	0	0	0	0	0	1	1	1
8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10000 - 10999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RESERVOIRS	40	1	2	2	1	0	0	0	0	0	0	46	55	55



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TABLE B-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

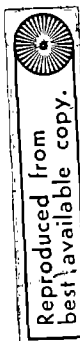
GEOLOGIC SYSTEM: QUATERNARY		MINIMUM DEPTH:		187		MAXIMUM DEPTH:		8+350		RESERVOIRS:		46		SAMPLES:		55		STATES: 6	
		CARBON DIOXIDE CONTENT IN PERCENTAGE																	
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES					
AVERAGE DEPTH, FEET	LESS THAN 5.0	0 - 999	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3
		1000 - 1999	7	0	0	0	0	0	0	0	0	0	0	7	13	2	2	2	2
		2000 - 2999	6	0	0	0	0	0	0	0	0	0	0	8	8	2	2	2	2
		3000 - 3999	7	0	0	0	0	0	0	0	0	0	0	7	8	2	2	2	2
		4000 - 4999	13	0	0	0	0	0	0	0	0	0	0	13	15	2	2	2	2
		5000 - 5999	2	0	0	0	0	0	0	0	0	0	0	2	2	1	1	1	1
		6000 - 6999	3	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3
		7000 - 7999	2	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2
		8000 - 8999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
		9000 - 9999	0	0	0	0	0	0	0	0	0	0	0						
		10000 - 10999	0	0	0	0	0	0	0	0	0	0	0						
		11000 - 11999	0	0	0	0	0	0	0	0	0	0	0						
		12000 - 12999*	0	0	0	0	0	0	0	0	0	0	0						
		13000 - 13999	0	0	0	0	0	0	0	0	0	0	0						
		14000 - 14999	0	0	0	0	0	0	0	0	0	0	0						
		15000 - 15999	0	0	0	0	0	0	0	0	0	0	0						
		16000 - 16999	0	0	0	0	0	0	0	0	0	0	0						
		17000 - 17999	0	0	0	0	0	0	0	0	0	0	0						
		18000 - 18999	0	0	0	0	0	0	0	0	0	0	0						
		19000 - 19999	0	0	0	0	0	0	0	0	0	0	0						
		20000 - 20999	0	0	0	0	0	0	0	0	0	0	0						
		21000 - 21999	0	0	0	0	0	0	0	0	0	0	0						
		22000 - 22999	0	0	0	0	0	0	0	0	0	0	0						
		RESERVOIRS	44	0	2	0	0	0	0	0	0	0	0	46	55				



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TABLE B-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM: QUANTITARY	AVERAGE DEPTH, FEET	ARGON CONTENT IN PERCENTAGE					MAXIMUM DEPTH: 8,350	RESERVOIRS:	28	SAMPLES:	34	STATES:	3
		LESS THAN 0.1	.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49			
	0 - 999	0	0	0	0	0	0	0	0	0			
	1000 - 1999	4	0	0	0	0	0	0	0	0	4	10	2
	2000 - 2999	3	0	0	0	0	0	0	0	0	3	3	2
	3000 - 3999	4	0	0	0	0	0	0	0	0	4	4	2
	4000 - 4999	11	0	0	0	0	0	0	0	0	11	11	2
	5000 - 5999	2	0	0	0	0	0	0	0	0	2	2	1
	6000 - 6999	2	0	0	0	0	0	0	0	0	2	2	2
	7000 - 7999	1	0	0	0	0	0	0	0	0	1	1	1
	8000 - 8999	1	0	0	0	0	0	0	0	0	1	1	1
	9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0
	10000 - 10999	0	0	0	0	0	0	0	0	0	0	0	0
	11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0
	12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0
	13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0
	14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0
	15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0
	16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0
	17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0
	18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0
	19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0
	20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0
	21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0
	22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0
	RESERVOIRS	28	0	0	0	0	0	0	0	0	28	34	



APPENDIX C.--TERTIARY SYSTEM

Tertiary System reservoirs containing the highest percentage of helium (0.30 to 0.49) are found below a depth of 1,000 feet and above 4,000 feet. Below 4,000 feet, the helium contents drop off rapidly to less than 0.005 percent. This system includes 1,058 reservoirs and represents 16.4 percent of the total number of reservoirs, and it is the second largest group of reservoirs studied. Only eight reservoirs in this system contained 0.30 percent or more of helium, and none of them contained 1 percent or more of helium. The reservoir with the highest helium content, 0.45 percent, was found in Texas at a depth of 2,450 feet. The gas contained 19.9 percent of methane, 39.9 percent of nitrogen, 29.9 percent of carbon dioxide, and 0.0 percent of argon. The shallowest reservoir in this system was found in Texas at a depth of 120 feet and contained less than 0.005 percent of helium, 13.3 percent of methane, 85.8 percent of nitrogen, 0.5 percent of carbon dioxide, and 0.0 percent of argon. The deepest reservoir was found in Louisiana at a depth of 20,440 feet and contained less than 0.005 percent of helium, 92.7 percent of methane, 0.6 percent of nitrogen, 1.4 percent of carbon dioxide, and 0.0 percent of argon. The average depth of the reservoirs of this system is 6,820 feet, and the average percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon, are 0.01 percent, 89.5 percent, 1.7 percent, 0.7 percent, and less than 0.01 percent, respectively.

Appendix C contains the following seven tables concerning the Tertiary System:

TABLE C-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TERTIARY		MINIMUM DEPTH:		120		HELIUM CONTENT IN PERCENTAGE				DEPTH: 20,440		RESERVOIRS: 1053		SAMPLES: 1,205		STATES: 12		
AVERAGE DEPTH, FEET	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99		2.00 TO 2.99		3.00 TO 4.99		5.00 TO 6.99		7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
0 - 999	8	5	3	0	0	0	0	0	0	0	0	0	0	0	0	16	24	6
1000 - 1999	14	24	1	0	0	0	0	0	0	0	0	0	0	0	0	39	46	8
2000 - 2999	25	81	2	3	0	0	0	0	0	0	0	0	0	0	0	111	130	9
3000 - 3999	23	70	1	0	0	0	0	0	0	0	0	0	0	0	0	94	111	8
4000 - 4999	37	70	3	1	0	0	0	0	0	0	0	0	0	0	0	111	125	7
5000 - 5999	28	65	1	0	0	0	0	0	0	0	0	0	0	0	0	94	105	8
6000 - 6999	37	56	0	0	0	0	0	0	0	0	0	0	0	0	0	95	112	8
7000 - 7999	48	62	0	0	0	0	0	0	0	0	0	0	0	0	0	110	117	5
8000 - 8999	51	55	0	0	0	0	0	0	0	0	0	0	0	0	0	106	124	8
9000 - 9999	46	31	1	0	0	0	0	0	0	0	0	0	0	0	0	78	95	6
10000 - 10999	49	18	0	0	0	0	0	0	0	0	0	0	0	0	0	67	76	6
11000 - 11999	35	16	0	0	0	0	0	0	0	0	0	0	0	0	0	51	55	2
12000 - 12999	21	7	0	0	0	0	0	0	0	0	0	0	0	0	0	28	31	2
13000 - 13999	16	5	0	0	0	0	0	0	0	0	0	0	0	0	0	21	22	3
14000 - 14999	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	2
15000 - 15999	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	2
16000 - 16999	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1
17000 - 17999	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1
18000 - 18999	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
20000 - 20999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
RESERVOIRS	461	576	12	4	0	0	0	0	0	0	0	0	0	0	0	1053	1205	1205

TABLE C-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TERTIARY		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		HELIUM CONTENT IN PERCENTAGE														
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE																
0.0 - 0.9		353	349	3	1	0	0	0	0	0	0	0	0	706	795	11
1.0 - 1.9		48	137	2	0	0	0	0	0	0	0	0	0	187	212	9
2.0 - 2.9		12	32	2	0	0	0	0	0	0	0	0	0	46	55	8
3.0 - 3.9		14	21	2	0	0	0	0	0	0	0	0	0	37	45	6
4.0 - 4.9		10	10	0	0	0	0	0	0	0	0	0	0	20	22	6
5.0 - 5.9		4	8	0	0	0	0	0	0	0	0	0	0	12	14	5
6.0 - 6.9		2	2	0	0	0	0	0	0	0	0	0	0	4	4	3
7.0 - 7.9		2	1	0	0	0	0	0	0	0	0	0	0	3	3	3
8.0 - 8.9		2	5	0	0	0	0	0	0	0	0	0	0	7	7	3
9.0 - 9.9		3	1	1	1	0	0	0	0	0	0	0	0	6	6	4
0.0 - 9.9		450	566	10	2	0	0	0	0	0	0	0	0	1028	1163	
10.0 - 19.9		7	9	1	2	0	0	0	0	0	0	0	0	19	30	7
20.0 - 29.9		2	2	0	0	0	0	0	0	0	0	0	0	4	9	3
30.0 - 39.9		0	0	0	0	0	0	0	0	0	0	0	0			
40.0 - 49.9		0	0	0	0	0	0	0	0	0	0	0	0			
50.0 - 59.9		0	0	0	0	0	0	0	0	0	0	0	0			
60.0 - 69.9		0	0	0	0	0	0	0	0	0	0	0	0			
70.0 - 79.9		0	0	0	0	0	0	0	0	0	0	0	0			
80.0 - 89.9		1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
90.0 - 100.0		1	0	1	0	0	0	0	0	0	0	0	0	2	2	2
TOTAL		461	577	12	4	0	0	0	0	0	0	0	0	1054	1205	

TABLE C-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

AVERAGE DEPTH, FEET	GEOLOGIC SYSTEM	MINIMUM DEPTH				MAXIMUM DEPTH				DEPTH: 20,440				SAMPLES: 1,199				STATES: 12			
		120				NITROGEN CONTENT IN PERCENTAGE				RESERVOIRS: 1049				STATES: 1199							
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	NUMBER OF STATES						
0 - 999		0	4	0	1	0	0	0	0	0	1	2	16	24	6						
1000 - 1999		33	1	5	0	0	0	0	0	0	0	0	39	46	8						
2000 - 2999		96	3	7	2	0	0	0	0	0	0	0	108	125	9						
3000 - 3999		90	3	1	0	0	0	0	0	0	0	0	94	111	8						
4000 - 4999		102	9	0	0	0	0	0	0	0	0	0	111	125	7						
5000 - 5999		89	2	3	0	0	0	0	0	0	0	0	94	105	8						
6000 - 6999		89	3	1	1	0	0	0	0	0	0	0	94	111	8						
7000 - 7999		106	1	1	0	0	0	0	0	0	0	0	110	117	5						
8000 - 8999		105	1	0	0	0	0	0	0	0	0	0	106	124	8						
9000 - 9999		78	0	0	0	0	0	0	0	0	0	0	78	95	6						
10000 - 10999		65	2	0	0	0	0	0	0	0	0	0	67	76	6						
11000 - 11999		50	1	6	0	0	0	0	0	0	0	0	51	55	2						
12000 - 12999		28	0	0	0	0	0	0	0	0	0	0	28	31	2						
13000 - 13999		19	2	0	0	0	0	0	0	0	0	0	21	22	3						
14000 - 14999		10	0	1	0	0	0	0	0	0	0	0	11	11	2						
15000 - 15999		12	0	0	0	0	0	0	0	0	0	0	12	12	2						
16000 - 16999		3	0	0	0	0	0	0	0	0	0	0	3	3	1						
17000 - 17999		2	0	0	0	0	0	0	0	0	0	0	2	2	1						
18000 - 18999		3	0	0	0	0	0	0	0	0	0	0	3	3	1						
19000 - 19999		0	0	0	0	0	0	0	0	0	0	0	1	1	1						
20000 - 20999		1	0	0	0	0	0	0	0	0	0	0	1	1	1						
21000 - 21999		0	0	0	0	0	0	0	0	0	0	0	0	0	0						
22000 - 22999		0	0	0	0	0	0	0	0	0	0	0	0	0	0						
RESERVOIRS		991	32	19	4	0	0	0	0	0	1	2	1049	1199							

TABLE C-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TERTIARY		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		CARBON DIOXIDE PERCENTAGE													
LESS THAN .005		.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
0.0 - 0.9	337	489	11	4	0	0	0	0	0	0	0	841	954	12	
1.0 - 1.9	74	55	0	0	0	0	0	0	0	0	0	129	147	5	
2.0 - 2.9	29	22	1	0	0	0	0	0	0	0	0	52	65	6	
3.0 - 3.9	15	6	0	0	0	0	0	0	0	0	0	21	26	3	
4.0 - 4.9	5	3	0	0	0	0	0	0	0	0	0	8	10	3	
5.0 - 5.9	0	1	0	0	0	0	0	0	0	0	0	1	3	1	
6.0 - 6.9	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1	
8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0				
9.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0				
0.0 - 9.9	461	576	12	4	0	0	0	0	0	0	0	1053	1206		
10.0 - 19.9	1	3	0	0	0	0	0	0	0	0	0	4	4	2	
20.0 - 29.9	0	0	0	0	0	0	0	0	0	0	0				
30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0				
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0				
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0				
TOTAL	462	579	12	4	0	0	0	0	0	0	0	1057	1210		

APPENDIX D.--CRETACEOUS SYSTEM

Cretaceous System reservoirs found above a depth of 1,000 feet contained the highest helium contents. At depths below 7,000 feet, the helium contents drop below 0.30 percent with the deeper reservoirs containing the lowest percentages of helium. This system includes 910 reservoirs for 14.1 percent of the total reservoirs studied. Twenty-two of the reservoirs in this system contained 0.30 percent or more of helium, and only one reservoir contained 1 percent or more of helium. The reservoir with the highest helium content, 1.04 percent, was found in Colorado at a depth of 453 feet. The gas contained 78.4 percent of methane, 19.8 percent of nitrogen, 0.2 percent of carbon dioxide, and an unknown percent of argon. The shallowest reservoir in this system was found at a depth of 301 feet in Oklahoma and contained 0.02 percent of helium, 88.2 percent of methane, 10.0 percent of nitrogen, 0.8 percent of carbon dioxide, and an unknown percent of argon. The deepest reservoir was found in Texas at a depth of 14,124 feet and contained less than 0.005 percent of helium, 89.2 percent of methane, 0.2 percent of nitrogen, 8.0 percent of carbon dioxide, and 0.0 percent of argon. The average depth of the reservoirs in this system is 5,177 feet, and the average percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon, are 0.05 percent, 84.1 percent, 3.6 percent, 1.8 percent, and less than 0.01 percent, respectively.

Appendix D contains the following seven tables concerning the Cretaceous System:

TABLE D-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:CRETACEOUS		MINIMUM DEPTH:		301		MAXIMUM DEPTH:14,124		RESERVOIRS: 885		SAMPLES: 1,167		STATES: 18		
		HELIUM CONTENT IN PERCENTAGE												
AVERAGE DEPTH, FEET	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
0 - 999	7	24	10	0	1	1	0	0	0	0	0	43	63	9
1000 - 1999	12	35	23	3	3	0	0	0	0	0	0	76	130	10
2000 - 2999	23	73	24	2	2	0	0	0	0	0	0	124	177	10
3000 - 3999	9	59	10	2	2	0	0	0	0	0	0	82	107	12
4000 - 4999	9	86	19	0	0	0	0	0	0	0	0	114	148	9
5000 - 5999	7	90	17	1	3	0	0	0	0	0	0	118	156	10
6000 - 6999	12	72	7	1	1	0	0	0	0	0	0	93	110	9
7000 - 7999	6	84	3	0	0	0	0	0	0	0	0	93	115	9
8000 - 8999	3	61	0	0	0	0	0	0	0	0	0	64	78	7
9000 - 9999	4	31	0	0	0	0	0	0	0	0	0	35	38	6
10000 - 10999	3	10	1	0	0	0	0	0	0	0	0	14	14	4
11000 - 11999	1	13	0	0	0	0	0	0	0	0	0	14	15	5
12000 - 12999	0	7	0	0	0	0	0	0	0	0	0	7	8	3
13000 - 13999	0	7	0	0	0	0	0	0	0	0	0	7	7	2
14000 - 14999	1	0	0	0	0	0	0	0	0	0	0	1	1	1
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0			
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0			
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0			
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0			
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0			
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0			
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0			
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0			
RESERVOIRS	97	652	114	9	12	1	0	0	0	0	0	885	1167	

TABLE D-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:CRETACEOUS		HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0					
NITROGEN PERCENTAGE																
0.0 - 0.9	55	248	5	0	0	0	0	0	0	0	0	0	306	402	11	
1.0 - 1.9	18	152	19	1	0	0	0	0	0	0	0	0	190	260	10	
2.0 - 2.9	4	76	19	0	0	0	0	0	0	0	0	0	99	121	10	
3.0 - 3.9	7	52	20	0	0	0	0	0	0	0	0	0	79	93	10	
4.0 - 4.9	4	43	7	1	0	0	0	0	0	0	0	0	55	59	10	
5.0 - 5.9	2	33	10	0	0	0	0	0	0	0	0	0	45	67	10	
6.0 - 6.9	2	22	10	1	0	0	0	0	0	0	0	0	35	57	11	
7.0 - 7.9	1	4	9	3	1	0	0	0	0	0	0	0	18	24	8	
8.0 - 8.9	0	9	7	0	0	0	0	0	0	0	0	0	16	19	5	
9.0 - 9.9	0	4	3	0	0	0	0	0	0	0	0	0	7	9	4	
0.0 - 9.9	93	643	107	6	1	0	0	0	0	0	0	0	850	1111		
10.0 - 19.9	7	17	9	2	7	1	0	0	0	0	0	0	43	63	9	
20.0 - 29.9	1	3	2	0	1	0	0	0	0	0	0	0	7	7	5	
30.0 - 39.9	0	1	1	1	0	0	0	0	0	0	0	0	3	3	3	
40.0 - 49.9	0	1	0	0	0	0	0	0	0	0	0	0	1	4	1	
50.0 - 59.9	1	1	0	0	0	3	0	0	0	0	0	0	5	5	2	
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	0	1	0	0	0	0	0	0	0	0	0	0				
TOTAL	102	667	119	9	12	1	0	0	0	0	0	0	910	1194	1	

TABLE D-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:CRETACEOUS		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		LESS THAN .005	.005 .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
CARBON DIOXIDE PERCENTAGE																
0.0 - 0.9	64	433	85	6	5	1	0	0	0	0	0	0	592	807	17	
1.0 - 1.9	18	167	15	1	3	0	0	0	0	0	0	0	204	247	10	
2.0 - 2.9	9	38	7	0	2	0	0	0	0	0	0	0	56	75	7	
3.0 - 3.9	5	7	2	0	0	0	0	0	0	0	0	0	14	15	7	
4.0 - 4.9	1	5	2	0	0	0	0	0	0	0	0	0	8	8	5	
5.0 - 5.9	2	3	2	0	0	0	0	0	0	0	0	0	7	8	3	
6.0 - 6.9	0	5	0	1	0	0	0	0	0	0	0	0	6	6	4	
7.0 - 7.9	0	3	0	0	0	0	0	0	0	0	0	0	3	4	2	
8.0 - 8.9	2	1	0	0	1	0	0	0	0	0	0	0	4	4	3	
9.0 - 9.9	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
0.0 - 9.9	101	663	111	8	11	1	0	0	0	0	0	0	895	1175		
10.0 - 19.9	0	2	1	0	1	0	0	0	0	0	0	0	4	6	1	
20.0 - 29.9	1	0	3	0	0	0	0	0	0	0	0	0	4	5	1	
30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0	0				
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0	0				
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	0	1	4	1	0	0	0	0	0	0	0	0	6	7	1	
TOTAL	102	667	119	9	12	1	0	0	0	0	0	0	910	1194		

APPENDIX E.--JURASSIC SYSTEM

The Jurassic System reservoirs above a depth of 9,000 feet contained the highest percentages of helium. The helium content of the gas at depths below 9,000 feet was less than 0.30 percent, with the deeper reservoirs containing the lowest helium contents. This system includes 151 reservoirs representing 2.4 percent of the total reservoirs, with 26 of the reservoirs containing 0.30 percent or more of helium. There were five reservoirs with 1 percent or more of helium, and two of these contained 5 percent or more of helium. The reservoir with the highest helium content was found in Colorado at a depth of 959 feet and contained 7.51 percent of helium. The gas contained 0.1 percent of methane, 75.6 percent of nitrogen, 14.2 percent of carbon dioxide, and an unknown percent of argon. The shallowest reservoir in this system was found at 210 feet in Colorado and contained less than 0.005 percent of helium, 0.0 percent of methane, 0.6 percent of nitrogen, 99.4 percent of carbon dioxide, and an unknown percent of argon. The deepest reservoir was found in Mississippi at a depth of 18,207 feet and contained 0.01 percent of helium, 69.4 percent of methane, 2.6 percent of nitrogen, 2.5 percent of carbon dioxide, and 0.10 percent of argon. The average depth of a reservoir is 6,714 feet, and the average percentages of the gas components, helium, methane, nitrogen, carbon dioxide, and argon, are 0.29 percent, 70.2 percent, 10.4 percent, 7.6 percent, and 0.01 percent, respectively.

Appendix E contains the following seven tables concerning the Jurassic System:

TABLE E-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: JURASSIC		HELIUM CONTENT IN PERCENTAGE													
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
NITROGEN PERCENTAGE	0.0 - 0.9	6	28	4	0	0	0	0	0	0	0	0	38	41	8
	1.0 - 1.9	5	12	2	0	0	0	0	0	0	0	0	19	21	9
	2.0 - 2.9	0	11	2	0	0	0	0	0	0	0	0	13	15	7
	3.0 - 3.9	1	8	3	2	0	0	0	0	0	0	0	14	15	9
	4.0 - 4.9	0	2	0	2	0	0	0	0	0	0	0	4	4	3
	5.0 - 5.9	0	3	1	0	1	0	0	0	0	0	0	5	5	4
	6.0 - 6.9	0	4	2	0	0	0	0	1	0	0	0	7	12	7
	7.0 - 7.9	0	1	1	0	0	0	0	0	0	0	0	2	3	2
	8.0 - 8.9	2	0	0	1	1	0	0	0	0	0	0	4	5	2
	9.0 - 9.9	0	1	0	0	2	0	0	0	0	0	0	3	3	2
	0.0 - 9.9	14	70	15	5	4	0	0	1	0	0	0	109	124	
	10.0 - 19.9	1	8	0	2	5	1	0	0	0	0	0	17	20	7
	20.0 - 29.9	0	4	2	0	4	0	0	0	0	0	0	10	20	5
	30.0 - 39.9	0	1	2	0	1	0	0	0	0	0	0	4	6	2
	40.0 - 49.9	0	0	5	0	0	0	1	0	0	0	0	6	10	2
	50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0			
60.0 - 69.9	0	0	3	0	0	0	0	0	0	0	0	3	3	1	
70.0 - 79.9	0	0	0	0	0	0	0	0	0	1	0	1	4	1	
80.0 - 89.9	0	0	0	0	0	0	0	0	1	0	0	1	5	1	
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0				
TOTAL	15	83	27	7	14	1	1	1	1	1	0	151	192		

TABLE E-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

AVERAGE DEPTH, FEET	GEOLOGIC SYSTEM : JURASSIC	MINIMUM DEPTH:				MAXIMUM DEPTH: 10,207				RESERVOIRS:		SAMPLES:		STATES: 13	
		NITROGEN CONTENT IN PERCENTAGE								90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES		
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9						
0 - 999	LESS THAN 5.0	3	0	0	0	1	0	0	1	0	9	21	3		
1000 - 1999		8	4	1	0	0	0	0	0	0	13	16	4		
2000 - 2999	15	3	1	0	0	0	0	0	0	0	17	24	5		
3000 - 3999	4	1	3	1	0	0	0	0	0	0	13	13	4		
4000 - 4999	6	1	1	0	0	0	0	0	0	0	8	9	3		
5000 - 5999	2	1	1	2	0	0	0	0	0	0	6	15	3		
6000 - 6999	2	2	0	1	1	0	0	1	0	0	7	8	3		
7000 - 7999	2	2	2	2	1	0	0	1	0	0	10	11	4		
8000 - 8999	4	0	1	1	1	0	0	0	0	0	11	14	4		
9000 - 9999	9	0	0	0	1	3	0	0	0	0	13	13	4		
10000 - 10999	7	4	0	1	0	0	0	0	0	0	12	13	2		
11000 - 11999	7	0	1	0	0	0	0	0	0	0	8	9	2		
12000 - 12999	4	1	2	0	0	2	0	0	0	0	9	11	1		
13000 - 13999	1	0	0	1	0	0	0	1	0	0	3	3	2		
14000 - 14999	1	0	0	0	0	0	0	0	0	0	1	1	1		
15000 - 15999	3	1	0	0	0	0	0	0	0	0	4	4	3		
16000 - 16999	0	0	1	0	0	0	0	0	0	0	1	1	1		
17000 - 17999	0	0	0	0	0	0	0	0	0	0					
18000 - 18999	1	0	0	0	0	0	0	0	0	0	1	1	1		
19000 - 19999	0	0	0	0	0	0	0	0	0	0					
20000 - 20999	0	0	0	0	0	0	0	0	0	0					
21000 - 21999	0	0	0	0	0	0	0	0	0	0					
22000 - 22999	0	0	0	0	0	0	0	0	0	0					
RESERVOIRS	85	20	16	10	4	6	0	3	1	0	146	187			

TABLE E-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	JURASSIC	ARGON PERCENTAGE	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
				.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0			
		0.0 - 0.09	4	63	18	3	2	0	0	1	0	0	0	91	105	11
		0.1 - 0.29	0	3	3	3	10	0	0	0	0	0	0	19	32	5
		0.3 - 0.49	0	0	0	0	0	0	0	0	0	0	0			
		0.5 - 0.69	0	0	0	0	0	0	0	0	0	0	0			
		0.7 - 0.89	0	0	0	0	0	0	0	0	0	0	0			
		0.9 - 1.09	0	0	0	0	0	0	0	0	0	0	0			
		1.1 - 1.29	0	0	0	0	0	0	0	0	0	0	0			
		1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0			
		> 1.49	0	0	0	0	0	0	0	0	0	0	0			
		TOTAL	4	66	21	6	12	0	0	1	0	0	0	110	137	

TABLE E-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM: JURASSIC		MINIMUM DEPTH:		ARGON CONTENT IN PERCENTAGE					MAXIMUM DEPTH: 210		DEPTH: 18-207		RESEKVOIRS: 107		SAMPLES: 134		STATES: 12	
		LESS THAN 0.1	.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES
AVERAGE DEPTH, FEET		0	1	0	0	0	0	0	0	0	0	0	1	3	1			
0 - 999																		
1000 - 1999		3	3	0	0	0	0	0	0	0	0	0	6	7	3			
2000 - 2999		9	2	0	0	0	0	0	0	0	0	0	11	17	5			
3000 - 3999		6	3	0	0	0	0	0	0	0	0	0	9	9	3			
4000 - 4999		4	1	0	0	0	0	0	0	0	0	0	5	6	2			
5000 - 5999		1	4	0	0	0	0	0	0	0	0	0	5	14	3			
6000 - 6999		4	2	0	0	0	0	0	0	0	0	0	6	7	2			
7000 - 7999		2	1	0	0	0	0	0	0	0	0	0	3	3	3			
8000 - 8999		9	1	0	0	0	0	0	0	0	0	0	10	13	4			
9000 - 9999		12	0	0	0	0	0	0	0	0	0	0	12	12	4			
10000 - 10999		12	0	0	0	0	0	0	0	0	0	0	12	13	2			
11000 - 11999		8	0	0	0	0	0	0	0	0	0	0	8	9	2			
12000 - 12999		9	0	0	0	0	0	0	0	0	0	0	9	11	1			
13000 - 13999		3	0	0	0	0	0	0	0	0	0	0	3	3	2			
14000 - 14999		1	0	0	0	0	0	0	0	0	0	0	1	1	1			
15000 - 15999		4	0	0	0	0	0	0	0	0	0	0	4	4	3			
16000 - 16999		1	0	0	0	0	0	0	0	0	0	0	1	1	1			
17000 - 17999		0	0	0	0	0	0	0	0	0	0	0	0	0	0			
18000 - 18999		1	0	0	0	0	0	0	0	0	0	0	1	1	1			
19000 - 19999		0	0	0	0	0	0	0	0	0	0	0	0	0	0			
20000 - 20999		0	0	0	0	0	0	0	0	0	0	0	0	0	0			
21000 - 21999		0	0	0	0	0	0	0	0	0	0	0	0	0	0			
22000 - 22999		0	0	0	0	0	0	0	0	0	0	0	0	0	0			
RESERVOIRS		89	18	0	0	0	0	0	0	0	0	0	107	134	134			

APPENDIX F.--TRIASSIC SYSTEM

Triassic System reservoirs found above a depth of 2,000 feet contained gas with higher helium contents than the deeper reservoirs. This system includes only 28 reservoirs and represents 0.4 percent of the reservoirs in this study. Half of the 28 reservoirs in this system contained 0.30 percent or more of helium, and 13 reservoirs contained 1 percent or more of helium. The reservoir with the highest helium content, 9.23 percent, was found in Arizona at a depth of 1,196 feet. The gas contained 0.0 percent of methane, 89.5 percent of nitrogen, 0.7 percent of carbon dioxide, and 0.8 percent of argon. The shallowest reservoir in this system was found at 200 feet in Arizona and contained 5.13 percent helium, 0.3 percent of methane, 93.5 percent of nitrogen, 0.2 percent of carbon dioxide, and 0.4 percent of argon. The deepest reservoir was found in Utah at a depth of 10,819 feet and contained 0.05 percent of helium, 1.3 percent of methane, 3.7 percent of nitrogen, 94.4 percent of carbon dioxide, and 0.1 percent of argon. The average depth of the reservoirs in this system is 2,008 feet, and the average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 2.53 percent, 19.4 percent, 45.0 percent, 29.2 percent, and 0.17 percent, respectively.

Appendix F contains the following seven tables concerning the Triassic System:

TABLE F-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TRIASSIC	AVERAGE DEPTH, FEET	MINIMUM DEPTH:		MAXIMUM DEPTH: 10-819								RESERVOIRS:		27 SAMPLES:		44 STATES:		7	
		LESS THAN .005		HELIUM CONTENT IN PERCENTAGE								GREATER THAN 10.0		NUMBER OF RESERVOIRS		NUMBER OF SAMPLES		NUMBER OF STATES	
		.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	10.00 TO 19.99	20.00 TO 29.99	30.00 TO 39.99	40.00 TO 49.99	50.00 TO 59.99	60.00 TO 69.99	70.00 TO 79.99	80.00 TO 89.99	90.00 TO 99.99
	0 - 999	1	0	1	1	0	0	0	1	2	4	0	0	10	25	1	1	3	
	1000 - 1999	1	2	1	0	0	3	0	0	0	2	0	0	9	10	4	4		
	2000 - 2999	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1		
	3000 - 3999	1	3	1	0	0	0	0	0	0	0	0	0	5	5	3	3		
	4000 - 4999	0	0	0	0	0	0	0	0	0	0	0	0						
	5000 - 5999	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1		
	6000 - 6999	0	0	0	0	0	0	0	0	0	0	0	0						
	7000 - 7999	0	0	0	0	0	0	0	0	0	0	0	0						
	8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0						
	9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0						
	10000 - 10999	0	1	0	0	0	0	0	0	0	0	0	0	1	2	1	1		
	11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0						
	12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0						
	13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0						
	14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0						
	15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0						
	16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0						
	17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0						
	18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0						
	19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0						
	20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0						
	21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0						
	22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0						
	RESERVOIRS	3	6	4	1	0	4	0	1	2	6	0	0	27	44				

TABLE F-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TRIASSIC		HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE	0.0 - 0.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
	1.0 - 1.9	2	2	0	0	0	0	0	0	0	0	0	4	4	1	
	2.0 - 2.9	1	0	1	0	0	0	0	0	0	0	0	2	2	1	
	3.0 - 3.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
	4.0 - 4.9	0	0	0	0	0	0	0	0	0	0	0	2	2	1	
	5.0 - 5.9	0	0	0	0	0	0	0	0	0	0	0				
	6.0 - 6.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
	7.0 - 7.9	0	0	2	0	0	0	0	0	0	0	0	2	2	2	
	8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0				
	9.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0				
	0.0 - 9.9	3	5	3	0	0	0	0	0	0	0	0	11	12		
	10.0 - 19.9	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
	20.0 - 29.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
30.0 - 39.9	0	0	0	0	0	2	0	0	0	0	0	2	3	1		
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0					
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0					
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0					
70.0 - 79.9	0	0	0	0	0	1	0	0	0	0	0	1	1	1		
80.0 - 89.9	0	0	0	0	0	1	0	0	0	1	0	2	5	1		
90.0 - 100.0	0	0	1	1	0	0	0	0	2	1	0	5	6	2		
TOTAL		4	6	4	1	0	4	0	1	2	6	28	45			

TABLE P-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM: TRIASSIC		MINIMUM DEPTH:		200		MAXIMUM DEPTH: 10,819					RESERVOIRS:		27		SAMPLES:		44		STATES: 7	
						DEPTH IN PERCENTAGE														
						LESS THAN 5.0	5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9										
AVERAGE DEPTH, FEET		1	0	0	0	0	0	0	0	0	1	3	5	10	25	3				
1000 - 1999		2	2	0	0	2	0	0	0	0	1	2	0	9	10	4				
2000 - 2999		1	0	0	0	0	0	0	0	0	0	0	0	1	1	1				
3000 - 3999		2	1	1	1	0	0	0	0	0	0	0	0	5	5	3				
4000 - 4999		0	0	0	0	0	0	0	0	0	0	0	0							
5000 - 5999		0	0	0	0	0	0	0	0	0	1	0	0	1	1	1				
6000 - 6999		0	0	0	0	0	0	0	0	0	0	0	0							
7000 - 7999		0	0	0	0	0	0	0	0	0	0	0	0							
8000 - 8999		0	0	0	0	0	0	0	0	0	0	0	0							
9000 - 9999		0	0	0	0	0	0	0	0	0	0	0	0							
10000 - 10999		1	0	0	0	0	0	0	0	0	0	0	0	1	2	1				
11000 - 11999		0	0	0	0	0	0	0	0	0	0	0	0							
12000 - 12999		0	0	0	0	0	0	0	0	0	0	0	0							
13000 - 13999		0	0	0	0	0	0	0	0	0	0	0	0							
14000 - 14999		0	0	0	0	0	0	0	0	0	0	0	0							
15000 - 15999		0	0	0	0	0	0	0	0	0	0	0	0							
16000 - 16999		0	0	0	0	0	0	0	0	0	0	0	0							
17000 - 17999		0	0	0	0	0	0	0	0	0	0	0	0							
18000 - 18999		0	0	0	0	0	0	0	0	0	0	0	0							
19000 - 19999		0	0	0	0	0	0	0	0	0	0	0	0							
20000 - 20999		0	0	0	0	0	0	0	0	0	0	0	0							
21000 - 21999		0	0	0	0	0	0	0	0	0	0	0	0							
22000 - 22999		0	0	0	0	0	0	0	0	0	0	0	0							
RESERVOIRS		7	3	1	1	2	0	0	0	1	2	5	5	27	44					



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TABLE F-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: TRIASSIC		HELIUM CONTENT IN PERCENTAGE													
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
CARBON DIOXIDE PERCENTAGE	0.0 - 0.9	1	2	3	1	0	2	0	0	2	5	0	16	30	6
	1.0 - 1.9	0	0	0	0	0	0	0	0	0	0	0			
	2.0 - 2.9	0	0	0	0	0	0	0	0	0	0	0			
	3.0 - 3.9	0	0	0	0	0	0	0	0	0	0	0			
	4.0 - 4.9	0	0	0	0	0	0	0	0	0	0	0			
	5.0 - 5.9	0	0	0	0	0	0	0	0	0	0	0			
	6.0 - 6.9	0	0	0	0	0	1	0	0	0	0	0	1	1	1
	7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0			
	8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0			
	9.0 - 9.9	0	0	0	0	0	0	0	1	0	0	0	2	4	1
	0.0 - 9.9	1	2	3	1	0	3	0	1	2	6	0	19	35	
	10.0 - 19.9	0	0	0	0	0	1	0	0	0	0	0	1	1	1
	20.0 - 29.9	0	0	0	0	0	0	0	0	0	0	0			
	30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0			
	40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0			
	50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0			
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	3	4	1	0	0	0	0	0	0	0	0	8	9	3	
TOTAL	4	6	4	1	0	4	0	1	2	6	0	28	45		

TABLE F-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGICAL SYSTEM: TRIASSIC		MINIMUM DEPTH:		200		MAXIMUM DEPTH: 10,819		RESERVOIRS: 27		SAMPLES: 44		STATES: 7		
AVERAGE DEPTH, FEET	LESS THAN 5.0	5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		CARBON DIOXIDE CONTENT IN PERCENTAGE												
0 - 999	8	1	0	0	0	0	0	0	0	0	1	10	25	3
1000 - 1999	4	1	1	0	0	0	0	0	0	0	3	9	10	4
2000 - 2999	1	0	0	0	0	0	0	0	0	0	0	1	1	1
3000 - 3999	3	0	0	0	0	0	0	0	0	0	2	5	5	3
4000 - 4999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5000 - 5999	0	1	0	0	0	0	0	0	0	0	0	1	1	1
6000 - 6999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7000 - 7999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10000 - 10999	0	0	0	0	0	0	0	0	0	0	1	1	2	1
11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RESERVOIRS	16	3	1	0	0	0	0	0	0	0	7	27	44	



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TABLE F-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	ARGON PERCENTAGE	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
			.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0			
	0.0 - 0.09	0	3	2	0	0	0	0	0	0	0	0	5	5	4
	0.1 - 0.29	1	1	1	0	0	2	0	0	0	0	0	5	7	2
	0.3 - 0.49	0	0	1	0	0	1	0	0	2	0	0	4	5	3
	0.5 - 0.69	0	0	0	0	0	0	0	0	0	2	0	2	10	1
	0.7 - 0.89	0	0	0	0	0	0	0	1	0	3	0	4	9	1
	0.9 - 1.09	0	0	0	1	0	0	0	0	0	0	0	1	1	1
	1.1 - 1.29	0	0	0	0	0	1	0	0	0	0	0	1	1	1
	1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0	1	1	1
	> 1.49	0	0	0	0	0	0	0	0	0	0	0			
TOTAL		1	4	4	1	0	4	0	1	2	5	0	22	38	

TABLE F-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM: TRIASSIC		ARGON CONTENT IN PERCENTAGE										200	DEPTH: 10-819	RESERVOIRS:	22	SAMPLES:	38	STATES:	7	
AVERAGE DEPTH, FEET	LESS THAN 0.1	.10 TO .29		.30 TO .49		.50 TO .69		.70 TO .89		.90 TO 1.09		1.10 TO 1.29		1.30 TO 1.49		GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		.10	.29	.30	.49	.50	.69	.70	.89	.90	1.09	1.10	1.29	1.30	1.49					
0 - 999	0	0	0	3	2	2	1	0	0	0	0	0	0	0	0	0	8	22	2	2
1000 - 1999	2	2	0	0	0	2	0	0	2	0	1	0	0	0	0	0	7	8	4	4
2000 - 2999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
3000 - 3999	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	3	3
4000 - 4999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
5000 - 5999	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
6000 - 6999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
7000 - 7999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
10000 - 10999	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1
11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
RESERVOIRS	5	5	4	2	4	4	1	1	1	1	1	1	1	1	1	1	22	38		

APPENDIX G.--PERMIAN SYSTEM

Permian System reservoirs found above a depth of 2,000 feet contained the highest percentages of helium, although reservoir gases above 4,000 feet contained high percentages of helium. This system represents 7.3 percent of the reservoirs studied which includes 468 reservoirs, and 187 contained 0.30 percent or more of helium. Forty-six reservoirs contained 1 percent or more of helium, and 10 contained 5 percent or more of helium. The reservoir with the highest helium content was found in the Permian System. The reservoir contained 9.74 percent of helium and was located in Arizona at a depth of 1,354 feet. The gas contained 0.1 percent of methane, 88.9 percent of nitrogen, 0.7 percent of carbon dioxide, and 0.7 percent of argon. The shallowest reservoir of this system was found in Wyoming at a depth of 190 feet and contained 0.52 percent of helium, 0.1 percent of methane, 97.9 percent of nitrogen, 1.3 percent of carbon dioxide, and 0.0 percent of argon. The deepest reservoir was found in Texas at a depth of 15,257 and contained 0.01 percent of helium, 94.4 percent of methane, 0.7 percent of nitrogen, 0.6 percent of carbon dioxide, and 0.0 percent of argon. The average depth of a reservoir in the Permian System is 3,259 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.51 percent, 62.0 percent, 21.1 percent, 2.8 percent, and 0.30 percent, respectively.

Appendix G contains the following seven tables concerning the Permian System:

TABLE C-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:PERMIAN		MINIMUM DEPTH:				190				MAXIMUM DEPTH:15-257				RESEVNOINS: 448		SAMPLES: 1,714		STATES: 11	
AVERAGE DEPTH, FEET	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE										GREATER TO 10.0	NUMBER OF RESEVNOIRS	NUMBER OF SAMPLES	NUMBER OF STATES				
		.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99										
0 - 999	4	7	5	0	5	0	1	0	1	2	0	25	46	7					
1000 - 1999	4	20	26	6	10	9	2	0	0	6	0	83	319	9					
2000 - 2999	8	31	16	36	56	8	0	0	0	0	0	155	931	7					
3000 - 3999	1	40	19	6	17	9	3	0	0	0	0	95	241	7					
4000 - 4999	1	22	7	0	0	2	0	0	0	0	0	32	39	6					
5000 - 5999	0	13	5	0	0	0	0	0	0	0	0	18	89	4					
6000 - 6999	0	8	0	0	0	0	0	0	0	0	0	8	9	3					
7000 - 7999	0	10	1	0	0	0	0	0	0	0	0	11	14	5					
8000 - 8999	0	4	1	0	1	0	0	0	0	0	0	6	7	4					
9000 - 9999	0	4	0	0	0	0	0	0	0	0	0	4	4	2					
10000 - 10999	0	5	0	0	0	0	0	0	0	0	0	5	9	3					
11000 - 11999	0	3	0	0	0	0	0	0	0	0	0	3	3	3					
12000 - 12999	0	1	0	0	0	0	0	0	0	0	0	1	1	1					
13000 - 13999	0	0	1	0	0	0	0	0	0	0	0	1	1	1					
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
15000 - 15999	0	1	0	0	0	0	0	0	0	0	0	1	1	1					
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	1	1	1					
RESERVOIRS	18	169	81	48	89	28	6	0	1	8	0	448	1714	11					

TABLE G-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:PERMIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE																
0.0 - 0.9	2	22	1	1	0	1	0	0	0	0	0	27	30	7	7	
1.0 - 1.9	7	42	5	0	0	0	0	0	0	0	0	54	81	7	6	
2.0 - 2.9	3	27	5	0	0	0	0	0	0	0	0	35	42	6	6	
3.0 - 3.9	0	10	4	0	2	0	0	0	0	0	0	16	49	5	5	
4.0 - 4.9	1	8	6	0	0	0	0	0	0	0	0	15	25	5	5	
5.0 - 5.9	0	7	5	1	0	0	0	0	0	0	0	13	18	6	6	
6.0 - 6.9	1	5	5	1	1	0	0	0	0	0	0	13	23	5	5	
7.0 - 7.9	0	5	7	2	0	0	0	0	0	0	0	14	214	4	4	
8.0 - 8.9	0	4	2	8	1	0	0	0	0	0	0	15	22	5	5	
9.0 - 9.9	1	2	7	3	4	0	0	0	0	0	0	17	22	4	4	
0.0 - 9.9	15	132	47	16	8	1	0	0	0	0	0	219	566			
10.0 - 19.9	0	6	12	29	52	5	0	0	0	0	0	104	837	7	7	
20.0 - 29.9	1	10	5	1	12	10	0	0	0	0	0	39	114	5	5	
30.0 - 39.9	0	5	2	2	12	7	2	0	0	0	0	30	95	4	4	
40.0 - 49.9	0	5	3	1	3	2	0	0	0	0	0	14	36	4	4	
50.0 - 59.9	0	4	0	0	1	1	1	0	0	0	0	7	8	3	3	
60.0 - 69.9	0	2	2	0	0	3	1	0	0	0	0	8	9	5	5	
70.0 - 79.9	0	1	3	0	1	0	2	0	0	3	0	10	12	4	4	
80.0 - 89.9	0	2	2	1	0	0	0	0	0	6	0	11	23	4	4	
90.0 - 100.0	3	8	8	0	2	1	0	0	1	0	0	23	35	6	6	
TOTAL	19	175	84	50	91	30	6	0	1	9	0	465	1735			

TABLE G-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM PERIOD		MINIMUM DEPTH				MAXIMUM DEPTH: 15,257				RESERVOIRS: 445		SAMPLES: 1,711		STATES: 11	
AVERAGE DEPTH, FEET	LESS THAN 5.0	NITROGEN CONTENT IN PERCENTAGE								80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9						
0 - 999	4	1	1	2	2	0	1	0	2	1	10	24	45	7	
1000 - 1999	14	17	5	6	4	5	4	4	5	7	9	81	317	9	
2000 - 2999	28	17	71	15	15	5	0	1	1	1	1	155	931	7	
3000 - 3999	27	21	16	15	8	3	2	1	2	0	0	95	241	7	
4000 - 4999	19	5	2	1	1	1	0	2	0	1	0	32	39	6	
5000 - 5999	13	3	2	0	0	0	0	0	0	0	0	18	89	4	
6000 - 6999	8	0	0	0	0	0	0	0	0	0	0	8	9	3	
7000 - 7999	8	2	1	0	0	0	0	0	0	0	0	11	14	5	
8000 - 8999	5	1	0	0	0	0	0	0	0	0	0	6	7	4	
9000 - 9999	4	0	0	0	0	0	0	0	0	0	0	4	4	2	
10000 - 10999	4	1	0	0	0	0	0	0	0	0	0	5	9	3	
11000 - 11999	3	0	0	0	0	0	0	0	0	0	0	3	3	3	
12000 - 12999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
13000 - 13999	0	0	1	0	0	0	0	0	0	0	0	1	1	1	
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	
15000 - 15999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
RESERVOIRS	139	68	100	39	30	14	7	8	10	10	20	445	1711		

TABLE G-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:PERMIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
CARBON DIOXIDE PERCENTAGE																
0.0 - 0.9		11	136	73	48	85	25	5	0	0	4	0	387	1520	11	
1.0 - 1.9		1	17	1	1	2	0	0	0	1	1	0	24	55	5	
2.0 - 2.9		1	11	0	0	0	0	0	0	0	0	0	12	22	3	
3.0 - 3.9		1	3	1	0	0	0	1	0	0	0	0	6	6	3	
4.0 - 4.9		0	1	0	0	0	1	0	0	0	0	0	2	3	2	
5.0 - 5.9		1	3	1	0	0	1	0	0	0	0	0	6	78	3	
6.0 - 6.9		1	0	1	0	0	1	0	0	0	0	0	3	9	2	
7.0 - 7.9		0	1	1	0	0	0	0	0	0	0	0	2	4	2	
8.0 - 8.9		0	0	0	0	0	0	0	0	0	0	0	1	2	1	
9.0 - 9.9		0	1	0	0	0	0	0	0	0	0	0	443	1699		
0.0 - 9.9		16	173	78	49	87	28	6	0	1	5	0				
10.0 - 19.9		0	1	2	1	1	0	0	0	0	4	0	9	10	6	
20.0 - 29.9		0	0	0	0	2	0	0	0	0	0	0	2	4	1	
30.0 - 39.9		0	0	1	0	0	1	0	0	0	0	0	2	4	1	
40.0 - 49.9		0	0	0	0	0	0	0	0	0	0	0				
50.0 - 59.9		0	0	0	0	0	1	0	0	0	0	0	1	4	1	
60.0 - 69.9		0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9		0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9		0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0		3	1	3	0	1	0	0	0	0	0	0	8	14	3	
TOTAL		19	175	84	50	91	30	6	0	1	9	0	465	1735		

TABLE G-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: PERMIAN		CARBON DIOXIDE CONTENT IN PERCENTAGE										RESERVOIRS: 445		SAMPLES: 1,711		STATES: 11	
AVERAGE DEPTH, FEET	LESS THAN 5.0	MINIMUM DEPTH:										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES			
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0						
0 - 999	20	0	2	0	0	0	0	0	0	0	2	24	45	7			
1000 - 1999	76	1	3	0	0	0	1	0	0	0	0	81	317	9			
2000 - 2999	150	3	1	0	0	0	0	0	0	0	1	155	931	7			
3000 - 3999	68	2	1	2	1	0	0	0	0	0	1	95	241	7			
4000 - 4999	27	4	1	0	0	0	0	0	0	0	0	32	39	6			
5000 - 5999	17	1	0	0	0	0	0	0	0	0	0	18	89	4			
6000 - 6999	8	0	0	0	0	0	0	0	0	0	0	8	9	3			
7000 - 7999	10	0	0	0	1	0	0	0	0	0	0	11	14	5			
8000 - 8999	4	0	0	0	0	0	0	0	0	0	2	6	7	4			
9000 - 9999	4	0	0	0	0	0	0	0	0	0	0	4	4	2			
10000 - 10999	5	0	0	0	0	0	0	0	0	0	0	5	9	3			
11000 - 11999	2	0	0	0	0	0	0	0	0	0	1	3	3	3			
12000 - 12999	1	0	0	0	0	0	0	0	0	0	0	1	1	1			
13000 - 13999	1	0	0	0	0	0	0	0	0	0	0	1	1	1			
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
15000 - 15999	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
RESERVOIRS	414	11	8	2	2	0	1	0	0	0	7	445	1711				

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TABLE G-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	PERMIAN	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	HELIUM CONTENT IN PERCENTAGE										GREATER THAN 10.0	NUMBER OF RESEVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
						.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99								
ARGON PERCENTAGE																			
0.0 - 0.09	3	107	49	32	18	2	0	0	0	0	0	0	0	211	765	10			
0.1 - 0.29	1	14	8	4	44	21	5	0	0	0	0	0	0	97	684	8			
0.3 - 0.49	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1			
0.5 - 0.69	0	0	0	0	0	1	0	0	0	0	0	1	0	2	5	2			
0.7 - 0.89	0	0	0	0	0	0	0	0	0	1	5	0	0	6	22	2			
0.9 - 1.09	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1			
1.1 - 1.29	2	0	0	0	1	0	0	0	0	0	0	0	0	3	3	2			
1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
> 1.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
TOTAL	6	121	57	36	64	24	5	0	1	7	0	0	0	321	1481				

TABLE C-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM: PETROLIUM		MINIMUM DEPTH:		ARGON CONTENT IN PERCENTAGE				190		MAXIMUM DEPTH: 15,257		RESERVOIRS: 308		SAMPLES: 1,465		STATES: 10	
		LESS THAN 0.1	0.1 TO .43	.43 TO .50	.50 TO .69	.69 TO .70	.70 TO .89	.89 TO 1.09	1.09 TO 1.29	1.29 TO 1.49	GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES			
AVERAGE DEPTH, FEET		3	1	1	0	2	0	2	0	0	0	9	21	5			
0 - 999		22	19	0	1	4	1	0	0	0	0	46	259	7			
1000 - 1999		63	38	0	0	0	0	0	0	0	0	101	820	7			
2000 - 2999		40	28	0	0	0	0	0	0	0	0	68	194	7			
3000 - 3999		24	4	0	0	0	0	0	0	0	0	28	35	6			
4000 - 4999		16	1	0	0	0	0	0	0	0	0	17	88	4			
5000 - 5999		8	0	0	0	0	0	0	0	0	0	8	9	3			
6000 - 6999		10	1	0	0	0	0	0	0	0	0	11	14	5			
7000 - 7999		5	1	0	0	0	0	0	0	0	0	6	7	4			
8000 - 8999		4	0	0	0	0	0	0	0	0	0	4	4	2			
9000 - 9999		4	1	0	0	0	0	0	0	0	0	5	9	3			
10000 - 10999		2	0	0	0	0	0	0	0	0	0	2	2	2			
11000 - 11999		1	0	0	0	0	0	0	0	0	0	1	1	1			
12000 - 12999		1	0	0	0	0	0	0	0	0	0	1	1	1			
13000 - 13999		0	0	0	0	0	0	0	0	0	0	1	1	1			
14000 - 14999		1	9	0	0	0	0	0	0	0	0	1	1	1			
15000 - 15999		0	0	0	0	0	0	0	0	0	0	1	1	1			
16000 - 16999		0	0	0	0	0	0	0	0	0	0	1	1	1			
17000 - 17999		0	0	0	0	0	0	0	0	0	0	1	1	1			
18000 - 18999		0	0	0	0	0	0	0	0	0	0	1	1	1			
19000 - 19999		0	0	0	0	0	0	0	0	0	0	1	1	1			
20000 - 20999		0	0	0	0	0	0	0	0	0	0	1	1	1			
21000 - 21999		0	0	0	0	0	0	0	0	0	0	1	1	1			
22000 - 22999		0	0	0	0	0	0	0	0	0	0	1	1	1			
RESERVOIRS	209	93	1	1	6	1	2	0	0	0	0	308	1465	1			

APPENDIX H.--PENNSYLVANIAN SYSTEM

The Pennsylvanian System reservoirs with the highest helium contents are found at depths ranging from 3,000 to 8,000 feet. This system has 1,945 reservoirs, a larger number of reservoirs than any of the other systems, and represents 30.1 percent of the total reservoirs studied. There were 471 reservoirs with 0.30 percent or more of helium, and 142 contained 1 percent or more of helium, and 11 contained 5 percent or more of helium. The reservoir with the highest helium content, 8.00 percent, was found in New Mexico at a depth of 6,514 feet. The gas contained 12.8 percent of methane, 70.1 percent of nitrogen, 0.9 percent of carbon dioxide, and 0.7 percent of argon. The shallowest reservoir, found in Ohio at a depth of 118 feet, contained 0.01 percent of helium and is the shallowest of all the reservoirs studied. The gas contained 35.8 percent of methane, 61.3 percent of nitrogen, 1.9 percent of carbon dioxide, and 0.7 percent of argon. The deepest reservoir for this system was found in Oklahoma at a depth of 21,604 feet, and the gas contained 0.02 percent of helium, 94.8 percent of methane, 0.3 percent of nitrogen, 4.6 percent of carbon dioxide, and 0.0 percent of argon. The average depth of a reservoir in this system is 5,350 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon are 0.32 percent, 77.4 percent, 8.5 percent, 1.02 percent, and 0.01 percent, respectively.

Appendix H contains the following seven tables concerning the Pennsylvanian System:

TABLE H-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: PENNSYLVANIAN		MINIMUM DEPTH:		118		MAXIMUM DEPTH: 21,604		RESERVOIRS: 1874		SAMPLES: 3,012		STATES: 21						
		HELIUM CONTENT IN PERCENTAGE																
AVERAGE DEPTH, FEET	LESS THAN .005	.10 TO .29		.50 TO .99		1.00 TO 1.99		2.00 TO 2.99		3.00 TO 4.99		5.00 TO 6.99		7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		.10 TO .29	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99											
0 - 999	11	11	23	8	14	10	0	1	0	0	0	0	0	78	118	11		
1000 - 1999	5	31	61	18	21	6	0	0	0	0	0	0	0	142	273	13		
2000 - 2999	10	31	68	20	35	10	3	0	0	0	0	0	0	177	232	7		
3000 - 3999	5	42	132	27	38	33	10	2	0	1	0	0	0	290	449	9		
4000 - 4999	4	51	113	50	36	23	8	2	0	0	0	0	0	287	581	9		
5000 - 5999	1	70	144	16	13	3	1	2	0	0	0	0	0	250	364	9		
6000 - 6999	2	51	128	9	3	2	2	3	4	1	0	0	0	205	368	9		
7000 - 7999	0	47	64	3	0	2	0	2	3	0	0	0	0	121	198	8		
8000 - 8999	1	53	29	0	0	0	0	0	0	0	0	0	0	83	122	6		
9000 - 9999	1	67	6	2	0	0	0	0	0	0	0	0	0	76	94	5		
10000 - 10999	0	61	0	0	0	0	0	0	0	0	0	0	0	61	86	5		
11000 - 11999	0	32	1	0	0	0	0	0	0	0	0	0	0	33	45	3		
12000 - 12999	0	26	1	0	1	0	0	0	0	0	0	0	0	28	35	4		
13000 - 13999	1	13	1	0	0	0	0	0	0	0	0	0	0	15	15	4		
14000 - 14999	0	12	0	0	0	0	0	0	0	0	0	0	0	12	12	3		
15000 - 15999	1	7	0	0	0	0	0	0	0	0	0	0	0	8	8	3		
16000 - 16999	0	3	0	0	0	0	0	0	0	0	0	0	0	3	4	2		
17000 - 17999	0	0	2	0	0	0	0	0	0	0	0	0	0	2	3	1		
18000 - 18999	0	1	1	0	0	0	0	0	0	0	0	0	0	2	4	2		
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0					
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0					
21000 - 21999	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1		
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0					
RESERVOIRS	42	610	774	153	161	89	24	12	7	2	0			1874	3012			

TABLE H-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM; PENNSYLVANIAN		HELIUM CONTENT IN PERCENTAGE													GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99							
NITROGEN PERCENTAGE	0.0 - 0.9	14	268	109	0	0	0	0	0	0	0	0	0	0	411	506	13	
	1.0 - 1.9	6	158	125	1	1	1	0	0	0	0	0	0	0	292	445	11	
	2.0 - 2.9	4	71	123	6	0	0	0	0	0	0	0	0	0	11	280	11	
	3.0 - 3.9	7	32	92	6	0	0	0	0	0	0	0	0	0	137	189	11	
	4.0 - 4.9	1	30	77	8	1	0	0	0	0	0	0	0	0	117	150	9	
	5.0 - 5.9	2	11	60	11	0	0	0	0	0	0	0	0	0	84	127	7	
	6.0 - 6.9	0	6	45	6	4	0	0	0	0	0	0	0	0	61	84	7	
	7.0 - 7.9	0	6	42	4	8	0	0	0	0	0	0	0	0	60	71	9	
	8.0 - 8.9	4	3	25	7	5	3	0	0	0	0	0	0	0	47	72	8	
	9.0 - 9.9	0	5	23	8	2	1	0	0	0	0	0	0	0	39	51	6	
	0.0 - 9.9	38	610	721	57	21	5	0	0	0	0	0	0	0	1452	1975		
	10.0 - 19.9	1	13	70	75	71	19	2	0	0	0	0	0	0	251	381	11	
20.0 - 29.9	0	0	9	19	54	37	14	0	1	0	0	0	0	134	486	9		
30.0 - 39.9	1	0	1	4	19	15	3	2	0	0	0	0	0	45	121	7		
40.0 - 49.9	1	0	0	1	3	8	1	1	2	0	0	0	0	17	25	5		
50.0 - 59.9	0	0	0	0	1	0	1	3	1	0	0	0	0	6	10	3		
60.0 - 69.9	0	1	0	0	1	3	1	3	4	0	0	0	0	13	56	6		
70.0 - 79.9	1	0	1	0	1	4	2	3	1	1	0	0	0	14	17	9		
80.0 - 89.9	0	0	0	1	0	1	0	0	0	1	0	0	0	3	3	3		
90.0 - 100.0	2	3	0	1	0	0	1	1	0	0	0	0	0	8	11	6		
TOTAL	44	627	802	158	171	92	25	13	9	2	0	0	0	1943	3085			

TABLE H-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: PENNSYLVANIAN														
HELIUM CONTENT IN PERCENTAGE														
CARBON DIOXIDE PERCENTAGE	CARBON DIOXIDE PERCENTAGE													
	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS		
												NUMBER OF SAMPLES		
												NUMBER OF STATES		
0.0 - 0.9	37	488	752	147	152	82	20	8	5	2	0	1693	2684	18
1.0 - 1.9	2	103	21	2	6	1	2	3	1	0	0	141	190	10
2.0 - 2.9	2	16	5	0	2	1	0	1	0	0	0	27	6	7
3.0 - 3.9	0	7	4	1	1	2	1	0	0	0	0	16	29	7
4.0 - 4.9	0	3	2	1	1	0	0	0	3	0	0	10	12	4
5.0 - 5.9	0	4	2	0	1	0	0	0	0	0	0	7	9	4
6.0 - 6.9	2	1	4	1	3	0	0	0	0	0	0	11	22	6
7.0 - 7.9	0	1	0	1	0	1	0	0	0	0	0	3	4	3
8.0 - 8.9	1	0	1	0	3	0	0	0	0	0	0	5	8	5
9.0 - 9.9	0	0	3	0	0	1	2	1	0	0	0	7	13	5
0.0 - 9.9	44	623	794	153	169	88	25	13	9	2	0	1920	3049	
10.0 - 19.9	0	1	4	1	1	3	0	0	0	0	0	10	16	5
20.0 - 29.9	0	0	2	0	0	0	0	0	0	0	0	2	5	1
30.0 - 39.9	0	0	1	2	0	1	0	0	0	0	0	4	7	3
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0			
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0			
60.0 - 69.9	0	0	0	0	1	0	0	0	0	0	0	1	1	1
70.0 - 79.9	0	0	1	1	0	0	0	0	0	0	0	2	2	2
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0			
90.0 - 100.0	0	3	0	1	0	0	0	0	0	0	0	4	5	1
TOTAL	44	627	802	156	171	92	25	13	9	2	0	1943	3085	

TABLE H-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: PENNSYLVANIAN		MINIMUM DEPTH:		116		MAXIMUM DEPTH: 21.604		RESERVOIRS: 1873		SAMPLES: 3,011		STATES: 21					
AVERAGE DEPTH, FEET		CARBON DIOXIDE CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS		NUMBER OF SAMPLES		NUMBER OF STATES	
5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0								
0 - 499	76	2	0	0	0	0	0	0	0	0	78	118	11	11	11	11	11
1000 - 1999	137	1	1	0	0	0	0	0	3	0	142	273	13	13	13	13	13
2000 - 2999	175	2	0	0	0	0	0	0	0	0	177	232	7	7	7	7	7
3000 - 3999	285	3	0	0	1	0	0	0	0	0	289	448	9	9	9	9	9
4000 - 4999	276	9	2	0	0	0	0	0	0	0	287	581	9	9	9	9	9
5000 - 5999	246	3	1	0	0	0	0	0	0	0	250	364	9	9	9	9	9
6000 - 6999	200	3	0	0	1	0	0	0	0	0	205	368	9	9	9	9	9
7000 - 7999	117	3	1	0	0	0	0	0	0	0	121	198	8	8	8	8	8
8000 - 8999	80	1	1	0	1	0	0	0	0	0	83	122	6	6	6	6	6
9000 - 9999	71	2	2	0	1	0	0	0	0	0	76	94	5	5	5	5	5
10000 - 10999	61	0	0	0	0	0	0	0	0	0	61	86	5	5	5	5	5
11000 - 11999	32	1	0	0	0	0	0	0	0	0	33	45	3	3	3	3	3
12000 - 12999	26	1	0	0	0	0	1	0	0	0	28	35	4	4	4	4	4
13000 - 13999	15	0	0	0	0	0	0	0	0	0	15	15	4	4	4	4	4
14000 - 14999	12	0	0	0	0	0	0	0	0	0	12	12	3	3	3	3	3
15000 - 15999	8	0	0	0	0	0	0	0	0	0	8	8	3	3	3	3	3
16000 - 16999	3	0	0	0	0	0	0	0	0	0	3	4	2	2	2	2	2
17000 - 17999	0	0	1	1	0	0	0	0	0	0	2	3	1	1	1	1	1
18000 - 18999	1	0	0	1	0	0	0	0	0	0	2	4	2	2	2	2	2
19000 - 19999	0	0	0	0	0	0	0	0	0	0							
20000 - 20999	0	0	0	0	0	0	0	0	0	0							
21000 - 21999	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
22000 - 22999	0	0	0	0	0	0	0	0	0	0							
RESERVOIRS	1822	31	9	2	4	0	1	1	0	3	1873	3011	1873	3011	1873	3011	1873

TABLE B-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM		HELIUM CONTENT IN PERCENTAGE														NUMBER OF RESERVOIRS		NUMBER OF SAMPLES		NUMBER OF STATES	
ARGON PERCENTAGE	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE														GREATER THAN 10.0					
		.10 TO .29	.30 TO .49	.50 TO .77	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99												
0.0 - 0.09	10	512	639	113	77	17	0	0	0	0	0	0	0	0	0	1368	1890	17			
0.1 - 0.29	1	20	19	18	56	49	18	3	0	0	0	0	0	0	0	184	511	10			
0.3 - 0.49	0	1	0	2	1	1	2	2	0	0	0	0	0	0	0	9	39	4			
0.5 - 0.69	0	0	0	0	0	0	1	4	4	0	0	0	0	0	0	9	18	3			
0.7 - 0.89	0	1	0	0	0	0	0	3	5	1	0	0	0	0	0	10	50	3			
0.9 - 1.09	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	2	1			
1.1 - 1.29	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1			
1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
> 1.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
TOTAL	12	535	658	133	134	67	21	12	9	2	0	0	0	0	0	1583	2511				

TABLE H-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

DEPTH OF WATER IN FEET			ARGON CONTENT IN PERCENTAGE					DEPTH: 21-604		RESERVOIRS: 1520		SAMPLES: 2,445		STATES: 18		
AVERAGE DEPTH, FEET	LESS THAN 0.1	.10 to .29	.30 to .49	.50 to .69	.70 to .89	.90 to 1.09	1.10 to 1.29	1.30 to 1.49	GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES				
0 - 999	0	5	0	0	1	0	0	0	0	14	17	6				
1000 - 1999	56	0	0	0	0	0	1	0	0	65	92	11				
2000 - 2999	74	25	0	0	0	0	0	0	0	99	135	7				
3000 - 3999	175	41	0	2	1	1	0	0	0	220	359	8				
4000 - 4999	207	46	0	0	0	0	0	0	0	253	538	9				
5000 - 5999	268	19	2	0	1	0	0	0	0	230	321	9				
6000 - 6999	163	7	3	5	2	0	0	0	0	200	363	9				
7000 - 7999	100	4	2	1	4	0	0	0	0	119	196	7				
8000 - 8999	77	3	0	0	0	0	0	0	0	80	116	5				
9000 - 9999	68	6	1	0	0	0	0	0	0	75	93	5				
10000 - 10999	59	2	0	0	0	0	0	0	0	61	86	5				
11000 - 11999	52	1	0	0	0	0	0	0	0	33	45	3				
12000 - 12999	24	4	0	0	0	0	0	0	0	28	35	4				
13000 - 13999	15	0	0	0	0	0	0	0	0	15	15	4				
14000 - 14999	12	0	0	0	0	0	0	0	0	12	12	3				
15000 - 15999	6	0	0	0	0	0	0	0	0	6	6	3				
16000 - 16999	2	1	0	0	0	0	0	0	0	3	4	2				
17000 - 17999	1	1	0	0	0	0	0	0	0	2	3	1				
18000 - 18999	1	1	0	0	0	0	0	0	0	2	4	2				
19000 - 19999	0	0	0	0	0	0	0	0	0							
20000 - 20999	0	0	0	0	0	0	0	0	0							
21000 - 21999	1	0	0	0	0	0	0	0	0	1	1	1				
22000 - 22999	0	0	0	0	0	0	0	0	0							
RESERVOIRS	1319	174	6	8	4	1	1	0	0	1520	2445					

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APPENDIX I.--MISSISSIPPIAN SYSTEM

Mississippian System reservoirs containing 0.30 percent or more of helium are found at depths ranging from less than 1,000 to about 18,000 feet. The helium contents of this system increase with depth down to about 8,000 feet, then, as the depths increase, the helium contents decrease. This system has 748 reservoirs, or 11.6 percent, of the total reservoirs studied. There are 227 reservoirs with 0.30 percent or more of helium, and 65 of these reservoirs contained gas with 1 percent or more of helium. Twelve of these reservoirs contained 5 percent or more of helium. The highest helium content of a reservoir in this system was 8.01 percent found in New Mexico at a depth of 6,950 feet. This is the deepest reservoir for which a maximum helium content has been found in any of the geologic system reservoirs studied. The gas contained 9.8 percent of methane, 75.4 percent of nitrogen, 0.5 percent of carbon dioxide, and an unknown percent of argon. The shallowest reservoir was found in Illinois at a depth of 205 feet and contained less than 0.005 percent of helium. The gas contained 97.0 percent of methane, 0.4 percent of nitrogen, 2.6 percent of carbon dioxide, and 0.0 percent of argon. The deepest reservoir in this system was found in Wyoming at a depth of 18,431 feet, and the gas contained 0.26 percent of helium, 6.1 percent of methane, 6.4 percent of nitrogen, 86.6 percent of carbon dioxide, and 0.1 percent of argon. The average depth of a reservoir in this system is 3,936 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.42 percent, 74.6 percent, 8.7 percent, 3.4 percent, and 0.02 percent, respectively.

Appendix I contains the following seven tables concerning the Mississippian System:

TABLE 1-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: MISSISSIPPIAN		HELIUM CONTENT IN PERCENTAGE										MINIMUM DEPTH: 205		MAXIMUM DEPTH: 10,431		RESERVOIRS: 734		SAMPLES: 1,038		STATES: 23	
AVERAGE DEPTH, FEET	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE										MINIMUM DEPTH: 205		MAXIMUM DEPTH: 10,431		RESERVOIRS: 734		SAMPLES: 1,038		STATES: 23	
		.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	MINIMUM DEPTH: 205		MAXIMUM DEPTH: 10,431		RESERVOIRS: 734		SAMPLES: 1,038		STATES: 23	
0 - 999	3	7	15	2	6	0	0	0	0	1	0	34	9	168	230	13	9	13	13	13	13
1000 - 1999	3	43	77	37	25	2	1	0	0	0	0	122	138	10	10	84	9	7	7	7	7
2000 - 2999	2	51	47	16	6	0	0	0	0	0	0	68	172	7	7	36	47	7	7	7	7
3000 - 3999	1	25	18	10	8	6	0	0	0	0	0	126	172	7	7	54	123	8	8	8	8
4000 - 4999	0	14	67	15	8	7	11	4	0	0	0	40	81	6	6	37	89	7	7	7	7
5000 - 5999	0	6	18	1	4	4	0	2	1	0	0	12	17	4	4	6	6	4	4	4	4
6000 - 6999	1	19	19	3	4	1	1	0	3	3	0	3	0	0	0	40	81	6	6	6	6
7000 - 7999	0	22	7	0	1	4	1	1	4	0	0	3	0	0	0	37	89	7	7	7	7
8000 - 8999	1	18	4	1	7	5	1	0	0	0	0	12	17	4	4	6	6	4	4	4	4
9000 - 9999	0	7	2	1	2	0	0	0	0	0	0	3	0	0	0	12	17	4	4	4	4
10000 - 10999	0	4	0	2	0	0	0	0	0	0	0	3	0	0	0	3	3	2	2	2	2
11000 - 11999	1	2	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
12000 - 12999	0	1	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2
13000 - 13999	0	2	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
14000 - 14999	0	1	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2
15000 - 15999	0	1	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
17000 - 17999	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
18000 - 18999	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
RESERVOIRS	12	223	275	68	73	29	15	7	8	4	0	734	1038								

TABLE I-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:MISSISSIPPIAN		HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE																
0.0 - 0.9	7	125	38	1	1	0	0	0	0	0	0	0	172	200	14	
1.0 - 1.9	1	55	87	3	0	0	0	0	0	0	0	0	146	188	15	
2.0 - 2.9	2	23	55	6	0	0	0	0	0	0	0	0	86	121	16	
3.0 - 3.9	0	7	23	7	0	0	0	0	0	0	0	0	37	50	12	
4.0 - 4.9	0	5	17	9	2	0	0	0	0	0	0	0	33	37	11	
5.0 - 5.9	1	1	23	19	1	0	0	0	0	0	0	0	45	65	11	
6.0 - 6.9	0	0	12	6	4	1	0	0	0	0	0	0	23	33	12	
7.0 - 7.9	0	2	5	13	2	0	0	0	0	0	0	0	22	35	7	
8.0 - 8.9	0	3	4	5	2	1	0	0	0	0	0	0	15	23	7	
9.0 - 9.9	0	0	7	0	7	0	0	0	0	0	0	0	14	16	9	
0.0 - 9.9	11	221	271	69	19	2	0	0	0	0	0	0	593	768		
10.0 - 19.9	0	2	10	16	34	10	0	0	0	0	0	0	72	126	12	
20.0 - 29.9	0	0	1	4	16	4	1	0	0	0	0	0	26	39	7	
30.0 - 39.9	0	1	1	0	1	3	6	2	0	0	0	0	14	17	4	
40.0 - 49.9	0	1	0	0	0	2	3	0	0	0	0	0	6	6	3	
50.0 - 59.9	0	0	0	0	0	0	2	1	3	0	0	0	6	17	3	
60.0 - 69.9	0	0	0	0	1	5	0	2	1	1	0	0	10	18	5	
70.0 - 79.9	0	0	0	0	2	4	0	0	1	1	0	0	11	44	3	
80.0 - 89.9	1	0	0	0	0	0	1	0	0	0	0	0	5	11	2	
90.0 - 100.0	0	1	0	0	0	1	1	1	1	0	0	0	4	6	4	
TOTAL	12	226	283	89	73	31	14	7	8	4	0	0	747	1052		

TABLE I-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM: MISSISSIPPIAN		MINIMUM DEPTH:		205		MAXIMUM DEPTH: 18,431		RESERVOIRS: 733										SAMPLES: 1,037		STATES: 23	
								NITROGEN CONTENT IN PERCENTAGE													
AVERAGE DEPTH, FEET	LESS THAN 5.0	5.0 TO 19.9	20.0 TO 29.9	30.0 TO 34.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES								
		19.9	29.9	34.9	49.9	59.9	69.9	79.9	89.9	100.0											
0 - 999	13	12	7	0	1	0	1	0	0	0	34	39	9								
1000 - 1499	104	40	21	13	2	1	0	0	1	1	168	230	13								
1500 - 1999	97	14	9	2	0	0	0	0	0	0	122	138	10								
2000 - 2499	42	12	7	2	1	2	0	2	0	0	68	84	9								
2500 - 2999	70	25	13	4	7	3	2	2	0	0	126	172	7								
3000 - 3499	21	3	3	3	2	0	0	1	1	2	36	47	7								
3500 - 3999	57	4	4	1	0	0	3	0	4	1	54	123	8								
4000 - 4499	28	2	1	0	0	0	0	2	2	3	39	80	6								
4500 - 4999	23	3	4	0	0	0	1	2	4	0	37	89	7								
5000 - 5499	10	1	1	0	0	0	0	0	0	0	12	17	7								
5500 - 5999	6	0	0	0	0	0	0	0	0	0	6	6	4								
6000 - 6499	3	0	0	0	0	0	0	0	0	0	3	3	2								
6500 - 6999	1	0	0	0	0	0	0	0	0	0	1	1	1								
7000 - 7499	2	0	0	0	0	0	0	0	0	0	2	2	2								
7500 - 7999	1	0	0	0	0	0	0	0	0	0	1	1	1								
8000 - 8499	1	1	0	0	0	0	0	0	0	0	2	2	2								
8500 - 8999	0	0	0	0	0	0	0	0	0	0	0	0	0								
9000 - 9499	0	0	0	0	0	0	0	0	0	0	1	2	1								
9500 - 9999	0	0	0	0	0	0	0	0	0	0	1	1	1								
10000 - 10499	0	0	0	0	0	0	0	0	0	0	0	0	0								
10500 - 10999	0	0	0	0	0	0	0	0	0	0	0	0	0								
11000 - 11499	0	0	0	0	0	0	0	0	0	0	0	0	0								
11500 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0								
12000 - 12499	0	0	0	0	0	0	0	0	0	0	0	0	0								
12500 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0								
13000 - 13499	0	0	0	0	0	0	0	0	0	0	0	0	0								
13500 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0								
14000 - 14499	0	0	0	0	0	0	0	0	0	0	0	0	0								
14500 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0								
15000 - 15499	0	0	0	0	0	0	0	0	0	0	0	0	0								
15500 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0								
16000 - 16499	0	0	0	0	0	0	0	0	0	0	0	0	0								
16500 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0								
17000 - 17499	0	0	0	0	0	0	0	0	0	0	0	0	0								
17500 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0								
18000 - 18499	0	0	0	0	0	0	0	0	0	0	0	0	0								
18500 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0								
19000 - 19499	0	0	0	0	0	0	0	0	0	0	0	0	0								
19500 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0								
20000 - 20499	0	0	0	0	0	0	0	0	0	0	0	0	0								
20500 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0								
21000 - 21499	0	0	0	0	0	0	0	0	0	0	0	0	0								
21500 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0								
22000 - 22499	0	0	0	0	0	0	0	0	0	0	0	0	0								
22500 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0								
RESERVOIRS	464	110	71	25	13	6	6	10	11	5	733	1037	733								



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TABLE I-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:MISSISSIPPIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0			
CARBON DIOXIDE PERCENTAGE	0.0 - 0.9	7	196	272	77	57	19	10	3	1	3	0	645	850	20
	1.0 - 1.9	1	13	3	6	2	2	1	2	2	0	0	32	40	12
	2.0 - 2.9	2	9	0	0	0	3	0	0	1	1	0	16	36	8
	3.0 - 3.9	0	2	2	0	0	2	0	0	0	0	0	6	13	3
	4.0 - 4.9	1	1	0	0	0	1	0	0	0	0	0	3	5	3
	5.0 - 5.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1
	6.0 - 6.9	0	0	0	0	1	0	0	0	0	0	0	1	1	1
	7.0 - 7.9	0	0	0	0	0	0	0	1	0	0	0	1	1	1
	8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1
	9.0 - 9.9	0	0	0	0	1	1	1	1	0	0	0	4	10	3
	0.0 - 9.9	11	222	277	83	61	28	12	7	4	4	0	709	957	
	10.0 - 19.9	1	1	1	0	2	0	1	1	0	1	0	7	14	6
20.0 - 29.9	0	0	0	0	3	1	0	0	0	3	0	7	42	3	
30.0 - 39.9	0	0	0	0	0	0	1	0	0	0	0	1	7	1	
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
50.0 - 59.9	0	0	1	1	0	0	0	0	0	0	0	2	4	2	
60.0 - 69.9	0	0	0	1	2	0	0	0	0	0	0	3	3	2	
70.0 - 79.9	0	0	0	0	1	0	0	0	0	0	0	1	1	1	
80.0 - 89.9	0	0	1	0	3	2	0	0	0	0	0	6	7	3	
90.0 - 100.0	0	3	3	4	1	0	0	0	0	0	0	11	17	5	
TOTAL	12	226	283	89	73	31	14	7	8	4	0	747	1052		

TABLE I-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: MISSISSIPPIAN																					
AVERAGE DEPTH, FEET	MINIMUM DEPTH: 205			CARBON DIOXIDE CONTENT IN PERCENTAGE								205		MAXIMUM DEPTH: 10,431		RESERVOIRS: 733		SAMPLES: 1,037		STATES: 23	
	LESS THAN 5.0	5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	50.0 TO 59.9	60.0 TO 69.9	60.0 TO 69.9	70.0 TO 79.9	70.0 TO 79.9	80.0 TO 89.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES			
0 - 999	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	39	9			
1000 - 1999	187	0	1	0	0	0	0	0	0	0	0	0	0	0	0	188	230	13			
2000 - 2999	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	138	10			
3000 - 3999	66	0	1	0	0	0	0	0	0	0	0	0	0	0	1	68	84	9			
4000 - 4999	123	2	1	0	0	0	0	0	0	0	0	0	0	0	0	126	172	7			
5000 - 5999	34	1	0	1	0	0	0	0	0	0	0	0	0	0	0	36	47	7			
6000 - 6999	44	0	1	3	0	0	1	1	1	1	1	1	2	2	2	54	123	8			
7000 - 7999	34	0	1	0	0	0	0	0	0	0	0	0	2	2	2	39	80	6			
8000 - 8999	26	4	0	3	1	0	1	0	0	0	0	1	1	1	1	37	89	7			
9000 - 9999	7	0	2	0	0	0	0	0	0	0	0	0	0	3	3	12	17	7			
10000 - 10999	4	0	0	0	0	0	0	0	0	0	0	0	0	2	2	6	6	4			
11000 - 11999	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2			
12000 - 12999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1			
13000 - 13999	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2			
14000 - 14999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1			
15000 - 15999	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2	2			
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1			
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	1			
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1			
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1			
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1			
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
RESERVOIRS	689	7	7	7	1	0	2	2	2	1	6	11	733	1037							



TABLE I-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEM: MISSISSIPPIAN			MINIMUM DEPTH: 205		MAXIMUM DEPTH: 18,431				RESERVOIRS: 550		SAMPLES: 811		STATES: 22	
AVERAGE DEPTH, FEET			ARGON CONTENT IN PERCENTAGE								NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	
			LESS THAN 0.1	.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49				GREATER THAN 1.49
0 - 999	7	0	0	0	0	1	0	0	0	0	8	8	7	
1000 - 1999	90	7	0	1	0	1	0	0	0	0	99	119	11	
2000 - 2999	91	1	0	0	0	0	0	0	0	0	92	98	10	
3000 - 3999	48	2	0	0	0	0	0	0	0	0	50	61	9	
4000 - 4999	89	23	1	1	1	1	0	0	0	0	115	161	7	
5000 - 5999	24	4	2	0	0	0	1	0	0	0	31	41	6	
6000 - 6999	37	7	0	2	2	2	2	0	0	0	50	119	8	
7000 - 7999	28	6	0	1	4	0	0	0	0	0	39	80	6	
8000 - 8999	24	7	5	1	0	0	0	0	0	0	37	89	7	
9000 - 9999	12	0	0	0	0	0	0	0	0	0	12	17	7	
10000 - 10999	6	0	0	0	0	0	0	0	0	0	6	6	4	
11000 - 11999	3	0	0	0	0	0	0	0	0	0	3	3	2	
12000 - 12999	1	0	0	0	0	0	0	0	0	0	1	1	1	
13000 - 13999	2	0	0	0	0	0	0	0	0	0	2	2	2	
14000 - 14999	1	0	0	0	0	0	0	0	0	0	1	1	1	
15000 - 15999	1	1	0	0	0	0	0	0	0	0	2	2	2	
16000 - 16999	0	0	0	0	0	0	0	0	0	0	1	2	1	
17000 - 17999	0	1	0	0	0	0	0	0	0	0	1	1	1	
18000 - 18999	0	1	0	0	0	0	0	0	0	0	1	1	1	
19000 - 19999	0	0	0	0	0	0	0	0	0	0				
20000 - 20999	0	0	0	0	0	0	0	0	0	0				
21000 - 21999	0	0	0	0	0	0	0	0	0	0				
22000 - 22999	0	0	0	0	0	0	0	0	0	0				
RESERVOIRS	464	60	8	6	8	4	0	0	0	0	550	811		

APPENDIX J.--DEVONIAN SYSTEM

Devonian System reservoirs containing 0.30 percent or more of helium increase with depth down to about 7,000 feet, then they begin to drop off until a depth of about 11,000 feet is reached. None of the reservoirs contained 0.30 percent or more of helium at depths below 11,000 feet. This system contains 504 reservoirs, but only 32 contained 0.30 percent or more of helium. Eighteen of these reservoirs contained 1 percent or more of helium, and eight of these contained 5 percent or more of helium in the gas. The highest helium content of a reservoir in this system was 7.80 percent found in New Mexico at a depth of 6,020 feet. The gas contained 0.6 percent of methane, 90.5 percent of nitrogen, 0.1 percent of carbon dioxide, and 1.0 percent of argon. The shallowest reservoir was found in Kentucky at a depth of 309 feet and contained less than 0.005 percent of helium. The gas contained 45.6 percent of methane, 3.5 percent of nitrogen, 0.6 percent of carbon dioxide, and an unknown percent of argon. The deepest reservoir was found in Oklahoma at a depth of 22,566 feet and contained 0.06 percent of helium. This is the deepest reservoir found in any of the 13 geologic systems. The gas contained 91.6 percent of methane, 3.5 percent of nitrogen, 4.7 percent of carbon dioxide, and 0.0 percent of argon. The average depth of a reservoir in this system was 5,427 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.25 percent, 79.7 percent, 5.9 percent, 2.3 percent, and 0.02 percent, respectively.

Appendix J contains the following seven tables concerning the Devonian System:

TABLE J-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:DEVONIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0			
0.0 - 0.9	8	134	25	0	0	0	0	0	0	0	0	167	187	12	
1.0 - 1.9	3	113	53	1	0	0	0	0	0	0	0	170	197	11	
2.0 - 2.9	1	34	25	0	0	0	0	0	0	0	0	60	68	13	
3.0 - 3.9	3	11	7	0	0	0	0	0	0	0	0	21	23	9	
4.0 - 4.9	0	8	13	0	0	0	0	0	0	0	0	21	29	9	
5.0 - 5.9	0	4	9	1	0	0	0	0	0	0	0	14	15	7	
6.0 - 6.9	1	0	4	0	0	0	0	0	0	0	0	5	7	4	
7.0 - 7.9	0	3	6	0	0	0	0	0	0	0	0	9	12	7	
8.0 - 8.9	0	1	1	1	0	0	0	0	0	0	0	3	3	2	
9.0 - 9.9	0	0	4	0	0	0	0	0	0	0	0	4	4	3	
0.0 - 9.9	16	308	147	3	0	0	0	0	0	0	0	474	545		
10.0 - 19.9	0	5	4	3	4	1	0	0	0	0	0	17	23	11	
20.0 - 29.9	2	0	1	1	0	0	0	0	0	0	0	4	4		
30.0 - 39.9	0	0	1	0	0	2	0	0	0	0	0	3	4	3	
40.0 - 49.9	0	0	0	1	0	0	0	0	0	0	0	1	1	1	
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	1	4		
70.0 - 79.9	0	0	0	0	1	0	0	0	1	2	0	4	7	3	
80.0 - 89.9	1	0	0	0	0	0	1	1	3	0	0	5	10	3	
90.0 - 100.0	0	0	0	0	1	0	2	3	2	2	0	10	14	4	
TOTAL	19	313	153	8	6	3	3	4	6	4	0	519	612		

TABLE J-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

AVERAGE DEPTH, FEET	GEOLOGIC SYSTEM: DEVONIAN	LESS THAN 5.0	MINIMUM DEPTH:			MAXIMUM DEPTH: 22,566			RESERVOIRS:			SAMPLES:			STATES: 21		
			NITROGEN CONTENT IN PERCENTAGE			NITROGEN CONTENT IN PERCENTAGE			RESERVOIRS			SAMPLES			STATES		
			5.0 10 4.9	20.0 10 29.9	30.0 10 39.9	40.0 10 49.9	50.0 10 59.9	60.0 10 69.9	70.0 10 79.9	80.0 10 89.9	90.0 10 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES	NUMBER OF STATES
0 - 499		15	4	1	0	0	0	0	0	0	0	20	26	6			
1000 - 1999		28	7	2	0	0	0	0	0	0	0	37	47	7			
2000 - 2999		79	4	4	2	1	0	0	0	0	1	91	101	8			
3000 - 3999		76	7	1	1	1	0	0	1	1	1	89	105	12			
4000 - 4999		57	5	3	0	0	0	0	1	2	2	70	81	9			
5000 - 5999		28	0	1	0	1	0	0	0	0	1	31	34	7			
6000 - 6999		21	2	1	0	0	0	1	1	1	5	32	40	6			
7000 - 7999		30	0	1	0	0	0	0	0	1	0	32	36	6			
8000 - 8999		28	1	1	0	0	0	0	0	0	0	31	37	7			
9000 - 9999		4	0	0	0	0	0	0	0	0	0	4	6	2			
10000 - 10999		5	2	0	0	0	1	0	0	0	0	8	10	3			
11000 - 11999		15	2	0	0	0	0	0	0	0	0	17	20	5			
12000 - 12999		10	0	2	0	0	0	0	0	0	0	12	14	3			
13000 - 13999		8	0	0	0	0	0	0	0	0	0	8	8	2			
14000 - 14999		7	0	0	0	0	0	0	0	0	0	7	8	3			
15000 - 15999		4	1	0	0	0	0	0	0	0	0	5	6	3			
16000 - 16999		4	0	0	0	0	0	0	0	0	0	4	6	2			
17000 - 17999		2	0	0	0	0	0	0	0	0	0	2	3	1			
18000 - 18999		0	0	0	0	0	0	0	0	0	0						
19000 - 19999		2	0	0	0	0	0	0	0	0	0	2	3	1			
20000 - 20999		1	0	0	0	0	0	0	0	0	0	1	2	1			
21000 - 21999		0	0	0	0	0	0	0	0	0	0						
22000 - 22999		1	0	0	0	0	0	0	0	0	0	1	1	1			
RESERVOIRS		425	35	17	4	3	1	0	1	3	5	504	594				

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TABLE J-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:UEVONIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		HELIUM CONTENT IN PERCENTAGE													
		CARBON DIOXIDE PERCENTAGE	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99			
0.0 - 0.9	8	134	25	0	0	0	0	0	0	0	0	0	167	187	12
1.0 - 1.9	3	113	53	1	0	0	0	0	0	0	0	0	170	197	11
2.0 - 2.9	1	34	25	0	0	0	0	0	0	0	0	0	60	68	13
3.0 - 3.9	3	11	7	0	0	0	0	0	0	0	0	0	21	23	9
4.0 - 4.9	0	8	13	0	0	0	0	0	0	0	0	0	21	29	9
5.0 - 5.9	0	4	9	1	0	0	0	0	0	0	0	0	14	15	7
6.0 - 6.9	1	0	4	0	0	0	0	0	0	0	0	0	5	7	4
7.0 - 7.9	0	3	6	0	0	0	0	0	0	0	0	0	9	12	7
8.0 - 8.9	0	1	1	1	0	0	0	0	0	0	0	0	3	3	2
9.0 - 9.9	0	0	4	0	0	0	0	0	0	0	0	0	4	4	3
0.0 - 9.9	16	308	147	3	0	0	0	0	0	0	0	0	474	545	3
10.0 - 19.9	0	5	4	3	4	1	0	0	0	0	0	0	17	23	11
20.0 - 29.9	2	0	1	1	0	0	0	0	0	0	0	0	4	4	4
30.0 - 39.9	0	0	1	0	0	2	0	0	0	0	0	0	3	4	4
40.0 - 49.9	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	0	1	4	1
70.0 - 79.9	0	0	0	0	0	1	0	0	0	1	2	0	4	7	3
80.0 - 89.9	1	0	0	0	0	0	0	1	1	2	0	0	9	10	3
90.0 - 100.0	0	0	0	0	0	1	0	2	3	2	0	0	10	14	4
TOTAL	19	313	153	8	6	3	3	4	6	6	4	0	919	612	4

TABLE J-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: DEVONIAN		CARBON DIOXIDE CONTENT IN PERCENTAGE										504 SAMPLES:		594 STATES: 21	
AVERAGE DEPTH, FEET	LESS THAN 5.0	MINIMUM DEPTH:		MAXIMUM DEPTH: 22,566		RESERVOIRS:		90.0 TO 100.0		NUMBER OF RESERVOIRS		NUMBER OF SAMPLES		NUMBER OF STATES	
		5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0				
0 - 999	18	0	2	0	0	0	0	0	0	0	0	20	26	6	6
1000 - 1999	35	1	1	0	0	0	0	0	0	0	0	37	47	7	7
2000 - 2999	91	0	0	0	0	0	0	0	0	0	0	91	101	8	8
3000 - 3999	84	1	0	0	0	1	0	0	0	1	2	89	105	12	12
4000 - 4999	66	1	2	0	0	0	0	0	1	0	0	70	81	9	9
5000 - 5999	29	0	0	0	0	0	1	0	1	0	0	31	54	7	7
6000 - 6999	51	0	0	0	0	0	0	0	0	1	0	32	40	6	6
7000 - 7999	52	0	0	0	0	0	0	0	0	0	0	32	36	6	6
8000 - 8999	29	0	0	1	0	0	0	0	0	0	1	31	37	7	7
9000 - 9999	4	0	0	0	0	0	0	0	0	0	0	4	6	2	2
10000 - 10999	7	0	1	0	0	0	0	0	0	0	0	8	10	3	3
11000 - 11999	17	0	0	0	0	0	0	0	0	0	0	17	20	5	5
12000 - 12999	9	2	0	0	0	1	0	0	0	0	0	12	14	3	3
13000 - 13999	6	0	1	0	0	1	0	0	0	0	0	8	8	2	2
14000 - 14999	6	0	1	0	0	0	0	0	0	0	0	7	8	3	3
15000 - 15999	4	1	0	0	0	0	0	0	0	0	0	5	6	3	3
16000 - 16999	3	1	0	0	0	0	0	0	0	0	0	4	6	2	2
17000 - 17999	1	1	0	0	0	0	0	0	0	0	0	2	3	1	1
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0				
19000 - 19999	0	2	0	0	0	0	0	0	0	0	0	2	3	1	1
20000 - 20999	1	0	0	0	0	0	0	0	0	0	0	1	2	1	1
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0				
22000 - 22999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
RESERVOIRS	474	10	8	1	0	3	1	0	2	2	3	504	594		



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TABLE J-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	ARGON PERCENTAGE	DEVONIAN	HELIUM CONTENT IN PERCENTAGE										GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
			LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99				
	0.0 - 0.09	9	268	113	5	3	0	0	0	0	0	0	0	391	438	18
	0.1 - 0.29	0	12	5	3	3	3	0	0	0	0	0	0	26	33	12
	0.3 - 0.49	0	0	0	0	1	0	0	1	0	0	0	0	2	2	2
	0.5 - 0.69	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1
	0.7 - 0.89	0	0	0	0	0	0	0	1	2	5	0	0	8	19	2
	0.9 - 1.09	0	0	0	0	0	0	0	0	2	0	2	0	4	5	1
	1.1 - 1.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.3 - 1.49	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1
	> 1.49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		9	280	118	4	4	3	3	3	4	6	2	0	433	499	

TABLE J-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SECTION: 01	AVERAGE DEPTH, FEET	LESS THAN 0.1	ARGON CONTENT IN PERCENTAGE										MAXIMUM DEPTH: 22,566 RESERVOIRS:	424 SAMPLES:	490 STATES: 20
			MINIMUM DEPTH:					50% TO 1.04							
			.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.04	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES			
0 - 999	9	2	0	0	0	0	0	0	0	0	11	12	4		
1000 - 1999	19	2	0	0	0	0	0	0	0	0	21	21	7		
2000 - 2999	69	3	0	0	1	0	0	0	0	0	73	80	6		
3000 - 3999	68	3	0	0	1	0	0	0	0	0	72	83	11		
4000 - 4999	50	3	1	0	3	0	0	0	1	0	58	69	9		
5000 - 5999	23	4	0	0	0	0	0	0	0	0	27	30	7		
6000 - 6999	20	2	0	1	2	4	0	0	0	0	29	36	6		
7000 - 7999	30	1	0	0	1	0	0	0	0	0	32	36	6		
8000 - 8999	28	2	0	0	0	0	0	0	0	0	30	36	7		
9000 - 9999	4	0	0	0	0	0	0	0	0	0	4	6	2		
10000 - 10999	6	1	1	0	0	0	0	0	0	0	8	10	3		
11000 - 11999	16	1	0	0	0	0	0	0	0	0	17	20	5		
12000 - 12999	10	2	0	0	0	0	0	0	0	0	12	14	3		
13000 - 13999	4	0	0	0	0	0	0	0	0	0	6	8	2		
14000 - 14999	7	0	0	0	0	0	0	0	0	0	7	8	3		
15000 - 15999	5	0	0	0	0	0	0	0	0	0	5	6	3		
16000 - 16999	4	0	0	0	0	0	0	0	0	0	4	6	2		
17000 - 17999	2	0	0	0	0	0	0	0	0	0	2	3	1		
18000 - 18999	0	0	0	0	0	0	0	0	0	0					
19000 - 19999	2	0	0	0	0	0	0	0	0	0	2	3	1		
20000 - 20999	1	0	0	0	0	0	0	0	0	0	1	2	1		
21000 - 21999	0	0	0	0	0	0	0	0	0	0					
22000 - 22999	1	0	0	0	0	0	0	0	0	0	1	1	1		
RESERVOIRS	382	26	2	1	6	4	0	1	0	1	424	490			



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APPENDIX K.--SILURIAN SYSTEM

Silurian System reservoirs are the poorest for finding high-helium content-gas of all the reservoirs in rocks of Paleozoic age (Permian and older). This system includes 261 reservoirs, and only 21 reservoirs contained 0.30 percent or more of helium. None of the reservoirs contained 1 percent or more of helium. The highest observed helium content of a reservoir gas in this system was 0.90 percent found in West Virginia at a depth of 4,180 feet. The gas contained 67.3 percent of methane, 29.5 percent of nitrogen, 0.1 percent of carbon dioxide, and 0.1 percent of argon. The shallowest reservoir was found in New York at a depth of 720 feet and contained 0.22 percent of helium. The gas contained 84.6 percent of methane, 3.2 percent of nitrogen, 0.0 percent of carbon dioxide, and 0.0 percent of argon. The deepest reservoir was found in Texas at a depth of 18,988 feet and contained 0.03 percent of helium. The gas contained 96.3 percent of methane, 1.0 percent of nitrogen, 1.7 percent of carbon dioxide, and 0.0 percent of argon. The average depth of a reservoir in this system is 4,569 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.15 percent, 82.1 percent, 5.2 percent, 0.8 percent, and less than 0.01 percent, respectively.

Appendix K contains the following seven tables concerning the Silurian System:

TABLE K-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:SILURIAN		HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0				
NITROGEN PERCENTAGE																
0.0 - 0.9	4	21	2	1	0	0	0	0	0	0	0	0	28	31	6	
1.0 - 1.9	2	11	14	0	0	0	0	0	0	0	0	0	27	33	5	
2.0 - 2.9	1	6	22	0	0	0	0	0	0	0	0	0	29	36	7	
3.0 - 3.9	0	8	41	1	0	0	0	0	0	0	0	0	50	57	6	
4.0 - 4.9	0	2	25	0	0	0	0	0	0	0	0	0	27	34	7	
5.0 - 5.9	0	1	24	2	0	0	0	0	0	0	0	0	27	33	8	
6.0 - 6.9	0	0	16	0	0	0	0	0	0	0	0	0	16	20	4	
7.0 - 7.9	0	0	9	2	0	0	0	0	0	0	0	0	11	11	5	
8.0 - 8.9	0	1	5	0	0	0	0	0	0	0	0	0	6	7	3	
9.0 - 9.9	0	0	6	2	0	0	0	0	0	0	0	0	8	13	3	
0.0 - 9.9	7	50	164	8	0	0	0	0	0	0	0	0	229	275		
10.0 - 19.9	2	0	16	10	1	0	0	0	0	0	0	0	29	34	3	
20.0 - 29.9	1	0	0	1	1	0	0	0	0	0	0	0	3	3	2	
30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0	0				
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0	0				
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	0				
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0	0				
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0	0				
TOTAL	10	50	180	19	2	0	0	0	0	0	0	0	261	312		

TABLE K-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM: SILURIAN		ALUMINUM DEPTH: 10.0		720		NITROGEN CONTENT IN PERCENTAGE								RESERVOIRS: 249		SAMPLES: 300		STATES: 13	
						MAXIMUM DEPTH: 10,988													
AVERAGE DEPTH, FEET	LESS THAN 5.0	5.0 to 9.9	10.0 to 19.9	20.0 to 29.9	30.0 to 39.9	40.0 to 49.9	50.0 to 59.9	60.0 to 69.9	70.0 to 79.9	80.0 to 89.9	90.0 to 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES					
		1	0	0	0	0	0	0	0	0	0				1	1			
0 - 999		0	4	2	0	0	0	0	0	0	0	15	20	4					
1000 - 1999		31	23	13	0	0	0	0	0	0	0	67	84	6					
2000 - 2999		36	19	7	0	0	0	0	0	0	0	62	74	5					
3000 - 3999		29	7	2	1	0	0	0	0	0	0	39	43	3					
4000 - 4999		19	5	1	0	0	0	0	0	0	0	25	32	4					
5000 - 5999		9	2	1	0	0	0	0	0	0	0	12	12	5					
6000 - 6999		3	1	1	1	0	0	0	0	0	0	6	6	3					
7000 - 7999		3	1	0	0	0	0	0	0	0	0	4	5	3					
8000 - 8999		1	0	0	0	0	0	0	0	0	0	1	1	1					
9000 - 9999		0	1	0	0	0	0	0	0	0	0	1	1	1					
10000 - 10999		1	2	0	0	0	0	0	0	0	0	3	3	2					
11000 - 11999		3	0	0	0	0	0	0	0	0	0	3	3	1					
12000 - 12999		0	0	0	0	0	0	0	0	0	0								
13000 - 13999		0	0	0	0	0	0	0	0	0	0								
14000 - 14999		0	0	0	0	0	0	0	0	0	0								
15000 - 15999		2	0	0	0	0	0	0	0	0	0	2	5	1					
16000 - 16999		4	0	0	0	0	0	0	0	0	0	4	4	2					
17000 - 17999		3	0	0	0	0	0	0	0	0	0	3	5	1					
18000 - 18999		1	0	0	0	0	0	0	0	0	0	1	1	1					
19000 - 19999		0	0	0	0	0	0	0	0	0	0								
20000 - 20999		0	0	0	0	0	0	0	0	0	0								
21000 - 21999		0	0	0	0	0	0	0	0	0	0								
22000 - 22999		0	0	0	0	0	0	0	0	0	0								
RESERVOIRS	155	65	27	2	0	0	0	0	0	0	0	249	300						

TABLE K-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: SILURIAN		MINIMUM DEPTH:			720			MAXIMUM DEPTH: 18,988			RESERVOIRS: 249			SAMPLES: 300			STATES: 13					
AVERAGE DEPTH, FEET		CARBON DIOXIDE CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS			NUMBER OF SAMPLES			NUMBER OF STATES		
		70.0 TO 79.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0											
LESS THAN 500	0 - 999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1				
	1000 - 1999	15	0	0	0	0	0	0	0	0	0	0	15	20	4	4	4	4				
	2000 - 2999	67	0	0	0	0	0	0	0	0	0	0	67	84	6	6	6	6				
	3000 - 3999	62	0	0	0	0	0	0	0	0	0	0	62	74	5	5	5	5				
	4000 - 4999	39	0	0	0	0	0	0	0	0	0	0	39	43	3	3	3	3				
	5000 - 5999	25	0	0	0	0	0	0	0	0	0	0	25	32	4	4	4	4				
	6000 - 6999	11	0	0	0	0	0	1	0	0	0	0	12	12	5	5	5	5				
	7000 - 7999	6	0	0	0	0	0	0	0	0	0	0	6	6	3	3	3	3				
	8000 - 8999	4	0	0	0	0	0	0	0	0	0	0	4	5	3	3	3	3				
	9000 - 9999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1				
	10000 - 10999	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1				
	11000 - 11999	3	0	0	0	0	0	0	0	0	0	0	3	3	2	2	2	2				
	12000 - 12999	2	1	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3				
	13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	15000 - 15999	1	0	0	1	0	0	0	0	0	0	0	2	5	1	1	1	1				
	16000 - 16999	2	2	0	0	0	0	0	0	0	0	0	4	4	2	2	2	2				
	17000 - 17999	3	0	0	0	0	0	0	0	0	0	0	3	5	1	1	1	1				
	18000 - 18999	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1				
	19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
RESERVOIRS		243	3	1	1	1	0	1	0	0	0	0	249	300								

TABLE K-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

AVERAGE DEPTH, FEET	GEOLOGIC SYSTEM:ILLINOIAN	MINIMUM DEPTH:						MAXIMUM DEPTH:18,988						RESERVOIRS:		188		SAMPLES:		225		STATES: 12	
		ARGON CONTENT IN PERCENTAGE						THAN						NUMBER		OF		NUMBER		OF		NUMBER	
		.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49	NUMBER		OF		NUMBER		OF		NUMBER		OF		NUMBER	
		LESS THAN 0.1								RESERVOIRS		RESERVOIRS		SAMPLES		SAMPLES		STATES		STATES		STATES	
0 - 999		1	0	0	0	0	0	0	0	1		1		1		1		1		1		1	
1000 - 1999		7	0	0	0	0	0	0	0	7		7		8		8		3		3		3	
2000 - 2999		32	2	0	0	0	0	0	0	34		34		41		41		6		6		6	
3000 - 3999		46	1	0	0	0	0	0	0	47		47		59		59		5		5		5	
4000 - 4999		51	3	0	0	0	0	0	0	34		34		38		38		3		3		3	
5000 - 5999		25	0	0	0	0	0	0	0	25		25		32		32		4		4		4	
6000 - 6999		11	1	0	0	0	0	0	0	12		12		12		12		5		5		5	
7000 - 7999		6	0	0	0	0	0	0	0	6		6		6		6		3		3		3	
8000 - 8999		2	2	0	0	0	0	0	0	4		4		5		5		3		3		3	
9000 - 9999		1	0	0	0	0	0	0	0	1		1		1		1		1		1		1	
10000 - 10999		0	1	0	0	0	0	0	0	1		1		1		1		1		1		1	
11000 - 11999		2	1	0	0	0	0	0	0	3		3		3		3		2		2		2	
12000 - 12999		3	0	0	0	0	0	0	0	3		3		3		3		1		1		1	
13000 - 13999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
14000 - 14999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
15000 - 15999		2	0	0	0	0	0	0	0	2		2		5		5		1		1		1	
16000 - 16999		4	0	0	0	0	0	0	0	4		4		4		4		2		2		2	
17000 - 17999		3	0	0	0	0	0	0	0	3		3		3		3		1		1		1	
18000 - 18999		1	0	0	0	0	0	0	0	1		1		1		1		1		1		1	
19000 - 19999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
20000 - 20999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
21000 - 21999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
22000 - 22999		0	0	0	0	0	0	0	0	0		0		0		0		0		0		0	
RESERVOIRS		177	11	0	0	0	0	0	0	188		188		225		225		188		225		188	



APPENDIX L.--ORDOVICIAN SYSTEM

With depth, Ordovician System reservoirs generally increase in helium content. The system includes 228 reservoirs, with 47 reservoirs containing 0.30 percent or more of helium. Seventeen reservoirs contained 1 percent or more of helium, but none of them contained 5 percent or more of helium. The highest observed helium content of a reservoir in this system was 2.72 percent found in Kansas at a depth of 4,026 feet. The gas contained 46.9 percent of methane, 41.6 percent of nitrogen, 0.1 percent of carbon dioxide, and 0.2 percent of argon. The shallowest reservoir was found in Indiana at a depth of 280 feet and contained 0.10 percent of helium. The gas contained 80.2 percent of methane, 9.4 percent of nitrogen, 0.4 percent of carbon dioxide, and an unknown percent of argon. The deepest reservoir was found in Texas at a depth of 21,630 feet and contained 0.02 percent of helium. The gas contained 98.0 percent of methane, 0.3 percent of nitrogen, 1.5 percent of carbon dioxide, and 0.0 percent of argon. The average depth of the reservoirs in the Ordovician System is 7,724 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.24 percent, 72.6 percent, 6.7 percent, 2.2 percent, and 0.01 percent, respectively.

Appendix L contains the following seven tables concerning the Ordovician System:

TABLE L-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

AVERAGE DEPTH, FEET	GEOLOGICAL SYSTEM: ORDOVICIAN	MINIMUM DEPTH:					MAXIMUM DEPTH: 21,450					RESERVOIRS: 216		SAMPLES: 320		STATES: 16	
		NITROGEN CONTENT IN PERCENTAGE															
		LESS THAN 5.0	5.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES		
0 - 999		10	4	2	0	0	0	0	0	0	0	0	16	21	4		
1000 - 1999		4	4	5	1	0	0	0	0	0	0	0	14	17	6		
2000 - 2999		6	2	2	1	0	0	0	0	0	0	0	11	13	4		
3000 - 3999		4	4	3	2	1	0	0	0	0	1	0	15	24	4		
4000 - 4999		10	14	7	5	0	1	0	0	0	0	0	37	100	6		
5000 - 5999		7	5	3	1	0	0	0	0	0	0	1	15	17	6		
6000 - 6999		4	1	0	0	0	0	0	0	0	0	0	5	6	2		
7000 - 7999		9	4	0	0	0	0	0	0	0	0	0	13	16	3		
8000 - 8999		14	0	0	0	1	0	0	0	0	0	0	15	17	4		
9000 - 9999		10	2	0	0	0	0	0	0	0	0	0	12	14	2		
10000 - 10999		7	1	0	0	0	0	0	0	0	0	0	8	8	2		
11000 - 11999		7	1	0	0	0	0	0	0	0	0	0	8	8	3		
12000 - 12999		8	1	0	0	0	0	0	0	0	0	0	9	9	4		
13000 - 13999		7	0	1	0	0	0	0	0	0	0	0	8	13	3		
14000 - 14999		4	0	1	0	0	0	0	0	0	0	0	5	5	1		
15000 - 15999		5	1	0	0	0	0	0	0	0	0	0	6	8	3		
16000 - 16999		4	0	0	0	0	0	0	0	0	0	0	4	6	2		
17000 - 17999		1	0	0	0	0	0	0	0	0	0	0	1	2	1		
18000 - 18999		3	0	0	0	0	0	0	0	0	0	0	3	3	1		
19000 - 19999		2	0	0	0	0	0	0	0	0	0	0	2	2	1		
20000 - 20999		5	0	0	0	0	0	0	0	0	0	0	5	6	1		
21000 - 21999		4	0	0	0	0	0	0	0	0	0	0	4	5	1		
22000 - 22999		0	0	0	0	0	0	0	0	0	0	0					
RESERVOIRS		135	42	24	10	2	1	0	0	0	1	1	216	320			

TABLE L-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM:ORIOVICIAN		HELIUM CONTENT IN PERCENTAGE												
		CARBON DIOXIDE PERCENTAGE												
LESS THAN .005		.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
0.0 - 0.9	6	74	49	10	22	16	1	0	0	0	0	178	274	15
1.0 - 1.9	4	13	4	1	0	0	0	0	0	0	0	22	28	6
2.0 - 2.9	2	5	2	0	0	0	0	0	0	0	0	9	10	4
3.0 - 3.9	1	1	0	0	0	0	0	0	0	0	0	2	3	1
4.0 - 4.9	0	1	1	0	0	0	0	0	0	0	0	2	3	2
5.0 - 5.9	0	2	0	0	0	0	0	0	0	0	0	2	2	2
6.0 - 6.9	0	0	1	0	0	0	0	0	0	0	0	1	1	1
7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0	3	3	1
8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0	219	324	1
9.0 - 9.9	0	3	0	0	0	0	0	0	0	0	0	3	3	1
0.0 - 9.9	13	99	57	11	22	16	1	0	0	0	0	219	324	1
10.0 - 19.9	0	2	0	0	0	0	0	0	0	0	0	2	2	1
20.0 - 29.9	0	2	0	0	0	0	0	0	0	0	0	2	4	1
30.0 - 39.9	1	1	0	0	0	0	0	0	0	0	0	2	5	1
40.0 - 49.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1
50.0 - 59.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1
80.0 - 89.9	0	0	0	0	1	0	0	0	0	0	0	1	1	1
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
TOTAL	14	106	57	11	23	16	1	0	0	0	0	228	338	1

TABLE L-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	ARGON PERCENTAGE	LESS THAN .005	HELIUM CONTENT IN PERCENTAGE										GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
			.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99					
ORUOVICIAN	0.0 - 0.09	11	88	30	0	5	2	0	0	0	0	0	0	136	160	10
	0.1 - 0.29	0	4	4	3	7	2	1	0	0	0	0	0	21	34	9
	0.3 - 0.49	1	0	0	0	0	1	0	0	0	0	0	0	2	2	2
	0.5 - 0.69	0	0	0	0	0	0	0	0	0	0	0	0			
	0.7 - 0.89	0	0	0	0	0	0	0	0	0	0	0	0			
	0.9 - 1.09	0	0	1	0	0	0	0	0	0	0	0	0	1	2	1
	1.1 - 1.29	0	0	0	0	0	0	0	0	0	0	0	0			
	1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0	0			
	> 1.49	0	0	0	0	0	0	0	0	0	0	0	0			
	TOTAL	12	92	35	3	12	5	1	0	0	0	0	0	160	198	

APPENDIX M.--CAMBRIAN AND ORDOVICIAN SYSTEM

Cambrian and Ordovician System reservoirs were not found above a depth of 1,000 feet. The system includes 63 reservoirs, with 55 of them containing 0.30 percent or more of helium. Forty-three reservoirs contained 1 percent or more of helium, and four reservoirs contained 5 percent or more of helium in the gases. This system has a higher percentage of reservoirs containing 0.30 percent or more of helium than any of the other geologic systems. The highest observed helium content of 6.50 percent was found in a reservoir in Kansas at a depth of 3,556 feet. The gas contained 12.0 percent of methane, 77.2 percent of nitrogen, 0.4 percent of carbon dioxide, and 0.2 percent of argon. The shallowest reservoir was also found in Kansas and contained 1.22 percent of helium at a depth of 1,350 feet. The gas contained 64.3 percent of methane, 15.1 percent of nitrogen, 0.2 percent of carbon dioxide, and an unknown percent of argon. The deepest reservoir was found in Texas at a depth of 11,440 feet and contained 0.07 percent of helium. The gas contained 85.9 percent of methane, 2.1 percent of nitrogen, 0.2 percent of carbon dioxide, and 0.0 percent of argon. The average depth of the reservoirs in this system is 4,037 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 1.80 percent, 66.6 percent, 20.0 percent, 0.4 percent, and 0.05 percent, respectively.

Appendix M contains the following seven tables concerning the Cambrian and Ordovician System:

TABLE M-1. - Depth distribution of U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: CAMBRO-ORDOVICIAN		MINIMUM DEPTH: 1.350		HELIUM CONTENT IN PERCENTAGE						RESERVOIRS: 60		SAMPLES: 154		STATES: 4	
AVERAGE DEPTH, FEET	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	MAXIMUM DEPTH: 11.440						GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
						1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99					
0 - 999	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1
1000 - 1999	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1
2000 - 2999	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1
3000 - 3999	0	0	2	0	9	16	4	4	4	4	0	0	39	111	3
4000 - 4999	0	0	0	0	5	9	1	1	1	0	0	0	16	35	1
5000 - 5999	0	0	0	0	0	0	0	0	0	0	0	0			
6000 - 6999	0	0	0	0	0	0	0	0	0	0	0	0			
7000 - 7999	0	0	0	0	0	0	0	0	0	0	0	0			
8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0			
9000 - 9999	1	1	0	0	0	0	0	0	0	0	0	0	2	3	1
10000 - 10999	0	0	0	0	0	0	0	0	0	0	0	0			
11000 - 11999	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0			
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0			
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0			
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0			
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0			
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0			
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0			
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0			
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0			
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0			
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0			
RESERVOIRS	1	2	2	0	14	26	6	5	4	4	0	0	60	154	

TABLE M-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

NITROGEN PERCENTAGE	HELIUM CONTENT IN PERCENTAGE										GREATER THAN 10.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99				
0.0 - 0.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1
1.0 - 1.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1
2.0 - 2.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1
3.0 - 3.9	0	0	1	0	0	0	0	0	0	0	0	1	1	1
4.0 - 4.9	0	0	0	0	0	0	0	0	0	0	0	4	10	2
5.0 - 5.9	1	0	0	0	3	0	0	0	0	0	0	7	42	1
6.0 - 6.9	0	0	0	0	5	2	0	0	0	0	0	3	3	2
7.0 - 7.9	0	0	1	0	1	1	0	0	0	0	0	7	12	1
8.0 - 8.9	0	0	0	1	1	5	0	0	0	0	0	2	2	1
9.0 - 9.9	0	0	0	0	2	8	0	0	0	0	0	26	73	1
0.0 - 9.9	1	2	2	1	12	8	0	0	0	0	0	63	159	
10.0 - 19.9	0	0	0	0	1	16	2	0	0	0	0	19	51	1
20.0 - 29.9	0	0	0	0	1	1	4	1	0	0	0	7	17	1
30.0 - 39.9	0	0	0	0	0	2	0	0	0	0	0	2	4	1
40.0 - 49.9	0	0	0	0	0	0	0	3	0	0	0	3	6	1
50.0 - 59.9	0	0	0	0	0	0	0	0	1	0	0	1	3	1
60.0 - 69.9	0	0	0	0	0	0	0	1	0	0	0	1	1	1
70.0 - 79.9	0	0	0	0	0	0	0	0	3	0	0	3	3	1
80.0 - 89.9	0	0	0	0	0	0	0	1	0	0	0	1	1	1
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
TOTAL	1	2	2	1	14	27	6	6	4	0	0	63	159	

TABLE M-3. - Depth of distribution of U.S. natural gas reservoirs according to nitrogen content

AVERAGE DEPTH, FT.	MINIMUM DEPTH: 1,350										MAXIMUM DEPTH: 11,440										RESERVOIRS:		60	SAMPLES:	154	STATES: 4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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	0-5.0	5.0-10.0	10.0-15.0	15.0-20.0	20.0-25.0	25.0-30.0	30.0-35.0	35.0-40.0	40.0-45.0	45.0-50.0	50.0-55.0	55.0-60.0	60.0-65.0	65.0-70.0	70.0-75.0	75.0-80.0	80.0-85.0	85.0-90.0	90.0-100.0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															



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TABLE M-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: CARBON-UNDUVICIAN				HELIUM CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0						
0.0 - 0.9	1	2	2	1	14	27	6	5	4	0	0	62	158	4		
1.0 - 1.9	0	0	0	0	0	0	0	0	0	0	0	1	1	1		
2.0 - 2.9	0	0	0	0	0	0	0	1	0	0	0					
3.0 - 3.9	0	0	0	0	0	0	0	0	0	0	0					
4.0 - 4.9	0	0	0	0	0	0	0	0	0	0	0					
5.0 - 5.9	0	0	0	0	0	0	0	0	0	0	0					
6.0 - 6.9	0	0	0	0	0	0	0	0	0	0	0					
7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0					
8.0 - 8.9	0	0	0	0	0	0	0	0	0	0	0					
9.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0					
0.0 - 9.9	1	2	2	1	14	27	6	6	4	0	0	63	159			
10.0 - 19.9	0	0	0	0	0	0	0	0	0	0	0					
20.0 - 29.9	0	0	0	0	0	0	0	0	0	0	0					
30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0					
40.0 - 49.9	0	0	0	0	0	0	0	0	0	0	0					
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0					
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0					
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0					
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0					
90.0 - 100.0	0	0	0	0	0	0	0	0	0	0	0					
TOTAL	1	2	2	1	14	27	6	6	4	0	0	63	159			

TABLE M-6. - Argon distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM	ARGON PERCENTAGE	HELIUM CONTENT IN PERCENTAGE										NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0		
CAMBRO-ORDOVICIAN	0.0 - 0.09	1	2	1	0	8	1	0	0	0	0	0	13	20
	0.1 - 0.29	0	0	0	1	2	15	6	3	3	0	0	30	104
	0.3 - 0.49	0	0	0	0	1	0	0	2	1	0	0	4	4
	0.5 - 0.69	0	0	0	0	0	1	0	0	0	0	0	1	2
	0.7 - 0.89	0	0	0	0	0	1	0	0	0	0	0	1	1
	0.9 - 1.09	0	0	0	0	0	0	0	0	0	0	0		
	1.1 - 1.29	0	0	0	0	0	0	0	0	0	0	0		
	1.3 - 1.49	0	0	0	0	0	0	0	0	0	0	0		
	> 1.49	0	0	0	0	0	0	0	0	0	0	0		
	TOTAL	1	2	1	1	11	18	6	5	4	0	0	49	131

TABLE M-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

GEOLOGIC SYSTEMS-CARBONATE-ROCKS	AVERAGE DEPTH, FEET	ARGON CONTENT IN PERCENTAGE										DEPTH: 11,440 MAXIMUM 1.49	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	STATES: 4
		LESS THAN 0.1														
		0-10 0.24	10-20 0.43	20-30 0.69	30-40 1.00	40-50 1.29	50-60 1.58	60-70 1.87	70-80 2.16	80-90 2.45	90-100 2.74					
0 - 999		0	0	0	0	0	0	0	0	0	0					
1000 - 1999		0	0	0	0	0	0	0	0	0	0					
2000 - 2999		0	1	0	0	0	0	0	0	0	0		1	1	1	
3000 - 3999		5	24	4	1	0	0	0	0	0	0		30	92	2	
4000 - 4999		0	0	0	0	1	0	0	0	0	0		14	33	1	
5000 - 5999		0	0	0	0	0	0	0	0	0	0					
6000 - 6999		0	0	0	0	0	0	0	0	0	0					
7000 - 7999		0	0	0	0	0	0	0	0	0	0					
8000 - 8999		0	0	0	0	0	0	0	0	0	0					
9000 - 9999		2	0	0	0	0	0	0	0	0	0		2	3	1	
10000 - 10999		0	0	0	0	0	0	0	0	0	0					
11000 - 11999		1	0	0	0	0	0	0	0	0	0		1	1	1	
12000 - 12999		0	0	0	0	0	0	0	0	0	0					
13000 - 13999		0	0	0	0	0	0	0	0	0	0					
14000 - 14999		0	0	0	0	0	0	0	0	0	0					
15000 - 15999		0	0	0	0	0	0	0	0	0	0					
16000 - 16999		0	0	0	0	0	0	0	0	0	0					
17000 - 17999		0	0	0	0	0	0	0	0	0	0					
18000 - 18999		0	0	0	0	0	0	0	0	0	0					
19000 - 19999		0	0	0	0	0	0	0	0	0	0					
20000 - 20999		0	0	0	0	0	0	0	0	0	0					
21000 - 21999		0	0	0	0	0	0	0	0	0	0					
22000 - 22999		0	0	0	0	0	0	0	0	0	0					
23000 - 23999		0	0	0	0	0	0	0	0	0	0					
24000 - 24999		0	0	0	0	0	0	0	0	0	0					
25000 - 25999		0	0	0	0	0	0	0	0	0	0					
26000 - 26999		0	0	0	0	0	0	0	0	0	0					
27000 - 27999		0	0	0	0	0	0	0	0	0	0					
28000 - 28999		0	0	0	0	0	0	0	0	0	0					
29000 - 29999		0	0	0	0	0	0	0	0	0	0					
30000 - 30999		0	0	0	0	0	0	0	0	0	0					
31000 - 31999		0	0	0	0	0	0	0	0	0	0					
32000 - 32999		0	0	0	0	0	0	0	0	0	0					
33000 - 33999		0	0	0	0	0	0	0	0	0	0					
34000 - 34999		0	0	0	0	0	0	0	0	0	0					
35000 - 35999		0	0	0	0	0	0	0	0	0	0					
36000 - 36999		0	0	0	0	0	0	0	0	0	0					
37000 - 37999		0	0	0	0	0	0	0	0	0	0					
38000 - 38999		0	0	0	0	0	0	0	0	0	0					
39000 - 39999		0	0	0	0	0	0	0	0	0	0					
40000 - 40999		0	0	0	0	0	0	0	0	0	0					
41000 - 41999		0	0	0	0	0	0	0	0	0	0					
42000 - 42999		0	0	0	0	0	0	0	0	0	0					
43000 - 43999		0	0	0	0	0	0	0	0	0	0					
44000 - 44999		0	0	0	0	0	0	0	0	0	0					
45000 - 45999		0	0	0	0	0	0	0	0	0	0					
46000 - 46999		0	0	0	0	0	0	0	0	0	0					
47000 - 47999		0	0	0	0	0	0	0	0	0	0					
48000 - 48999		0	0	0	0	0	0	0	0	0	0					
49000 - 49999		0	0	0	0	0	0	0	0	0	0					
50000 - 50999		0	0	0	0	0	0	0	0	0	0					
51000 - 51999		0	0	0	0	0	0	0	0	0	0					
52000 - 52999		0	0	0	0	0	0	0	0	0	0					
53000 - 53999		0	0	0	0	0	0	0	0	0	0					
54000 - 54999		0	0	0	0	0	0	0	0	0	0					
55000 - 55999		0	0	0	0	0	0	0	0	0	0					
56000 - 56999		0	0	0	0	0	0	0	0	0	0					
57000 - 57999		0	0	0	0	0	0	0	0	0	0					
58000 - 58999		0	0	0	0	0	0	0	0	0	0					
59000 - 59999		0	0	0	0	0	0	0	0	0	0					
60000 - 60999		0	0	0	0	0	0	0	0	0	0					
61000 - 61999		0	0	0	0	0	0	0	0	0	0					
62000 - 62999		0	0	0	0	0	0	0	0	0	0					
63000 - 63999		0	0	0	0	0	0	0	0	0	0					
64000 - 64999		0	0	0	0	0	0	0	0	0	0					
65000 - 65999		0	0	0	0	0	0	0	0	0	0					
66000 - 66999		0	0	0	0	0	0	0	0	0	0					
67000 - 67999		0	0	0	0	0	0	0	0	0	0					
68000 - 68999		0	0	0	0	0	0	0	0	0	0					
69000 - 69999		0	0	0	0	0	0	0	0	0	0					
70000 - 70999		0	0	0	0	0	0	0	0	0	0					
71000 - 71999		0	0	0	0	0	0	0	0	0	0					
72000 - 72999		0	0	0	0	0	0	0	0	0	0					
73000 - 73999		0	0	0	0	0	0	0	0	0	0					
74000 - 74999		0	0	0	0	0	0	0	0	0	0					
75000 - 75999		0	0	0	0	0	0	0	0	0	0					
76000 - 76999		0	0	0	0	0	0	0	0	0	0					
77000 - 77999		0	0	0	0	0	0	0	0	0	0					
78000 - 78999		0	0	0	0	0	0	0	0	0	0					
79000 - 79999		0	0	0	0	0	0	0	0	0	0					
80000 - 80999		0	0	0	0	0	0	0	0	0	0					
81000 - 81999		0	0	0	0	0	0	0	0	0	0					
82000 - 82999		0	0	0	0	0	0	0	0	0	0					
83000 - 83999		0	0	0	0	0	0	0	0	0	0					
84000 - 84999		0	0	0	0	0	0	0	0	0	0					
85000 - 85999		0	0	0	0	0	0	0	0	0	0					
86000 - 86999		0	0	0	0	0	0	0	0	0	0					
87000 - 87999		0	0	0	0	0	0	0	0	0	0					
88000 - 88999		0	0	0	0	0	0	0	0	0	0					
89000 - 89999		0	0	0	0	0	0	0	0	0	0					
90000 - 90999		0	0	0	0	0	0	0	0	0	0					
91000 - 91999		0	0	0	0	0	0	0	0	0	0					
92000 - 92999		0	0	0	0	0	0	0	0	0	0					
93000 - 93999		0	0	0	0	0	0	0	0	0	0					
94000 - 94999		0	0	0	0	0	0	0	0	0	0					
95000 - 95999		0	0	0	0	0	0	0	0	0	0					
96000 - 96999		0	0	0	0	0	0	0	0	0	0					
97000 - 97999		0	0	0	0	0	0	0	0	0	0					
98000 - 98999		0	0	0	0	0	0	0	0	0	0					
99000 - 99999		0	0	0	0	0	0	0	0	0	0					
100000 - 100999		0	0	0	0	0	0	0	0	0	0					
101000 - 101999		0	0	0	0	0	0	0	0	0	0					
102000 - 102999		0	0	0	0	0	0	0	0	0	0					

APPENDIX N.--CAMBRIAN SYSTEM

Cambrian System reservoirs, 30 in all, were found at depths ranging from 1,000 to 11,000 feet. Nineteen reservoirs contained 0.30 percent or more of helium, with 14 containing 1 percent or more, and 1 contained 5 percent or more of helium in the gas. The highest observed helium content of 5.50 percent was found in New Mexico at a depth of 3,902 feet. The gas contained 0.6 percent of methane, 92.9 percent of nitrogen, 0.03 percent of carbon dioxide, and 0.7 percent of argon. The shallowest reservoir was found at a depth of 1,476 feet in Nevada with 0.05 percent of helium. The gas contained 0.3 percent of methane, 95.1 percent of nitrogen, 1.8 percent of carbon dioxide, and 1.4 percent of argon. The deepest reservoir was found in Montana at a depth of 10,086 feet and contained 0.40 percent of helium in the gas. The gas contained 7.5 percent of methane, 89.3 percent of nitrogen, 0.7 percent of carbon dioxide, and 0.2 percent of argon. The average reservoir depth for this system is 4,004 feet. The average percentages of the component gases, helium, methane, nitrogen, carbon dioxide, and argon, are 0.99 percent, 56.0 percent, 27.0 percent, 5.8 percent, and 0.07 percent, respectively.

Appendix N contains the following seven tables concerning the Cambrian System:

TABLE N-2. - Nitrogen distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: CAMBRIAN		HELIUM CONTENT IN PERCENTAGE											NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
		NITROGEN PERCENTAGE													
LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0					
		0.0 - 0.9	0	0	0	0	0	0	0	0	0	0	3	3	2
1.0 - 1.9	0	1	0	0	0	0	0	0	0	0	0	3	4	2	
2.0 - 2.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
3.0 - 3.9	0	1	0	0	0	0	0	0	0	0	0	2	2	2	
4.0 - 4.9	0	0	1	0	0	0	0	0	0	0	0	1	1	1	
5.0 - 5.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
6.0 - 6.9	0	1	0	0	0	0	0	0	0	0	0	1	1	1	
7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1	
8.0 - 8.9	0	0	0	0	1	0	0	0	0	0	0	12	14		
9.0 - 9.9	0	0	0	0	0	1	0	0	0	0	0				
0.0 - 9.9	0	5	1	0	1	0	0	0	0	0	0				
10.0 - 19.9	0	0	2	0	7	0	0	0	0	0	0	9	66	2	
20.0 - 29.9	0	0	0	0	0	1	0	0	0	0	0	1	1	1	
30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0				
40.0 - 49.9	0	0	1	0	0	0	0	0	0	0	0	1	2	1	
50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0				
60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0				
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	3	3	3	
80.0 - 89.9	0	0	1	0	1	0	0	0	0	0	0	2	2	2	
90.0 - 99.9	0	1	0	0	0	0	0	1	0	0	0	2	2	2	
100.0	0	6	5	0	11	2	0	1	0	0	0	30	90		
TOTAL	0														

TABLE N-3. - Depth distribution of U.S. natural gas reservoirs according to nitrogen content

GEOLOGIC SYSTEM: CARBONATE		MINIMUM DEPTH: 1.47%		NITROGEN CONTENT IN PERCENTAGE										RESERVOIRS:		20	SAMPLES:	88	STATES: 0
				DEPTH: 10.0 TO 100.0															
AVERAGE DEPTH, FEET	CLASS THICK 5.0	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES						
		10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0									
0 - 999	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2		
1000 - 1999	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1		
2000 - 2999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
3000 - 3999	2	3	9	0	0	0	0	2	1	1	18	76	5	5	5	5	5		
4000 - 4999	0	0	1	0	1	0	0	1	0	0	3	4	3	3	3	3	3		
5000 - 5999	3	0	0	0	0	0	0	0	0	0	1	2	1	1	1	1	1		
6000 - 6999	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
7000 - 7999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
8000 - 8999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
9000 - 9999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10000 - 10999	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1		
11000 - 11999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
12000 - 12999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13000 - 13999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14000 - 14999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
15000 - 15999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16000 - 16999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
17000 - 17999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
18000 - 18999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
19000 - 19999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20000 - 20999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
21000 - 21999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
22000 - 22999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
RESERVOIRS	7	3	9	1	0	1	0	0	3	2	28	88							

TABLE N-4. - Carbon dioxide distribution in U.S. natural gas reservoirs according to helium content

GEOLOGIC SYSTEM: CAMBRIAN	HELIUM CONTENT IN PERCENTAGE												NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES
	CARBON DIOXIDE PERCENTAGE	LESS THAN .005	.005 TO .09	.10 TO .29	.30 TO .49	.50 TO .99	1.00 TO 1.99	2.00 TO 2.99	3.00 TO 4.99	5.00 TO 6.99	7.00 TO 9.99	GREATER THAN 10.0			
	0.0 - 0.9	0	0	0	0	0	0	0	0	0	0	0	3	3	2
	1.0 - 1.9	0	2	1	0	0	0	0	0	0	0	0	3	4	2
	2.0 - 2.9	0	2	1	0	0	0	0	0	0	0	0	1	1	1
	3.0 - 3.9	0	0	1	0	0	0	0	0	0	0	0	2	2	2
	4.0 - 4.9	0	1	0	1	0	0	0	0	0	0	0	1	1	1
	5.0 - 5.9	0	0	1	0	0	0	0	0	0	0	0	1	1	1
	6.0 - 6.9	0	0	1	0	0	0	0	0	0	0	0	1	1	1
	7.0 - 7.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1
	8.0 - 8.9	0	0	0	0	0	1	0	0	0	0	0	1	14	1
	9.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0	12	14	1
	0.0 - 9.9	0	5	5	1	1	1	0	0	0	0	0	9	66	2
	10.0 - 19.9	0	0	0	2	0	7	0	0	0	0	0	1	1	1
	20.0 - 29.9	0	0	0	0	0	0	1	0	0	0	0	1	1	1
	30.0 - 39.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1
	40.0 - 49.9	0	0	0	1	0	0	0	0	0	0	0	1	2	1
	50.0 - 59.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1
	60.0 - 69.9	0	0	0	0	0	0	0	0	0	0	0	1	2	1
	70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	3	3	3
	80.0 - 89.9	0	0	0	0	0	2	1	0	0	0	0	2	2	2
	90.0 - 99.9	0	0	0	1	0	1	0	0	0	0	0	2	2	2
	100.0	0	1	0	0	0	0	0	0	1	0	0	2	2	2
	TOTAL	0	6	5	5	0	11	2	0	1	0	0	30	90	

TABLE N-5. - Depth distribution of U.S. natural gas reservoirs according to carbon dioxide content

GEOLOGIC SYSTEM: CARBONIFEROUS	MAXIMUM DEPTH: 1.47% MAXIMUM DEPTH: 10.00%												28 SAMPLES:	88 STATES: 8			
	CARBON DIOXIDE CONTENT IN PERCENTAGE																
	0.0 TO 9.9	10.0 TO 19.9	20.0 TO 29.9	30.0 TO 39.9	40.0 TO 49.9	50.0 TO 59.9	60.0 TO 69.9	70.0 TO 79.9	80.0 TO 89.9	90.0 TO 100.0	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES			NUMBER OF STATES		
LESS THAN 5.0	0	0	0	0	0	0	0	0	0	0	0	2	2	2			
5.0 - 9.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
10.0 - 19.9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
20.0 - 29.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
30.0 - 39.9	17	1	0	0	0	0	0	0	0	0	0	18	76	5	5		
40.0 - 49.9	2	0	0	0	0	1	0	0	0	0	0	3	4	3	3		
50.0 - 59.9	3	0	0	0	0	0	0	0	0	0	0	3	3	1	1		
60.0 - 69.9	1	0	0	0	0	0	0	0	0	0	0	1	2	1	1		
70.0 - 79.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
80.0 - 89.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
90.0 - 99.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
100.0 - 109.9	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1		
110.0 - 119.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
120.0 - 129.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
130.0 - 139.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
140.0 - 149.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
150.0 - 159.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
160.0 - 169.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
170.0 - 179.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
180.0 - 189.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
190.0 - 199.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
200.0 - 209.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
210.0 - 219.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
220.0 - 229.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
RESERVOIRS	25	1	0	0	0	1	0	0	0	0	1	28	88	88	88		

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TABLE N-7. - Depth distribution of U.S. natural gas reservoirs according to argon content

DEPTH OF RESERVOIR, FEET	PERCENT OF RESERVOIRS	ARGON CONTENT, CC PERCENTAGE										MAXIMUM DEPTH, FEET	RESERVOIRS	NUMBER OF RESERVOIRS	NUMBER OF SAMPLES	NUMBER OF STATES	STATES
		.10 TO .29	.30 TO .49	.50 TO .69	.70 TO .89	.90 TO 1.09	1.10 TO 1.29	1.30 TO 1.49	GREATER THAN 1.49								
0 - 999	0	0	0	0	0	0	0	0	0				1	1	1	1	
1000 - 1999	0	0	0	0	0	0	0	1	0								
2000 - 2999	0	0	0	0	0	0	0	0	0								
3000 - 3999	6	5	1	0	1	0	0	0	0				13	32	4	4	
4000 - 4999	0	0	0	1	0	0	0	0	0				1	1	1	1	
5000 - 5999	5	0	0	0	0	0	0	0	0				3	3	3	1	
6000 - 6999	1	0	3	0	0	0	0	0	0				1	2	2	1	
7000 - 7999	0	0	0	0	0	0	0	0	0								
8000 - 8999	0	0	0	0	0	0	0	0	0								
9000 - 9999	0	0	0	0	0	0	0	0	0								
10000 - 10999	0	1	0	0	0	0	0	0	0				1	1	1	1	
11000 - 11999	0	0	0	0	0	0	0	0	0								
12000 - 12999	0	0	0	0	0	0	0	0	0								
13000 - 13999	0	0	0	0	0	0	0	0	0								
14000 - 14999	0	0	0	0	0	0	0	0	0								
15000 - 15999	0	0	0	0	0	0	0	0	0								
16000 - 16999	0	0	0	0	0	0	0	0	0								
17000 - 17999	0	0	0	0	0	0	0	0	0								
18000 - 18999	0	0	0	0	0	0	0	0	0								
19000 - 19999	0	0	0	0	0	0	0	0	0								
20000 - 20999	0	0	0	0	0	0	0	0	0								
21000 - 21999	0	0	0	0	0	0	0	0	0								
22000 - 22999	0	0	0	0	0	0	0	0	0								
RESERVOIRS	10	6	1	1	1	0	0	1	0				20	40			