

# Porosity and Bulk Density of Sedimentary Rocks

By G. EDWARD MANGER

CONTRIBUTIONS TO GEOCHEMISTRY

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**STEWART L. UDALL, *Secretary***

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**Thomas B. Nolan, *Director***

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By G. EDWARD MANGER

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#### ABSTRACT

More than 900 items of porosity and bulk density data for sedimentary rocks have been tabulated. Most of the data are from the more accessible American, British, German, and Swiss literature. The number of porosity determinations per item ranges from 1 to 2,109. The tabulation reflects the fact that more porosity than bulk density data are available for sedimentary rocks.

#### INTRODUCTION

Data on the porosity and bulk or lump density of sedimentary rocks have been assembled for the Division of Reactor Development of the U.S. Atomic Energy Commission. Most of the data are from the more accessible American, British, German, and Swiss literature. They are tabulated under headings according to rock type and geologic age, and grouped according to geographic locality. To the extent that information is available, the following items are included: The name of the stratigraphic unit, the source of the material or depth below the surface, the number of samples, the average and range of porosity, the average dry and saturated bulk density, the source of the data, and the method of porosity determination. The tabulation reflects the fact that more porosity than density data for sedimentary rocks are available in the literature. The stratigraphic nomenclature in this report is from various sources and does not necessarily follow that of the U.S. Geological Survey.

Total porosity is a measure of all the void space of porous material. It includes the sealed-off pores as well as those which are connected with the surface of the test specimen. The equation for total porosity ( $P_T$ ) by percent is

$$P_T = 100 \left( 1 - \frac{V_G}{V_B} \right), \quad (1)$$

where ( $V_B$ ) is bulk volume and ( $V_G$ ) is grain volume. Alternatively and more usually, grain density is substituted for grain volume, and

bulk density for bulk volume. Total porosity by percent correspondingly is

$$P_T=100\left(1-\frac{D_B}{D_G}\right). \quad (2)$$

Apparent porosity, otherwise called effective or net porosity, is a measure of the interconnected void space which communicates with the surface of the test specimen. It therefore does not include the sealed-off or occluded pores. Apparent porosity is obtained by determining the fluid capacity of the interconnected pores, that is, the pore volume ( $V_P$ ), and by dividing this volume by the bulk volume ( $V_B$ ). The equation for apparent porosity ( $P_A$ ) by percent is

$$P_A=100\left(\frac{V_P}{V_B}\right). \quad (3)$$

The method of determining bulk volume may result in greater differences in porosity than the usually small differences between total and apparent porosity that are recorded in the literature. For 10 specimens of fire brick Hartmann (1926) found that bulk volume by immersion in water was consistently slightly more than by mercury displacement. The average total porosity by the grain density-bulk density relation was 25.5 percent where bulk volume was determined by the displacement of water by a previously wetted specimen, but 24.6 percent where bulk volume was determined by mercury displacement. Steinhoff and Mell (1924), using 73 cubes of porous refractory material 2 cm along the edges, found that the bulk volume obtained by micrometer measurement was significantly greater than by mercury displacement. The average total porosity, determined by the grain density-bulk density relation, was 25.0 percent where the bulk volume was obtained by micrometer measurement, but the total porosity was 23.6 percent where the bulk volume was obtained by mercury displacement. These results indicate that mercury displacement determinations of bulk volume tend toward minimum values. A comparison of equations (1) and (3) shows that a decrease in bulk volume due to the method of measurement will decrease the computed total porosity but will increase the computed apparent porosity. That mercury displacement determinations of bulk volume may at times be less than true values of bulk volume is shown by the fact that the computed apparent porosity occasionally exceeds the computed total porosity where bulk volume is obtained by mercury displacement, and where there is no evidence that adsorptive effects have resulted in erroneously large determinations of pore volume.

Nutting (1930) stated that in the determination of grain density by pycnometry the adsorption of water by very finely powdered quartz grains (or other material) may cause an error of 1 or 2 percent in the grain density. Apparently, however, such large errors due to the adsorption of water do not commonly occur in practice. Hirschwald (1912) showed that an erroneously large deficiency of porosity may result from obtaining pore volume by imbibition of water under atmospheric pressure. He obtained better results by letting the specimens imbibe water for 3 hours under a partial vacuum equal to the vapor pressure of water at room temperature, but he had to supplement this process by applying a pressure of 50 to 150 atmospheres to obtain the optimum saturation of the pores.

Among the more important earlier publications which give extensive data on porosity and bulk density is that of Buckley (1898), who determined the porosity of building stones of Wisconsin by slowly immersing the specimens in boiling water and then maintaining a reduced pressure of one twelfth of an atmosphere on the specimen for 36 hours. Gary (1898) listed the bulk density of numerous building stones, and the total porosity as determined by the grain density-bulk density relation, but his specimens are usually not identified according to the geologic formation. Moore (1904) determined the porosity of specimens of sedimentary rocks by saturating them with water under a vacuum of 29 inches of mercury and listed many determinations. Fuller (1906) calculated the porosity of some sedimentary and other rocks by using the data of Geikie, Delesse and Merrill, but the original data were obtained from the imbibition of water under atmospheric pressure, and it is not clear whether Fuller used an arbitrary value of  $2.65 \text{ gcm}^{-3}$  for bulk density in his calculations. Sorby (1908) gave the porosity of sandstone, shale, and slate obtained by imbibition of water for several days under a partial vacuum resulting from the condensation of steam. Sorby used almond oil or benzol to saturate specimens of clay. Hirschwald (1912) determined the porosity of many sandstone, limestone, and slate specimens of building stone by saturating the specimens under a partial vacuum followed by applying a pressure of 150 atmospheres. Grubenmann, Niggli, and others (1915) have presented extensive data on the total porosity and bulk density of the building and roofing stones of Switzerland. Kessler (1919) determined the bulk density of commercial marbles of the United States and derived total porosity by the grain density-bulk density relation.

More recently Melcher (1924) gave a critical discussion of previous methods of porosity determination and presented many determinations of bulk density and total porosity of oil sands obtained by the

grain density-bulk density relation. Hedberg (1926) and Athy (1930) determined the total porosity and bulk density of subsurface samples of shale with particular reference to the relation of compaction to the thickness of overburden. Stearns (1927) determined the bulk density and total porosity of many samples of water-bearing rock. Fancher, Lewis, and Barnes (1933) gave extensive references to the various methods of porosity determination, summarized many of the methods and techniques evolved up to the year 1933, and presented many original apparent porosity determinations. A recent extensive list of porosity determinations of oil sands is given by Rall, Hamontre, and Taliaferro (1954). In their method pore volume is determined by the pressure and volume relationships of a gas system with and without a rock specimen.

Average values for the porosity of sedimentary rocks have been given by Barrell (1914) as: shale, 8.2 percent; sandstone, 14.8 percent; limestone, 5.3 percent; and all sedimentary rocks, 8.5 percent. Additional data since the publication of Barrell's summary indicate that the average value of 8.2 percent for the porosity of shale may be low. Athy's graph (1930) for Pennsylvanian and Permian shales from structurally disturbed areas shows an average porosity of 8.8 percent for a depth range from 1,000 to 5,000 feet, but Hedberg's data (1936) for undisturbed Tertiary shale show an average porosity of 19.8 percent for a depth range from 219 to 7,994 feet.

Tabulations of the assembled data on porosity and bulk density follow (tables 1-5). Nearly all the measurements were made at room temperature and 1 atmosphere. Numbers in parentheses following bulk density entries are the number of determinations on which the averages are based. Methods of porosity determination and sources of data are keyed in the tabulations to lists that appear on pages E45 to E47 and E47 to E55, respectively. A "Remarks" column contains miscellaneous notes from the cited sources that may be useful in evaluating the porosity and bulk density data.

The tabulations indicate that the porosity of sandstone generally but not invariably decreases and the bulk density increases with depth of burial, age, degree of tectonic disturbance, and departure from homogeneous texture. The carbonate rocks show a much less sensitive variation in porosity and bulk density in relation to these factors. Pure shales show the most sensitive decrease in porosity and increase in bulk density with depth of burial and degree of tectonic disturbance.



TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Precambrian</b>											
Goodrich Quartzite.....	Ishpeming, Mich.....	Mine.....	-----	-----	-----	-----	3.24	-----	17	A-16	
Nonesuch Shale (calcareous sandstone).	White Pine, Mich.....	do.....	-----	-----	-----	5.3	2.60	2.65	16	A-16	
<b>Cambrian</b>											
Antietam Quartzite.....	Martinsville, Pa.....	Outcrop(?).....	1	-----	-----	1.7	3.05	3.07	17	A-16	
Chickies Quartzite.....	Pennsylvania.....	Outcrop.....	5	3.8	7.8	5.4	-----	-----	43	T-1	
"Mt. Simon" sandstone (dolomitic).	Sand Hill well, Wood County, W. Va.	13,005-13,165.....	9	.2	2.5	.7	2.69	2.70	(1)	A-15	
Southern "Potsdam" sandstone.	Wisconsin.....	Quarry.....	14	4.8	28.3	11.4	2.30	2.41	22	A-1	
Northern "Potsdam" sandstone.	do.....	do.....	16	10.4	22.6	19.4	2.13	2.32	22	A-1	
Reagan Sandstone.....	Otis and Panny-Wann fields, Kans.	3,449-3,683.....	24	5.5	17.8	11.2	-----	-----	123	A-9	
Sandstone.....	Conley, Great Britain.....	Quarry.....	1	-----	-----	6.1	2.45	2.51	105	A-2	
<b>Upper Cambrian and Lower Ordovician</b>											
Potsdam and Beekmantown Groups (sandstone).	Ontario, Canada.....	Quarry.....	6	5.0	12.4	8.0	2.44	2.52	112	A-2	5 localities.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Ordovician</b>											
Juniata Formation.....	Sand Hill well, Wood County, W. Va.	7,833.....	1	-----	-----	1.2	2.67	2.68	(1)	A-15	
St. Peter Sandstone.....	Wisconsin	Quarry	2	18.1	20.0	19.1	2.15	2.34	22	A-1	
Do.....	Ozark Plateau, Ark.	Outcrop.....	12	3.6	14.1	8.8	2.41	2.50	20	T-2	
Crystal Mountain Sandstone.	Ouachita Mountains, Ark.	.....do.....	1	-----	-----	17.5	2.19	2.37	20	T-2	
Simpson Group (sandstone).	Cunningham pool, Kansas.	4,051-4,117.....	36	5.7	22.7	13.3	-----	-----	123	A-9	
Wilcox sand.....	Bowlegs field, Oklahoma.	-----	2	12.1	12.8	12.5	-----	-----	9	A-6	
Do.....	Oklahoma City field, Oklahoma.	≈ 6,300.....	12	16.9	23.3	20.7	-----	-----	123	A-9	
Do.....	do	≈ 6,300.....	2	8.0	16.9	12.5	-----	-----	9	A-6	
Do.....	Ramsay pool, Oklahoma.	≈ 4,800.....	-----	-----	-----	20	-----	-----	52	N-1	
Do.....	Seminole field, Oklahoma.	≈ 4,300.....	2	15.6	15.6	15.6	-----	-----	9	A-6	Clean, uniform.
Second Wilcox sandstone..	Arcadia-Coon Creek pool, Oklahoma.	≈ 6,000.....	-----	9	18	-----	-----	-----	25	N-1	
Second Simpson sand.....	West Edmond field, Oklahoma.	7,000+.....	2	14.9	15.1	15.0	-----	-----	123	A-9	
First Bromide sand.....	Fitts pool, Oklahoma.....	≈ 4,150.....	1	-----	-----	7.7	-----	-----	123	A-9	
Bromide Formation (sandstone).	Lindsay area, Oklahoma..	9,500-11,300.....	-----	1	24	14	-----	-----	148	N-1	
Do.....	Maysville pool, Oklahoma.	7,400.....	1	-----	-----	14.1	-----	-----	148	N-1	
Hammar-Handl sand.....	Oklahoma City field, Oklahoma.	≈ 6,600.....	12	7.1	26.5	15.0	-----	-----	123	A-9	
Do.....	do	≈ 6,600.....	2	-----	-----	14.1	-----	-----	9	A-6	
Johnson sand.....	do	≈ 6,600.....	5	18.2	30.3	24.3	-----	-----	123	A-9	
Do.....	do	≈ 6,600.....	32	5.3	21.3	14.1	-----	-----	9	A-6	
Mollman sand.....	do	≈ 6,600.....	2	12.5	15.7	14.1	-----	-----	123	A-9	
School Land sand.....	do	≈ 6,600.....	4	11.4	14.8	13.1	-----	-----	9	A-6	
McKee sand.....	Hare field, New Mexico.	7,795.....	2	-----	-----	8.5	2.51	2.60	76	A-5	
Swan Peak quartzite.....	Afton quadrangle, Wyoming.	-----	-----	-----	-----	2.0	2.56	2.58	110	T-2	
Chazy Group.....	Ontario, Canada.....	Quarry	1	-----	-----	17.5	2.19	2.37	114	A-2	

Silurian

Clinch Sandstone.....	Lee County, Va.....					9.6				84	N	
Tuscarora Sandstone.....	Sand Hill well, Wood County, West Virginia.	7,668-7,763.....	5	0.9	1.5	1.1	2.59	2.60	(1)	A-15		
Tuscarora Sandstone, do- lomitic.	do	7,777-7,803.....	2	.5	1.1	.8	2.64	2.65	(1)	A-15		
Red Mountain Formation.	Bessemer, Alabama.....	Mine, 1,400.....				3.1	3.14	3.17		172	A-16	Ferruginous sandstones.
Do.....	do	do				2.9	3.26	3.29		172	A-16	Red sandstones.
Do.....	do	do				.8	2.76	2.77		172	A-16	Siltstone and shale.
Blaylock Sandstone.....	Ouachita Mountains, Ar- kansas.	Outcrop.....	4	2.3	17.4	7.3	2.42	2.49		20	T-2	
Medina group.....	Ontario, Canada.....	Quarry.....	2	12.0	14.9	13.5	2.30	2.44		112	A-2	2 localities.

Devonian

Oriskany Sandstone.....	Wayne-Dundee field, New York.	≈1,924.....	4	7.1	9.0	8.3				47	T	1 well.
Do.....	State Line field, New York.	≈4,700.....	18	7.9	12.2	10.3				47	T	5.7 ft of core.
Bradford sand.....	Bradford field, Pennsyl- vania.	≈600-≈2,300.....	297	6.0	23.3	15.0	2.25	2.40		46	T-6	Estimated grain density, 2.65.
Do.....	do	≈600-≈2,300.....	1			13.1				123	A-9	
Do.....	do	≈600-≈2,300.....	1			18.6	2.17	2.36		98	T-2	
Do.....	do	≈600-≈2,300.....	75	3.8	26.0	12.9				43	A-6	
Do.....	do	≈600-≈2,300.....	40	4.5	22.7	12.5				9	A-6	
Do.....	Kane field, Pennsylvania.	Subsurface.....	17	2.0	14.4	11.9				43	A-6	
Do.....	do	do	69	3.0	16.4	10.6				9	A-6	
Chipmunk sand.....	Cattaraugus County, N.Y.	do	2	14.5	15.1	14.8				123	A-9	
Clarendon sand.....	Saybrook field, Pennsyl- vania.	do	2	11.5	13.4	12.5				9	A-6	
Do.....	Warren field, Pennsylva- nia.	do	5	8.8	18.5	14.4				9	A-6	
Do.....	do	do	13	2.6	25.6	10.6				43	A-6	
Kane sand.....	Kane field, Pennsylvania.	do	7	14.2	22.2	18.9				9	A-6	
Oriskany Group (sand- stone).	Toga field, Pennsylvania.	≈4,000.....	65	2.9	11.8					47	T	19 wells.
Do.....	Sabinsville pool, Penn- sylvania.	≈4,350.....	1			9.9				47	T	
Do.....	Hebron field, Pennsylva- nia.	≈5,130.....	6	9.1	10.1	9.4				47	T	2 wells.
Do.....	Hebron gas field, Penn- sylvania.	5,174-5,179.....		9	14					125	N-1	
Do.....	Hebron-Ellisville field, Pennsylvania.	≈5,500.....				10				49	N	

Footnotes on p. E25.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Devonian—Continued</b>											
Sandstone.....	Butler and Zelenople, quadrangle, Pennsylvania.	Subsurface....	8	4.5	22.2	10.1	2.39	2.49	99	T-2	
Do.....	Dorseyville field, Pennsylvania.	1,910.....	11			8.6	2.42	2.51	98	T-2	
Speechley sand.....	Oil City field, Pennsylvania.	Subsurface....	11	3.7	15.7	11.4			43	A-6	
Do.....	Butler County, Pa.	2,032 to 2,049..	3	4.3	15.4	10.9	2.42	2.53	98	T-2	
Third Bradford sand.....	Bradford field, Pennsylvania.	Subsurface....	10	13.1	16.9	14.6			43	T-1	
Do.....	do.	do.	5	14.9	18.5	16.2	2.25	2.41	98	T-2	
Third sandstone.....	Allegheny and Butler Counties, Pa.	1,700-1,800.....	13	4.6	9.1	6.7	2.46	2.53	98	T-2	
Fourth and Top sand.....	Butler County, Pa.	Subsurface....	3	10.6	15.9	12.7	2.31	2.44	98	T-2	
Fifth sandstone.....	New Kensington quadrangle, Pennsylvania.	2,300.....	3	6.2	13.2	10.5	2.43	2.54	98	T-2	
Thirty-foot sand.....	Glenshaw field, Pennsylvania.	1,850.....	7	7.2	9.8	9.0	2.41	2.50	98	T-2	
Oriskany Group (sandstone).	Kanawha County, W. Va.			6.8	11				85	N-1	
Huntersville chert.....	Sand Hill well, Wood County, W. Va.	3,455.....	1			.7	2.58	2.59	(1)	A-15	Calcareous.
Sandstone.....	Ravenna, Ky.	Mine.....	2	10.4	11.9	11.2	2.55(1)	2.65(1)	98	T-2	
Williamsburg sand.....	Williamsburg, Ky.	800(?).....	1			12.4			98	T-2	
Hoing sand.....	Colmar-Plymouth pool, Illinois.	415-500.....	137	5.7	23.9	18.6			118	A-6	
Oriskany sandstone.....	Ontario, Canada.	Quarry.....	1			6.6	2.48	2.55	112	A-2	
Old Red sandstone.....	Cradley, Great Britain.	Outcrop.....	1			2.5	2.57	2.60	105	A-2	
Graywacke.....	Germany.	Quarry.....	3	.5	9.1	3.6			72	A-3	Granular.
Do.....	do.	do.	3	.7	7.2	4.3			72	A-3	Slaty.
Sandstone.....	do.	do.	2	7.7	18.7	13.2			72	A-3	
Upper Old Red sandstone.	Micheldean, Great Britain.	Outcrop.....	1			16.0	2.18	2.34	105	A-2	Coarse.
Do.....	do.	do.	1			9.1	2.40	2.49	105	A-2	Fine.

Upper Devonian and Lower Mississippian

Three Forks shale, (red sandstone).	Afton quadrangle, Wyoming.					6.4	2.62	2.68	110	T-2	
First Venango sand	Franklin Heavy field, Pennsylvania.	Subsurface	12	11.2	18.5	13.9			123	A-9	
Do	Pleasantville field, Pennsylvania.	do	2	12.4	20.7	16.5			43	A-6	
Second Venango sand	Oil City field, Pennsylvania.	do	30	5.8	20.1	15.0			9	A-6	
Do	Pleasantville field, Pennsylvania.	do	1			17.2			43	A-6	
Second sand, Venango oil sand group.	Oil City area, Pennsylvania.	618-873	115	2.0	23.2	14.6	2.28	2.43	45	T-2	Average grain density, 2.664.
Third Venango sand	do	Subsurface	2	10.2	10.2	10.2			9	A-6	
Do	do	do	17	3.4	22.3	13.7			43	A-6	
Boulder sand	Allegheny County, Pa.		4	4.4	12.6	7.9	2.45	2.53	98	T-2	

Mississippian

Berea sandstone	Hancock County, W. Va.	Subsurface	2	16.7	22.2	19.5			9	A-6	
Do	Cabin Creek field, West Virginia.	≈2,500				4			161	T-2	Quartzite cap.
Do	do	≈2,500				16			161	T-2	Pay sand.
Sandstone, well-sorted	Tucker County, W. Va.		1			4.4			131	T-1	Carbon ratio, 72.5-77.5 percent.
Berea Sandstone	Harrison County, Ohio	Subsurface	3	15.4	17.2	16.6	2.24	2.40	98	T-2	
Do	Monroe, Noble, and Belmont Counties, Ohio.	1,440-2,160	8	4.7	17.1	11.1	2.37	2.48	99	T-2	
Do	Monroe County, Ohio	Subsurface	1			11.7			9	A-6	
Do	S. Amherst, West View, and Berea, Ohio.	Quarry	6	15.9	17.8	16.6	2.12	2.29	19	A-1	
Berea (?) Sandstone	Berea, Ohio	Outcrop	2	10.2	13.2	11.7			100	A-13	Building stone.
Do	Amherst, Ohio	Quarry				16	2.06	2.22	172	A-16	
Keener sand	Monroe County, Ohio	1,220-1,570	5	11.3	18.4	14.9	2.25	2.40	98	T-2	Mississippian(?).
Maxville Limestone (siltstone).	Muskingum County, Ohio.	≈200	2				2.67		17	A-16	
Sandstones	Monroe County, Ohio	1,350-1,500	3	11.3	13.1	12.5	2.35	2.48	99	T-2	Do.
Mooretown Formation (sandstone).	Tri-County oil field, Indiana.	≈1,300				5			42	N	Clayey and limy.
Sample sand	Francisco pool, Indiana	1,400				17			107	N	
Waltersburg Sandstone	Lower Wabash area, Illinois and Indiana.	1,900				19.5			146	N-1	Clean, fine sandstone.
Do	Powell's Lake oil field, Kentucky.	1,810-1,820		14	21	18.5			79	N-1	
Fort Payne Chert	Near Smithville, Tenn.	Subsurface	2	3.8	4.8	4.2	2.65	2.69	17	A-16	

Footnotes on p. E25.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Mississippian—Continued</b>											
Aux Vases Sandstone.....	Salem pool, Illinois.....	1,760-1,794.....	28	7.9	19.2	14.7			118	A-6	
Do.....	do.....	≈1,800.....				16.1			5	N-1	
Benoist sand.....	do.....	≈1,725.....				17.5			5	N-1	
Do.....	Hoodville field, Illinois.....	2,999-3,003.....	6	15.3	17.0	16.1			123	A-6	
Bethel Sandstone.....	Louden, Centralia, Patoka, and Salem pools, Illinois.....	1,360-1,853.....	102	10.0	24.9	18.3			118	A-6	
Do.....	South-central Illinois.....	1,363-1,724.....	33	10.0	22.2	18.2			122	N-1	Well sorted.
Cypress Sandstone.....	Bartelso, Carlyle, Lawrence County, Louden, Noble, and Patoka pools, Illinois.....	1,009-2,024.....	126	5.7	23.8	18.6			118	A-6	
Paint Creek Shale (stray sand).....	Fayette County, Ill.....	1,363-1,724.....	33	10.0	22.2	18.2			122	N-1	Do.
Tar Springs Sandstone.....	Benton field, Illinois.....	2,000-2,100.....		13	25	20			74	N-1	
Carlyle sand.....	Carlyle, Ill.....	1,026.....	3	20.6	27.6	23.4	2.02	2.26	98	T-2	
Michigan stray sand.....	Millbrook field, Illinois.....	1,235-1,282.....	7	9.7	20.7	19.1			123	A-9	
Sandstones.....	Ozark Plateau, Ark.....	Outcrop.....	4	8.6	17.3	13.3	2.30	2.43	20	T-2	
Boone Formation (chert).....	Near Picher, Okla.....	Mine.....				5.0	2.56	2.61	16	A-16	
Boone Formation (quartzite).....	do.....	do.....				2.0	2.72	2.74	16	A-16	
Boone Formation (calcareous chert).....	do.....	do.....				8.9	2.39	2.48	16	A-16	
<b>Mississippian or Pennsylvanian</b>											
Deaner sand.....	Deaner field, Oklahoma.....	2,522.....	1			12.5	2.35	2.47	98	T-2	
Kingwood sand.....	do.....	2,659.....	2	15.7	16.0	15.9	2.27	2.43	98	T-2	
Red sand.....	Osage County, Okla.....	Subsurface.....	5	7.5	18.4	14.0	2.36	2.50	98	T-2	

Pennsylvanian

Olean Formation (sandstone).	Rock City, N.Y.-----	Outcrop(?)-----	2	14.4	15.8	15.1			9	A-6	
Allegheny Formation (sandstone).	Bakerton, Pa.-----	≈ 500-----				1.4	2.70	2.71	17	A-16	
Allegheny Formation (siltstone).	do-----	≈ 500-----				1.8	2.76	2.78	17	A-16	
Do-----	Colver, Pa.-----	Mine-----					2.66		17	A-16	
Kanawha Formation (sandstone).	Near Franklin, Pa.-----	5-140-----	3	7.8	12.0	10.3	2.29	2.39	17	A-16	
Do-----	do-----	0-20-----	2				2.46		16	A-16	
Do-----	do-----	0-20-----				11.0	2.16	2.27	16	A-16	
Do-----	do-----	0-20-----					2.15		16	A-16	
Do-----	do-----	0-20-----					2.70		16	A-16	
Kanawha Formation (sandstone).	Dehuc, W. Va.-----										
Monongahela Formation (sandstone).	Scotts Run, W. Va.-----	Mine-----	3	3.1	4.8	4.1	2.5		173	A-16	
Sandstones, well-sorted	West Virginia, Ohio-----	Outcrop-----	7	16.5	25.3	21.5			131	T-1	Carbon ratio, 52.5-57.5 per cent.
Do-----	do-----	do-----	8	6.8	20.1	16.2			131	T-1	Carbon ratio, 57.5-62.5 per cent.
Do-----	West Virginia-----	do-----	10	3.0	9.5	5.4			131	T-1	Carbon ratio, 72.5-77.5 per cent.
Do-----	do-----	do-----	4	1.9	3.9	2.7			131	T-1	Carbon ratio, 80-82.5 per cent.
Mansfield Formation (sandstone).	Powell's Lake oil field, Kentucky-----	1,200-----		15	23	18.7			79	N-1	
Biehl sand	Allendale pool, Illinois-----	1,416-1,555-----	93	6.2	20.3	13.3			118	A-6	
Makanda sand	Boskey Dell, Ill-----	Outcrop-----	4	16.2	19.6	18.3			123	A-9	
Robinson sand	Crawford-Main pool, Illinois-----	905-1,014-----	289	3.4	27.1	18.6			118	A-6	
Do-----	Flat Rock, Lawrence County, New Hebron, and Parker pools, Illinois-----	880-1,030-----	47	6.3	24.3	16.8			118	A-6	
Upper Partlow sand	North Johnson pool, Illinois-----	504-561-----	15	15.5	23.4	20.8			118	A-6	
Bartlesville sand	Anderson County, Kans-----					17.5			84	N	Now "Burbank" sand.
Do-----	Various fields, Kansas-----	695-1,183-----	82	7.0	24.8	20.4			123	A-9	Do.
Peru sand	Sedan and Cunningham fields, Kansas-----	197-208-----	14	14.4	22.4	17.5			123	A-9	
Wayside sand	Montgomery County, Kans-----	586-631-----				9.7	2.47	2.56	98	T-2	
Do-----	Jefferson field, Kansas-----	243-424-----	16	15.7	23.0	20.0			123	A-9	

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Pennsylvanian—Continued</b>											
Atoka Formation (sandstone).	Ozark Plateau, Ark.	Outerop	15	4.7	19.8	11.5	2.32	2.44	20	T-2	11 wells.
Do.	Arkansas Valley, Ark.	do	23	0	20.6	7.6	2.43	2.51	20	T-2	
Do.	Ouachita Mountains, Ark.	do	13	0	10.4	5.5	2.50	2.55	20	T-2	
Sandstones.	Ozark Plateau, Ark.	do	2	13.8	18.1	16.0	2.26	2.42	20	T-2	
Do.	Arkansas Valley, Ark.	do	12	5.4	10.7	8.2	2.42	2.51	20	T-2	
Do.	Ouachita Mountains, Ark.	do	12	.9	9.6	4.6	2.52	2.57	20	T-2	
Armstrong sand.	W. Duncan field, Oklahoma.	≈2,000	63			26.7			121	N-1	
Bartlesville sand.	Creek and Osage Counties, Oklahoma.	1,570-2,267	14	13.5	38.7	20.1	2.17	2.37	98	T-2	
Do.	Cushing field, Oklahoma.	2,639-2,680	2	28.9	32.0	30.5	2.20(1)	2.49(1)	98	T-2	
Do.	Pershing field, Oklahoma.	1,988-2,132	10	7.6	16.0	13.3	2.31	2.44	98	T-2	
Do.	Various fields, Oklahoma.	813-6,592	587	3.3	33.7	17.4			123	A-9	
Basal Pennsylvanian sand.	Pauls Valley field, Oklahoma.	Subsurface	6	5.9	12.3	8.8			123	A-9	
Booth sand.	Various fields, Oklahoma.	2,913-(?)	5	17.5	25.4	22.1			123	A-9	
Burbank sand.	Burbank field, Oklahoma.	2,920-2,970	2	15.2	15.7	15.4			123	A-9	
Burgess sand.	S. Moore pool, Oklahoma.	7,791-7,795		1.8	35	17			104	N-1	
Do.	Washington County, Okla.	≈1,650	2	16.4	22.0	19.2	2.24(1)	2.40(1)	104	N-1	
Cisco Formation.	West Red River field, Oklahoma.	≈1,550	6	22.6	26.1	24.6			123	A-9	
Cleveland sand.	Osage County, Okla.	Subsurface	1			17.7	2.21	2.39	98	T-2	
Coffeyville Formation (sandstone).	Turley, Okla.	do				16.8	2.14	2.31	17	A-16	
Cromwell sand.	Hughes County, Okla.	do	1			12.1			123	A-9	
Do.	Little River field, Oklahoma.	≈3,220	22	16.2	23.2	19.9			9	A-6	
Do.	Kanawa field, Oklahoma.	≈2,300	6	16.6	22.6	19.0			9	A-6	
Deese Formation (sandstone).	Southwest Antloch field, Oklahoma.	≈6,550	1			15			128	N-1	
Do.	Velma oil field, Oklahoma.	3,330-4,320				21			132	N-1	
Dutcher sand.	South Depew field, Oklahoma.	2,410	2	14.6	18.2	16.4			123	A-9	
Do.	Slack field, Oklahoma.	2,575-2,613	5	9.9	14.9	10.8			98	T-2	
Gilcrease sand.	Francis field, Oklahoma.	≈2,500	2	27.3	27.5	27.4			9	A-6	



Do.....	Holdenville field, Oklahoma.	≈3,200.....	2	16.8	16.8	16.8			9	A-6
Do.....	Sasakwa, Okla	≈2,830.....	2	18.1	18.3	18.2			9	A-6
Glenn sand.....	Creek County, Okla	1,514-1,592.....	1			21.4	2.12	2.33	98	T-2
Healdton sand zone.....	Healdton field, Oklahoma.	849-1,356.....	92	2.3	35.8	23.8			123	A-9
Hewitt sand.....	Hewitt field, Oklahoma.	1,408-1,435.....	3	17.3	21.7	19.5	2.13(1)	2.32(1)	98	T-2
Hickman sand.....	Burbank field, Oklahoma	2,782-3,005.....	84	6.1	32.7	20.4	2.15	2.35	98	T-2
Holdenville Shale (sandstone).	Tulsa, Okla	Subsurface.....				17.0	2.50	2.67	17	A-16
Hoover sandstone.....	Laverne district, Okla	≈4,200.....				18			114	N-1
Hoxbar Formation.....	Superior well, Caddo County, Okla.	8,353-8,362.....	6	3.8	7.8	6.55			(?)	A
		9,448-9,492.....	39	4.7	8.7	6.90			(S)	A
		10,215-10,224.....	3	9.5	10.9	10.17			(S)	A
Deese Formation.....	do.....	13,083-13,095.....	7	2.1	6.3	4.36			(S)	A
		15,075-15,085.....	8	7.2	9.2	8.20			(S)	A
		16,953-16,956.....	1			28.2			(S)	A
Humphrey sand.....	Velma oil field, Oklahoma.	Subsurface.....				17			132	N-1
Layton gas sand.....	Pawnee and Creek Counties, Okla.	853-1,525.....	2	22.1	26.3	24.2	2.02	2.26	98	T-2
Lower part of Dornick Hills Formation and Springer Formation.	Velma pool, Oklahoma.....	≈5,000.....				21			39	N-1
		≈5,300.....				19			39	N-1
		≈6,100.....	3,500			16			39	N-1
		≈6,600.....				14			39	N-1
		≈7,100.....				12			39	N-1
Medrano sand.....	Caddo County, Okla.....	4,596-5,823.....	242	2.2	25.5	17.3			123	A-9
Middle Rowe Formation.....	Cement field, Oklahoma.....	3,346-3,354.....	17	3.4	28.9	22.9			123	A-9
Morrow Series (sandstone).	Laverne district, Oklahoma.	Subsurface.....				14			114	N-1
Olympic sand.....	Olympia pool, Oklahoma.	≈1,800.....		11.9	21.7	18			150	N-1
Do.....	Hughes County, Okla.....					20.5			84	N-1
Peru sand.....	Bartlesville field, Oklahoma.	710-720.....	17	14.7	20.2	18.6			123	A-9
Sandstone.....	Garber field, Oklahoma.....	1,784-1,800.....	2	10.3	16.4	13.4	2.25(1)	2.41(1)	98	T-2
Do.....	Stone Bluff field, Oklahoma.	1,144-1,162.....	1			16.5	2.22	2.38	98	T-2
Seminole Formation (sandy zone).	Tulsa, Okla.....	Subsurface.....				20.5	2.26	2.47	17	A-16
Sims sand.....	Velma field, Oklahoma.....	do.....				18-20			132	N-1
Skinner sand.....	West Chandler field, Oklahoma.	≈4,120.....	1			12.1			123	A-9
Stray sand.....	Osage County, Okla.....	1,536 or deeper.....				15.2	2.37	2.47	98	T-2
Third Deese sand.....	Southwest Antioch field, Oklahoma.	≈6,500.....	400			15.5			111	N-1
Thomas sandstone.....	Southwest Randlett field, Oklahoma.	≈1,600.....		21.8	25.8	22.2			26	N-1
Tonkawa sandstone.....	Laverne district, Oklahoma.	Subsurface.....				18			114	N-1
Tucker sand.....	Washington County, Okla.....	1,355-1,371.....	16	5.3	20.6	16.5			123	A-9
Upper Rowe Formation.....	Cement field, Oklahoma.....	3,379-3,393.....	22	15.7	26.2	23.3			123	A-9

Shaly, limy.

Do.  
Do.  
Do.  
Do.  
Do.

Shaly.

Footnotes on p. E25.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Pennsylvanian—Continued</b>											
Wayside sand.....	Bartlesville field, Oklahoma.	525-530.....	4	15.7	19.4	18.0			9	A-9	
Do.....	Keystone field, Oklahoma.	1,119-1,235.....	8	6.7	20.9	15.4	2.37(5)	2.49(5)	98	T-2	
Do.....	Muskogee and Pawnee Counties, Okla.	1,116-1,304(?)	2	15.8	20.1	18.0	2.22	2.40	98	T-2	
Wilson sand.....	Stephens County, Okla.	1,380.....	1			20.0	2.16	2.36	98	T-2	
Cisco Group.....	Archer County oil fields, Texas.	900-1,750.....		19.4	24.6	22.8			75	T-2	9 wells.
Cook sand.....	Cook Ranch field, Texas.	≈1,300.....	46	12.5	28.2	24.0			171	N-1	
Hickman(?) sand.....	Petrolia field, Texas.	Subsurface.....	4	18.5	26.6	22.9	2.08	2.31	99	T-2	
McClesky sand.....	Eastland County, Tex.	3,135-3,142.....	2	6.6	8.5	7.6	2.49(1)	2.55(1)	98	T-2	
Middle Strawn sandstone	Walnut Bend field, Texas	4,866-4,888.....	20	8.9	21.7	16.1			123	A-9	
Strawn Group (sandstone)	Cooke County, Tex.					22			84	N	
Do.....	Coleman County, Tex.	1,950.....	10	23.6	24.6	24.2			119	A-11	
Strawn Group (sand).....	Langston-Kleiner field, Texas.	≈3,500.....	Many			15.2			126	N-1	8 wells.
Weber Sandstone.....	Rangely field, Colorado.....	5,600-6,300.....		6	19				117	N-1	Calcareous.
Weber Sandstone (quartzite).	do.....	≈5,800.....	10	11.1	13.6	12.2			128	N-1	
Weber Sandstone.....	do.....	5,943-6,429.....	36	0.4	15.6	9.8			57	A-9	Fine sandstone, hard.
Bell sand.....	Lance Creek field, Wyoming.	5,776-5,936.....	2	7.5	10.5	9.0			157	T-2	2 wells.
Converse sand.....	do.....	4,615-4,625.....	1			13.5			157	T-2	
Leo sand.....	do.....	5,160-5,723.....	7	2.9	16.9	8.6			157	T-2	
Second Leo sand.....	do.....	5,244-5,275.....	1			5.9			157	T-2	
Tensleep Sandstone.....	Big Medicine Bow field, Wyoming.	7,016-7,474.....	3	9.8	19.5	15.0			157	T-2	
Do.....	Elk Basin field, Wyoming.	≈4,000.....				10.7			145	N-1	
Do.....	Longs Creek, Wyo.	5,955-5,956.....	2			13.7			76	A-5	
Do.....	Salt Creek field, Wyoming.	3,992-4,039.....	2	10.9	18.7	14.8			157	T-2	
Do.....	Steamboat Butte oil field, Wyoming.	6,923-7,104.....				12-13			11	N-1	

**Pennsylvanian and Permian**

Wells Formation (quartzite).	Afton quadrangle, Wyoming.	Outcrop.....	-----	-----	-----	15.1	2.27	2.42	110	T-2	
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**Carboniferous**

Lower Coal Measures.....	Great Britain.....	Quarry.....	1	-----	-----	20.5	2.16	2.37	105	A-2	
Millstone grit.....	Meanwood, Great Britain.	Outcrop.....	2	13.0	18.2	15.6	2.23	2.38	105	A-2	
Sandstone.....	Germany.....	do.....	3	2.7	13.8	6.9	2.47	2.54	56	T-3	
Do.....	do.....	Quarry.....	9	3.8	23.5	11.7	-----	-----	72	A-3	
Do.....	Aktyubin area, U.S.S.R..	1,150-4,430.....	9	-----	-----	11.8	2.41	2.53	108	T	
Do.....	do.....	7,610-8,510.....	14	-----	-----	3.9	2.50	2.54	108	T	

**Permian**

Washington(?) Formation (sandstone).	Waterford, Ohio.....	Quarry.....	3	-----	-----	16	2.17	2.33	172	A-16	
First sand.....	KMA field, Texas.....	3,769-3,787.....	21	7.0	22.3	16.2	-----	-----	123	A-9	Permian. Do.
KMA sand.....	do.....	3,687-3,824.....	156	.5	19.6	7.5	-----	-----	123	A-9	
Spraberry siltstone.....	Spraberry field, Texas.....	6,800.....	-----	-----	-----	8	-----	-----	169	N-1	2 localities.
Sandstone.....	Great Britain.....	Outcrop(?).....	2	12.1	24.8	18.5	2.22	2.41	105	A-2	
Dyas Sandstone.....	Germany.....	Quarry.....	7	9.1	20.7	15.9	-----	-----	72	A-3	
Zechstein conglomerate.....	do.....	Outcrop.....	1	-----	-----	2.8	2.55	2.58	56	T-3	
Sandstone.....	Aktyubin area, U.S.S.R..	Subsurface.....	45	-----	-----	10.1	2.42	2.52	108	T	
Do.....	do.....	do.....	98	-----	-----	10.5	2.43	2.54	108	T	
Conglomerate.....	do.....	do.....	1	-----	-----	10.9	2.59	2.70	108	T	

**Permian and Triassic**

Sandstone.....	Aktyubin area, U.S.S.R..	Subsurface.....	3	-----	-----	18.5	2.19	2.38	108	T	
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**Triassic**

Amherst sandstone.....	Connecticut Valley.....	Outcrop.....	1	-----	-----	23	1.92	2.15	18	A-12	
Stockton Formation (sandstone).	New Jersey.....	do.....	5	1.3	7.9	4.0	-----	-----	43	T-1	
Santa Rosa Sandstone.....	Guadalupe County, N. Mex.	Outcrop(?).....	1	-----	-----	18.0	2.17	2.35	98	T-2	
Shublik Formation.....	Barrow, Alaska.....	2,651-2,766.....	2	9.3	16.0	12.7	-----	-----	175	A	

**POROSITY AND BULK DENSITY OF SEDIMENTARY ROCKS E15**

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Triassic—Continued</b>											
Bunter Sandstone	Great Britain	Quarry, outcrop.	18	5.8	30.8	20.4	2.09	2.29	105	A-2	
Do	Caldy Grange, Great Britain.	Outcrop	1			14.8	2.22	2.37	105	A-2	3 in from fault.
Do	do	do	1			15.5	2.21	2.36	105	A-2	1 ft from fault.
Do	do	do	1			22.5	2.02	2.25	105	A-2	2 ft from fault.
Do	do	do	1			25.5	1.94	2.20	105	A-2	12 ft from fault.
Do	do	do	1			25.5	1.94	2.20	105	A-2	25 ft from fault.
Keuper Sandstone	Great Britain	do	16	16.5	28.6	22.6	2.02	2.25	105	A-2	
Do	Caldy Grange, Great Britain.	do	1			16.5	2.18	2.35	105	A-2	3 in from fault.
Do	do	do	1			18.0	2.14	2.32	105	A-2	1 ft from fault.
Do	do	do	1			20.1	2.08	2.28	105	A-2	2 ft from fault.
Do	do	do	1			22.5	2.02	2.25	105	A-2	12 ft from fault.
Do	do	do	1			22.6	2.01	2.24	105	A-2	24 ft from fault.
Bunter Sandstone	Near Hanover, Germany.	In place						2.25	14		Torsion balance.
Buntsandstein	Germany	Outcrop	1			20.5	2.09	2.30	56	T-3	
Do	do	Quarry	39	7.7	26.4	18.3			72	A-3	
Keuper Sandstone	do	do	11	12.1	28.3	19.9			72	A-3	
Sandstone	Cantons of Basel-Land, Basel-Stadt, Schwyz and St. Gallen, Switzerland.	do	7	3.6	21.1	11.1	2.42	2.53	63	T-4	Dips 0°-20°.
<b>Jurassic</b>											
Jones sand	Schuler field, Arkansas	7,500-7,700		0	35	20.2			163	N-1	
Do	do	7,564-7,632	62	5.4	29.2	20.9			41	N-1	1 well.
Do	Various fields, Arkansas	7,530-7,664	53	8.1	27.3	15.3			123	A-9	
Morgan sands	Schuler field, Arkansas	5,300-5,850			26	16			163	N-1	
Morrison Formation (sandstone)	Long Park, Montrose County, Colo.	239-313	62	4.9	24.1	18.6			(3)	A-9	Well sorted.
Do	do	215-284	22	5.2	27.8	17.9			(3)	A-9	Moderately well sorted.
Do	do	229-267	3	11.7	16.7	14.5			(3)	A-9	Poorly sorted.

Morrison Formation (siltstone).	do.	200-247	22	7.1	27.3	15.6			(9)	A-9	Do.
Morrison Formation	Cisco dome, Utah.	Outcrop	1			4.0			166	T-2	Very limy. 2 wells.
Do.	Two structures Wyoming.	8,255-8,400	6	1.9	11.1	6.0			157	T-2	
Nugget Sandstone.	Steamboat Butte oil field, Wyoming.	≈5,200		8.7	24.9				11	N-1	
Nugget Sandstone (quartzite).	Afton quadrangle, Wyoming.		1?			8.2	2.46	2.54	110	T-2	
Nugget Sandstone.	Fremont County, Wyo.					24.9			84	N	
Sundance Formation.	Big Medicine Bow field, Wyoming.	5,165-5,855	24	6.0	23.2	12.9			123	A-9	
Do.	do.	5,419	1			12.6			157	T-2	5 wells.
Do.	Iles dome, Colorado.	≈3,250	1			16.8			123	A-9	
Do.	Iles dome and Lance Creek fields, Colorado and Wyoming.	3,316-3,955	11	2.3	22.1	11.8			157	T-2	
Sundance Formation, basal part.	Lance Creek field, Wyoming.	3,200-4,400	Many	20	30	25			40	N-1	
Sundance Formation.	Quealy and Lance Creek fields, Wyoming.	4,051-4,300	3	19.1	24.9	22.5			157	T-2	2 wells.
Do.	Salt Creek field, Wyoming.	2,717-2,944	4	4.5	17.6	11.7			157	T-2	Do.
Preuss Sandstone.	Afton quadrangle, Wyoming.	Outcrop				3.4	2.59	2.62	110	T-2	
Stump Sandstone.	do.					5.0	2.58	2.63	110	T-2	
Kingsk Shale.	Barrow, Alaska.	1,739-2,430	20	8.5	25.0	15.8			175	A	
Do.	Simpson, Alaska.	6,153-6,269	3	17	23	19.0			175	A	
Dogger sandstone.	Wesendorf field, Germany.	Subsurface(?)				23			124	N	
Do.	do.			12	22				124	N	
Sandstone.	Oberg field, Germany.	Quarry	4	5.2	24.6	17.1			72	A-3	
Do.	Luxemburg.	Outcrop.	1			15.0	2.28	2.43	56	T-3	Fine sandstone, uniform.

Cretaceous

Raritan Formation (gravel).	New Jersey	185	1			31.9	1.67	1.99	143	T-5	
Raritan Formation (sandstone).	do.	Outcrop and water well.	4	41.7	48.4	45.6	1.43	1.89	143	T-5	Medium sand.
Do.	do.	Pit.	2	39.9	44.8	42.3	1.49	1.91	143	T-5	Fine sand.
Raritan (?) Formation (sandstone).	do.	do.	1			41.5	1.54	1.96	143	T-5	Very coarse sand.
Do.	do.	do.	1			35.7	1.75	2.11	143	T-5	Fine gravel.
Sands.	Dare County, N.C.	6,487-6,581	22	2.5	33.9	26.6			142	N-1	
Do.	do.	7,021-7,201	15	12.8	32.6	25.5			142	N-1	
Eutaw Formation (sands).	do.	3,657-4,285	8	15.9	41.2	32.1			142	N-1	
Do.	Gilbertown field, Alabama.	3,300-3,400				30			36	N-1	
Tuscaloosa Group.	Brookhaven oil field, Mississippi.	10,135-10,545				24			174	N-1	Pilot zone.
						26			174	N-1	Smith zone.
						26			174	N-1	Arrington zone.

Footnotes on p. E25.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Cretaceous—Continued</b>											
Sturgis zone sand	Fouke field, Arkansas	≈3,600	—	15	36	27.3			135	N-1	
Trinity Group	Miller County, Ark	Subsurface	2	28.7	29.9	29.3			123	A-9	
Dees sand	Rodessa field Louisiana	do	3	13.1	24.9	17.9			123	A-9	
Gas Sand	Monroe gas field, Louisiana	≈2,150	5	14.3	40.3	27.8	2.04(4)	2.29(4)	98	T-2	
Hill sand	Rodessa field, Louisiana	Subsurface	2	18.0	22.8	20.4			123	A-9	
Tokio sand	Claiborne Parish La	do	2	29.3	30.7	30.0			123	A-9	
Do	Pine Island field, Louisiana	do	3	3.2	18.4	13.3			9	A-6	
Trinity Group sand	North Lisbon field, Louisiana	do	2	20.3	26.4	23.4			123	A-9	
Elledge sand	New Hope field, Texas	≈8,200	Many			10.8			154	N-1	
Hill sand	Carthage and New Hope fields, Texas	7,352-7,533	83	5.4	26.1	15.6			123	A-9	
Do	New Hope field, Texas	≈7,400	Many			16.6			154	N-1	
Do	Ham Gossett field, Texas	≈6,500				20			168	N-1	Calcareous.
Lower Pettit sand	Carthage field, Texas	5,885-6,164	32	3.9	31.0	21.2			123	A-9	
Faluxy Sandstone	Talco field, Texas	≈4,000				25			165	N-1	
Pittsburg sand	New Hope field, Texas	7,888-8,140	315	1.7	20.6	11.5			123	A-9	
Do	do	≈7,900	Many			13.4			154	N-1	
Travis Peak Formation	Limestone County, Tex	729-731	2	13.5	14.3	13.9	2.08	2.22	119	A-11	
Upper Pettit sand	Carthage field, Texas	5,675-5,691	16	13.0	20.7	16.7			123	A-9	
Woodbine Formation (sand)	Rusk County, Tex	2,436-3,701	10	19.0	32.0	24.7	2.00	2.25	119	A-11	
Do	Gregg County, Tex	3,514-3,715	31	19.8	31.4	26.7			123	A-9	
Do	Tyler County, Tex					22.1			84	N	
Do	E. Texas field, Texas	≈3,650	7	23.8	29.0	26.0			43	A-6	
Do	do	3,504-3,513	1			17.5			103	N	Silty.
Do	do	3,522	1			17.6			103	N	Conglomerate.
Do	do	3,537-3,546	1			5.5			103	N	Chalk conglomerate.
Do	do	3,537-3,546	1			6.3			103	N	Conglomerate, clayey.
Do	do	3,774-3,778	1			11.0			103	N	Poor saturation.
Do	do	3,774-3,778	1			17.6			103	N	Fair saturation.
Do	do	3,774-3,778	1			22.2			103	N	Excellent saturation.
Do	do	3,778-3,780	1			19.7			103	N	Good saturation.

Do.....	do.....	3,785-3,786	1			11.0			103	N	Slight saturation. 10 wells.
Do.....	do.....	≈3,650	25	0(?)	27.2	19.0			103	N	
Do.....	Ham Gossett field, Texas.	3,400-4,100				23			169	N-1	
Lewisville Member.....	Hawkins field, Texas.	≈4,850				26.4			166	N-1	
Dexter Member.....	do.....	≈4,850				27.4			166	N-1	
Woodbine Formation (sand).	Mexia-Groesbeck field, Texas.	≈3,000	8	10.7	37.7	24.4	2.05	2.29	99	T-2	
Do.....	Limestone County, Tex.	2,910-3,025	100	5.1	29.7	18.6			123	A-9	
Sandstone, well-sorted.....	Iowa, Nebraska.....		9	33.1	41.3	37.3			131	T-1	
Sandstone, well-sorted, coaly.	South Dakota.....		2	27.7	29.9	28.8			131	T-1	
Sandstone, cemented.....	Lincoln County, Kans.....	Outerop.....	7	1.1	3.4	1.5			149	A-8	
Do.....	Ellsworth County, Kans.....	do.....	1			1.5			149	A-8	
Dakota Sandstone (D sand).	Denver Basin, Colorado.....	Subsurface.....		8.6	29.5	21.6			93	N-1	
Dakota Sandstone (J sand).	do.....	do.....		8.9	32.7	19.6			93	N-1	
Dakota Sandstone (D sand).	Little Beaver field, Colorado.	≈5,200				19.7			44	N-1	
Do.....	do.....	≈5,400				20.7			44	N-1	
Dakota Sandstone (J sand).	do.....	≈5,400				22.8			44	N-1	
Dakota Sandstone.....	Several structures, Wyoming and Colorado.	2,465-3,600	7	13.5	23.4	18.5			157	T-2	
Do.....	Beaver Creek and Nieber domes Wyoming.	7,949-8,634	6	4.0	7.6	5.4			157	T-2	
Bearpaw Shale (siltstone).	Rosebud County, Mont.....	Outerop.....	1			41.1	1.57	1.98	143	T-5	
Claggett Formation (siltstone).	do.....	do.....	1			36.3	1.81	2.17	143	T-5	
Cut Bank sand.....	Glacier County, Mont.....					15.4			84	N	
First Cat Creek sand.....	Fergus County Mont.....		1			22.6	2.07	2.30	143	T-5	
Hell Creek Formation.....	Rosebud County Mont.....	Outerop.....	5	24.8	38.3	35.3	1.80	2.15	143	T-5	
Do.....	Yellowstone County, Mont.	do.....	1			26.8	1.97	2.24	143	T-5	
Judith River Formation.....	Rosebud County Mont.....	do.....	2	32.3	44.8	38.5	1.66	2.05	143	T-5	
Do.....	do.....	do.....	2	33.2	51.2	42.2	1.82	2.24	143	T-5	
Lance Formation.....	do.....	do.....	3	36.7	43.0	39.4	1.66	2.05	143	T-5	
Do.....	do.....	do.....	1			30.8	1.87	2.18	143	T-5	
Do.....	do.....	do.....	1			27.4	2.01	2.28	143	T-5	
Peay sand.....	Big Horn Mountains	do.....	1			5.1	2.52	2.57	99	T-2	
Do.....	Jack Creek, Mont.....	do.....	1			5.0	2.58	2.63	99	T-2	
Second Cat Creek sand.....	Fergus County, Mont.....	do.....	1			23.2	2.06	2.29	143	T-5	
Third Cat Creek sand.....	do.....	do.....	1			25.8	1.96	2.22	143	T-5	
Virgelle Sandstone Member of Eagle Sandstone.	Yellowstone County, Mont.	do.....	1			23.6	2.06	2.30	143	T-5	
Do.....	Fergus County, Mont.....	do.....	1			27.1	1.93	2.20	143	T-5	

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
Cretaceous—Continued											
Adaville Formation (sandstone).	Sublette County, Wyo.	12, 726-12, 734	6	10.3	13.7	12.0			(4)	A	
Do.	do.	13, 248-13, 874	36	7.7	16.5	12.2			(4)	A	
Do.	do.	14, 554-14, 767	11	8.1	11.9	10.1			(4)	A	
Blair Formation (sandstone).	do.	15, 764-15, 784	11	7.8	15.4	11.0			(4)	A	
Blair(?) Formation (sandstone).	do.	16, 683-16, 880	15	4.3	10.4	7.6			(4)	A	
Frontier Formation (sandstone).	do.	20, 384-20, 503	21	4.6	9.5	7.4			(4)	A	
Bear River Formation	Afton quadrangle, Wyoming.		1			7.2	2.48	2.55	110	T-2	Quartzite.
Do.	do.		1			13.8	2.32	2.46	110	T-2	
Do.	do.		1			12.9	2.28	2.41	110	T-2	
Do.	do.		1			7.4	2.47	2.54	110	T-2	Conglomerate.
Cody Formation	Beaver Creek structure, Wyoming.	3,728				7.1			157	T-2	Siltstone.
Ephraim Conglomerate	Afton quadrangle, Wyoming.	Outcrop	1			13.2	2.31	2.44	110	T-2	
Frontier Formation	Grass Creek field, Wyoming.	Subsurface				27.0	1.93	2.20	98	T-2	
Do.	Afton quadrangle, Wyoming.					17.1	2.30	2.47	110	T-2	
Frontier Formation (sandstone).	Wyoming	4,270-6,895	4	2.7	20.8	14.1			157	T-2	3 wells.
Do.	do.	7,054-8,435	17	.7	25.9	10.7			157	T-2	
Lakota Formation (sandstone).	Quealy and Lance Creek structures, Woming.	3,715-3,966	4	12.7	23.2	17.6			157	T-2	Do.
Do.	Nieber dome, Wyoming.	8,365	1			6.8			157	T-2	2 wells.
Lower Muddy sand	S. Glen Rock field, Wyoming.	5,500-6,800				20			37	N-1	
Upper Muddy sand	do.	5,500-6,800				14			37	N-1	
Mesaverde Formation	Beaver Creek structure, Wyoming.	2,025	1			20.2			157	T-2	
Newcastle Sandstone	Lance Creek field, Wyoming.	2,900-2,915	2	14.9	20.7	17.8	2.29(1)	2.44(1)	98	T-2	
Do.	Osage field, Wyoming.	40(?)	12	11.3	26.0	16.7	2.15(5)	2.34(5)	98	T-2	
Do.	do.	1,415-1,450	3	21.3	23.6	22.7	2.04(1)	2.28(1)	98	T-2	



Do.....	Weston, Crook and Carbon Counties, Wyo.	Outcrop.....	9	8.8	24.8	21.2	2.17(4)	2.35(4)	98	T-2	
Do.....	Weston County, Wyo.	1,435	2	19.0	19.5	19.3	2.14	2.33	98	T-2	
Torchlight Sandstone Member of Frontier Formation.	Big Horn County, Wyo.	Outcrop.....	2			29.4			99	T-2	
First Wall Creek sand.	Carbon County, Wyo.	do.....	1			19.0			99	T-2	
Do.....	Lost Soldier field, Wyoming.	289-313	2	17.5	20.1	18.8	2.19(1)	2.37(1)	98	T-2	
Do.....	Salt Creek field, Wyoming.	1,235	1			19.8	2.18	2.38	98	T-2	
Do.....	Big Muddy field, Wyoming.	3,040-3,187	6	17.4	23.4	20.5	2.07	2.29	98	T-2	
Wall Creek Sandstone.	Salt Creek field, Wyoming.	1,033-1,454	4	12.1	20.8	15.3			157	T-2	2 wells.
Do.....	do.....	≈1,500	1			25.8	1.96	2.22	99	T-2	
Do.....	Natrona County, Wyo.	Outcrop.....	1			7.6	2.47	2.55	99	T-2	Calcareous.
Wayan Formation.	Afton quadrangle, Wyoming.	do.....	1			7.7	2.45	2.53	110	T-2	
Ferron Sandstone Member of Mancos Shale.	Wasatch Plateau gas fields, Utah.	4,600-5,100		1	21	12-15			159	N-1	
Dakota Sandstone	North of Chama, N. Mex.	Outcrop.....	27	3.9	24.5	17.0			158	T-2	
Okpikruak Formation	Oumalik, Alaska	9,278-10,468	10	2.8	10.0	4.8			175	A	Graywacke.
Seabee Formation	Umiat, Alaska	536-577	3	6.1	17	11			175	A	
Topagoruk Formation	Barrow, Alaska	200-1,916	10	24	29	25.9			175	A	
Do.....	Fish Creek, Alaska	2,923-2,970	2	25	31	28.0			175	A	
Do.....	Oumalik, Alaska	919-2,756	24	4	15.0	8.3			175	A	
Do.....	Simpson, Alaska	133-683	22	30	38	35.0			175	A	
Do.....	Umiat, Alaska	100-3,009	97	4	44	13.6			175	A	
Torok Formation	Barrow, Alaska	1,210-3,198	44	6.4	24.0	15.0			175	A	Do.
Tuktu Formation	Fish Creek, Alaska	5,481-6,010	8	6.0	10.0	7.8			175	A	Do.
Do.....	Oumalik, Alaska	3,244-3,756	10	6.0	16.0	10.9			175	A	Do.
Do.....	Barrow, Alaska	2,094-2,095	1			24.0			175	A	Do.
Tuluga Member (former usage) of Schrader Bluff Formation.	Fish Creek, Alaska	1,633-1,640	2	28	33	30.5			175	A	
Basal quartz sand.....	Bellshill Lake field, Alberta, Canada.	≈3,100	25			26.6			130	N-1	
Ellerlie quartz sands	White Mud oil field, Alberta, Canada.	≈4,100				25.5			77	N-1	
Viking sandstone.....	Alberta, Canada	Subsurface	2	17	22	20			128	N-1	
Guasare formation	La Paz field, Venezuela	1,800-2,300				22			24	N-1	
Eudower sandstone.	Germany	Outcrop.....	2	12.5	15.9	14.2	2.26	2.40	56	T-3	
Quadersandstein	do.....	do.....	16	12.2	26.2	21.7			72	A-3	
Sandstone.....	do.....	do.....	13	8.8	23.6	18.9			72	A-3	
Valendis sand.....	Emlichheim field, Germany.	Subsurface		25	39				124	N	
Do.....	Lingen field, Germany	do.....		12	15				124	N	
Wealden sands.....	Nienhagen and Hänigsen fields, Germany.			25	30				124	N	

Footnotes on p. E25.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Paleocene</b>											
Fort Union Formation.....	North of Buckley, Mont..	Outcrop.....	1			22.6	2.09	2.32	143	T-5	Fine sandstone. Do.
Lebo shale Member of Fort Union Formation (sandstone).	Rosebud County, Mont..	do.....	1			27.7	1.93	2.21	143	T-5	
Lebo shale Member of Fort Union Formation (siltstone).	do.....	do.....	1			40.1	1.65	2.05	143	T-5	Siltstone.
Tongue River Member of Fort Union Formation.	do.....	do.....	7	9.4	36.6	27.3	1.96	2.24	143	T-5	Fine stonestone.
Do.....	do.....	do.....	3	31.4	53.6	40.0	1.63	2.03	143	T-5	Very fine sandstone. Siltstone.
Do.....	do.....	do.....	1			26.2	1.91	2.17	143	T-5	
Tullock Member of Fort Union Formation.	do.....	do.....	2	26.7	36.6	31.7	1.87	2.19	143	T-5	Very fine sandstone. Siltstone.
Do.....	do.....	do.....	1			29.8	1.92	2.22	143	T-5	
Do.....	do.....	do.....	1			34.0	1.73	2.07	143	T-5	Medium sandstone.
<b>Paleocene and Eocene</b>											
Wasatch Formation.....	Powder Wash field, Colorado.	3,090-3,113.....	4	25.9	30.2	27.7			123	A-9	
<b>Eocene</b>											
Sparta Sand.....	Gulf coast, U.S.A.....	359-736	13	33.7	46.5	42.2			81	N-2	From core graphs.
Do.....	Gulf coast oil fields, U.S.A.	≈9,000	Many			18-20			151	N-1	
Do.....	Nachitoches, La.	556-588	3	41.1	41.8	41.4			81	N-2	
Do.....	Ville Platte field, Louisiana.	9,075				26			151	N-1	
Wilcox Group (sands)	Gulf coast, U.S.A.....	212-556	10	40.0	43.9	41.6			81	N-2	
Do.....	Gulf coast oil fields, U.S.A.	Subsurface	Many			20-22			151	N-1	
Do.....	Eola field, Louisiana.	≈8,500	68	9	23	22			13		
Do.....	do.....	8,559				24			151	N-1	

Morein (Wilcox) sand.....	Mamou field, Louisiana.....	≈11,500.....	200			19.7			32	N-1	
Cockfield sands.....	Conroe field, Texas.....	5,250 (av.).....				25-28			101	N-1	
Lower Pawelek (Wilcox) sand.....	Falls City field, Texas.....	≈6,300.....	45			24.5			34	N-1	
O'Hern sand.....	Duval County, Tex.....					28.4			84	N	
Wilcox Group (sands).....	Coastal fields, Louisiana, Texas.....	7,630-10,156.....	Many	7	23	18.4			35	N-1	14 fields.
Wilcox Group (massive sand).....	Slick-Wilcox field, Texas.....	≈8,000.....				22			137	N-1	
Yegua Formation (sands).....	Katy field, Texas.....	6,250-7,450.....				27			2	N-1	
Knight Conglomerate.....	Afton quadrangle, Wyoming.....		1(?)			7.4	2.47	2.54	110	T-2	Siltstone.
Lyre Formation.....	Olympic Peninsula, Wash.....	Outcrop.....	4	7.4	9.7	8.7			21	A	
Gatchell sand.....	Pleasant Valley field, California.....	≈9,150.....	Many			15			162	N-1	
Chorro sands.....	Infantes field, Columbia.....	≈2,200-≈2,600.....		15	22				4	N	
Middle Pauji sandstone.....	Venezuela.....	Subsurface.....				12			24	N	
Misoa-Trujillo sandstone.....	do.....	do.....				10			24	N	
Ramillete sands.....	La Concepcion field, Venezuela.....	≈3,000.....				21			24	N	
Punta Gorda sands.....	do.....	≈4,000.....				18.5			24	N	
Upper sands.....	La Paz field, Venezuela.....	≈1,600.....				26			24	N	
Tabla sands.....	Los Manueles field, Venezuela.....	6,000-7,500.....			20	8-10			24	N	
Sandstone.....	Isle of Wight.....	Outcrop.....	1			33.8	1.73	2.07	105	A-2	Banded sandstone.

**Eocene and Oligocene**

Merecure Formation.....	Anaco field, Venezuela.....	≈7,000-≈10,000.....	Many			15-20			54	N-1	
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**Eocene to Miocene**

Sandstone.....	Wasco field, California.....	10,500-15,004.....				15			156	N-1	
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**Oligocene**

Sands.....	Saxet field, Texas.....	≈5,800.....	Many	7	45	31			120	N-1	Medium to coarse.
Do.....	do.....	≈6,300.....	Many	20	31	23			120	N-1	Do.
Do.....	do.....	≈6,900.....	Many	21	34	28			120	N-1	Do.
B zone sands.....	La Cara field, Colombia.....	1,100-2,000.....				22			4	N	
Sandstone.....	Cantons of Freiburg, Luzern, Vaud, and Zug, Switzerland.....	Quarry.....	6	1.5	13.9	5.8	2.53	2.59	63	T-4	Dip low to 25°, in part calcareous.
Do.....	Cantons of Unterwalden, Vaud, and Wallis, Switzerland.....	do.....	4	.8	4.1	2.3	2.64	2.66	63	T-4	Dip 15°-50°, calcareous.

TABLE 1.—Sandstone, siltstone, quartzite, chert, and conglomerate—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Oligocene(?)</b>											
Frio Clay (sand)-----	Amelia field, Texas-----	6,694-6,785-----				30			65	N-1	
Do-----	Anahuac field-----	6,960-7,078-----	22	23.4	37.1	30.4			123	A-9	
Frio Clay (sand No. 1)-----	South Cotton Lake field, Texas-----	≈6,500-----				30-35			170	N-1	
Frio Clay (sand No. 2)-----	do-----	≈6,500-----				30-35			170	N-1	
Marginulina sand-----	do-----	≈6,500-----				25-30			170	N-1	
Sand in Frio Clay-----	La Rosa field, Texas-----	≈5,900-----				32			60	N-1	
<b>Oligocene and Miocene</b>											
Amarillo F sand-----	Guarío dome, Venezuela-----	≈6,500-----				22-26			54	N-1	
Oficina formation (sands)-----	Anaco fields, Venezuela-----	≈4,500-≈9,500-----				18-20			54	N-1	
Do-----	Greater Oficina area, Venezuela-----	3,000-7,700-----	Many			21-30			69	N-1	Average of averages, 26 percent.
<b>Miocene</b>											
Kirkwood Formation-----	New Jersey-----	≈800-----	5	30.2	44.3	38.0	1.63	2.01	143	T-5	Fine to gravelly.
Catahoula Sandstone-----	Gulf coast, U.S.A-----	232-248-----	2	40.0	40.9	40.5			81	N-2	
Do-----	Saxet field, Texas-----	≈4,400-----	Many	29	42	35			121	N-1	Medium to coarse.
Fleming Formation of former usage-----	Gulf coast, U.S.A-----	346-1,852-----	9	31.3	50.1	41.2			81	N-2	
Lombardi sand-----	San Ardo field, California-----	≈2,100-----		40	45				8	N-1	
Modelo Formation, lower part-----	Santa Monica Mountains, Calif-----	Outcrop-----	2	22.4	24.0	23.2			80	T-2	Graywacke.
Miocene A-2 sand-----	Wasco field, California-----	13,095-13,130-----		12	24				156	N-1	
Salinas Shale (sandstone)-----	Santa Barbara County, Calif-----	Outcrop-----	1			33.3	1.78	2.11	98	T-2	Dip 55°.
Stevens sand zone-----	Paloma field, California-----	10,008-10,178-----		18	20				28	N-1	
Stevens sand-----	do-----	≈10,000-----	2			21.9	2.08	2.30	76	A-5	
Stevens sand, F-1 section-----	South Coles Levee field, Calif-----	9,294-9,438-----	103	3.8	24.9	18.9			57	A-9	Standard deviation, 4.1 percent.
Stevens sand-----	Ten Section field, California-----	≈8,100-----	Many	15	30	20			90	N-1	
Temblor Formation (sands)-----	Kettleman Hills field, California-----	6,250-9,332-----	Many			14			59	N	

Tembler Formation (sandy shales)	do	6,250-9,332	Many							59	N	300 ft. of sand.
Upper Terminal zone	Wilmington oil field, California	3,000-3,500								25		
Conglomerate	Cantons of Appenzel and St. Gallen, Switzerland	Quarry	2	1.1	1.1	1.1	2.72	2.73		63	T-4	Dips 16°-17°.
Sandstone	Cantons of Aargau, Schwyz, Solothurn, St. Gallen, Zug, Appenzell-A - Rh, Basel - Land, Bern, Freiburg, and Luzern, Switzerland.	do	15	13.3	22.1	18.7	2.19	2.37		63	T-4	Dips 7° or less.
			53	.4	17.3	6.5	2.52	2.59		63	T-4	Dips 10° or more.
Tipam series sand	Digboi field, Assam	≈ 5,000		3	27	12				30	N-1	

**Pliocene**

First grubb pool	San Miguelito field, California	≈ 6,000	800			18				60	N-1	20 wells, poorly sorted sands.
First grubb zone	do	6,570-7,447				20.6				96	N-1	
Second grubb zone	do	7,706-8,259				19				96	N-1	
Third grubb zone	do	8,472-8,938				14.2				96	N-1	

**Pliocene and Pleistocene**

Sands	Mamou, La.	510-957	4	36.2	38.7	37.8				81	N-2	
Do	Gulf coast, U.S.A.	2,062-2,135	3	40.0	40.6	40.3				81	N-2	

**Tertiary**

Sandstone	Germany	Quarry	1			29.1				72	A-3	
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**Age not specified**

Sandstone	Lancashire and Derby, England	Outerop(?)	2	12.8	13.7	13.3	2.27	2.40		73	T-2	
Sandstone (dolomitic)	Mansfield, England	Outerop	1			14.1	2.31	2.45		73	T-2	
			1			6.4	2.48	2.54		73	T-2	
Do	Nuneaton, England	do				.21				58	A-14	
Conglomerate	St. Marcet anticline, France	≈ 5,000		2	18					134	N	
Pechelbronn sand	Pechelbronn, France	Subsurface	1			17.8				9	A-6	

<sup>1</sup> E. C. Robertson, written communication, 1962.

<sup>2</sup> Superior Oil Co., written communication, 1959; D. A. Beaudry, 1950, Pore space reduction in some deeply buried sandstones: Unpublished dissertation, Univ. Cincinnati.

<sup>3</sup> R. A. Cadigan, W. H. Caraway, G. L. Gates, and F. C. Morris, written communication, 1955.

<sup>4</sup> Superior Oil Co., written communication, 1959; F. R. Hays, 1951, A petrographic study of deeply buried sandstones from the Superior Pacific Creek unit No. 1 well, Sublette County, Wyoming: Unpublished dissertation, Univ. Cincinnati.

TABLE 2.—Limestone, dolomite, chalk, and marble

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Precambrian</b>											
Grenville Marble.....	Ontario, Canada.....	Quarry.....	9	0.01	1.06	0.35	2.77	2.77	112	A-2	
<b>Cambrian</b>											
Bonneterre Dolomite.....	Near Bonne Terre, Mo.....	Subsurface.....				3.3	2.66	2.69	16	A-16	Galena bearing.
Do.....	do.....	do.....					3.30		16	A-16	
Gallatin Limestone.....	Afton quadrangle, Wyoming.....	Outcrop.....				8.6	2.61	2.70	110	T-2	
Gros Ventre Formation.....	do.....	do.....				11.0	2.40	2.51	110	T-2	
Ophir Formation (limestone).	Ophir, Utah.....	Mine.....				.26	2.78	2.78	173	A-16	
<b>Upper Cambrian and Lower Ordovician</b>											
Arbuckle Group (limestone).	Various fields, Kansas.....	2,887-4,202.....	26	1.2	19.8	10.3			123	A-9	
Do.....	Woodrow field, Oklahoma.....	≈1,900.....				2-8			95	N-1	
<b>Lower Ordovician</b>											
Ellenburger Group (limestone).	Riley Mountain, Llano County, Tex.	Outcrop.....	12	0.1	0.7	0.5	2.69	2.70	62	T-2	Sublithographic.
Ellenburger Group (dolomite).	do.....	do.....	23	1.1	12.6	4.3	2.72	2.76	62	T-2	Micro-granular.
Do.....	do.....	do.....	11	1.3	7.1	3.6	2.73	2.77	62	T-2	Fine grained.
Do.....	do.....	do.....	6	1.7	4.3	2.6	2.75	2.78	62	T-2	Medium grained.
Do.....	do.....	do.....	2	2.6	5.0	3.8	2.73	2.77	62	T-2	Coarse grained.
Ellenburger Group (cherty limestone).	do.....	do.....	1			.4	2.69	2.69	62	T-2	
Ellenburger Group (calclitic dolomite).	do.....	do.....	1			.8	2.74	2.75	62	T-2	
Ellenburger Group (dolomitic limestone).	do.....	do.....	1			1.5	2.75	2.77	62	T-2	

Do.....	Permian Basin, West Tex.	≈8,800.....	63			2.5			7	A-4	Matrix porosity. All porosity. Fracture and vug porosity.
Do.....	do.....	8,857-8,893.....	36			3.30			7	A-4	
Do.....	do.....	8,857-8,893.....	36			1.51			7	A-4	
Do.....	do.....	8,857-8,893.....	36			1.79			7	A-4	

**Ordovician**

Trenton Limestone (medium crystalline).	Rose Hill field, Virginia...	Subsurface.....				1.2			102	N-1	Producing, 2 wells. Producing, 1 well.
Trenton Limestone (finer crystalline).	do.....	do.....				.6			102	N-1	
Kingsport Formation (dolomite).	Mascot, Tenn.....	do.....	3			.7	2.84	2.85	172	A-16	
Do.....	Jefferson City, Tenn Sand Hill well, Wood County, W. Va.....	56-285 9,416.....	7 1	0.4	2.3	1.3 .6	2.78 2.71	2.79 2.72	(1) 172	A-16 A-15	
Trenton Limestone (quartzitic).	do.....	9,577-9,664.....	6	.3	2.7	.9	2.67	2.68	(1)	A-15	
Black River Limestone.	do.....	9,791-10,511.....	35	.1	1.4	.4	2.70	2.70	(1)	A-15	
Beekmantown Group (dolomite).	do.....	10,531-11,945.....	56	.1	1.1	.4	2.80	2.80	(1)	A-15	
Prairie du Chien Group (dolomite).	Wisconsin.....	Quarry.....	4	11.1	13.4	12.4	2.43	2.55	22	A-1	
Trenton Limestone (dolomite).	do.....	do.....	2	.9	1.2	1.0	2.81	2.82	22	A-1	
Kimmswick Limestone.	Dupo pool, Illinois.....	401-445.....	44	1.9	17.0	10.8			118	A-6	
Do.....	do.....	≈600.....	4	11.6	16.5	15.8			123	A-9	
Viola Limestone.....	Cunningham field, Kansas.	4,048-4,051.....	3	2.9	3.1	3.0			123	A-9	
Simpson Group.	do.....	4,051-4,117.....	36	5.7	22.3	13.3			123	A-9	
Bighorn Dolomite.....	Afton quadrangle, Wyoming.	Outcrop.....				8.6	2.59	2.68	110	T-2	
Beekmantown Group (limestone, dolomite).	Ontario, Canada.....	Quarry.....	4	1.3	12.6	4.6	2.66	2.71	112	A-2	4 localities.
Black River Group (limestone).	do.....	do.....	11	.07	1.67	.46	2.72	2.72	112	A-2	10 localities.

**Silurian**

Brassfield Limestone	Piqua, Ohio.....	Quarry.....				1.3	2.8		173	A-16	Dolomitic.
Do.....	do.....	do.....				2.7	2.6		173	A-16	
Niagara Group (dolomite).	Maple Grove, Ohio.....	do.....				8.6	2.4		173	A-16	
Do.....	Gibsonburg, Ohio.....	do.....	2	3.4	4.0	3.7	2.6		173	A-16	
Do.....	Lucky, Ohio.....	do.....	2	3.0	8.5	5.8	2.5		173	A-16	
Red Mountain Formation (limestone).	Bessemer, Ala.....	1,400.....				.9	2.83	2.84	172	A-16	
Do.....	do.....	Mine.....				.6	2.92	2.93	172	A-16	Limonitic.

Footnotes on p. E34.





D-3 zone dolomite.....	Leduc field, Alberta, Canada.	4,850-5,400.....	-----	-----	-----	13	-----	-----	86	N-1	
D-3 zone.....	do.....	5,150-5,300.....	25	2.5	3.5	-----	-----	-----	160	N-1	Dense matrix.
Limestone.....	Various localities, Germany.	-----	6	.6	2.7	6.8	-----	-----	160	N-1	Entire matrix.
						1.9	-----	-----	72	A-3	
<b>Mississippian</b>											
McClosky lime.....	Lawrence County, and Noble pools, Illinois.	1,739-2,970.....	60	2.3	25.9	14.2	-----	-----	118	A-6	Oolitic.
Do.....	Olney and Salem pools, Illinois.	1,900-3,004.....	18	5.1	14.1	10.7	-----	-----	118	A-6	Do.
Do.....	Salem pool, Illinois.	≈2,000.....	-----	-----	-----	10.3	-----	-----	5	N-1	Do.
McClosky limestone.....	Hitesville Cons. field, Kentucky.	2,525-2,578.....	-----	-----	-----	13.2	-----	-----	23	N-1	Do.
McClosky limestone (D zone).....	do.....	≈2,600.....	-----	-----	-----	13.5	-----	-----	-----	-----	-----
Maxville Limestone.....	Muskingum County, Ohio.	≈200.....	2	.9	2.0	1.5	2.77	2.79	17	A-16	-----
Maxville Limestone (marl).....	do.....	≈200.....	6	-----	-----	-----	2.67	-----	17	A-16	-----
Spargen Limestone.....	Bedford, Ind.	Quarry.....	7	11	15.4	13	2.29	2.42	172	A-16	-----
Do.....	Ste. Genevieve, Mo.	≈100.....	15	-----	-----	-----	2.59	-----	172	A-16	-----
St. Louis Limestone.....	Prarie du Rocher, Ill.	250-350.....	3	-----	-----	8	2.68	2.69	16	A-16	-----
Do.....	Ste. Genevieve, Mo.	≈50.....	6	-----	-----	-----	2.62	-----	17	A-16	-----
Boone Formation, siliceous, Do.....	Near Picher, Okla.	Mine.....	2	-----	-----	1.2	2.67	2.68	16	A-16	-----
Do.....	do.....	do.....	2	-----	-----	8.9	2.39	2.48	16	A-16	-----
Brazer Limestone.....	Afton quadrangle, Wyoming.	-----	2	-----	-----	4.0	2.64	2.68	110	T-2	-----
Madison Limestone.....	Beaver Lodge and Tioga fields, Montana.	≈8,400.....	Many	-----	-----	6	-----	-----	31	N-1	12 wells.
Do.....	Afton quadrangle, Wyoming.	-----	1	-----	-----	3.6	2.61	2.65	110	T-2	-----
Rundle Formation: Upper porous zone.....	Turner Valley field, Alberta, Canada.	≈6,900.....	48	2.0	19.6	10.8	-----	-----	55	N-1	Dolomite, limestone.
Lower porous zone.....	do.....	≈7,100.....	84	-----	-----	10.4	-----	-----	55	N-1	Do.
Upper porous zone.....	do.....	4,570-6,730.....	-----	1	20	10	-----	-----	92	T-2	Dolomitic.
Lower porous zone.....	do.....	5,020-6,970.....	-----	1	20	10	-----	-----	92	T-2	Do.
<b>Pennsylvanian</b>											
Lansing and Kansas City Formations.....	Ellingwood field, Kansas.	≈3,340.....	5	6.2	25.3	12.6	-----	-----	123	A-9	-----
Canyon reef limestone.....	Scurry field, Texas.	≈6,800.....	2,109	0	31.6	6.3	-----	-----	123	A-9	-----
Crinoidal limestone.....	Todd Deep field, Texas.	≈5,800.....	-----	-----	-----	11.7	-----	-----	78	N-1	-----
Marble Falls Limestone.....	Erath County, Tex.	3,363-3,461.....	3	7.3	20.7	15.3	-----	-----	119	A-11	-----

TABLE 2.—Limestone, dolomite, chalk, and marble—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Carboniferous</b>											
Carboniferous limestone	Midlands, England	Outcrop	24	2.2	14.9	5.7	2.52	2.58	113	T-2	30 percent MgCO <sub>3</sub> .
Limestone	Micheldean, Great Britain	do	2	9.0	9.4	9.2	2.45	2.53	105	A-2	
Do	Hilton, Great Britain	Outcrop	1			2.2	2.59	2.61	105	A-2	Under Whinsill, 2 localities.
Do	Germany	Quarry	2	.6	1.3	1.0			72		
<b>Permian</b>											
Brown dolomite	Moore County, Tex.	3,574-3,614	15	3.2	27.1	11.7			(2)	A-10	Permeable.
Limestone	do	3,614-3,644	8	6.3	12.2	8.5			(2)	A-10	
Permian limestone	Big Springs field, Texas	≈9,000	5	11.9	22.2	17.9			123	A-9	
Rex chert Member of Phosphoria Formation, Zechstein	Afton quadrangle, Wyoming					17.0	2.33	2.50	110	T-2	
Do	Germany	Outcrop	1			3.1	2.64	2.67	76	T-3	
Do	Various localities, Germany	Quarry	3	4.1	21.3	12.3			72	A-3	
Dolomite	Aktyubin area, U.S.S.R.	Subsurface	4			4.1	2.62	2.66	108	T	
Limestone	do	do	1			5.2	2.75	2.80	108	T	
Marl	Kungur salt basin, U.S.S.R.	do	5			7.6	2.62	2.70	108	T	
Do	Aktyubin area, U.S.S.R.	do	14			8.4	2.53	2.61	108	T	
<b>Paleozoic(?)</b>											
Cockeysville Marble	Cockeysville, Md.	Quarry				0.6	2.87	2.88	172	A-16	Dolomitic.
<b>Triassic</b>											
Dinwoody Formation (sandy limestone)	Afton quadrangle, Wyoming					12.9	2.42	2.55	110	T-2	
Thaynes Limestone	do			8.3	8.7				110	T-2	
Do	do		1			.7	2.65	2.66	110	T-2	
Ross Fork Limestone	do					7.0	2.52	2.59	110	T-2	

Limestone	Germany	Quarry	2	1.8	2.4	2.1			72	A-3	Oolitic.  Dip 3°-65°; in part dolomitic.  Dip about 25°.	
Muschelkalk	Mutzig, Germany	Outerop	1			1.0	2.68	2.69	56	T-3		
Do	Various localities, Germany.	Quarry	19	1.2	36.5	15.5			72	A-3		
Do	Galicja, Poland	do	1			13.4	2.46	2.59	56	T-3		
Limestone	Cantons of Vaud, Aargau, and Basel-Stadt, Switzerland.	do	6	1.1	4.4	2.9	2.67	2.70	63	T-4		
Do	Canton Tessin, Switzerland.	do	7	.4	4.0	2.0	2.68	2.70	63	T-4		
Marble	Canton Graubünden, Switzerland.	do	2	2.1	2.9	2.5	2.64	2.67	63	T-4		
<b>Jurassic</b>												
Reynolds oolite	Cairo field, Arkansas	≈7,800				17			61	N-1		Porous.
Reynolds oolitic, Member of Smackover Formation.	Dorchest pool, Arkansas	9,018-9,093		2	20	12			152	N-1		
Reynolds oolite	Schuler field, Arkansas	7,650-7,750			23	16.7			163	N-1		
Reynolds oolitic limestone	Various fields, Arkansas	7,250-7,650	4	16.4	20.0	18.0			123	A-9		
Smackover Formation	do	≈7,850	150	0	23.9	14.5			123	A-9		
Do	McKamie-Patton pool, Arkansas.	≈9,300	1,767			14.2			133	N-1		
Do	McKamie field, Arkansas	9,120-9,381	14	0	16.4	7.5			123	A-9		
Twin Creek Limestone	Afton quadrangle, Wyoming.					0.2	2.75	2.75	110	T-2		
Carmel formation (limestone).	Near Huntington Utah	5-20	6	.2	4.6	2.0	2.65	2.67	173	A-16		
Inferior oolite	Cotteswolds, England	Outerop	3	5.5	24.0	13.4	2.33	2.46	105	A-2		
Oolite	Clove Hill and Lockhampton Hall, England.	do	2	14.3	18.3	16.3	2.25	2.41	105	A-2		
New Red marl	Leamington, England	do	1	30.0	34.4	32.2			141	A-2		
Do	England	Deep boring	4	4.8	10.0	7.5			141	A-2		
Portland limestone	Great Britain	Outerop	1			8.6	2.54	2.63	73	A-2		
White Lias	Tiverton, England	do	1			9.4	2.44	2.53	105	A-2		
Limestone	St. Marcet anticline, France.	≈6,000			18-20	10			134	N		
Do	Germany		1			5.0			72	A-3		
Solenhofen Limestone	do	Outerop(?)	23	1.2	5.7	3.9	2.57	2.61	(1)	A-15		
Limestone	Cantons of Aargau, Basel-Land, Bern, Freiburg, Neuenberg, Solothurn, St. Gallen, Tessin, Vaud, and Zurich, Switzerland.	Quarry	114	.4	25.6	3.6	2.63	2.66	63	T-4		
Do	Mostly from Canton Schaffhausen, Switzerland.	do	18	.9	10.7	5.4	2.57	2.63	63	T-4		
No. 3 limestone	Dukhan field, Qatar	5,600-6,600	Many			16			38	N-1		
No. 4 limestone	do	5,600-6,600	do			21			38	N-1		

Footnotes on p. E34.

TABLE 2.—Limestone, dolomite, chalk, and marble—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Cretaceous</b>											
Dees oolitic limestone	Rodessa field, Louisiana	≈ 5,450	74	8.0	32.0	22.0			123	A-9	
Dees Coquina limestone	do	≈ 5,450	20	7.0	29.7	20.2			123	A-9	
Kilpatrick zone	Sugar Creek field, Louisiana	≈ 4,520		14	23	18			27	N-1	
Sligo Formation	Haynesville field, Louisiana, Arkansas	≈ 5,300				19.0			1	N-1	
Caddo limestone	Eastland County, Texas	2,913(?)	2	4.2	4.4	4.3	2.58	2.62	99	T-2	
Glen Rose Limestone	Bell County Texas	20.5-33.5	10	16.0	18.8	16.8	2.21	2.37	119	A-11	
Do	Ham Gossett field, Texas	5,700-6,200				18			168	N-1	
Glen Rose ("Bacon") Limestone	do	6,400-6,500				6			168	N-1	
Do	New Hope field, Texas	7,237-7,426	61	1.2	23.3	12.9			123	A-9	
Do	do	≈ 7,300	Many			18.9			154	N-1	
Do	Pickton field, Texas	≈ 7,900	380			19			164	N-1	
Rodessa Formation (limestone)	Ham Gossett field, Texas	6,600-6,800				16			168	N-1	19 wells.
Niobrara Formation (chalk)	Pickston, S. Dak	Subsurface	15				1.63		16	A-16	
Bear River Formation (sandy limestone)	Afton quadrangle, Wyoming					4.6	2.61	2.66	110	T-2	
Peterson Limestone	do					9.5	2.45	2.54	110	T-2	
Limestone	La Paz field, Venezuela	≈ 4,000-≈ 8,000				1 to 2			48	N-1	
Chalk	Balmoral, Great Britain	Outcrop	1			9.1	2.44	2.53	105	A-2	Altered by basalt.
Do	Various localities, Great Britain	do	3	17.6	42.8	28.8	1.94	2.23	105	A-2	
Do	Germany	Quarry	3	2.3	7.0	5.8			72	A-3	
Senonian chalk	Reitbrook field, Germany	Subsurface				25			124	N	
Limestone	Cantons of Bern, Neuenberg, Schwyz, St. Gallen, Unterwalden, Vaud, and Wallis, Switzerland	Quarry	29	.4	18.3	4.3	2.60	2.65	63	T-4	Folded rocks; dip 10° or more.
Globigerina (marly) limestone	Ain Zalah field, Iraq	Subsurface				0-11			38	N-1	

## Eocene

Green River Formation (marlstone).	Rifle, Colo.....	Mine.....	11	0.2	12.0	2.9	2.23	2.26	172, 173	A-16	Dip 20°-80°.
Green River Formation (limestone).	.....do.....	.....do.....	3			1.6	2.10	2.12	16	A-16	
Limestone, porous.....	Eniwetok Atoll, Marshall Islands.	≈ 4,000.....	4				1.84-1.89		17	A-16	
Limestone, hard.....	.....do.....	≈ 4,000.....	2				2.31		17	A-16	
Limestone.....	Cantons of Bern, Schwyz, St. Gallen, and Vaud, Switzerland.	Quarry.....	4	.7	2.6	1.7	2.68	2.70	63	T-4	

## Miocene

Limestone, sandy.....	Eniwetok Atoll, Marshall Island.	1,100-2,687.....	2				1.21		17	A-16	Well D. Well H. Dolomite, 0-10 percent. Dolomite, 11-25 percent. Dolomite, 26-50 percent. Dolomite, 51-75 percent. Dolomite, 75 percent.
Limestone, porous.....			2				1.83		17	A-16	
Limestone, semiporous.....							2.39		17	A-16	
Limestone, hard.....							2.25-2.51		17	A-16	
Limestone.....	Canton Schaffhausen, Switzerland.	Quarry.....	1			18.3	2.24	2.42	63	T-4	
Asmari limestone.....	Masjidi Sulaiman field, Iran.	Subsurface.....	140		22.8	5.6			88	A	
Do.....	.....do.....	.....do.....			19.3	6.6			88	A	
Do.....	.....do.....	.....do.....	27	1.1	13.0				88	A	
Do.....	.....do.....	.....do.....	12	1.5	12.0				88	A	
Do.....	.....do.....	.....do.....	8	2.5	8.9				88	A	
Do.....	.....do.....	.....do.....	2	13.0	15.8				88	A	
Do.....	.....do.....	.....do.....	7	4.2	16.1				88	A	

## Quaternary

Calcareous tufa.....	Cantons of Freiburg, St. Gallen, and Unterwalden, Switzerland.	Outcrop.....	4	7.0	27.8	19.2	2.03	2.22	63	T-4
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TABLE 2.—Limestone, dolomite, chalk, and marble—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Age not specified</b>											
Marble.....	Eastern U.S.A. (31 localities).	Mostly quarry.	100	0.4	0.8	0.6	2.74	2.75	82	T-2	
Do.....	Missouri.....	Quarry.....	4	-----	-----	2.1	2.66	2.68	82	T-2	
Do.....	California.....	do.....	4	-----	-----	.6	2.84	2.85	82	T-2	
Do.....	Tokeen, Alaska.....	do.....	3	-----	-----	.5	2.72	2.72	82	T-2	
Do.....	Tiree, Great Britain.....	Outcrop.....	1	-----	-----	1.0	2.65	2.66	105	A-2	
Oolitic limestone.....	Great Britain.....	Outcrop.....	1	-----	-----	20.3	2.16	2.36	73	T-2	
Dolomite.....	Micheldean, England.....	do.....	1	-----	-----	8.6	2.54	2.63	73	T-2	
Limestone.....	Buxton, Darby, England.....	do.....	1	-----	-----	14.1	2.31	2.45	73	T-2	

<sup>1</sup> E. C. Robertson, written communication, 1962.<sup>2</sup> Phillips Petroleum Co., written communication.

TABLE 3.—Shale, claystone, and slate

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Precambrian</b>											
Goodrich Quartzite (argillite).	Ishpeming, Michigan.....	Mine.....	3	-----	-----	-----	2.85	-----	17	A-16	
Negaunee Iron-Formation (white slate).	do.....	1,000.....	2	-----	-----	0.6	2.93	2.94	172	A-16	
Nonesuch Shale (siliceous).	White Pine, Michigan.....	Mine.....	6	1.5	1.7	1.6	2.76	2.78	16	A-16	

## Cambrian

Gros Ventre Formation (shale).	Afton quadrangle, Wyoming.	Outcrop.....				11.1	2.38	2.49	110	T-2	
Ophir Formation (shale)...	Ophir, Utah.....	Subsurface....	2			.9	2.81	2.82	173	A-16	
Ophir Formation (silicified shale).	do.....	do.....	1			.6	2.80	2.81	173	A-16	
Ophir Formation (limestone, shale).	do.....	do.....	1			.6	2.92	2.93	173	A-16	Mineralized.

## Ordovician

Martinsburg Shale.....	Bangor, Pennsylvania....	Quarry.....				1.0	2.74	2.75	172	A-16	Slate.
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## Silurian

Shale.....	Various localities, Great Britain.	Outcrop.....	5	2.0	10.1	5.2	2.54	2.59	105	A-2	
Wenlock Shale: Weathered.....	Malvern, England.....	do.....	1			14.1			141	A-2	
Unweathered.....	do.....	do.....	1			5.8			141	A-2	

## Devonian

Slate.....	Various localities, Germany.	Quarry.....	19	1.7	13.0	3.4			72	A-3	Roofing slate.
Do.....	Hele, Great Britain.....	Outcrop.....	2	1.3	3.5	2.4			141	A-2	

## Devonian and Mississippian

Chattanooga Shale.....	Irvine field, Kentucky....	Subsurface....	2	7.4	7.6	7.5	2.38	2.45	99	T-2	
Do.....	Near Smithville, Tenn....	Mine.....					2.53		17	A-16	
Chattanooga Shale, silty.....	do.....	do.....	2	1.6	1.7	1.7	2.30	2.32	17	A-16	
Hamilton shale.....	Hannibal, Mo.....	Outcrop.....	1			11.3	2.32	2.43	67	T-2	

## Mississippian

Maxville Limestone (shale).	Muskingum County, Ohio.	Subsurface....	3				2.56		17	A-16	
Shale overlying Keener sand.	Monroe County, Ohio.....	1,445-1,475.....	2	9.7	11.0	10.4	2.43	2.54	98	T-2	
Ridgetop Shale (silty).....	Near Smithville, Tenn....	≈150.....	6				2.71		17	A-16	

TABLE 3.—*Shale, claystone, and slate*—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Pennsylvanian</b>											
Allegheny Formation (silty shale)	Colver, Pa.	Mine	3				2.67		17	A-16	
Allegheny Formation (shale, slate)	Bakerton, Pa.	≈500	2			1.7	2.72	2.74	17	A-16	
Kanawha Formation (shale)	Dehue, W. Va.	Mine	6				2.75		16	A-16	
Monongahela Formation	Scotts Run, W. Va.	do	5			6.1	2.5		173	A-16	
Upper Block underclay	New Brazil, Ind.	Trench	1			19.1			3	T-2	
Cherokee Shale	Fulton, Mo.	Outcrop	2	17.0	17.2	17.1	2.29	2.46	67	T-2	
Flint clay	do	do	2	10.1	10.1	10.1	2.37	2.47	67	T-2	
Weston Shale	Bonner Springs, Kans.	do	2	15.5	16.0	15.8	2.28	2.44	67	T-2	
Chanute Shale	Independence, Kans.	do	2	14.8	15.0	14.9	2.31	2.46	67	T-2	
Chanute(?) Shale	Montgomery County, Kans.	500-975	4	7.3	10.6	9.1	2.51	2.60	67	T-2	
Do.	do	1,300-1,305	3	7.1	8.5	7.7	2.53	2.61	67	T-2	
Burgess sandstone (shale)	S. Moore pool, Oklahoma.	7,813-7,820				3-4			104	N-1	From graph.
<b>Carboniferous</b>											
Coal Measure clay	Brightside and Darnall, England.	Outcrop		12.8	14.3	13.5			141	A-2	
Do.	Near Nottingham, England.	510				13.4			141	A-2	
do	do	829				14.6			141	A-2	
do	do	1,190				10.7			141	A-2	
Middle Coal Measure Shale under basalt	St. Helens, Great Britain.	Outcrop	2	4.0	7.3	5.7	2.84	2.89	105	A-2	
do	Edinburg Castle, Great Britain.	do	1			1.6	2.58	2.60	105	A-2	
Slate	Various localities, Germany.	Quarry	4	1.2	3.8	2.5			72	A-3	Roofing slate.
Clay, nonplastic	Near Dabrowa, Poland	Mine, hanging wall.	1			.85	2.44	2.45	115	T-2	
Do.	do	Sabatziarer bed 8.	1			1.2	2.48	2.49	115	T-2	
Clay	Aktyubin area, U.S.S.R.	1,150-4,430	2			15.3	2.30	2.45	108	T	
do	do	7,610-8,510	1			12.5	2.31	2.44	108	T	



**Pennsylvanian and Permian**

Shale.....	Ponca City and Garber areas, Oklahoma.	1,000.....				17	2.25	2.42	6	N	From graph.
Do.....		2,000.....				11	2.42	2.53	6	N	Do.
Do.....		3,000.....				7	2.52	2.59	6	N	Do.
Do.....		4,000.....				5	2.57	2.62	6	N	Do.
Do.....		5,000.....				4	2.62	2.66	6	N	Do.

**Permian**

Wellington Formation (shale).	Selma, Kans.....	Outcrop.....	2	15.3	15.5	15.4	2.40	2.55	67	T-2	
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**Permian and Triassic**

Clay.....	Aktyubin area, U.S.S.R..	Subsurface....	4			16.0	2.33	2.49	108	T	
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**Triassic**

Ankareh Shale.....	Afton quadrangle, Wyoming.	Outcrop.....				9.2	2.40	2.49	110	T-2	
Woodside Formation (shale).	do.....	do.....				16.1	2.24	2.40	110	T-2	
Clay, nonplastic (Bröckelschiefer).	Heidelberg, Germany.....		1			18.0	2.21	2.39	115	T-2	Weak folding.

**Jurassic**

Morrison Formation (claystone).	Long Park, Colo.....	203-245.....	6	8.8	20.3	16.5			(1)	A-9	
Kimmeridge clay.....	Oxford and Filey, England.	Outcrop.....	2	19.0	30.7	24.8			141	A-2	
Lias clay.....	Bath and Robin Hoods Bay, England.	do.....	3	22.5	27.7	24.4			141	A-2	

Footnotes on p. E40.

TABLE 3.—*Shale, claystone, and slate*—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Cretaceous</b>											
Middendorf Formation (white clay).	Aiken and Richland Counties, S.C.	Outcrop-----	2	39.0	42.3	40.7	1.55	1.96	67	T-2	
Graneros shale-----	Hamilton County, Kans.	do	2	24.6	25.2	24.9	1.99	2.23	67	T-2	Not weathered. Ransom well. Do. Do.
Graneros(?) shale-----	do	3,029-3,950	3	9.2	11.6	10.6	2.37	2.47	67	T-2	
Do-----	do	4,485-5,006	3	8.7	9.6	9.1	2.46	2.55	67	T-2	
Pennsylvanian(?) shale-----	do	5,355-5,440	3	7.7	8.4	8.1	2.52	2.61	67	T-2	
Mentor Formation (shale).	Falun, Kans.	Outcrop-----	2	22.9	23.3	23.1	2.06	2.29	67	T-2	
Adaville Formation (mudstone).	Afton quadrangle, Wyoming.	do-----	-----	-----	-----	23.0	2.07	2.30	110	T-2	
Adaville Formation (shale).	do-----	do-----	-----	-----	-----	11.9	2.34	2.46	110	T-2	
Do-----	Sublette County, Wyo.	13,620-----	1	-----	-----	7.8	-----	-----	(?)	A	Permeability, 0.1 md.
		13,694-----	1	-----	-----	5.7	-----	-----	(?)	A	Permeability, <0.1 md.
Hillard Formation (shale).	Afton quadrangle, Wyoming.	Outcrop(?)-----	-----	13.9	26.8	-----	1.98-2.28	2.25-2.42	110	T-2	
Shale-----	Black Hills, Wyo., Mont.	-----	3	32.5	37.6	34.5	1.80	2.14	129	T-2	Dip 1°-5°. Dip 5°-10°. Dip 33°. Dip 45°. Dip 50°.
Do-----	do	-----	3	25.4	26.0	25.6	1.99	2.24	129	T-2	
Do-----	do	-----	1	-----	-----	23.8	2.00	2.24	129	T-2	
Do-----	do	-----	1	-----	-----	35.8	1.56	1.92	129	T-2	
Do-----	do	-----	1	-----	-----	25.3	1.99	2.24	129	T-2	
Wayan Formation (clay)	Afton quadrangle, Wyoming.	-----	-----	-----	-----	25.3	1.80	2.05	110	T-2	
Wayan Formation (mudstone).	do-----	-----	-----	-----	-----	28.6	1.90	2.19	110	T-2	
Gault clay-----	Aylesford and Folkestone, England.	Outcrop-----	3	18.9	28.1	24.0	-----	-----	141	A-2	
Specton clay-----	do	-----	1	-----	-----	13.6	-----	-----	141	A-2	Weathered. Unweathered. Folded.
	do	-----	1	-----	-----	8	-----	-----	141	A-2	
Gosauschichten-----	Austria(?)	Outcrop(?)-----	3	.8	4.7	2.2	2.61	2.63	115	T-2	
<b>Paleocene</b>											
Fort Union Formation: Lebo Shale Member--	Rosebud County, Mont.	Outcrop(?)-----	1	-----	-----	21.2	2.07	2.28	143	T-5	
Tongue River Member.	do-----	Outcrop-----	2	23.5	36.9	30.2	1.87	2.17	143	T-5	

## Eocene and Oligocene

Shales, sandy.....	Los Manueles field, Venezuela.	3,000-5,000				20			24	N	
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## Oligocene

Clay, plastic.....	Baden, Germany.....	Pit.....	1			26.0	1.90	2.16	115	T-2	
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## Oligocene and Miocene

Shale, undisturbed and nearly horizontal.	Eastern Venezuela.....	291-922.....	6	31.3	35.8	33.5	1.73	2.06	68	T-2	Wells AB, CD, EF.
Do.....	do.....	1,637-1,920.....	3	27.4	28.7	28.0	1.93	2.21	68	T-2	Wells AB, EF.
Do.....	do.....	2,031-2,996.....	9	22.9	28.9	25.4	2.00	2.25	68	T-2	Well AB.
Do.....	do.....	3,015-3,973.....	9	17.8	25.6	21.1	2.14	2.35	68	T-2	Do.
Do.....	do.....	4,336-4,849.....	3	14.2	17.8	16.3	2.22	2.38	68	T-2	Do.
Do.....	do.....	5,007-5,502.....	4	12.8	14.6	13.5	2.32	2.46	68	T-2	Do.
Do.....	do.....	6,013-6,175.....	3	9.1	10.6	9.6	2.42	2.52	68	T-2	Do.
Do.....	do.....	6,523.....	1			12.1			68	T-2	Well GH.
Do.....	do.....	7,749-7,994.....	2	10.3	10.4	10.4			68	T-2	Do.

## Miocene

Kirkwood Formation.....	Yorktown, N.J.....	4.....	1			51.9	1.30	1.86	67	T-2	Yellow clay.
Do.....	do.....	11.....	1			40.3	1.62	2.02	67	T-2	Yellowish clay.
		13.....	1			38.6	1.70	2.08	67	T-2	Blue clay.
Shale in Stevens sand.....	S. Coles Levee field, Calif.....	9,437-9,439.....	1			8.0			57	A-9	
Tembor Formation.....	Kettleman Hills, Calif.....	6,250-9,332.....	Many			≅3			59	N	
Clay, nonplastic.....	Austria.....	Mine.....	1			7.0	2.69	2.76	115	T-2	Slight folding.
Do.....	do.....	Subsurface.....	1			22.5	2.01	2.24	115	T-2	Above coal.
Clay (plastic).....	do.....	Pit.....	1(?)			24.0	1.90	2.14	115	T-2	Miocene(?)
Do.....	Near Egger, Austria.....		2	42.0	45.0	43.5	1.43	1.87	115	T-2	Do.

## Miocene(?) and Pliocene(?)

Cohansey sand (clay).....	Crossley, N.J.....	Outerop.....	2	36.6	37.4	37.0	1.67	2.04	68	T-2	
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Footnotes on p. E40.

TABLE 3.—*Shale, claystone, and slate*—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Minimum	Maximum	Average	Dry	Water-saturated			
<b>Pliocene</b>											
Clay (plastic in Congeria beds).	Austria.....	Pit.....	2	26.0	26.1	26.1	1.80	2.06	115	T-2	Impure.
<b>Tertiary</b>											
Clays.....	Missouri.....	Pit or bank.....	3	28.3	29.8	28.8		1.96-2.13	167	A-2	Natural state(?).
Clay.....	Various localities, England.	Outcrop.....							141		
<b>Age not specified</b>											
Clay.....	49 localities, New Jersey...	Outcrop.....	49				1.83		29		Range 1.53-2.17 gcm <sup>-3</sup> air dried. Natural state(?).
Kaolins.....	Missouri.....	Pit or bank.....						1.90	167		
Loess clays.....	do.....	do.....						2.05	167		
Gumbo clays.....	do.....	do.....						2.01	167		
Fire clay.....	do.....	Subsurface.....						2.40	167		
Shales.....	do.....	Pit or bank.....						2.38	167		
Shale.....	Phillips well, Russell County, Kans.	1,400-1,485.....	4	22.0	23.3	22.5	2.15	2.37	67	T-2	Do.
Do.....	do.....	2,575.....	2	16.5	17.6	17.1	2.31	2.48	67	T-2	Moist.
Shale, weathered.....	Near Ponca City, Okla.	37.....		37	48			1.52-1.85	6	N-2	
Clay.....						53			58	A-14	
Slate.....	Cornwall, Great Britain.....	Outcrop.....	1			5.9			141	A-2	
Slate, black.....	Moffat, Great Britain.....	do.....		3.8	5.2	4.5			141	A-2	
Slate, red.....	do.....	do.....				3.4			141	A-2	
Slate, green.....	do.....	do.....				2.1			141	A-2	
Slate, black.....	Westmorland, Great Britain.....	do.....	3	.40	.50	.49			141	A-2	
Slate, purple.....	Penrhyn, Great Britain.....	do.....				.24			141	A-2	
Slate.....	Great Britain.....	do.....	6	1.3	5.2	3.2			141	A-2	
Do.....	Settle, Great Britain.....		1			.9	2.73	2.74	105	A-2	
Slate, ordinary.....	Great Britain.....		2	.6	.6	.6	2.83	2.84	105	A-2	
Slate.....	Cornwall, Great Britain.....		2	4.0	6.0	5.0	2.60	2.65	105	A-2	
Schist.....	Great Britain.....		2	1.2	2.3	1.8	2.73	2.75	105	A-2	
Do.....	Tasmania.....		1			6.0	2.64	2.70	105	A-2	

<sup>1</sup>R. A. Cadigan, W. H. Caraway, G. L. Gates, and F. C. Morris, written communication, 1955.

<sup>2</sup>Superior Oil Co., written communication, 1959; F. R. Hays, 1951, A petrographic study of deeply buried sandstones from the Superior Pacific Creek unit No. 1 well, Sublette County, Wyoming: Unpublished dissertation, Univ. Cincinnati,

TABLE 4.—Unconsolidated materials

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Sand, clay, gravel, and alluvium of Quaternary age</b>											
Beach sand, well-sorted.....	Revere Beach, Mass.....	Surface.....	3	39.2	39.4	39.3	-----	-----	51	T-7	1 mm in diameter.
Do.....	do.....	do.....	3	40.1	40.2	40.1	-----	-----	51	T-7	
Beach sand.....	do.....	do.....	9	38.7	44.8	42.9	-----	-----	51	T-7	0.5 mm in diameter.
Do.....	Lynn Beach, Mass.....	do.....	4	41.1	43.6	42.9	-----	-----	51	T-7	Adjacent to boulders.
Do.....	Marblehead Beach, Mass.....	do.....	1	-----	-----	42.1	-----	-----	51	T-7	
Do.....	do.....	do.....	1	-----	-----	42.9	-----	-----	51	T-7	Fine, wet.
Do.....	do.....	do.....	1	-----	-----	39.0	-----	-----	51	T-7	Fine, dry.
Do.....	do.....	do.....	1	-----	-----	34.0	-----	-----	51	T-7	Coarse, damp.
Do.....	do.....	do.....	1	-----	-----	37.0	-----	-----	51	T-7	Coarser, damp.
Sand, artificially packed.....	do.....	do.....	1	-----	-----	37.9	-----	-----	51	T-7	Wet.
Do.....	do.....	do.....	1	-----	-----	37.0	-----	-----	51	T-7	Dry.
Cape May Formation (sand).....	Runyon, N.J.....	Mostly pits.....	8	30.8	45.3	40.1	1.50	1.90	143	T-5	Fine to medium grained.
Do.....	Pleasantville, N.J.....	≈1.....	4	25.5	30.0	27.7	1.74	2.02	143	T-5	Poorly sorted.
Do.....	Absecon, N.J.....	0-3½.....	4	30.8	39.9	36.6	1.63	2.00	143	T-5	Medium grained.
Cape May Formation (gravel).....	do.....	0-2.....	2	23.4	27.4	25.4	1.83	2.08	143	T-5	Loose.
Silt.....	Princeton, N.J.....	1.....	1	-----	-----	53.2	1.25	1.78	143	T-5	Recent(?)
Sand.....	Old Bridge, N.J.....	2-6.....	4	43.6	46.6	45.0	1.47	1.92	143	T-5	
Sand and gravel.....	Pine Island, La.....	122-692.....	19	24.9	40.1	32.4	-----	-----	81	N-2	Do.
Sands.....	Gulf coast, U.S.A.....	63-84.....	2	36.4	40.8	38.6	-----	-----	81	N-2	
Terrace gravel.....	Various localities, Montana.....	Surface.....	4	23.6	27.1	25.0	2.03	2.28	143	T-5	
Gravel.....	Yellowstone River, Rosebud County, Mont.....	do.....	1	-----	-----	20.2	2.19	2.39	143	T-5	
Gravel (clinkered shale and sandstone).....	Tongue River, Mont.....	do.....	1	-----	-----	29.3	1.36	1.65	143	T-5	
Sand, very fine.....	do.....	do.....	1	-----	-----	49.9	1.36	1.86	143	T-5	
Gravel.....	Fergus County, Mont.....	do.....	1	-----	-----	25.1	1.89	2.14	143	T-5	
Clay.....	Clark County, Idaho.....	56½.....	1	-----	-----	42.4	1.51	1.93	143	T-2	
Do.....	Jefferson County, Idaho.....	2¼.....	1	-----	-----	62.9	1.00	1.63	143	T-2	
Surface material.....	Rogers Dry Lake, Calif.....	Surface.....	2	-----	-----	38.1	-----	-----	98	T-2	
Upper clay member.....	Mojave River, Calif.....	Outcrop.....	1	37.8	38.3	43.1	1.55	1.98	98	T-2	Above gravel bank.
Lower clay member.....	do.....	do.....	1	-----	-----	35.7	1.73	2.09	98	T-2	Below gravel bank.

TABLE 4.—Unconsolidated materials—Continued

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gcm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
<b>Sand, clay, gravel, and alluvium of Quaternary age—Continued</b>											
Coarse sand.....	San Diego County, Calif.	do		39	41				87	T-5	Valley fill.
Medium sand.....	do	do		41	48				87	T-5	Do.
Fine sand.....	do	do		44	49				87	T-5	Do.
Fine sandy loam.....	do	do		50	54				87	T-5	Do.
Clay.....	Old lakebed, Sewerby, England.	do	1			49.5			141	A-2	
Boulder clay.....	Bridlington, England.	do	3	23.4	25.5	24.8			141	A-2	Pleistocene.
Do.....	Balby, England.	do	2	23.9	24.1	24.0			141	A-2	Do.
Alluvial clay.....	Orgreave, England.	do	1			30.2			141	A-2	Do.
Glacial clay.....	Mecklenburg, Germany.	Railroad cut.	4	37	51	45			116	A	Porosity by water content.
Glacial fine sand.....	Pomerania, Germany.	12-13.	1			42	1.52	1.94	116	T-2	
		18-19.	1			45	1.46	1.91	116	T-2	
		25.	1			39	1.63	2.02	116	T-2	
		42-44.	1			41	1.58	1.99	116	T-2	
<b>Soils of Recent age</b>											
Black Gumbo.....	Carbon County, Idaho.	Surface.	1			54.1	1.19	1.73	143	T-5	
Gravelly loam.....	Fremont County, Idaho.	do	1			53.7	1.19	1.73	143	T-5	
Loess soil.....	Caribou, Fremont, and Jerome Counties, Idaho.	do	3	53.2	69.4	61.2	1.00	1.61	143	T-5	
Soils.....	U.S.A.	do		45	65	55			155	N	Common range.
Arable soil.....	Near Hamburg, Germany.	0-2.1.	13					1.73	83	N	Natural state(?).
Loamy sand.....	do	0.6-8.7.	16				1.88		83	N	Do.
Marshy loam.....	do	Surface(?)				84.0			136	T	82 percent organic material.
Sandy loam.....	Near Hamburg, Germany.	2.1-10.2.	3				2.00		83	N	Natural state(?).
Wet sandy loam.....	do	4.9-8.2.	2				2.08		83	N	Do.

Subaqueous materials of Recent age

Coarse sand.....	San Diego, Calif.....	Sea floor sedi- ments, from 0-1 in. below depositional surface.	3			38.3		2.08	64	A-7	
Medium sand.....	do.....	do.....	3			40.9		2.00	64	A-7	
Fine sand.....	do.....	do.....	54			46.2		1.93	64	A-7	
Very fine sand.....	do.....	do.....	15			47.7		1.92	64	A-7	
Sandy coarse silt.....	do.....	do.....	7			51.2		1.86	64	A-7	
Silty very fine sand.....	do.....	do.....	7			61.3		1.68	64	A-7	
Medium silt.....	do.....	do.....	2			60.9		1.69	64	A-7	
Clayey fine silt.....	do.....	do.....	4			65.6		1.60	64	A-7	
Sand, silt, and clay.....	do.....	do.....	3			74.7		1.44	64	A-7	
Fine sand.....	Channel Islands region, California.	Sea bottom.....				29.5			153	N	
Fine silt.....	do.....	do.....				66			153	N	
Mud.....	Hudson River, near Canal Street, New York City, N.Y.	River bottom.....		77.2	88.4				89	A-7	
Do.....	Hudson River at Jersey City, N.J.	Mud on a submerged crate.				88.2			89	A-7	
Silt.....	Hudson River.....	50 ft below riverbed.				55			70	A-7	
Newly deposited material..	Mississippi River Delta.....					80-90			140	A	
Mud.....	Seacoasts, U.S.A.....			40	>90				139	A	
Soft mud.....	Clyde Sea, Great Britain.....	0-2.5 cm in mud.	9	80	87	82			106	A	
		22.5-25 cm in mud.	9	72	80	75			106	A	

83 percent  
through No.  
200 sieve.

TABLE 5.—Other rock types

Stratigraphic unit	Locality	Source of material or depth (feet)	Number of samples	Porosity (percent)			Average bulk density (gm <sup>-3</sup> )		Reference	Method of porosity determination	Remarks
				Min-imum	Max-imum	Average	Dry	Water-saturated			
Phosphoria Formation.....	Idaho, Utah, and Wyoming.		9				2.91		94		Permian.
Negaunee Iron-Formation (ore).	Ishpeming, Mich.....	Mine.....	12				4.53		17	A-16	Precambrian.
Negaunee Iron-Formation (hematitic).	do.....	do.....	3				4.07		17	A-16	Do.
Wabana series (ore).....	Wabana, Newfoundland..	300 ft. sea water plus 1,000 ft. rock.	3				3.46		17	A-16	Ordovician.
		≈1,400	3				4.26		17	A-16	Do.
Red Mountain Formation (ore).	Bessemer, Ala.....		2	2.3	3.0	2.7	3.73	3.76	172	A-16	Silurian.
Biwabik Iron-Formation "Granite".....	Virginia, Minn.....	Subsurface.....	1			.3	2.75	2.75	16	A-16	Precambrian.
	Sand Hill well, Wood County, W. Va.	13,314-13,318..	2	.2	.4	.3	2.78	2.78	(1)	A-15	
Younger rock salt.....	Near Hanover, Germany..	In place.....						2.1	14		Torsion balance.
Older rock salt.....	do.....	do.....						2.1	14		Do.
Anhydrite.....	do.....	do.....						2.9	14		Do.
Potash bed.....	do.....	do.....						1.6	14		Do.
Gypsum and anhydrite.....	do.....	do.....						2.6	14		Do.
Gypsum.....	do.....	do.....						2.2	14		Do.
Borax, Ricardo Formation (Pliocene).	Boron, Calif.....	300-1,000.....					2.14		17	A-16	33 percent ore.
Do.....	do.....	300-1,000.....					1.74		17	A-16	80 percent ore.
Do.....	do.....	300-1,000.....					1.72		17	A-16	92 percent ore.
Serpentine.....	Hilbig oil field, Texas.	≈2,500.....		2.2	25.7	22			15	N	Productive.
Altered basalt.....	Oil fields, Texas.....	Subsurface.....		21.7	35.6				138	N	

1 E. C. Robertson, written communication, 1962.



## METHODS OF POROSITY DETERMINATIONS

## TOTAL POROSITY

- T. Total porosity is determined but the method is not stated.
- T-1. Russell's method. Bulk volume ( $V_B$ ) and grain volume are measured by the displacement of an organic liquid in a volumeter (Russell tube). Percent porosity is  $100(1 - V_G/V_B)$ .
- T-2. Bulk density-grain density method. Bulk density ( $D_B$ ) is obtained from the dry weight and the loss of weight in water. Grain density ( $D_G$ ) is obtained by pycnometry. Percent porosity is  $100(1 - D_B/D_G)$ .
- T-3. Bulk density-grain density method.  $D_B$  is obtained from the dry weight and micrometer measurement for volume.  $D_G$  is obtained by pycnometry.
- T-4. Bulk volume-grain volume method.  $V_B$  is determined by loss of weight in water.  $V_G$  is determined by the displacement of liquid as in method T-1.
- T-5. Bulk density-grain density method.  $D_B$  is determined from the dry weight and the volume of unconsolidated rock in a sampling tube.  $D_G$  is determined by pycnometry.
- T-6. Bulk density-grain density method.  $D_B$  is determined from the dry weight and by liquid displacement.  $D_G$  is assumed to be constant at  $2.65 \text{ gm}^{-3}$ .
- T-7. Bulk volume-grain volume method.  $V_B$  is determined by loss of weight in water.  $V_G$  is determined by pycnometry.

## APPARENT OR EFFECTIVE POROSITY

A. Apparent porosity is determined but the method is not stated.

The following methods are all based on the determination of pore volume ( $V_P$ ) and bulk volume ( $V_B$ ). Percent porosity is  $100 V_P/V_B$ .

- A-1.  $V_P$  is determined by water absorption by immersion in hot or boiling water, followed by evacuation to the vapor pressure of water at room temperature for about 1 day.  $V_B$  is determined by the loss of weight in water.
- A-2.  $V_P$  is determined by water absorption by immersion in water at room temperature while evacuated at the vapor pressure of water at room temperature.  $V_B$  is determined from pore volume and grain density.
- A-3.  $V_P$  is determined as in method A-2, but water absorption is followed by the application of pressure from 750 to 2,250 psi.  $V_B$  is determined by the displacement of water.

- A-4.  $V_P$  is determined by water absorption under high vacuum.  $V_B$  is determined by the displacement of water. Large openings are covered with rubber sheeting to include fracture and vuggy porosity with matrix porosity.
- A-5.  $V_P$  is determined by water absorption under high vacuum (0.002 mm Hg), followed by application of pressure of 1000 bars. Method of determining ( $V_B$ ) is not stated.
- A-6. Barnes' method.  $V_P$  is determined by the volume of organic liquid absorbed under vacuum.  $V_B$  is determined by the volume of organic liquid displaced in a volumeter.
- A-7.  $V_P$  is determined as the volume of natural-state water.  $V_B$  is determined as the volume of a sampling chamber or by loss of weight in water. Where A-7 is enclosed in parentheses, method of determining bulk volume is not stated.
- A-8. A.S.T.M. method C127-42  $V_P$  is determined by water absorption during boiling for 2 hours.  $V_B$  is determined by water displacement.
- A-9. U.S. Bureau of Mines method.  $V_P$  is determined by the pressure and volume relationships of a gas system with and without a rock specimen.  $V_B$  is determined by mercury displacement.
- A-10.  $V_P$  is determined by the volume of mercury injected at 1,000 psi.  $V_B$  is determined by mercury displacement.
- A-11.  $V_P$  is determined by the volume of liquid injected by fluid flow.  $V_B$  is determined by the loss of weight in liquid.
- A-12.  $V_P$  is determined as the volume of water absorbed after evacuation.  $V_B$  is determined from the bulk density of the dry specimen.
- A-13.  $V_P$  is determined as the volume of water imbibed at room temperature and pressure.  $V_B$  is determined by the loss of weight in water.
- A-14.  $V_P$  is obtained by Fuller's conversion of Geikie's values of water absorbed at atmospheric pressure.  $V_B$  is obtained from an assumed natural-state bulk density of 2.65 (?)  $\text{gcm}^{-3}$ .
- A-15.  $V_P$  is determined by the volume of water absorbed after evacuation to 0.1 mm Hg at 80° C.  $V_B$  is determined from the loss of weight in water.
- A-16.  $V_P$  is determined by the volume of water imbibed for one week at room temperature and pressure by a specimen previously oven dried.  $V_B$  is determined by dimensional measurement.

**POROSITY METHOD NOT CERTAIN**

- N. Method is not specified.
- N-1. Very likely apparent porosity.

N-2. Probably apparent porosity.  $V_P$  probably is determined by water displacement.  $V_B$  is determined by the volume of a containing cell.

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