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SHORT PAPERS AND PRELIMINARY REPORTS

BY

N. H. DARTON, D. A. ANDREWS, W. S. BURBANK
AND OTHERS

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Bulletin 906–A

GRAVEL AND SAND DEPOSITS OF EASTERN MARYLAND

Adjacent to Washington and Baltimore

BY

N. H. DARTON

Contributions to economic geology, 1938–39

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GRAVEL AND SAND DEPOSITS OF EASTERN MARYLAND ADJACENT TO WASHINGTON AND BALTIMORE

By N. H. DARTON

ABSTRACT

Large amounts of gravel and sand are used in building in Washington and Baltimore and in road making in eastern Maryland. The material is obtained mostly from local sources on the Coastal Plain and derived from deposits from rivers old and recent. The quality of the gravel and sand is excellent, the cost of production is low, and transportation is not expensive. Fortunately the coarsest material is nearest the cities, and a large amount has come from dredging in the Potomac and other rivers, a process that yields a finished product, although in places much useless material such as stripping and mud has to be moved by the dredges.

In the summer of 1934 an extensive study was made of the gravel and sand deposits near Washington and Baltimore in continuation of investigations of previous years. The workable deposits were mapped on a scale of 1 mile to the inch, many borings were made, and representative samples were assayed as to size and components.

It was impossible to learn much regarding the extent of gravel deposits in submerged areas, especially along the Potomac River and its confluent streams, but from the continued success of extensive dredging operations it is evident that this cheap source of materials still holds large resources. These, however, are mostly under private lands outside of the main channel.

The Coastal Plain province near Washington consists largely of a plateau several hundred feet above sea level and deeply dissected by valleys, which to the north and west are so wide that much of the plateau is gone. Over a wide area, however, it is capped by a mantle of coarse gravel, sand, and loam deposited by an old delta of the Potomac River on the surface of fine-grained eastward-dipping Tertiary and Cretaceous formations of the Coastal Plain province, which were mostly of marine deposition. This mantle, which averages 25 feet in thickness, consists in large part of coarse materials in a zone of considerable width but becomes finer-grained toward the southeast. The quantity of the coarser deposits is many millions of tons. There are also similar deposits on lower terrace plains in the region, especially in Virginia southwest of Washington and at places in the Baltimore region. Another important source of upland gravel is the coarse material in the basal formation of the Potomac group, which lies on a basement of old gneiss and other crystalline rocks that rises to the surface along the western margin of the Coastal Plain province. Gravel deposits of this sort are thick and coarse in places where they were laid down on shores or in stream beds in early Cretaceous time, but in many areas they are absent, and fine-grained sediments lie directly on the old floor of crystalline rocks. The upland gravel is excavated by steam shovels, drags, or hydraulic jets and washed thoroughly to remove

adhering loam, and most of the product competes in cost and quality with materials dredged from the rivers and flats. The supply is great, but extensive commerical workings for gravel and sand are not numerous. There are pits of moderate size at many localities which yield a large aggregate tonnage, especially of material that is to be used for building or covering roads and therefore does not require the separation of loam, sand, and gravel. For concrete roads, asphalt admixture, culverts, and other uses in highway construction the sand has to be separated, the gravel graded in size, and the loam all washed out.

The basal gravel of the Potomac group is worked at various places along the western margin of the Coastal Plain. Some deposits that consist of loose gravel and sand are easily prepared, but other deposits have a loam or clay admixture, which is troublesome. In all these upland-gravel developments a suitable supply of wash water is essential, and this is not everywhere available. However, the plants have settling ponds and are so arranged that the water is used over and over again.

Various kinds of sand are produced in the Coastal Plain region, but the principal product is for use in mortar and concrete. The dredging in rivers and river flats yields a large percentage of sand available for both these uses and ordinarily in an amount exceeding the demand. Much sand comes from the upland-gravel workings, and in parts of the plateau fine sand underlies the main gravel cap. In most of the area sand for mortar is so easily obtained from local pits that little is hauled long distances. A large volume of sand occurs in the various formations of the Potomac group in the Baltimore region, and sand of the Magothy formation is worked extensively east of Washington, mostly for local use in mortar.

It was found that there was much misconception of the geologic relations of the deposits, especially by the producers of upland gravel. In the estimates of prospects, talus slopes and slides have been included in the thickness of the gravel cap, but when this loose material is removed it is found that the gravel cap is only at the top of the plateau and rarely more than 25 feet thick, although of great extent. In some such places the washing and sorting machinery has been placed too low on the slope, and the excavated material has to be moved a long distance.

GEOLOGY OF THE COASTAL PLAIN

General structure.—The Coastal Plain in Maryland is a region of plains, hills, and terraces, of which a few of the higher parts rise to an altitude of about 500 feet, and the lower part extends below sea level. It is underlain by a wedge-shaped succession of eastward-dipping, widespread sheets of clays and sands lying on an eastward-sloping floor of gneiss and other old crystalline rocks. This floor rises to the surface at Washington, Laurel, Baltimore, and Havre de Grace and constitutes the Piedmont zone to the west. To the east it sinks more than 2,000 feet below sea level near the ocean. The Coastal Plain is also widely trenched by the valleys of rivers and smaller streams and by Chesapeake Bay, which is a southeasterly extension of the valley of the Susquehanna River, submerged by tidewater.

Washington region.—The cross section in figure 1, shows the general relations and succession of formations in the Coastal Plain near the latitude of Washington. The sedimentary rocks under the Coastal Plain near Washington comprise the several formations of the Potomac group (Lower Cretaceous), somewhat more than 600 feet

thick; sand and brown sandstone of the Magothy formation (Upper Cretaceous), apparently restricted to old stream channels or beaches; the dark sands and clays of the Monmouth formation (Upper Cretaceous), 80 feet or more thick; the Aquia and Nanjemoy formations of the Pamunkey group (Eocene), more than 100 feet thick; and the Calvert formation (Miocene), which underlies the wide plateau east and southeast of the Anacostia Valley. This plateau is capped by a widely extended mantle of gravel, which in much of the area lies on the Calvert formation, as shown in plate 7, *C*. Valleys that trench this plateau are margined by terraces mantled with gravel, and the valleys are floored by alluvial deposits consisting of sand, gravel, and clay. Most of Washington is built on terraces of the Potomac and Anacostia Rivers, which consist of gravel, sand, and loam. These deposits lie on the Potomac group in the eastern part of the city and overlap the crystalline schists in the western part, where these old rocks rise to the surface. The character of these terrace deposits and some of their relations are shown in plates 2, *C*, and 3, *A*, *B*. On some of the higher ridges, such as the one extending to Tenleytown and another at the Soldiers' Home, there are outliers of the Calvert formation capped by the plateau gravel. At Silver Spring, Whiteoak, and northward are other remnants of this gravel lying on the western

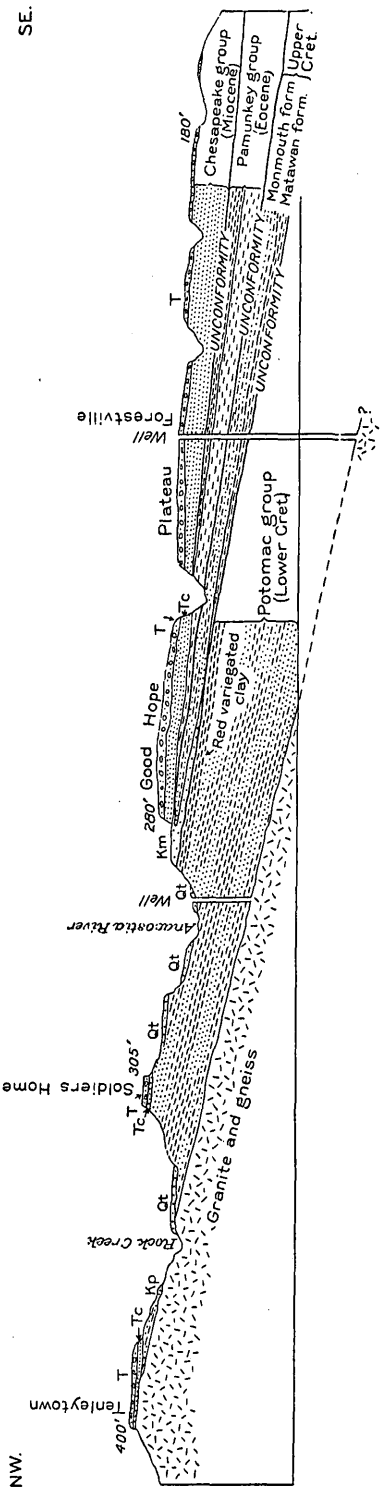


FIGURE 1.—Cross section of the Coastal Plain in Maryland east of Washington, D. C., Qt, Terrace gravel; T, plateau gravel; Tc, Chesapeake group; Km, Magothy formation; Kp, Potomac group.

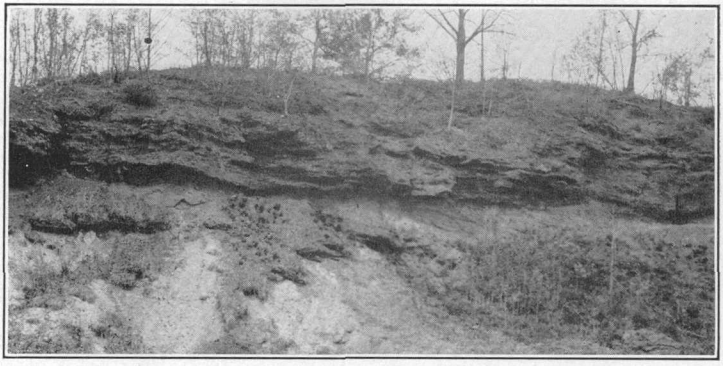
margin of the Potomac group or overlapping on the schists and granites.

The deposits of the Potomac group are comprised in several formations, of which the lowest one, the Patuxent, lies on the eastward-sloping floor of granite, schist, and other old crystalline rocks. A typical contact in the western part of Washington, where the floor rises above the surface, is shown in plate 2, *A*. In general, the floor is smooth, but there are many local irregularities in its configuration and some variation in the rate of eastward slope. The basal sedimentary deposits are mostly a mixture of gravel and sand, as shown in plate 2, *A*, grading upward into arkose, a mixture of sand and feldspar grains, and scales of mica, all derived from nearby ledges of granite or schist. Overlying beds exposed to the east are mostly clay and alternations and mixtures of sand and clay, in places containing extensive sand deposits. The Magothy formation, overlying the Potomac beds east of Washington, consists of gray or yellow sand and of brown sand with local gravelly or conglomeratic beds, as shown in plate 2, *B*. The overlying succession of dark clay, marls, and sand of the Monmouth formation, and the Pamunkey and Calvert formations occur in widely extended sheets dipping gently and also thickening gradually toward the east.

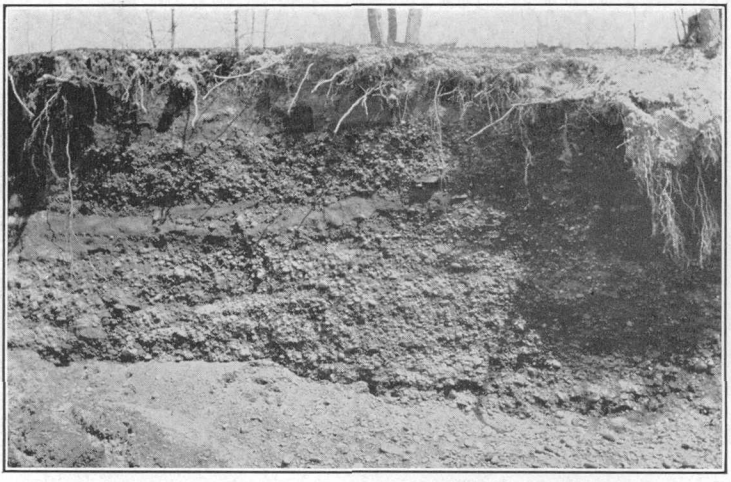
Patuxent-Patapsco region.—In the Coastal Plain northeast of Washington, east of Laurel, and eastward to the region about the Severn and Magothy Rivers, as shown in plate 6, there is a succession of Potomac and overlying sands and clays, about 1,000 feet thick, up to and including the greensands of the Pamunkey group. The Calvert and overlying formations of the Chesapeake group have been removed except in certain small outliers, and there are only a few remnants of the plateau that is so extensive in the region east and southeast of Washington. Gravel- and sand-covered terraces and alluvial flats extend along the valleys, especially those of the Patuxent and the head branches of the Anacostia. The bedrock floor of schists and other old crystalline rocks appears in the deeper valleys on a line from Washington to Baltimore through Laurel and Relay and rises rapidly toward the west in the Piedmont zone. Most of the general features are shown in the accompanying cross section (fig. 2).

The Potomac group is 600 feet or more thick, and its component formations dip eastward at a low angle. It is composed of irregular alternations of sand and clay, with a preponderance of gravelly sand near the base and thick deposits of light-gray to white sand near the top. It is overlain by the Magothy formation, a deposit of sand, in many places gravelly, 20 to 60 feet thick. In places the sand is cemented into a brown ironstone or conglomerate by iron oxide. A contact of the Magothy formation on Potomac clay is shown in plate 2, *B*, and one with Matawan clay in plate 4, *A*. The dark mixture of sand, greensand, and clay of the Matawan and Monmouth formations, in all about 150 feet thick, overlain by the greensands of the

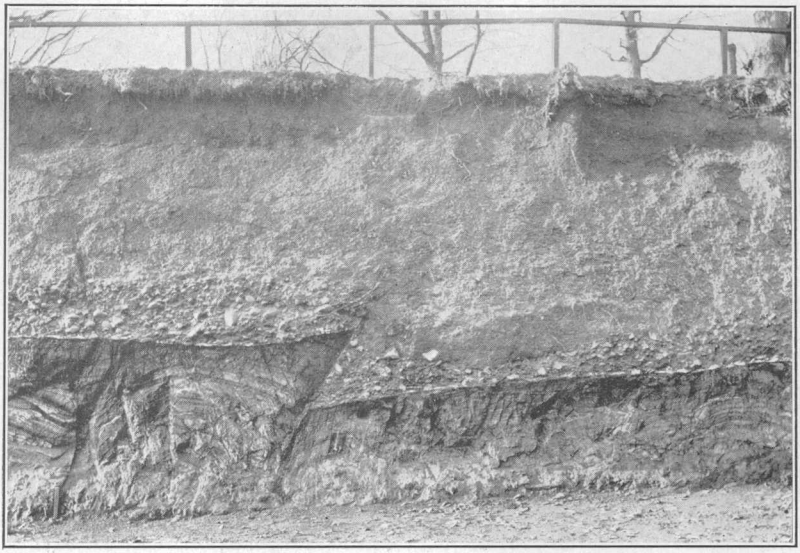
A. GRAVEL AND ARKOSE ON SCHIST, WASHINGTON, D. C.



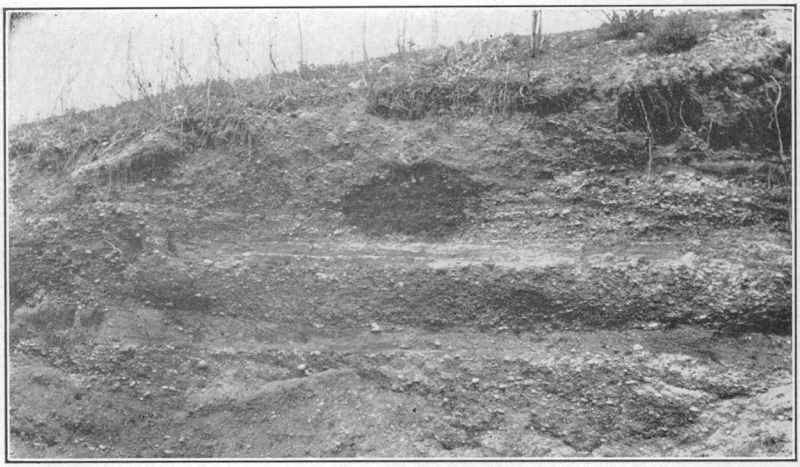
B. CONGLOMERATE OF MAGOTHY FORMATION ON CLAY OF POTOMAC GROUP NEAR ANACOSTIA, D. C.



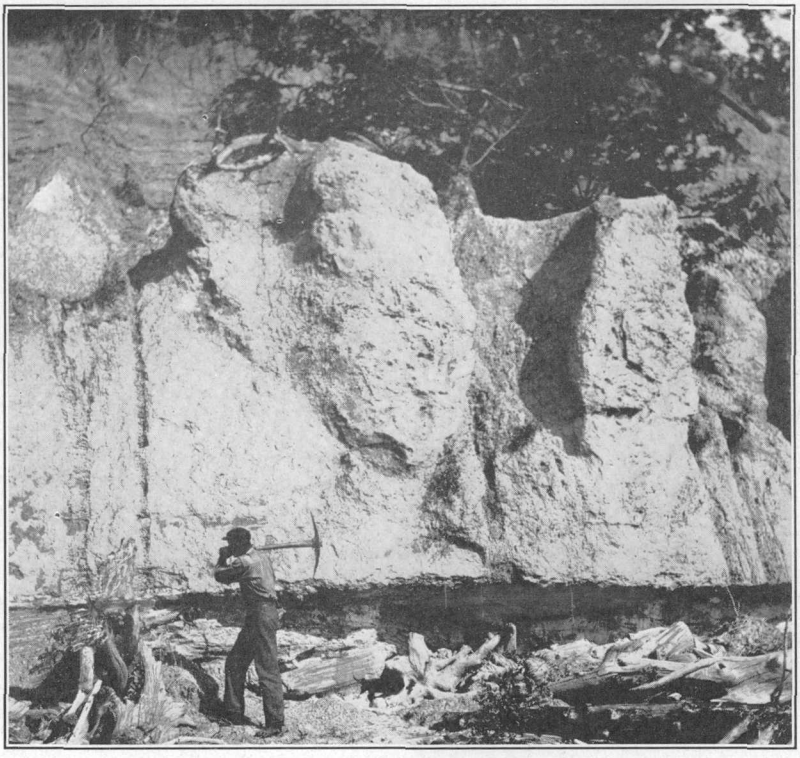
C. TERRACE GRAVEL IN CUT OF WHEELER ROAD EAST OF OXON RUN.



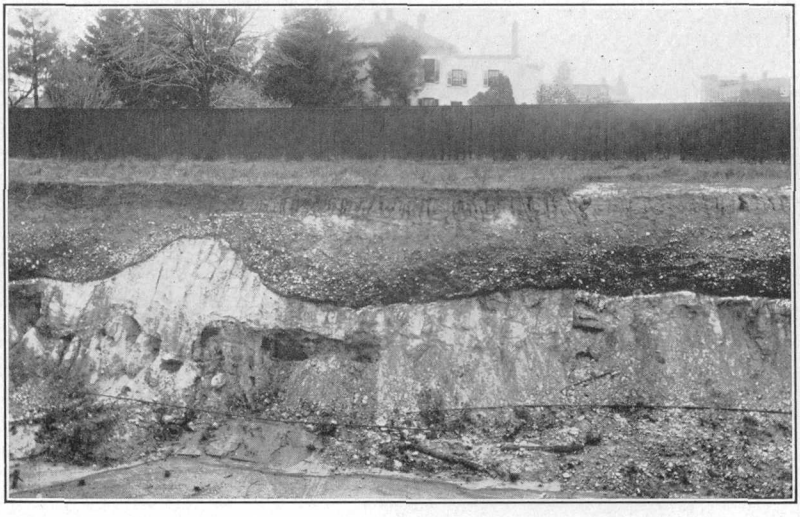
A. TERRACE GRAVEL ON SCHIST NEAR ROCK CREEK, WASHINGTON, D. C., SHOWING FAULT.



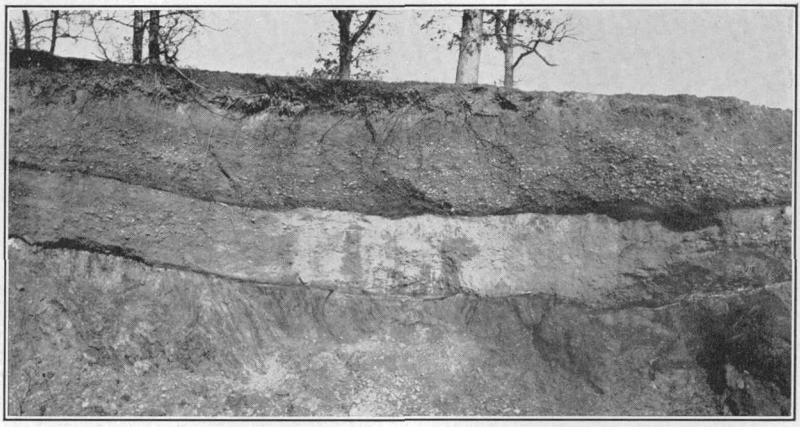
B. TERRACE GRAVEL SOUTHEAST OF ANACOSTIA, D. C.



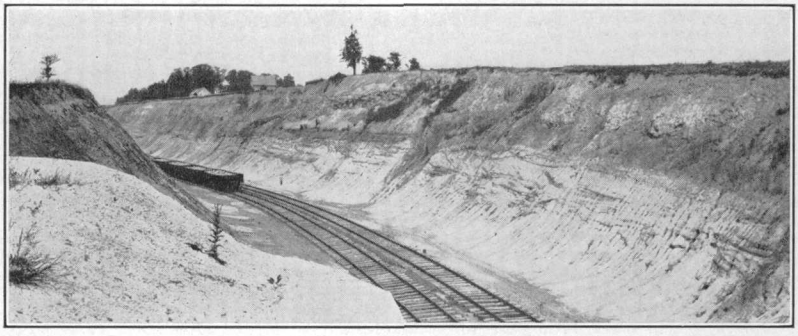
A. MATAWAN CLAY ON MAGOTHY SAND, GROVE POINT, MD.



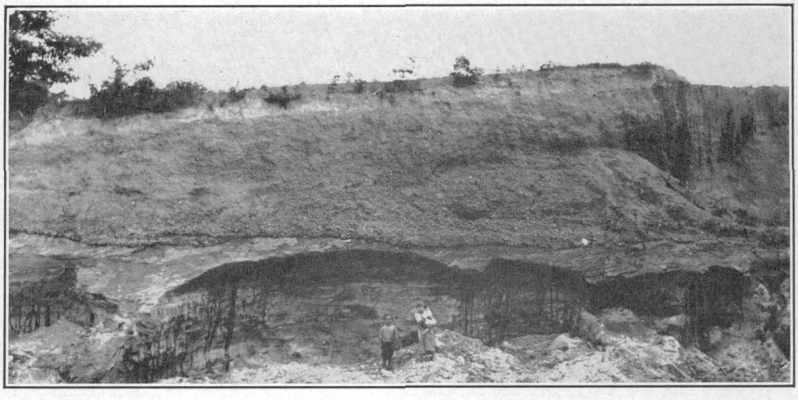
B. TERRACE GRAVEL ON POTOMAC GROUP IN BALTIMORE, MD.



A. TERRACE GRAVEL ON POTOMAC GROUP IN BALTIMORE, MD.



B. SAND AND GRAVEL OF POTOMAC GROUP IN EASTERN PART OF BALTIMORE.



C. TERRACE GRAVEL ON POTOMAC GROUP SOUTH OF BROOKLYN, MD.

Aquia formation, occupies a broad zone southeast of a line passing near Bowie, Odenton, and Round Bay. The greensands in the Matawan, Monmouth, and Aquia formations are considerably weathered near the surface, so that most outcrops present brown sands with ironstone layers.

Baltimore region and northeastern Maryland.—The character and relations of the deposits in the Coastal Plain region near Baltimore and farther northeast are similar to those in the region east of Washington. However, the thick body of overlying Upper Cretaceous and Tertiary sediments is absent, and the wide, low terraces along Chesapeake Bay are conspicuous features. The Patuxent formation, lowest of the Potomac group, lies on an eastward-sloping floor of the old crystalline rocks, but the surface of this floor appears to be much less regular than in the regions farther south. As this floor rises it is revealed and trenched by the various streams running out of the Piedmont region, and the intervening ridges are capped by the lower beds of the Patuxent formation, consisting largely of gravel and sand but in places mixed with considerable clay of various colors. Some features of this contact and of the overlying gravel and sand are shown in plates 4, *B*, and 5, *A*. The lower deposits of the Patuxent formation are mostly a mixture of gravel and sand throughout northeastern Maryland, and in places the thickness of this material is 100 feet or more. A notable exposure is shown in plate 5, *B*. This formation constitutes many of the ridges separating the many streams between

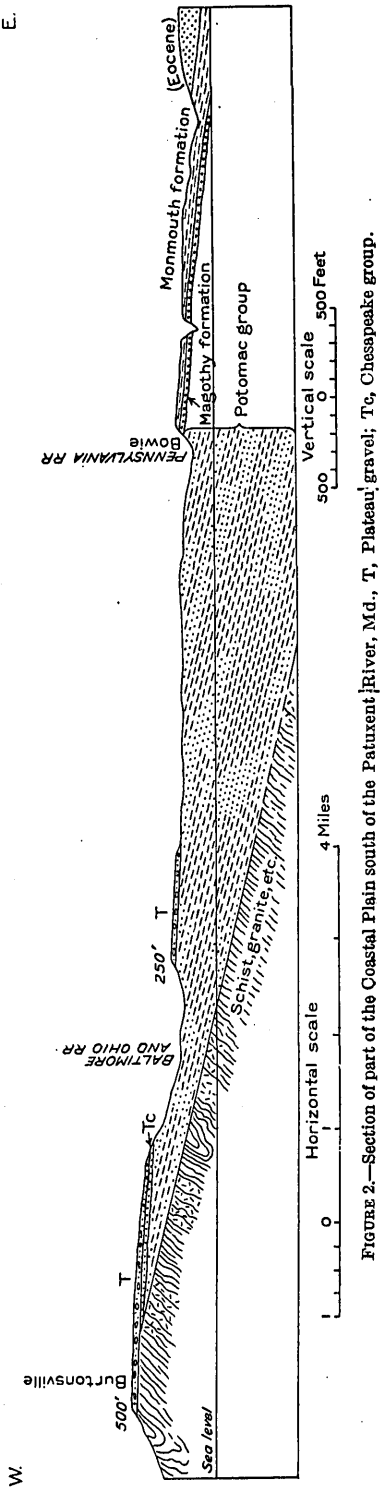


FIGURE 2.—Section of part of the Coastal Plain south of the Patuxent River, Md., T, Plateau gravel; Tc, Chesapeake group.

the Patapsco and Susquehanna Rivers and between the Susquehanna and Elk Rivers. Some of the relations in this district are shown in the three sections in figure 3. As shown in these sections the principal feature is the thick mass of sediments of the Potomac group lying on the eastward-sloping floor of old crystalline rocks. Farther east, on the east side of Chesapeake Bay, is an overlying succession, in ascending order, of Magothy, Matawan, Monmouth, Pamunkey, and other strata. They all constitute widely extended sheets dipping gently to the southeast. One of the contacts of the Matawan on the Magothy formation is shown in plate 4, *A*.

The outcrop area of the Potomac group east and northeast of Baltimore is extensively terraced at various levels, and the terraces are capped by mixtures of gravel and sand deposited by rivers at various stages. On the higher lands to the west are remnants of the old plateau with a gravel cap, as shown in the sections in figure 3. In the vicinity of Baltimore there are gravel terraces, mostly at altitudes of 100 to 200 feet, on parts of which some of the city was built. Some features of these terraces and their deposits are shown in plates 4, *B*, and 5; *A* and *C*. Lower terraces constitute wide, low plains along the west side of Chesapeake Bay from the Patapsco River to Havre de Grace; they consist mostly of sand and loam.

GRAVEL AND SAND DEPOSITS[1]

GENERAL USES AND STATISTICS

Gravel and sand are used in large amounts in building and road making, and sand has various additional uses. They are of low value per ton, but according to the returns of the fifteenth census of the United States the output is so great that they rank sixth among the mineral-producing industries of the United States, both in value of products and in the number of persons employed. A canvass of 1,165 of the larger producers of gravel and sand used in construction, in 1929, gave an output of 168,885,607 tons, with a total value of $102,311,914. This required the services of nearly 16,000 wage earners, with a remuneration of about $35,000,000, and about $20,000,000 of additional expense, exclusive of royalties and rents. These figures do not include sand used for glass and other special purposes, with an aggregate value of nearly $7,250,000. Statistics obtained from commercial producers and many local sources throughout the United States by the United States Bureau of Mines for 1934 indicate a production of 116,611,689 short tons of contruction gravel and

[1] Circulars are published by the U. S. Bureau of Mines giving very detailed information as to methods of prospecting, developing, and working sand and gravel. For the latest ones see Thoenen, J. R., Prospecting and exploration for sand and gravel: U. S. Bur. Mines Inf. Circ. 6668, 1932; Development of sand and gravel deposits: U. S. Bur. Mines Inf. Circ. 6689, 1933.

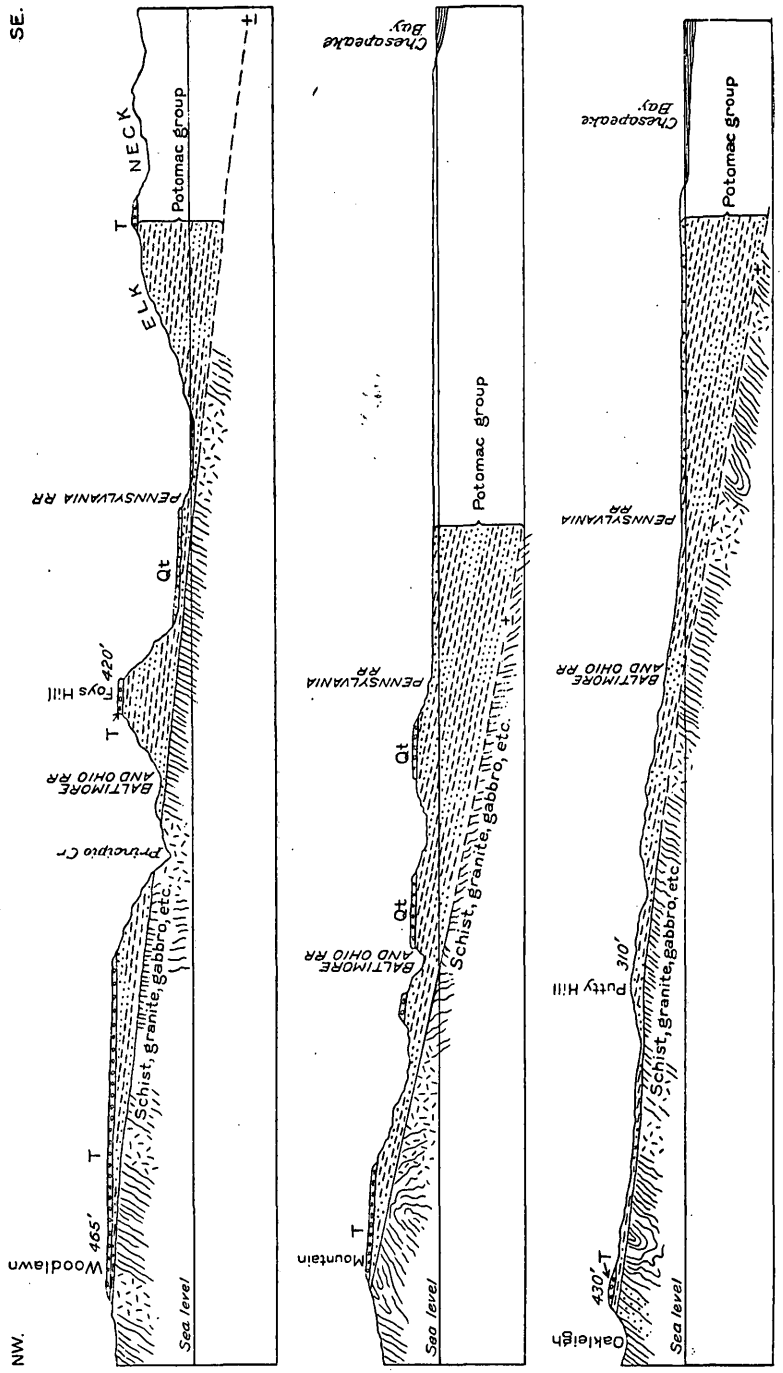


FIGURE 3.—Sections of the western margin of the Coastal Plain in northeastern Maryland. T, Plateau gravels; Qt, terrace gravels.

sand, valued at $61,247,173, exclusive of the great amount of material used in local filling. The ratio of gravel to sand is about 2 to 1, but this is partly because considerable unprepared material for local use is included in the statistics of gravel. In 1932 and 1933 average prices were from 53 to 61 cents a ton for sand and 68 to 73 cents a ton for building gravel. In 1928 to 1931 about half of the material classed as commercial was shipped by rail, but in 1933 only 32 percent was transported by that means, the remainder being moved mainly by truck and to a minor extent by water.

In 1933 and 1934 the production of sand and gravel reported to the United States Bureau of Mines[2] from nearly 2,000 commercial producers through the country was as follows:

Gravel and sand sold or used by commercial producers in the United States in 1933 and 1934, in tons

	1933	1934
Gravel:		
Concrete	11, 934, 080	14, 244, 016
Paving	17, 719, 859	19, 276, 791
Railroad ballast and similar uses	5, 427, 636	7, 177, 788
Total	35, 081, 575	40, 698, 595
Sand:		
Glass	1, 781, 423	1, 923, 614
Molding	1, 718, 251	2, 167, 731
Building	13, 024, 174	14, 534, 565
Paving	10, 903, 447	12, 476, 833
Grinding and polishing	572, 735	571, 191
Engine	1, 051, 695	1, 211, 033
Filter	24, 387	35, 750
Other	1, 948, 785	1, 703, 597
Total	31, 024, 897	34, 624, 314
Total sand and gravel	66, 106, 472	75, 322, 909
Total value	$39, 395, 027	$48, 364, 767

To this may be added about 50,000,000 tons from commercial and noncommercial operations that are not recorded in detail, much of it gravel produced by State highway departments. Of the reported production in 1934 the Maryland output was 838,096 tons of sand and 855,016 tons of gravel. The production of sand and gravel from 1910 to 1934 is shown in the accompanying table.

In 1935 the selling price in Washington for construction sand was 70 cents a ton and for gravel of all sizes $1.20 a ton.

Sand used for making light-colored glass must consist of nearly pure silica with less than 0.1 percent of iron. Its value ordinarily is from $1.50 to $1.80 a ton, f. o. b. About 1,800,000 tons is produced annually, but very little, if any, comes from eastern Maryland.

[2] Hughes, H. H., and Allan, M., Sand and gravel: U. S. Bur. Mines Minerals Yearbook, 1935, pp. 939–948, 1935.

Gravel and sand produced in Maryland, 1910–34

[Statistics compiled by U. S. Geological Survey, 1910–23; by U. S. Bureau of Mines, 1924–34. A large but unknown proportion of these materials is obtained in the Coastal Plain region]

	Gravel		Building sand		Paving sand		Total sand [1]		Total gravel and sand	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1910	416,835	$187,829	476,817	$163,213	[2]	[2]	537,558	$208,528	954,393	$396,357
1911	118,020	70,070	311,079	134,134	4,188	$1,333	364,132	176,416	482,152	246,486
1912	807,295	305,871	798,720	285,446	[2]	[2]	831,775	313,675	1,639,070	619,546
1913	861,928	281,371	421,538	192,670	[2]	[2]	959,286	341,196	1,821,214	622,567
1914	760,204	268,338	445,092	145,827	327,750	76,212	810,920	255,382	1,571,124	523,720
1915	854,180	284,410	628,460	186,327	163,304	71,517	834,247	295,145	1,688,427	579,555
1916	864,663	439,955	825,379	367,130	[2]	[2]	1,007,496	460,106	1,872,159	900,061
1917	782,614	470,751	730,323	319,632	148,721	63,515	944,826	452,712	1,727,440	923,463
1918	876,964	768,182	795,848	395,155	[2]	[2]	882,455	535,598	1,759,419	1,303,780
1919	792,716	985,686	873,952	685,403	[2]	[2]	954,871	815,196	1,747,587	1,800,882
1920	634,905	813,691	828,729	636,000	[2]	[2]	908,886	814,198	1,543,791	1,627,889
1921	670,970	854,448	689,524	536,701	122,895	91,388	872,483	738,287	1,543,453	1,592,735
1922	688,441	903,374	731,290	551,355	113,000	77,250	898,474	703,002	1,586,915	1,606,376
1923	[3] 834,617	[3] 1,121,201	323,770	313,008	772,915	546,538	[3] 1,170,622	[3] 960,863	2,044,490	2,155,353
1924	949,716	1,250,367	1,195,671	775,896	179,497	150,659	1,468,421	1,118,446	2,418,137	2,368,813
1925	[3] 1,421,598	[3] 1,841,759	1,747,347	1,264,030	277,586	198,942	[3] 2,024,933	[3] 1,462,972	3,619,534	3,500,130
1926	1,441,311	1,715,318	534,384	306,589	1,391,391	907,549	2,025,900	1,400,136	3,467,211	3,115,454
1927	[2]	[2]	274,379	165,591	1,360,714	732,748	[3] 1,636,791	[3] 899,825	2,914,448	2,185,248
1928	1,130,119	1,355,731	465,902	298,051	924,524	609,617	1,472,023	1,053,813	2,602,142	2,409,544
1929	[3] 1,394,531	[3] 1,649,527	409,473	209,228	1,311,231	858,682	[3] 1,720,704	[3] 1,067,910	3,193,486	2,853,617
1930	[3] 1,216,442	[3] 1,277,569	165,776	120,494	1,249,854	875,000	[3] 1,417,630	[3] 997,049	2,678,914	2,330,324
1931	[3] 777,337	[3] 836,496	115,411	62,770	993,573	675,199	[3] 1,108,984	[3] 737,969	2,017,788	1,701,037
1932	[3] 733,204	[3] 704,274	78,830	54,856	792,896	412,658	[3] 871,726	467,514	1,622,298	1,200,802
1933	673,223	783,726	225,802	182,103	545,095	362,437	770,897	544,540	1,444,120	1,328,266
1934	855,016	1,031,961	160,914	127,674	648,600	517,692	838,096	676,558	1,693,112	1,708,519

[1] Includes figures for engine sand, glass sand, molding, grinding, and polishing sand, fire or furnace sand, filter sand, and sand for other uses.
[2] Figures not published; included in total sand and gravel.
[3] Exclusive of unrevealed statistics of production for certain uses, included in total sand and gravel.

GRAVEL FOR ROADS

The larger part of the gravel used for road making is dug from banks in which there is a suitable admixture of sand and loam to make a compact, hard surface. Larger boulders are discarded or are separated for use in a pervious subbase, which is required in the higher-class roads. By far the largest amount used, however, is simply a sheathing of the raw material from the gravel pit, ranging in thickness from an inch to 2 inches or more. In most minor roads the gravel is spread on the old roadway but in many localities preliminary scraping and ditching is done. For work of this sort small local pits are the principal sources of supply, and the aggregate amount of gravel used has been very great; much of it is not reported. The character of the gravel in different deposits varies, but a large proportion of the capping on the plateaus and terraces of the Coastal Plain is suitable for road surfacing. The clay nearly everywhere present in moderate percentage makes an excellent binder. In places where the material is too sandy a small amount of loamy material from the roadside tempers it satisfactorily. For concrete highways and for concrete for bridges, culverts, and other structures, clean sorted gravel and coarse sharp sand are necessary. Of these an ample local supply is available in sizes and quality to meet the definite specifications for various kinds of work.

Quality.—The testing of gravel and sand as to sizes and quality is important, especially where specifications have to be met for building and road construction. Methods have been described by various writers,[3] and some laboratories, notably the one at the National Bureau of Standards in Washington, have developed standards of classification.[4]

Weight and volume.—Sand and gravel are produced and sold both by weight in tons and by volume in cubic yards. Gravel for concrete is mostly sold by the ton, and gravel for roads by the cubic yard. The weight of a cubic yard varies with different materials, shapes, and percentages of moisture. Averages calculated by the United States Geological Survey in 1915 gave the weight of a cubic yard of sand at 2,665 pounds and of gravel at 2,820 pounds. Reports from producers varied greatly, but some of the more reasonable ranges were 2,505 to 2,985 pounds for sand and 2,810 to 2,970 pounds for gravel. Theoretically a cubic yard of sand and a cubic yard of gravel, all spherical and of the same mineral composition, should have the same weight, for the pore space would be equal to about 27 percent of the volume. However, gravel is usually more heterogeneous in

[3] Wentworth, C. K., Methods of mechanical analysis of sediments: Iowa Univ. Studies in Nat. History, vol. 11, no. 11, 1926. Dake, C. L., Sand and gravel resources of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 15, pp. 1–86, 1918. Weigel, W. M., Technology and uses of silica and sand: U. S. Bur. Mines Bull. 266, 1927. Teas, L. P., Preliminary report on the sand and gravel deposits of Georgia: Georgia Geol. Survey Bull. 37, pp. 1–144, 1921. Searle, A. B., Sand and crushed rocks, London, 1923.

[4] Standards and specifications for nonmetallic minerals: Nat. Bur. Standards Misc. Pub. 110, 1930.

mineral composition, containing some heavy minerals, and it is less uniform in shape than sand. Sand is more nearly pure quartz and of more nearly uniform grain, so that it has more free space. Weighing, however, gives a much more definite measure than the "cubic yards," which are usually estimated from a wagon box whose dimensions are not accurately determined and on which the material may be heaped up. Moisture adds much to weight and but slightly to measure. A cubic yard of solid pure quartz weighs 4,478 pounds.

The grading of gravel and sand is done by sifting to assort the material by size, by chemical and mineralogical tests to determine components, and by crushing and other tests, especially of pebbles, to ascertain certain qualities. Sizes of grains are ascertained by taking carefully collected samples of certain weights, passing them through a series of sieves, and weighing the various portions to ascertain percentages. Samples to be tested in this way have to be of suitable size and intelligently selected so as to be representative of the deposit or of a shipment. Ordinarily large erratic boulders are excluded from gravel; any material proportion of very fine material is regarded as clay or "dirt." In many gravel deposits the pebbles are coated with a film of clay or iron oxide that adheres in the sifting; ordinarily most of this has been removed from gravel that has been washed. This film of clay even when small in proportion is generally objectionable in gravel to be used for concrete, as it weakens the bond between the pebbles and the cement matrix. For road making it has the advantage of increasing cohesion. A large amount of the plateau and higher terrace gravel east and south of Washington is of this character, having a sticky red loam or clay matrix. Some of it however, is not sufficiently pervious for a subbase for highways.

The strength of gravel and sand is closely related to their mineral or chemical character. Most of the gravel and sand in eastern Maryland consists of silica in the form of vein quartz, quartz grains from granular rocks, sandstone, quartzite, and chert, mixed in various proportions, together with varying amounts of fragments of softer materials. Quartzite and sandstone are predominant ingredients. These rocks consist of quartz grains cemented by silica, but they vary greatly in strength. In nearly all deposits there is a certain percentage of quartzite or sandstone, not strongly cemented, so that their crushing strength is low compared with that of vein quartz, hard quartzite, or chert. Most of the gravel deposits contain some of these "rotten" pebbles, and at some localities the proportion is sufficient to diminish seriously the usefulness of the product. In many areas the gravel contains pebbles and boulders of granite, gabbro, diabase, and other crystalline rocks, limestone, slate, and feldspar, and the finer sands contain flakes of mica and grains of feldspar. Some of these rocks are as hard as the other materials in the gravel and usually are not

objectionable, but large percentages of the softer ones are disadvantageous. Washing removes most of the silty materials mixed with sand. At some localities the gravel and sand have been cleaned by surface washing and stream flow, so that clay and dirt have been removed, but such reworked material is not present in large amount on the upland areas. Much of the gravel and sand dredged from the river beds and later alluvial deposits is free from clay coatings and admixtures of softer materials not easily removed by washing. Some of the coarse deposits, however, are very irregularly interlaminated and intermixed with bodies of silt and other fine sediments and in some places are not of satisfactory extent and thickness. Lifted by dredging and screened and washed they are mostly of high grade as to hardness and cleanness. The largest producing companies obtain their supplies from this source, in both Washington and Baltimore.

Specifications.—The Maryland State Roads Commission has established precise requirements for gravel for roads, especially for the highways and higher-class roads. It is specified that the surface shall consist of two courses of gravel and filler according to plans. The gravel must be hard, tough, and durable, perfectly clean and free from soft, thin, elongated, or laminated pieces. All must pass through a 2½-inch circular screen and be graded and used in accordance with the following requirements as to sizes and thicknesses:

Percent retained on screens	Basal course (compacted) (inches)	Surface course (loose) (inches)	Percent retained on screens	Basal course (compacted) (inches)	Surface course (loose) (inches)
60 on ¼-inch	5	4	60 on ⅛-inch	6½	4
55 on ¼-inch	5½	4	55 on ⅛-inch	7	4
50 on ¼-inch	6	4	50 on ⅛-inch	7½	4

Where the quality of the material is such that sand or clay is to be added due allowance is made in screening to permit the addition. The gravel cover complete is to be compacted to 8 inches. Some exception is made in requirements in the lower counties of the State in which material as small as one-eighth inch is permitted, but in that event the first course is laid thicker.

The standard sizes of gravel for concrete aggregate required in most Government specifications are as follows:

Screen No. 4 to ½ inch.
Screen No. 4 to ¾ inch.
Screen No. 4 to 1 inch.
Screen No. 4 to 2 inches.
¾ inch to 1½ inches.
1 inch to 2 inches.

The two last-named sizes are specified where it is desired to use separated sizes, the first to be used in combination with the No. 4 to ¾-inch size and the second with the No. 4 to 1-inch size.

The percentages by weight passing laboratory sieves having square openings are specified as follows:

	2½ inches	2 inches	1½ inches	1 inch	¾ inch	½ inch	⅜ inch	No. 4
No. 4 to ½ inch					100	90–100		[1] 0–15
No. 4 to ¾ inch				100	90–100		20–55	0–10
No. 4 to 1 inch			100	90–100		25– 60		0–10
No. 4 to 1½ inches		100	95–100		35– 70		10–30	0– 5
No. 4 to 2 inches	100	95–100		35– 70		10– 30		0– 5
¾ to 1½ inches		100	90–100	20– 55	0– 15			
1 to 2 inches	100	90–100	35– 70	0– 15				

[1] Not more than 5 percent shall pass a No. 8 sieve.

According to Federal Standard Stock Catalog SS–A–281, section 14, part 5, April 4, 1933, the following deleterious components are allowable: Soft fragments, 5 percent; clay lumps, 0.25 percent; material removable by decantation, 1 percent.

The soundness of the gravel as determined by the modified Deval abrasion test and the accelerated sodium sulphate test should show no more than 15 percent of wear by abrasion and no more than 15 percent of loss in sodium sulphate.

It is required that 50-pound samples shall be taken from each 150 tons and subjected to American Association of State Highways tentative standard method III. Clay lumps should be picked out, and any material that can be broken up with the fingers shall be so classified. Other soft materials are picked out for consideration as to their deleterious character.

The nomenclature of gravel and sand used in the United States Geological Survey is as follows:

Boulder, 10 inches or more.
Cobble, 2½ inches.
Pebble or gravel, ⅛ inch.
Small gravel, 1/12 inch.
Very coarse sand, 1/25 inch.
Coarse sand, 1/50 inch.
Medium sand, 1/100 inch.
Fine sand, 1/200 inch.
Very fine sand, less than 1/200 inch.
Silt.
Clay.

CONSTRUCTION SAND

Occurrence.—In eastern Maryland sand for construction is largely derived by screening from the Potomac, Magothy, plateau, terrace, and alluvial deposits. It is also dug directly from sand deposits in the Potomac and Magothy formations.

A large tonnage is produced from pits, dredgings, and cuts, many of them of considerable size, but sand is also dug in small quantities for local use from innumerable places in banks and stream beds. The aggregate amount of this local production is very large, but much of it is not reported in the statistics.

Standards.—In construction work sand is used mainly in making concrete and mortar, of which it forms a considerable proportion. It is also used in plaster made of plaster of paris or cement, and it is mixed with asphalt for pavement. The requirements as to size of grain and degree of purity vary greatly. For high-grade concrete the sand must be sharp, coarse, and free from dirt, shale fragments, silt, fine sand grains, and other soft materials, but these can in large part be removed by screening and washing. Much sand used for mortar is not washed.

Sand used in construction work consists of grains of rock ranging from less than one-fourth inch in diameter down to perhaps one two-hundredths of an inch. Material consisting of grains one-fourth inch or slightly less in diameter without admixture of smaller material is ordinarily designated "fine gravel." Very fine sand, especially if it is mixed with a small amount of clay, is generally regarded as loam or sandy clay, even if it includes considerable granular material, and it is of very slight usefulness in construction. Sand grains are of very many sizes and shapes, but sifting and washing remove the finer materials and also diminish the number of flat grains. Mica and clay are deleterious, especially for concrete.

The specifications of the State Roads Commission of Maryland for construction sand requires 100 percent strength, with no more than 3 percent of clay separable by decantation. In material of class A, which is required for concrete of the usual standard, the following qualities are exacted:

	Percentage passing
⅜-inch screen	100
¼-inch screen	85–100
No. 16 screen	35–80
No. 50 screen	2–30
No. 100 screen	5

The standard for sand for concrete aggregate required in Government specifications is as follows:

	Percent by weight
Passing No. 4 sieve	95–100
Passing No. 16 sieve	40–80
Passing No. 5 sieve	5–30
Passing No. 100 sieve	0–10

Variation up to 2 percent is permitted. Deleterious components are restricted to 1 percent or less. Samples weighing 25 pounds must be submitted for testing according to standard methods of the American Society for Testing Materials. The modulus of fineness is determined by adding the percentage of weight retained on United States Standard sieves Nos. 4, 8, 16, 30, 50, and 100, and dividing by 100.

For sand used in building and plastering material a recent contract of the District of Columbia in 1935 specified the following gradation of sizes:

	Percent
Passing No. 8 sieve	100
Passing No. 30 sieve	80
Passing No. 50 sieve	20

Under the same contract sand used in portland-cement mortar was to have a strength not less than 90 percent of that obtained from standard Ottawa sand and was to grade as follows:

	Percent
Passing No. 8 sieve	100
Passing No. 50 sieve	15–40
Passing No. 100 sieve	0–5

SANDS FOR SPECIAL USES

There is doubtless a large amount of sand in eastern Maryland that can be utilized for many purposes other than construction, such as glass making, molding, furnace linings, and filtration, and some of it has been used to a moderate extent for these purposes. However, in the present investigation no special study was given to these sands. Such a study would require sampling with chemical and physical tests, for which provision could not be made at this time.

On pages 35–38 of this report are given a few statements as to the requisites of sands used for glass, molding, furnace linings, filtration, and other purposes, in order that persons producing building sands may consider their suitability for other purposes.

GRAVEL IN THE WASHINGTON REGION

PLATEAU GRAVEL

Distribution.—The wide plateau lying between the Potomac River and Chesapeake Bay is mantled by a thin sheet of gravel mixed with more or less sand and loam. This material was deposited by flowing streams, mainly the Potomac River, at a time when the land was considerably lower than it is at present. Although the continuity of the plateau is broken by numerous valleys, many square miles of the gravel cover remains. The deposit is 30 feet thick in much of the region, the proportion of coarse material is large at most places, and the aggregate amount of gravel and sand is very great. In general, smaller gravel and finer materials predominate in the extension of the region to the east and south, so that the area in which gravel could be produced commercially is mostly north of latitude 38° 35′ and west of longitude 76° 45′. This area is shown on plate 1. However, the gravel, sand, and loam deposits that cap the plateau far south of these limits are available for road making and local use in building. Some portions of these deposits contain coarse materials.

Much of the plateau capping in the area shown on plate 1 consists of an intimate mixture of gravel, sand, and reddish loam, the loam adhering rather tightly to the sand and gravel. This adherence generally is very useful in road making, but it is of great disadvantage in concrete. However, the film of clay can be removed by washing in revolving screens, a process requiring considerable water and power. In some areas, moreover, the gravel is less mixed with the clay than in others, and large plants operating in such areas find no difficulty in separating the gravel and sand from the clay matrix and supplying large amounts of material suitable for making concrete.

General relations.—Most persons have an erroneous idea of the thickness and relations of the gravel deposits in the plateau areas. This is mainly because there is a thick talus or wash of gravel lying on the slopes below the gravel cap and partly also because generally the gravel lies on a surface that slopes toward the valleys. This relation is shown in figure 4. At this place where the top of the plateau is at

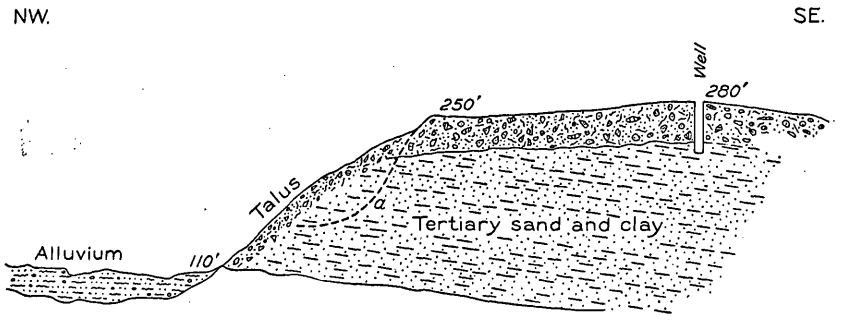


FIGURE 4.—Typical section of the gravel deposit of the plateau southeast of Washington.

an altitude of 280 feet and the foot of the gravelly slope at 110 feet, it might be inferred that the gravel bank would be 170 feet thick and possibly continuous with the alluvial gravel deposit in the valley. This would appear to be the relation in the early stages of excavation, but eventually as the face was cut back to the point marked *a* it would be found that the main body of gravel was in the cap and had a thickness of only 30 feet or less. However, suitable test pits on the top would reveal this fact in advance, and such pits should be dug before estimating the probable yield per acre and planning for the location of machinery. A series of test pits is always advisable also to ascertain the percentage and quality of the various sizes of gravel, the amount and character of the sand, and the amount of washing required to clean the products to the standards required in most specifications for concrete making. An adequate water supply is absolutely essential, and it must be remembered that many of the springs and smaller streams dwindle greatly in very dry seasons.

However, when a good reservoir is established the water can be used over again many times, and depletion by leakage and evaporation may not be great.

Relations of the gravel to underlying formations.—Most of the gravel, sand, and loam covering the plateau southeast of Washington lies on fine sand and clay of the Calvert formation, of Miocene age, a somewhat irregular surface which slopes gently to the southeast. A contact of this kind is shown in plate 7, *C*. The gravel occupies old river channels that were shallow and criss-crossed or interlocked, so that the resulting deposit is an irregular sheet. Excavations, especially wells, quarries, and some of the deeper road cuts, show a thickness of about 30 feet as a maximum, with lesser amounts in some areas. In general the deposit thins greatly to the north and east, especially in the hills and ridges near Upper Marlboro. The predominating material is a mixture of sand, gravel, and loam in varying proportions, so that no two cross sections are closely alike. Near the top there is usually a preponderance of buff loam, which grades down to bodies of coarser gravel interbedded to some extent with irregular deposits of finer materials, all typical of deposits by a river with shifting courses and varying currents.

On the high ridges north of Washington at intervals from Silver Spring to and beyond Laurel the gravel of the plateau remnants lies mostly on sand of the Potomac group, in a few areas overlapping westward onto the granite and gneiss.

Good Hope region.—In the eastern part of the District of Columbia the gravel cap of the plateau ranges from 20 to 30 feet in thickness, and although course materials preponderate, there is much admixture of sand and loam. A section at the southwest corner of Thirty-first Street and U Place SE. shows a top member of reddish loam 3 to 5 feet thick, with a few scattered pebbles, which consists of about 70 percent of sand and 30 percent of clay. Below this is 4 to 5 feet of gravel containing the following:

	Percent
Gravel larger than 2 inches	5
Gravel 2 inches to 1 inch	20
Gravel less than 1 inch	25
Sand	50
Clay	5

This is separated by 1 foot of loam from a basal gravel member 5 to 6 feet thick with the following components:

	Percent
Gravel larger than 2 inches	5
Gravel 2 inches to 1 inch	25
Gravel less than 1 inch	20
Sand	40
Clay	10

On the Good Hope-Naylor road just east of Alabama Avenue, where the gravel cap is about 15 feet thick, it consists of about 5 percent of gravel larger than 2 inches, 15 percent of gravel from 2 inches to 1 inch, 15 percent of gravel less than 1 inch, and 65 percent of sand, clay, and loam.

Silver Hill region.—The section exposed in the cut of the Southern Maryland Highway a mile southeast of Silver Hill (pl. 1) shows clearly the character of the gravel cap and practically its entire thickness. At the top is 3 to 4 feet of clay and loam. Next below is fine gravel (sample 1) grading down irregularly into fine gravel mixed with considerable buff loam (samples 2 and 5). A thick deposit of coarse gravel (sample 3) lies on a basal member of alternating deposits of sand loam, and fine gravel (sample 4).

Analyses of gravel 1 mile southeast of Silver Hill, Md.

Size	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
½-inch or more	18	20	57	2	23	24
½ to ¼ inch	10	5	3	5	11	7
¼ to ⅛ inch	16	10	7	8	13	11
Fine sand and clay	56	65	37	[1] 85	57	60

[1] Very little clay.

The largest excavations in this region are those of Frank Carozza on the edge of the plateau on a branch of Henson Creek 1 mile southeast of Silver Hill. A water supply has been developed by damming and excavating a small creek making a reservoir, part of which is used for settling the silt. Much of the excavating is done by a "little giant" water jet which softens and undermines the gravel and washes away clay and dirt. The material is lifted into a revolving screen by clam shell and conveyor. The gravel cap is about 30 feet thick, has about 8 feet of sandy loam overburden, and lies on fine sand of the Calvert formation. The section in figure 5 shows the principal features. (See also pl. 8, *B*.)

Most of the gravel is clean, the proportion of coarse sand is moderate, and practically all clay washes out in hydraulicking or on the screens. Boulders occur in very moderate proportions. Most of the pebbles are hard quartzite, but some are vein quartz and chert. Only a few of the pebbles crush under moderate pressure.

The Prince George Gravel Co. is operating extensively in the edge of the plateau on the east side of Henson Creek Valley, 2 miles southeast of Silver Hill. The pits and works are a few rods northeast of the Southern Maryland Highway, and the products are delivered by truck. The capacity of the plant is stated to be about 700 tons a 10-hour day, and the products are high-grade gravel and sand for concrete and other uses. The water supply for washing is obtained

from a pond fed by an excellent spring. The gravel is excavated by a steam shovel and hauled a few rods to screens and conveyors, where it is thoroughly washed and sorted. In this vicinity the gravel is not very highly coated with the red loamy clay that forms the matrix for the gravel in much of the plateau region. The products from this plant are gravel of 2- to 1¼-inch size, some larger gravel mostly 3½ to 2 inches, considerable three-fourths-inch gravel and pea gravel, and 20 percent or more of sand. The plateau cap here is about 25 feet thick and includes a small amount of surface loam and irregular streaks of

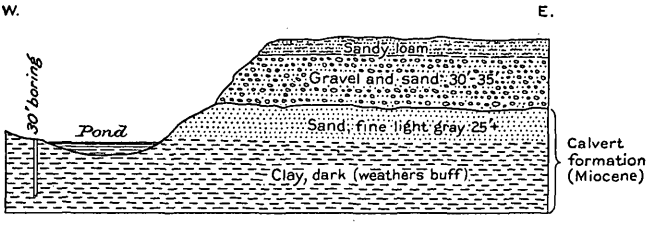


FIGURE 5.—Section at Carozza gravel pit, southeast of Silver Hill, Md.

sand and loam. It lies on fine light-colored sand of the weathered Calvert formation, which also is excavated to some extent for making mortar. In this vicinity this sand member is 30 feet or more thick including a thin layer of blue clay, and it lies on the blue clay of the medial portion of the Calvert formation (Miocene).

In a pit for road material just north of the road about a mile southeast of Suitland (pl. 1) the gravel is intermixed with considerable red loam of rather tenacious character and is streaked with coarse sand. Four samples showed the following components:

Analyses of gravel 1 mile southeast of Suitland, Md.

Size	Sample 1	Sample 2	Sample 3	Sample 4	Average
1½ inches and larger	10	9	18	15	13
1½ to ½ inch	13	11	12	15	13
½ to ¼ inch	11	12	13	12	12
¼ inch or less	66	68	57	58	62

NOTE.—This composition shows a marked fining of material toward the east.

In cuts on the Southern Maryland Highway a mile northwest of Silver Hill (pl. 1) the gravel cap of the plateau consists of 20 feet of gravel with more or less reddish sand and loam admixtures, grading up into 5 feet of sandy loam, mostly fine-grained. The gravel contains about 10 percent of pebbles more than 2 inches in diameter, from 30 to 35 percent of pebbles 2 inches to 1 inch, and 15 to 20 percent of material less than 1 inch, the remainder being sand and clay. There is but little sorting or arrangement in the deposit, but a thin horizontal bed of ironstone occurs near the middle. About Silver Hill 31 feet is

the general average thickness of the plateau deposit. A well on the Soper farm in this vicinity did not reach the base of the gravel at 32 feet, and it penetrated an overlying bed of clay 6 feet thick. There is more or less of this surface clay at all localities in this vicinity. In wells on the Dorsey farm near Silver Hill the surface clay is 1 to 5 feet thick and lies on 5 to 8 feet of sandy loam. Next below is red sandy loam mixed with gravel, 18 to 19 feet thick, lying on fine soft white sand (Calvert). One well nearby was in red gravel and sand from 8 to 23 feet.

Oakland-Forestville region and northward.—In a gravel pit furnishing road metal a short distance west of Oakland (pl. 1) the deposit contains about 70 percent of sand and clay, 25 percent of gravel measuring 2 inches to half an inch, and 5 percent of smaller gravel.

According to Mr. Boswell, well digger, the gravel cap at Forestville averages about 27 feet in thickness and lies on fine white sand of the Calvert formation. One pit near Forestville shows a 20-foot face of gravel.

The northernmost occurrence of the plateau gravel in any useful amount is on the high hill nearly 2 miles due east of Seat Pleasant post office (pl. 1), which has a cap about 20 feet thick, about 1 acre in extent. It has been extensively excavated for road making. Most of the pebbles are less than 1 inch in diameter, and the matrix is sand with some reddish clay. A few large boulders occur; one of quartz schist is 10 by 6 by 2 inches. The following screen tests were made of well-averaged samples from the quarry face:

Analyses of gravel 2 miles east of Seat Pleasant, Md.

[Percentage]

Size	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Average
Larger than ½ inch	10	10	9	9	24	29	21	16
¼ to ½ inch	10	8	10	10	10	12	10	10
⅛ to ¼ inch	15	15	16	18	13	18	14	15
Sand and clay	65	67	65	63	53	41	55	59

Southern Prince Georges County.—The gravel cap of the plateau is trenched by the Southern Maryland Highway 3 miles northeast of T B (pl. 1); in the ascent to the south from Piscataway Creek. The relations are shown in figure 6. The following analyses were made on samples collected at regular intervals from north to south. The deposit is about 20 feet thick and lies on white, mealy sand of weathered Calvert formation:

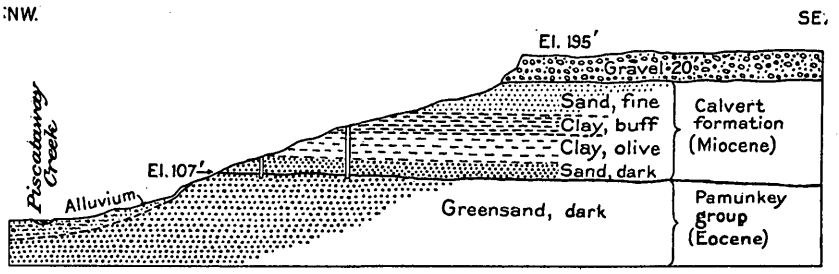


FIGURE 6.—Section of the plateau on Southern Maryland Highway about 3 miles northeast of T B, Md.

Analyses of gravel 3 miles northeast of T B, Md.

[Percentage]

Size	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
1½ inches and larger	19	24	45	19	23	26
1½ to ½ inch	32	30	15	22	16	23
½ to ¼ inch	9	8	22	15	10	13
Less than ¼ inch	40	38	19	44	51	38

There is much variation in the sizes of pebbles from place to place and up and down in the section, but pebbles 1½ inches and larger in diameter average more than 25 percent. The pebbles near the top and bottom of the section are mostly smaller. Gravel from one-fourth to one-eighth inch in diameter constitutes about 10 percent of the deposit, and the finer material is predominantly sand rather than clay. At the top there is a local sand deposit from 1 to 4 feet thick which has been utilized locally for making mortar.

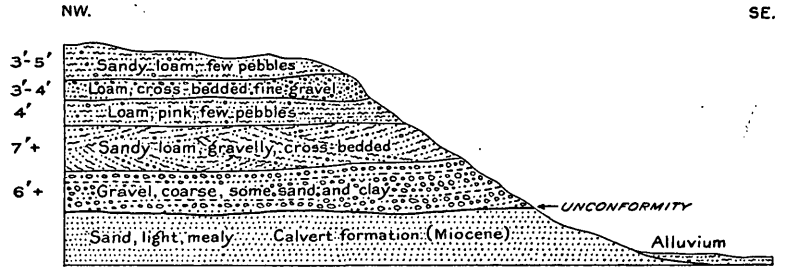


FIGURE 7.—Section of plateau gravel deposit on highway 5 miles southeast of Waldorf, Md.

Charles County.—An excellent cross section of the gravel cap of the southern extension of the plateau is afforded by the deep cut of the highway on the west side of Zekiah Swamp, 5 miles southeast of Waldorf (pl. 1). It presents the features shown in figure 7. The lower gravel bed contains gravel ranging in size as follows: 2 inches or larger, 5 percent; 2 inches to 1 inch, 20 percent; 1 inch or less, 10 percent; sand, 60 percent; clay, 5 percent. This lower member grades up into a 7-foot deposit containing about 50 percent of gravel,

most of which averages from half an inch to 1¼ inches in diameter, with a large admixture of sand and loam. The higher beds contain considerable gravel, some of it between one-half and 1 inch in size but consisting mostly of finer material. The entire bank except the top cover of loam (3 to 5 feet) would yield only about 20 percent of merchantable gravel; the fine sand would average 25 percent; loam 55 percent; and gravel larger than 2 inches not over 1 percent.

In road cuts about three-quarters of a mile southwest of Allens Fresh and south of the area shown on plate 1 the plateau capping consists of an upper member of loam about 10 feet thick and a lower member 20 feet thick, of cross-bedded orange-colored sand containing a small admixture and some interbeds containing about 5 percent of small gravel. Most of the gravel is less than half an inch in diameter, but there are a few scattered larger pebbles.

A cut on the Dentsville-La Plata road about half a mile east of Newtown shows a clear section of the plateau gravel lying on sand of the Calvert formation (Miocene), as shown in plate 7, *C*. At the base is a deposit of coarse gravel about 1 foot thick containing a few clay pebbles from the underlying Calvert formation. Above this is 3 feet of cross-bedded loam containing about 10 percent of small gravel (mostly less than 1 inch in diameter), next a 6-foot gravel bed, and at the top about 5 feet of sandy loam with but little gravel. The 6-foot gravel bed consists of about 40 percent of gravel larger than 1 inch in diameter, 40 percent of gravel less than 1 inch in diameter, and 20 percent of loam. This material is very good for road making but not advantageous as a source of gravel for use in concrete.

On the Dentsville-La Plata road about a mile east of La Plata a section of the plateau cap shows the following components:

Section of gravel cap about 1 mile east of La Plata, Md.

	Feet
Loam, some gravel in places	5
Gravel with most pebbles near 1 inch in diameter and about 30 percent of sandy-clay matrix	6
Clay with scattered pebbles, and boulders, a few as much as 10 inches in diameter	1 to 2
Sand of Calvert formation.	

On the bluff at the edge of the terrace plain half a mile east of Chapel Point, the capping consists of an upper member of red loam about 10 feet thick with few scattered pebbles, mostly small, and a lower member, 10 feet thick, of gravel in layers. At the top of this lower member are irregularly alternating beds of loam and gravel containing about 50 percent of gravel, mostly from 2 inches to half an inch in diameter, with a few larger scattered boulders. Near the base there is a thick mass of coarse gravel, much of it from 6 to 3 inches in diameter, and about 20 percent of gravel less than 2 inches in diameter.

The matrix of reddish sandy loam constitutes from 20 to 25 percent of the deposit.

Washington-Laurel region.—The Contee Gravel Co. has an extensive excavation on the hillside near the headwaters of Indian Creek, 2 miles northwest of Muirkirk (pl. 6). The floor of this pit is about 240 feet above sea level. The product is clean, hard gravel, mostly quartzite, concrete sand, and sand for mortar. The excavations began low on the slope in a mass of talus that furnished much gravel and sand, but in advancing westward they have cut into the edge of the higher slope. This has a cap of gravel of a remnant of the old plateau but is underlain by a thick body of sand of the lower formation of the Potomac group. The relations are shown in figure 8. At the beginning of operations it was supposed that the talus material was the outcrop of a very thick gravel deposit, but as excavation progressed the fine sand of the Potomac group was revealed. This sand is of excellent quality for mortar and does not contain much gravel or coarse sand.

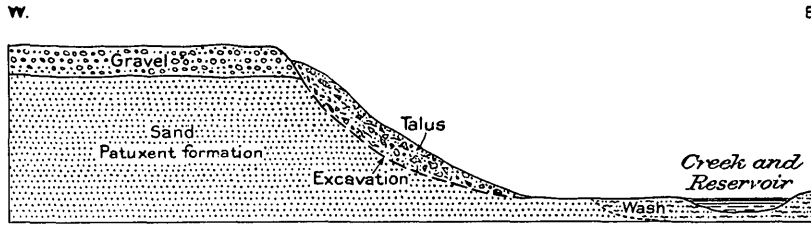


FIGURE 8.—Section of gravel and sand pits of Contee Gravel Co. 2 miles northwest of Muirkirk, Md.

The ordinary working capacity of the Contee plant is about 700 tons a day, consisting of the following materials:

	Tons
Large gravel, 1¼ to 2¾ inches in diameter, for road base and heavy foundations	100
Medium or 2-inch gravel, 1¼ to ½ inch in diameter	300
Pea gravel, ½ to ⅛ inch and smaller	40
Sand, washed; suitable for concrete	300

The proportions vary greatly in different parts of the workings, especially in the talus materials, and in places there is more or less admixture of the fine-grained Potomac sand.

TERRACE GRAVEL

Occurrence.—At a level about 100 feet below the high plateau that occupies a wide area east and southeast of Washington are lower terraces of considerable extent, which are covered by gravel and sand deposits laid down by the Potomac and associated streams after the region had been uplifted about 100 feet and widely trenched. This

terrace is conspicuous in Congress Heights (pl. 1), about St. Elizabeths Hospital, and in Mount Pleasant, in the northern part of Washington, also west of Alexandria. This sheet of river deposits is from 20 to 25 feet thick in greater part, and much of it consists of material closely resembling the older deposit that mantles the higher plateau. In general, however, it contains less of the red-loam admixture, especially as a coating on the gravel, so that the gravel is easier to clean for concrete. The deposits have been dug at many places, but none of the operations have been large, and nearly all the material has been used for road making. The larger areas of these terrace deposits are shown on plate 1 but there are many small ones which have had to be omitted. The character of this material varies greatly from place to place. Characteristic exposures are shown on plate 5.

Gravel pits.—Several small pits have been made about Anacostia and on the ridges on each side of Oxon Run.

At a gravel pit 3 miles south of Oxon Hill School and a short distance northeast of Broad Creek settlement the gravel of the 160-foot terrace is well exposed. It has been excavated for road building, and the face of the pit is about 20 feet high and 80 feet long. Samples taken along this face at regular intervals from west to east show the following assortments of sizes:

Analyses of terrace gravel 3 miles south of Oxon Hill, Md.

Sizes	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average
Larger than ½ inch	23	30	15	25	20	24	23
½ to ¼ inch	10	9	10	13	10	13	11
¼ to ⅛ inch	19	11	20	10	70	63	66
Sand and clay	48	50	55	52			

A few large boulders occur in the upper part of the deposit. Some of the beds show well-marked stratification. It will be seen from these analyses that the material closely resembles the cap on the plateau farther northeast.

RIVER AND VALLEY DEPOSITS

Potomac River.—The largest production of gravel and sand in the Washington region has come from dredging in the Potomac River, either in the bed of the stream or in the adjoining low banks. Some of the product has been dredged from the ship channels, the coarser detritus being saved and the fine-grained washings returned. This dredging in the river channel has been done under authorization of the War Department, which has jurisdiction over navigable streams. The most extensive dredging, however, has been in bars and delta deposits away from the channel. The Smoot Corporation has been dredging along the Potomac River since 1899 and has produced a vast amount of sand and gravel amounting in some years to more

than 1,000,000 tons. Some is also produced by the Capital Materials Co., and for a time the Columbia Gravel Co. was engaged in dredging along the river. The coarser deposits have been found to be somewhat variable in extent, thickness, and purity, and there are large areas in which the predominance of fine-grained material is too great.

There have also been extensive excavations by dredging in the banks of the Potomac River and of confluent streams, notably Broad Creek and Piscataway Creek. In the deltas of these streams there is much coarse material, brought down from the plateau and terraces to the east and north. The deposits consist of an irregular mixture and alternations of coarse and fine materials, but the finer sediments are washed out in the dredging process, and sand and gravel are separated and sorted on the screens on the dredges.

Among the larger areas of the more recent dredging operations in the alluvial flats on or near the Potomac River are the wide tracts on the east bank about a mile southeast of Jones Point, on the south side of Broad Creek not far west of Silicia, on the south side of Piscataway Creek about a mile south of Fort Washington, and at the mouth of Oxon Run (pl. 1). This material is all taken on barges to Washington, where it is stored in various places for commercial distribution. A typical river dredge is shown in plate 8, *C*.

Indian Creek.—A large amount of sand and gravel is obtained by dredging from Indian Creek a short distance north of Branchville (pl. 6) by the A. H. Smith Gravel & Sand Co. The dredging is done in the alluvial bottom, and a long basin has been excavated. The material lifted is carried by barges to a screening and washing plant, where practically all clay and dirt are removed and the gravel and sand assorted. The production ranges usually from 50 to 200 tons a day, including ordinary gravel of various sizes, considerable pea gravel, concrete sand (98 percent pure silica), and building sand.

Patuxent River.—The Massaponax Sand & Gravel Co. has a large plant on the south side of the alluvial flat of the Patuxent River a short distance east of Arundel station on the Pennsylvania Railroad (pl. 6). A few years ago the average daily production was about 25 carloads of 50 tons each, but for the last year or two it has diminished to less than one-quarter that amount. The gravel is lifted by "clam shells", loaded on cars on temporary tracks, and hauled up an incline to revolving screens. It is then conveyed to washers and sorting screens, and the finished products are kept in storage piles, as shown in plate 8, *A*. The material is shipped on the nearby railroad and formerly also on the Washington, Baltimore & Annapolis Electric Railroad, now abandoned.

These alluvial deposits extend all along the river from Laurel down, but the amount of suitable material available varies greatly from place to place.

The Alan Barton Co. is producing gravel and sand in large amounts from the flat of the Little Patuxent River just east of Brager station on the electric railroad. The material is passed through screens for washing and sorting, and excellent gravel and sand for concrete and other purposes are obtained. This material has been derived from the gravel-capped terraces and the detritus of the crystalline rocks in the region to the west and washed down the Patuxent Valley by stream action, especially by floods. The alluvial flat is more than half a mile wide at most places and contains a large amount of coarse material. Its character, however, varies greatly from place to place, and in general it becomes finer as the valley is descended. Much gravel has been dug from the west side of the valley just below Priests Bridge and from the east side 3 miles below Governor Bridge, 6 miles southeast of Bowie. Formerly gravel was obtained from the valley bottom just north of Patuxent station (Woodwardville) and at other places.

GRAVEL IN THE BALTIMORE REGION AND NORTHEASTWARD

General relations and character.—A very large amount of gravel used in building and road construction in northeastern Maryland is produced from local sources and transported by autotrucks. Most of the lower portion of the Potomac group consists of gravel more or less mixed with sand as shown in plates 4 and 5, and in places with clay, which, however, can generally be separated without difficulty. There is also much gravel in the terrace deposits and the alluvium along the rivers. The predominant material is quartz in the form of quartzite, but there is considerable vein quartz and flint and a smaller proportion of fragments of various crystalline rocks. These have all come from older sediments, some of those in the terrace and river deposits having been moved several times. In some of the quartzite pebbles and boulders the grains are not strongly cemented, and these disintegrate readily by weathering or pressure. Such material greatly diminishes the strength of concrete and the durability of road metal. Most gravel deposits contain some material of this kind, and in some localities its amount is so great that the gravel is not acceptable. These "rotten" pebbles or boulders are readily detected, for they are easily crushed under the blow of a hammer or by the pressure in testing machines. Some of them can be crushed in the hand.

Patapsco Valley.—The Arundel Co. has a very large gravel and sand plant at Patapsco station on the south side of the Patapsco River about a mile east of Relay (pl. 6). It was begun in 1917. The deposit is a relatively recent delta or "bar" of the Patapsco River and lies on white clay of the Patapsco formation. The excavation is large, and extensive machinery is used for washing and sorting

the material. The larger boulders are crushed except some very large ones, which are left in the excavation. It is estimated that the plant can produce 30,000 tons of gravel and sand a day of 10 hours, and 36,000 tons a day has been produced. The proportion of sand varies greatly but may average near 60 percent. The sand is ordinarily separated in the first revolving screen, with ¼-inch mesh, and pumped out into settling pits from which the fine dirt and clay is carried away by the water overflow. A section across this working is shown in figure 9.

Deep Run.—The Standard Gravel & Sand Co. produces considerable material by dredging the alluvial deposits of Deep Run a short distance east of Hanover station (pl. 6). This valley is excavated in the sand and clay of the Potomac group, and though it is not wide it contains a considerable body of coarse material washed from the higher lands to the west. The depth of the deposit has not been ascertained, but it is more than 25 feet. The products are excellent

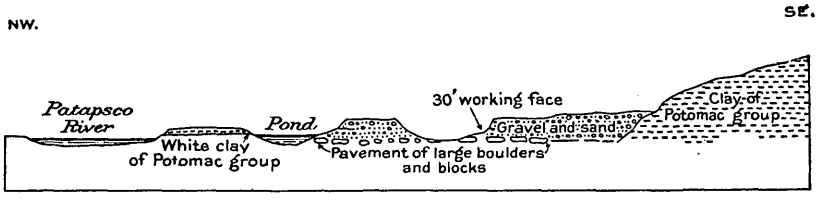


FIGURE 9.—Section at gravel pits of Arundel Co. near Patapsco station, Md.

gravel of various sizes and coarse and fine sand intermixed with but little clay or other objectionable matter.

Baltimore Harbor.—The Arundel Co. has produced a large amount of gravel and sand from Baltimore Harbor with large ladder dredges. Mud and dirt are washed out by the process and either dropped back in the excavation or used for filling adjoining areas. The sand and gravel are separated and sorted by revolving screen. One large operation of this sort was the excavation of part of Middle Branch Harbor, south of Spring Gardens (pl. 6).

The products of dredging by this company are gravel, coarse sand, and fine sand. The gravel is mostly of two sizes, 2¼ and 1¼ inches. About 20 percent of the sand is used for plaster and mortar, and 80 percent is suitable for concrete. The proportion of sand and gravel is variable but averages nearly half and half. Most of the specifications for gravel to be used for concrete aggregate in the larger construction operations call for about 40 percent of the 2¼-inch size and 60 percent of the 1¼-inch size, but smaller gravel is separated for various special purposes. Large cobbles and angular rock masses are crushed or used for coarse aggregate.

Whitemarsh region.—Gravel and sand are produced at various places about Whitemarsh (pl. 9). One opening just west of the highway has a face 30 feet high from which considerable material has been removed from lower beds in the Patuxent formation. Near Whitemarsh Run, about a mile south of Whitemarsh, are the Richardson workings in valley fill. Here a barge, operating in a basin, lifts the sand and gravel by a centrifugal pump, from which the material passes through a washing screen to separate the sand and eliminate dirt. The excavation covers about half an acre to a depth of 20 feet, and in places the water is 10 feet deep. The products are loaded on trucks, but there is a siding nearby on the Baltimore & Ohio Railroad for rail shipment.

Terrace gravel.—The various terraces of the Coastal Plain about Baltimore are capped by a thin mantle of gravel and sand similar to that covering the terraces in the Washington region. Similarly also these deposits were laid down by streams flowing out of the higher lands to the west and consists of detritus from the old crystalline rocks and the coarser, more enduring materials of the formations of the Potomac group and some later formations. The distribution of the larger areas is shown on plate 6.

The deposits are extensive, and they are worked at various places on the terraces south of the Patapsco River extending from a point near Patapsco station to South Baltimore. There are some small pits in gravel caps on Patapsco River Neck, northeast of Baltimore, and larger deposits cap the interstream terraces at altitudes mostly from 100 to 200 feet, at intervals from Patapsco River in the northeast corner of the State (pl. 9). There are some large areas between the Susquehanna and Northeast Rivers and constituting the terraces adjoining the Elk River. The gravel has been dug at many places, but mostly for local use on roads. Some of the larger openings are on Patapsco River Neck, at Abingdon, and near Aberdeen, and formerly considerable gravel and sand was excavated at Mount Winans (pl. 6) and in other parts of Baltimore, which is built largely on gravel-covered terraces.

GRAVEL IN HARFORD AND CECIL COUNTIES

Mountain.—The ridge between Little Gunpowder Falls and Winters Run is capped by the lower formation of the Potomac group, and the settlement known as Mountain is built on a remnant of the old high plateau, which here reaches an altitude of 400 feet (pl. 9). The material of this plateau remnant is a red-loam gravel which has been utilized to some extent for road metal. It is well adapted for this use because the red loam serves as a binder to hold the gravel together. One pit just northwest of Mountain has a 25-foot face, in which, however, the lower part, consisting of gravelly sand with some clay, is

probably of Potomac age. Pits in similar material have been opened a few rods southeast of Mountain. This gravel has been hauled considerable distances to be used for building or surfacing roads. Small amounts of gravel have been dug at various points in the southern part of this ridge, where much of the material is sandy.

Abingdon region.—The ridge between Bynum Run and Winters Run is capped by sand, gravel, and clay of the lower formation of the Potomac group, overlain in places by terrace gravel. The 260-foot summit, a mile northwest of Abingdon, is capped by the red-loam gravel of a small remnant of the old high plateau. There are several gravel pits in these formations. The largest is one opened in 1933 by R. J. Cremen. It operates a screen and washer and has a capacity of 400 tons a day, producing gravel and sand of specification sizes for concrete and other uses. About 50 percent is fine enough to go through a ⅛-inch screen. Some of the gravel, however, is soft.

Half a mile southeast of Abingdon is the pit of F. Maxa, Jr., which has been in operation since 1930. The material is worked from a 25-foot face in terrace (and perhaps also Potomac) gravel. It is washed and sorted by screening. Many large cobbles are included which are useful for foundation work, and there is a moderate proportion of three-fourths-inch size and about 70 percent of three-eighths-inch or less. A large amount of material appears to be available.

Aberdeen region.—The ridge between Carsins Run and Union Run northwest of Aberdeen is capped by the lower formation of the Potomac group, overlain by a remnant of the gravel of the old plateau, which has an altitude of 260 to 320 feet. The gravel of the Potomac group has been worked extensively in the pits of F. Maxa & Son, a mile northwest of Aberdeen. These pits have been in active operation for about 10 years and by washing and sifting produce gravel and sand for concrete. The proportion of the two materials is about equal. Gravel of three-fourths-inch size is the principal coarser product. The output is about 1,500 tons a month.

A short distance south of Carsins Crossroads is a large pit in red-loam gravel of a remnant of the old plateau. It presents a long working face about 25 feet high. Sand, probably of Potomac age, is at the base.

Webster Ridge.—There is a large remnant of the old plateau at Webster, at an altitude of 390 to 415 feet, which consists of red-loam gravel in part lying on gravel and sand of the basal portion of the Potomac group. A smaller outlier constitutes the 400- to 420-foot plateau remnant 2 miles southeast of Webster. The plateau gravel has been worked in moderate amount near Webster for road making. It presents a 10-foot face of material excellent for this purpose.

Woodlawn Ridge.—Gravel has been obtained for road making from several pits in the plateau remnant that constitutes the ridge between the Susquehanna River and Principio Creek, south of Woodlawn. Its altitude is from 390 to 470 feet. The material is the typical red-loam gravel of the old plateau, lying on sand and gravel merging into clay of the lower formation of the Potomac group. Nearly all of the capping is suitable for road making, and there is much good gravel in the underlying Potomac. As a rule the Potomac contains harder gravel and a larger proportion of vein-quartz material, but on the other hand portions of it grade into clay, which is objectionable.

Northeast.—The Arundel Co. has dredged extensively for gravel and sand in the tidewater head of the Northeast River, a short distance south of Northeast. This material has been deposited by Stony Run and Northeast Creek in a delta of considerable extent lying mostly below tide level. Bucket dredges lift the gravel, which is washed and assorted in revolving screens. The product is of high grade and includes considerable sharp sand suitable for concrete and other uses.

There are several gravel pits, mostly for road metal, on the ridges north and southwest of Northeast. Some of the material is red loamy gravel of the old plateau capping, of which there are notable remnants at Bayview, east and south of Theodore, on Foys Hill, and on other high summits. A pit half a mile west of Leslie station is in a later terrace deposit where the gravel caps crystalline rock. Portions of the outliers of the lower beds of the Potomac group consist of gravel and sand, which to the south, however, merge into clay.

SAND FOR CONSTRUCTION

In eastern Maryland a large amount of sand is separated from the gravel deposits by washing and screening, and there are also very extensive sand deposits in several formations of the Coastal Plain. Sand also occurs along the streams and on some of the beaches. This material is therefore very abundant, but its character and quality vary considerably, and some special varieties are not available everywhere. Sand is dug in large aggregate amounts from small pits and banks for local use, especially for mortar, which does not require material of great purity. Coarse sharp sand suitable for concrete and paving is mostly derived by washing and screening the gravel deposits, but some sand suitable for these uses is excavated directly from deposits of the Potomac group, mainly in the upper part, and from the overlying Magothy formation. Screening and washing are necessary for most of these deposits.

SAND IN THE WASHINGTON REGION

Parts of the Potomac group in the District of Columbia and in the city area consist of sand suitable for mortar and other purposes, and a large amount has been dug for local use. Most of the sand used in

construction, however, is obtained from the gravel deposits already described.

For many years an important source of building sand in Washington has been small pits in the Magothy formation in and near Anacostia. This formation consists mostly of sand, in large part clean, coarse, and sharp, but much of it is cemented into a brown ironstone by iron solutions that have permeated the sand underground and deposited iron oxide. Where this ironstone predominates the sand cannot be worked profitably. The distribution of the formation is shown on plate 1. The thickness of the Magothy formation averages 25 feet over a wide area, and at most places it lies on red variegated clay at the top of the Potomac group. The largest pit in the Anacostia region is on the slope of the Fort Stanton ridge. It exposes 40 feet of white sand of the Magothy formation overlain by 10 feet of black Monmouth sand capped by gray Calvert clay extending to the cover of plateau gravel. It thins out toward the north for a few miles in the region due east of the central part of Washington, but it comes in again to the northeast and is prominent in the Patuxent, Severn, and Magothy Basins, as shown on plate 6. In most of this area the red clay below the Magothy formation is underlain by a widespread sand deposit, which is part of an upper formation of the Potomac group. This deposit begins in the northeastern part of Washington and extends to the Patapsco River. In places, however, it merges laterally into gray or red sandy clay.

This upper Potomac sand is dug in many pits in northern Prince Georges and Anne Arundel Counties, notably along the Severn River above Round Bay, where there are many extensive excavations (mostly old). There are also many old and new pits in the hills about Severn, Harmans, and Stony River stations. One of the largest producers was the Brennan pit on the west side of Forked Creek 2 miles west of Round Bay station, which was in active operation from 1906 to 1920. Considerable stripping was necessary to uncover the sand, much of which was regarded as suitable for glass making. Borings showed that it was 30 feet or more thick and underlain by a large deposit of building sand 47 feet thick, including a 10-foot member of clay. The sand was worked in tunnels and an open pit.

Some years ago there were many sand pits about the heads of the tidewater inlets of the Severn and Magothy Rivers. A mile south of Severn station was the W. F. Clarke pit, which presented a 25-foot face of light-colored sand. In 1903 and 1904 large sand pits were developed along the Patapsco River a few miles east of Laurel, mainly if not all in alluvial deposits. The sand was screened to separate a small amount of gravel and used for making the filter beds for the District of Columbia water system. Some material was also

obtained from these pits for the great mound on which the Union Station in Washington is built.

SAND IN THE BALTIMORE REGION

General relations.—A very large amount of sand occurs in the vicinity of Baltimore, mainly in the Potomac group. It is used mostly for mortar but to some extent also in concrete and for various other purposes. From early times a large aggregate tonnage has been derived from small pits within a short distance from the points where the sand was utilized. Ordinarily it was selected for size and cleanness and screened to separate gravel. A large amount of sand has been produced by screening from the gravel deposits.

The location of the principal sand pits near Baltimore is shown on plate 6, which also shows the outcrop zone of the formations of the Potomac group and the contact of these formations on the crystalline rocks. The largest pits for sand are near Lansdowne and South Baltimore, near the southern boundary of the city. Formerly much sand was dug at Mount Winans, Mount Royal, Federal Hill, and other points in Baltimore now occupied by buildings or held for building lots.

The Patuxent or lower formation of the Potomac group includes large bodies of sand, mostly light-colored and sharp, more or less intermixed with gravel, especially in its lower part, and grading into clays of red, white, and other colors. Its wide outcrop zone extends through Baltimore and far to the northeast and southwest. Its lower beds lie on a floor of schists and other old crystalline rocks, which slopes eastward at a rate approaching 100 feet to the mile but presents many irregularities of configuration. It is revealed widely in the larger valleys, such as those of the Patapsco, Gwynns Falls, Jones Falls, and other rivers northeast of Baltimore. A notable exposure is shown on plate 5, *B*. The alluvial deposits on the river flats and the gravel beds of lower terraces also yield considerable sand, which is separated from the gravel by screening.

Arundel Co.—Probably the largest amount of sand produced by any one operator in the Baltimore region is obtained by dredging by the Arundel Co., of Baltimore, which operates near Northeast and in the Patapsco River and also has large gravel pits near Patapsco station. The material is handled by large dredges, and the products are well washed and accurately sorted. In dredging there is the disadvantage of having to handle or to avoid deposits consisting of large proportions of mud, which not only has to be lifted and passed through the screens but which at most places has to be disposed of afterward. Extensive dredging for the deepening of Baltimore Harbor and the development of Middle Branch Harbor has afforded a large amount of sand with the gravel. Middle Branch Harbor is part of the delta of Gwynns

Falls Creek, where this active stream had deposited an extensive body of coarse material.

South Baltimore.—The pits near South Baltimore are on the slope of a high ridge west of Curtis Bay. The Crimmins pits, which have been worked for many years, expose an 80-foot face mostly of light-gray sand of excellent quality for building. (See pl. 7, *B*.) The sand has an irregular cap of gravel and ironstone, which are discarded. There are several old pits in the vicinity, for the body of sand is extensive. In the northern margin of South Baltimore is the large active pit of Kotchen Bros., in which there is some clay in places, and a cap of Pleistocene gravel that is used for roads. Figure 10 shows the principal features at this place.

Lansdowne.—The largest excavations for sand near Baltimore are the Link pits, just west of U. S. Highway 1 (Washington to Baltimore), a short distance west of Lansdowne. (See pl. 7, *A*). These pits are cut back into a high ridge and present a face several hundred feet long and 60 to 80 feet high. There is some clay present in lenses and

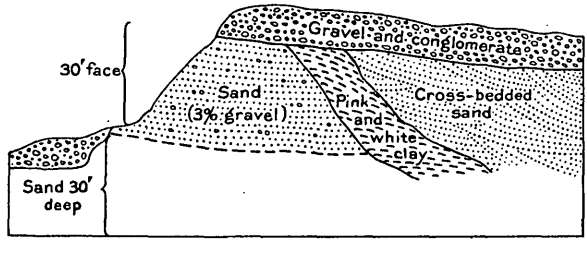


FIGURE 10.—Section of Kotchen Bros.' sand pit, South Baltimore, Md.

streaks, but the principal deposit is white cross-bedded sand of moderately fine grain but mostly pure. It is dry-screened, handled by conveyor belts, and stored in bins. It is used extensively for mortar and plaster in the Baltimore region. Several other pits obtain or have obtained sand from this deposit, which underlies an irregular area of considerable extent about Lansdowne and westward to and beyond Arbutus. It also underlies the region about Mount Winans, where sand was extensively excavated in former times. A fine exposure of the sand is visible in the cuts of the Baltimore & Ohio Railroad about three-fourths of a mile north of Lansdowne, where the deposit is more than 50 feet thick.

Necker.—Gravel and sand are produced by several large pits in the Patuxent formation (Potomac group) near Necker and Putty Hill (pl. 9). Most of the material is not washed, but much of it on screening yields products sold to some extent for making concrete. Some of the gravel is used on roads, and the finer sand is utilized for mortar and plaster. In places the formation includes some clay and ironstone fragments, but little stripping is necessary. Several of the

pits have working faces 20 to 30 feet high, and a large aggregate tonnage has been removed. About half of the product has been taken to Baltimore. Considerable of the coarse clean sand has been used in the manufacture of concrete building blocks at the pits a quarter of a mile east of Putty Hill.

The largest pits in the neighborhood are in the slope north of Whitemarsh Run north of Putty Hill. One of them is more than 300 feet long and 250 feet wide, with a working face from 10 to 30 feet high. Gravel preponderates, but there is a considerable admixture of sand, and several thin bodies of clay, which has to be discarded. The fine sand is sold for mortar and in small part as molding sand. An extensive conveying, screening, and washing plant washes the sand and sorts the gravel into such sizes as are specified for road and concrete work. A moderate percentage of large pebbles and boulders, mostly from 2 to 4 inches in diameter, is separated, and some ironstone fragments are rejected.

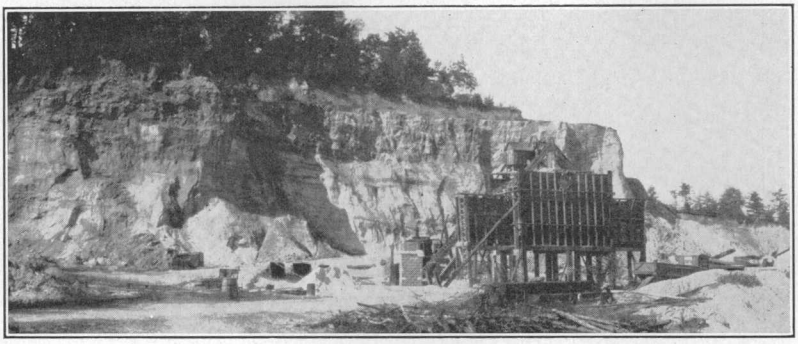
Rosedale.—The pits of the Diamond Grit Co. just south of the highway half a mile southwest of Rosedale (pl. 9), produce considerable gravel and sand, most of which is taken to Baltimore in trucks. The formation is the Patuxent, with a predominance of excellent sand, but there is also some clay and ironstone. The materials are screened to separate gravel and fine sand, the former for concrete and the latter for mortar and plaster. Some of the coarser gravel is crushed. The coarser sands are washed and sorted for a variety of uses. Some of the products are filtration sand, railroad engine sand, poultry grit, scouring sand, bricklaying sand, and core sand for molding iron. The ordinary output of the various products averages about 2,000 tons a month.

Sand and gravel have been dug at various other points near Rosedale, in part for local use and in part hauled to Baltimore.

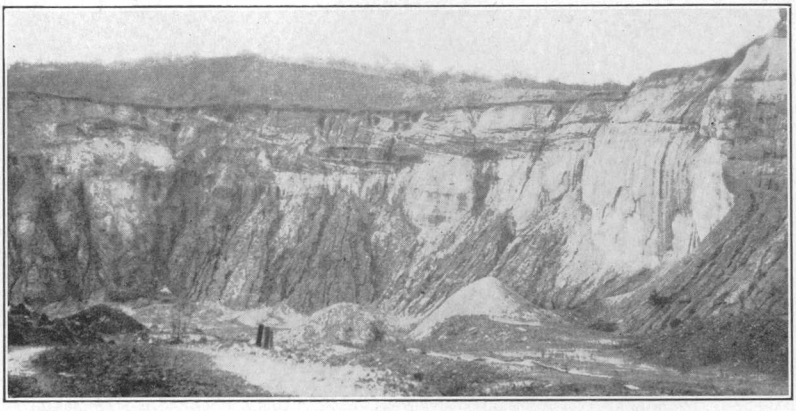
SAND FOR GLASS MAKING, MOLDING, AND OTHER PURPOSES

Although in this investigation no special attention was given to sands other than those used in construction, it was noted that some of the sands might be suitable for various other purposes. Samples tested in times past have been found satisfactory for glass making, metal molding, and other uses, and doubtless some of the deposits can be developed for a wider utilization. In the following pages a few facts are given as to the characteristics and requirements of various special kinds of sands which probably can be obtained in the Coastal Plain region of eastern Maryland.

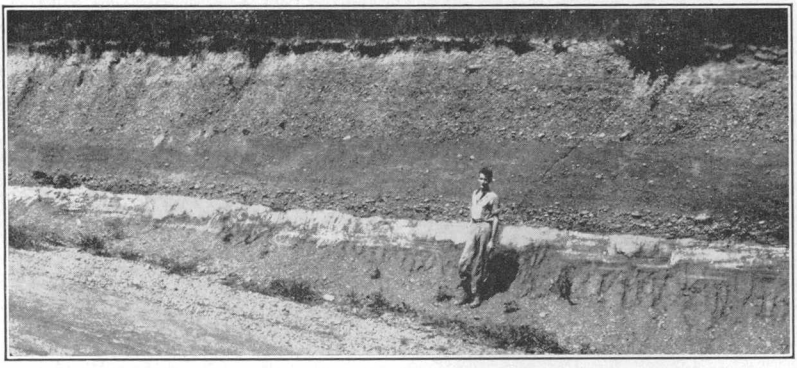
Glass sand.—Sand is the larger constituent in glass, its proportions being from 52 to 65 percent in the raw mixture and from 65 to 75 percent in the product when volatile materials have been separated



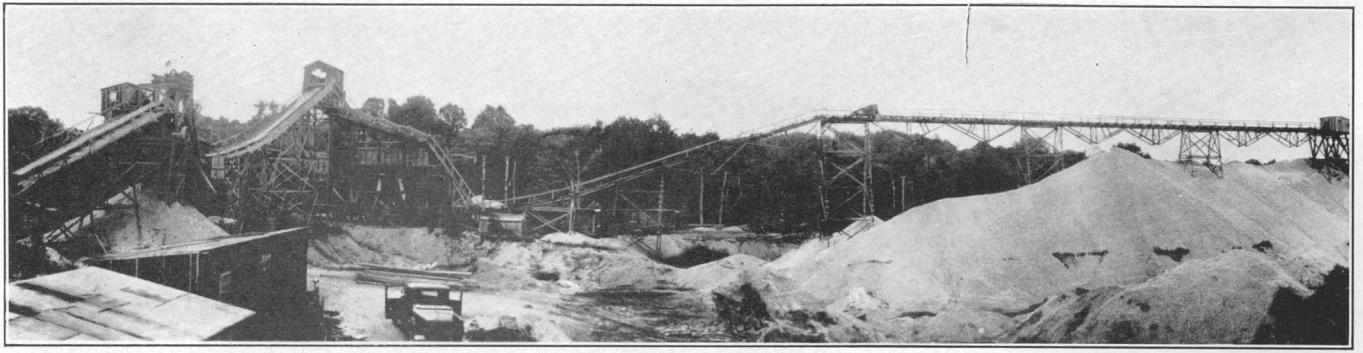
A. LINK SAND PIT, LANSDOWNE, MD.



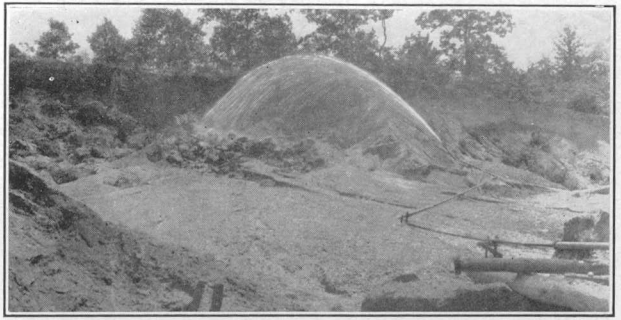
B. PITS IN SAND OF POTOMAC GROUP, CURTIS BAY, BALTIMORE, MD



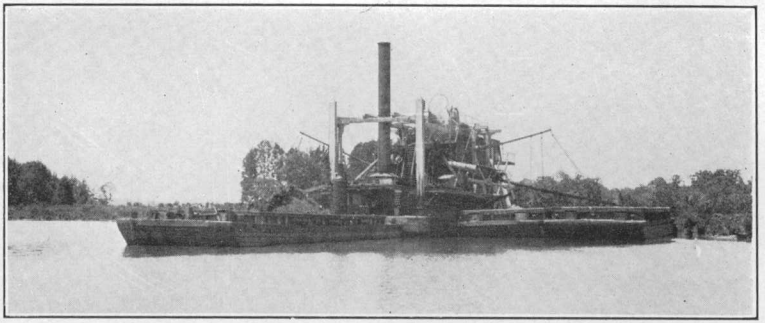
C. PLATEAU GRAVEL ON CALVERT FORMATION SOUTHEAST OF LA PLATA, MD.



A. GRAVEL PLANT OF MASSAPONAX CO. NEAR BOWIE, MD.



B. WORKING PLATEAU GRAVEL NEAR SILVER HILL, MD.



C. RIVER DREDGE, POTOMAC RIVER.

by the highest heat of melting. For white glass a silica sand of great purity is required, as a very small percentage of some metals, notably iron, causes color. This in a small degree is less objectionable in window and plate glass, some of which may have a slight green or amber tint, but even for these iron oxide in excess of 0.2 percent may be objectionable. In sand for green and amber bottles from 0.4 to more than 1 percent of ferric oxide is present. In some sands the iron constituent may be greatly diminished by washing and magnetic separation, and careful selection of the material is always important. However, some of the best-looking sand is not the freest from iron. Chemical decolorizers are used to a considerable extent in glass making, but the effect is slight. Clay is an objectionable ingredient in glass sand, because it may cloud the glass; it can, however, be removed in larger part by washing. Sand of medium fineness, passing a 20- to 50-mesh sieve, is required, and the grains should be uniform in size and angular in form. In some regions there is a strong prejudice against rounded grains. Very fine sand is not acceptable, and it is claimed that in mixtures of coarser and finer sands the latter are liable to settle and make the glass uneven in texture. Most glass sand is produced from disintegrated sandstone, in which the grains separate intact, especially when the material is passed through crushers. For an extended discussion of the requisites of glass sand see a paper by Fettke.[5]

Molding sand.—Sand is used extensively for casting metals, such as iron, steel, and brass and other alloys, and material suitable for this purpose occurs in several formations of the Coastal Plain.[6] So far it has not been produced in large amount, and as it cannot bear the expense of long transportation it has to be utilized at nearby points. Baltimore, the nearest market to Maryland deposits, is not a large consumer of molding sand. For some special work, such as high-class castings of bronze and other metals, molding sand has been imported from Europe.

There is considerable variety in the character of sand that can be used for molding, the choice depending largely upon the size and nature of the castings, and as a rule the suitability of the sand cannot be satisfactorily determined without practical tests. A fair degree of purity and high refractory quality are necessary, especially for molding steel and large castings. The size of grain varies, but for fine objects of brass, bronze, or aluminum very fine and even grain and capability of strong bond are required. For some uses bond is effected by the addition of fine clay or dilute molasses, and in certain uses a somewhat loamy material serves best. For steel molding more than 95 percent of silica is required, and the size of grain is considered in connection

[5] Fettke, C. R., American glass sands, their properties and preparation: Am. Inst. Min. Met. Eng. Trans., vol. 73, pp. 398-423, 1926.

[6] For a special report see Trainer, D. W., Jr., The molding sands of Maryland; Maryland Geol. Survey, vol 12, pp. 27-89, 1928.

with the weight of the casting and the place in the mold. Color is not important, and some molding sands are yellowish.

Sands in the Potomac group, Magothy, Matawan, Monmouth, Aquia, Nanjemoy, and Calvert formations and in Pleistocene terrace deposits appear to be the most promising sources of supply. During this investigation a body of fine buff sand apparently suitable for molding was discovered on the slope 1½ miles east of Burtonsville (pl. 6), in Montgomery County. I have bored into it 10 feet and it also crops out in a shallow road cut.

In judging and testing molding sands consideration has to be given to texture, permeability to moisture and gas, strength of bond, refractoriness, and life. Chemical and mineral determinations are inadequate beyond indicating if the material is clearly unsuitable. Apparently microscopic examination also is of no great assistance. Texture is ascertained by separating the clay by suspension in a weak solution of sodium hydroxide and after drying the residue finding the proportion of sizes of sand grains on sieves with 6, 12, 20, 40, 70, 100, 140, 200, and 270 meshes to the inch. The results are expressed in various ways,[7] but the simplest one is to give a list of the proportions of the various screenings. Sand that contains less than 5 percent of clay is used for two kinds of castings, the finer ones for case work and the coarser for molds for steel castings. Sand with a clay content of 15 percent is used mostly for heavy castings if it is coarse, but it may be used for lighter castings if it is of finer texture. The property of permeability is important, for it controls the passage of gases; the "tight" or "closed" sand is less permeable, and the "open" sand shows high permeability. This property depends on the coarseness and arrangement of grains, the amount and nature of the bonding material, the "temper" or water content, and the density of packing. Permeability is tested by measuring the flow of air through a standard specimen of known water content which has been rammed to a certain density. The tests are made at several water contents, but core sands are tested dry. Steel sand is tested both wet and dry. The bond, which is the very important quality of cohesiveness, is based in part on the clay admixture and in part on the granular constitution of the sand; it is tested at several water contents. The strength of molding sand is tested by compression or by a tensile test of a cylinder. The test for adsorption is made by treating with a dye to ascertain how rapidly it will permeate the sand, and a sand with high adsorption is not advantageous. A mineral examination will reveal easily fusible grains that might cause pitting of the casting, and a melting test for refractoriness is useful to eliminate sands that cannot bear heat. Molding sand should have the property of being re-usable many times, a feature which depends on the disposition of the clay binder to take

[7] These are discussed in detail by Trainer, D. W., Jr., op. cit., pp. 32–35.

up water again after the dehydration caused by the contact with the hot metal.

Samples of several sands from other localities which have fitted molding requirements as high-grade sands have been tested in the laboratory of the United States Geological Survey. The results are given below for possible comparison with materials from the Baltimore-Washington region.

Sieve tests of steel-molding sands

Locality	40-mesh	80-mesh	100-mesh	Pan
Burlington, N. J.	15	83	1.5	0.5
Lake Majella, Calif.	11.5	87	1.5	
Millville, N. J.	64	32	2	2
Niles, Ohio	32	61	4	3
Ottawa, Ill. (glass)	47	50	1.5	1.5
Ottawa, Ill. (white, steel)	37.5	43.5	12.8	6.2
Ottawa, Ill. (yellow, steel)	54	40	3	3
Pacific Grove, Mo.	1	95.5	2	1.5

The sand from Burlington, N. J., was shipped to the Panama Canal in large amounts for steel molding. The sand from Lake Majella, Calif., although a dune sand, is closely similar in texture to the sand at Burlington. The sand from Niles, Ohio, used for steel molding in Cleveland and elsewhere, is about one-third 20- to 40-mesh and two-thirds 40- to 80-mesh, very different from the two grades from Millville, N. J., which are two-thirds 20- to 40-mesh and one-third 40- to 80-mesh. The purer sands are without binder, so that various adhesive mixtures have to be made for different kinds of molding. Cores for steel molds especially are made of admixtures of sands of various characters.

Filter sand.—Sand and gravel are used in moderate amounts for filtering liquids, mainly water for municipal use. Clear white quartz sand is needed on a floor of broken rock or gravel. The material must be free from dirt and test very low in soluble components. As it can be reused after suitable cleaning, the item of replacement is a small one. Specifications for materials at the city filtration plant in Washington, D. C.,[8] calling for 140,200 yards of sand and 42,300 yards of gravel, included the following features:

> The lower 7 inches shall consist of broken stone or gravel which will remain upon a screen with a mesh of 1 inch and has but few stones over 2 inches in diameter. Above them shall be placed 2½ inches of broken stone or gravel which has passed a screen with mesh of 1 inch and which remains upon a screen with a clear mesh of ⅜ inch, and above this shall be placed 2½ inches of broken stone or gravel which has passed a screen with a mesh of ⅜ inch and which is coarser than ordinary sand, and entirely free from fine material so that water passing through it or agitated in contact with it will remain substantially clean. * * * Filter sand may be in either sharp or rounded grains. It shall be free from clay, dust

[8] This sand was supplied by the Smoot Corporation from pits near the Patuxent River, a mile east of Laurel, Md.

or organic impurities. * * * The grains shall all of them be of hard material which will not disintegrate and shall be of the following diameters: Not more than one-half of 1 percent by weight shall be less than 0.13 millimeter; not more than 8 percent less than 0.26 millimeter. At least 7 percent by weight shall be less than 0.34 millimeter, at least 70 percent less than 0.83 millimeter and at least 90 percent less than 2.1 millimeters. No particle shall be more than 5 millimeters in diameter, and the sand shall be passed through sieves of such mesh as to stop all such particles, and no screen or sieve shall be used containing at any point holes or passages allowing grains larger than the above to pass. The diameter of the sand grains shall be computed as the diameters of all spheres of equal volumes. The sand shall not contain more than 2 percent by weight of lime and magnesia taken together and calculated as carbonates. In all other respects the sand shall be of a quality satisfactory to the engineer officer in charge. The filter sand shall be placed in the filters in three layers, each layer to be about 1 foot thick, and the sand shall not be dropped from a height into final position or otherwise unduly compacted. The first two layers may be filled in to only approximate depths, and the surface need not be smoothed. The final layer shall be brought to a true and even grade, the surface left smooth and uniform.

The specifications for plants in Springfield, Mass., and Toronto, Canada, are as follows:

The filter sand shall be clean sand with either sharp or rounded grains. It shall be entirely free from clay, dust, or organic impurities. The grains shall all of them be of hard material which will not disintegrate. The effective size shall not be less than 0.25 millimeter nor more than 0.35 millimeter. The uniformity coefficient shall not be more than 3.0. The sand shall be free from dust and shall not contain more than 1 percent finer than 0.13 millimeter and shall be entirely free from particles over 5 millimeters in diameter. The sand shall not contain more than 2 percent by weight of lime and magnesia taken together as carbonates.

Probably some of the sands in the Washington-Baltimore region would meet these requirements, but no tests were made.

Engine, fire, polishing, and other sands.—Sand is used in locomotives and some other vehicles to increase friction on slippery rails, with an annual consumption of about 1,200,000 tons. Sand for this purpose must be dried and be fairly even grained, tough, and sharp.

Considerable sand is used in furnace practice for lining and patching reverberatory and other furnaces, cupolas, and ladles, and also for runners for pig-iron casting. Material for this use must have a high silica content to insure a suitably refractory quality.

Blast sand used for smoothing metal castings, glass, and stone must consist of quartz sand in either round or angular grains of suitable size and free from clay or other soft matter. For cleaning metal castings and dressing stone it is driven through a hose, and heavy metal castings require considerable treatment of this kind to clean off adhering sand from the mold. Much sand is used for grinding and polishing glass and other materials and for sawing, cutting, and polishing stone. Sand is used to some extent as an absorbent of corrosive fluids, as a cover for hot metal in annealing, and as a filler and adulterant. Some of the clay used for terra cotta and brick is tempered with sands of various kinds.

It is probable that sands suitable for the purposes above mentioned are available in the Washington-Baltimore region, but as the investigation was confined mainly to building materials, no sampling was done and no tests were made. An important function in utilizing sands for special uses is to find a market for them and to ascertain the extent and relations of the deposits that have the requisites for the various uses. Ordinarily they have to be introduced in competition with materials already in demand and known to be satisfactory.

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