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Liberian Investigations

GEOLOGY OF THE BUSHROD ISLAND-NEW GEORGIA CLAY DEPOSIT NEAR MONROVIA, LIBERIA

by

LAWRENCE Vernon BLADE, 1917-

U.S. Geological Survey

OPEN FILE REPORT

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

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LIBERIAN GEOLOGICAL SURVEY

BUREAU OF NATURAL RESOURCES AND SURVEYS

MEMORANDUM REPORT NO. 34

(USGS IR-LI-26)

Geology of

THE BUSHROD ISLAND-NEW GEORGIA CLAY DEPOSIT NEAR MONROVIA, LIBERIA

by

Lawrence V. Blade

U.S. Geological Survey

Monrovia, Liberia

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1. Palynological investigations in the Upper Cretaceous and Tertiary of the Mississippi Embayment Region--VI, by Robert H. Tschudy. 29 p. USGS, 710 West High St., Lexington, Ky. 40508; Kentucky Geological Survey, 307 Mineral Industries Bldg., University of Kentucky, 120 Graham Ave., Lexington, Ky. 40506.

2. Preliminary structure map of the Blackford quadrangle, western Kentucky, by Dewey H. Amos. 1 sheet, scale 1:24,000. USGS, 710 West High St., Lexington, Ky. 40508; Kentucky Geological Survey, 307 Mineral Industries Bldg., University of Kentucky, 120 Graham Ave., Lexington, Ky. 40506. /Material from which copy can be made at private expense is available in the two Lexington offices listed. This map supersedes the version open-filed in June 1968 by the same author, entitled "Preliminary map showing faults in the Blackford quadrangle, western Kentucky."/

3. Availability of palynological material from Naval Petroleum Reserve No. 4, XIX: Umiat Test Wells Nos. 3 and 11, Simpson Core Tests 21, 27, 30, 30A, by Richard A. Scott. 2 p.

4. Remote detection of geochemical soil anomalies, by F. C. Canney. 6 p., plus 1 sheet tabular data.

5. Geology of the Bushrod Island-New Georgia clay deposit near Monrovia, Liberia, by Lawrence V. Blade. 35 p., including 7 figs., 4 tables.

6. Seismic-reflection records from a survey at the Rocky Mountain Arsenal near Denver, Colorado, by R. E. Mattick and D. B. Hoover. 4 p., 1 pl. /Material from which copy can be made at private expense is available in the USGS Library, Bldg. 25, Federal Center, Denver, Colo. 80225./

7. Digital computer terrain mapping from multispectral data, and evaluation of proposed Earth Resources Technology Satellite (ERTS) data channels, Yellowstone National Park: preliminary report, by Harry W. Smedes, Kenneth L. Pierce, and Roger M. Hoffer. 43 p., 19 figs., 1 colored photo. 1012 Federal Bldg., Denver, Colo. 80202; 8102 Federal Office Bldg., Salt Lake City, Utah 84111; Geological Survey of Wyoming, University of Wyoming, Laramie, Wyo. 82070 /P.O.Box 3008, Univ. Sta./.

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NEAR MONROVIA, LIBERIA

by
Lawrence V. Blade
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ABSTRACT

The Bushrod Island-New Georgia clay deposit near Monrovia, Liberia, consisted of interlensing clay and very fine to fine quartz sand; it was deposited in elongate subparallel troughs that had been eroded in coarse-grained sediments. The troughs are interpreted as abandoned stream channels on a former delta of the St. Paul River. The clay of the deposit is essentially a quartz-rich kaolinitic clay that has undergone sufficient weathering in the upper part of the deposit to redistribute iron and alumina.

The clay may be divided into three groups: an iron-rich group (A) in which total iron expressed as Fe_2O_3 averages 6.5 percent and ranges from 4.4 to 9.2 percent, a group (B) relatively lower in iron in which total iron expressed as Fe_2O_3 averages 2.7 percent and ranges from 1.6 to 7.4 percent, and a group (C) high in both organic material and iron in which total iron expressed as Fe_2O_3 averages 3.9 percent and ranges from 3.3 to 4.9 percent.

Potential indicated reserves for the three groups are estimated at 1,800,000, 5,300,000, and 470,000 tons, respectively.

Tests of the physical properties of the raw and fired clay indicate the clay is suitable for the following commercial uses: building brick, hollow tile, drain tile, roofing tile, quarry tile, flower pots, porous earthenware, low to intermediate duty refractory products, and probably stoneware and small diameter sewer pipe.

INTRODUCTION

Purpose and scope

This study was part of the Geological Exploration and Resources Appraisal Project, a cooperative effort of the Government of Liberia and the U.S. Agency for International Development, carried out through activities of a combined Liberian Geological Survey and U.S. Geological Survey staff. The investigation of the Bushrod Island-New Georgia clay deposit was designed to determine the approximate quantity and quality of the clay. The vertical extent of the deposit. was determined by exploration drilling with a hand auger and the lateral extent was determined by reconnaissance mapping. In the urban areas surface mapping was difficult because of contamination by fill material.

Forty-seven hand-auger holes ranging in depth from 4 to 24 feet were drilled during the investigation. Seven clay samples were analysed by x-ray methods, 27 clay samples were analysed by chemical methods, 38 samples were studied by differential thermal analysis, 3 clay samples were tested to determine potential commercial uses, and the age of 1 clay sample was determined by radiocarbon measurement.

Rocks are described by hand lens observation, and size classifications are those of the Wentworth scale. Most of the colors of the burned powders from the differential thermal analyses were determined with the aid of a rock-color chart. (Geological Society of America, 1963).

Location and accessibility

Most of the clay deposit is located on both sides of Stockton Creek (figs. 1,2) about 5 miles northwest of downtown Monrovia and is readily accessible. The road from Monrovia to Harrisburg crosses the main part of the deposit on the north, the freeway from Monrovia to Paynesville crosses the deposit on the south, and the main road north from Monrovia to Bomi Hills crosses the deposit on the northwest.

Previous investigations

The Battelle Institute (1963) investigated the deposit as part of a larger study of the Monrovia district. They found the clay in the New Georgia area suitable for brick, and the clay on Bushrod Island suitable for form-pressed wall tile and pottery, as well as for brick.

Worrall and Dinkins (1965) made a soil map of the area. Two of their soil units fit the outlines of the clay deposit in parts of the area.

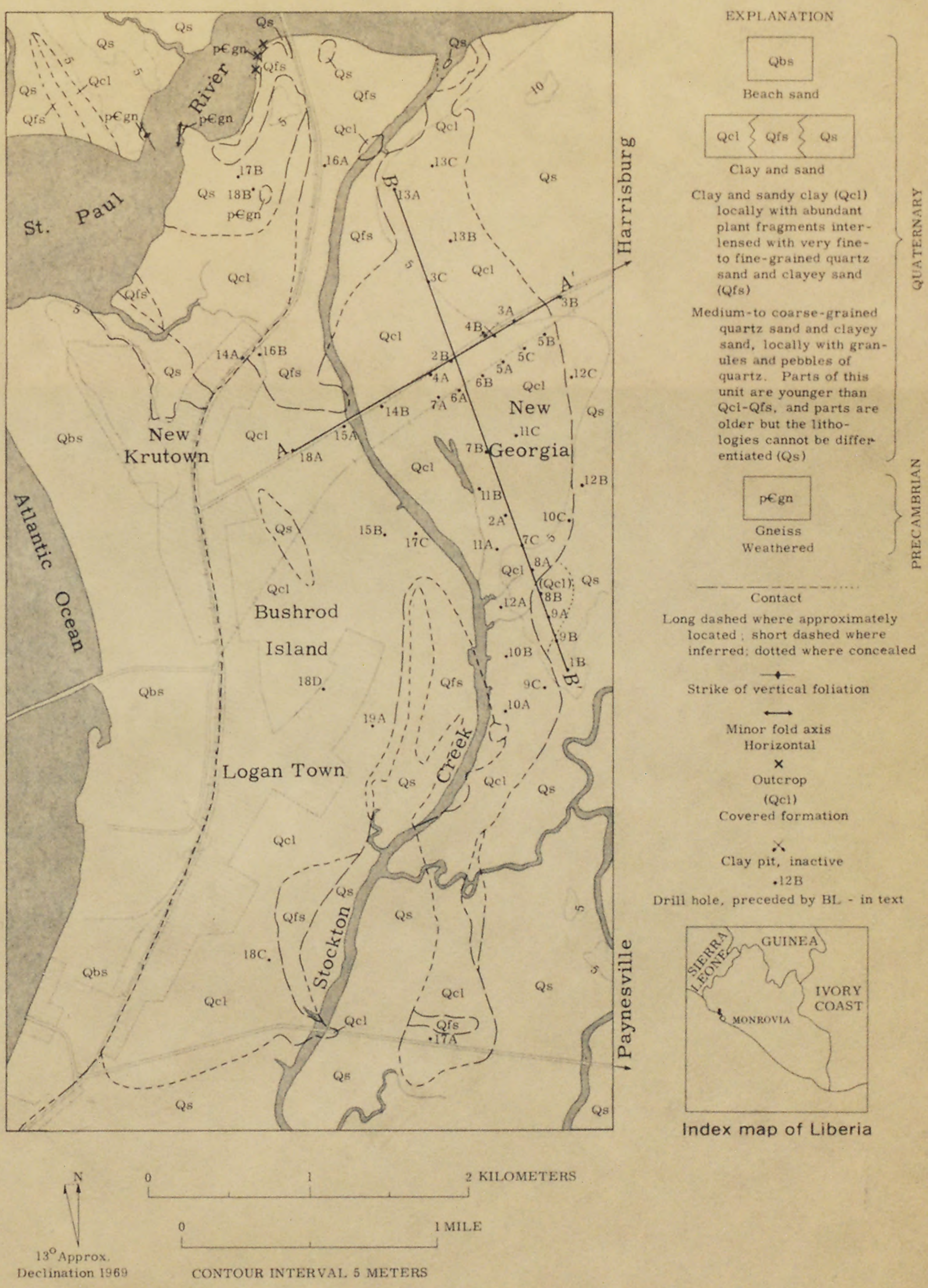


Figure 1. - Geologic map of the Bushrod Island-New Georgia clay deposit

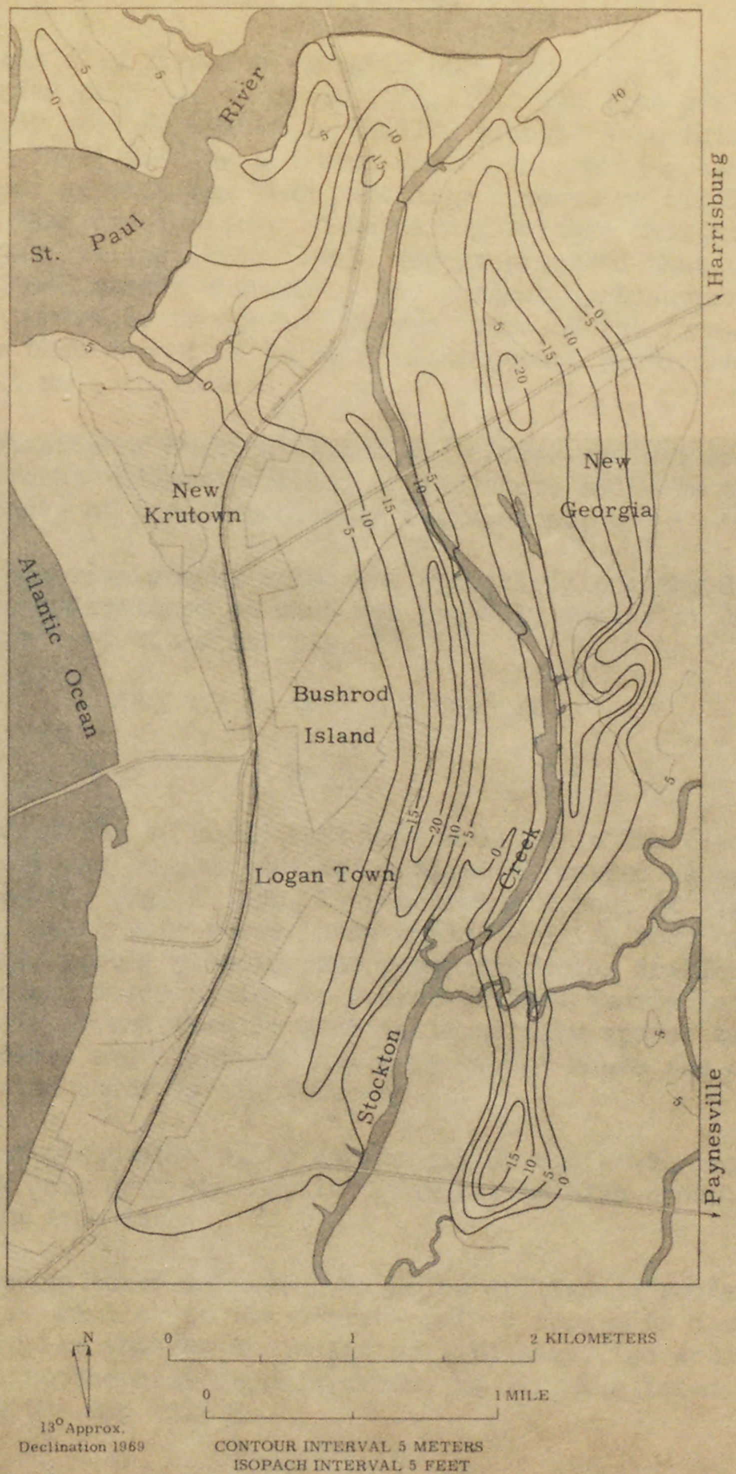


Figure 2. - Isopach map showing thickness of New Georgia clay

GEOLOGIC SETTING

The New Georgia clay forms an elongate body about 1 1/2 by 4 miles in size along both sides of Stockton Creek (fig. 1). The fine-grained sediments which form this body were deposited in shallow troughs to a thickness exceeding 20 feet (fig. 2). These troughs had been eroded in coarse-grained sediments, and the fine-grained deposit has been partially covered by similar coarse-grained sediments that are inferred to be partly deltaic and partly littoral in origin. The Battelle Institute (1963) report proposed that the clay was deposited in abandoned stream channels. The present work supports this interpretation for the two major troughs. However, some of the fine-grained sediments may have been deposited in marginal lagoons, particularly in that part of the deposit near the ocean.

Along the west side of Bushrod Island the coarse-grained sediments have been formed into arcuate ridges parallel to the shore and were mapped separately as beach sands because of this topographic expression.

Weathered Precambrian gneiss crops out sparsely along the St. Paul River, and laterite has been developed on what was probably gneiss at one spot in the north-central part of the area (fig. 1).

GEOLOGY OF THE CLAY DEPOSIT

Sand

More than half of the 40 holes that were drilled in the clay deposit penetrated the underlying coarser-grained sediments (mapped as sand); of these, one hole (BL-16A, fig. 1. app. 1) penetrated 2 feet of light bluish-gray clay containing medium to very coarse sand grains and 1/2 foot of light-gray clayey, sandy, quartz pebble gravel. The remaining holes drilled through the clay penetrated predominately medium-to coarse-grained quartz sand that is commonly silty or clayey and locally contains generally sparse quartz granules and/or pebbles. Colors are light to dark gray except where the overlying clay is thin, and there the color is light brown.

Two drill holes penetrated silty and/or clayey medium-to coarse -grained quartz sand colored dark gray and mottled gray and reddish-brown, before penetrating the clay deposit.

The material encountered in the seven holes drilled in sediments outside the clay deposit were similar to the coarse-grained sediments described above. Thus, there is a problem that on the basis of lithology, the sediments below, above, and adjacent to the clay deposit cannot be diffetentiated. Hence, they are all included in the map unit Qs.

New Georgia clay

Lithology and age

The New Georgia clay is composed of interlensing clay, sandy in part, and very fine to fine-grained quartz sand, clayey in part. In one drill hole (BL-15A, app. 1) a foot of very coarse to medium-grained quartz sand was observed within the very fine to fine-grained quartz sand; such coarse-grained units are apparently not abundant within the deposit. Colors of the units vary from browns to grays. The uppermost horizon commonly is gray because of the humus content (and charcoal if the area has been under cultivation); where the humus is not abundant or is absent and the level of the water table varies widely between the wet and dry seasons, the color varies from light to moderate brown; where the water table remains high, the color varies from very light gray to medium gray. Deeper in the section the browns are lighter and change to light gray which in turn shades to dark gray as the amount of organic material increases or the material is below the influence of oxygen in the water. In parts of the section, organic material in the form of plant remains is very abundant (fig. 3). The color changes described above occur as bands of varying width and depth; they were used as a basis for differentiating nine separate, recognizable units in the clay, described below in descending order of occurrence (all units are not present in every hole):

Unit	Description
1	Plastic clay, medium to dark gray and light to moderate brown and combinations of grays of gray and brown; generally contains humus, and on cultivated land fragments of charcoal; locally sandy.
2.	Plastic clay, very light gray to medium gray, locally sandy. This is the upper unit in low, generally saturated, ground.
3.	Plastic clay, light to moderate brown, grayish browwn, and brownish gray; locally sandy.
4.	Plastic clay, mottled light to moderate brown; locally light gray and reddish brown; locally sandy.
5.	Plastic clay, mottled light gray and light brown (locally reddish brown); locally sandy.
6.	Plastic clay, very light gray to medium gray.
7.	Plastic clay, medium dark gray to dark gray, locally brownish gray and moderate grayish brown; locally sandy, and locally with abundant plant remains.
8.	Plastic clay, grayish brown, dusky brown, and dark gray; generally changes to dark gray or grayish black on exposure to air; locally with abundant plant remains; locally sandy.
9.	Plastic clay, moderate to dusky brown, changes color to dark gray or grayish black on exposure to air, plant remains abundant, locally sandy.

The fine-grained sand is similarly banded.

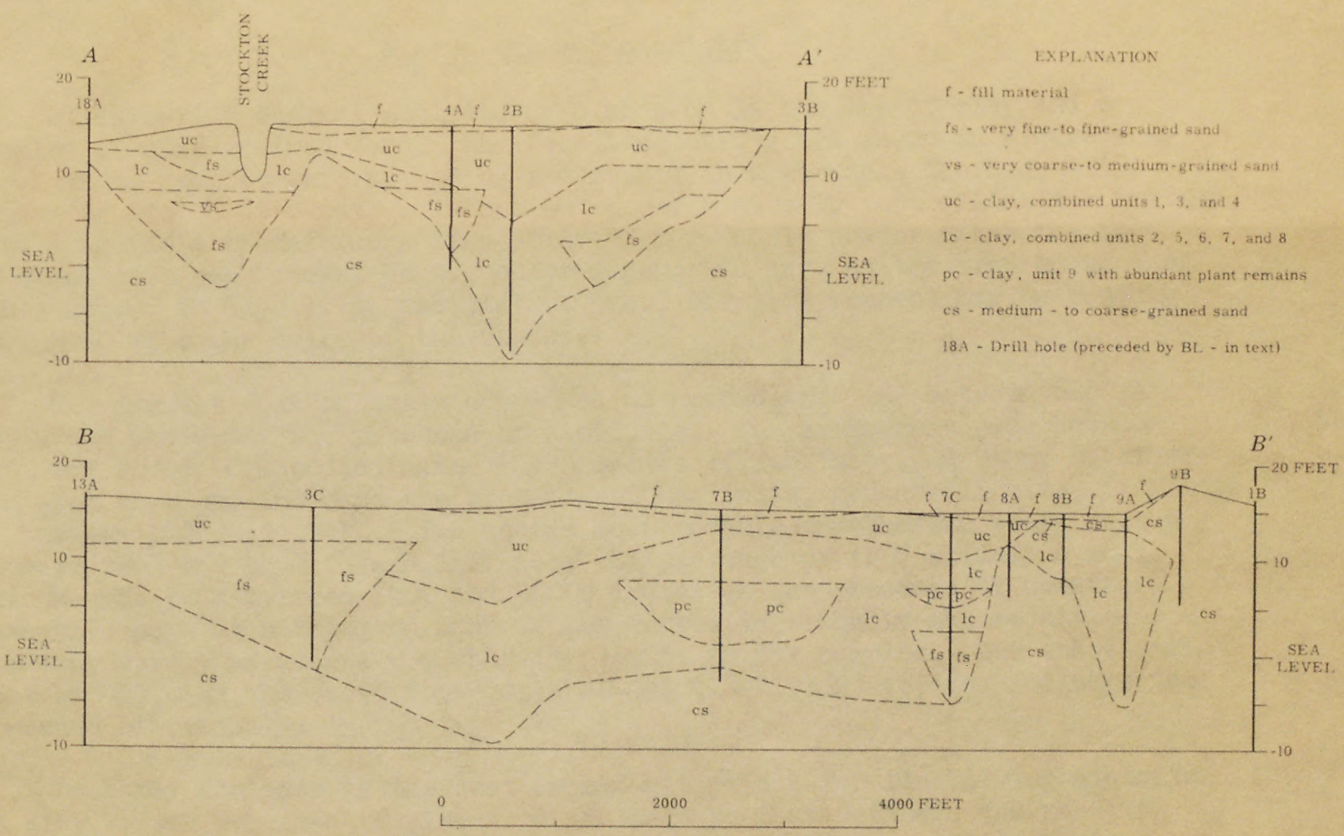


Figure 3. - Sketch showing sections along A-A' and B-B'

Unit 9, the interval from 14 to 15 feet in hole BL-16A, was sampled for radiocarbon age determination. Meyer Rubin, U. S. Geological Survey, reported a radiocarbon age of 6160±600 years B.P. for this sample (lab. No. W-2238). As stated previously some of the coarser sediments are younger than the New Georgia clay and some are older; hence, it seems best in this report to assign the whole sequence of sediments to the Quaternary Period.

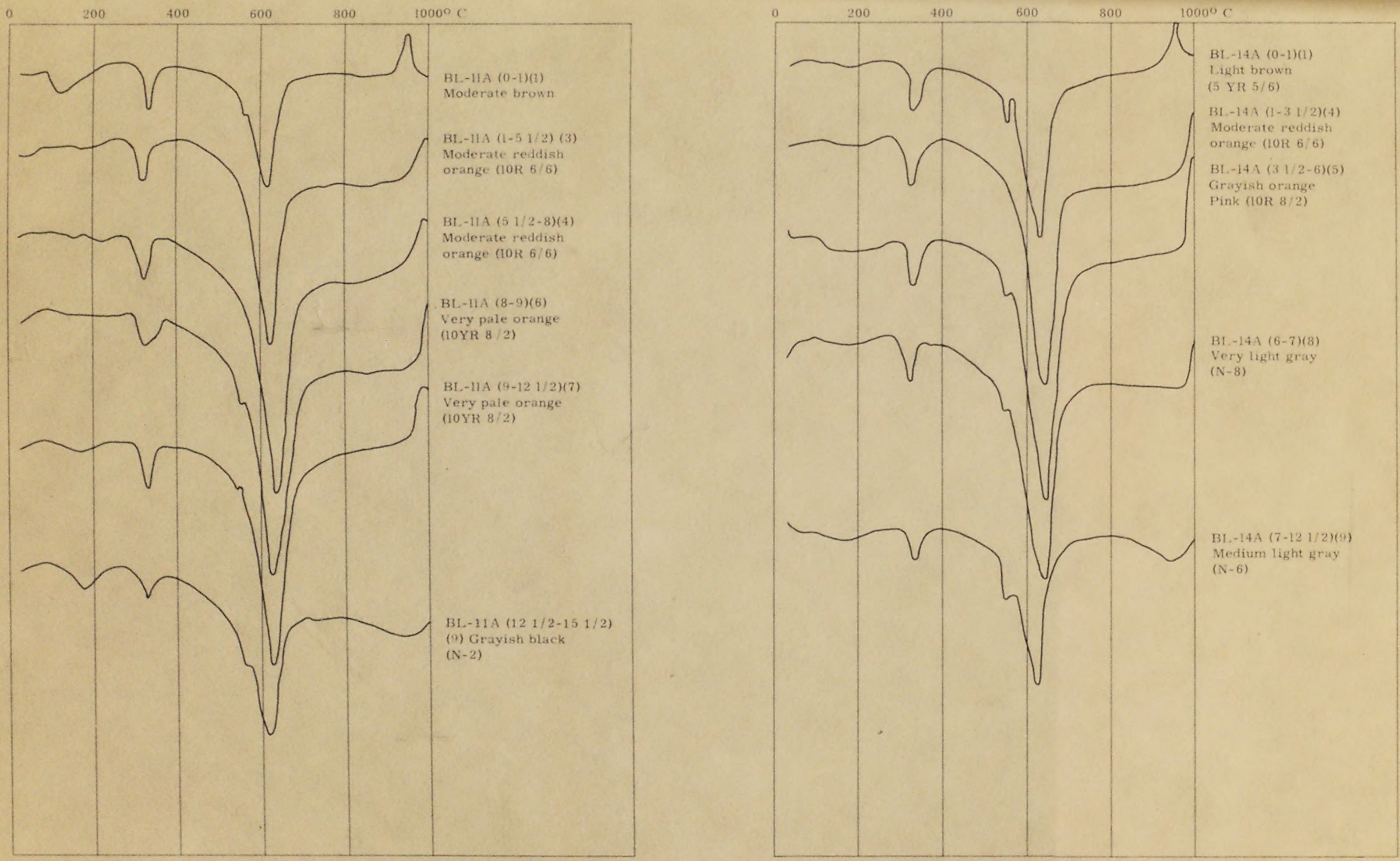
Mineralogy and chemistry

Differential thermal analyses were made on 34 samples of clay and 4 samples of fine-grained sand. The resulting curves are shown in Figure 4 a, b,c. These samples were tested by the author in a portable Eberbach DTA apparatus heated at a rate of about 40° C per minute by controlling the voltage with a variable transformer. The color of the sample powder after the test is shown with each curve, as the color depends in part on the iron content of the sample. In lieu of a quantitative test, the iron content may be roughly estimated from the color of the powder.

The largest peak on these curves is an endothermic one between 620° and 645°C and indicates the presence of kaolinite. The exothermic peak between 950° and 1000±° C also indicates the presence of kaolinite. Another endothermic peak that may indicate the presence of kaolinite, montmorillonite, or illite is between 120° and 175°C. The second most notable endothermic peak, occurs between 310° and 340° C, and indicates the presence of iron oxide. A small endothermic peak between 540° and 560°C indicates the presence of quartz. That this peak is missing on many of the curves is probably the result of operator error, as quartz probably is present in all samples. The endothermic peak at 450°C on the curve for sample BL-19A (18-21 1/2) (8) may indicate the presence of siderite.

As X-ray analysis is the most dependable method for identifying minerals in clay, seven selected samples were analyzed by that method. The results are shown in Table 1. In all these samples the most abundant mineral is kaolinite, followed by quartz and trace amounts of gibbsite, montmorillonite, and illite. Trace amounts of K-feldspar were found in all but one of the samples. Trace amounts of goethite were found in three samples, all of which were from the upper part of the deposit in the zone of oxidation or weathering. Trace amounts of organic matter were found in three samples below the zone of oxidation; two of them contained trace amounts of pyrite and one of these contained a trace amount of siderite. One sample contained a trace amount of amorphous silica or alumina.

From these data it is apparent that the clay is a mixture of minerals but that the dominant mineral is kaolinite. Kaolinite-rich clays are usually the ceramic clays of industry but more information is needed to determine the suitability of a specific clay. Part of this information can be obtained from chemical analyses of the clay. As previously shown, the color banding in the deposit changes with depth; three samples were analyzed from each of the units for a total of 27 samples. The results are shown in Table 2. A brief discussion of the oxides is given below.



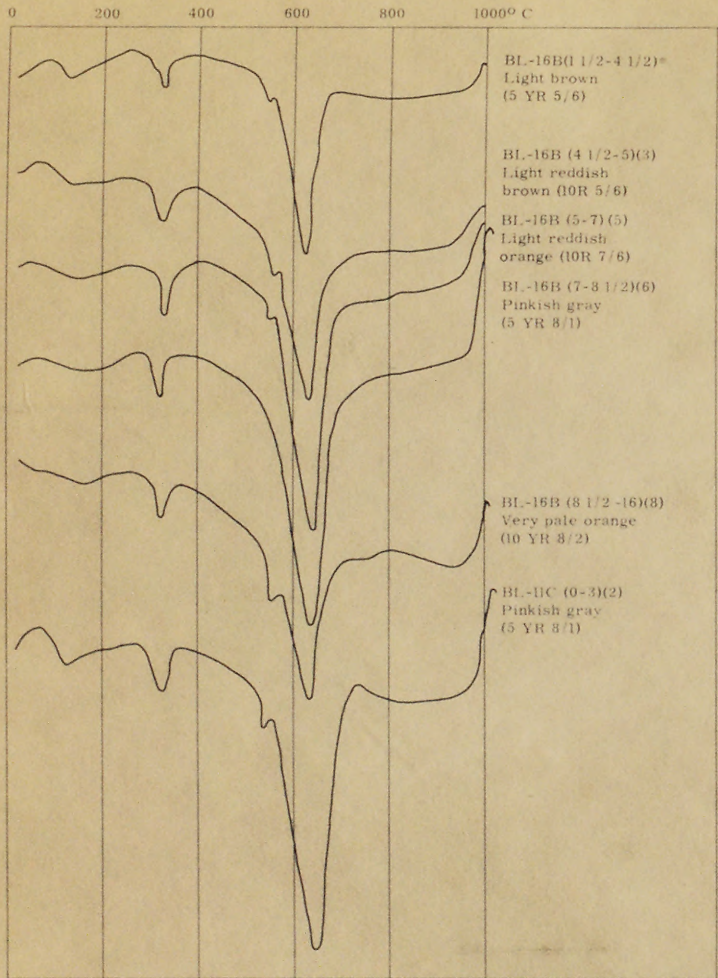
DRILL HOLE BL-11A

(0-1)-DEPTH IN FEET
(3)-UNIT NUMBER

DRILL HOLE BL-14A

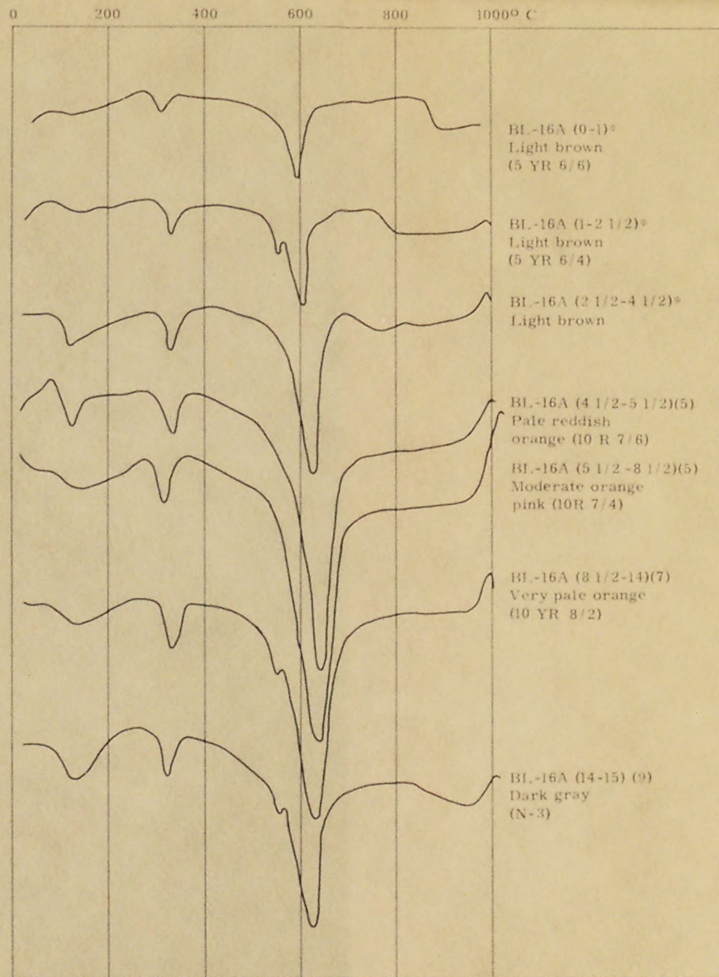
(0-1)-DEPTH IN FEET
(3)-UNIT NUMBER

Figure 4a. - Differential thermal analysis curves of samples



DRILL HOLES BL-16B AND BL-11C

(0-1)-DEPTH IN FEET
(3)-UNIT NUMBER
*clayey quartz sand



DRILL HOLE BL-16A

(0-1)-DEPTH IN FEET
(3)-UNIT NUMBER
* clayey quartz sand

Figure 4b. - Differential thermal analysis curves of samples

Table 1. --X-ray mineralogical analyses of clay from the Bushrod Island-New Georgia deposit.

by

Analyst, Paul D. Blackman. USGS Laboratory Report No. DEG-140

The following information is quoted from the report:

"Each sample was treated as follows: An appropriate portion was ground, packed in an aluminum holder, and an X-ray diffraction pattern prepared of the total sample. Then a portion was dispersed in water, utilizing an ultrasonic transducer, and the fine fraction was removed and deposited on tiles for X-ray diffraction examination. A series of treatments were performed, including heating, glycolation and cation saturation to determine the clay type mineralogy.

"The mineralogical content of the samples is listed below as parts in ten. As these estimates are derived from the relative intensities of the diffracted lines, and other factors in addition to quantity of a mineral affect diffraction intensity, these estimates are not intended to give more than an indication of the relative amounts of the various minerals present."

Samples	Minerals present	Estimated amount (parts in ten)
Field No. BL-14A	Kaolinite	6
Depth - 0-1'	Gibbsite	tr*
Unit No. 1	Montmorillonite (aluminum interlayered)	tr
	Illinte	tr
	Goethite	tr
	Quartz	3
	K-feldspar	tr
Field No. BL-14A	Kaolinite	6+
Depth - 1-3 1/2'	Gibbsite	tr
Unit No. 4	Montmorillonite (aluminum interlayered)	tr
	Illite	tr
	Goethite	tr
	Quartz	1+
	K-feldspar	tr
Field No. BL-14A	Kaolinite	7+
Depth - 3 1/2-6'	Gibbsite	tr
Unit No. 5	Montmorillonite (aluminum interlayered)	tr
	Illite	tr
	Quartz	1
	K-feldspar	tr
	Amorphous silica or alumina?	tr
Field No. BL-14A	Organic matter	tr
Depth - 6-7'	Kaolinite	7
Unit No. 8	Gibbsite	tr
	Montmorillonite (aluminum interlayered)	tr
	Illite	tr
	Quartz	2
	K-feldspar	tr

*tr - less than 5%

Table 1.--X-ray mineralogical analyses of clay from the Bushrod Island-New Georgia deposits (cont.)

Samples	Minerals present	Estimated amount (parts in ten)
Field No. BL-14A	Organic matter	tr
Depth - 7-12 1/2'	Kaolinite	7
Unit No. 9	Gibbsite	tr
	Montmorillonite (aluminum interlayered	tr
	Illite	tr
	Quartz	1+
	K-feldspar	tr
	Pyrite	tr
Field No. BL-19A	Kaolinite	7+
Depth - 2-3 1/2'	Gibbsite	tr
Unit No. 4	Montmorillonite (aluminum interlayered)	tr
	Illite	tr
	Quartz	1+
	Goethite	tr
Field No. BL-19A	Organic matter	tr
Depth - 18-21 1/2'	Kaolinite	6+
Unit No. 8	Gibbsite	tr
	Montmorillonite (aluminum interlayered)	tr
	Illite	tr
	Quartz	2+
	K-feldspar	tr
	Siderite	tr
	Pyrite	tr

*tr - less than 5%

Table 2.--Chemical analyses of clay samples from the Bushrod Island-New Georgia deposits[1/]
(In percent)

Lab. No. W170	-349	-350	-351	-352	-353	-354	-355	-356	-357	-358	-359	-360	-361	-362
Field No.	BL-4B	BL-9A	BL-11A	BL-11A	BL-11A	BL-11A	BL-11A	BL-11A	BL-11C	BL-14A	BL-14A	BL-14A	BL-14A	BL-14A
Depth	10-12'	2-3'	0-1'	1-5 ½'	5½-8'	8-9'	9-12½'	12½-15½'	0-3'	0-1'	1-3½'	3½-6'	6-7'	7-12½'
Unit No.	6	2	1	3	4	6	7	9	2	1	4	5	8	9
Oxides:														
SiO_2	47.7	47.8	60.5	54.7	43.4	47.0	47.2	24.7	46.7	53.5	47.0	45.7	44.0	36.5
Al_2O_3	28.2	29.5	18.6	23.6	28.8	33.0	30.7	16.3	33.4	23.2	27.2	33.2	28.7	21.5
Fe_2O_3	1.3	2.2	4.0	6.4	8.9	2.5	2.1	4.9	1.6	4.6	8.4	2.6	.17	1.6
FeO	.86	.57	.72	.30	.23	.23	.63	2/	.26	.87	.46	.19	1.3	1.5
MgO	.65	.33	.37	.42	.64	.39	.51	.49	.38	.44	.39	.33	.32	.33
CaO	.54	.25	.54	.38	.75	.00	.22	1.0	.33	.85	.15	.57	.25	.15
Na_2O	.30	.12	.10	.20	.33	.10	.22	.30	.15	.30	.04	.05	.20	.18
K_2O	.95	.60	1.4	1.2	.78	.66	.86	.49	.51	1.0	.82	.61	.83	.69
H_2O-	2.2	2.3	1.8	1.7	2.2	1.9	1.9	6.5	2.0	1.9	2.0	2.0	2.4	4.3
H_2O+	11.7	12.7	8.1	9.8	12.5	12.7	12.7	10.5	13.2	10.7	11.4	13.3	12.2	11.1
TiO_2	1.1	1.3	.98	.98	1.1	1.2	1.2	.63	1.2	1.0	1.1	1.2	1.2	.90
P_2O_5	.06	.08	.07	.12	.25	.27	.09	.04	.04	.09	.14	.07	.05	.02
MnO	.04	.04	.07	.04	.03	.02	.04	.00	.04	.07	.00	.04	.04	.00
CO_2	$<.05$	.05	.05	.11	.08	.05	$<.05$	.08	.08	$<.05$	.05	$<.05$	.10	$<.05$
Volatiles other than H_2O and CO_2	4.4	2.1	2.7	.00	.00	.00	1.5	33.7	.00	1.5	.60	.00	8.0	21.3
Sum	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total iron as Fe_2O_3	2.3	2.8	4.8	6.7	9.2	2.8	2.8	4.9	1.9	5.6	8.9	2.8	1.6	3.3

1/ Analysis performed in the Rapid Rock Analysis Laboratory under Leonard Shapiro, U.S. Geological Survey laboratory, Report No. 68 WRC 99.

2/ Color prevents determination.

Table 2.--Chemical analyses of clay samples from the Bushrod Island-New Georgia deposit (continued)

Lab. No. W170	-363	-364	-365	-366	-367	-368	-369	-370	-371	-372	-373	-374	-375
Field No.	BL-16A	BL-16B	BL-16B	BL-17A	BL-17A	BL-18A	BL-19A	BL-19A	BL-19A	BL-19A	BL-19A	BL-19A	BL-19A
Depth	14-15'	4½-5'	7-8½'	7½-9½'	9½-13'	½-2½'	0-1'	1-2'	2-3½'	3½-6½'	6½-9'	12-15'	18-21½'
Unit No.	9	3	6	5	7	2	1	3	4	5	7	8	8
Oxides:													
SiO_2	41.7	53.7	46.2	64.0	59.2	49.7	45.4	46.1	43.9	48.0	46.4	54.8	49.8
Al_2O_3	20.9	23.3	32.8	21.2	22.4	30.0	28.2	30.8	30.0	31.6	30.8	22.2	20.2
Fe_2O_3	1.5	6.7	1.5	2.4	1.5	1.5	4.2	3.9	6.1	2.1	1.6	1.3	2.1
FeO	1.9	.68	.34	.36	.79	.32	.52	.48	.56	.26	.76	1.4	4.8
MgO	.40	.41	.35	.33	.64	.36	.45	.41	.42	.28	.46	.46	.66
CaO	.02	.68	.54	.22	.85	.35	1.0	.34	.70	.09	.34	.17	.96
Na_2O	.18	.09	.04	.02	.95	.65	.30	.78	.85	.02	.13	.31	.52
K_2O	.48	1.3	.67	1.7	1.7	.70	.70	.66	.69	.62	.64	1.3	1.2
H_2O-	3.5	1.7	1.9	.98	1.2	2.0	2.2	1.8	1.8	1.8	1.8	1.8	1.8
H_2O+	9.5	10.0	13.7	7.7	9.3	13.0	12.9	13.4	13.5	13.5	12.8	9.9	9.3
TiO_2	1.0	.98	1.2	.95	1.0	1.3	1.2	1.2	1.2	1.2	1.2	.98	.90
P_2O_5	.04	.18	.07	.07	.09	.03	.09	.06	.08	.09	.11	.09	.08
MnO	.00	.03	.07	.10	.04	.00	.07	.00	.04	.04	.00	.07	.03
CO_2	$<$.05	.11	.10	$<$.05	.09	$<$.05	$<$.05	.05	$<$.05	$<$.05	$<$.05	$<$.05	2.3
Volatiles other than H_2O and CO_2	18.7	.00	.80	.00	.30	.00	2.2	.00	.20	.00	3.0	5.3	5.2
Sum	100	100	100	100	100	100	100	100	100	100	100	100	100
Total iron as Fe_2O_3	3.6	7.5	1.9	2.8	2.4	1.9	4.8	4.4	6.7	2.4	2.4	2.9	7.4

SiO_2 ranges from 24.7 to 64.0 percent and shows no systematic variation. The distribution appears to be the result of original deposition. In general, there is a positive correlation with the amount of quartz.

Al_2O_3 ranges from 16.3 to 33.4 percent, generally increasing with depth within the zone of oxidation, then decreasing below. The distribution appears to be the result of original deposition slightly modified by weathering.

Fe_2O_3 ranges from 0.17 to 8.9 percent and is generally high at the surface, increasing with depth to a point above the base of the zone of oxidation, then decreasing sharply and varying in amount with further increase in depth. The distribution appears to be the result of original deposition and diagenesis strongly modified by weathering in the upper part of the deposit.

FeO ranges from 0.19 to 4.8 percent and is relatively high in the upper foot or so, generally, decreasing with depth within the zone of oxidation then, generally, increasing with depth. The distribution appears to be the result of original deposition and diagenesis strongly modified by weathering in the upper part of the deposit. The apparently anomalous high near the surface may be explained as the result of a temporary reducing environment caused by the presence of humus and charcoal.

Each of the oxides MgO, CaO, K_2O, TiO_2, P_2O_5, and CO_2 is present in quantities of less than 2 percent and shows no systematic variation. The distribution appears to be the result of original deposition and diagenesis.

Na_2O ranges from 0.02 to 0.95 percent and shows no systematic variation. However, the upper 3 1/2 feet of the deposit at location BL-19A anomalously high in Na_2O and the normal K_2O/Na_2O ratio of greater than 1 in sedimentary rocks is reversed here. This may be due to the activity of man; elsewhere the distribution appears to be the result of original deposition and diagenesis.

H_2O+ ranges from 8.1 to 13.7 percent and varies with Al_2O_3. The Al_2O_3/H_2O+ ratio ranges from 1.6 to 2.8, averages 2.3 with a mode of 2.4 and shows the abundance of kaolinite, in which this ratio is 2.8 to 2.9.

MnO ranges from 0.00 to 0.10 percent; it is slightly higher at the surface than at depth but otherwise shows no systematic variation. The distribution except for the concentration at the surface appears to be the result of original deposition. The concentration at the surface may come from decaying vegetation.

Volatiles other than H_2O and CO_2 range from 0 to 33.7 percent and show in part the amount of sulfide present, but mostly they indicate the amount of organic material present, as there is a direct correlation between the amounts of these volatiles and the abundance of plant remains.

From these data it is apparent that the color banding varies with the amount of Fe_2O_3 and organic material but that the amount of FeO cannot be estimated. However, there is a rude, direct correlation between total iron content and the amount of plant remains or organic material in the unweathered parts of the deposit.

Because of the preceding correlations and for convenience in tonnage estimates and further discussion, the units may be combined so that the clay deposit is divided into three groups: Group A, high in iron; Group B, relatively low in iron; and Group C, high in both organic material and iron. Group A is formed from the combination of units 1, 3 and 4; Group B from units 2, 5, 6, 7, and 8; and Group C is unit 9. The unweighted averages and ranges of the oxides and volatiles are given in Table 3.

POTENTIAL RESERVES

As there is no commercial production of ceramics in this area at the present time, the reserves estimated below must be considered as potential reserves.

The potential indicated reserves for each of the three groups of clay (Table 3) were estimated for that portion of the deposit south of the St. Paul River, east of Stockton Creek, and north of the short road from New Georgia to Stockton Creek (fig. 1). For each of the groups an isopach map was compiled (figs. 5, 6, and 7); the areas were measured by planimeter and the volumes computed by means of the prismoidal formula. The volumes obtained were generally reduced for geologic reasons and were then converted to tons of clay. From the geology of the deposit it seems reasonable to infer an amount of clay for each of the three groups in the remaining portion of the deposit equal to that estimated for the potential indicated reserves.

The volume of clay in the group (A) formed from combined units 1,3, and 4 is 76,000,000 cu. ft. This was reduced by 50 percent for thinness along the edges of the area and irregularities of the surface to a volume 38,000,000 cu. ft. This was reduced by 30 percent for air shrinkage; 2.2 was assumed to be the specific gravity of the dry clay; and the computed result is a potential indicated reserve of 1,800,000 short tons of clay.

The volume of clay in the group (B) formed from the combined units 2, 5, 6, 7, and 8 is 110,000,000 cu. ft. This was reduced by 30 percent allowing for possible sand lenses (the drilling is too widely spaced for development drilling) to a volume of 77,000,000 cu. ft. This was reduced by 30 percent for air shrinkage; 2.2 was assumed to be the specific gravity of the dry clay; and the computed result is a potential indicated reserve of 5,300,000 short tons of clay.

The volume of clay in unit 9 (C) is 14,000,000 cu. ft. This was reduced by 30 percent for air shrinkage; 1.5 was assumed to be the specific gravity of the dry clay (the specific gravity was reduced because of the abundant plant remains in the clay); and the computed result is a potential indicated reserve of 470,000 short tons of clay.

The amount of reserves depends on what can be mined economically, and the problem in this deposit will be one of high water part of the year in the upper part of the deposit and water all year in the lower part of the deposit. However, the water problem has been solved successfully in other places and presumably will be solved here.

Table 3.--Averages and ranges of the oxides and volatiles in the three subdivisions of the clay in the Bushrod Island-New Georgia deposit. (In percent)

Oxides	Combined units 1, 3 and 4		Combined units 2, 5, 6, 7, and 8		Unit 9	
	Average	Range	Average	Range	Average	Range
SiO_2	49.8	43.4-60.5	49.6	44.0-64.0	34.3	24.7-41.7
Al_2O_3	26.0	18.6-30.8	28.5	20.2-33.4	19.6	16.3-21.5
Fe_2O_3	5.9	3.9- 8.9	1.8	.17-2.6	2.7	1.5- 4.9
FeO	.54	.23- .87	.87	.13-4.8	1.7	1.5- 1.9
Total iron as Fe_2O_3	6.5	4.4- 9.2	2.7	1.6 -7.4	3.9	3.3- 4.9
MgO	.44	.37- .64	.43	.28- .66	.41	.33- .49
CaO	.60	.15-1.0	.38	.00- .96	.39	.02-1.0
Na_2O	.39	.04-.85	.26	.02- .95	.22	.18- .30
K_2O	.95	.66-1.4	.91	.48-1.7	.55	.48- .69
H_2O-	1.9	1.7- 2.2	1.9	.98-2.4	4.8	3.5- 6.5
H_2O+	11.4	8.1-13.5	11.9	7.7-13.7	10.4	9.5-11.1
TiO_2	1.1	.98-1.2	1.1	.90-1.3	.84	.63-1.0
P_2O_5	.12	.06- .25	.07	.03- .27	.03	.02- .04
MnO	.04	.00- .07	.04	.00- .10	.00	
CO_2	.06	$<$.05- .11	.20	$<$.05-2.3	$<$.05	$<$.05- .08
Volatiles other than H_2O and CO_2	.8	.00-2.7	1.7	.00-8.0	24.7	18.7-33.7

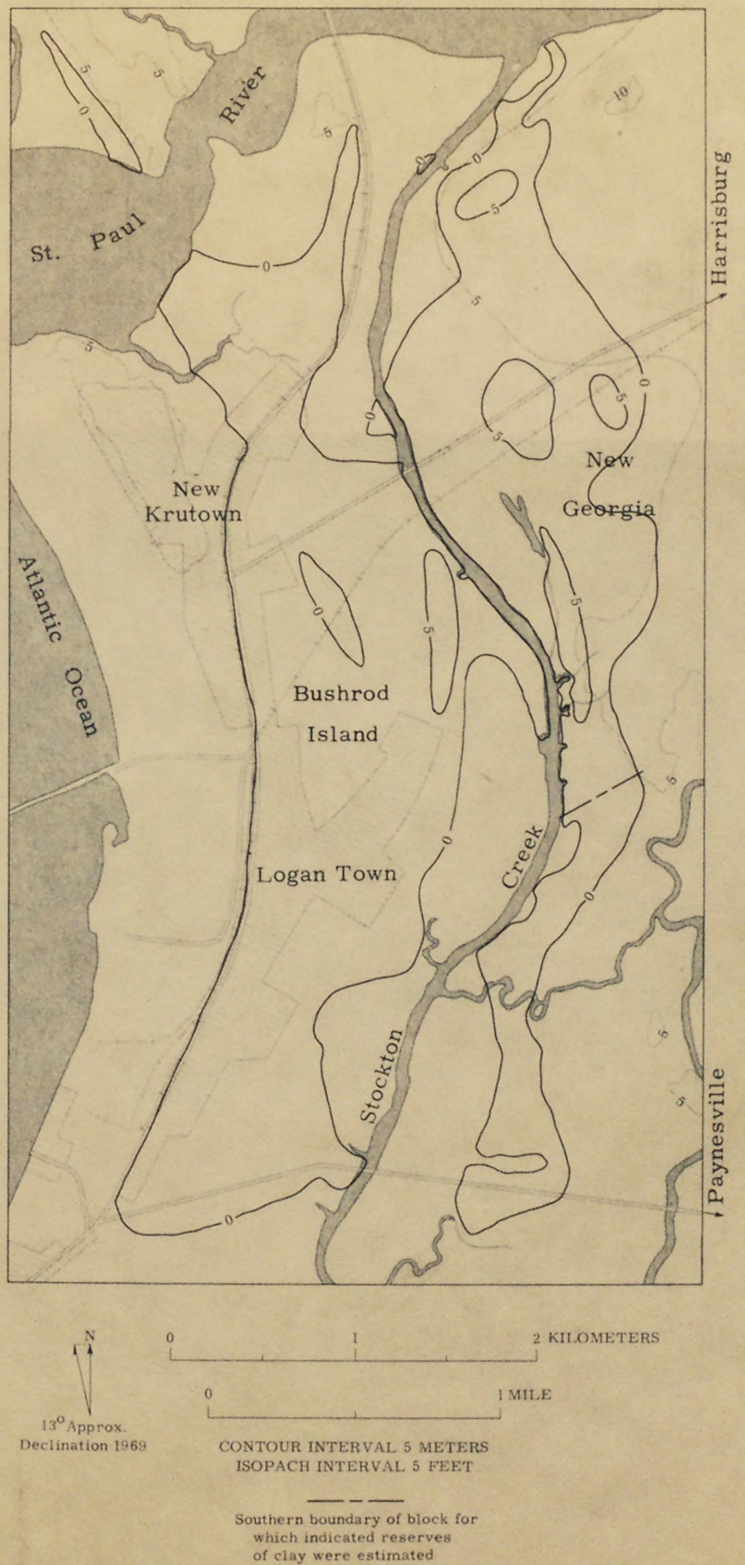


Figure 5. - Isopach map showing thickness of combined units 1, 3, and 4

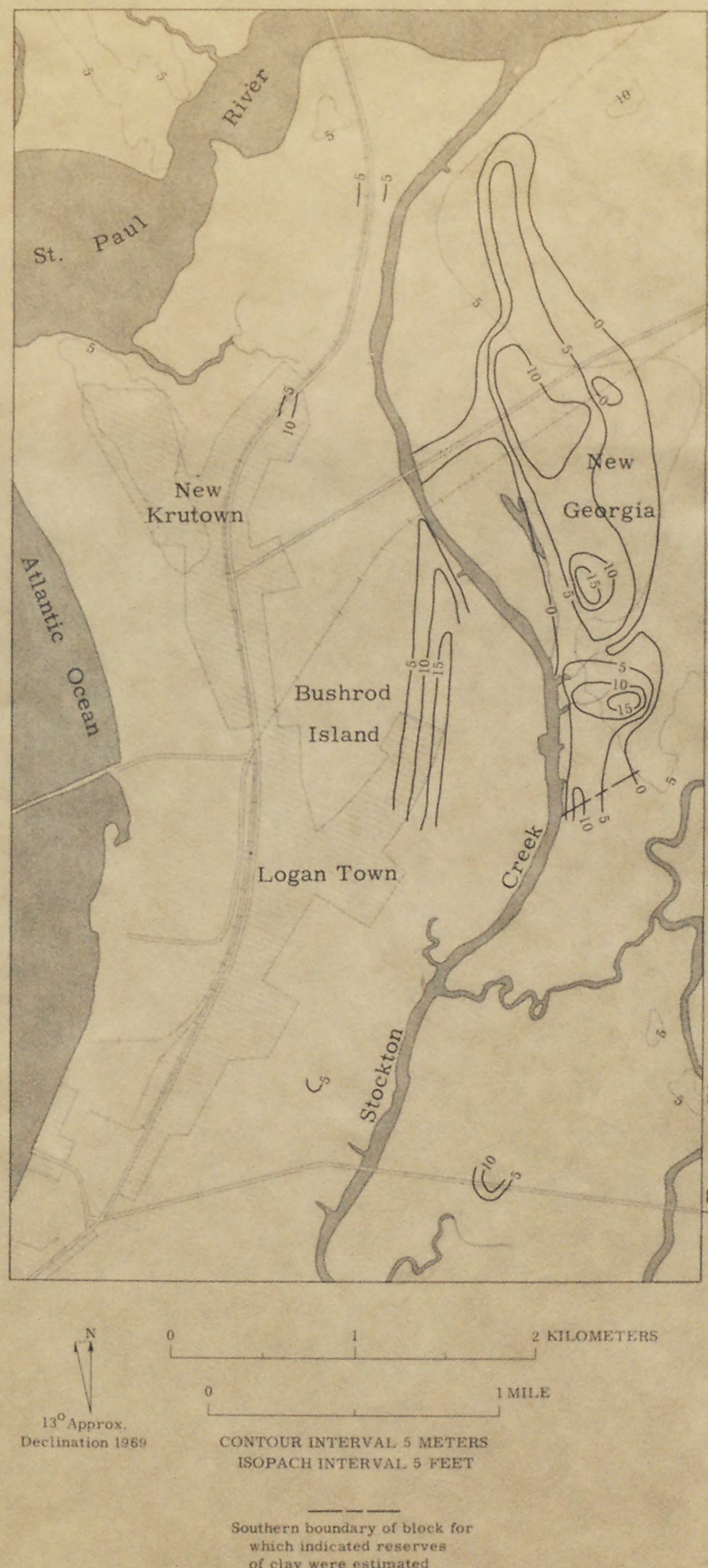


Figure 6. - Isopach map showing thickness of combined units 2, 5, 6, 7, and 8

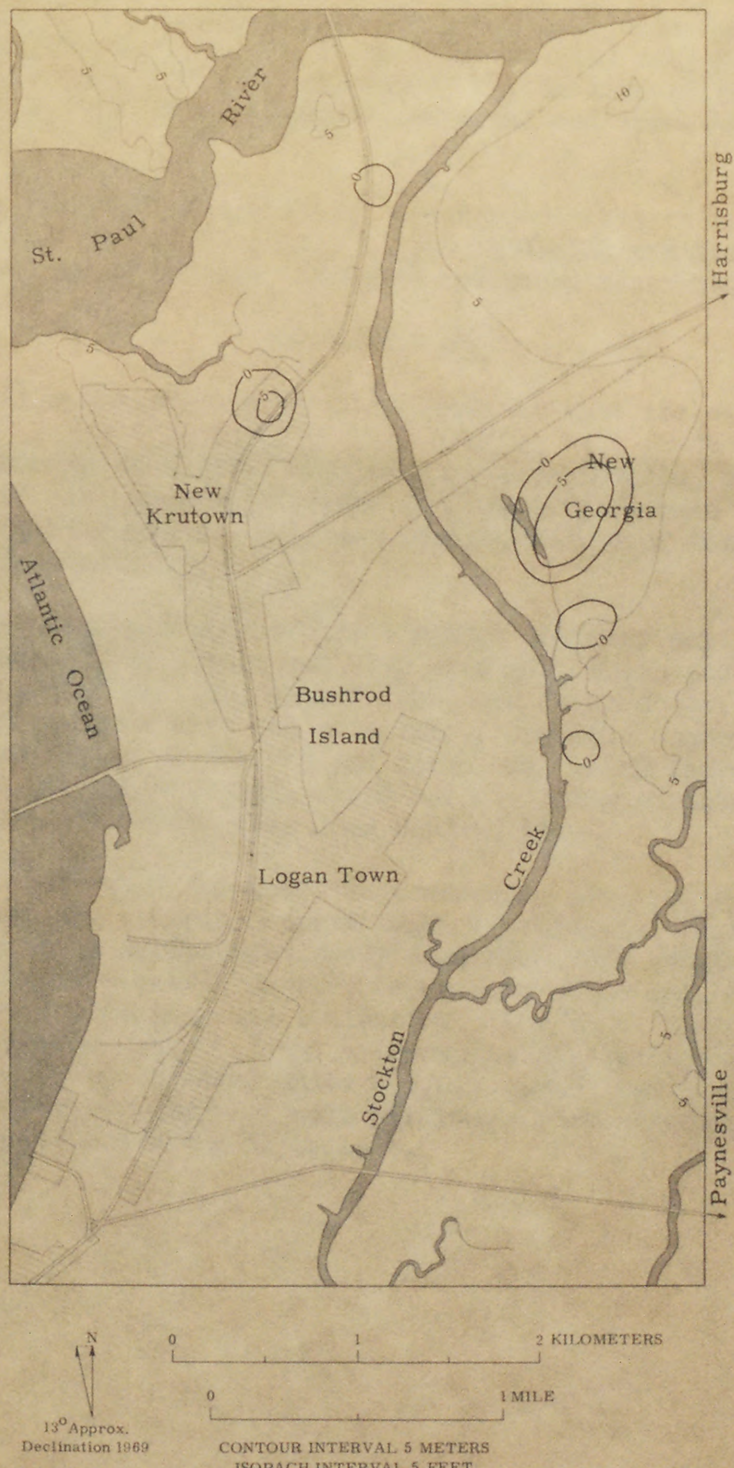


Figure 7. - Isopach map showing thickness of unit 9

In summary, it is estimated that the potential indicated reserves of clay for each of the three groups is as follows: (A) clay high in iron --1,800,000 short tons; (B) clay relatively low in iron--5,300,000 short tons; and (C) clay high in both organic material and iron--470,000 short tons.

Because of geologic similarity it seems reasonable to infer an amount of clay for each of the three groups in the remaining portion of the deposit equal to that estimated for the potential indicated reserves.

COMMERCIAL USES

From the foregoing discussion it is apparent that the clay in this deposit is a mixed clay composed dominantly of kaolinite, with generally abundant quartz, trace amounts of illite, montmorillonite, gibbsite, and K-feldspar, varing amounts of iron-bearing minerals, and varying amounts of organic material in the form of plant remains. The main commercial use of this type of clay is in the ceramics industry.

Manufactured clay products of the ceramics industry may be divided into the following categories: structural clay products, which includes brick, drain tile, sewer pipe, conduit tile, glazed tile, and terra cotta; pottery or stoneware; refractories; whiteware; and porcelain. Specific commercial uses depend upon physical properties of the raw and fired clay which include: plasticity, drying shrinkage, drying strength, fired color, firing shrinkage, absorption, modulus of rupture, and pyrometric cone equivalent.

In order to determine the specific commercial uses for which the clay of the Bushrod Island-New Georgia deposit might be suitable, representative samples from the three groups previously described were submitted to the Refractories Industry Research Center, Department of Ceramic Engineering, Ohio State University, for testing and evaluation. For these tests a representative sample of the combined units 1,3,and 4 (Group A) was designated A; a representative sample of the combined units 2,5,6,7, and 8 (Group B) was designated B; and a representative sample of unit 9 (Group C) was designated C. The results of the tests are shown in table 4.

Table 4.-- Physical properties of the raw and fired clay as determined in the laboratories of the Refractories Industry Research Center, Department of Ceramic Engineering, Ohio State University.

Physical properties*	Sample A	Sample B	Sample C
Plasticity and extrusion properties	good	good	good
Water of plasticity (percent)	34.85	32.30	32.10
Drying shrinkage (linear in percent)	10.74	7.06	7.82
Drying strength (lbs. per sq. in.)	515	605	740
Pyrometric cone equivalent (in cones)	26-27	29-31	31-31½
Fired color	red to dark-red	buff to dark buff-gray	buff to gray-buff
Firing shrinkage (lineau in percent)			
1800°F	2.51	2.40	3.59
1900°F	2.89	3.11	4.06
2000°F	2.84	2.72	3.50
2100°F	7.21	5.38	7.05
2200°F	9.72	8.73	10.58
2300°F	10.91	9.81	11.83
2400°F	10.66	9.93	12.56
Absorption (in percent)			
1800°F	27.9	28.53	38.04
1900°F	25.2	25.22	33.89
2000°F	20.4	22.61	26.28
2100°F	13.5	14.20	20.39
2200°F	8.6	7.48	11.79
2300°F	3.42	4.39	8.60
2400°F	2.24	1.89	4.44
Modulus of rupture (lbs. per sq. in.)			
1800°F	315	1080	320
1900°F	295	570	710
2000°F	300	520	360
2100°F	1050	1020	1070
2200°F	720	2370	2220
2300°F	850	2210	2240
2400°F	1490	1620	1830

* The values of the physical properties dependent upon firing were obtained on specimens fired in electrically heated laboratory kilns. It is the opinion of Metzgar (written commun., 1969) that in commercial kilns these values will be developed at temperatures approximately 200°F lower than those given in this table.

A. J. Metzger (written commun., 1969), Director of the Refractories Industry Research Center, evaluated the clays for specific commercial uses. The results of this evaluation for the three groups of clay are:

A. The clay designated A is suitable for making building brick, hollow tile, drain tile, roofing tile, quarry tile, flower pots, and porous earthenware pots such as those used for water coolers.

B. The clay designated B is suitable for making the items listed above and probably for stoneware and small diameter sewer pipe.

C. The clay designated C is suitable for making the items previously listed, low-to intermediate-duty refractory products, and possibly an insulating refractory if a ready source of sawdust or other inexpensive combustible is available.

It was also recommended that precalcined clay of minus 1/4 inch particle size be added to the raw clays B and C in making the more refractory products. The addition of precalcined clay would improve the firing properties of the clays and make the finished products more resistant to thermal shock.

In the past, Munariz S. A. located on Bushrod Island has made bricks from the clay of the Bushrod Island-New Georgia deposit (the inactive pit in the New Georgia area is shown on Figure 1). The Firestone Company makes bricks for its own use from alluvial sandy clay found in its Harbel concession area.

REFERENCES

Battelle Institute, 1963, Clay and Kaolin, in City and regional planning, Monrovia, Liberia, Part I: Frankfurt, Battelle Institute, v. 6, p. 219-224.

Geological Society of America, 1963, Rock-color chart: distributed by the Geological Society of America, New York, N. Y.

Worrall, G. A., and Dinkins, E. L., 1965, Soils of the Monrovia district: Liberia Univ., College of Agriculture, unpub. rept., 17p.

APPENDIX I: Logs of hand-auger holes drilled during the investigation of the Bushrod Island-New Georgia clay deposit.

All holes were logged by L. V. Blade. All the samples were moist or wet and the colors recorded are those of the wet samples. The approximate altitudes were taken from the Hansa Luftbild 1963 topographic map.

Hole number, date, and altitude Depth (feet)	Description

Hole BL-1B, August 9, 1967, approximate altitude 16 feet.

Depth (feet)	Description
0 - 1	Dark gray, silty, coarse-grained quartz sand with humus.
1 - 1½	Light gray, slightly silty, medium- to coarse-grained quartz sand.
1½ - 3½	Reddish-brown, slightly silty, medium- to coarse-grained quartz sand.
3½ - 10	Light brown, silty, medium- to coarse-grained quartz sand. Grains are angular to subrounded. Water table was 9 feet below surface.
10 - 15½	Light reddish-brown, silty, medium- to coarse-grained quartz sand. Grains are angular to subrounded.
15½ - 24	Reddish-brown slightly silty medium- to coarse-grained quartz sand with sparse quartz granules. Grains are angular to subrounded. Thin cemented zones occur from 22 to 24 feet.

Hole BL-2A, August 10, 1967, approximate altitude 15 feet.

Depth (feet)	Description
0 - ½	Brownish-gray plastic clay with humus. Unit 1.
½ - 1	Brown plastic clay. Unit 3.
1 - 3	Brown and reddish-brown mottled plastic clay. Unit 4.
3 - 6½	Light brown and light gray mottled plastic clay. Water table was 3½ feet below surface. Unit 5.
6½ - 19	Gray to dark gray plastic clay with plant remains below 8½ feet. Units 7 and 8.

Hole BL-2B, August 15, 1967, approximate altitude 15 feet.

Depth (feet)	Description
0 - ½	Road fill.
½ - 3½	Brown to light brown plastic clay. Unit 3.
3½ 10	Light brown, brown, and light gray mottled plastic clay. Water table was 7 feet below surface. Unit 4
10 - 13	Light gray and light brown mottled, slightly sandy, plastic clay. Unit 5.
13 - 23½	Gray to dark gray plastic clay with plant remains below 19 feet. Upper 1 foot unit 7, remainder unit 8.

Hole BL-3A, August 16, 1967, approximate altitude 15 feet.

Depth (feet)	Description
0 - ½	Road fill.
½ - 4	Light brown and reddish brown mottled plastic clay. Upper 1 foot gray with humus. Units 1 and 4.
4 - 7	Light gray and light brown mottled plastic clay. Water table was 4½ feet below surface. Unit 5.
7 - 10	Dark gray, clayey, very fine-grained quartz sand with plant remains below 8 feet.
10 - 13	Dark to light gray, medium- to coarse-grained quartz sand with scarce granules. Grains are angular to subrounded.

Hole number, date, and altitude Depth (feet)	Description
Hole BL-3B, August 16, 1967, approximate altitude 15 feet.	
0 - ½	Dark gray, silty, medium- to coarse-grained quartz sand with humus.
½ - 2½	Yellowish-gray, silty, medium- to coarse-grained quartz sand. Grains angular to subrounded.
2½ - 13½	Yellowish-brown, silty, medium- to coarse-grained quartz sand. Grains are angular to subrounded. Water table was 3 feet below surface.
Hole BL-3C, August 17, 1967, approximate altitude 15 feet.	
0 - 1	Grayish-brown, sandy, plastic clay. Unit 1. Quartz sand is very fine grained.
1 - 3½	Brown, sandy, plastic clay. Quartz sand is very fine grained. Below 1½ feet the clay is mottled brown and reddish-brown. Units 3 and 4.
3½ - 6½	Light and moderate brown mottled, clayey, very fine-grained quartz sand with light gray mottling below 5 feet. Water table was 6½ feet below surface.
6½ - 10	Light gray and light brown mottled, clayey, very fine- to fine-grained quartz sand.
10 - 16	Gray, clayey, very fine- to fine-grained quartz sand with plant remains below 11 feet.
Hole BL-4A, August 17, 1967, approximate altitude 15 feet.	
0 - ½	Road fill.
½ - 1½	Dark brown, sandy, plastic clay. Unit 3
1½ - 6½	Moderate to light brown, slightly sandy, plastic clay with gray and brown mottling below 6 feet. Units 3 and 5.
6½ - 10	Light gray and light brown mottled, clayey, veryfine- to fine-grained quartz sand. Water table was 8 feet below surface.
10 - 13½	Dark gray, clayey, very fine- to fine-grained quartz sand thinly interbedded with dark gray clay. Plant remains below 12 feet.
13½ - 15	Light gray, medium- to coarse-grained quartz sand with sparse granules and pebbles. Grains are angular to subrounded.
Hole BL-4B, August 18, 1967, approximate altitude 15 feet.	
0 - 2½	Dark gray and brown mottled plastic clay with humus. Unit 1.
2½ - 4	Brown plastic clay. Water table was 4 feet below surface. Unit 3.
4 - 10	Light gray and reddish-brown mottled plastic clay. Unit 5.
10 - 12	Gray plastic clay. Unit 6.
12 - 15½	Dark gray, clayey, very fine- to fine-grained quartz sand. The color is a lighter gray below 14 feet.
Hole BL-5A, August 18, 1967, approximate altitude 15 feet.	
0 - 1	Material washed in from railroad fill.
1 - 3	Brown plastic clay with humus in upper ½ foot. The color is mottled brown and reddish-brown below 2 feet. Water table was 3 feet below surface. Units 1, 3, and 4.
3 - 7	Light gray and reddish-brown mottled plastic clay. Unit 5.
7 - 13½	Grayish-brown plastic clay with plant remains at 7½ feet. Unit 7.
13½ - 14½	Dark gray, clayey, very fine- to fine-grained quartz sand above light gray, medium- to coarse-grained quartz sand.

Hole number, date, and altitude Depth (feet)	

Hole BL-5B, August 22, 1967, approximate altitude 15 feet.

0 - $1\frac{1}{2}$	Material washed in from railroad fill.
$1\frac{1}{2}$ - 2	Grayish-brown sandy plastic clay. Unit 3.
2 - $4\frac{1}{2}$	Light brown and moderate brown mottled, slightly sandy, plastic clay. The lowest $\frac{1}{2}$ foot is gray in color. Water table was 4 feet below surface. Units 4 and 6.
$4\frac{1}{2}$ - $5\frac{1}{2}$	Light gray, slightly silty, medium- to coarse-grained quartz sand.

Hole BL-5C, August 22, 1967, approximate altitude 15 feet.

0 - $\frac{1}{2}$	Material washed in from railroad fill.
$\frac{1}{2}$ - 7	Light brown and reddish-brown mottled plastic clay with additional light gray mottling below 3 feet. Water table was $3\frac{1}{2}$ feet below surface. Unit 4.
7 - 8	Gray, clayey, very fine-grained quartz sand.
8 - 10	Dark gray, silty, very fine- to fine-grained quartz sand.
10 - $10\frac{1}{2}$	Gray to light gray, silty, medium- to coarse-grained quartz sand.

Hole BL-6A, August 22, 1967, approximate altitude 16 feet.

0 - $\frac{1}{2}$	Material washed in from railroad fill.
$\frac{1}{2}$ - 2	Grayish-brown, sandy, plastic clay. Unit 1.
2 - 7	Light brown plastic clay. Water table was 4 feet below surface. Unit 3.
7 - 10	Light gray and light brown mottled plastic clay with light gray color predominent below 9 feet. Units 5 and 6.
10 - 18	Gray plastic clay with abundant plant remains. Unit 8.

Hole BL-6B, August 23, 1967, approximate altitude 15 feet.

0 - 2	Material washed in from railroad fill.
2 - $2\frac{1}{2}$	Grayish-brown plastic clay. Unit 1.
$2\frac{1}{2}$ - $4\frac{1}{2}$	Light brown and reddish-brown mottled plastic clay, slightly sandy in upper $\frac{1}{2}$ foot. Light gray was added to the brown mottling below 3 feet. Water table was 3 feet below surface. Unit 4.
$4\frac{1}{2}$ - $7\frac{1}{2}$	Light gray and reddish-brown mottled plastic clay with light gray color predominent below 5 feet. Unit 5.
$7\frac{1}{2}$ - 16	Dark gray plastic clay with plant remains. Unit 8.
16 - $17\frac{1}{2}$	Light gray, silty, very fine- to fine-grained quartz sand.

Hole BL-7A, August 23, 1967, approximate altitude 11 feet.

0 - 3	Light brown plastic clay. Unit 3. (This hole was drilled in a cut and the collar is probably about 4 feet below the original ground level.)
3 - $4\frac{1}{2}$	Light brown and reddish-brown mottled plastic clay. Unit 4.
$4\frac{1}{2}$ - 5	Light gray, very fine- to fine-grained quartz sand. Water table was 5 feet below surface.
5 - $9\frac{1}{2}$	Dark gray, silty, very fine-grained quartz sand.

Hole number, date, and altitude Depth (feet)	Description

Hole BL-7B, August 25, 1967, approximate altitude 15 feet.

0 - 1	Material washed into ditch.
1 - 2	Light brown and reddish-brown mottled plastic clay. Unit 3.
2 - 5½	Light gray, light brown, and reddish-brown mottled plastic clay. Water table was 3½ feet below surface. Unit 5.
5½ - 7½	Light gray plastic clay with a darker gray color the lowest ½ foot. Units 6 and 7.
7½ - 14	Moderate brown plastic clay with abundant plant remains turned grayish black on exposure to the air. Unit 9.
14 - 16½	Dark gray plastic clay with plant remains. Unit 8.
16½ - 18	Gray, medium- to coarse-grained quartz sand.

Hole BL-7C, August 25, 1967, approximate altitude 15 feet.

0 - ½	Road fill.
½ - 3½	Brown plastic clay. Unit 3.
3½ - 5	Light brown, light gray, and reddish-brown mottled plastic clay. Water table was 4½ feet below surface. Unit 4.
5 - 8	Light gray plastic clay with the lower ½ foot brownish-gray in color. Units 6 and 7.
8 - 10	Dark brown plastic clay with abundant plant remains that turn grayish-black when exposed to the air. Unit 9.
10 - 12½	Dark gray plastic clay with plant remains. Unit 8
12½ - 19	Gray, silty, very fine- to fine-grained quartz sand with plant remains locally abundant.

Hole BL-8A, August 29, 1967, approximate altitude 15 feet.

0 - 1	Material washed in from road.
1 - 3	Brown, slightly sandy, plastic clay. Unit 3.
3 - 3½	Light brown, light gray, and reddish-brown mottled sandy clay. Unit 4.
3½ - 9	Light brown, slightly silty, medium- to coarse-grained quartz sand. Grains are angular to subrounded. Water table was 4½ feet below surface.

Hole BL-8B, August 29, 1967, approximate altitude 15 feet.

0 - ½	Road metal.
½ - 1	Dark gray, silty, medium- to coarse-grained quartz sand with humus. Grains are angular to subrounded.
1 - 1½	Gray and reddish-brown mottled, clayey, medium- to coarse-grained quartz sand.
1½ - 3½	Gray plastic clay slightly sandy upper ½ foot. Water table was 3 feet below surface. Unit 2
3½ - 6	Light gray, light brown, and reddish-brown mottled plastic clay. Unit 5.
6 - 7	Dark gray plastic clay with plant remains. Unit 8
7 - 8½	Gray to light gray, medium- to coarse-grained quartz sand.

Hole number, date, and altitude Depth (feet)	Description
Hole BL-9A, August 29, 1967, approximate altitude 15 feet.	
0 - 1	Road fill.
1 - 2	Gray, clayey, medium- to coarse-grained quartz sand. Unit 2.
2 - 3	Gray to light gray plastic clay. Water table was $2\frac{1}{2}$ feet below surface./
3 - 6	Light gray and light brown mottled plastic clay. Unit 5.
6 - $8\frac{1}{2}$	Light gray plastic clay with dark gray color and plant remains in lower foot. Units 6 and 7.
$8\frac{1}{2}$ - 19	Brown plastic clay with plant remains that are locally abundant. Color changes to dark gray on exposure to the air. Unit 8.
Hole BL-9B, August 30, 1967, approximate altitude 18 feet.	
0 - $\frac{1}{2}$	Dark gray, silty, medium- to coarse-grained quartz sand with humus.
$\frac{1}{2}$ - $8\frac{1}{2}$	Grayish-brown to light brown, silty, medium- to coarse-grained quartz sand. Water table was $6\frac{1}{2}$ feet below surface.
$8\frac{1}{2}$ - $12\frac{1}{2}$	Pinkish-brown, silty, medium- to coarse-grained quartz sand.
Hole BL-9C, August 30, 1967, approximate altitude 15 feet.	
0 - 1	Road fill.
1 - 3	Brown plastic clay. Slightly sandy in upper $\frac{1}{2}$ foot. Light brown and reddish-brown mottled below $2\frac{1}{2}$ feet. Water table was $2\frac{1}{2}$ feet below surface. Units 3 and 4.
3 - $3\frac{1}{2}$	Light gray and reddish-brown mottled plastic clay. Unit 5.
$3\frac{1}{2}$ - $9\frac{1}{2}$	Light gray, silty, medium- to coarse-grained quartz sand.
Hole BL-10A, August 30, 1967, approximate altitude 15 feet.	
0 - $3\frac{1}{2}$	Light brown, light gray, and reddish-brown mottled plastic clay. Unit 4.
$3\frac{1}{2}$ - $7\frac{1}{2}$	Light gray and light brown mottled plastic clay. Water table was 4 feet below surface. Unit 5.
$7\frac{1}{2}$ - $15\frac{1}{2}$	Gray to dark gray plastic clay with plant remains. Unit 7.
Hole BL-10B, August 31, 1967, approximate altitude 15 feet.	
0 - 1	Grayish-brown, slightly sandy, plastic clay with humus. Unit 1.
1 - 4	Brown plastic clay. Water table was $3\frac{1}{2}$ feet below surface. Unit 3.
4 - $7\frac{1}{2}$	Light brown, light gray, and reddish-brown mottled, very clayey, very fine- to fine-grained quartz sand.
$7\frac{1}{2}$ - $8\frac{1}{2}$	Light gray, very clayey, very fine- to fine-grained quartz sand. Unit 7.
$8\frac{1}{2}$ - 15	Gray plastic clay with plant remains; slightly sandy in upper 2 feet. /
15 - $15\frac{1}{2}$	Dark brown plastic clay with abundant plant remains. The color changes to dark gray on exposure to the air. Unit 9
Hole BL-10C, August 31, 1967, approximate altitude 13 feet.	
0 - $\frac{1}{2}$	Dark gray, slightly sandy, plastic clay with humus. Unit 1
$\frac{1}{2}$ - 2	Light brownish-gray, slightly sandy, plastic clay. Unit 3.
2 - $4\frac{1}{2}$	Light gray, silty, medium- to coarse-grained quartz sand. Water table was $2\frac{1}{2}$ feet below surface.

Hole number, date, and altitude Depth (feet)	Description

Hole BL-11A, September 1, 1967, approximate altitude 15 feet.

0 - 1	Dark gray, slightly sandy, plastic clay with humus. Unit 1.
1 - 5½	Brown to light brown, slightly sandy, plastic clay. Water table was 5½ feet below surface. Unit 3
5½ - 8	Light brown, light gray, and reddish-brown mottled plastic clay. Unit 4.
8 - 12½	Light to dark gray plastic clay; plant remains in lower portion. Units 6&7
12½ - 15½	Brown plastic clay with abundant plant remains. The color changes to grayish-black on exposure to the air. Unit 9.

Hole BL-11B, September 6, 1967, approximate altitude 15 feet.

0 - ½	Grayish-brown, slightly sandy, plastic clay with humus. Unit 1.
½ - 4	Grayish-brown to light brown plastic clay that is slightly sandy in upper foot. Unit 3.
4 - 6½	Light brown, reddish-brown, and light gray mottled plastic clay. Water table was 6½ feet below surface. Unit 4.
6½ - 11	Light gray to dark gray plastic clay with plant remains locally abundant. Units 6 and 7.
11 - 18½	Brown plastic clay with abundant plant remains. The color changes to grayish-black on exposure to the air. Unit 9.

Hole BL-11C, September 6, 1967, approximate altitude 13 feet.

0 - 4	Light gray plastic clay with roots. Water table was at the surface.
4 - 5	Brownish-gray plastic clay with plant remains. Unit 8.
5 - 13½	Dusky brown plastic clay with abundant plant reamins. Unit 9.
13½ - 15½	Gray, silty, medium- to coarse-grained quartz sand.

Hole BL-12A, September 14, 1967, approximate altitude 15 feet.

0 - ½	Grayish-brown plastic clay with humus. Unit 1.
½ - 5½	Grayish-brown to brown plastic clay with iron oxide nodules at 2 feet and mottled with reddish-brown color below 2 feet. Water table was 3 feet below the surface. Units 3 and 4.
5½ - 6½	Light gray, light brown, and lesser reddish-brown mottled plastic clay./ Unit 5.
6½ - 9	Gray to dark gray plastic clay with plant remains abundant in lower ½ foot. Unit 7.
9 - 15½	Brown plastic clay with plant remains; changes color to dark gray on exposure to the air. The lower ½ foot is slightly sandy. Unit 8.
15½ - 18½	Gray to light gray, slightly silty, medium- to coarse-grained quartz sand.

Hole BL-12B, September 15, 1967, approximate altitude 13 feet.

0 - 1	Grayish-brown, slightly sandy, plastic clay with humus and small fragments of charcoal.
1 - 3	Brown to light brown, slightly sandy, plastic clay. Water table was 3 feet below surface.
3 - 3½	Light gray, silty, fine- to coarse-grained quartz sand.
3½ - 4½	Light gray, coarse- to medium-grained quartz sand.

Hole number, date, and altitude Depth (feet)	Description
Hole BL-12C, September 15, 1967, approximate altitude 13 feet.	
0 - ½	Gray, slightly sandy, plastic clay with humus and fragments of charcoal.
½ - 1	Light gray, sandy, plastic clay. Water table was 1 foot below surface.
1 - 2½	Light gray, clayey, coarse- to medium-grained quartz sand.
2½ - 3½	Light gray, sandy, plastic clay.
3½ - 4½	Light gray, coarse- to medium-grained quartz sand.
Hole BL-13A, September 15, 1967, approximate altitude 16 feet.	
0 - ½	Grayish-brown, slightly sandy, plastic clay with humus and fragments of charcoal. Unit 1.
½ - 5	Brown to light brown, slightly sandy, plastic clay. Unit 3.
5 - 5½	Brown and reddish-brown mottled, clayey, very fine- to fine-grained quartz sand.
5½ - 7½	Light gray, clayey, very fine- to fine-grained quartz sand. Water table was 7½ feet below surface.
7½ - 8½	Light brown, coarse- to medium-grained quartz sand with sparse granules. A thin clayey sand lens occurs at 8 feet.
Hole BL-13B, September 19, 1967, approximate altitude 13 feet.	
0 - 1	Gray and brown mottled plastic clay with humus and fragments of charcoal. / Unit 1.
1 - 5	Light gray and light brown mottled plastic clay. Water table was 1½ feet below surface. Unit 5.
5 - 6	Light gray plastic clay. Unit 6.
6 - 9	Gray plastic clay with plant remains locally abundant. Unit 7.
9 - 12	Gray, clayey, very fine- to fine-grained quartz sand with plant remains locally abundant.
12 - 13	Gray to light gray, medium- to coarse-grained quartz sand.
Hole BL-13C, September 19, 1967, approximate altitude 13 feet.	
0 - 1	Gray and brown mottled plastic clay with humus and fragments of charcoal. / Unit 1.
1 - 9	Light brown, light gray, and reddish-brown mottled plastic clay with a larger proportion of gray in the lower part. Water table was 2 feet below surface. Units 4 and 5.
9 - 13	Gray plastic clay with a small amount of plant remains. Unit 7.
13 - 14	Light gray, slightly clayey, medium- to coarse-grained quartz sand.
Hole BL-14A, September 21, 1967, approximate altitude 16 feet.	
0 - 1	Gray to brown plastic clay with humus and fragments of charcoal. Unit 1.
1 - 3½	Light brown and reddish-brown mottled plastic clay. Water table was 2½ feet below surface. Unit 5.
3½ - 6	Light gray and light brown mottled plastic clay. Unit 5.
6 - 7	Brownish-gray plastic clay with plant remains abundant in last ½ foot. The color changes to gray on exposure to the air. Unit 8.
7 - 12½	Moderate brown plastic clay with abundant plant remains. The clay is slightly sandy in the lower ½ foot. Unit 9.
12½ - 17	Gray to light gray, silty, fine- to coarse-grained quartz sand with plant remains in the upper ½ foot.

Hole number, date, and altitude Depth (feet)	Description

Hole BL-14B, September 21, 1967, approximate altitude 15 feet.

0 - 1	Road fill.
1 - 1½	Gray plastic clay with humus and fragments of charcoal. Unit 1.
1½ - 2½	Brown plastic clay with sparse sand grains. Unit 3.
2½ - 3	Light to dark gray, slightly sandy, plastic clay. Water table was 3 feet below surface. Unit 7.
3 - 5	Gray to light gray, silty, very coarse- to medium-grained quartz sand with wood fragments in upper ½ foot.

Hole BL-15A, September 21, 1967, approximate altitude 15 feet.

0 - 1½	Grayish-brown to light brown, sandy, plastic clay with humus. Unit 1.
1½ - 3	Brown, light brown, and reddish-brown mottled, sandy, plastic clay. Unit 4.
3 - 6	Light brown and light gray mottled clayey, very fine- to fine-grained quartz sand. Water table was 3½ feet below surface.
6 - 7	Light gray and light brown mottled, sandy, plastic clay. Unit 5.
7 - 8	Light gray and light brown mottled, clayey, very fine- to fine-grained quartz sand.
8 - 9	Light gray to light brown, very coarse- to medium-grained quartz sand.
9 - 16½	Gray, clayey, very fine- to fine-grained quartz sand.

Hole BL-15B, September 22, 1967, approximate altitude 13 feet.

0 - 1	Grayish-brown plastic clay with humus, fragments of charcoal, and sparse grains of sand. Unit 1.
1 - 6	Brown, light brown, and reddish-brown mottled plastic clay. Water table was 2½ feet below surface. Unit 4.
6 - 8	Light gray and light brown mottled plastic clay. Unit 5.
8 - 13½	Light gray to gray plastic clay. Units 6 and 7.
13½ - 16½	Brownish-gray, clayey, very fine- to fine-grained quartz sand that changes to dark gray on exposure to the air.
16½ - 23½	Brownish-gray, sandy, plastic clay that turns dark gray on exposure to air. Unit 8.

Hole BL-16A, September 26, 1967, approximate altitude 15 feet.

0 - 1	Dark gray to brownish-gray, clayey, very fine- to fine-grained quartz sand with humus and fragments of charcoal.
1 - 2½	Brown to light brown, clayey, very fine- to fine-grained quartz sand with nodules up to ½ inch in diameter of iron oxide.
2½ - 4½	Light brown, clayey, very fine- to fine-grained quartz sand.
4½ - 5½	Light brown and light gray mottled, sandy, plastic clay. Water table was 5½ feet below surface. Unit 5.
5½ - 8½	Light gray and light brown mottled plastic clay. Unit 5.
8½ - 14	Dark gray plastic clay. Unit 7.
14 - 15	Brown plastic clay with abundant plant remains. The color changes to dark gray on exposure to the air. Unit 9.
15 - 17	Light bluish-gray, sandy, plastic clay. Sand grains are medium- to very coarse-grained.
17 - 17½	Light gray, clayey, sandy, pebble gravel. Pebbles are of quartz and are well-rounded.

Hole number, date, and altitude
Depth (feet) — Description

Hole BL-16B, September 26, 1967, approximate altitude 15 feet.

0 - 1½ Washed-in fill material.
1½ - 4½ Light brown, clayey, very fine- to fine-grained quartz sand. Water table was 2½ feet below surface. Unit 3.
4½ - 5 Light brown, sandy, plastic clay. Sand is very fine- to fine-grained.
5 - 7 Light gray and light brown mottled plastic clay. Unit 5.
7 - 8½ Light gray plastic clay. Unit 6.
8½ - 16 Brownish-gray plastic clay that turns dark gray on exposure to the air. Plant remains are locally abundant. Unit 8.

Hole BL-17A, September 27, 1967, approximate altitude 18 feet.

0 - 3½ Road fill.
3½ - 4½ Dark gray plastic clay with humus and fragments of charcoal. Unit 1.
4½ - 7½ Brown, light brown, and reddish-brown mottled plastic clay. Water table was 5 feet below surface. Unit 4.
7½ - 9½ Light gray and light brown mottled plastic clay. Unit 5.
9½ - 13 Brownish-gray plastic clay that turns gray on exposure to the air and contains plant remains. Unit 7.
13 - 21 Brownish-gray plastic clay with plant remains locally abundant. The color of the clay changes to dark gray on exposure to the air. Unit 8.

Hole BL-17B, September 27, 1967, approximate altitude 18 feet.

0 - 1½ Dark gray to brown, clayey, medium- to coarse-grained quartz sand with humus and fragments of charcoal.
1½ - 6½ Brown to light brown, clayey, medium- to coarse-grained quartz sand. Water table was 4½ feet below surface.

Hole BL-17C, September 28, 1967, approximate altitude 12 feet.

0 - ½ Brown, slightly sandy, plastic clay with humus. Unit 1.
½ - 2 Light brown plastic clay with plant roots. Water table was 2 feet below surface. Unit 3.
2 - 3 Brownish-gray plastic clay with plant remains. Unit 7.
3 - 4 Dark gray, clayey, very fine- to fine-grained quartz sand with plant remains.
4 - 6½ Gray, very coarse- to medium-grained quartz sand with granules of quartz.

Hole BL-18A, September 28, 1967, approximate altitude 13 feet.

0 - ½ Brownish-gray plastic clay with humus. Unit 1.
½ - 2½ Light gray plastic clay. Water table was 1½ feet below surface. Unit 2.
2½ - 9½ Light gray to gray, silty, medium- to coarse-grained quartz sand.

Hole number, date, and altitude Depth (feet)	Description

Hole BL-18B, September 28, 1967, approximate altitude 15 feet.

0 - 1	Dark gray to brownish-gray, clayey, medium- to coarse-grained quartz sand with humus.
1 - 2	Brown, clayey, medium- to coarse-grained quartz sand.
2 - 5	Grayish-brown to mottled brown and reddish-brown, clayey, medium- to coarse-grained quartz sand with angular granules and pebbles of quartz and thoroughly weathered quartz-mica(?) schist.

Hole BL-18C, September 29, 1967, approximate altitude 12 feet.

0 - ½	Washed in fill from the road. Water table was ½ foot below surface.
½ - 1	Dark gray plastic clay with humus. Unit 1.
1 - 2½	Gray, light gray, and brown mottled plastic clay. Unit 5.
2½ - 3	Light gray plastic clay. Unit 6.
3 - 3½	Brown plastic clay. Unit 7.
3½ - 6	Dusky brown plastic clay with plant remains. The clay changes color to a dark gray on exposure to the air. Unit 8.
6 - 9	Dark gray to gray, clayey, fine- to coarse-grained quartz sand.

Hole BL-18D, September 29, 1967, approximate altitude 10 feet.

0 - 1	Grayish-brown, slightly sandy, plastic clay with humus and fragments of charcoal. Unit 1.
1 - 2½	Brown, light brown, and reddish-brown mottled plastic clay. Water table was 2½ feet below surface. Unit 4
2½ - 3	Light gray and brown mottled, very sandy, plastic clay. Sand is coarse-grained.
3 - 4	Very light brown, coarse- to medium-grained quartz sand.

Hole BL-19A, September 29, 1967, approximate altitude 12 feet.

0 - 1	Grayish-brown plastic clay with humus. Unit 1.
1 - 2	Brown to light brown plastic clay. Unit 3.
2 - 3½	Light brown and reddish-brown mottled plastic clay. Water table was 2½ feet below surface. Unit 4.
3½ - 6½	Light gray and light brown mottled plastic clay. Unit 5.
6½ - 9	Gray to dark gray plastic clay. Unit 7.
9 - 21½	Brown plastic clay with plant remains dispersed through the clay. The color changes to dark gray on exposure to the air. Unit 8.