U. S. Geological Survey.

REPORTS-OPEN FILE SERIES, no. 1434: 1970.

SILICA SAND DEPOSITS IN THE MONROVIA AREA, LIBERIA

by

Sam Rosenblum 1923-
U. S. Geological Survey

and

S. P. Srivastava
Liberian Geological Survey

Released to open file July 23, 1970

CONTENTS

ILLUSTRATIONS

SILICA SAND DEPOSITS IN THE MONROVIA AREA, LIBERIA

by

Sam Rosenblum, U.S. Geological Survey

and

S. P. Srivastava, Liberian Geological Survey

ABSTRACT

Thin surficial deposits of white silica sand occupy much of the flat coastal area of Liberia from Monrovia to Buchanan 100 km southeast; most of the sand is of good quality for glass manufacture. A lagoonal mode of origin is suggested for these essentially monomineralic deposits. Based on the average thickness of one meter and a conservative bulk density of 1.6, the easily accessible deposts along the Freeway, the Kakata highway, and the Schieffelin road cover about 68 square kilometers and contain at least 109 million metric tons of silica sand.

INTRODUCTION

Purpose and scope

This brief report is based on a reconnaissance investigation, made on a time-available basis, of the silica-rich white sand deposits in the Monrovia area of Liberia. Heretofore, these sands were mined for construction purposes, but preliminary tests show that they are suitable as raw material for the manufacture of all types of glass used in the country. With glass manufacture in mind, the investigation concentrated on the quality of the silica sand deposits, as indicated by physical, mineralogical, and chemical analyses, and on the location in the Monrovia area of easily accessible and minable reserves adequate for at least 20 years. This study represents a contribution of the Geological Exploration and Resources Appraisal program (GERA), a cooperative effort of the Government of Liberia and the U.S. Agency for International Development, carried out jointly by the Liberian Geological Survey and the U.S. Geological Survey

Background

To ascertain the feasibility of developing a glass-manufacturing industry in Liberia, we requested a study of this by engineers of the Monrovia office of the Checchi Engineering Company. In February 1968 the firm reported that the annual (1967) turnover of glass bottles was about 34 million units, 8 million of which were new purchases. The market for sheet, plate, and window glass was estimated at about 400 tons annually with a wholesale value of $200,000, and the market for household glassware amounted to 165 tons, with a wholesale value of approximately $82,000.

The report noted that in the production of glass, silica sand constitutes 40 percent of the total weight of raw materials, but only 4 percent of the total value; all other materials, including sodium, calcium, magnesium, and potassium carbonates, soda ash, and limestone, would have to be imported.

The Checchi report recommended a followup survey be undertaken by the Liberian Development Corporation in 1972-73 in order to determine the size of the market and the viability of a local glass manufacturing plant. This report is offered in anticipation of the recommended resurvey.

Previous investigations

A Battelle Institute (Germany) report of 1963 (p. 217) on city and regional planning, Monrovia, Liberia, mentioned silica sand, ". . . a raw material present in Liberia in practically unlimited quantities . . . between the Po River and the mouth of the Junk River . . . white sands derived from disintegrated sandstone. . ." A screen analysis of a samples taken 2 km east of radio station ELWA showed that 97 percent of all grains are in the usable range of granulation for glass manufacture which is 0.09 to 1.0 mm. Seventy-four percent of the grains were in the optimum range, 0.1 to 0.4 mm. Also, the report states ". . . the mean content . . . is as low as 0.03% Fe_2O_3" (p. 217). Little other information is given on character and distribution of the resource.

G. W. Leo (written commun., 1966) indicated that silica sand from the ELWA area was essentially similar to a quartz sand from Holland that is used for glass manufacture; however, Leo cautioned that the appraisal was based on one sample of ELWA area sand weighing about 150 grams.

Acknowledgments

We wish to acknowledge the valuable field data in the coastal area of Liberia collected by R. W. White which is incorporated in part in figure 1 of this report. We also appreciate the many discussions on silica sand deposits in the Monrovia area with our colleagues in the GERA project.

GEOLOGY

Geologic setting

White silica sand deposits invariably occupy bare flat-lying areas within 12 km (7 1/2 miles) of the coast in a zone that extends from the Po River, 17 km (11 miles) NNW of Monrovia to at least Buchanan, almost 100 km (60 miles) southeastward. Figure 1 shows the extent of this zone between Monrovia and Marshall, based mainly on field observations and in part on photogeology. The majority of the flats are elongate parallel to the coastline, range in altitude from 0. 5 to 15 meters (1 1/2 - 46 feet) above sea level, and are usually sparsely covered by grass and a few shrubs. The highest area is a basin-like plain along the Kakata highway between Paynesville and the northern margin of the area shown in figure 1; the average altitude here is about 12 meters (37 feet). To the west the white sand surfaces are at 7 - 8 meters (22 - 25 feet) along the north side of the Freeway, and about 4 meters (13 feet) west of Warner Creek. Southward the altitude averages 3 - 4 meters (10 - 13 feet) along the Schieffelin road, except in a large flat just east of Schieffelin, where the surface averages 7 - 8 meters (22 - 25 feet).

The areas of white sand are discontinuous in the coastal belt and range in size from patches barely 100 meters (330 feet) across to one area about 15 km (9 miles) long and 4 km (2 1/2 miles) wide (fig. 2). Thicknesses measured by post hole digger, and hand and power augers were 30 to 150 cm (1 - 5 feet) and averaged about one meter (3 1/3 feet).

From Warner Creek west to Freeport, silica sand deposits stand a few meters higher than the swampy Mesurado River drainage area. Elsewhere the deposits are generally in depressed areas, surrounded by low hills of weathered rock or brown sand. The borders of these areas are sharp against the weathered rocks, but are gradational in contact with the brown to buff beach sand. These borders are fairly straight and subparallel to the coastline in the areas closest to the

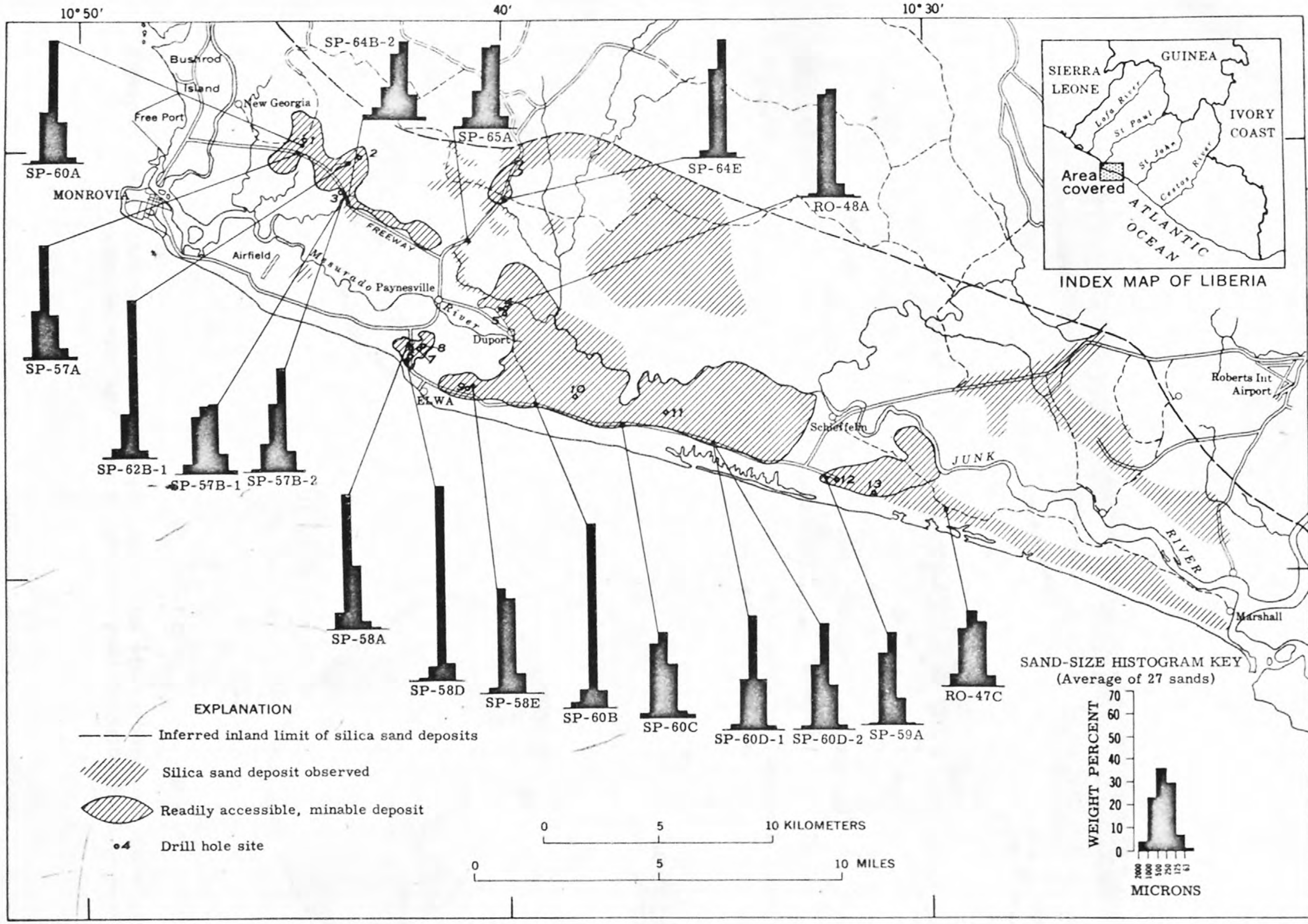

Figure 1.–Map showing silica sand deposits in the Monrovia, Liberia area

Figure 2. -Silica sand deposit along the Schieffelin road 15 miles from Monrovia. Shallow water-filled area in foreground is former sand pit.

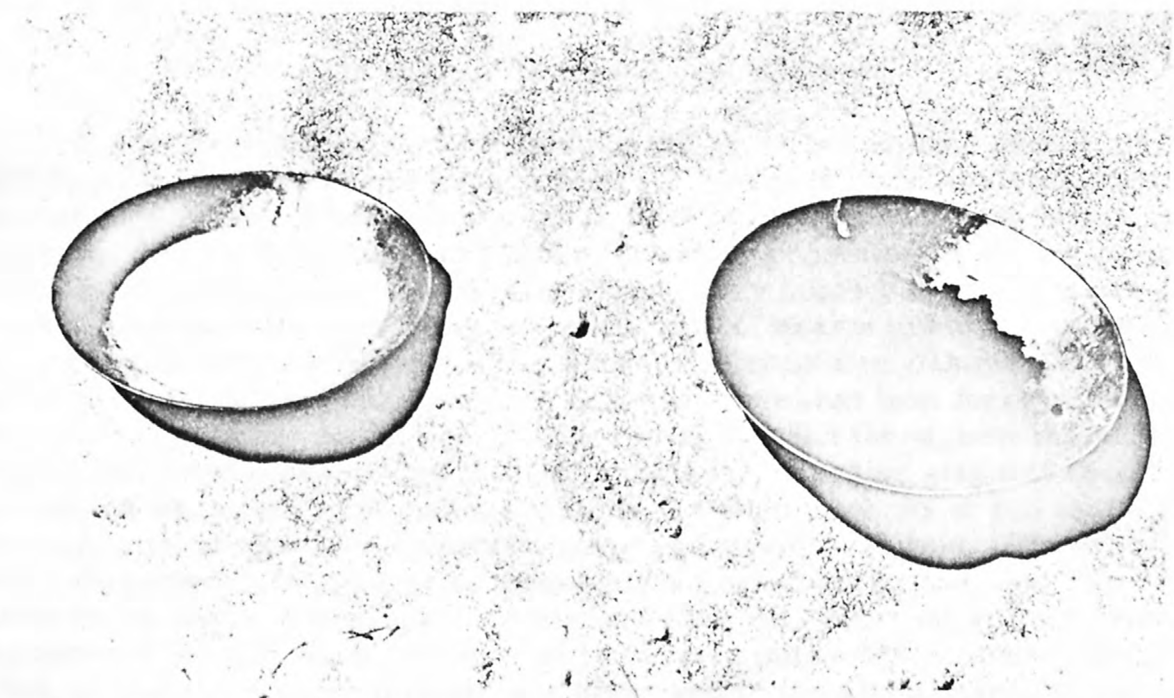

Figure 3. -White silica sand (left) and dark gray silica sand with carbonaceous matter (right) compared with light brown to buff beach sand (background).

shore, but inland flats have sinuous borders which probably resulted from erosion and redeposition of the white sand by small streams on the coastal savanna.

The pure silica sand is a dazzling white when dry, but only grayish white when moist. In places just within the borders of the deposit, a gray to black color is imparted by fine-grained carbonaceous material which is interpreted to be the remains of vegetation that grew within the white sand area at the time of deposition in lagoons (fig. 3).

As one of the youngest geologic units in the Monrovia area, the unconsolidated silica sands cover and butt against Precambrian crystalline rocks, lower Paleozoic(?) to Tertiary(?) sandstones (White, 1969), Mesozoic diabases, and Quaternary littoral sands. The source rocks for the silica sands may be, in part, the weakly consolidated sandstones in the coastal area of Liberia as mentioned by the Battelle Institute (1963, p. 217). We believe, however, that the major part of the quartz grains are derived from upcountry crystalline rocks that contain quartz. These include mainly massive to gneissoid granitic rocks, granitic to quartz dioritic gneisses, quartzo-feldspathic gneisses of sedimentary origin, some quartzites, amphibolites, and quartz-bearing granulites (Leo and White, 1967).

Origin of the silica sand deposits

Contrary to the brief conclusion of the Battelle Institute report (1963, p. 217) that the white sands are ". . . derived from disintegrated sandstone, . . ." we infer that a special set of circumstances is required to produce these deposits. The simplest theory consistent with our observations requires intense weathering of upcountry quartzose rocks to produce a thick laterite consisting predominantly of quartz grains in a fine-grained clay matrix with or without hydrous iron oxides. During this period of intense lateritization, erosion was somewhat less forceful than at present, perhaps due to precipitation being spread throughout the year instead of being concentrated in a rainy season. Sluggish streams thus developed were able to transport particles of sand up to about 1.5 mm across, accompanied by suspended clays and iron in solution. These were deposited in lagoons at successively lower levels as the land was elevated in successive steps. In this environment, clay and silt particles maintained in suspension are gradually carried out to sea. At the same time, any soluble iron minerals are dissolved in the slightly acid reducing conditions of lagoons and ionic iron is flushed out to sea.

Modern lagoon water tested with pH paper shows a pH of 5 1/2 in stagnant water amid reeds, and a pH of 6 in the flowing part; seawater at the shore is 6 1/2. A simple laboratory test with the same pH test papers indicated that precipitation of both ferrous and ferric hydroxides begins at room temperature at pH 5 and is essentially complete at pH 7. By extrapolation to lagoonal temperatures (about 20° - 22° C) and invoking a lowering of the pH, we presume that conditions were just acid enough to allow all soluble iron to be flushed out of the depositing sand.

Derivation of the white sand from the brown to buff beach sand by similar leaching of the soluble iron minerals is rejected as a mode of origin for the following reasons:

1. Lateral boundaries with brown beach sand are generally gradational over a few meters and only rarely over longer distances. The latter would be the rule if the white sand were derived from bleaching of beach sand.

2. The lower contact of the white sand against beach sand is sharp, through a few centimeters, as would be expected if the white sand were deposited on the brown.

3. The average content of heavy minerals in the silica sands is 0.65 percent; the maximum is 2 percent. In contrast, heavy minerals in the recent beach sands between Robertsport and Buchanan average 6.87 percent in 37 composite samples; only 9 of the samples had less than 2 percent (Hockin, 1957, written commun.).

4. Beach sands contain some feldspars that weathered to form clayey hardpans in places below the white sand; the silica sand contains no feldspar.

Derivation only from disintegration of the coastal sandstones is rejected as a mode of origin on the basis of the differences in heavy-mineral suites. Kyanite is abundant among the heavy minerals of the silica sands, but it is absent in the sandstone. Hydrous iron oxides are a major part of the heavy minerals of the sandstones, but are relatively scarce in the silica sands. Also, the degree of rounding and sorting in the silica sand is greater than in the sandstone, based on size analyses of silica sands and examination of a thin section of a typical sandstone near Warner Creek.

Lake Piso is a large shallow lagoon about 16 km long and 10 km wide (10 by 6 miles) near Robertsport, about 60 km northwest of Monrovia. If the white sands were derived from the disintegration of the sandstone, silica sand should be depositing to form the silica sand layers like those near Monrovia. Modern sediments in the lake bottom, however, are poorly sorted, muddy in some places and coarse in others. This is probably due to irregular deposition by streams which are at times torrential and at other times sluggish. In the silica sand deposits near Monrovia the excellent sorting can only be attributed to winnowing out of most clay and silt particles during deposition by slow-moving streams over a considerable period of time. A tentative maximum age of deposition for these deposits is about 1,440 ± 250 years, based on a radiocarbon age of a truncated tree root found below the white sand horizon (M. Rubin, written commun., 1968[1]; White, 1969, p. 25).

Laboratory data

Size analyses

Sieve analyses according to the Wentworth scale were made of 27 silica sand samples and one beach sand sample (from ELWA beach). Histograms of 18 representative samples in the area between Monrovia and Marshall are presented in figure 1 to show the sorting characteristics of these sands. Table 1 shows the average size distribution calculated from the 27 samples.

The usable range of granulation for glass manufacture, approximately 0.125 to 1.0 mm, includes 89 percent of this average sample with 65 percent of the grains in the optimum range, about 0.125 to 0.500 mm. The sample with the best sorting has 92 percent of the grains in the usable range and 91 percent in the optimum range; and in the poorest sample the respective percentages are 59 and 42. In all, 19 samples have grain sizes that are 90 percent or more in the usable range; 3 are between 80 and 90 percent; and 5 have less than 80 percent in the usable range.

1/ Specimen W-2141, Radiocarbon Laboratory, U.S. Geological Survey.

Table 1.--Average size analysis of silica sand

Particle size	ASTM screens Mesh	ASTM screens Microns	Weight percent	Cumulative percent
4 - 2 mm (granule)	10	2000	0.42	0.42
2 - 1 mm (very coarse sand)	18	1000	2.86	3.28
1 - 1/2 mm (coarse sand)	35	500	23.07	26.35
1/2 - 1/4 mm (medium sand)	60	250	35.39	61.74
1/4 - 1/8 mm (fine sand)	120	125	30.07	91.81
1/8 - 1/16 (very fine sand)	230	63	6.78	98.59
below 1/16 mm (silt and clay)	pan	--	0.61	99.20

A small variation in grain size was noted between two samples (SP-57B-1 and SP-57B-2) taken a few meters apart in an old sandpit near Warner Creek. On the other hand, no essential difference was observed between histograms of two samples (SP-60D-1 and SP-60D-2) taken about one-half meter apart vertically, in the large deposit along the Schieffelin road. Noteworthy is the grain-size distribution of two sand samples (SP-58-D and SP-60-B) taken from the ELWA beach area: 92 percent in the usable range, and 89-91 percent in the optimum range.

Mineralogy

The predominant mineral in the white sand deposits is quartz, ranging from about 98 percent to almost 100 percent. At least two-thirds of the grains are white translucent; the balance are colorless and transparent to translucent. The grains are angular to subrounded and a considerable number are elongate or tabular. The surfaces of the coarser grains show more pitting than those in the finer fractions, and hydrous iron oxides fill some of the pits. Frosting was not observed. Considering the shapes of these grains, we infer a relatively short transport from source to deposition site, for most of the particles; probably less than 200 miles.

Heavy minerals constitute 0.02 to 2.19 percent of the silica sands, and average 0.65 percent. The minerals observed and their abundances are presented in table 2 for most of the sample sites in figure 1. The heavy-mineral suite in one sandstone (field sample SP-64C) is given for comparison. In the white sands ilmenite and kyanite are the most abundant heavy minerals; staurolite, tourmaline, zircon, and rutile are less abundant, and the other heavy minerals are present in only minor amounts. The sandstone sample differs in that it has a large amount of hydrous iron oxide ("limonite"), and abundant tourmaline. No attempt was made to identify individual species of minerals in the tourmaline, spinel, amphibole, and other families.

Table 2.--Abundance of heavy minerals in the silica sands.

/Abundance shown by the following symbols, representing percentages of the heavy-mineral suite: - = absent; T = trace, less than 1 percent; R = rare, 1-5 percent; S = scattered, 5-10 percent; C = common, 10-20 percent; A = abundant, 20-50 percent; F = flood, over 50 percent./

Field No.	Magnetite	Ilmenite	Limonite	Staurolite	Kyanite	Tourmaline	Zircon	Monazite	Sillimanite	Corundum	Spinel	Almandine	Rutile	Amphibole	Pyroxene	Biotite	Muscovite
SP-57A	T	A	C	C	A	S	R	T	R	-	-	T	C	T	-	T	T
SP-57B-1	T	A	C	C	F	S	S	T	R	-	-	T	C	T	-	-	-
SP-57B-2	T	A	C	C	A	C	R	R	R	T	T	T	C	T	-	-	-
SP-58A	-	A	T	S	A	S	C	-	R	-	-	-	S	T	-	-	T
SP-58D	-	A	T	S	C	S	S	T	R	-	-	T	S	T	-	-	T
SP-58E	T	A	R	S	A	S	C	T	R	-	-	-	S	T	-	-	T
SP-59A-1	T	A	R	C	F	S	S	T	R	-	T	T	C	T	-	-	-
SP-60A	-	A	R	S	C	S	S	T	R	-	T	-	S	S	-	-	-
SP-60B	-	A	T	S	C	S	S	-	C	-	-	-	S	T	-	-	-
SP-60C	-	F	T	S	A	S	C	T	R	-	T	-	S	T	-	-	-
SP-60D-1	T	A	R	S	F	S	C	T	S	-	T	T	S	T	-	-	-
SP-60D-2	T	A	R	S	F	S	C	T	R	T	T	-	S	T	-	-	-
SP-62B-1	-	A	R	C	A	S	S	T	-	-	-	-	R	R	-	-	-
SP-64E-2	T	C	S	R	F	S	C	-	C	T	-	-	T	T	-	T	-
SP-65A	-	A	A	C	F	R	S	T	T	T	T	-	R	T	-	-	-
SP-64C (sandstone)	-	A	F	R	-	A	C	T	-	-	-	T	S	T	T	T	T

Chemical analyses

Total iron in nine representative samples of silica sand are as follows:

Table 3.--Total iron in silica sand samples (in percent)

/Analyses performed in the U. S. Geological Survey Laboratory under the direction of Leonard Shapiro./

Field sample no.	Total percent Fe as Fe_2O_3
SP-57B-1	0.04
SP-58E	0.00
SP-59A-1	0.07
SP-60B	0.00
SP-60C	0.04
SP-60D-1	0.17
SP-60D-2	0.17
SP-62B-1	0.00
SP-64E-2	0.00

These data confirm the estimates of iron content based on mineralogical analysis and simple computation using the iron content of ilmenite, the most abundant iron-bearing mineral.

A positive qualitative test for carbon was obtained on the small amount of dark gray to black coloring matter found along the margins of some deposits. No other analyses were performed on these samples. It seems clear from mineralogical considerations that the remainder is pure silica.

ECONOMIC POTENTIAL

Reserves

A planimeter plot of the easily accessible deposits of silica sand in the Monrovia area indicated a total area of at least 68 square kilometers. This comprises 9 square kilometers along the Freeway, 1 1/2 square kilometers each along the Kakata highway and the road to the radio station ELWA, 48 square kilometers along the Schieffelin road, and 8 square kilometers in the area southeast of Schieffelin. At an average thickness of one meter, this amounts to at least 68 million cubic meters of sand. An empirical bulk density was computed by weighing a quantity of sand in a 25-ml. pycnometer; the bulk density so derived was 1.6. Using this value, the tonnage of silica sand in the accessible areas totals at least 109 million metric tons.

CONCLUSION

The results of this study show that sufficient reserves of high-quality silica sand exist in the Monrovia area to supply a glass manufacturing industry with all foreseeable needs, even for the development of a large-scale export trade. The possibility of using the silica sand for other valuable silica products such as abrasives, refractory materials, and optical products should not be overlooked.

REFERENCES

Battelle Institute, 1963, City and regional planning, Monrovia, Liberia: Battelle-Institute, Frankfurt-Main, pt. 1, vol. 6, p. 191-226.

Leo, G. W., and White, R. W., 1967, Geologic reconnaissance in western Liberia: U.S. Geol. Survey open-file report, 29 p.

White, R. W., 1969, Sedimentary rocks of the coast of Liberia: U.S. Geol. Survey open-file report, 35 p., 2 pls., 2 figs.