thin outer zone is free of these inclusions; $\gamma = 1.733$, $2V = (ca.)\ 60°$, $(+)$, $r > v$, strong, $\gamma \wedge c = 44°$. It is estimated to contain 56% hedenbergite molecule. Before exsolution the Mg/Fe and Ca/Mg + Fe ratios were both lower.

The optical properties of the olivine are: very pale pink; $\alpha = 1.785$, $2V = 65°$, $(-)$ $r > v$, very strong. It is estimated to contain 78% of the fayalite molecule.

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HEAVY MINERALS IN SANDS FROM THE OLD FORT AREA, QUEBEC

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Introduction

Extensive deposits of sand occur along the coastal areas bordering the northeastern arm of the Gulf of St. Lawrence. Sand, similar to that along the coast, is also found inland as far as 75 miles from tidal waters. These buff sands are composed essentially of feldspar and quartz but they also contain distinctive and irregularly distributed "streaks"[1] consisting of dark, heavy minerals.

The general geological features of a larger region which includes the Old Fort Area (Fig. 1) have been described by Hale (1961). Most of this region is underlain by granitic gneisses in which narrow bands of quartzitic, biotitic, amphibolitic, calcareous, and pyroxenitic, gneiss and schist occur. In addition to the gneisses, there are large irregular masses of amphibole- and pyroxene-rich rocks and several discrete masses of gabbro-anorthosite, one of which is exposed about Old Fort Lake.

The consolidated rocks of the region are extensively exposed along the shore of the Gulf and inland from it for an average of five miles. The shoreline exhibits evidence of recent submergence followed by more recent emergence. Beach strands, paralleling the coastline but up to several miles inland from it, are a characteristic feature of this part of the Gulf. The widespread, buff sands now appear to be part of what was

[1]The word, "streak," is used here rather than "horizon" or "layer" both of which suggest greater horizontal continuity than is characteristic of the black portions of the St. Lawrence sands.

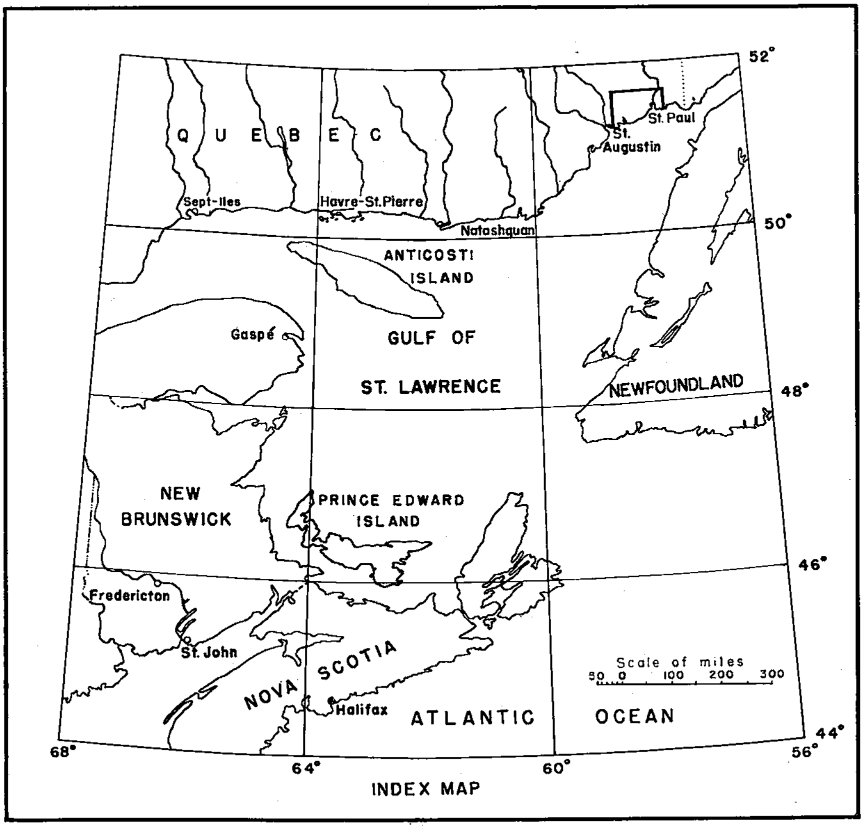

FIG. 1.

formerly a continuous "blanket." Erosional and depositional features of glacial origin indicate ice movement from the north towards the coast.

Results

Qualitative mineralogical examinations were made on fifteen sand samples from the Old Fort Area (Fig. 2). Samples 1 and 4 were selected as representative of the buff sand and black "streaks" respectively. Tetrabromoethane and the Frantz magnetic separator were used to obtain heavy mineral concentrates from each of the representative samples. Further separation of the individual mineral components was effected with the Frantz separator (Fig. 3) and, where necessary, hand picking. Mineral identifications were confirmed by refractive indices and the x-ray powder method. Mineralogical data on the heavy minerals is summarized in Table 1.

TABLE 1. HEAVY MINERALS IN BLACK "STREAK" AND IN HEAVY MINERAL-FRACTION OF BUFF SAND

Mineral	Ref. Fig. 4	Black "streak" (sample 4) (Total wt. %)	Buff sand (Sample 1) (Wt. % heavy minerals[a])	Roundness[b] (sample 4)	Probable source[c]	Remarks
Ilmenite	1, 2, 3	55.00	31.8	.27+	Anorthosite and gabbro	Common constituent in all samples studied. Generally fresh but some grains show partial alteration to "leucoxene."
Magnetite	4, 5	14.40	4.0	.35	Anorthosite and gabbro	Common to all samples. Generally fresh.
Hypersthene	6, 7, 8, 9	6.63	3.9	.19	Gabbro and pyroxene-rich bands in gneiss	Common in all samples. Locally abundant where sand occurs near gabbro. Strongly pleochroic in brown, pink, and green. Schiller inclusions of magnetite in some specimens sufficient to render mineral markedly magnetic.
Altered Hypersthene	10, 11, 12			.17+		
Garnet	13–18		3.4	.33+	Granitic gneiss	Almandite most common but spessartite also noted. Abundant incls. and pitted surfaces.
Apatite	19			.28+	?	Rare.
Actinolite	20		48.6	.26+	Amphibolite bands and masses + gabbro	Dark green to greenish blue hornblende is much more common than actinolite.
Hornblende	21, 22			.37+		

TABLE 1 (*cont'd*)

Mineral	Ref. Fig. 4	Black "streak" (sample 4) (Total wt. %)	Buff sand (Sample 1) (Wt. % heavy minerals[a])	Roundness[b] (sample 4)	Probable source[c]	Remarks
Diopside	23–26 incl.	1.75	6.1	.40	Gneiss	General distribution and abundance similar to that of hypersthene.
Augite	27, 28, 29	<1%	2.2 (Augite, Sphene, Zircon)	.25	Gneiss	Less common than diopside. Usually fresh, prismatic outline characteristic.
Sphene	30–33 incl.	1.00 (Sphene, Zircon)		.31+	?	Common in small amounts.
Zircon	34–39 incl.			.35 – .82+	?	Some purplish grains noted.
Quartz	40–43	21.22 (Quartz, Feldspar)		.23+	Gneiss	Common in all samples.
Feldspar					Gneiss	Orthoclase and albite dominant minerals in buff sand.
Biotite		<1%			Gneiss	Minor constituent of most samples in Old Fort Area.
		≑100.00%	100.00%			

[a]The total heavy minerals in this sample constitute 2.85% by weight of the whole sample. The remainder consists of quartz, orthoclase and minor plagioclase.

[b]Pettijohn (1956), p. 57.

[c]The probable source is cited only when the specific mineral has been definitely identified in samples of bedrock.

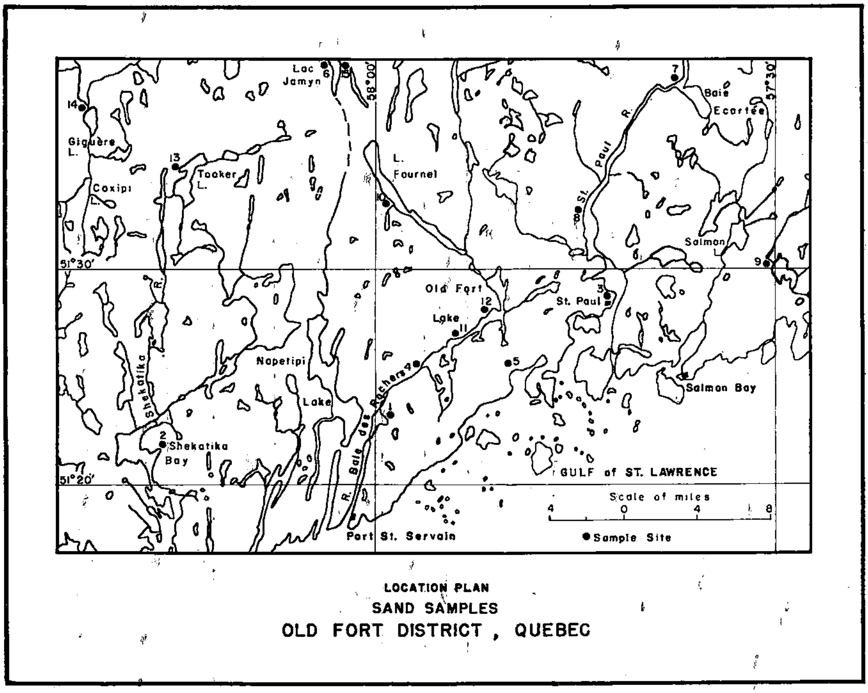

FIG. 2.

Size analyses were made (Fig. 4) on three samples (1, 11, and 15) considered to be representative of the normal buff sand, one sample (4) believed to be typical of the black "streaks," and one sample (25), composed of the magnetite fraction of sample 4, to illustrate the influence that this omnipresent component exerts on size-frequency characteristics. Critical size values are given in Table 2.

TABLE 2. CRITICAL SIZE VALUES[a] (ϕ UNITS)

Sample	Mdϕ	Q_3	Q_1	QDϕ	Mode
1	0.81	1.22	0.46	0.38	0.91
11	0.88	1.20	0.58	0.31	0.80
15	0.96	1.50	0.47	0.51	0.90
4	2.05	2.35	1.72	0.31	2.23
25	2.38	2.63	2.14	0.25	2.50

[a]Mdϕ—Median diameter of 50 percentile, Q_3—75 percentile, Q_1—25 percentile, QDϕ—quartile deviation or sorting coefficient ($Q_3 - Q_1/2$).

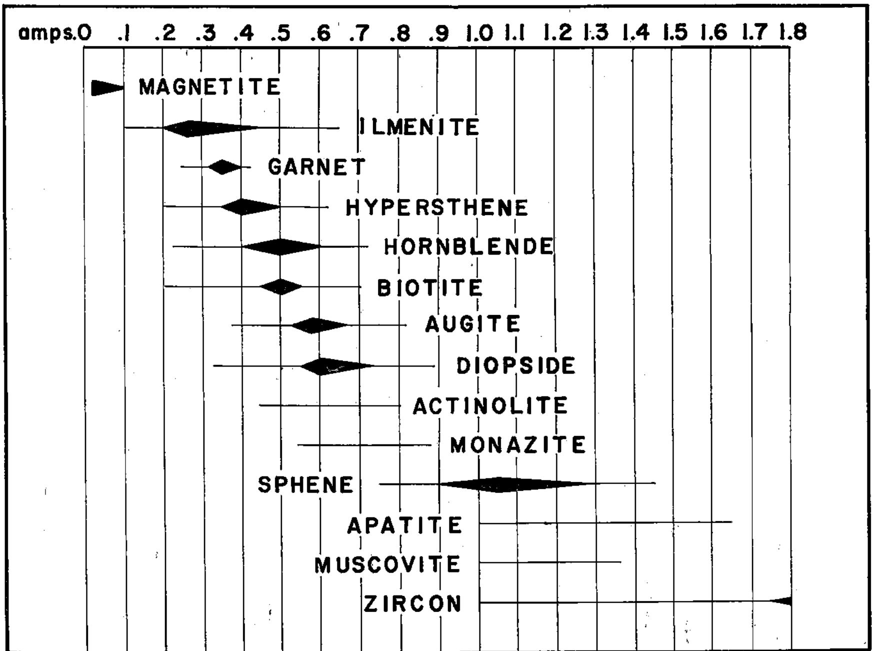

FIG. 3. Magnetic susceptibilities of minerals in the Frantz isodynamic magnetic separator (side tilt 15°; forward tilt 15°; grain size .177 to .350 mm.).

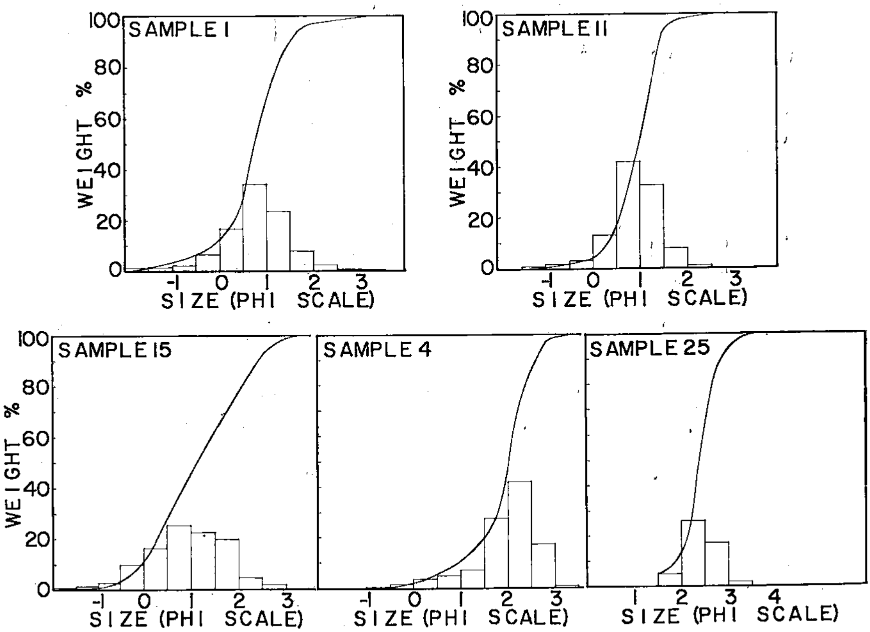

FIG. 4. Histograms and cumulative curves (Krumbein & Pettijohn, 1938): sample 1, Baie des Rochers; sample 11, Old Fort Lake; sample 15, Lac Jamyn; sample 4, black "streak," Old Fort Lake; sample 25, magnetite from sample 4.

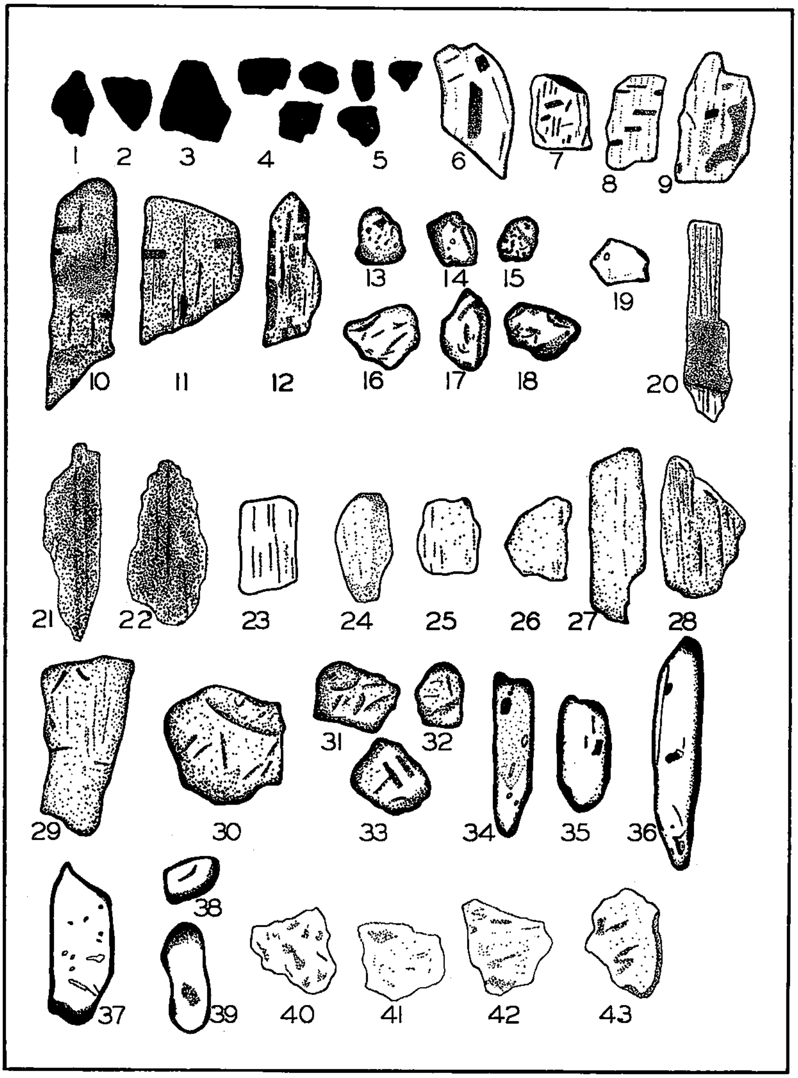

FIG. 5. Typical grain outlines for heavy minerals and quartz. 1–3, ilmenite; 4, 5, magnetite; 6–12, hypersthene; 13–18, garnet; 19, apatite; 20, actinolite; 21, 22, hornblende; 23–26, diopside; 27–29, augite; 30–33, sphene; 34–39, zircon; 40–43, quartz.

Conclusions

Appropriate bedrock sources for the minerals in the sands of the Old Fort Area directly underlie the sands themselves. A rough parallelism exists between the proportions; buff sands to black "streaks," and granite gneisses to mafic rocks. Mineralogical variations in bedrock appear to be reflected closely by comparable variations in the nearby sands, particularly the black "streaks."

The close mineralogical correlation between sand and bedrock and the roundness and shape characteristics of typical grains (Fig. 5) indicate limited transportation of the Old Fort sands. Size-frequency characteristics correspond to those to be expected in glacial outwash deposits.

The black "streaks," characteristic of sands along the Gulf of St. Lawrence, are the result of postdepositional reworking of the buff sands by the wind and waters of the coast, rivers, and lakes; the dark minerals being locally and residually concentrated due to their shape and mass relative to the much more abundant quartz and feldspar.

Some interest in the economic possibilities of the black "streaks" has been demonstrated (MacKenzie, 1912, and more recent but unpublished information). However, it appears that the continuity and tenor of these natural concentrates is adversely affected by their geologically recent origin and the continuing change in the distribution of the surface waters instrumental in their development.

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