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SILICA (DUNE) SAND

FROM THE MEDICINE HAT AREA, ALBERTA

by

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FROM THE MEDICINE HAT AREA, ALBERTA

Abstract

Dune sands from the Medicine Hat area in southeastern Alberta contain particle sizes predominating in the 50- to 100-mesh (0.297 to 0.149 mm) range. The chemical composition varies between 85 to 89 per cent SiO_2, 5 to 7 per cent Al_2O_3, 0.7 to 1.4 per cent Fe_2O_3 0.6 to 1.5 per cent CaO, 0.2 to 0.5 per cent MgO, and 0.4 to 1.8 per cent loss on ignition. Mineralogically the sands contain more than 80 per cent quartz, approximately 10 per cent feldspar, and 5 per cent or more other minerals. Heavy mineral assemblages include goethite, garnet, hornblende, and magnetite. The grains are mainly subrounded and commonly stained.

Beneficiation tests on the sands involved screening, washing, heavy liquid separation, magnetic separation, and acid treatment. The results of these tests show that heavy liquid and magnetic separation techniques are most efficient in reducing the iron content of the sands to a minimum of approximately 0.30 per cent in selected samples.

INTRODUCTION

Fifteen samples from sand dunes in the Medicine Hat area of southeastern Alberta were collected, analyzed, and treated, in an effort to evaluate them for industrial applications. Locations of the dune fields and sampling sites are indicated in figure 1, and surveyed descriptions of the sample locations are provided in table 1. Methods used in the report are essentially the same as those adopted by Carrigy (1970) to evaluate similar dune sands in the Edmonton area. Details of the procedures followed are indicated on the flow sheet in figure 2. Three samples from two locations outside the limits of the Suffield Military Reserve were subjected to more detailed study.

Uses for sand within Alberta are varied, and demands for quality sources are increasing. The specifications of sand for various applications have been discussed by Carrigy (1970) and McLaws (1971) and are not included herein.

Acknowledgments

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DESCRIPTION OF DUNES

Six major dune fields are found in the Medicine Hat area as indicated in figure 1. Individual dunes within the fields comprise both stabilized and active forms and show a marked east-west orientation of their long axes. Two main configurations are noted: U-shaped dunes up to 30 feet high and 1000 feet wide with "horns" pointing westward, towards the direction of the prevailing winds; and linear dunes approximately 15 feet high, 100 feet wide, and up to 1 mile long. Samples 1 to 4 were taken from U-shaped dunes, and samples 5 to 7 were obtained from linear dunes.

The sands have been derived from glacial outwash deposited on lake clays and tills of Late Pleistocene (Wisconsin) age. Soil cover is very thin.

PHYSICAL AND CHEMICAL PROPERTIES

Particle-Size Distribution

Approximately 100 grams of each sample were washed and screened through a nest of sieves according to procedures outlined by the American Society for Testing Materials. The results thus obtained are given in graphical form in figure 3 and are tabulated in table 2. The modal size (the fraction predominating over any other single fraction by weight) ranges from 50- to 100-mesh (fine- to medium-grained sand). The 70-mesh size (0.210 mm – fine-grained sand) is most commonly the modal size.

The cumulative amount of sand retained on the 100-mesh sieve varies from about 49 to 94 per cent. However, only three samples exceed greater than 90 per cent retention on the 100-mesh.

It has been pointed out by Carrigy (1970) that the mechanical analyses obtained by the ASTM procedures are idealized and that a commercial operation obtains less efficient returns of each grain size. For this reason the treatment of selected samples analyzed in detail involved fractions obtained by excessive loading of the screens, in an attempt to simulate a large-scale operation.

Mineral Composition

All of the washed samples were examined microscopically for mineral content. Table 3 indicates the composition of 100 representative grains from each sample. Feldspar grains were stained in a few cases for more accurate differentiation of these mineral grains from others.

Quartz is the major component, accounting for 82 to 88 per cent of the mineral grains, and lesser quantities of feldspar, mica, and other minerals are present. There is little variability in mineral content.

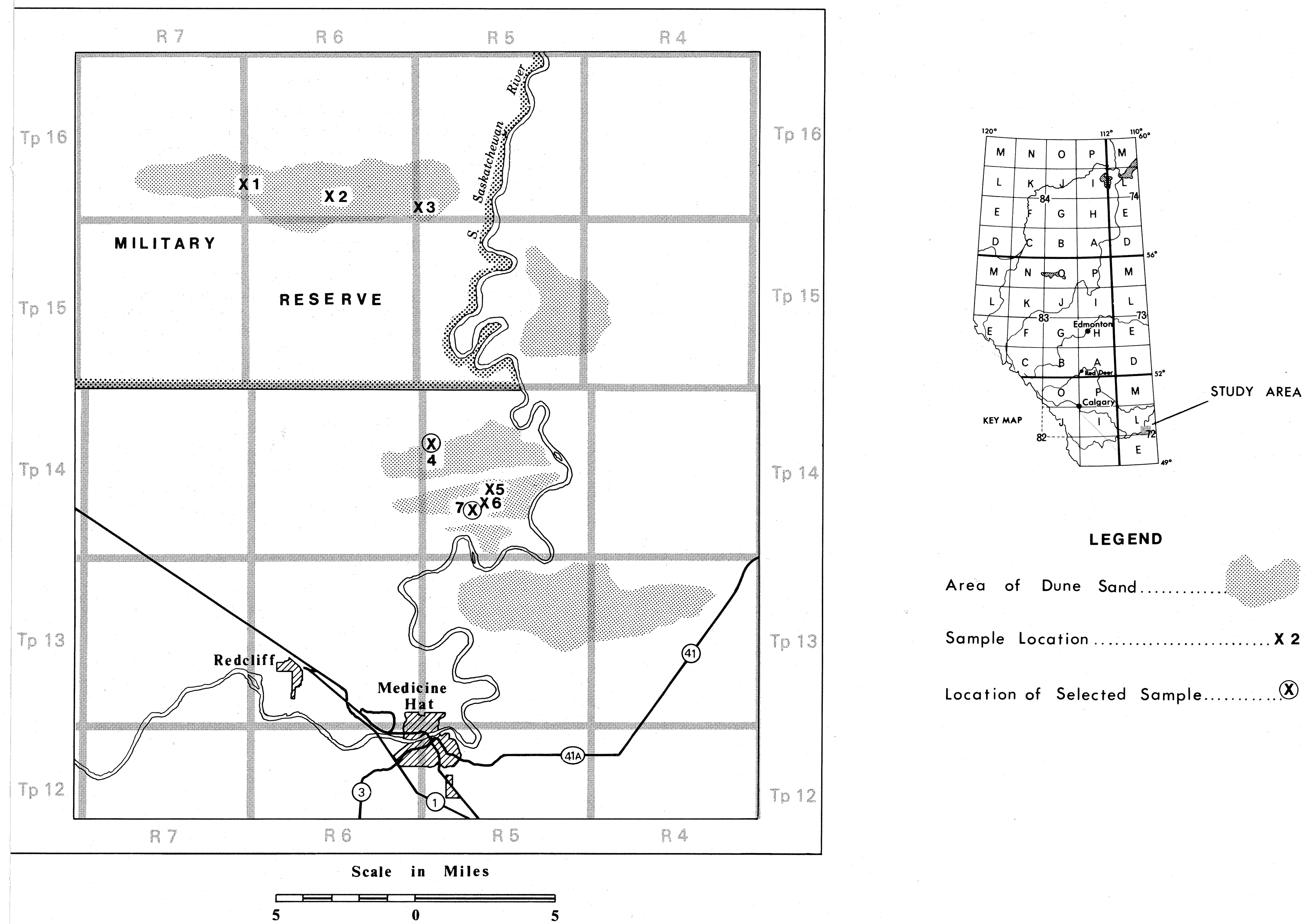

Figure 1. Dune fields and sample locations.

Chemical Composition

Table 4 lists the chemical analyses of unwashed and washed bulk samples. There is little change in composition between unwashed and washed sands except for the slight decrease in iron content in the latter case. The silica content varies between 84 and 89 per cent. The alumina percentages are between 5 and 7 per cent; this component is probably a direct expression of the amount of feldspar and clay present. The Fe_2O_3, content ranges from 0.7 to 1.3 per cent in the washed sands.

Surface Staining and Inclusions

Brown and orange surface staining of the quartz grains is common, and in a few cases inclusions also were noted. As both these features probably contribute to the iron content of the sands, an attempt was made to record the amounts of each (Table 3). Quartz staining which renders the grains opaque or transluscent over more than half the surface area was classified as "heavy". If the staining results in transparent grains or covers less than half the surface area, it was regarded as being "light".

Grain Shape

Mineral grains were assigned to four main categories: angular, if they possess sharp corners; subround, if corners are smooth; round, if there are no angular projections; and spherical, if they approach the shape of a sphere. Results of grain counts recorded in table 3 indicate that most of the grains are subround.

COMPOSITION OF SELECTED SAMPLES

Three samples, having 90 per cent or more sand retained on the 100-mesh sieve and collected outside the boundaries of the Suffield Military Reserve, were subjected to detailed study. The flow sheet (Fig. 2) shows the details of their treatment. Three size fractions of each sample (0.30 to 0.60 mm, 0.21 to 0.30 mm, and 0.15 to 0.21 mm) were subjected to washing, heavy mineral separation, magnetic separation, and acid treatment. They were subsequently examined and analyzed in order to determine the results of each operation. Particular emphasis was placed upon the modal size fraction, which in each case is fraction 1 (0.30 to 0.60 mm).

Mineral Composition

Sand

Little variation in mineral composition of the three size fractions was noted upon microscopic examination (Table 5). The average composition of all the fractions of any one sample compares closely with that of the bulk washed sample. There is only a slight difference in the amount of staining in different fractions of the same sample. There is a slight tendency for the angularity of the grains to be greater in finer fractions.

Clay

The clay fraction from each of the three selected samples was subjected to X-ray diffraction analysis. All clay fractions contain montmorillonite, illite, kaolinite, and chlorite. Montmorillonite predominates in samples from locality 4 and illite is the most common clay mineral in sample 7 (Table 6).

Heavy Minerals

The heavy minerals described herein are those which sink in a liquid of specific gravity 2.9. X-ray diffraction analyses and microscopic examination indicate the presence of goethite, garnet, hornblende, and magnetite (in order of decreasing abundance). Goethite is commonly in the form of a cement bonding other mineral grains together. Magnetite may occur as inclusions in quartz grains.

Magnetic Minerals

A Franz Isodynamic Separator was utilized to isolate magnetic minerals. At low magnetic intensity (0.1 amps) magnetite and minerals bearing magnetite inclusions form the main magnetic fraction. At higher intensities (0.9 amps) a more heterogeneous mixture was separated, goethite being the most notable magnetic addition.

Chemical Composition

The modal sizes of each of the selected samples has slightly greater amounts of SiO_2 than the corresponding bulk samples. The percentages of each of the remaining components are correspondingly less (Table 7).

BENEFICIATION TESTS

Heavy Liquid Separation

Heavy minerals are present in the three fractions of the selected samples in amounts ranging between 1.0 and 1.6 per cent (Table 8). The amount of heavy minerals is greater in finer fractions of the same sample.

There is a reduction in the Fe_2O_3 content by means of this treatment from approximately 1 per cent before separation to less than 0.5 per cent after removal of heavy minerals (Tables 7 and 10).

Magnetic Separation

The amounts of minerals extracted by magnetic separation were increased considerably by increasing the magnetic intensity (Table 9). By increasing the amperage from 0.1 to 0.9 the percentage of magnetic minerals retained was increased from an average of 0.2 per cent (weight of the original sample) to an average of 4 per cent. The ultimate limit of magnetic separation was not determined. At any given intensity slightly greater amounts of the magnetic materials are extracted from finer fractions of the same sample.

Chemical analyses of the nonmagnetic minerals passing through the separator at 0.9 amperes indicate that the Fe_2O_3 content is decreased from about 1 per cent to approximately 0.3 per cent (Tables 7 and 11).

Acid Treatment

Both the light and nonmagnetic modal size fractions from the selected samples were boiled in a solution of 1 per cent HCl for 10 minutes. There was a noticeable reduction in the amount of staining on the grains as a result (Tables 5, 12, and 13), although surface coloration is not completely eliminated.

Chemical analyses reveal that there is little or no reduction in the Fe_2O_3 contents, although CaO and MgO are decreased appreciably (Tables 10 and 11).

Summary of Tests

Beneficiation tests on the sands are summarized in table 14. Washing of the sands appears to increase the SiO_2 content slightly with a resultant corresponding decrease in all other components. The modal size of each of the selected samples has higher quantities of SiO_2 than the washed bulk samples. Heavy liquid and magnetic separation appear to be the best means of reducing the Fe_2O_3 content, whereas CaO and MgO values are more efficiently reduced by acid treatment.

REFERENCES CITED

Carrigy, M. A. (1970): Silica sand in the vicinity of Edmonton, Alberta; Res. Coun. Alberta Rept. 70-1, 30 pages.

McLaws, I. J. (1971): Uses and specifications of silica sand; Res. Coun. Alberta Rept. 71-4.

APPENDIX A

TEST RESULTS ON BULK SAMPLES

Table 1. Locations and depths of dune sand samples

Sample No.	Depth (in feet)	Location			
		Qtr.	Sec.	Tp.	R.[1]
1	2-3	SW	7	16	6
	3-4				
2	2-4	NW	3	16	6
3	0-3	SW	6	16	5
	3-6				
	6-9				
	9-12				
	12-15				
4	0-4	SW	30	14	5
	4-8				
	8-12				
5	0-3	-	16	14	5
	3-6				
6	0-2	NW	9	14	5
7	0-3	NE	8	14	5

[1] West of 4th Meridian

Table 2. Mechanical analyses of dune sands

Sample No.	U.S. Standard Sieve No. (per cent retained)										
	12 (1.680)[1]	16 (1.190)	20 (0.841)	30 (0.595)	40 (0.420)	50 (0.297)	70 (0.210)	100 (0.149)	140 (0.105)	200 (0.074)	> 200
1 (2-3 ft)	0.01	0.19	0.64	2.59	6.71	19.00	29.39	22.75	10.70	3.78	4.15
1 (3-4 ft)	0.02	0.13	0.59	2.27	5.68	20.22	34.55	22.37	8.55	2.73	3.35
2 (2-4 ft)	0.01	0.07	0.10	0.37	1.33	4.97	15.23	26.30	21.81	13.98	15.54
3 (0-3 ft)	0.01	0.05	0.24	1.44	4.15	13.92	29.43	28.13	14.60	4.90	3.05
3 (3-6 ft)	-	0.01	0.09	0.71	2.91	10.54	24.57	30.41	20.12	6.89	3.56
3 (6-9 ft)	-	0.01	0.09	1.14	4.96	16.29	27.71	24.39	14.64	6.66	4.26
3 (9-12 ft)	-	0.02	0.10	0.97	4.13	17.25	32.69	24.82	11.39	4.62	3.35
3 (12-15 ft)	-	0.04	0.15	1.07	4.57	16.64	29.11	25.70	14.24	5.39	3.37
4 (0-4 ft)[2]	-	0.12	1.50	7.10	20.44	32.77	20.34	11.44	3.48	0.67	2.26
4 (4-8 ft)[2]	-	0.07	0.46	2.80	10.99	29.01	28.09	18.39	5.78	1.29	3.26
4 (8-12 ft)	0.59	0.45	0.73	2.81	9.12	22.64	24.54	22.39	8.24	2.34	6.39
5 (0-3 ft)	-	0.01	0.06	0.62	4.15	18.86	36.24	23.53	9.92	3.20	4.47
5 (3-6 ft)	-	0.01	0.04	0.54	3.80	18.43	34.18	23.43	10.64	3.73	4.84
6 (0-2 ft)	-	0.01	0.17	0.41	6.68	22.01	31.47	21.41	9.41	3.16	4.69
7 (0-3 ft)[2]	0.01	0.47	2.28	8.79	19.09	28.00	20.45	11.31	4.80	1.53	2.91

[1] Screen size (mm) corresponding to sieve number
[2] Denotes samples subjected to detailed analysis

Table 3. Composition, staining and grain shape of washed dune sands

Sample No.	Grain Shape (%)				Mineral Composition (%)					Iron Staining (%)			
	Angular	Subrounded	Rounded	Spherical	Quartz	Feldspar	Chert	Mica	Others	Heavy	Light	Inclusions	Clear
1 (2-3 ft)	6	74	17	3	85	12	-	-	3	-	5	-	95
1 (3-4 ft)	3	82	15	-	84	10	-	-	6	2	6	1	91
2 (2-4 ft)	3	89	8	-	85	10	-	-	5	1	2	-	97
3 (0-3 ft)	5	75	18	2	84	10	-	-	6	5	5	1	90
3 (3-6 ft)	4	77	17	2	83	10	-	-	7	1	4	-	95
3 (6-9 ft)	2	81	14	3	85	9	-	-	6	2	5	-	93
3 (9-12 ft)	2	81	14	3	83	9	-	1	7	2	5	-	93
3 (12-15 ft)	1	83	13	3	86	8	-	1	5	2	1	1	96
4 (0-4 ft)[1]	3	87	10	-	85	10	-	-	5	1	5	-	94
4 (4-8 ft)[1]	6	77	15	2	84	11	-	-	5	5	6	1	88
4 (8-12 ft)	2	87	9	1	82	10	-	-	8	4	5	-	91
5 (0-3 ft)	2	91	7	-	85	10	-	-	5	4	6	1	89
5 (3-6 ft)	2	93	4	-	87	9	-	-	4	2	8	-	90
6 (0-2 ft)	1	88	9	2	88	8	-	-	4	5	5	1	89
7 (0-3 ft)[1]	2	89	8	1	85	5	-	-	10	7	5	-	88

[1]Denotes samples subjected to detailed analysis

Table 4. Chemical analyses of washed and unwashed dune sands

Sample No.		Chemical Analysis					
		SiO_2	Al_2O_3[1]	Fe_2O_3[2]	CaO	MgO	L.O.I.
1 (2-3 ft)	A[3]	87.92	5.62	0.85	1.00	0.33	0.94
	B[4]	88.54	5.22	0.77	0.82	0.25	0.47
1 (3-4 ft)	A	88.79	5.23	0.88	0.92	0.32	0.83
	B	88.86	5.04	0.73	0.75	0.22	0.51
2 (2-4 ft)	A	84.27	7.14	1.19	1.47	0.48	1.77
	B	86.06	6.66	0.81	1.27	0.29	0.91
3 (0-3 ft)	A	88.56	5.79	0.86	0.70	0.26	0.63
	B	87.93	5.50	0.78	0.71	0.18	0.43
3 (3-6 ft)	A	87.99	6.06	0.94	0.76	0.29	0.60
	B	87.88	5.59	0.75	0.73	0.17	0.47
3 (6-9 ft)	A	88.39	5.77	0.92	0.71	0.27	0.58
	B	88.21	5.27	0.73	0.70	0.21	0.50
3 (9-12 ft)	A	88.31	5.55	0.89	0.61	0.24	0.56
	B	88.87	5.37	0.73	0.65	0.18	0.39
3 (12-15 ft)	A	88.45	5.47	1.00	0.67	0.26	0.58
	B	88.68	5.61	0.73	0.72	0.21	0.41
4 (0-4 ft)[5]	A	87.19	5.04	1.25	1.43	0.32	1.40
	B	86.63	5.12	0.97	1.41	0.27	1.19
4 (4-8 ft)[5]	A	86.99	5.21	1.22	1.29	0.34	1.45
	B	88.07	5.23	1.13	1.12	0.28	1.10
4 (8-12 ft)	A	85.48	5.48	1.35	1.46	0.23	1.82
	B	87.19	5.25	1.29	1.31	0.29	1.16
5 (0-3 ft)	A	86.35	5.66	1.22	1.38	0.48	1.58
	B	87.42	5.47	0.99	1.21	0.34	1.15
5 (3-6 ft)	A	85.88	5.63	1.20	1.34	0.48	1.73
	B	87.34	5.54	1.00	1.04	0.34	1.19
6 (0-2 ft)	A	86.34	5.70	1.19	1.30	0.43	1.56
	B	88.05	5.52	1.07	1.19	0.33	1.12
7 (0-3 ft)[5]	A	87.97	5.10	1.10	0.98	0.34	1.14
	B	88.72	5.12	0.90	0.99	0.28	0.81

[1] Includes P_2O_5 and TiO_2
[2] Total iron calculated as Fe_2O_3
[3] Unwashed (bulk) sample
[4] Washed sample
[5] Denotes sample subjected to detailed analysis

APPENDIX B

TEST RESULTS ON THREE SELECTED SAMPLES

Table 5. Composition, staining, and grain shape of washed sieve fractions of three dune sands

Sample No.	Description	Grain Shape (%)				Mineral Composition (%)					Iron Staining (%)			
		Angular	Subrounded	Rounded	Spherical	Quartz	Feldspar	Chert	Mica	Others	Heavy	Light	Inclusions	Clear
4 (0-4 ft)	Fraction 1[1]	-	85	14	1	89	4	-	-	7	-	5	1	95
	Fraction 2[2]	4	85	10	1	89	5	-	-	6	3	7	-	90
	Fraction 3[3]	4	82	13	1	92	2	-	-	6	4	7	1	88
4 (4-8 ft)	Fraction 1	1	85	14	-	92	2	-	1	5	4	8	-	88
	Fraction 2	2	93	5	-	92	3	-	-	5	4	4	-	92
	Fraction 3	5	86	9	-	93	3	-	-	4	1	5	-	94
7 (0-3 ft)	Fraction 1	2	87	10	1	94	3	1	-	2	6	5	2	87
	Fraction 2	-	85	15	-	85	7	-	-	8	3	5	-	92
	Fraction 3	4	84	12	-	91	4	-	-	5	3	5	-	92

[1] Modal size (-30+50 mesh)
[2] Modal size (-50+70 mesh)
[3] Modal size (-70+100 mesh)

Table 6. Relative proportions of clay minerals and clay-size fractions of three dune sands

Sample No.	Clay Minerals
4 (0-4 ft)	Montmorillonite > illite > kaolinite and/or chlorite
4 (4-8 ft)	Montmorillonite > illite > kaolinite and/or chlorite
7 (0-3 ft)	Illite > montmorillonite > kaolinite and/or chlorite

Table 7. Chemical analyses of washed modal size fractions of three dune sands

Sample No.	Chemical Analysis					
	SiO_2	Al_2O_3[1]	Fe_2O_3[2]	CaO	MgO	L.O.I.
4 (0-4 ft)	89.68	3.89	1.13	1.22	0.22	1.09
4 (4-8 ft)	89.22	3.87	0.99	1.19	0.23	1.07
7 (0-3 ft)	90.98	3.81	0.89	0.77	0.21	0.67

[1]Includes P_2O_5 and TiO_2
[2]Total iron calculated as Fe_2O_3

Table 8. Weight percentages of heavy minerals in three sieve fractions of three dune sands

Sample No.	Sieve Fraction	U.S. Standard Sieve No.	Per Cent
4 (0-4 ft)	1[1]	-30+50	1.36
	2	-50+70	1.41
	3	-70+100	1.63
4 (4-8 ft)	1[1]	-30+50	1.19
	2	-50+70	1.08
	3	-70+100	1.34
7 (0-3 ft)	1[1]	-30+50	1.03
	2	-50+70	1.12
	3	-70+100	1.50

[1]Modal size

Table 9. Weight percentages of magnetic minerals removed from three sieve fractions of three dune sands

Sample No.	Sieve Fraction	U.S. Standard Sieve No.	Magnetic Minerals (weight per cent)	
			0.1 amps[1]	0.9 amps[1]
4 (0-4 ft)	1[2]	30-50	0.18	3.31
	2	50-70	0.18	4.51
	3	70-100	0.26	5.17
4 (4-8 ft)	1[2]	30-50	0.18	3.42
	2	50-70	0.18	4.28
	3	70-100	0.20	4.99
7 (0-3 ft)	1[2]	30-50	0.17	3.52
	2	50-70	0.18	4.45
	3	70-100	0.19	4.90

[1] Power applied to electromagnet when Franz Isodynamic Separator set at a slope of 18° and a tilt of 10°
[2] Modal size

Table 10. Chemical analyses of light minerals in the modal size fractions of three dune sands before and after acid treatment

Sample No.	Treatment	Chemical Analysis					
		SiO_2	Al_2O_3[1]	Fe_2O_3[2]	CaO	MgO	L.O.I.
4 (0-4 ft)	C[3]	89.24	3.76	0.44	1.18	0.18	1.01
	D[4]	91.56	3.83	0.39	0.46	0.14	0.29
4 (4-8 ft)	C	91.23	3.79	0.47	1.06	0.18	0.88
	D	92.16	3.64	0.43	0.41	0.13	0.32
7 (0-3 ft)	C	91.27	3.90	0.41	0.79	0.17	0.59
	D	92.18	3.67	0.37	0.42	0.12	0.29

[1] Includes P_2O_5 and TiO_2
[2] Total iron calculated as Fe_2O_3
[3] Untreated light mineral fraction
[4] Acid treated light mineral fraction

Table 11. Chemical analyses of the nonmagnetic minerals in the modal size fractions of three dune sands before and after acid treatment

Sample No.	Treatment	Chemical Analysis					
		SiO_2	Al_2O_3[1]	Fe_2O_3[2]	CaO	MgO	L.O.I.
4 (0-4 ft)	C[3]	90.23	3.70	0.29	1.24	0.16	1.02
	D[4]	91.23	3.36	0.31	0.45	0.10	0.33
4 (4-8 ft)	C	90.39	3.57	0.33	1.02	0.15	0.82
	D	92.69	3.56	0.31	0.41	0.11	0.27
7 (0-3 ft)	C	91.90	3.62	0.29	0.75	0.14	0.58
	D	92.44	3.31	0.33	0.38	0.09	0.22

[1]Includes P_2O_5 and TiO_2
[2]Total iron calculated as Fe_2O_3
[3]Untreated nonmagnetic mineral fraction
[4]Acid treated nonmagnetic mineral fraction

Table 12. Surface staining on light mineral grains in the modal size fractions of three dune sands before and after acid treatment

Sample No.	Treatment	Iron Staining		
		Heavy	Light	Clear
4 (0-4 ft)	C[1]	3	10	87
	D[2]	1	4	95
4 (4-8 ft)	C	4	10	86
	D	1	4	95
7 (0-3 ft)	C	4	5	91
	D	-	5	95

[1]Untreated nonmagnetic mineral fraction
[2]Acid treated nonmagnetic mineral fraction

Table 13. Surface staining on nonmagnetic minerals in the modal size fractions of three dune sands before and after acid treatment

Sample No.	Treatment	Iron Staining		
		Heavy	Light	Clear
4 (0-4 ft)	C[1]	2	6	92
	D[2]	1	2	97
4 (4-8 ft)	C	1	10	89
	D	3	4	93
7 (0-3 ft)	C	1	8	91
	D	1	5	94

[1]Untreated light mineral fraction
[2]Acid treated light mineral fraction

Table 14. Summary of analytical results for three dune sands

Sample No.	Treatment[1]	Chemical Analysis					
		SiO_2	Al_2O_3[2]	Fe_2O_3[3]	CaO	MgO	L.O.I.
4 (0-4 ft)	A	87.19	5.04	1.25	1.43	0.37	1.40
	B	86.63	5.12	0.97	1.41	0.27	1.19
	C	89.68	3.89	1.13	1.22	0.22	1.09
	D	89.24	3.76	0.44	1.18	0.18	1.01
	E	91.56	3.83	0.39	0.46	0.14	0.29
	F	90.23	3.70	0.29	1.24	0.16	1.02
	G	91.23	3.36	0.31	0.45	0.10	0.33
4 (4-8 ft)	A	86.99	5.21	1.22	1.29	0.34	1.45
	B	88.07	5.23	1.13	1.12	0.28	1.10
	C	89.22	3.87	0.99	1.19	0.23	1.07
	D	91.23	3.79	0.47	1.06	0.18	0.88
	E	92.16	3.64	0.43	0.41	0.13	0.32
	F	90.39	3.57	0.33	1.02	0.15	0.82
	G	92.69	3.56	0.31	0.41	0.11	0.27
7 (0-3 ft)	A	87.97	5.10	1.10	0.98	0.34	1.14
	B	88.72	5.12	0.90	0.99	0.28	0.81
	C	90.98	3.81	0.89	0.77	0.21	0.67
	D	91.27	3.90	0.41	0.79	0.17	0.59
	E	92.18	3.67	0.37	0.42	0.12	0.29
	F	91.90	3.62	0.29	0.75	0.14	0.58
	G	92.44	3.31	0.33	0.38	0.09	0.22

[1] A Unwashed bulk sand
B Washed bulk sand
C Washed modal size fraction
D Untreated light modal size fraction
E Acid treated light modal size fraction
F Untreated nonmagnetic modal size fraction
G Acid treated nonmagnetic modal size fraction

[2] Includes P_2O_5 and TiO_2

[3] Total iron calculated as Fe_2O_3

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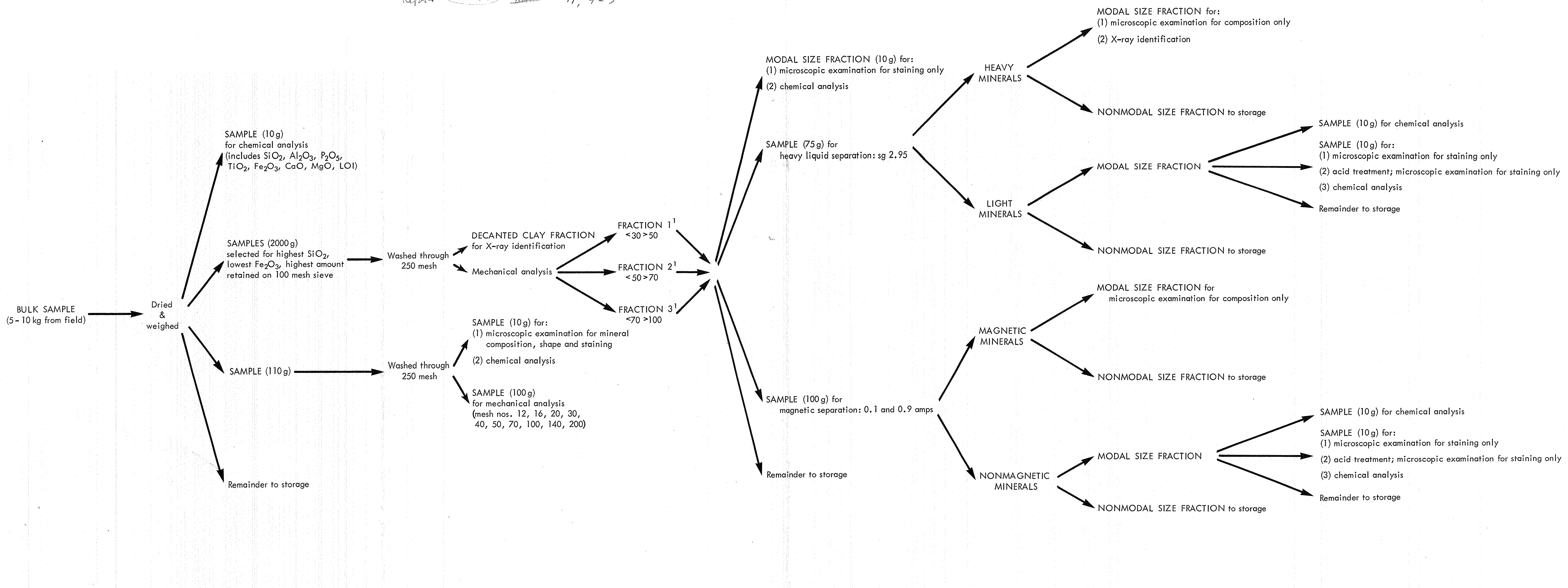

[1] Subject to microscopic examination for mineral composition, shape and staining

FIGURE 2. FLOW SHEET FOR LABORATORY TREATMENT OF DUNE SAND SAMPLES.

To accompany RCA Report 71-5
by M.E. Holter

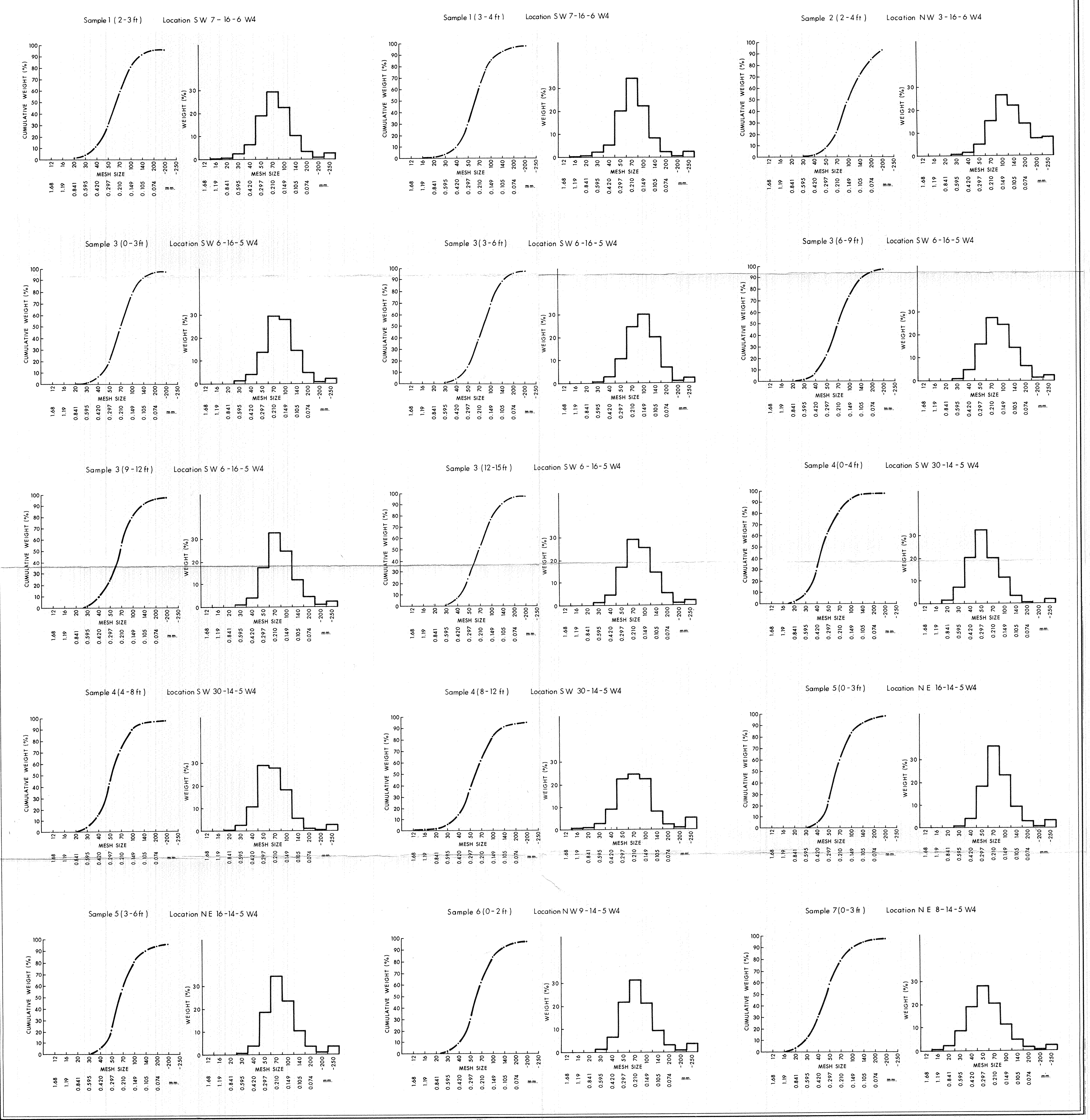

FIGURE 3. GRAIN SIZE DISTRIBUTIONS OF DUNE SAND SAMPLES.

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