Statistical Data on Glacial Boulders[1]

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While doing field work in the James River area in eastern South Dakota and in the Crosby-Minot area in northwestern North Dakota, both of which areas are covered by glacial drift, the writer recorded the distribution of boulders as a help in mapping small moraines that might have a significant relation to the occurrence of shallow ground-water supplies.

There are, of course, many more small boulders than large ones. The total number in each area examined was too great to be easily recorded, but all boulders noted that were 4′ long or longer were measured. On grouping the measurements into half-foot sizes it was found, as could be expected, that the number in each group increased rapidly with the decrease in size. For boulders between about 4′ and 9′ in length the rate of change seemed to follow nearly a mathematical sequence. The number of boulders more than 9′ in length was too small to form groups showing such a regular change. J. B. Mertie, Jr., considers that, within the size limits measured, the data suggest some logarithmic law of distribution (written communication). When plotted on semilogarithmic paper the numbers lay nearly along a straight line, as shown in Fig. 1. The rate of increase seems to be nearly the same in each of the two areas examined, as the plotted lines are nearly parallel. Partial calculations have indicated that size-groups based on the product of the three principal dimensions of the boulders would give a similar mathematical series; perhaps because the great majority of the boulders are of approximately the same shape, being roughly oval in both transverse and longitudinal cross sections.

The average number of boulders 4′ long or longer to the square mile is nearly twice as great in the James River area as in the Crosby-Minot area. In the James River area, however, boulders less than 4′ long are not very plentiful, and piles of cobbles are uncommon; whereas in the Crosby-Minot area small boulders and great piles of cobbles in the fields and road corners are very common. An attempt to extrapolate from the observed data, in order to estimate the number of boulders 2′–4′ in length that might be available for riprap on irrigation works, seemed to be of doubtful value because of the scarcity of small boulders in the James River area and the rapid increase in their number with decrease in size in the Crosby-Minot area. In the latter area, the tendency for the number to increase more rapidly with smaller size may be indicated by the 825 boulders 4.0′ to 4.4′ long that were noted, as this number is greater than it should be to accord with the number in the larger size groups.

R. F. Flint has found that in glaciated areas the proportion of large boulders increases as the age of the drift decreases and that this seems to hold true from the Nebraskan through the late Wisconsin drift. He has also found that deeply weathered boulders are usually associated with the earlier ages of drift (written communication). The distribution of boulders in parts of Ohio was recorded by R. P. Goldthwait as a help in tracing minor moraines (oral communication).

Studies of glacial drift, based on the percentages of pebbles of different sizes in the gravels, have been made;

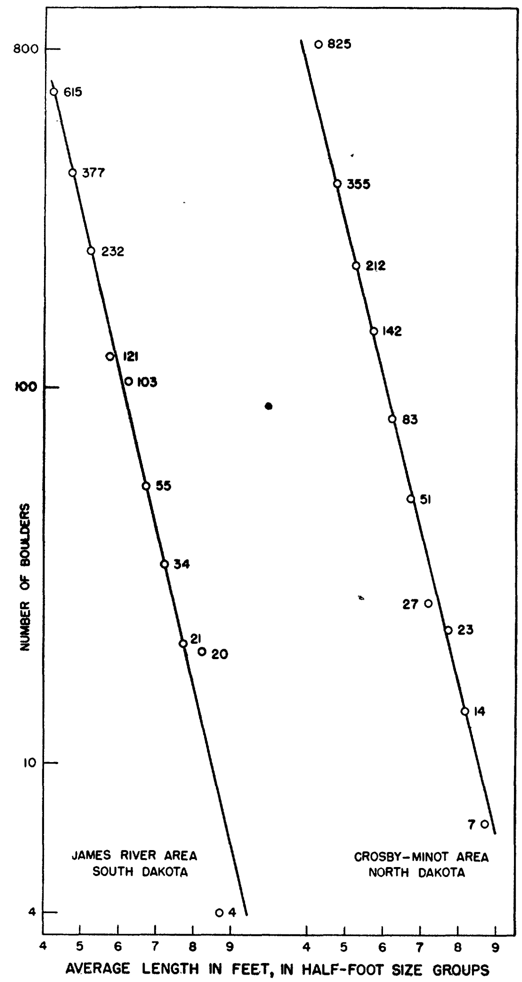

FIG. 1. Number of glacial boulders of different size-groups in areas in South Dakota and North Dakota.

but the writer has not learned of any statistical studies that may have been made on the number of boulders of different size-groups in areas of glacial drift. However, studies of similar logarithmic sequence in the sizes of crushed materials have been made by Austin (*1*), who mentions that the mathematical data may be applicable to the determination of concrete aggregates; by Roller (*3*); and by Epstein (*2*), who has applied them to the sizing of coke. The mathematical sequences present in many natural phenomena have been commented on by Sawyer (*4*), who states: "It is indeed remarkable how much of the physical world, amid the conflicting action

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of a great variety of unconnected forces, can be described by the simplest mathematical function, x^n and e^x.''

TABLE 1

Sizes of glacial boulders

Boulder length (feet)	James River area*	Crosby-Minot area†
4.0 to 4.4	615	825
4.5 " 4.9	377	355
5.0 " 5.4	232	212
5.5 " 5.9	121	142
6.0 " 6.4	103	83
6.5 " 6.9	55	51
7.0 " 7.4	34	27
7.5 " 7.9	21	23
8.0 " 8.4	20	14
8.5 " 8.9	4	7
9.0	8	
9.1		4
9.2		1
9.3		1
9.5	6	5
9.6	1	
10.0	7	1
10.2	1	
10.5	2	3
10.7	1	
10.8		1
11.0	1	
11.2		3
11.3		1
11.6		1
12.0	1	
13.0	2	1
13.5	1	1
15.0	1	
17.0	1	1
Totals	1,615	1,763

Rock types of glacial boulders

	James River area		Crosby-Minot area	
	Number of boulders	Percent of total	Number of boulders	Percent of total
Granite	1,481	91.7	1,084	61.5
Granitic gneiss	54	3.3	476	27.0
Very hard hornblende-biotite gneiss	40	2.5	43	2.4
Garnet schist			14	0.8
Paleozoic limestone	30	1.8	99	5.6
Very hard siliceous sandstone			32	1.8
Basic igneous rock	1		8	
Greenstone	7	0.7		0.9
Tertiary sandstone (Fort Union form)	2		7	
Totals	1,615	100.0	1,763	100.0

* James River area, 1,170 square miles examined; average, 1 boulder to 0.73 square mile.

† Crosby-Minot area, 2,600 square miles examined; average, 1 boulder to 1.47 square miles.

More than 90% of the large boulders in each area are of granite, gneiss, and schist, and nearly all are of hard, unweathered rock. No large weathered boulders were seen in the Crosby-Minot area, but 10 large boulders of deeply weathered granite were recorded in the James River area. Table 1 shows the number of boulders of each size-group and the kinds of rock in each area.

References

1. AUSTIN, J. B. *Ind. eng. Chem.* (Anal. ed.), 1939, **11**, 334–339.
2. EPSTEIN, BENJAMIN. *Ind. eng. Chem.*, 1948, **40**, 2289–2291.
3. ROLLER, PAUL S. *J. phys. Chem.*, 1941, **45**, 241–281.
4. SAWYER, W. W. *Mathematician's delight.* London: Penguin, 1943. P. 183.

Characteristics of the Desoxycholate-treated Cytochrome Oxidase[1]

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In 1947 the authors reported the preparation and partial purification of a solubilized cytochrome oxidase (*9*). This article is concerned with its further characteristics and the methods employed in an attempt to purify the desoxycholate-treated cytochrome oxidase.

Physical appearance: The insoluble cytochrome oxidase complex (*1, 5*) is tan, opaque, and particulate in appearance. A partially purified preparation (2–3%), made as previously described (*10*), is clear to the naked eye and light yellow in color.

Lyophilization: All of the desoxycholate-treated oxidase preparations reported in this and in previous papers may be lyophilized from the frozen state and stored at 0° without loss of activity.

Variations in Q_{O_2} protein: The partially purified preparations from lamb heart vary in their activity by as much as 35%, having Q_{O_2} protein values ranging from 1,500 to above 2,000 when tested with the hydroquinone system previously described (*10*). These variations may be ascribed in part, at least, to the amount of protein in the insoluble cytochrome oxidase suspension which seems to be directly related to the amount of sodium desoxycholate that must be used for the first extraction.

Gel formation: The preparation of the partially purified enzyme is often made difficult by the formation of a gel. This gelation seems to be a property of the desoxycholate when dissolved in phosphate buffer (*7, 8*). The oxidase activity is not impaired, however. If the final supernatant is left to stand at 0°, it will invariably gel. This gel may be liquefied by simply warming the tube in the hand.

Denaturation on standing: A partially purified preparation (1.5–3%) has been kept at 0° in both the con-

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