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A METHOD OF ASSIGNING NUMERICAL AND PERCENTAGE VALUES TO THE DEGREE OF ROUNDNESS OF SAND GRAINS

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"How round is a rock?" This is a question that the geologist is often forced to ask himself when he wishes to consider the amount of erosion that a stone has received, and he usually finds it a very difficult question to answer definitely. But he will find it even more difficult to answer the question "How round is a sand grain?"

The customary way of indicating the roundness of a sand grain is to say merely that it is "well rounded," "fairly well rounded," "subangular," or "angular"—as, for instance, have Mortimore and Trowbridge.[1] But how are two individual workers to select the same division point between any two of the classes named? What one person might call "subangular" another might call "angular" and still another might call "fairly well rounded." So for any real comparison there must be some way of actually measuring this "degree of roundness."

Chester K. Wentworth[2] has given this question considerable study and has devised some methods of assigning definite numerical values to the degree of roundness of cobblestones.[3] By one of these methods he divides the smallest radius of "developed" curvature of the pebble by the mean radius of curvature, and plots this value against the value obtained by dividing the greatest radius of curvature by the mean radius. That is, he plots

$$\frac{r_1}{R} \text{ against } \frac{r_2}{R}\,,$$

where r_1 is the radius of curvature of the "sharpest" developed edge and r_2 is the radius of curvature, in the most convex direction, of the flattest "developed" face or portion of the stone. In the other method he employs the formula

$$\frac{r_1}{\frac{1}{2}D}=R\,.$$

[1] "Correlation of Sands by Sedimentary Analysis," *Econ. Geol.*, vol. 20, no. 5 (August, 1925), p. 405.

[2] "A Laboratory and Field Study of Cobble Abrasion," *Jour. of Geol.*, vol. 29 (1919), p. 507.

[3] "A Method of Measuring and Plotting Shapes of Pebbles," *U. S. G. S. Bulletin 730C.*

R is here the "roundness" value; r_1 is, as before, the radius of the "sharpest developed curvature," and D is the diameter of the pebble starting from the point where r_1 was measured. For a complete discussion of these methods, together with means of making the measurements, the choice of gauges, and so forth, the reader is referred to the original articles. It is only necessary to point out here the extreme difficulty of measuring these angles on very small grains (it being impossible to use gauges as Wentworth suggests for pebbles), and also to call attention to the fact that, by this method, in any case where the "sharpest developed face" is a sharp angle, the value for the roundness of the pebble is zero, regardless of the shape of the rest of the specimen. This is well and good for Mr. Wentworth's purpose, for he apparently takes these sharp "developed edges" as an indication that the pebble has had no wear at all; and consequently his factor, which is in reality a factor of wear, should be zero. In the case, however, of the arkosic sands that the writer was interested in examining, there were very few grains that did not show at least one, and often many, such sharp angles. Consequently, these methods were useless for this problem, and another method had to be devised.

By "roundness" let us understand that we mean either the sphericity of a three-dimensional body or the circularity of a two-dimensional figure. The sphericity of a three-dimensional body may be expressed by the degree to which the ratio of its volume to its surface approaches the same ratio for a sphere; and if we could make such measurements on our grains, we would at once have a measure of their roundness. But while the volume of a grain may be fairly easily measured, the measurement of the surface is a much more difficult problem. If, however, we take a large number of random sections through a number of grains, the average of these sections will be the average section of the average grain; and the degree to which this average section approaches a circle will be the measure of the roundness of the grains. In this case, of course, the roundness is measured by the degree to which the ratio of the area to the circumference approaches the same ratio for a circle, and this value lends itself very readily to measurement.

Expressed mathematically,

$$\frac{\text{area}}{(\text{perimeter})^2} = \text{a constant,}$$

which is $\frac{1}{4}\pi$ for a circle. Therefore, if we multiply the equation by 4π we will have,

$$\frac{\text{area } 4\pi}{(\text{perimeter})^2} = K\,.$$

K is a constant that is dependent upon the shape of the figure, being 1 for a circle and less than 1 for any other shape; but it is the same for all figures of the same shape; regardless of size. That is to say, it means that a small circle is just as round as a large circle but no more so. Furthermore, the value of K for a figure of any given shape represents the percentage ratio that the area of the figure holds to the area of a circle with the same perimeter. That is, for example, in the case of the square, where the constant is 0.785, it means that a square contains just 78.5 per cent of the area that a circle with the same perimeter would contain. Likewise, any right isosceles triangle has a roundness of 0.54 or contains 54 per cent of the area that a circle with the same perimeter would contain. In other words, this constant K gives the percentage roundness of the figure.

D	E	F	G
"rounded"	"fairly well rounded"	"subangular"	"angular"
0.96 to 0.81	0.97 to 0.74	0.92 to 0.86	0.83 to 0.60
av. 0.902	av. 0.85	av. 0.88	av. 0.76

FIG. 1

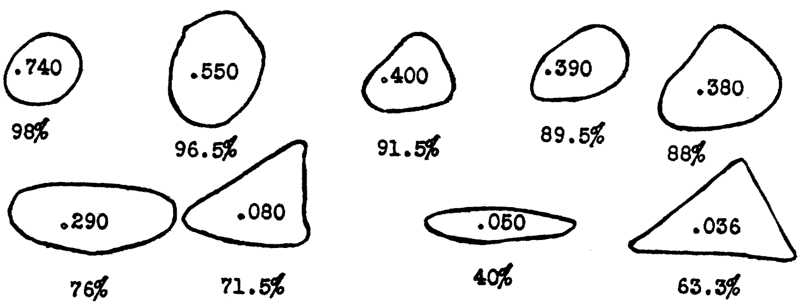

FIG. 2

D, E, F, and G of Fig. 1 are tracings of photographs published by Trowbridge and Mortimore* together with their classification. The numbers are those that would have been given by the present system of classification.

* *Loc. cit.*, p. 1.

In order to measure these values for a set of grains, it is only necessary, where thin-sections have been made, to project the image of the thin-section on a screen, or where a photograph has been taken of the detrital material, to project the image of the photograph on the screen, where it may be traced or measured directly. Or the grains may be sprinkled over a lantern slide that has been previously covered with glue or a suitable cement, the slide inserted in a projection camera, and the image obtained on the screen. A camera lucida may also be used but is usually much slower than the methods described above.

The area is measured by means of a planimeter; and the perimeter, by means of a cyclometer-map measurer. The writer mounted his map-measurer so that it took the place of the pointer of the planimeter; then by a single tracing of the outline, both the perimeter and the area of the figure were obtained; and by setting

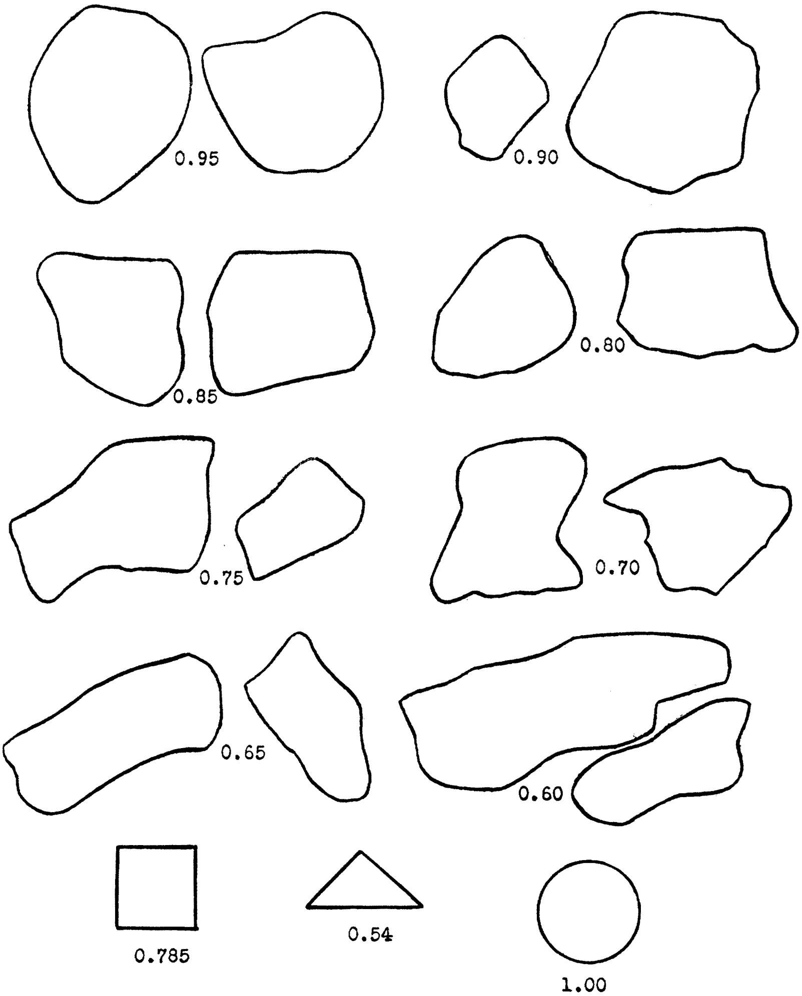

FIG. 3—This plate shows a couple of grains for each of a number of degrees of "roundness" together with some simple geometrical forms for the purpose of comparison and reference.

these values on the slide rule, the roundness could be read off directly. It thus required only from twenty seconds to a minute to measure accurately the roundness of any given grain.

The eye soon becomes trained so that the operator can estimate the roundness of a given grain to within 4 or 5 per cent in most cases. It is then necessary to measure only the doubtful grains or make an occasional measurement for the purpose of checking the estimates.

The disadvantage of the system lies in the fact that where grains that have a decidedly tabular form, such as mica particles, are to be measured, it is necessary to imbed the material in some supporting medium and cut a thin section at random in order to insure a true sample of the shapes.

The principal advantages of the system are that it is simple, accurate, applicable to all sizes and shapes of grains, and will give numerical and uniform results in the hands of different operators and will thus serve as a true basis of comparison.

Figures 1, 2, and 3 are inserted for the purpose of comparing the percentage system with those previously discussed.

Figure 2 shows the outlines published by Wentworth, and inclosed within the outlines are the values for roundness that he assigned to the given figure. The percentage roundness by the present system is given just under each outline.

It will be noticed in figure 1 that by the percentage-roundness system, *e* and *f* should be reversed as to degree of roundness. This is because the grains in *f* are more equant than those in *e*. Again, the Wentworth values for roundness would arrange the outlines in the same manner as the percentage-roundness system with the exception of the last two where the percentage roundness of the last figure is larger than that of the preceding one.