A Comparison Between Sieving-, Elutriation- and Measurement-Analyses of Sand

By

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Abstract

A series of sand samples is sieved by means of square mesh sieves as well as elutriated by successive elutriations in a single-vessel elutriator (ORTH's vessel). A comparison of the results of the analyses shows that the equivalent diameters ought to be calculated after RUBEY's formula and not after OSEEN's as the latter yields bad errors in the results of the analyses. — Measurements of the breadths and lengths of the grains in the sieving and elutriation fractions show characteristic regularities. The effect of the elutriation time on the results of the analyses has been examined and the conclusion has been arrived at that half an hour's elutriation suffices. — Too large quantities of material in the elutriation vessel disturb the result of the analysis, and with the method applied the quantity of sand analysed should not exceed abt. 30 g. A table of settling velocities calculated for important grain sizes after RUBEY's formula is given in the Appendix.

Introduction - Methods

The two most important methods for the investigation of grain distribution conditions of sanded sediments are sieving and elutriation. As separation after grain size in the case of the said two methods is based on widely differing principles it is of importance to ascertain how closely sieving and elutriation analyses may be brought to conform, and to realize why differences in the results of the analyses arise so that such conditions may be taken into consideration when analyses undertaken on the basis of the two different methods are to be compared. The aim of the investigations represented here is to throw light on the said questions by means of comparative sieving and elutriation analyses and measurements of the dimensions of the sand particles.

A. VON NOSTITZ has previously (in 1926) published direct comparisons between sieving and elutriation analyses. By means of KOPECKY-KRAUSS's elutriator VON NOSTITZ divided the samples examined into three fractions; one containing grains under 0.1 mm (diameter), another with grains between 0.1 and 0.2 mm, and a third with grains over 0.2 mm; he found that the analysis-results obtained agreed quite well with the fractioning that arose by separation by means of square mesh sieves with the same fraction limits. VON NOSTITZ does not, however, deal with the question of elutriation velocities employed for the analyses; nor does he mention the relationship between elutriation velocities and grain sizes.

It is, however, obvious that information about the elutriation velocities employed is not only necessary, but fundamental when investigations are to be undertaken concerning the relationship between sieving and elutriation. It is of course well known that separation by elutriation takes place according to the settling velocity of the grains; and the expression 'grain-size' in elutriation (equivalent diameter, elutriation diameter) is in reality a fixed size only that under certain circumstances is ascribed to the grains according to their settling velocities.

Much vagueness and disagreement, however, still prevails concerning the relationship of grain size and settling velocity, as various qualities of the grains — qualities that to some extent are difficult to measure — affect the settling velocity, thus for instance the mass, the specific gravity, the shape, and the character of the surface, etc.

Several of the velocities determined by experiments in earlier days (SCHÖNE, ATTERBERG and others) are still widely used in practical elutriation analyses. Theoretical formulas are, however, now to a great extent employed for the determination of the relationship between the size of the grain and its settling velocity. The theoretically computed settling velocities apply on the assumption that the particles are spheres, and the size of differently shaped particles then becomes a theoretical magnitude determined by the settling velocity of the grains and the settling formula applied. Of such settling formulas there exist — in the author's knowledge — two that do not contain empirical constants, namely OSEEN's and RUBEY's. Judging by the existing literature OSEEN's formula appears to be the best known and most widely used in modern laboratories. It is thus recommended by GESSNER who (p. 24) writes "dass der STOKES-OSEENSCHE Gleichung theoretisch einwandfrei begrundet und experimentell sehr wohl belegt ist."

I therefore employed OSEEN's settling velocities in the first analyses undertaken by me. The following methods were besides employed for the experiments:

The sieving was done with DIN square mesh sieves, mostly by half an hour's mechanical sieving. To avoid any accidental deviations in the selection of the samples the same material was used for the elutriation analysis, that was carried out by successive elutriations in ORTH's vessel. The latter was fitted with outlet tubes with different openings varying with the current velocity required. The waterflow was adjustable and the current velocity was controlled by means of a piezometer tube so as to obtain the exact current velocity corresponding to the temperature of the water. In the majority of the experiments the elutriation was continued till practically speaking no more grains passed through.

All current velocities were calculated for grains with the specific gravity of quartz, and the sediments that were used in the experiments consisted almost exclusively of quartz grains.

Settling Formulas and the Results of the Analyses

Figure 1 shows the results of two comparative experiments between sieving with square meshed sieves and elutriation by means of OSEEN's settling values. For the first experiment (fig. 1 A) a comparatively small quantity (abt. 26 g) of sediments was used; for the next (fig. 1 B) a large quantity (abt. 146 g). It appears direct from the cumulative curves that the agreement between the sieving and elutriation analyses is very bad, and moreover it is ascertained that the position of the curve of the elutriation analysis in relation to that of the sieving curve varies in the two instances. Attention must at once be drawn to the fact that it proved to be the great quantity of material, that was used for experiment 1 B, that caused, too many (and accordingly too large) grains to pass the elutriator.

In all the experiments, however, that have been carried out with about 30 g material I have found the same difference between sieving and elutriation curves as shown in figure 1 A (see figs. 3, 4, & 5). The deviation of the elutriation from the sieving curve always appears in the same way, as the elutriation curve is always lying to the left (where the coarse grains are plotted in the diagram) but in such a way that the distance from the sieving curve is slight in the case of the small grain sizes and increases with the increasing sizes. This regularity seems to indicate that the difference between the sieving and elutriation analyses in the first line is due to the settling formula employed. If this is really the case it means that OSEEN's equivalent diameters differ considerably from the real dimensions of the grains.

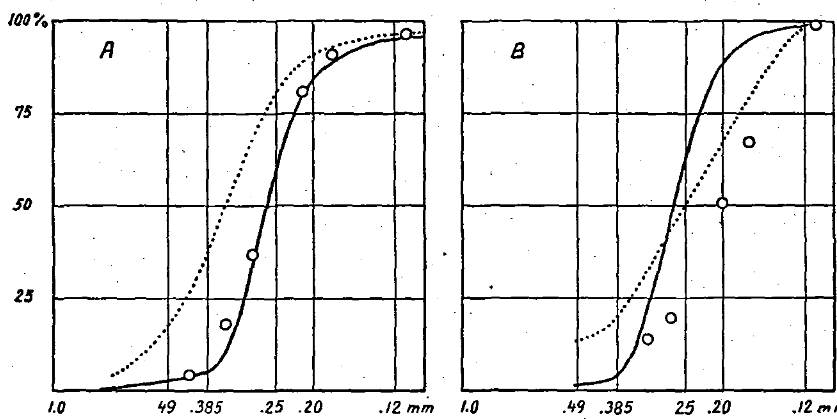

Fig. 1. Cumulative curves for sieving (——) and elutriation analyses with settling velocities after OSEEN's formula (·····). For A (left figure) abt. 26 g have been used, for B (right figure) abt. 146 g. Circles show the result of the elutriation analyses when the settling velocities are converted to grain sizes after RUBEY's formula.

If we compare OSEEN's settling velocities with the various empirically determined settling velocities (fig. 2) it appears that OSEEN's formula on the whole yields settling velocities that are considerably lower than those that are empirically determined, and this particularly applies to the coarsest grains, while the finer grains show a pretty good conformity.

If OSEEN's settling velocities really are too low, especially with regard to the great grain sizes, a sediment elutriated with OSEEN's velocities will seem to have too many coarse grains, and the elutriation analysis will differ from a grain size analysis in the same way as the elutriation analysis in fig. 1 A differs from the sieving analysis.

According to the above it might seem as if the most rational method accordingly would be to employ empirical settling velocities in the elutriation analysis, but it would in that case scarcely be

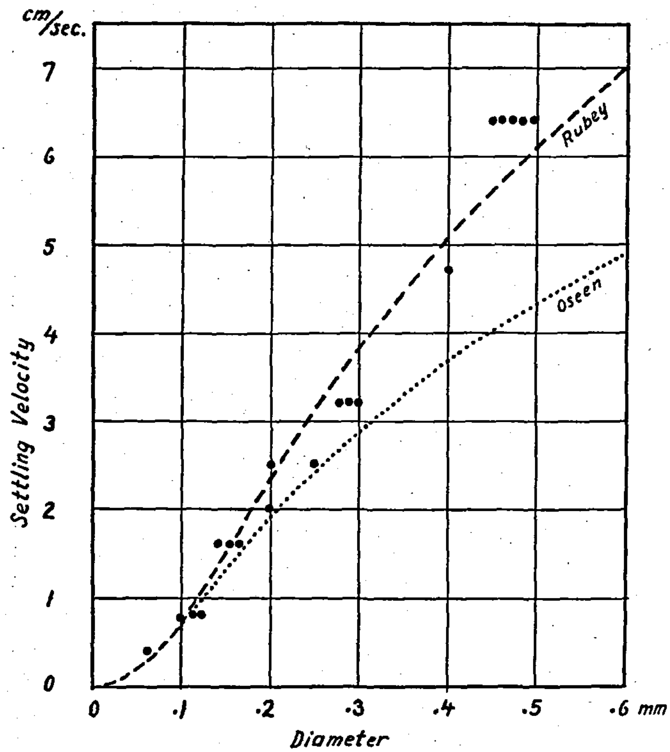

Fig. 2. Graph showing experimentally determined settling velocities after ATTERBERG, HILGARD, HOLMES, ORTH and SCHÖNE. For comparison OSEEN's formula is inscribed as well as RUBEY's.

possible to avoid a constant heterogeneousness in the analysing methods. It is my conviction that a theoretically derived formula ought to be used for the elutriation analysis, but on the other hand it is of great importance that the diameter computed (the equivalent diameter) for isodiametric grains should lie as close as possible to some other measure indicating the actual size, a mean diameter or the like.

As it now appeared from the experiments that OSEEN's formula yielded analysis-results that showed considerable deviations from the sieving results, and as it is probable that the deviations to a certain extent were due to the application of OSEEN's formula I converted the settling velocities applied into the grain diameters after RUBEY's formula. This caused an alteration of the elutriation curve as indicated by circles in fig. 1 A. The figure shows that the agreement between the sieving and elutriation analyses is now exceedingly fine. (Concerning fig. 1 B see p. 582).

RUBEY's formula (RUBEY 1933) is supported by theory, and as already mentioned it contains no empirical constants. It is based on a consideration of the forces that keep a particle balanced in upward streaming water as RUBEY expresses it:

weight of particle = viscous resistance + impact of fluid.

Solved for velocity the formula runs thus:

$$v = \frac{\sqrt{\frac{4}{3} \cdot g \cdot \varrho_F (\varrho_P - \varrho_F) r^3 + 9 \eta^2} - 3 \eta}{\varrho_F r}$$

where v = velocity; ϱ_P = the specific gravity of the particle; ϱ_F = the specific gravity of the liquid; r = radius in cm; η = the viscosity of the liquid; and g = the gravitation constant.

RUBEY has shown that his formula agrees extremely well with observed settling velocities of particles of pulverized quartz for small as well as for large particles (up to 16 mm).

For the purpose of the following experiments I have therefore calculated the settling velocities for the grain sizes of the sieve meshes after RUBEY's formula, and the experiments then showed a fairly good agreement between the results yielded by the sieving and elutriation analyses. An elutriation curve was in each case obtained that differed considerably less from the sieving curve than the curve that would have been obtained by the application of OSEEN's formula.

As shown by figs. 3, 4, and 5 there is not, however, any question of a complete agreement, and the results vary considerably in the case of the different experiments. Most frequently the elutriation curve still lies a little to the left of the sieving curve, i. e. the sediment, when elutriated, appears somewhat coarser than when sieved. This difference is due to the different nature of the sieving and elutriation processes and may be explained by observation of the grain dimensions as they appear from the investigations described below.

Sieving Analysis and Grain Size

Measurements of the dimensions of the grains under the microscope were carried out in the following way: By means of a net ocular the smallest cross section of any single grain (the breadth

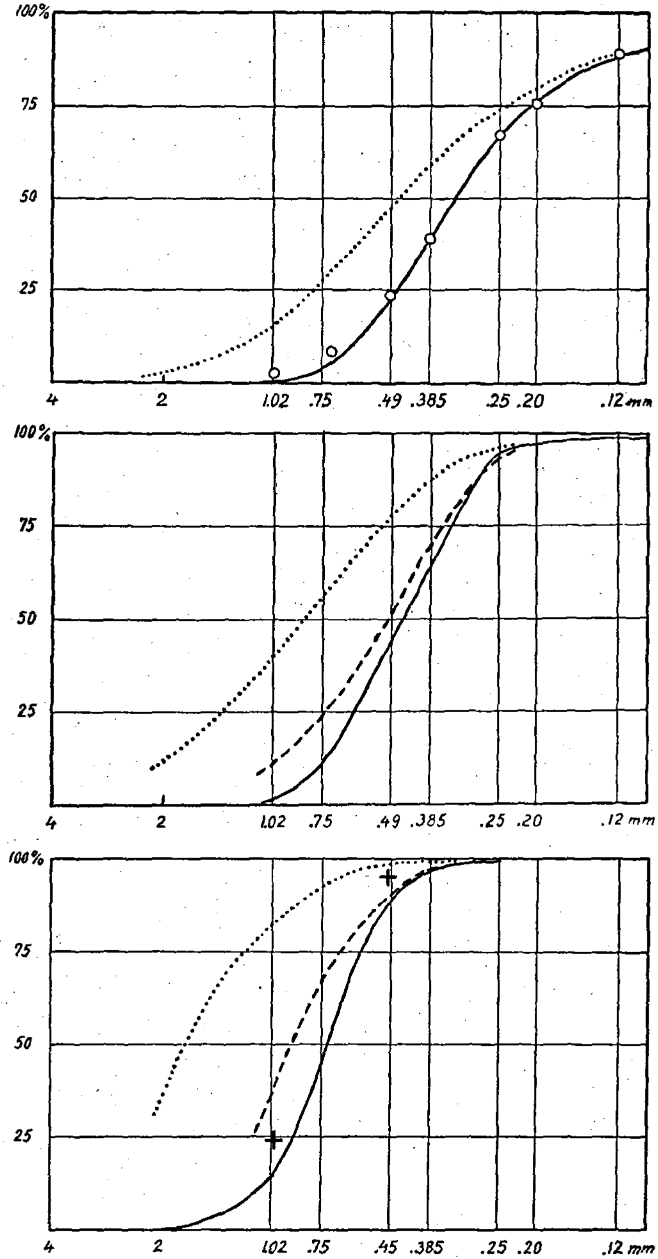

Fig. 3, 4 and 5. Cumulative curves for sieving and elutriation analyses. —— sieving analyses, + sieving with circular mesh sieves, o and - - - - elutriation analyses, RUBEY's equivalent diameters, ···· elutriation analyses, OSEEN's equivalent diameters.

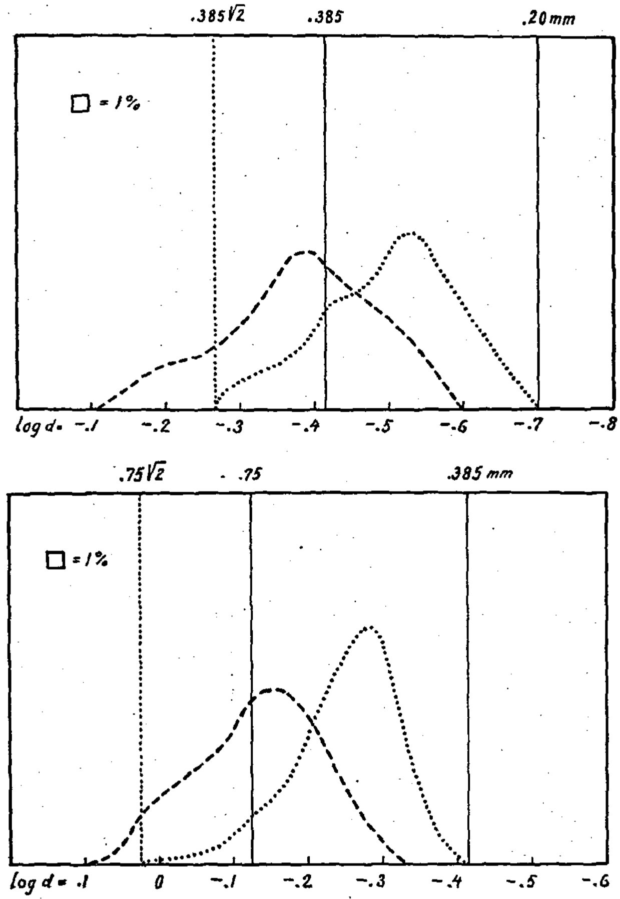

Fig. 6. The grain distribution in sieving fractions measured after the breadth (····) and after the length (- - - -) (number of grains). Above: fraction .20 — .385 mm, below: fraction .385 — .75. The breadth varies from .20 to .385 $\sqrt{2}$ and from .385 to .75 $\sqrt{2}$ respectively.

in the following called b) and the cross section at right angles to it (the length l) are measured. In this way we obtain in the first line the measure, namely b, that must be supposed to be of importance as determining whether the grain will pass a sieve or not; but simultaneously a measurement of this kind gives the sides in the smallest rectangle in which a grain in that position may be inscribed and as, roughly speaking, it may be considered that the smallest dimension of the grain is almost at right angles to the plane of the

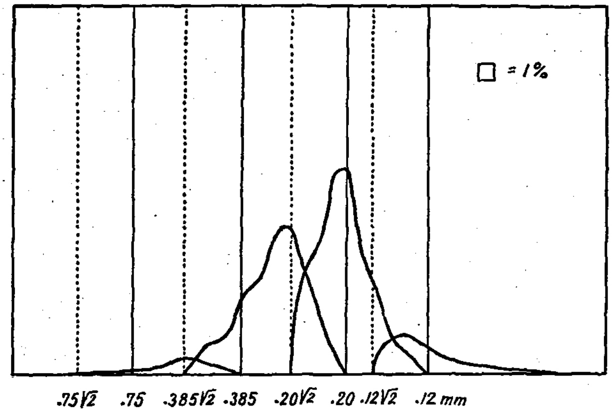

Fig. 7. The distribution of the breadths of the particles in the various sieving fractions of a sediment (number of grains). In each fraction the grain size varies from the smallest sieve mesh side till the largest $\cdot \sqrt{2}$.

object glass in the product lb we get a measure that is proportionate to the maximal cross section of the grain (or rather the maximal projection of the grain on a plane).

The measurements of the grains in the sieving fractions showed, as assumed, that the grains by the sieving process are separated after breadth independent of the length dimensions of the particles; but no effective fractioning takes place after definite fraction limits determined by the side lengths of the sieve meshes. The fact is that on a sieve particles only with breadths larger than, or equal to, the side of the sieve mesh are found; but through a sieve grains will pass whose breadths reach up to the diagonal of the sieve mesh. *All sieving fractions therefore contain particles whose breadths vary from the side length of the fine sieve to the side length $\cdot \sqrt{2}$ of the coarse sieve as shown by the distribution curves for the grain breadths* in the sieving fractions in fig. 6. Grains whose breadths lie between the side length and the diagonal of a sieve mesh will therefore in some cases be able to pass through the sieve; in others not. This overlapping is also clearly seen in fig. 7, that shows the distribution of the grains measured after the breadths in a sand sample's various sieving fractions. This figure is based on the countings of breadths within the various fractions and within the whole sample.

In a corresponding way I have measured the grain lengths within

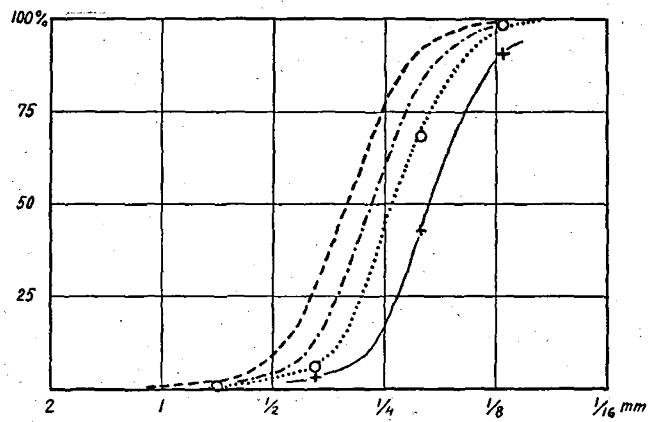

Fig. 8. Same sample as fig. 7. Cumulative curves for length measures (- - - -), breadth measures (····), $\sqrt{lb}$ (—·—·—), sieving (—+—) and elutriation (o).

the fractions as well as in the whole sample, and by means of the countings it is now possible to compute the distribution of grains according to the results yielded if the separation is made after breadth, length, and sieving. The results are illustrated in the cumulative curves in fig. 8. It is seen that in relation to the sieving curve the breadth curve is plotted to the left and the length curve still further in the direction of the coarser grains. The distance between the b and l curves is naturally dependent on the shape of the grains and greatest if $\frac{l}{b}$ is great. While the distance between the b and l curves thus varies greatly and depends on the shape of the grain, the distance between the sieving curve and the b curve must, notwithstandig the shape of the grain, lie within definite limits. If the logarithmic scale is applied to the grain size it cannot exceed 0.15 units, thus for an arbitrary ordinate the quotient $\frac{\text{breadth}}{\text{sieving diameter}}$ is smaller than, or equal to, $\sqrt{2}$. We know namely that the largest grains that can pass through a sieve with the mesh side d_{si} has the breadth $b = d_{si} \cdot \sqrt{2}$. If all particles up to this diameter passed through the sieve the distance between the curves would be 0.15 units; but as the grains whose breadths lie between d_{si} and $d_{si} \cdot \sqrt{2}$ only partly pass through the sieve the distance must be smaller.

Relationship between Square Mesh Sieving and Circular Mesh Sieving

It is a well known fact that when sieving is undertaken by means of square meshed sieves we obtain a distribution of grains that differs from that obtained by circular mesh sieves. VON NOSTITZ has thus published analyses in illustration of this question. A consideration of his figures shows that the application of circular mesh sieves always yields an apparently coarser sediment; the author arrived at the same result. (See fig. 5).

As was to be expected beforehand measurements of the grains have shown that any fraction that has appeared by sieving through circular mesh sieves contains grains whose breadths vary from the fine to the coarse sieve diameter. A separation by circular mesh sieves will therefore be identical with a separation according to the breadths of the grains.

We may therefore on the basis of the above data determine the following:

1) the circular mesh sieve separates the grains after their breadths.
2) By sieving through square meshed sieves more grains pass through the sieve than through the corresponding circular mesh sieve; the largest grains that can pass through have a breadth = $\sqrt{2}$ times the square mesh side.
3) Therefore the results of the analyses are modified in such a way that the sediment seems to be finer when the distribution is measured by means of square meshed sieves, but the distance between the cumulative curves cannot for an arbitrary ordinate exceed 0.15 units on the logarithmic scale.
4) If the shape of the grain is the same for the fine as for the coarse grain *the shape of the curve (the relative grain distribution) becomes uniform in case of the two analysing methods.*

Elutriation Analysis and Grain Size

In the same way as mentioned before the breadths and lengths of the grains were measured under the microscope in various elutriation fractions (fig. 10). The measurements showed that the largest grains in a fraction generally are of too great breadths and lengths compared to the elutriation diameter the grains ought to have according to their settling velocity after RUBEY's formula; and that the smal-

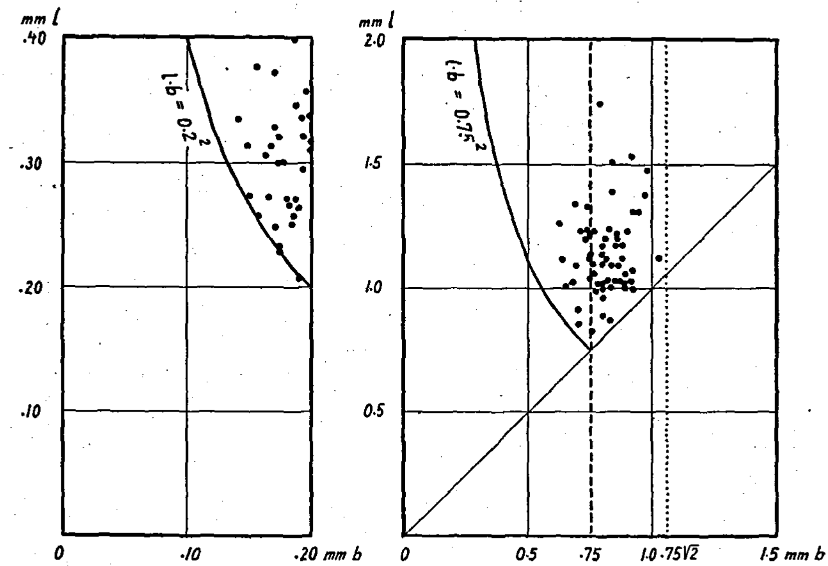

Fig. 9. Breadth-length-diagram of the finest grains from elutriation fractions. Left, grains whose equivalent diameters (after RUBEY) are over .20 mm, but whose breadths are under .20 mm, right, grains whose equivalent diameters are over .75 mm, but that have passed the .75 mm sieve.

lest grains have too little breadths, but also too great lengths. Accordingly neither breadth nor length may be used as a direct indicator of the correctness of the elutriation velocity.

The fact that the smallest grains within a fraction have too small breadths and too great lengths shows, however, that the elutriation diameter of the said grains lies somewhere between l and b, and it is clear that the too small breadths are counterbalanced by the greater lengths of the grains. For the purpose of a closer illustration of the question diagrams have been drawn up in which each separate grain is represented by a point in a right angular coordinate system with breadth and length as abscissa and ordinate respectively (fig. 9). An examination of the diagrams has shown that there is agreement between the elutriation diameter computed after RUBEY's formula and the geometric mean of the lengths and breadths of the grains so that the lowest limit of the computed mean diameter, $\sqrt{lb}$, corresponds to the elutriation diameter. Graphically this appears in fig. 9 illustrated by the fact that the grains lie to the right of the line described by the formula $d_R{}^2 = lb$ (in which d_R = the equivalent diameter after RUBEY).

The geometric mean of b and l thus seems to be the measure that in practice conforms best with the equivalent diameter after RUBEY.

From the measurements of b and l in the elutriation fractions it, however, also appears that the elutriation fractions contain grains that are too large (measured after b, l, and $\sqrt{lb}$) (see fig. 10).

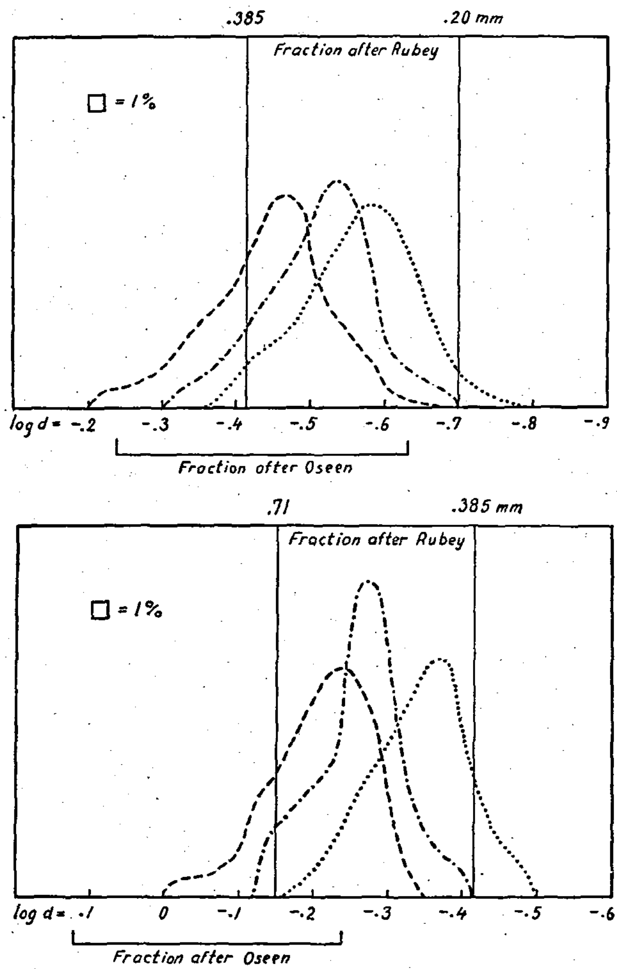

Fig. 10. Grain distribution in two elutriation fractions measured after breadth (····), length (- - - -) as well as $\sqrt{lb}$ (—·—·—) (number of grains). Above: fraction limits .20 — .385 mm (equivalent diameter after RUBEY), below fraction limits .385 — .71 mm. Note that the lower limit for the $\sqrt{lb}$-curve corresponds to the equivalent diameter.

In consideration of the fact that the shape of the grains in the natural sediments varies very much this is, however, not so remarkable. It is well known that among grains with the same true nominal diameter (grain with same volume, WADELL 1936) the isometric ones will obtain a higher velocity than the plate shaped ones. The latter accordingly will prove to have much larger breadth and length measures in relation to their equivalent diameter. In

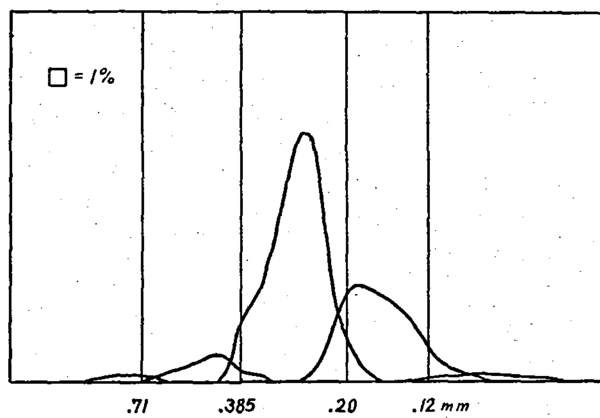

Fig. 11. The distribution of the breadths of the particles in the various elutriation fractions of same sample as in fig. 7.

this connection it may be mentioned that CASAGRANDE (1934) by an experiment in which he compared a sieving and sedimentation analysis of mica plates found that the equivalent diameter of the mica plates is 3½—4 times their square mesh sieve diameter.

As fig. 7 shows the distribution of grains in the sieving fractions of a sediment, fig. 11 represents the corresponding distribution curves of the breadth measures in the elutriation fractions of same sample. The figure clearly shows the overlapping of the grain sizes in the various fractions; but it is noticed that overlapping in the elutriation fractions is found both in the fine as well as in the coarse part of the fractions, while the sieving analysis showed a unilateral overlapping in the coarse end. This difference influences the final results of the analyses by sieving and elutriation and causes the sediment, if sieved, to appear finer than if elutriated (by means of RUBEY's velocities). Such a difference is thus generally to be expected when square mesh sieves are used for the sieving analyses.

Table 1.

		Mean[1])	Size ratio deviation[2])	$M\varphi$	$\sigma\varphi$[3])	$\log M_R - \log M_{si}$	$\log M_O - \log M_{si}$
glaciofluvial sand	Sieving	.160	1.40	2.64	.48	.008	.035
	Rubey	.163	1.34	2.62	.43		
	Oseen	.174	1.51	2.52	.60		
beach sand	Sieving	.253	1.28	1.98	.36	.016	.127
	Rubey	.262	1.29	1.93	.37		
	Oseen	.339	1.41	1.56	.50		
glaciofluvial sand	Sieving	.254	1.60	1.98	.68	.058	.287
	Rubey	.280	1.69	1.78	.76		
	Oseen	.492	2.08	1.02	1.06		
beach sand	Sieving	.258	1.29	1.95	.37	.007	.120
	Rubey	.263	1.32	1.93	.40		
	Oseen	.341	1.47	1.54	.56		
glaciofluvial sand	Sieving	.282	1.59	1.83	.67	.038	.177
	Rubey	.308	1.62	1.70	.69		
	Oseen	.423	1.94	1.24	.96		
Quarz from kaolinized granite, Bornholm	Sieving	.288	1.89	1.79	.91	.008	.138
	Rubey	.294	1.96	1.77	.97		
	Oseen	.396	2.59	1.34	1.37		
dune sand	Sieving	.457	1.48	1.13	.57	.065	.275
	Rubey	.531	1.70	.91	.77		
	Oseen	.862	2.02	.22	1.01		
(rhätic?) sand Bornholm	Sieving	.721	1.38	.47	.46	.077	.347
	Rubey	.861	1.46	.22	.55		
	Oseen	1.60	1.64	—.68	.71		

[1]) Geometric mean, identical with Wentworth's Mean and Krumbein's $GM\xi$

[2]) Wentworth's standard size ratio deviation. This is the reciprocal of Krumbein's $\sigma\xi$ for Wentworth *defines antilog$_2$ standard deviation = ratio deviation*, and Krumbein $\sigma\varphi = -\log_2 \sigma\xi$.

[3]) $\sigma\varphi$ is identical with Wentworth's standard deviation.

(See: Wentworth 1929 and Krumbein 1936.)

Concerning the difference between the analysing results it is difficult to lay down any rules, but generally it is small only when Rubey's elutriation velocities are employed. An impression of the effect of the various methods on the analysis-results (beyond the visual impression in figs. 1 A, 3, 4, and 5) may be gathered from table 1 in which the most important statistical values are given. The figures have been found graphically by means of probability paper after a method similar to that described by OTTO (1939). The statistical values are computed for the sieving analysis and for the two elutriation analyses that appear as the elutriation velocities applied are calculated after RUBEY's and after OSEEN's formulas.

The figures show that on the whole there is a rather close agreement between the sieving- and the elutriation-analyses when RUBEY's equivalent diameters are applied. Log M_R indicates the position of the geometric or logarithmic mean grain size of the elutriation curve calculated after RUBEY's formula on the logarithmic scale, and log M_{si} the corresponding position of the mean grain size of the sieving analysis. The difference log M_R—log M_{si} may therefore be considered as a measure of the distance between the two curves on the logarithmic scale. The said distance varies in the 8 experiments between 0.007 and 0.077, and is averagely 0.037, from which is seen that in these experiments M_R is on the average equal to 1.09 M_{si}. The difference thus is not very great.

The corresponding distance between the mean grain size of the OSEEN elutriation curves (M_O) and M_{si} on the logarithmic scale (log M_O—log M_{si}) varies from 0.035 to 0.347. The difference is thus seen to be considerable in this case, averagely 0.188, corresponding to M_O averagely being equal to 1.54 M_{si}.

A consideration of the standard deviations also shows that RUBEY's formula yields a considerably better agreement with the sieving analyses than OSEEN's formula.

If RUBEY's formula is applied elutriation analysis-results are obtained that differ little only from those obtained in the sieving analysis; if OSEEN's formula is applied a much too large mean grain size is obtained and a much too large standard deviation.

Duration of Elutriation

To get an impression of the way the elutriation time affects the result of the analysis some experiments were undertaken in which the elutriation material was gathered at intervals of a quarter of an hour. The results of one of the experiments appear from table 2 and figure 12. The experiment shows that much the greater part of the material is carried over in the course of the first quarter

Table 2

Elutriation time	Diameter in mm							
	below 0.12	0.12—0.20	0.20—0.25	0.25—0.385	0.385—0.49	0.49—$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}\sqrt{2}$—1.0	above 1.0
$^1/_4$ h.	9.1	11.8	5.8	21.1	8.3	12.3		2.2
$^1/_2$ h.	1.4	.6	.9	2.4	3.6	1.1	5.4	
$^3/_4$ h.	.4	.4	.8	2.1	1.8	.6		
1 h.	.3	.3	.5	1.4	.9	.4	.6	
$1^1/_4$ h.		.3	.4	1.1	.5	.4		
$1^1/_2$ h.					.4	.2	.2	

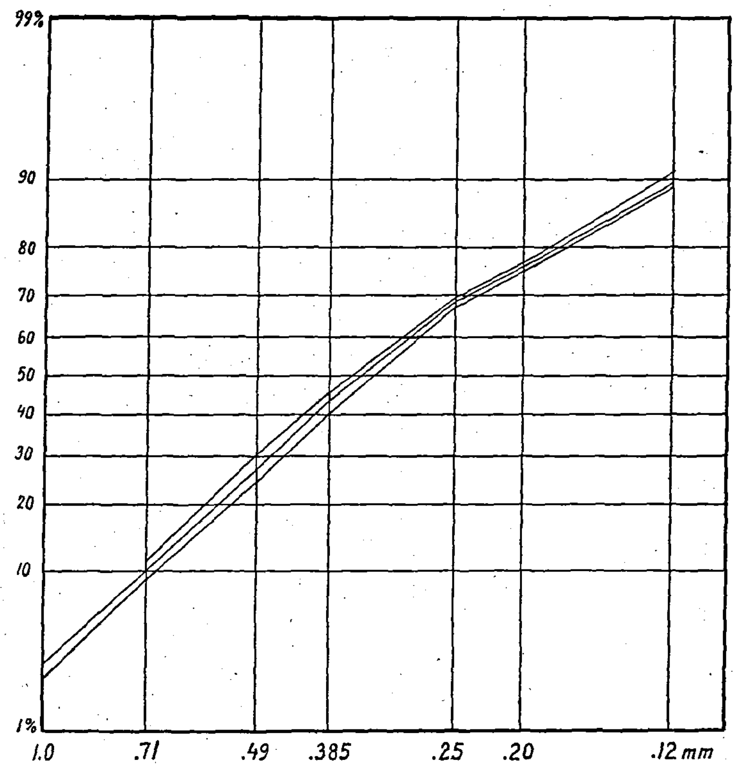

Fig. 12. Cumulative curves showing the result of various elutriation times. Elutriation time for uppermost curve $^1/_4$ h. for middle curve $^1/_2$ h, and for lowest curve 1 h.

hour, and the quantity carried over grows smaller and smaller per quarter hour the longer the elutriation lasts. The greatest variations are to be found at the fraction limits that lie nearest to the maximum of the distribution curve. An examination of the distribution of grains after different periods of elutriation shows that the relative distribution of the grains practically speaking keeps constant. If the cumulative curves are drawn up on a logarithmic scale for the grain size the shape of the curve thus appears to be uniform, while the position of the curve is slightly translated towards the fine end of the diagram with the increasing elutriation time. These conditions are most clearly observed when the results are drawn up in the probability paper (fig. 12). The influence of the elutriation time on the analysis also appears from the following graphically found statistical constants:

	Mean mm	Size ratio deviation	$M\varphi$	$\sigma\varphi$
$^1/_4$ hour	.318	1.98	1.65	.98
$^1/_2$ -	.304	1.98	1.72	.99
$^3/_4$ -	.298	1.98	1.75	.99
1 -	.293	1.98	1.77	.99

In practice sufficiently good analyses may certainly be obtained by abt. half an hour's elutriation of each grain size, but when required for special purposes the elutriating process must naturally be continued till practically speaking no more grains pass through the outlet of the elutriation vessel.

Experiments with Varying Quantities of Material

As mentioned on page 567 (fig. 1 B) a large quantity of material brings about a change in the elutriation result. That it actually is the quantity of material that plays a part for the said change appears from a series of experiments like the following.

A sample of beach sand of abt. 120 g was sieved for 15 minutes by mechanical sieving. For the sake of comparison the same material was also sieved by hand during the same period. Thereafter the sieving fractions were once more mixed and the sand was divided into portions of abt. 60 g, 30 g, 15 g, and 15 g. Then an elutriation analysis was undertaken for the 15 g. The latter were again mixed

Table 3

Sieving			Elutriation				
Diameter in mm	mechanical	by hand	Diameter in mm	13.915 g	30.332 g	62.889 g	120.243 g
below 0.12	.3	.4	below 0.12	.3	.2	.2	.2
0.12 —0.20	17.3	15.7	0.12 —0.20	11.4	13.4	25.6	36.8
0.20 —0.25	28.4	32.0	0.20 —0.25	34.6	36.1	29.0	23.6
0.25 —0.385	50.0	47.7	0.25 —0.385	47.6	42.6	37.3	31.9
0.385—0.49	2.1	2.3	0.385—0.49	3.5	5.2	4.6	4.1
0.49 —0.75	1.8	1.7	$0.49-\frac{1}{2}\sqrt{2}$	1.8	1.5	2.5	2.5
0.75 —1.02	.1	.1	$\frac{1}{2}\sqrt{2}-1.00$	.5	.7	.5	.6
			above 1.00	.3	.3	.3	.3

with the next 15 g, and all the 30 g were elutriated. In a corresponding way the 30 g were added, the resulting 60 g were elutriated, and finally the last 60 g were added and an analysis of all the 120 g was made. This process was employed in order, as far as possible, to secure the same material in all the experiments.

The results of the analyses appear from table 3 and fig. 13. The table and the figure show that the distribution of grains is almost identical in the case of 15 and 30 g; while a larger quantity of material brings about a change which is the larger the more material we take. The change is of the same nature as that shown in fig. 1 B.

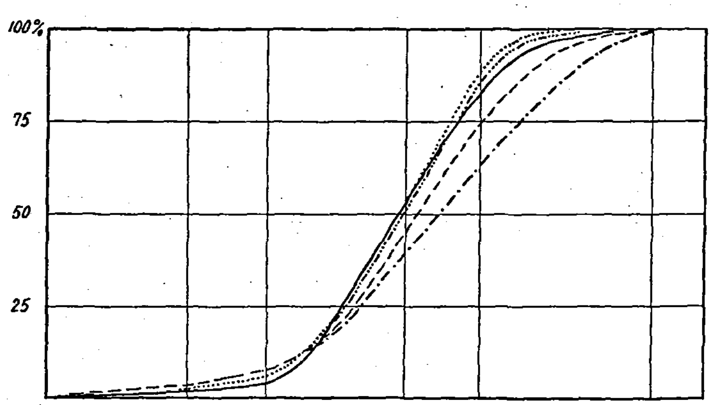

Fig. 13. Sieving analysis compared with elutriation analyses with different quantities of material. Sieving analysis (——), elutriation analyses of abt. 14 g (·····), 30 g (—···——···—), 63 g (- - - -), and 120 g (—·——·——·—).

The change denotes that too much material passes the elutriation tube when there is much material in the latter. The reason of this must be due to the fact that the numerous grains that under the elutriation are found in the liquid limit the effective elutriation tube diameter so that the velocity of the current in the tube where the grains are found becomes too great. In this way grains a little too large will be able to pass the elutriation tube.

The experiment shows that care must be taken not to use too great quantities of sediment for the analysis. For elutriation in ORTH's vessel not more than about 30 g ought to be used.

APPENDIX

Settling Velocities after Rubey's Formula

Diam. mm.	5° C	10° C	15° C
1	9.517	9.632	9.724
$\frac{1}{2}\sqrt{2}$	7.541	7.694	7.817
$\frac{1}{2}$	5.745	5.940	6.099
$\frac{1}{4}\sqrt{2}$	4.115	4.342	4.532
$\frac{1}{4}$	2.700	2.927	3.128
$\frac{1}{5}$	1.951	2.155	2.343
$\frac{1}{8}\sqrt{2}$	1.601	1.786	1.960
$\frac{1}{8}$	.873	1.004	1.114
$\frac{1}{10}$	.574	.659	.745
$\frac{1}{16}\sqrt{2}$	.453	.521	.592
$\frac{1}{16}$	.229	.266	.303
$\frac{1}{20}$	.147	.170	.196

The table attached gives the settling velocities (cm/sec) of quartz grains (sp. g. 2.65) in water computed after RUBEY's formula for the grain sizes most frequently used. The calculations have been carried out with logarithmic tables giving 5 figures and the following constants: g = 981, the viscosity of the water at 5° C: .01519, at 10° C: .01310, and at 15° C: .01145.

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RESUMÉ

En Række Sandprøver er sigtet med Kvadratmaskesigter og slemmet ved succesive Afslemninger i et Enkelt-rørs-slemmeglas (ORTHS Tragt). En Sammenligning af Analyseresultaterne viser, at Kornenes Faldhastigheder bør beregnes efter RUBEYS Formel og ikke efter OSEENS, der giver store Fejl i Analyseresultaterne. Dette vises grafisk i Fig. 1 A, 3, 4 og 5, hvori er indtegnet Sumkurverne for Sigteanalyserne (fuldt optrukket Linje) og Slemmeanalyserne med RUBEYS Slemmehastigheder (stiplet Linje) og med OSEENS Slemmehastigheder (punkteret Linje). Maalinger af Kornenes Bredde og Længde i Sigte- og Slemmefraktionerne viser karakteristiske Lovmæssigheder. I Sigtefraktionerne forekommer Korn, hvis Bredde varierer fra den fine Sigtes Maskekantlængde til den groves Maskediagonal (Fig. 6, punkteret Linje og Fig. 7). De fineste Korn i en Slemmefraktion har en Middeldiameter, $\sqrt{\text{Bredde} \cdot \text{Længde}}$, der er identisk med Slemmediametren, beregnet efter RUBEYS Formel. Slemmetidens Indvirkning paa Analyseresultaterne er undersøgt med den Konklusion, at den relative Kornfordeling holder sig konstant, men Middelkornstørrelsen bliver mindre jo længere man slemmer. I Almindelighed vil ca. $^1/_2$ Times Slemning være tilstrækkelig. For store Materialmængder i Slemmeglasset forrykker Analyseresultatet (Fig. 13 og Tabel 3) og med *den anvendte Metodik bør den analyserede Sandmængde ikke overstige* ca. 30 g. En Tabel over Slemmehastigheder beregnet for vigtige Kornstørrelser efter RUBEYS Formel er givet i et Appendiks.

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