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A new, universal method of thin-section – to – sieve transformation of granulometric data

ABSTRACT: Using artifical samples the problem of relationship between true grains in three-dimensional samples and apparent grains measured in thin sections has been considered. Distribution of sectioned true grains is more similar to the sieve-distribution of apparent grains. Based on this, a new method of thin-section — sieve conversion of granulometric data has been elaborated, to recognize the distribution of true grains from the distribution of apparent grains. The transformed distribution depicted by cumulative curve allows for the evaluation of the textural parameters, with the values approximately equal to "sieve" parameters obtained by the graphic method. The new method has a universal character, and it may also be used for indurated deposits with various grain sizes. A suggestion of modified manner of measurements of elongated apparent grains in a thin-section is given. For practical use of the newly proposed method the algorithm of procedure leading from the thin-section measurements to the "sieve" textural parameters evaluation is presented.

INTRODUCTION

One of goals in sedimentological investigations is the evaluation of granulometry of sediments. More often, the granulometric characteristics is given by grain size distribution curve or, numerically, by the values of textural parameters. A basic element of granulometric analysis is the size class of grains. The frequency in weight percent of a given class within the sample of sediment is commonly obtained using the sieve method. Finally, the values of textural parameters are calculated using the statistical moment method (FRIEDMAN 1961, 1967) or the so-called graphic method (FOLK & WARD 1957). The last one requires graphic expression of the grain size distribution, *i.e.* the cumulative curve. The textural parameters of sediments of numerous present-day sedimentary environments were pointed out (MASON & FOLK 1958, FRIEDMAN 1961, DUANE 1964, MOIOLA & WAISER 1968, FOLK 1971, SAUNDERSON 1977, KURTZ & ANDERSON 1979, MERTA 1982, CAHILL *fide* HAKANSON & JANSSON 1983, RUDOWSKI 1986). It seems impossible that such numerous data are not applied by analogy for the recognition of the ancient sedimentary enviroments. But it is not possible, indeed, bacause the sieve method for indurated deposits cannot be used.

Usually, the sieving is used for Tertiary (*see* DOKTOR 1983, HARDKOPF & STAPF 1984) and younger aged deposits. For the examination of indurated sediments, the one and only is the microscopic method. But the microscopic analysis gives the data in the so-called quantitative percent. For that reason the effects of the sieve analysis and the microscopic ones are not comparable immediately.

PREVIOUS CONCEPTS OF THIN-SECTION — SIEVE CONVERSIONS OF DATA

Investigations of effective method of thin-section — sieve conversions have a long history. The theoretical relationship between the grains and their images in thin-section has been taken under consideration. The given shapes of primary grains were assumed as having been either spherical (KRUMBEIN 1935, PACKHAM 1955) or ellipsoidal (GREENMAN 1951, KELLERHALS & *al.* 1975). But the methods elaborated theoretically, "*...because of their inaccuracies, none have met with general acceptance*" (*see* HARRELL & ERIKSSON 1979, p.273).

Using the natural grains having the various shapes, the empirical attempts have been made, too. ADAMS (1977) used plastic-cemented sediments for thin-section analysis and loose parts of the same sediments for sieve analysis. Comparing the textural parameters, he presented the regression model:

$$X = (Y - a) \times b^{-1}$$

where X — is a given "sieve" parametr, Y — analogical parametr in thin- section data, a and b — regression coefficients.

The other investigators (FRIEDMAN 1962, HARRELL & ERIKSSON 1979) brought into practice different procedure. The thin-section was made from one part of the real sandstone sample. Other part of the sample was dissagregated and examined by the sieve method. Comparison of the thin-section parameters and the sieve ones and the linear regression analysis was performed, giving the regression model:

$$X = a + bY$$

where X — is a given sieve parameter, Y — analogical parametr from thin-section data, a and b — regression coefficients. It has to be strongly emphasized, that the discussed simple method cannot be used credibly. It is useful only for deposits with the thin-section grain-size distribution the same as the mean grain-size distribution of samples used by HARRELL & ERIKSSON (1979). If the differences of the distributions are more distinctive, the final effects will be false, *i.e.* the thin-section textural parametres will not be converted into the "sieve" ones. Therefore, the discussed method is not universal.

Another problem must also be taken into account, because only the first two textural parameters (mean diametr and standard deviation) can be obtained by the regression equations method, while the skeweness and kurtosis cannot be derived (*see* values of correlation coefficient — FRIEDMAN 1962, HARRELL & ERIKSSON 1979).

MAIN DIFFERENCES BETWEEN THE DATA

Starting the elaboration of a new method of thin-section — sieve conversion of data one has to take into account that the given data the same termed for various analytical methods, sieve or microscopic, they have different meanings.

Grain size

In the sieve analysis the size of grains is determined by the size of square holes of a given sieve, while the class interval (or class size) is defined as a difference between the size squares of two juxtaposed sieves. Therefore, the usage of sieves with square holes assumes, that the grains of the sample have a high degree of isometry. If the sample consists of elongated grains, their dimensions evaluated by the sieve analysis and indicated by a given sieve may differ more than 40% (*see* SAHU 1968).

Very important attribute of the sieve analysis is the fact that all grains of the sample are taken under consideration; during the sieve procedure every grain, accordingly to its size, falls in a given sieve.

In the microscopic analysis the size of grain is indicated by one axis only, *i.e.* the longest one (*cf.* ROSENFELD 1953, FRIEDMAN 1958, HARRELL & ERIKSSON 1979), or by a chord defined as a lenght of a grain falling along a predetermined sample line (MÜNZER & SCHNEIDERHÖHN 1963, ROTHLISBERGER 1955, KELLERHALLS & *al.*1975). In contradistinction to the sieve analysis in the microscopic analysis, measured are not all the grains visible in a thin-section. Moreover, the different number of measurements are recommended in the microscopic analysis: 150 grains (ROSENFELD & *al.* 1953), 200 grains (GRADZIŃSKI & *al.* 1979, HARRELL & ERIKSSON 1979), and even 500 grains (FRIEDMAN 1958, LA PRADE 1979, EDWARDS 1979).

Single class participation

In the sieve analysis the participation of a given class size in a sample is defined by relationship of its weight and weight of sample. Such relationship is expressed as a *weight ratio* or *weight percent*. In the thin-section analysis the participation of the above mentioned class is defined as the number of grains of a class in relation to total number of measured grains. Value of such ratio is expressed as a *quantitative ratio* or *quantitative percent*. It is evident that the weight percent is not egual to quantitative percent. This dissimilarity of percents is the essential cause that the size distributions of identical samples differ because of their examinations — using the sieve method for loose sample and thin-section method for the indurated one.

Single grain participation

Due to the differences mentioned above, a single grain participation depends upon the examination method. In the sieve analysis single grain participation may be obtained analogically as a single size class one, *i.e.* by comparison of the weight of a single grain with the weight of all grains in the sample. If such proportion is measured in dimensionless units and all grains of the sample have the same mineralogical nature, the participation of a given grain depends only of its size, decreasing from coarse to fine grains. But it is possible that any grains of the same size have various participation values, because of their difference in specific gravity.

In the thin-section analysis the participation of a single grain is defined by the Author as a proportion of a single measurement (grain) and total number of measurements (grains) and it may be obtained by formula n^{-1}=constant, where n means the total number of measured grains in thin section. As can be seen in contradistintion to sieve analysis, in the thin-section analysis the participation of a single grain is independent of its size both for the samples with mineralogical homogeneity of grains and for the mixed ones.

METHODOLOGICAL ASSUMPTIONS OF THE NEW METHOD

The goal of the present investigation is to determine the interrelationship between microscopic and sieve granulometry, and to evaluate the possibility of transformation from the microscopic data to the sieve ones. The presented method of transformation assumes the one-way path only. The possibility of transformation from sieve to microscopic granulometry is omitted. As a general principle, the procedure taken under consideration is the possibility of transformation of the primary element analysis, *i.e.* frequency of a single size class of grains of the given sample. All methodological operations are depicted by the cumulative curves of grain-size distributions. The size of grains is expressed in *phi* unit scale. This scale allows for the examination of samples composed of coarser grains and the measure-errors are smaller. Furthermore, due to application of the *phi* units scale the relationship between grains in a given part of this scale are true for another ones. The textural parameters are evaluated by the graphic method only (*after* FOLK & WARD 1957) both for the "microscopic" and "sieve" distributions. Usage of graphic method results that the all curves presented in the present paper (*see* Text-figs 1, 5-7 and 13) are constructed up to the 95% values only.

As a basic size-grain interval (= class), the 0.25 phi is assumed. The magnification of interval up to 0.50 or 1.00 phi is possible. In the first phase of consideration, the optimal conditions were assumed as well the mineralogical homogeneity of grains as their spheroidal shapes. Because the relationship *grain* (in thin-section) — *grain* (in three-dimensional sample) was searched, for that reason the artificial samples were composed.

In the present paper the following definitions of grains are used:

— *true grain* — spherical grain with a given diameter, as a single element of a three-dimensional sample,

— *apparent grain* — two-dimensional image of grain visible in a thin-section, or a section of a given true grain,

— *calculated true grain* — reconstructed true grain on the basis of apparent grain image.

THEORETICAL RELATIONSHIP: TRUE GRAIN — APPARENT GRAIN

Let us consider the relationship between a spherical true grain and its flat image in thin-section, *i.e.* an apparent grain. If the diameter of the apparent grain is given (measurement in thin-section) it is not possible to determine what is the diameter of the sectioned grain.

Let us consider the theoretical three-dimensional sample. Let it consists of spherical true grains with diameters *a, b, c* and *d* (a_r in Text-fig. 1). A sample sectioned in this way gives the thin-section image with many circle-like contours of apparent grains. It is evident, that true grains *a* give sections of apparent grains a_1, i.e. with the diameter indicating the 1*th* class of apparent grains, a_2 — with the diameter of the 2*th* class, etc., true grains *b* give the apparent grains $b_2, b_3...b_n$ respectively, true grains *c* give $c_3...c_n$, and true grains *d* give the apparent grains $d_4...d_n$ (a_t in Text-fig. 1). It is evident that the diameter of an apparent grain is equal or smaller than the diameter of a true grain, which was sectioned. But it is worth mentioning, that the size of grains a_2 is equal to size of b_2 and furthermore $a_3 = b_3 = c_3$, etc. (Text-fig. 1). Therefore, it may be concluded, that the class of

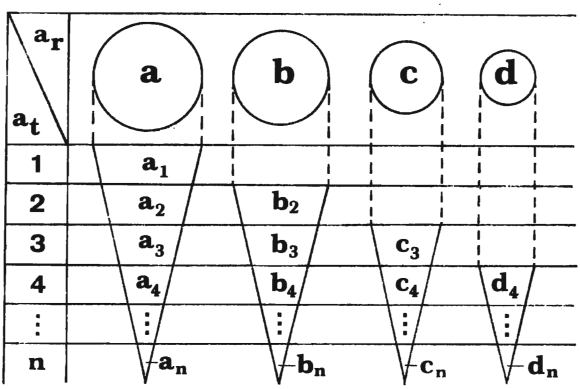


Fig. 1
Theoretical relationship between true grains (a_r) and apparent grains (a_t)

a-d — Size classes of true grains, **1-n** — size classes of apparent grains; detailed explanation in the text

coarsest apparent grains is the "pure" class, because the apparent grains a_1 are sections of the true grains *a* only. Other classes may consist of apparent grains being the sections of true grains from different classes of grains. This argumentation indicates that eventual reconstruction of true grains using only one magnification coefficient for different size of apparent grains (*see* MÜNZER & SCHNEIDERHÖHN 1963) is false. These theoretical arguments have been empirically verified.

EMPIRICAL STUDY — ARTIFICIAL SAMPLES

What is relationship between the true grains within the three-dimensional samples (sieve analysis) and the apparent grains visible on the thin-section surface? Comparative analysis has been made, using the artificial samples.

Spheroidal grains were made by rolling cuboid pieces of chalk in rotary mill (*compare* KUENEN 1956). These grains were selected and grouped in size classes with diameter defined precisely, from -4.0 *phi* to -2.0 *phi* with difference (class interval) 0.25 phi, *i.e.* 9 size classes. Spheroidal grains with the same diameter (class) were marked by indicative dye, diagonostic for the given size class.

PILOT SAMPLE

Predetermined numbers of grains of each size class (*see* Table 1) were mixed and cemented. The monolith was treated as a substitute of indurated sediment sample, but its "sieve" grain-size distribution might be obtained by data (Table 1) or graphically by the cumulative curve (*s* in Text-fig. 2). Equivalence of volume and weight ratios was taken into account, because the specific gravity of all grains was the same.

Indurated sample was sectioned by parallel surfaces giving on each of them (substitutes of thin sections) images of spherical contours of apparent grains.

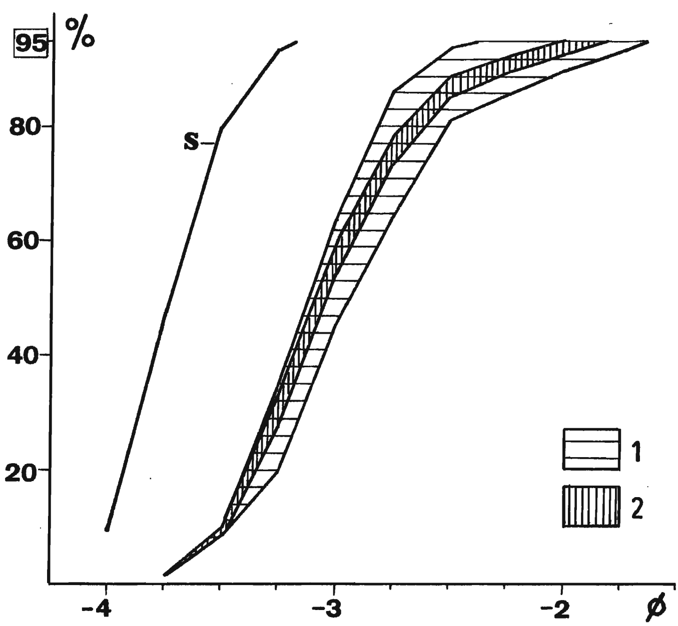


Fig. 2. Cumulative curves of grain size distributions of the pilot-sample *A*

s — Curve of "sieve" analysis; vertical scale in cumulative volume percent

1 — Field occupied by cumulative curves for thin-section measurements less than 300 apparent grains, 2 — field occupied by cumulative curves based upon the thin-section measurements more than 300 apparent grains; for *1* and *2* the vertical scale in quantitative percent

Table 1

Distribution of the true grains used for construction of the artificial pilot-sample *A*

size class	number of grains	quantitative %	cumulation of quantitative %	volume %	cumulation of volume %
1	26	3.1	3.1	9.10	9.10
2	190	23.0	26.1	39.50	48.60
3	265	31.0	57.1	31.65	80.25
4	179	21.7	78.8	13.26	93.51
5	129	15.6	94.4	5.63	99.14
6	25	3.0	97.4	0.62	99.76
7	16	1.9	99.3	0.21	99.97
8	3	0.4	99.7	0.02	100.00
9	2	0.2	99.9	0.01	100.01
total:	826				

Data in quantitative % are given for comparison with data of microscopic analysis.
Data in volume % illustrate distribution of grains in "sieve" sense.

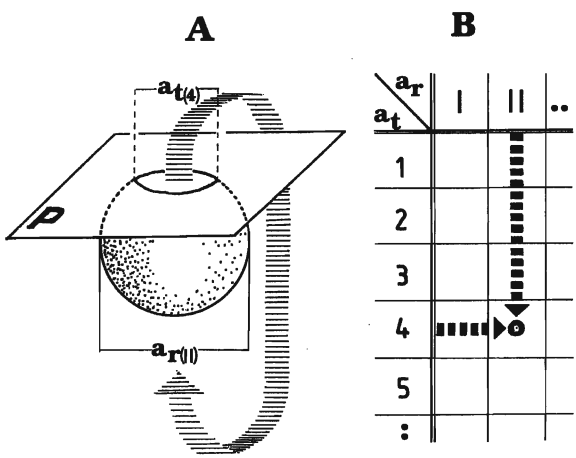


Fig. 3

Scheme of examination of a single grain in "thin-section" of an artificial sample

A — Measurement of apparent grain diameter (a_t) with qualification into size class (here for example — class *4*), and identification by the color of true size of grain (a_r — arrowed) with qualifications into true-grain size class (here — class *II*)

B — Position of examined single grain in table of data

Surfaces of sections were distanced from each other more than diameter of coarsest true grains. It gave the assurance that the "thin-section" images were disconnected, *i.e.* sectioned true grains and noticeable as apparent grains on a given surface were not visible on the others. For that reason, the data from all surfaces might be summarized.

Each grain on given surface was examined in a double manner; the diameter of an apparent grain was measured (a_t in Text-fig. 3*A*) and the size of the true grain was known, by indicative color (a_r in Text-fig. 3*A*). Both above data obtained for a single grain were tabled (Text-fig. 3*B*). Complete data of "thin-section" analysis of the pilot sample are registered in Table 2.

Table 2

Data of "thin-section" analysis for the pilot-sample *A*

a_c — sectioned true grains (size classes *I* — *IX*), identified by the color of apparent grain; a_t — number of measured apparent grains (size classes *1* — *14*)

For both types of grains the final data in quantitative percent

a_c / a_t	I	II	III	IV	V	VI	VII	VIII	IX	a_t	%	Σ%
1	9	-	-	-	-	-	-	-	-	9	1.8	1.8
2	7	34	-	-	-	-	-	-	-	41	8.3	10.1
3	1	67	57	-	-	-	-	-	-	125	25.3	35.4
4	1	26	71	26	-	-	-	-	-	124	25.1	60.5
5	-	10	36	26	18	-	-	-	-	90	18.2	78.7
6	-	4	22	9	10	-	-	-	-	45	9.1	87.8
7	-	1	8	3	5	-	-	-	-	17	3.4	91.2
8	-	2	6	5	3	-	-	-	-	16	3.2	94.4
9	-	3	3	2	-	-	-	-	-	8	1.6	96.0
10	-	2	2	3	2	-	-	-	-	9	1.8	97.8
11	-	3	2	1	-	-	-	-	-	6	1.2	99.0
12	-	-	-	-	1	-	-	-	-	1	0.2	99.2
13	-	1	1	-	-	-	-	-	-	2	0.4	99.6
14	-	1	-	-	-	-	-	-	-	1	0.2	99.8
a_c	18	154	208	75	39					494		
%	36	312	421	152	79	$\times 10^{-1}$						
Σ%	36	348	769	921	1000	$\times 10^{-1}$						

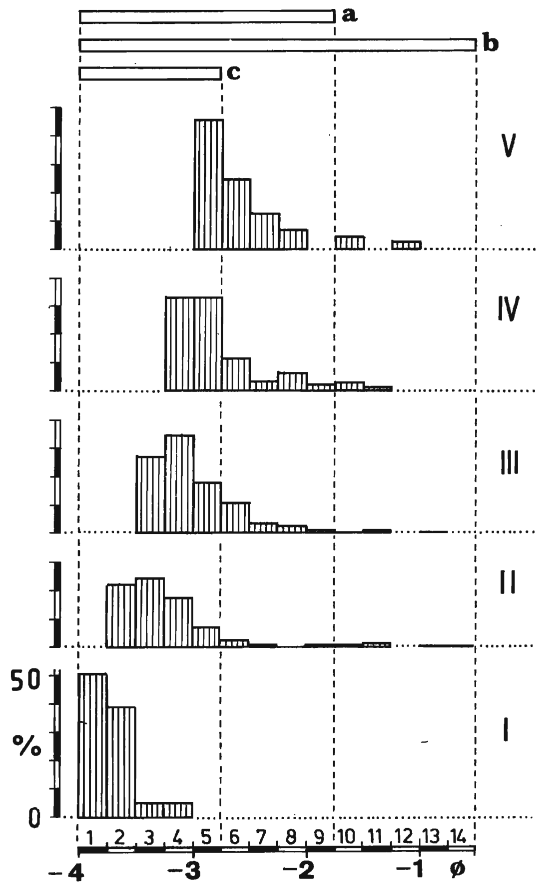
Essential differences between the data are visible; if the sample consists ("sieve" data) of true grains of nine size classes (*a* in Text-fig. 4), the "thin-section" analysis indicates fourteen size classes of apparent grains (*b* in Text-fig. 4) which are sections of true grains from the five coarsest size classes only (*c* in Text-fig. 4). It may be taken into account that sections of true grains of the single size class represent wide spectrum of apparent grain sizes with very distinctive trend; most of the grain sections fall up into the 1*th* class or both into the 1*th* and 2*nd* size classes of apparent grains. Among the apparent grains of further classes, the frequency of these grains decreases successively (*I-V* in Text-fig. 4).

The pilot sample was used too, for the evaluation of representative numbers of measurements in a single thin-section. "Thin-section" cumulative curves based upon the measurements of less than 300 apparent grains (for 50, 100, 200, and 250 measurements for the single thin-section) are varied (*1* in Text-fig. 2), while the curves based upon more than 300 measurements (300, 350, and 400) are stabilized (*2* in Text-fig. 2). For that reason in others investigations the lower limit of 350 measurements for a single sample was assumed.

Fig. 4
Graphical documentation of granulometry of the pilot-sample *A*

a — Range of size of true grains used for sample composition, **b** — range of size of apparent grains measured in a "thin-section", **c** — spread of size of sectioned true grains

1-14 — Size classes of apparent grains, **I-V** — size classes of true grains; histograms show distributions of apparent grains as sections of true grains of a given single size class



OTHER ARTIFICIALLY COMPOSED SAMPLES

In the same manner as the pilot sample the next 49 artificial samples were made. Each of them consisted of seven size classes of true grains. Including the pilot sample, fifty artificial samples with known "sieve" granulometry (*a* in Text-fig. 5) and "thin-section" one (*b* in Text-fig. 5) were compared. Procedure of elaboration of the new method *thin-section — sieve* conversion of data are exemplified by six samples, lettered *A-F* (Text-fig. 6).

RESULTS OF COMPARATIVE ANALYSIS

It should be pointed out that all the "microscopic" cumulative curves have the initial (=coarse-end) point displaced with one-class-interval toward the fine grains, in comparison with the coarse-end-points of "sieve" curves

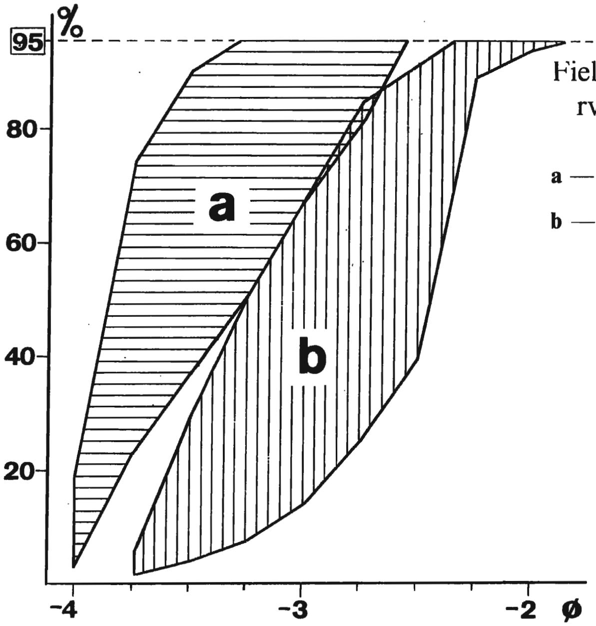


Fig. 5
Fields occupied by cumulative curves of fifty artificial samples

a — Sieve analyses; vertical scale read in volume percent
b — Thin-section analyses; vertical scale read in quantitative percent

(compare *a* and *b* in Text-fig. 6). It means that in 50 samples there was no "equatorial" section of a true grain. But objective comparison of "sieve" and "thin-section" curves of a single sample as yet is not possible, because their

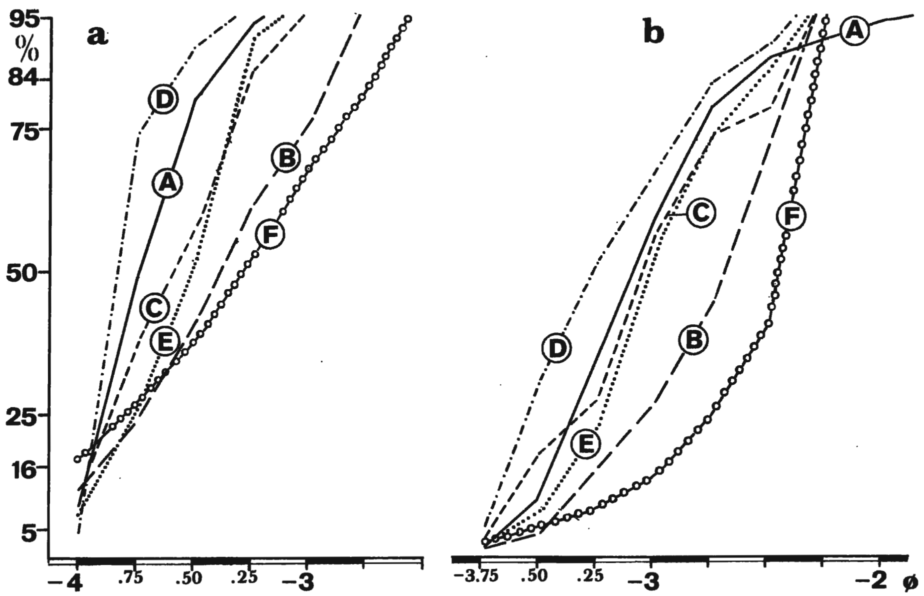


Fig. 6

Grain-size distributions of selected samples lettered *A-F*; **a** and **b** as in Text-fig. 5

unequivalence (weight ratio for "sieve" and quantitative percent for "thin-section"). Because the number of true grains in each size class of a given artificial sample was known, the distribution of true grains should be expressed in quantitative percent, too (curves *u* in *A-F* in Text-fig. 7). The distribution of sectioned true grains — identificated by color — was calculated (*c* in *A-F* in Text-fig. 7). Now, the distributions of true grains, apparent grains and sectioned true ones of a given sample have the same notation and may be compared objectively.

It is visible that distribution of true grains of a given three-dimensional sample is similar to the distribution of sectioned grains in the same sample (compare curves *c* and *u* in Text-fig. 7 *A-F*), but both curves differ distinctly from

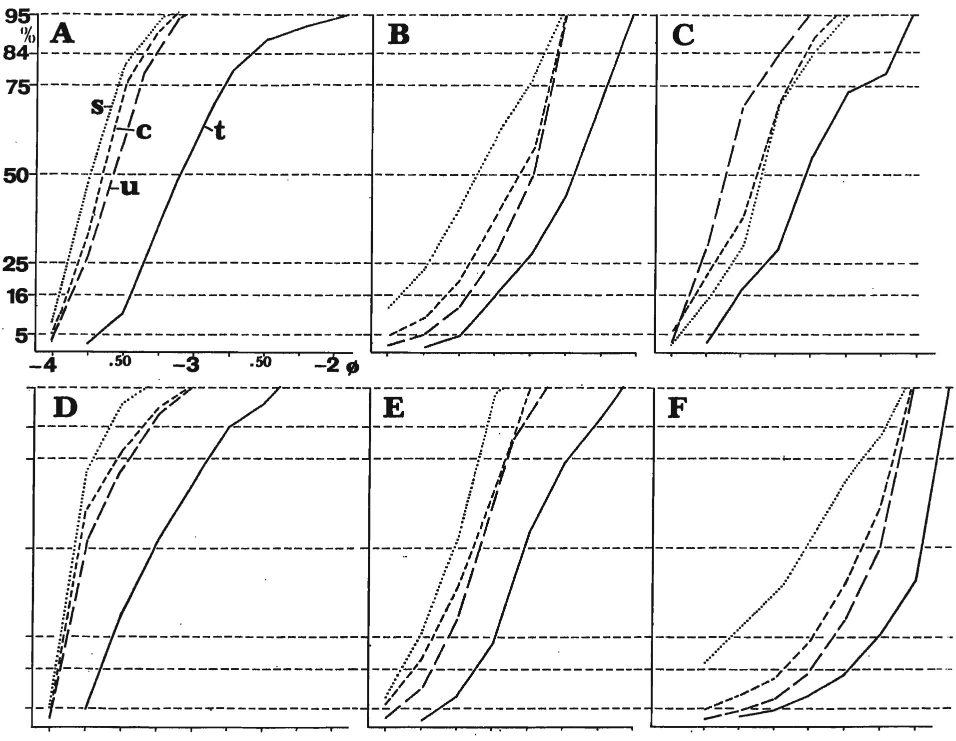


Fig. 7

Interrelation between cumulative curves of artificial samples *A-F*

s — Cumulative curve of "sieve" analysis, scaled in volume percent

t — Curve of apparent grains, **u** — curve of all true grains of the sample, **c** — curve of sectioned true grains; true grains were identified by the color of apparent grains; for curves *t*, *u*, and *c* vertical scale in quantitative percent the distribution of apparent grains (curve *t* in Text-fig. 7 *A-F*). Similarity of *c* and *u* curves is visible in all cases, independently from sieve (by volume or weight) distribution of grains in a given sample (e.g., compare *B* and *D* in Text-fig. 7).

STATISTICS: TRUE GRAINS — APPARENT GRAINS

The relationship *true grains* — *apparent grains* in fifty artificial samples was analyzed. The pairs of size classes with the same location were compared, i.e. 1*th* size class of true grains with 1*th* of apparent grains, 2*nd* class of true grains with

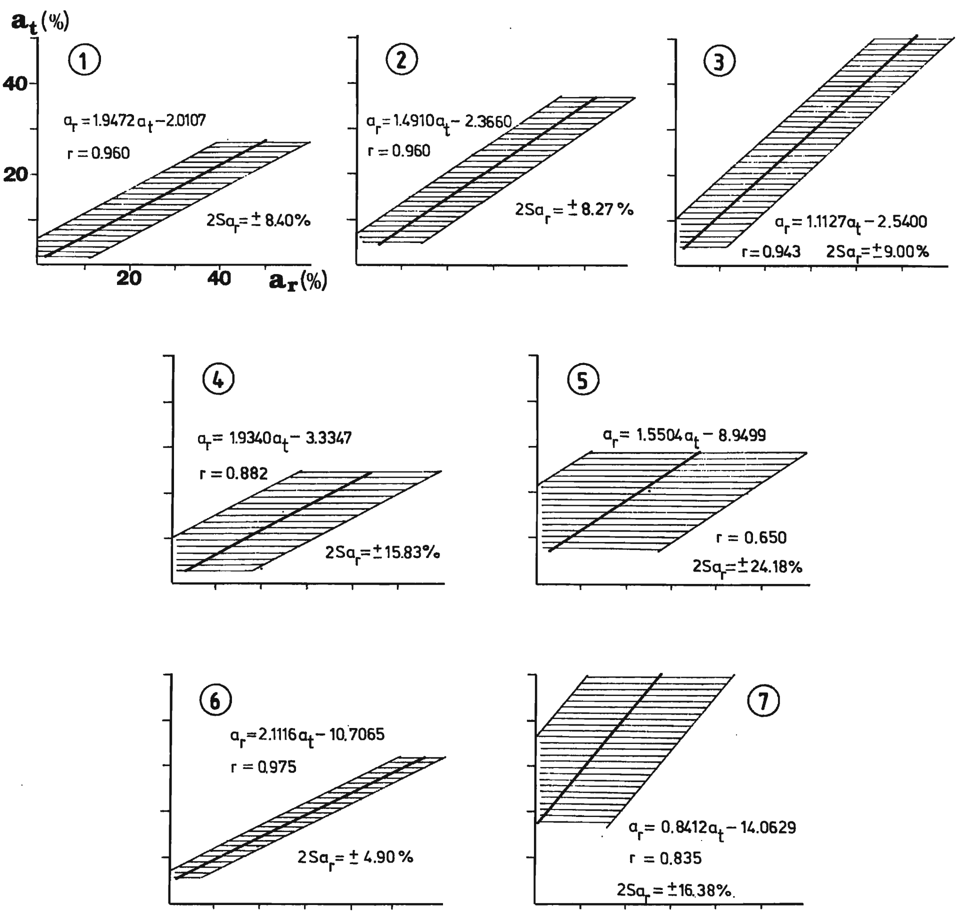


Fig. 8. Apparent grains (a_t) *vs* (a_r) in successive size classes, determined on the ground of data for fifty artificial samples

1-7 — Class of grain size from coarse (*1*) to fine (*7*)

a_t — Quantity of measured apparent grains in quantitative percent, $\mathbf{a_r}$ — quantity of true grains of the sample expressed in quantitative percent; linear regression is given by equation of $a_r = ma_t + n$ type and shown graphically (*black line*); limits of confidence ($2Sa_r$) are marked by lined field; further explanations in the text

2nd class of apparent grains, etc. These classes the same numbered differ in size by the 0.25 phi interval, in reality. Quantitative calculations were made. For each class the correlation coefficient was derived and relationship *true grains* (a_r) — *apparent grains* (a_t) was formulated by regression equation (Text-fig. 8). The values of correlation coefficient for all classes are high, but the limit of confidence in each case is very wide (Text-fig. 8). Thus, the *thin-section* — *sieve* conversions of data, using the regression equations, cannot be used.

STATISTICS: TRUE GRAINS — SECTIONED TRUE GRAINS

It is clear that among the true grains of the three-dimensional sample only some of them are sectioned by thin-section. But relationship between true grains (a_r) and sectioned true grains (a_c) is more distinctive than foresaid relationship of

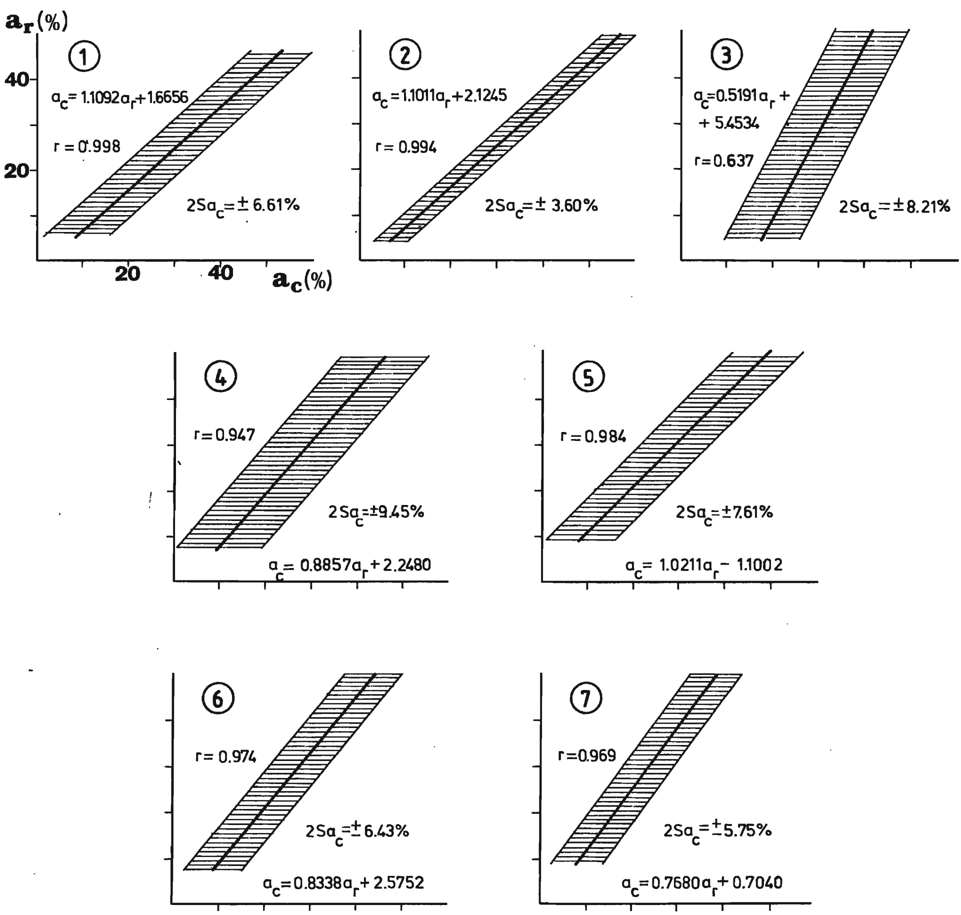


Fig. 9. Statistic relationship between true grains of a given size class in a sample (a_r) and sectioned true grains (a_c) of the same class (identified by the color of apparent grains); other explanations as in Text-fig. 8, with modification of regression equation: here is of $a_c = ma_r + n$ type

a_r *vs.* a_t. Comparing the same size classes, the regression analysis was done (Text-fig. 9). Here, the values of correlation coefficient are high too, but the confidence limits are narrower. Although this distinctive relationship cannot be used for transformation of thin-section data (because of lack of measurements of apparent grains), it indicates the further steps of elaboration of *thin-section — sieve conversion of data* — by the reconstruction of true grains in relation to apparent grains for a given sample.

PROBABILITY OF OBTAINING A GIVEN APPARENT GRAIN

Let us consider a true spherical grain having the *n*-phi diameter. If this grain is sectioned, the apparent grain will be observed in thin-section and its diameter will be theoretically equal with diameter of the true grain or shorter. All diameters of apparent grains possible to obtain from a given single true grain let us group into size classes with the interval 0.25 phi (Text-fig. 10*a*).

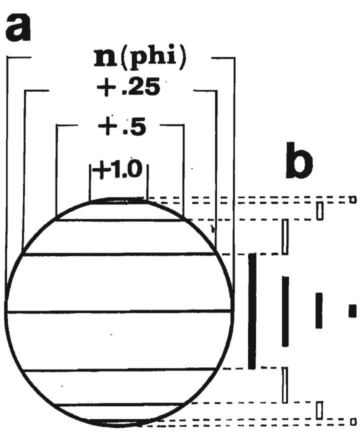


Fig. 10
Graphical scheme of probability evaluation for a single grain

a — Zonation of a true grain by chords (n — diameter, n + 0.25,..+0.50,..phi), **b** — parts of diameter for the same size class of apparent grains (*blank blocks*) and their sum (*black blocks*)

What is a probability that an apparent grain "falls up" into the given size class of apparent grains? Such probability may be obtained as a proportion of sum of parts (indicating the same size class of apparent grains) of the true grain diameter and total diameter of the true grain (Text-fig. 10*b*). For the 0.25 phi interval of size class, value of probability for successive classes is as follow: 54.12, 16.62, 9.62%, etc. (*see* Table 3, Text-fig. 10*A*; *compare* empirical distributions *I-V* in Text-fig. 4). If we assume the wider interval of class, *i.e.* 0.50 or 1.00 phi, these values will be changed (Table 3; *B* and *C* in Text-fig. 11, respectively). It has to be emphasized that the probability of "equatorial" section (*i.e.* the diameter of the apparent grain is equal to the diameter of the true grain) is equal to 0.00%.

Table 3

Probability of obtainment an apparent grain with the given diameter, by sectioning a true grain of a given size — for various values of the size-class interval (*compare* Text-fig. 11)

a — Value of probability (or frequency of apparent grains in class) expressed in percent, **b** — cumulative percent, **c** — percent of grains in other size classes

size	interval 0.25 phi			interval 0.50 phi			interval 1.00 phi		
class	a	b	c	a	b	c	a	b	c
1	54.12	54.12	45.88	70.75	70.75	29.25	86.61	86.61	13.39
2	16.62	70.74	29.26	15.87	86.62	13.38	10.24	96.85	3.15
3	9.62	80.36	19.64	6.87	93.49	6.51			
4	6.25	86.61	13.39	3.37	96.86	3.14			
5	4.12	90.73	9.27	1.55	98.41	1.59			
6	2.75	93.48	6.52	0.73	99.14	0.86			
7	2.00	95.48	4.52						
8	1.37	96.85	3.15						
9	0.87	97.72	2.28						

practically. Using these theoretically derived probability values for set of different grains, the observed frequency of apparent grains may be interpreted as follows: if the *n* number of true grains with the same diameter are sectioned, then the *a* apparent grains are visible in a thin section. Among them 54.12% grains are within the 1*th* class of apparent grains, 16.62% within the 2*nd* class, etc. (*see* Table 3). It is evident that in the microscopic analysis only the number of apparent grains is known. The number of true grains is unknown and it has to be calculated. For that, the probability values mentioned above may be interpreted as follow: if the 1*th* size class of apparent grains consists of *a* number of grains, they are sections of 54.12% of number of true grains with the diameter equal *n* phi. Other 45.88% of sections from these grains are visible among the apparent grains of the successive finer classes.

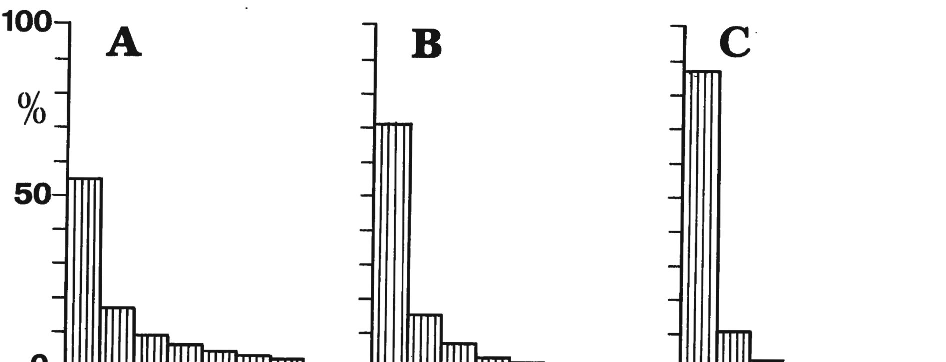


Fig. 11. Histograms of theoretical distributions of apparent grains from the same sized true grains, for different analytical intervals: A — 0.25, B — 0.50, C — 1.00 phi; the single stud represents one size class

FREQUENCY OF TRUE GRAINS FROM FREQUENCY OF APPARENT GRAINS

CALCULATED TRUE GRAINS

Demonstrated above the manner of determination the frequency of true grains from the frequency of apparent ones is possible only for calculation of grain number in coarsest grain class. As early mentioned, the finer classes of apparent grains are mixtures of sections of the true grains of various size. For such size classes the "step-by-step" procedure ought to be used. For demonstration of calculation the sample composed of seven size classes of grains was used. The last size class is an open one, *i.e.* grouping all the apparent grains with a given diameter and smaller one. Scheme of calculation is shown in Table 4.

Table 4

Scheme of conversion: number of apparent grains — number of calculated true grains; further explanations in the text

size class of apparent grains	number of grains	columns of calculation						number of calculated true grains
		I	II	III	IV	V	VI	
1	a	A	A	A	A	A	A	A
2	b	$b-a_b=b_1$	B	B	B	B	B	B
3	c	$c-a_c=c_1$	$c_1-b_c=c_2$	C	C	C	C	C
4	d	$d-a_d=d_1$	$d_1-b_d=d_2$	$d_2-c_d=d_3$	D	D	D	D
5	e	$e-a_e=e_1$	$e_1-b_e=e_2$	$e_2-c_e=e_3$	$e_3-d_e=e_4$	E	E	E
6	f	$f-a_f=f_1$	$f_1-b_f=f_2$	$f_2-c_f=f_3$	$f_3-d_f=f_4$	$f_4-e_f=f_5$	F	F
7	g	$g-a_g=g_1$	$g_1-b_g=g_2$	$g_2-c_g=g_3$	$g_3-d_g=g_4$	$g_4-e_g=g_5$	$g_5-g_f=g_6=G$	G
total:	L	L	L	L	L	L	L	L

The last size class is an open one, for that:
$g_1 = A - (a_b + ... + a_f)$, $g_2 = B - (b_c + ... + b_f)$, $g_3 = C - (c_d + ... + c_f)$, *etc.*

Remembering, only the class of the coarsest apparent grains is the "clear" class, *i.e.* only these grains are sections of the coarsest true grains — we have to start the calculation from this size class. Let *a, b...g* indicate numbers of apparent grains within the classes 1, 2,...n, respectively (Table 4). It is known that *a* is 54.12% of sectioned true grains of the coarsest size class. For that the total number of sectioned true grains (called here as *calculated true grains*) from this class may be obtained as $A = 100a \times 54.12^{-1}$. Among *A* the $a_b = 16.62A \times 10^{-2}$ grains will be present among the *b* apparent grains, $a_c = 9.62 \times 10^{-2}$ will be present among the *c* apparent grains, etc. (*see* Table 4). If the $b - a_b = b_1$, $c - a_c = c_1$, $d - a_d = d_1$, *etc.*, we obtain corrected values of grain numbers of each class of apparent grains (b_1, c_1, d_1...g_1), without the section of the true grains of the coarsest size class. Because the last class of apparent grains is an open one, for that $a_g = A - (a_b + ... + a_f)$. This "clearing" of the data of the first column results, the second class of apparent grains having b_1 number of grains is a "clear" size class now. It means that all grains of this class are the sestions of true grains of the *2nd* size class. Well, we can start to transformation of data of column *II*, where $B = 100b_1 \times 54.12^{-1}$ and afterwards — as in the first case — obtaining values of b_c, b_d,...b_g and next values of c_2, d_2 ... g_2 (*see* Table 4). The step-by-step transformation of data gives endmost column of calculated true grains with values A, B, ... G. Theoretically, such ought to be frequency of sectioned true grains if the sequence of apparent grains is expressed by a, b ... g values. The transformation of columns is proper — if the total number of the grains in each column (*L* in Table 4) is the same. Because the real distribution of sectioned true grains may slightly differ from theoretical one (*compare* empirical data *I-V* in Text-fig. 4 with *A* in Text-fig. 11) it is possible that in any column of calculation the succession of values will not be proper — for example if $d_e < e_3$. In such a case the transformation of data ought to be finished on the last column and all its elements as well transformed as the rest must be treated together as data of the final column.

The manner of calculation presented above was used for recalculation of all the artificial samples. For example the sample *F* is demonstrated. This sample consisted of 1,000 spherical true grains with very negative skewness and monomodal grain-size distribution for quantitative percent (Table 5, and curve *u* in Text-fig. 7*F*), or — in volume percent data — with the polymodal distribution of grains (Table 6, and curve *s* in Text-fig. 7*F*). Data of sectioned

Table 5

Grain size distribution of true grains used for construction of the artificial sample *F*

size class	number of grains	quantitative %	cumulative %
1	20	2.0	2.0
2	20	2.0	4.0
3	30	3.0	7.0
4	80	8.0	15.0
5	150	15.0	30.0
6	200	20.0	50.0
7	500	50.0	100.0
total:	1,000		

Table 6

"Sieve" grain-size distribution of true grains of the artificial sample *F*

size class	number of grains	volume %	cumulative %
1	20	17.52	17.52
2	20	10.41	27.93
3	30	9.26	37.19
4	80	14.67	51.86
5	150	16.48	68.34
6	200	12.89	81.23
7	500	18.77	100.00
total:	1,000		

grains (= microscopic analysis — *see* Table 7), *i.e.* distribution of apparent grains and distribution of sectioned true grains are presented graphically by curves *t* and *c*, respectively (Text-fig. 7*F*). Transformation of apparent grain distribution into calculated true grain one is shown in Table 8. It is worth to pay attention, that the distribution of sectioned true grains obtained empirically and distribution of calculated true grain obtained by the transformation of apparent grain distribution are very similar (*compare* column *VII* in Table 8 with data in Table 7).

Table 7
"Thin-section" data of the artificial sample *F*

a_c — Sectioned true grains (size classes *I-VIII*), identified by the color of apparent grains in a "thin-section"; a_t — number of measured apparent grains (classes *1-7*)

For both types of grains — final data in quantitative percent

a_t \ a_c	I	II	III	IV	V	VI	VII	a_t	%	Σ%
1	9	-	-	-	-	-	-	9	2.5	2.5
2	3	4	-	-	-	-	-	7	1.9	4.4
3	2	1	11	-	-	-	-	14	3.8	8.2
4	1	1	3	15	-	-	-	20	5.5	13.7
5	1	-	2	4	35	-	-	42	11.5	25.2
6	-	1	1	2	11	42		57	15.6	40.8
7	-	2	5	10	15	34	149	215	59.1	99.9
a_c	16	9	22	31	61	76	149	364		
%	44	25	60	185	167	209	409	× 10⁻¹		
Σ%	44	69	129	213	380	589	998	× 10⁻¹		

Table 8
Conversion of apparent grains into calculated true grains for the artificial sample *F*, using the scheme of conversion demonstrated in Table 4

Bolded values indicate transformed data; further explanations in the text

size class	number of grains	columns of calculation						number of calc. grains	quanti-tative percent	cumula-tive percent
		I	II	III	IV	V	VI			
1	9	**16.6**	**16.6**	**16.6**	**16.6**	**16.6**	**16.6**	**16.6**	4.6	4.6
2	7	4.3	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**	**7.9**	2.2	6.8
3	14	12.4	11.1	**20.5**	**20.5**	**20.5**	**20.5**	**20.5**	5.6	12.4
4	20	19.0	18.3	14.9	**27.5**	**27.5**	**27.5**	**27.5**	7.5	19.9
5	42	41.3	40.8	38.8	34.2	**63.2**	**63.2**	**63.2**	17.4	37.3
6	57	56.6	56.3	55.0	53.4	41.9	**77.4**	**77.4**	21.3	58.6
7	215	213.9	212.9	210.2	204.8	186.3	150.8	**150.8**	41.4	100.0
total:	364	363.9	363.9	363.9	363.9	363.9	363.9	363.9		

RELATIVE VOLUME UNITS

Previously, for comparison and statistic relationship between true grains and apparent ones of artificial samples the volume percent was changed into quantitative one. But now, if we want to make conversion from thin-section data to sieve analysis ones — we have to use the volume percent for both groups of data. If the true grains are spheres, their volume may be obtained without any problem. Instead of real volume units, *e.g.* cubic millimeters, the Author proposes the *relative volume units,* abbreviated as *RVU.*

Assuming, the observed single spherical grain in the coarsest size class has volume equal to 1.0 VU, one can determine the volume for all finer grains using the *volume-correction coefficient,* symbolled as c_v. This coefficient indicates how many times the volume of a given grain is smaller in proportion to the coarsest grain. Values of c_v for various grains sized in phi scale are given in Table 9.

Table 9

Values of coefficient for "thin-section" – to – "sieve" transformation of data

c_{vi} — Volume correction coefficient for apparent grains in *ith* class of size, c_{di} — spatial correction coefficient for *ith* class of size; detailed explanation in the text

No. of class for intervals (in phi units)			middle of class (in phi units)	C_{di}	C_{vi}	$C_{di} \cdot C_{vi}$
0.25	0.50	1.00				
1	1	1	n	1.000	1.0000	1.0000
2			+0.25	1.189	0.5944	0.7076
3	2		+0.50	1.414	0.3534	0.4997
4			+0.75	1.683	0.2102	0.3538
5	3	2	+1.00	2.000	0.1249	0.2498
6			+1.25	2.380	0.0741	0.1763
7	4		+1.50	2.828	0.0442	0.1250
8			+1.75	3.364	0.0261	0.0878
9	5	3	+2.00	4.000	0.0156	0.0624

For any size class: $C_{dn} = 0.841^{(1-n)}$
and $C_{vn} = 1.682^{(1-n)}$,
where n – number of size class for indication of classes with 0.25 phi intervals.

VOLUME OF G AINS IN i-*th* SIZE CLASS

Putting into practice the relative volume units (*RVU*), the total volume of grains in *ith* size class is given by equation:

$$V_{ci} = q_{ci} \times c_{vi} \qquad (1)$$

where: V_{ci} — volume of grains of *ith* size in VU, q_{ci} — number of calculated true grains of *ith* class, c_{vi} — value of volume-correction coefficient for *ith* class. Volume of all grains of a sample can be written as:

$$V_{ct} = \sum_{i=1}^{i=n} V_{ci} \qquad (2)$$

Therefore, the total volume of grains of the *ith* size class (U_i) expressed in volume percent (*i.e.* as in the sieve analysis) can be obtained by:

$$U_i = V_{ci} \times V_{ct}^{-1} \times 100\% \qquad (3)$$

Succesive cumulation of values of U_i from the coarsest class to finer one gives the position of points for "sieve" cumulative curve, but for sectioned true grains only. Such curve is similar to the curve of the sieved sample but it is not the same. It results from statistics a_r vs. a_c demonstrated earlier, with relationship not $a_c = a_r$ but $a_c = ma_r + n$ type (*see* Text-fig. 8).

SPATIAL CORRECTION COEFFICIENT

One of the most important difference between the sieve analysis and microscopic one is that in the first case the data come from three-dimensional sample, whereas the microscopic analysis gives the data from two-dimensional surface of thin-section.

Let us consider a set of grains. If the set consists of three size classes with the logarithmic trend of the grain sizes, then it gives the number of grains in any order , *e.g.*, — 1, 8, 64 grains, respectively (Text-fig. 12*a*). It means that the volume of the first grains is equal to summarized volume of eight grains of the second class or summarized volume of 64 grains of the third one. The foresaid theoretical sample may be treated as an analogue of a three-dimensional sample of the sieve analysis. After sectioning, the two-dimensional image is visible like in a thin-section. And in this case the size of grains as well as number of grains in size classes are in logarythmic order too, but their numbers differ as against the last case (Text-fig. 12*b*). However, the relationship between the grains is very distinctive; the value of quotient *number of true grains* by *number of apparent*

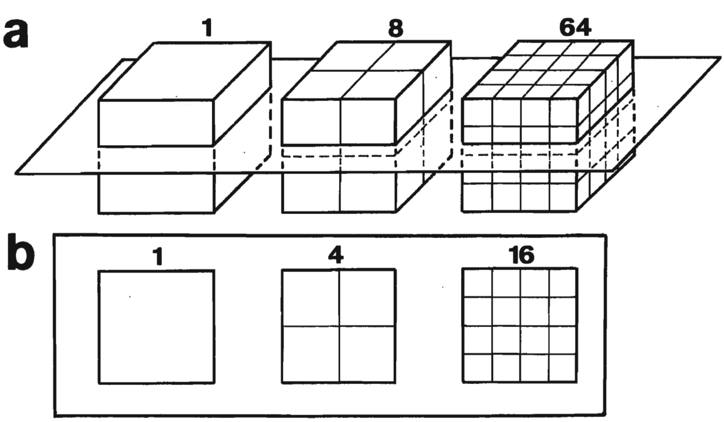


Fig. 12. Graphical explanations of the spatial correction coefficient

a — Idealized set of true grains in sectioned three-dimensional (= spatial) sample; numbers indicate the quantity of true grains of a given size, **b** — thin-section image; numbers indicate the quantity of apparent grains of the same size; detailed explanation in the text *grains* for a given size class is equal to *diameter of coarsest apparent grain — diameter of a given apparent grain ratio*. Such ratio is called by the Author as *spatial correction coefficient*, symbolled as c_d. This coefficient may be utilized for determination of the number of all true grain in a three-dimensional sample from the number of calculated true grains, *i.e.* estimated by transformation of apparent grain data from thin-section analysis. Values of c_d for grains noted in the phi-unit scale are given in Table 9.

FINAL CORRECTION OF GRAIN VOLUME

As mentioned previously, equations *1, 2* and *3* are useful for evaluation of grain volume but only the sectioned grains. Coefficient c_d enables the reconstruction of grain-fabric of three-dimensional sample, *i.e.* volume of all grains, both sectioned and not sectioned. Volume of all grains in *ith* class can be expressed:

$$V_{ci} = q_{ci} \times c_{vi} \times c_{di} \tag{4}$$

where: V_{ci} — volume of grains of *ith* size in RVU, q_{ci} — number of calculated true grains in *ith* size class, c_{vi} — value of c_v coefficient for *ith* class (*see* Table 9), c_{di} — value of c_d coefficient for *ith* class (*see* Table 9), and consequently:

$$V_{ct} = \sum_{i=1}^{i=n} V_{ci} \tag{5}$$

where: V_{ct} — total volume of all grains in a three-dimensional sample in RVU. Finally, the participation of the grains of a given size class expressed in volume percent (U_i) can be derived from:

$$U_i = V_{ci} \times V_{ct}^{-1} \times 100\% \tag{6}$$

If the value of U_i for each size class is known the distribution of grains may be depicted by histograms as well as by cumulative curve. The curve — if its "coarse-side" end-point will be translocated by one interval toward the coarse grains — is theoretically equal to sieve one, and the sieve textural parameters may be obtained. In practice, the "sieve"-microscopic and real sieve curves are not identical (*compare* lines *g* and *s* in *A-F* in Text-fig. 13), but the deviations of the same noted percentiles are no more than a half of the class interval (*compare* lines p_s and d_g in *A-F* in Text-fig. 13).

The conversion of the microscopic data into the "sieve" ones demonstrated above is called by the Author as the method of calculated grains. Schematic sequence of procedure from microscopic analysis to calculation of "sieve" textural parameters is given in Table 10 (path *3*).

SIMPLIFIED METHOD OF MICROSCOPIC — SIEVE CONVERSION OF DATA

The fact that the most of the section of true grains of a given size class falls into the next size class of apparent grains may be used as a base of simplification of microscopic — sieve conversion of data. Errors of transformation will be the minor the wider class interval will be used for microscopic measurements of the

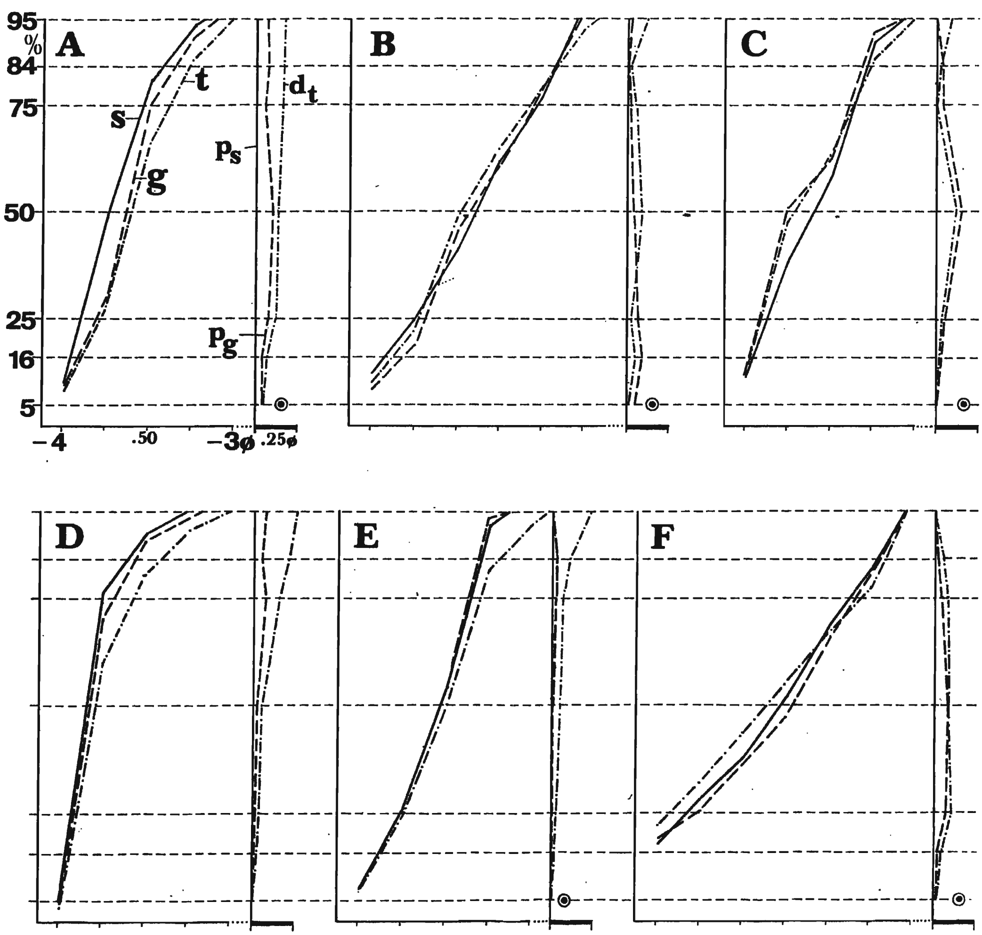


Fig. 13. Effects of transformation thin-section — to — sieve data for the selected artificial samples *A-F*

g — "Sieve" curve obtained by "calculated grains method", "sieve" curve obtained by "simplified method"; for comparison — the real sieve curve s is given

d_g, d_t — eviations of a given percentile obtained from curve *g* and *t*, respectively, in relation to the same real sieve percentile represented rectilinearly by p_s line, if the 0.25 phi size-class interval; percentiles with extrapolated values are circled apparent grains. Because the finer classes are enriched successively by sections of coarser true grains, this effect equiponderates the role of spatial correction coefficient approximately. Therefore, in simplified method of conversion only the volume-correction coefficient should be taken under consideration. Then the volume of grains of a given size class may be obtained from:

$$V_{ti} = q_{ti} \times c_{vi} \tag{7}$$

where: V_{ti} — volume of grains of *ith* size class (RVU), q_{ti} — number of apparent grains of an *ith* size class, c_{vi} — volume-correction coefficient for *ith* class (Table 9), and consequently, the total volume of all grains (grain-fabric):

$$V_t = \sum_{i=1}^{i=n} V_{ti} \tag{8}$$

where: V_t — total volume (RVU) of all grains in a three-dimensional sample. Values of U_i in volume percent we obtain analogously as shows the equation *6*. Schematic sequence of analytical procedure for simplified method of microscopic — sieve conversion is given in Table 10 (path *4*).

SAMPLES WITH MINERALOGICAL HETEROGENEITY OF GRAINS

The thin-section — sieve method of conversion of data presented above is true for samples composed of grains with mineralogical homogenity. Only in such a case the volume is equal to weight in percent. Most of the deposits consist of grains with the same specific gravity, *e.g.* pure quartz sandstones or oolitic limestones. However, some recent and ancient sediments, especially of beach environments, are the mixtures of quartz grains and heavy minerals ones. Concentration of the heavy minerals achieves a several dozen of weight percent of sediments (*see* RUDOWSKI 1986). In these cases there is no volume-weight equivalency of percent, and additional operations have to be made.

Let us consider the relationship given by:

$$k_r = s_m \times s_q^{-1} \tag{9}$$

where s_m — specific gravity of a given mineral, and s_q — specific gravity of quartz (the most common grains).

It is evident that the value of k_r determines, how many times a given mineral is heavier or lighter in relation to quartz grains having the same diameter.

Using the k_r values, if a given class consists of various mineralogical grains, their volume may be defined as:

$$V_i = (q_{qi} + q_{ai}k_{ra} + \dots + q_{ni}k_{rn}) \times c_{vi} \qquad \textbf{(10)}$$

where: V_i — modified volume of grains of *ith* class, q_{qi} — number of quartz grains among the grains of *ith* class, q_{ai}, q_{ni} — number of *a*-mineral and *n*-mineral grains among the grains of *ith* class, k_{ra} and k_{rn} — factors for *a*-mineral and *n*-mineral grain, respectively, c_{vi} — as in equation *1*. Values of factors may be obtained after the equation *9*.

For example, if the 3*th* size class of any sample consists of grains, among which are 30 quartz grains (specific gravity — 2.65 Gcm^{-3}), 20 garnet grains (mean specific gravity — 3.90 Gcm^{-3}) and 10 grains of the magnetite (s.g. — 5.18 Gcm^{-3}; specific gravities *after* DANA'S Manual... 1977), then the modified total volume of grains can be obtained as:

$$V_3 = (30 + 20 \times 1.47 + 10 \times 1.95) \times 0.3534 = 27.88 \text{ RVU}$$

For comparison — if all 60 grains were the quartz ones then:

$$V_3 = 60 \times 0.3534 = 21.20 \text{ RVU}$$

Such operation gives the weight-volume equivalency. Further elements as V_t and U_i can be evaluated by equations numbered *8* and *6*. However, one should remember that during the microscopic examination the minerological identification of grains has to be done.

MODIFICATION OF SIMPLIFIED METHOD FOR ELONGATED GRAINS

Assumption of spherical shapes of grains limits the usage of the presented method. Only deposits which consist of spherical or nearly spherical grains (especially fine sandstones and, over all, the deposits composed of microconcretions) may be taken under consideration. But most of the deposits consist of elongated grains. Such grains in thin-section are characterized by two axes — longest axis *a* (length of grain) and axis *b* (width of grain). Relationship between *a* and *b* is known as:

$$E = a \times b^{-1} \qquad \textbf{(11)}$$

where: *E* is the so-called *coefficient of elongation* (*cf.* SPOTTS 1964).

Introducing the term *middle axis*, symbolled as b_m, the Author proposes a new manner of elongated grain measurement. The axis b_m is measured not as axis *b*, that is in the widest part of the apparent grain, but along the line acrossing perpendicularly to the axis *a*, just by the midpoint of it (*A* in Text-fig. 14). Such manner of measurement is a quicker and more objective measure of the axis *b*. Accordingly to the new definition of b_m, the coefficient of grain elongation is redefined:

$$E_m = a \times b_m^{-1} \qquad \textbf{(12)}$$

Because only axes a and b have to be enough for reconstruction of a true, grain volume of a calculated grain can be obtained approximately by:

$$V_m = a \times b_m^{\,2} \qquad (13)$$

But a reconstructed grain in this manner is no sphere at all and its volume differs from volume of a spherical grain with the diameter equal to the axis a (B in Text-fig. 14). The comparison of volume of an angular grain defined by a and b_m axes with spherical grain defined by the axis a may be calculated as:

$$k_{Ei} = V_{mi} \times V_{si}^{\,-1} \qquad (14)$$

where: V_{mi} — volume of an elongated grain of *ith* size class: the size class is determined by axis a, V_{si} — volume of a spherical grain of *ith* size class with the a diameter. The relationship k_E *vs.* E_m illustrates line C in Text-fig. 14. Using the factor k_E, various coefficient for spherical grains computed previously may be used for elongated ones. In practice the mean E_m is useful and its value may be estimated by measurements of several grains in each size class of apparent grains.

Taking into account the elongation of grains, the volume of grains of *ith* size class is given by:

$$V_{ui} = k_{Ei} \times q_{ti} \times c_{vi} \qquad (15)$$

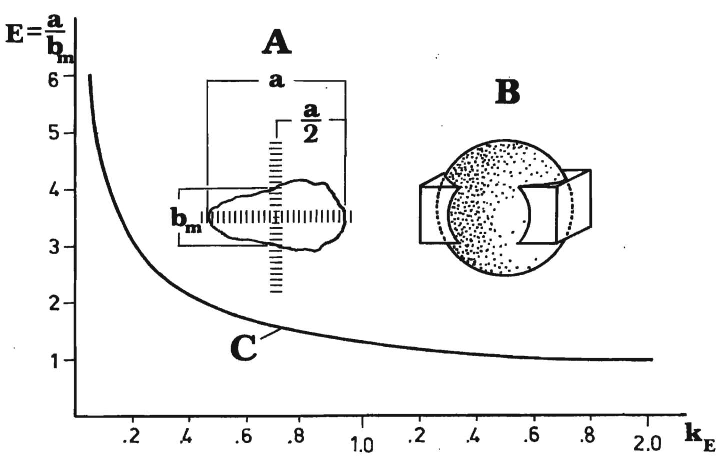


Fig. 14. Interrelationship between an elongated apparent grain, a calculated grain, and a spheroidal grain

A — Proposal of the new manner of measurement of apparent grains: **a** — longest axis, b_m — middle axis

B — Reconstructed true grain in relation to a spheroidal true grain with the diameter equal to the longest axis a

C — Scatter-plot E_m *vs.* k_E; detailed explanations in the text

Further calculation (V_{ui} is equivalent of V_{ci}) is the same as indicated by equations numbered *5* and *6*. Full procedure from thin-section analysis to "sieve" textural parameters is shown in Table 10 (path *5*).

ACCURACY OF THIN-SECTION — SIEVE CONVERSION OF DATA

Usually, the effects of granulometric analysis are illustrated by plots for pairs of textural parameters. A comparison *mean diameter* (M_z) vs. *standard deviation* (S_d) is demonstrated. These parameters were calculated from sieve analyses (= primary data of loose artificial samples — *1* in Text-fig. 15) as well as from "thin-section" analyses of the same samples after their induration (*2* in Text-fig. 15). Thin-section data were transformed into "sieve" ones, using both *simplified* (*4* in Text-fig. 15) and *calculated true grain* (*5* in Text-fig. 15) methods. For comparison the same data were converted using the *regression equations* (HARREL & ERIKSSON 1979).

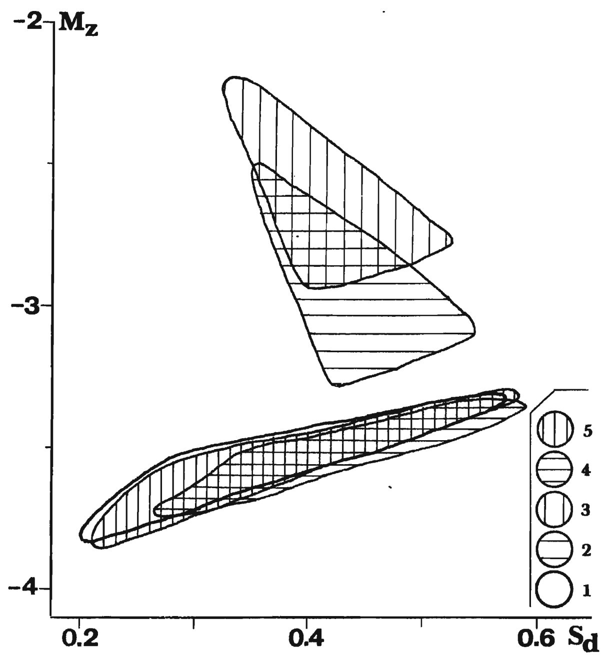


Fig. 15
Plot of M_z *vs.* S_d

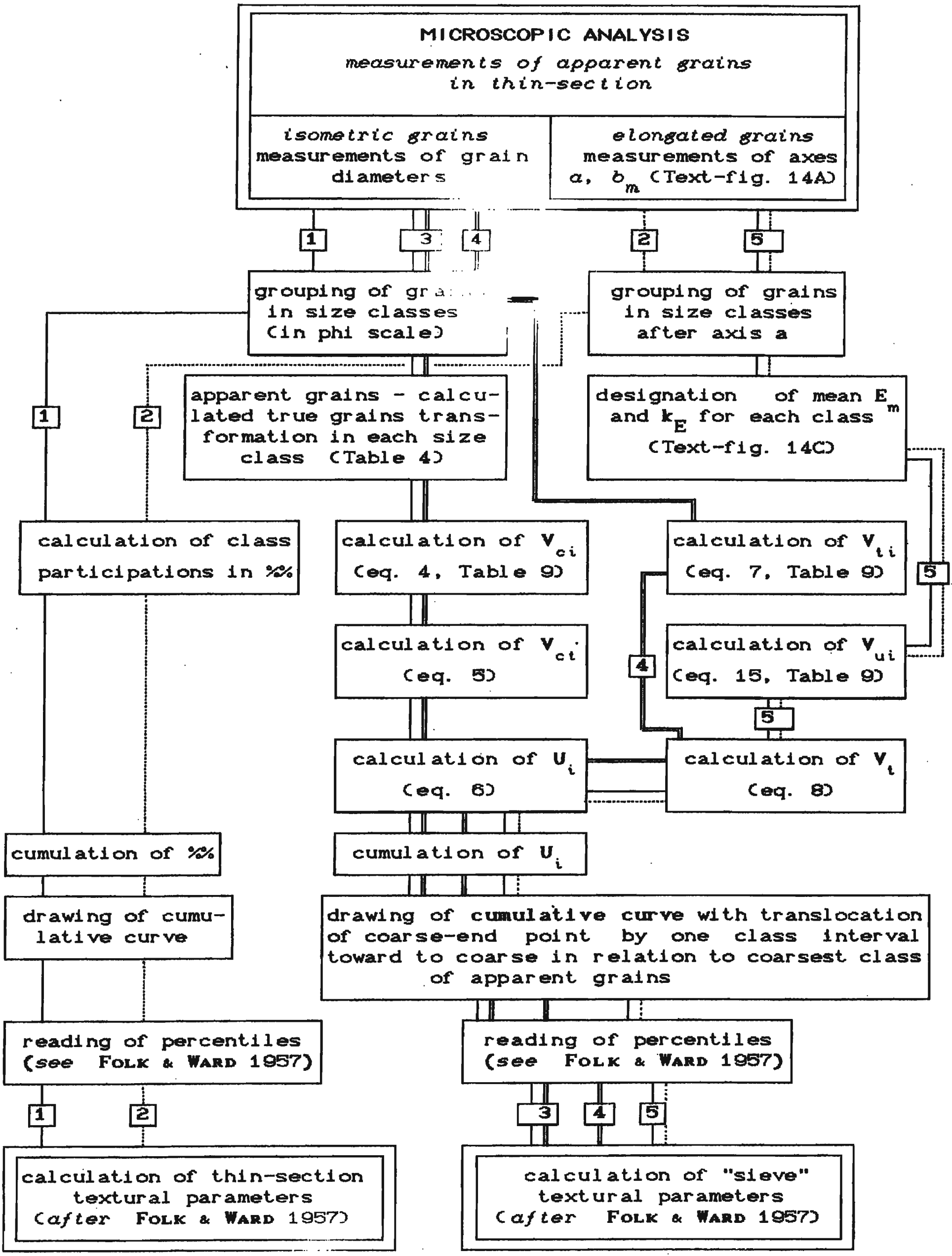
1 — Area of points for real sieve analyses, **2** — area for thin-section data, **3** — area of thin section to sieve converted parameters after the regression equations (*cf.* HARRELL & ERIKSSON 1979)

Other areas after the Author's methods: **4** — simplified method, **5** — calculated-grain method

It can be seen that the fields occupied by *calculated true grain* and *simplified* methods of transformation of data are approximately the same with the real sieve field, whereas the data converted by *regression equations* occupies the field (*3* in Text-fig. 15) located far in comparison with location of the field for sieve data.

Table 10

Schematic sequence for procedures from thin-section analysis to determination of sieve textural parameters



Determination of thin-section parameters: for isometric apparent grains — path *1*, for elongated apparent grains — path *2*

Determination of sieve textural parameters: by method of calculated true grains (CTG) for isometric apparent grains — path *3*, and simplified *CTG* method — path *4*; for elongated apparent grains, using *CTG* method only — path *5*. Equations and tables a given phase of transformation of data — in brackets (*see text*)

APPLYING OF THE PRESENTED METHOD FOR INDURATED SEDIMENTS

The demonstrated method was used to determine the sieve textural parameters (M_z, S_d) of the indurated recent as well as ancient real deposits. Very important were the recent sediments box-sampled from the coastal zone of the Tasman Sea (N. S. W., Australia; *see* RONIEWICZ 1984). One of the vertical wall of each sample with undisturbed texture of sediment was indurated artificially by epoxy cement (RONIEWICZ 1984, Pls 1-48). Loose parts of samples were examined by sieve analyses and from indurated walls the several thin-sections were made. These thin sections were examined under microscope by the present Author. It is worth to pay attention that the textural parameters (M_z, S_d) for sieve analyses (lined area in Text-fig. 16*A*) and for microscopic ones (*1* in Text-fig. 16*A*) differ distinctively. But transformed thin-section data, when using the simplified method for elongated grains, are practically the same as the real sieve ones (*2* in Text-fig. 16*A*). The simplified method was used also for transformation of microscopic data of Lower Triassic (Middle Buntsandstein) sandstones from Holy Cross Mts, and interpreted as ancient aeolian deposits (GRADZIŃSKI & *al.* 1979). In the last case, the microscopic granulometry was known (*see* GRADZIŃSKI & *al.*

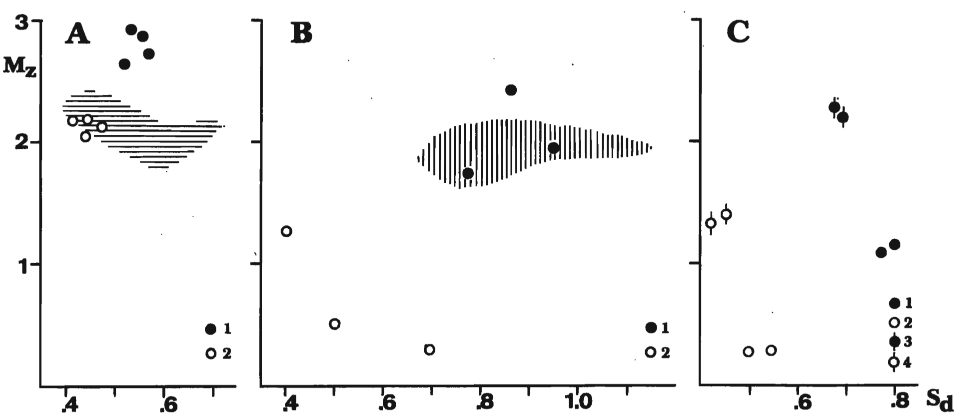


Fig. 16. Examples of transformations thin-sections — to — sieve data for samples of some natural deposits

A — Present-day sandy deposits indurated artificially from the coastal zone of the Tasman Sea (N.S.W., Australia; for detailed location *see* RONIEWICZ 1984)

1 — Thin-section data, 2 — transformed sieve data; lined field represents fluctuations of real sieve parameters (*after* RONIEWICZ 1984)

B — Lower Triassic eolianites from NW Mesozoic margin of the Holy Cross Mts, Central Poland

1 — Thin-section data obtained by the Author, 2 — "sieve" data; lined field — thin-section data *after* GRADZIŃSKI & *al.* (1979)

C — Middle and Upper Jurassic deposits from the Kujawy area, north-Central Poland

Sideritic spherulites: 1 — thin-section data, 2 — "sieve" data
Oolitic limestones: 3 — thin-section data, 4 — "sieve" data

1979, p. 155, Text-fig. 2 and Table 1) and only the control microscopic examinations were made by the present Author (*1* in Text-fig. 16*B*). After the transformation, the "sieve" parameters are more reliable for aeolianites than miscroscopic ones (compare *1* and *2* Text-fig. 16*B*).

The *calculated true grains method* was used for recalculation of microscopic granulometry of the Lower Jurassic sideritic spherulites and Upper Jurassic oolitic limestones, both from the Zalesie anticline within the Kujawy area (*see* MATYJA & *al.* 1985). The "sieve" parameters M_z and S_d for mentioned deposits are abated in comparison with analogous parameters, obtained from microscopic data (*compare* 1 and 2, *also* 3 and 4 in Text-fig. 16*C*). Trend of translation is campatible with changes of values of textural parameter, obtained empirically by transformation of thin-section data to "sieve" ones for an artificial samples.

The examples illustrated above indicate the usefulness of the presented method and its modification for "sieve" examinations of indurated real sediments.

FINAL REMARKS

The Author is aware of that the presented method *thin-section* to *sieve* conversion of data is not devoid of errors. The errors may result mainly from simplification of initial assumptions (sphericity of grains) and imperfect volume reconstruction of elongated grains. But it should be emphasized that the transformed data are compared with the data of sieve analysis, *i.e.* deficient analytical method, too. But using for formulation of the presented method the artificial samples and sequential supervision in each phase transformation of data result, that the effects of the new method are worthy of belief. Because the presented method requires the transformation of single class frequencies instead of transformation of parameter values, it has a universal character. It may be used with the same accuracy for deposits with different distribution of grains as well as for deposits with different distribution of grains as well as for various size of clastic components, *e.g.* from very fine sandstones to coarsest conglomerates. In the last case it stands to reason that examination cannot be realized on thin-section literary, but the wall (or its photo) of exposure of conglomerates may be treated as a huge "thin-section" image. Furthermore, the method makes possibilities of calculation for all the textural parameters, not only the *mean diameter* and *standard deviation* but also the *skewness* and *kurtosis,* on the same high level of confidence.

Using the presented method, the additional advantages may be received. After the transformation of data, the new "sieve" cumulative curve may be the subject another investigation; the *C-M* pattern (PASSEGA 1964) may be obtained and — using the probabilistic scale for cumulation of percent — the analysis of grain population (*cf.* VISHER 1969) can be possible.

The main drawback of presented method inheres in thin-section analysis; measuring of about 300 apparent grains in thin-section is an uphill task. Hence, it is evident that during the examinations of clastic sediments the very laborious microscopic analyses are ignored in the main. However, if the field of observations is strongly reduced, *e.g.* core samples, the microscopic analysis may be the only method for more detailed description of the deposits. Using the method of thin-section — sieve conversion of data, the comparisons of granulometric characteristics between the present-day loose sediments and indurated ancient ones are possible. For that reason, the presented method of transformation of data may become an important tool for reconstructions of ancient sedimentary environments.

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T. MERTA

PRZEKSZTAŁCANIE DANYCH GRANULOMETRYCZNYCH ANALIZY MIKROSKOPOWEJ NA DANE RÓWNOWAŻNE ANALIZIE SITOWEJ

(Streszczenie)

Przedmiotem pracy jest zagadnienie przekształcania danych granulometrycznych, uzyskanych na drodze pomiarów mikroskopowych w płytkach cienkich, na dane odpowiadające efektom analizy sitowej. Problem powyższy rozważono poprzez analizę porównawczą grup danych — „mikroskopowych" i „sitowych" — uzyskanych ze sztucznie komponowanych próbek imitujących utwory klastyczne, o założonych charakterystykach uziarnienia (fig. 1-9). Do konstrukcji próbek użyto „ziarn" barwionych diagnostycznym dla danej klasy wielkości kolorem. Umożliwiło to identyfikację rzeczywistej wielkości ziarn podległych przecięciu płaszczyzną „płytki cienkiej", a dających rozmaitej wielkości tzw. ziarna pozorne.

Na kanwie tak przeprowadzonej analizy opracowano nową metodę przekształceń wyników analizy mikroskopowej na dane w wysokim stopniu aproksymujące dane analizy sitowej (fig. 10-14). W etapie pomiarów mikroskopowych zaproponowano zobiektywizowany sposób mierzenia ziarn wydłużonych w płytkach cienkich (fig. 15).

Istotą zaprezentowanej metody jest przekształcanie danych odnoszących się do każdej klasy wielkości ziarn, a nie — jak dotąd proponowano — przekształcanie finalnych, liczbowych parametrów uziarnienia. Tym samym, przekształcone według nowej metody dane analizy mikroskopowej umożliwiają wykreślenie kumulacyjnej krzywej uziarnienia, odpowiadającej krzywej „siania", a stanowiącej podstawę do określania rozmaitych „sitowych" parametrów uziarnienia na drodze tzw. metody graficznej (*patrz* FOLK & WARD 1957). Taki tryb nadaje prezentowanej metodzie znamiona uniwersalności, tj. daje możliwość zastosowania jej do oceny granulometrii zlityfikowanych utworów klastycznych, zróżnicowanych zarówno pod względem wielkości składników jak i rozkładów uziarnienia (fig. 16). Oprócz metodologicznego udokumentowania kolejnych etapów transformacji danych (tab. 1-9), dla celów praktycznego stosowania metody przedstawiono algorytm procedury postępowania, począwszy od wykonania pomiarów mikroskopowych do uzyskania teksturalnych parametrów uziarnienia ekwiwalentnych analizie sitowej (tab. 10).

Prezentowana metoda transformacji danych stwarza możliwość porównania granulometrii zlityfikowanych utworów starszych formacji geologicznych z danymi, dość bogatymi już obecnie, dotyczącymi uziarnienia osadów współczesnych środowisk sedymentacyjnych. Tym samym przedstawiona metoda może stanowić istotne narzędzie analityczne przy odtwarzaniu warunków środowiska powstawania dawnych osadów klastycznych.