



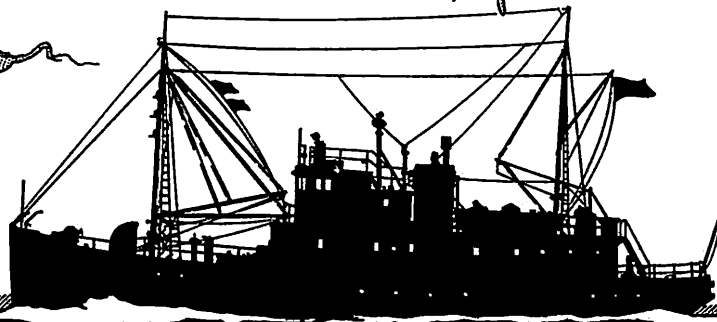
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Technical Report No. 90

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GRAVITY AND THE PROPERTIES OF SEA WATER, by Ricardo M. Pytkowicz. Limnology and Oceanography, 8(2):286-287, April 1963.

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POSTGLACIAL SEDIMENTS IN UNION BAY, LAKE WASHINGTON, SEATTLE, WASHINGTON, by Dean A. McManus. Northwest Science, 37(2):61-73, May 1963.

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RICHARD H. FLEMING  
Chairman

## ELECTRONIC DATA PROCESSING IN SEDIMENTARY SIZE ANALYSES<sup>1,2</sup>

JOE S. CREAGER, DEAN A. McMANUS AND EUGENE E. COLLIAS  
Department of Oceanography, University of Washington, Seattle, Washington

### ABSTRACT

The use of electronic computers must become a standard technique in the processing of data from sedimentary analysis. The efficiency of electronic data computing increases the number of samples that can be processed, permits the use of a wider variety of statistics, eliminates much of the operator error, and frees the geologist for interpretive work. The system is adaptable to an expanded statistical analysis. The total expense of using the electronic computer is less than that of the hand method, when a large number of samples are run.

A program for use with the IBM 650 magnetic-drum processing system has been written which computes phi values of several percentiles, sand-silt-clay relationships, Trask values, Inman values, and Folk and Ward values. The results from this program are compatible with those obtained using conventional hand methods.

### INTRODUCTION

Many of the techniques commonly used in the mechanical analysis of sediments are so time-consuming that a restriction must often be placed on the number of samples to be run or on the type of results to be obtained. Although the laboratory techniques of sieve and pipette differentiation of size grades might be modified, this paper is concerned with the modernization of data processing.

High-speed electronic computers provide the means for quickly obtaining a variety of computed results and at the same time for freeing the geologist for more profitable use of his training. Today, the electronic computer should be considered as permanent and as useful a tool in sedimentation studies as is the settling tube and other more conventional instruments.

This paper describes a program written for the IBM 650 magnetic-drum data processing system that produces many of the statistics commonly used in size analysis. A copy of the program and suggestions as to efficient preparation of data for the convenience of the computing center are available from the authors. A similar program for use with the IBM 709 computer also will be available.

Although the necessity of using electronic computers in stratigraphic and sedimento-

logic work is generally recognized, the availability of programs has not been emphasized. A program for facies analysis was published by Krumbein and Sloss (1958); reference to previous work with computers was also included in their paper. However, in the field of sedimentation, similar programs are not generally available. The present system of machine data processing will be described under the headings of input data, program consideration, and output data.

### INPUT DATA

The input data for the program are based on size analysis by means of sieving the sand and coarser particles, and pipette analysis of the silt and clay fractions. Other techniques could be used, provided that a weight of sediment for each phi class or fractional phi class is obtained. The use of phi size grades instead of millimeter size grades is required for all but the Trask (Krumbein and Pettijohn, 1938, p. 229-235) statistical computations.

Before the data can be fed into the computer, they must be punched in standard IBM cards. A suggested form to facilitate card punching is shown in figure 1. Two types of cards are punched for each sample: a Master card which includes identifying information, and Detail cards which contain the size class information.

The data to be punched on the Master card are written in the upper right-hand

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IM-DO-Q-11 (February 1961)

Geology Summary Sheet		University of Washington										Department of Oceanography																		
Cruise and Station No.		Cruise No.		Sample Number		Type		Extra ID No.		Date		Latitude					Longitude					Det								
Station Name		B	B	2	6	8	1	7	0	K	U	0	6	0	8	1	9	6	0	6	7	3	0	0	6	5	5	2	0	1
Vessel		1										23 24					28 29													
Date		000400										Post Analytical Weight																		
		30 31										50 51					55 56													
		00007440										Core Length					Cor													
		60 61										65 66					79 80													
DETAIL CARD																														
Duplicate from Master	C	T	Depth of Sample	φ Size	Sign	Fraction %	Fraction Weight	Post Analytical Weight											Con											
1-29	30		31-35	36-39	40	41-45	46-50	51-55	56-60	61-79										80										
			0400	0200	//	00000	00000	14018	00000																					
				0100	//		00042																							
				0000			00024																							
				0100			00034																							
				0200			00051																							
				0300			00407																							
				0400			01784																							
				0500			05976																							
				0600			02800																							
				0700			00950																							
				0800			00500																							
				0900			00700																							
				1000			00350																							
				1100			00200																							
				1200			00200																							

FIG. 1.—Example of form used to organize data for key-punching.

block (fig. 1). The first ten columns are a set of numbers or letters which uniquely identify the sample. The Extra ID field<sup>3</sup> is used to identify sub-samples taken from a core or larger sample. The latitude is expressed in degrees and tenths of minutes but the direction is omitted; thus 67°24.0' N becomes 67240. The longitude field does not include the 100° or direction, thus 164°23.0' W becomes 64230. The OCT field indicates the data omitted from the latitude and longitude fields by a single number representing one of eight octants of the earth's surface.

Inasmuch as the present program was developed for the study of recent marine sediments, some of the identification methods will differ from those used by geologists studying paleosediments. Thus, Cruise Number could be changed to Well Number, and latitude-longitude location might be replaced by Township-Range coordinates.

The card-type field is punched with a zero for the Master cards and a one (1) for Detail cards. Card types 2 through 9 are used for output data. The depth field and core length field apply only to core samples. The depth field is the sample depth in a core (in millimeters from the top of the core) and the length field is the over-all core length (in millimeters). The post-analytical weight field is the weight (in milligrams) of the original sample minus any loss of sample during the analysis. It must equal the summation of the size class fraction weights punched on the Detail cards.

The data to be punched on the Detail cards are written in the bottom portion of the suggested form (fig. 1). Each Detail card contains the phi size to the nearest 0.01 phi value with algebraic sign, and either the fraction percent or the fraction weight (in milligrams). The remainder of the columns, except card type, are duplicated from the Master card.

Although the number of phi sizes that can be considered for a sample are unlimited, certain assumptions must be made. The two most important ones are: (1) that the sediment contains no material coarser than the coarsest phi size present, so that the next

coarsest grade is indicated as zero percent, and (2) that all material finer than a certain size can be grouped together and considered as a distinct and final class.

#### PROGRAM CONSIDERATION

The program is divided into several major parts as shown in figure 2. The program deck, consisting of 234 cards, is read into the computer just prior to reading the Detail cards. As each data card is read, the fraction percent is computed from the fraction and post-analytical weights, or stored directly if it has been punched as input data. Then the accumulated percent at each successive phi level is obtained beginning with zero at the coarsest fraction. From the accumulated percent a "t"-value (representing the area under a normal distribution curve in standard deviation units) is found by "table-lookup". This procedure is analogous to plotting the data on normal probability paper. After all detail cards for a given sample have been read, the final accumulated percent must be  $100.00 \pm 0.06$ , or an error card is punched and the sample rejected.

Next, the phi values at percentiles of 5, 16, 25, 50, 75, 84, and 95 are interpolated from the corresponding "t" values by the Aitken four-point method (Milne, 1949). A two-point linear interpolation is also made and the two results are compared. If the values obtained by these two different methods agree within 0.20 phi units and the Aitken value is between the adjacent phi class sizes, the Aitken value is used in preference to the linear value. By using Aitken's method, a smoothed curve, rather than a curve composed of a series of chords, is constructed between the phi sizes. If the next-to-last accumulated percent is less than 95, the program will also extrapolate percentile values. Thus, the value of the 75, 84, or 95 percentile level will be extrapolated, provided the next-to-last accumulated percent is at least 72, 81, or 92 respectively. When it is necessary to extrapolate one of these levels, a suitable coding is made on the output data card and print-out sheet.

After the selected phi values have been computed, the sand-silt-clay relationships are computed as follows:

- (1) the percent of material coarser than

<sup>3</sup> A field is a group of related card columns: i.e., card columns 11 and 12 contain two numbers to identify the sub-sample.

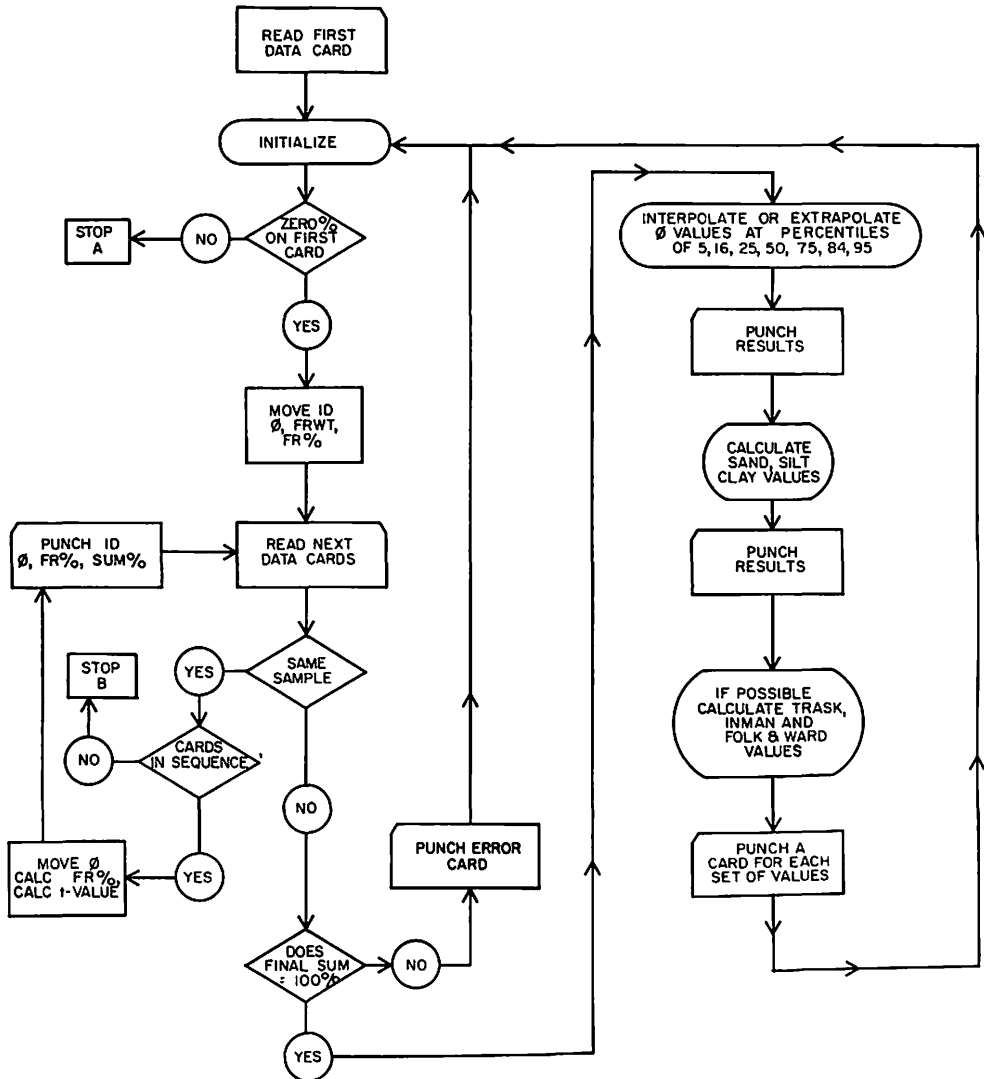


FIG. 2.—Flow chart of program to compute results of sediment size analysis.

- the 0 phi class is listed as larger than sand,
- (2) material finer than  $-1$  phi and coarser than 5 phi is listed as sand,
  - (3) material finer than 4 phi and coarser than 9 phi is listed as silt,
  - (4) all material finer than 8 phi is listed as clay,
  - (5) the ratio of material coarser than 5 phi to that finer than 4 phi is computed to give a sand to mud ratio, and
  - (6) the position of the sample on the tri-

angular classification of Shepard (1954) is coded according to figure 3.

Finally the Trask values (Krumbein and Pettijohn, 1938, p. 229–235), Inman values (Inman, 1952), and Folk and Ward values (Folk and Ward, 1957), are computed according to the published equations if the next-to-last accumulated percent is larger than 92. If the next-to-last accumulated percent is less than 92 only Trask and Inman values are computed, and if less than 84 only Trask values are computed.

At each step in the program (fig. 2) many decisions must be made. These decisions are under program control except for two error stops which require operator attention. One stop is for no zero percent card at the beginning of each sample and the other is for cards out-of-sequence.

#### OUTPUT DATA

After each major portion of the program has been completed (fig. 2), cards are punched with the computed results. These cards are then intermixed with appropriate header cards and the resultant deck tabulated using an IBM 407 tabulating machine with a specially wired control panel. The print-out sheet from a typical sample is shown in figure 4. The first three lines contain the identifying data punched on the Master card, but rearranged for clarity. The next group of lines lists the fraction and accumulated percent values. The third group of lines lists phi values of the selected percentiles; the five digits in the right margin of this line are a code indicating whether a linear or Aitken's four-point interpolation was used for each percentile.

Following the percentile print-out are the sand-silt-clay relationships. The percentages of coarse material, sand, silt, and clay are also used in arriving at the number designated as "Class". This number represents one of the ten fields in a triangular diagram shown in figure 3.

The remainder of the print-out, Trask values (in millimeters), Inman values (in

phi sizes), and Folk and Ward values (in phi sizes), presents increasing amounts of the tails of the frequency distribution. Not all the sediments, however, can be analyzed to the degree of completeness required for some of the calculations. Thus, if the 95th percentile is unobtainable, the Folk and Ward values and part of the Inman values will be left blank or coded as unobtainable. If the sediment is so fine-grained and of such composition that only thirty or forty percent of the distribution can be sampled, then only a single Trask value will be computed.

Next to three of the Folk and Ward values are figures designated as "Type". These numbers refer to the classes of these values proposed by Folk and Ward (1957). The range for each type is one to five or six, and an increase in number indicates poorer sorting, more positive skewness, and more leptokurtosis. If these types, the sand-mud ratio and Shepard's class are plotted for the samples from an area, a representative picture of the sediment can be obtained quickly with a minimum of numbers on the maps. A more complete representation can be made later from the abundance of information on the sheet.

#### COMPATIBILITY WITH HAND METHOD

Regardless of the increased speed, efficiency, and ease of operation of the electronic computer, the data output must be compatible with that of the conventional hand method to enable comparison with previous analyses. Comparison with the hand method does not imply that the hand method is a standard, nor that it is the most accurate or reliable approach to the statistical analysis of sediments, but the hand method of percentile estimation has been the method most widely accepted.

A total of 48 sediment samples from the Chukchi Sea were selected for a statistical comparison of hand and computer methods. The samples represented a variety of size distributions plotted on normal-probability paper as convex, irregular, almost straight-line, and slightly S-shaped curves.

The only part of the program output that warrants comparison is the estimation of the percentiles, because this involves interpolation along a normal-probability scale. The rest of the computations are arithmetical.

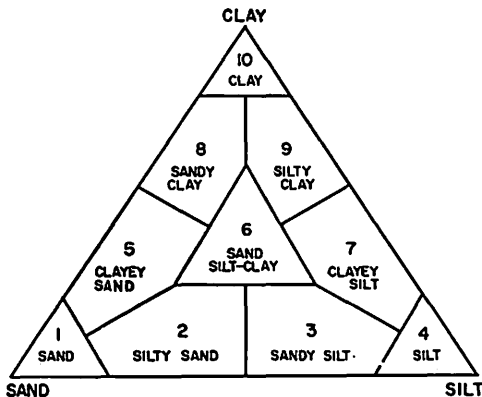


FIG. 3.—Nomenclature of sediment types based on sand-silt-clay ratios (after Shepard, 1954).

The percentile estimates from the two methods were compared in the following manner to determine whether the program added a constant bias: for each of the seven percentiles the value obtained by the program was subtracted from that obtained by hand (fig. 4). A positive deviation was noted as "1" and a negative deviation as "0" (equal values being omitted). The hypothe-

sis that the positive deviations formed 50 percent of the population ( $p=0.5$ ) was then tested. The normal deviate value obtained:

$$\sqrt{\frac{\bar{X}_1 - p}{p(1-p)}} = Z = -0.814$$

shows the hypothesis cannot be rejected at

CRUISE BB 268		STATION 170					
SAMPLER TYPE	KU	DATE	8/19/60	LAT.	67-30. N	LONG.	165-52.0W
DEPTH FROM TOP OF CORE	400 MM	LENGTH OF CORE	7440 MM	EX	ID06		
PHI SIZE	FRACTION PERCENT	ACCUMULATED PERCENT					
- 2.00	0.00	0.00	0.00				
- 1.00	0.30	0.30	0.30				
0.00	0.17	0.47	0.47				
1.00	0.24	0.71	0.71				
2.00	0.36	1.07	1.07				
3.00	2.90	3.97	3.97				
4.00	12.73	16.70	16.70				
5.00	42.63	59.33	59.33				
6.00	19.97	79.30	79.30				
7.00	6.78	86.08	86.08				
8.00	3.57	89.65	89.65				
9.00	4.99	94.64	94.64				
10.00	2.50	97.14	97.14				
11.00	1.43	98.57	98.57				
12.00	1.43	100.00	100.00				
PHI SIZES AT PERCENT LEVELS OF							
5	16	25	50	75	84	95	
3.17	3.97	4.22	4.74	5.63	6.61	9.11	11122
SAND, SILT, CLAY RELATIONSHIPS							
LARGER	SAND	SILT	CLAY	TOTAL	SAND/MUD	CLASS	
0.30	16.40	72.95	10.35	100.00	0.20	3	
TRASK VALUES							
Q1	Q2	Q3	S0	LOG S0	SKG		
0.054	0.037	0.020	1.630	0.212	8.81		
INMAN VALUES							
MEDIAN	MEAN	DEV.	SKEW.	2ND SKEW.	KURT.		
4.74	5.29	1.32	0.42	1.06	1.25		
FOLK AND WARD VALUES							
MEAN	DEV.	TYPE	SKEW.	TYPE	KURT.	TYPE	
5.11	1.56	4	0.45	5	1.73	4	

FIG. 4.—Example of output data sheet. The printout can also be made on vellum or other types paper for subsequent reproduction.

$\alpha = .05 (\pm 1.96)$ . Thus the program adds no constant bias to the computations and it can be assumed that there is no significant difference between the two methods. Finally, it is apparent that, even with the use of normal-probability paper for curve-drawing, the standard error of the hand method is greater than that of the program method.

#### TIME AND MONEY

Even though the program method is not significantly different from the hand method and the two can be used interchangeably, the economy of the new method must be also considered. To the geologist operating on a low-budget project, these considerations may be of decisive importance.

The average cost for computing the statistics and printing them out in the form of the Output Data Sheet is \$1.10 per sample (based on 100 samples). This cost is broken down as follows:

1. Technician preparing form for Key-Punch operator	\$0.30
2. Operations and equipment in computation center excluding computer cost	0.58
3. Computer cost	0.22
Total	\$1.10/sample

It should be noted that of this amount only \$.80 is the cost paid to the computation center and although this cost may change slightly, it is the first item that might vary significantly depending upon the local pay scale.

If the statistics were computed by hand, a technician would have to complete a sample in less than 23 minutes to provide less expensive results, but this time allotment is inversely related to his salary. To insure accuracy he would also have to check his

work in the allotted time. Finally, he would have to continue computing the statistics at the rate of less than 23 minutes/sample for more than 36 hours, continuously, in order to complete a normal group of 100 samples. A conservative estimate of the time required in all the stages of program computation from preparation of key-punch form to final print-out is 10 minutes. It should be apparent, however, that although only 10 minutes are required in preparation, the time interval until final print-out will be prolonged while the samples are being grouped together and while other projects are being run in the computation center.

#### CONCLUSIONS

The electronic computer processing of sedimentary size analysis data produces results that are not significantly different from those produced by the conventional hand method. The operator error in curve drawing, which can be considerable even when using normal-probability paper, is eliminated. The geologist is freed from the mechanical tedium of computation and can better utilize his training and experience. The results include more information than is usually obtained by hand, and data are available sooner. The method is less expensive than the hand method when a large number of samples are run, and when this is considered together with the increased speed of newer model computers, such as the IBM 709, the need for modernization of data processing of sedimentary size analysis is apparent.

#### ACKNOWLEDGMENTS

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