SOME SUGGESTIONS FOR HEAVY MINERAL INVESTIGATIONS OF SEDIMENTS

WILLIAM M. COGEN

Balch Graduate School of the Geological Sciences
California Institute of Technology, Pasadena, California

ABSTRACT

Attention is directed to the variability in quantitative relations between heavy minerals as a consequence of changes in the texture of sediments. It is suggested that for quantitative comparisons of heavy minerals, materials of the same grade-size should be utilized.

Various methods in use for describing quantitative relations between heavy minerals are critically analysed. A new method of representation is suggested. A standard or type sample is selected. It is screened and the heavy minerals are separated from the suitable grade-size fractions. A known portion of the heavy mineral crop is counted and the abundance of each mineral species is established for a definite weight of uniformly sized material. The abundance of any mineral species in other samples is then given by a comparison with this standard.

PART I

In the course of a petrological study of certain sediments it was found more suitable to mount heavy mineral grains of approximately uniform size rather than an ungraded aggregate of minerals. This raised the question as to whether the quantitative relations peculiar to a sediment could be observed better by examining and comparing heavy minerals of the same size rather than by making use of crops which had been secured from unscreened samples. Both schemes have been employed by investigators of sediments. A study of the problem has convinced the writer that results secured by the use of one of these methods can not be duplicated by the other except under very favorable circumstances. A review of the literature, prior to the writing of this paper, failed to disclose any definite statement regarding the superiority of either method. In a re-

cent paper, however, it is to be noted that Lincoln Dryden (1) decries the practice of making comparisons between heavy minerals of differing grade size.

Over a limited area, there may exist between the mineral constituents of any one formation a distinctive quantitative relationship. This observation is supported by many successful correlations that have been made on the basis of mineral percentages. From a consideration of various data the writer has been convinced that quantitative comparisons made between heavy minerals which have been secured from unscreened sands may often be misleading and that sometimes similarities between samples may be obscured by apparently inexplicable differences in their mineral proportions. This conclusion was reached after the relationship between textural variation of a sediment and the change in percentage

composition of minerals with grade-size was recognized.

Sediments are known to change in texture even over relatively short distances, currents being one of the most vigorous among the numerous agents which produce such changes (2). In the case of some beach sands the textural variation may be considerable (3) and even for marine sediments a variance in texture is commonly observed (4). Coupled with this variable is the significant fact that percentages of heavy minerals are usually different in each of the grade-sizes of a sediment. This is well illustrated by the work of Hawkes and Smythe (5). See figure 1.

FIG. 1. Illustrating variations in mineral proportions with grain size. From Hawkes and Smythe (5).

With these two facts in mind, viz., variations in texture and variation in the mineral proportions for the different grades, it becomes evident that quantitative comparisons of constituents, if they are to have any significance, should be made only between materials of like size. An inspection of table 1 shows the extreme variation that sometimes occurs in the ratio between the same two minerals in slightly different grades. For the size between one-eighth and one-six-

TABLE I. Heavy mineral analysis of glaciolacustrine sands. From G. A. Thiel (6)
Per cent by number of grains.

Mineral	Size in mm.			
	$\frac{1}{8}$ – $\frac{1}{4}$	$\frac{1}{4}$ – $\frac{1}{2}$	$\frac{1}{2}$ – $\frac{3}{4}$	$\frac{3}{4}$ –1
Magnetite	—	—	1	40
Hornblende	96	94	84	37
Zircon	1	2	7	6
Tourmaline	—	1	1	—
Titanite	1	—	5	3
Apatite	—	1	2	14
Garnet	1	1	—	—
Biotite	1	1	—	—

teenth mm., hornblende bears the ratio to magnetite of 84:1, whereas in the portion under one-sixteenth mm. the ratio is 37:40. It is obvious that a sediment with a texture that varied even a small amount in the fraction under one-eighth mm. would show striking variations in its mineral proportions and consequently correlations would be difficult or impossible if comparisons between unscreened materials were made.

It should be remembered that the arguments presented here are applicable only to the problem that relates to quantitative and not to qualitative comparisons of minerals. The writer realizes that probably the greater proportion of correlation work in which heavy minerals are used is done by qualitative means, but it was felt that a knowledge of the precautions necessary for correlating on a quantitative basis should be emphasized.

PART II

Several methods are now in use for describing the petrographic character of sediments. Undoubtedly the simplest of these is the one in which quantitative data are disregarded and the description consists merely

of a list of the minerals that are present. This is sufficient for correlation purposes if each of the formations of a series is characterized by distinctive species of minerals. Yet even at its best it represents a rather incomplete petrographic analysis of a sediment.

A second method in common use, particularly among British investigators of sediments, is the quantitative representation of the mineral constituents by descriptive adjectives or numbers (7).

Of late the tendency has been toward greater accuracy in quantitative description and a scheme in which the mineral constituents of a sediment are represented as percentages of the heavy mineral crop is frequently employed.

It has been recognized by some workers that this method, although more accurate than the two previously described, leaves much to be desired. Invariably the percentage composition of one sample will differ in some degree from a second, even though each has been taken from the same stratum and within a short distance of one another. A higher percentage of a particular mineral in one of the samples is not necessarily an indication of a real increase in the quantity of that mineral. Such an effect may be a consequence of several factors. It might result from a diminution in the quantities of all but that one of the constituents represented, or it might be the consequence of a general decrease in the total crop of heavy minerals with a relatively lesser shrinkage in the amount of the one particular min-

eral, or it might be caused by a general increase in the crop with a commensurately greater increase for the one constituent. It is evident, therefore, that an increase in the percentage of a mineral may be a consequence of several different combinations of events. Hence, the method of heavy mineral representation which employs percentages that are functions of the total number of heavy grains counted gives an equivocal petrographic description of a sediment.

In an effort to remove some of the defects inherent in the system which has just been described, F. J. Pettijohn (8) proposed a scheme in which the amount of a particularly stable mineral was used as a base from which percentages of the other heavy constituents were calculated; e.g., he arbitrarily chose the amount of garnet present in each sample to represent 100 per cent. This method apparently rests on the premise that minerals which are relatively resistant to abrasion and decomposition occur rather uniformly distributed through a stratum—a proposition that in some instances may be open to doubt. Nevertheless, this method presents an unequivocal petrographic representation of the constituents of a sediment as a function of a particular mineral, although it fails to record general fluctuations of the entire heavy mineral crop when the quantity of the reference mineral varies proportionately as the mass.

A method of recording the actual numerical counts of the heavy constituents of a formation has also been used (9). This scheme is free from the

defects which have been ascribed to the other methods, but similarities between samples are often obscured by general fluctuations of the entire heavy mineral crop.

The writer, therefore, wishes to suggest a plan that is independent of the fluctuations of any minerals within a suite, that records quantitative variations of the entire heavy mineral crop, and that makes similarities between corresponding samples readily apparent. In this method, the first step is to secure a representative mineral analysis of the stratum with which it is desired to correlate. Where the work is not entirely of a subsurface nature, this is accomplished best by collecting several samples from a known outcrop and averaging their results. In detail the work would be as follows: About three samples within a linear limit of 10 feet along the strike of a stratum would be taken. These would then be screened and each sample split into its constituent grade-sizes. The heavy minerals would be separated from the different grades, classified as to species, and counted. A count of all the heavy mineral grains that had been separated from a given grade of sand would not be necessary. By the use of a miniature sample splitter (10), a known fraction of the heavy crop, suitable for counting, could be secured. The grain counts in every case would be reduced mathematically to represent the number of grains in a given weight of graded sand; e.g. 10, 25, or 50 grams. An average of the three samples would be taken as the standard for further comparisons. The average number of grains of each

mineral species secured in this fashion would then be assumed to equal 100 per cent for each of the species represented. All future comparisons would be made with the type sample, and the percentages of the various heavy minerals would be functions of the quantities present in the type sample.

The scheme is best made clear by an illustration. Let the sample which will serve as a standard possess in a 20 gram portion of a given grade-size a heavy mineral crop constituted as follows: 150 grains of A, 200 of B, 50 of C, 25 of D, and 100 of E. Let there be four samples which show, respectively, an increase of the entire crop (No. 1 in table 2), a shrinkage of the entire crop (No. 2), little deviation from the reference sample (No. 3), and a strong fluctuation in the quantity of only one mineral species (No. 4).

The table shows that when the proportions between the constituents of a sample are comparable to the proportions which exist in the reference specimen, the effect is to give percentages that are nearly alike for all five components. A general mass increase of the crop produces a percentage ranging over 100 per cent, while a diminution in the crop is indicated by percentages less than 100 per cent. A fluctuation in the quantity of a single component is immediately recognizable by a percentage which differs widely from that of the other constituents.

The proposed scheme lends itself conveniently to graphical representation when the mineral percentages are plotted on a logarithmic scale (see Fig. 2). The norm or reference

sample will always be represented by a horizontal line cutting the ordinate at 100 per cent. Curves of other specimens may lie either above or below the norm but as long as they re-

ples, it is suggested that they be listed in the table under the head of "Other Minerals" and that their percentages be calculated as functions of an arbitrarily selected base number.

TABLE II.—*Analysis of heavy mineral samples on the basis of a reference sample.*

No. of grains in 20 gms. of — mm. grade size							
Sample No.	A	B	C	D	E	Other Minerals	
						F	G
Reference Sample	150	200	50	25	100		
1	305	435	100	55	210		
2	100	140	35	16	66		
3	145	210	50	27	98		
4	155	204	125	28	95		
5	a	b	c	d	e	f	g

Per cent by no. of grains*							
	A	B	C	D	E	Other Minerals	
						F	G
Reference Sample	100	100	100	100	100		
1	203	218	200	220	210		
2	67	70	70	64	66		
3	97	105	100	108	98		
4	103	102	250	112	95		
5	$100 \cdot \frac{a}{150}$	$100 \cdot \frac{b}{200}$	$100 \cdot \frac{c}{50}$	$100 \cdot \frac{d}{25}$	$100 \cdot \frac{e}{100}$	$100 \cdot \frac{f}{k}$	$100 \cdot \frac{g}{k}$

$$* P = 100 \frac{n}{t} \text{ where}$$

P = per cent.

n = number of grains of a mineral species in a given amount of a selected grade size of sand

t = number of grains of a mineral species in the same amount of a selected grade size of sand from the reference specimen.

k = any arbitrarily selected constant.

main nearly horizontal they suggest a close correspondence to the reference sample. Wide deviations from the horizontal are generally indicative of significant fluctuations in the mineral percentages of the specimen.

In the event that new minerals should appear in some of the sam-

The primary purpose of the method that has been suggested is to furnish a means of description for sediments which is complete, unequivocal, and easily comprehended. It should also be useful where it is desired to correlate with some definitely known formation or stratum.

FIG. 2. Graphical representation of mineral percentages. (Note) Curve 3 is left out to avoid confusion of crowded curves.

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