RELATIONSHIP BETWEEN GRAIN SIZE AND HEAVY MINERALS CONTENT

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INTRODUCTION

A river has a definite drainage area and the sediment deriving from it reflects the lithology of the source area. Sediments transported by large rivers usually mostly exhibit substantially different compositions. The differences in the composition of deposited sediments do not only facilitate to distinguish different facies, but also permit to determine the distribution in space of juxtaposed and superimposed sequences of identical and/or different origin.

As a matter of course, the lithological conditions of the drainage area are reflected by the micromineralogical composition of river-transported (or -deposited) sands, particularly so, by the assemblage of minerals of a specific gravity greater than 2,88 — the so-called heavy minerals.

Heavy mineral analyses are often used in geological investigations. A number of applications other than locating source areas are known. For instance, if used in ore prospecting by drilling in a grid pattern, they promote the determination of trends in metallization. Coal prospectors can use the characteristic heavy minerals compositions of barren rocks for the identification of coal seams. Hydrocarbon prospectors can use the method for locating reservoir structures; prospectors for subsurface waters can locate aquifers on the basis of the same results.

In many cases, single heavy minerals play the role of tracers associated with the commercial mineral being prospected. As a matter of fact, they are more common — and possibly more easily determinable — than the latter, thus being of good help in locating the deposit being prospected. An additional application is to use the method for studying the history of palaeohydrography of an area or for separating sedimentary and pyroclastic members within a sedimentary sequence.

Despite the multitude and high frequency of applications, many workers suspect that potential errors may lead to distortion of facts. Criticism against the distorting effect of changes in grain size has been enounced by a particularly great number of authors. Accordingly, when always the same fraction of sediments of identical origin is examined (what is mostly the case in routine work), the results obtained may prove different for a sediment of fine grain size and for a coarse-grained one. This fact, however, may lead the student to assume suggest different source areas for the two cases.

Not even the most important relevant papers do discuss this problem in sufficient detail. The interrelations of grain size and the abundance of quartz, magnetite and tourmaline — i. e. of three minerals only — were discussed theoretically, as deduced from STOKES' law, by W. W. RUBEY, [1933]. As shown by that author, magnetite having a high specific weight appears in the finest layer of a sediment of the 0,125 to 8,0 mm size range as early as the sample still lacks quartz, a mineral of lower specific weight. Magnetite has its concentration peak in the finer grained fraction (0,6 mm ∅), whereas quartz has it in the coarser one (1,0 mm ∅). The specific weight of tourmaline is intermediate between the two former minerals, thus its concentration peak can be found, correspondingly, between the two — at 0,9 mm ∅.

L. HAWKES and A. J. SMYTHE, [1931] examined the quantitative changes of the minerals of sea-shore sands of the 0,127 to 0,317 mm grain-size range as distributed among the different fractions. It is interesting in the results of these authors that garnet, though having a specific weight higher than that of feldspar and quartz, tends to increase towards the coarser fractions instead of doing so towards the finer ones, a fact probably due to the particular character of the source area and to the higher resistance of garnet. The investigations of A. VENDL, [1954] were confined to the relationship of grain-size and mineral composition of materials finer than sands, chiefly clays.

Other papers touching upon the subject include but occasional hints at relations between grain composition and heavy mineral composition [J. K. HSU, 1960; F. P. SHEPARD and D. G. MOORE, 1960; F. P. SHEPARD, 1960; A. MIRSKY, 1961; R. L. MCMASTER, 1962; T. H. VAN ANDEL, 1964/a, 1964/b; A. KODYMOVÁ, 1966].

The present paper aimes at contributing to the solution of the problem and at selecting, on the basis of the information available, that grain fraction whose analysis may yield the most reliable and valuable data as to the characteristics of the heavy mineral composition.

SAMPLING

In the present study preference had to be given to samples deriving assuredly from one and the same source area, comprising a wide range of size fractions and the greatest possible number of heavy minerals. What may fit

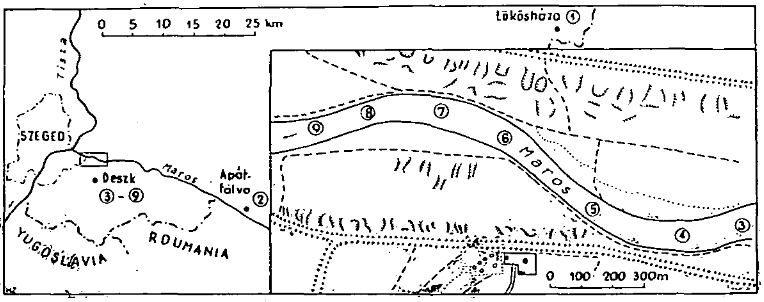

Fig. 1. Location map of sampling points

this condition best of all seems to be sediment transported and or deposited by a present-day river. Our choice fell on the Maros River [B. MOLNÁR, 1964/a; 1964/b].

Sample No *1* was collected at Lőkösháza, at 120 km or so from the mouth, from Latest Pleistocene deposits of the Maros River *(Fig. 1).* The source area of the river has not changed since the end of the Pleistocene [B. MOLNÁR, 1964/b, 1965/b]. Thus the coarser grain fraction, absent in the river bed, could be sampled here and used for the present analysis. Sample No *2* was taken in the river bed, at 50 km from Apátfalva; Samples No *3* to No *9* were taken in the river bed at Deszk, 3 km away from the mouth *(Fig. 1).*

GRANULOMETRIC ANALYSIS

The samples were analysed by sieving, and Sample *9* was also examined by the method of hydrometry. The results are shown in *Fig. 2* and Table I. The median diameter *(Md)* of the nine samples varies between 0,073 and

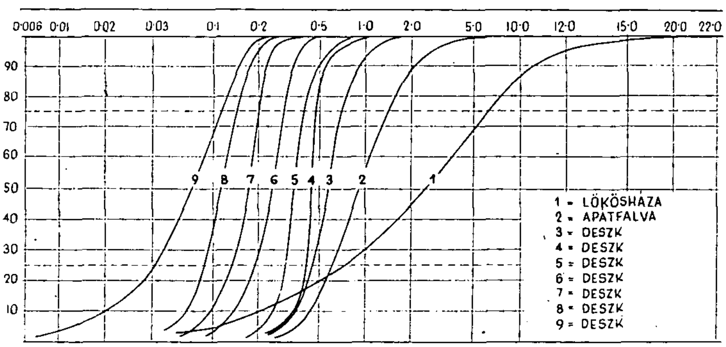

Fig. 2. Granulometric curves of the examined samples

2,5 mm. The coarsest sample (No *1*) is a gravelly coarse sand; the prevalent fraction of its grains is between 1,0 and 10,0 mm. That of Samples *2* and *3* is between 0,5 and 2,0 mm (Sample *3* being characterized by the same); consequently, both are coarse sands. In Samples *4* to *6* the medium grains, 0,2 to 0,5 mm ∅, are predominant.

Samples *7* and *8* are constituted by small sand (0,1 to 0,2 mm), whereas Sample *9* is a fine sand including a maximum of 40% of grains finer than 0,2 mm. All the analysed sands but the coarsest sample are well-sorted.

The nine samples comprise all grain fractions which may potentially be encountered in a heavy mineral study. A sediment coarser than the above does, in fact, rarely contain a grain fraction analysable with a mineralogical microscope and may abound in rock fragments. On the other hand, it is but in case of emergency, in absence of a coarser sediment in the formation, that a sediment finer than Sample *9* must be analysed. The results of such an analysis, however, do not stend up suit to closer scrutiny.

TABLE I.

Granulometric analyses of the examined samples

Number	Percentages of the different fractions (mm ∅)						*Md* in mm	*So*
	< 0,06	0,06—0,1	0,1—0,2	0,2—0,5	0,5—2,0	2,0 <		
1 (Lökösháza)	3,0	2,0	5,0	10,0	25,0	55,0	2,5	2,92
2 (Apátfalva)	0,0	0,0	0,0	15,0	74,0	11,0	0,92	1,55
3 (Deszk)	0,0	0,0	0,0	35,0	65,0	0,0	0,59	1,24
4 (Deszk)	0,0	0,0	0,0	83,0	17,0	0,0	0,45	1,08
5 (Deszk)	0,0	0,0	4,0	86,0	10,0	0,0	0,34	1,16
6 (Deszk)	0,0	3,0	26,0	71,0	0,0	0,0	0,25	1,23
7 (Deszk)	2,0	10,0	58,0	30,0	0,0	0,0	0,18	1,24
8 (Deszk)	7,0	30,0	58,0	5,0	0,0	0,0	0,12	1,28
9 (Deszk)	40,0	27,0	32,0	1,0	0,0	0,0	0,073	1,73

Table II.

Heavy mineral content of the samples

	Locality	Fraction in mm	Dominantly Magmatic Minerals: Hypersthene	Other Ortho-Rhombic Pyroxenes	Augite	Diopside	Basaltic Hornblende	Magnetite Ilmenite	Biotite	Apatite	Titanite	Zircon	Chlorite	Turmaline	Dominantly Metamorphic Minerals: Zoisite	Rutile	Hornblende	Actinolite-Tremolite	Garnet	Staurolite	Kyanite	Other Minerals: Calcite-Dolomite	Limonite	Weathered Minerals	Median diameter (*Md*) in mm
1.	1 (Lökösháza)	0,06—0,1	12,9	2,2	18,3	2,2	6,7	25,0	1,8	1,3	1,3	0,5	7,6	0,5	—	—	6,7	—	7,6	0,5	—	—	1,3	3,6	2,5
2.		0,1 —0,2	18,2	0,9	14,1	0,3	4,6	20,0	2,8	0,9	0,9	0,3	9,8	—	0,3	0,6	5,5	0,6	10,7	0,6	0,3	—	0,3	8,3	
3.		0,2 —0,32	12,1	0,4	18,5	1,9	2,3	15,4	1,5	0,4	—	—	12,5	—	—	—	6,8	0,4	7,6	1,1	2,3	0,8	0,8	15,2	
4.		0,32—0,63	11,2	—	18,6	1,2	2,3	17,1	1,9	—	—	—	10,1	0,4	—	—	1,9	—	11,2	0,4	0,4	1,6	—	21,7	
5.	2 (Apátfalva)	0,1 —0,2	16,2	2,3	14,8	1,6	5,2	15,7	1,3	1,6	0,3	—	7,2	—	—	—	9,2	0,3	14,1	—	0,3	3,0	0,3	6,6	0,92
6.		0,2 —0,32	15,9	1,2	18,9	0,4	3,7	12,2	0,4	1,2	—	—	5,7	—	—	—	5,7	—	16,3	—	1,6	2,9	0,4	13,5	
7.		0,32—0,63	6,9	0,5	11,2	—	0,5	16,5	3,2	—	—	—	30,9	—	—	—	2,1	—	9,6	—	1,1	0,5	—	17,0	
8.	3 (Deszk)	0,06—0,1	9,3	4,3	10,9	4,3	5,4	20,5	0,8	2,7	0,8	—	1,6	—	1,2	1,2	8,2	—	21,0	0,4	0,4	1,2	0,8	5,0	0,59
9.		0,1 —0,2	9,8	2,3	22,7	2,7	6,4	12,8	0,4	1,1	0,8	—	9,8	0,8	0,4	—	11,4	—	5,3	0,4	0,4	0,4	0,4	11,7	
10.		0,2 —0,32	19,8	1,3	26,3	0,9	5,2	10,8	1,3	0,4	—	—	4,3	—	0,4	0,4	2,2	0,4	18,5	0,9	—	0,4	0,9	5,6	
11.		0,32—0,63	8,6	—	16,7	—	2,7	22,6	2,7	—	—	—	17,7	0,5	—	—	3,8	—	2,7	—	1,6	—	—	20,4	
12.	4 (Deszk)	0,06—0,1	12,9	3,7	10,2	4,1	3,4	22,9	1,4	3,1	0,7	—	0,7	0,7	0,3	0,7	7,1	2,0	18,0	0,3	—	0,3	1,4	6,1	0,45
13.		0,1 —0,2	17,8	1,5	15,2	1,9	4,5	15,1	3,4	0,4	—	—	4,9	0,8	0,4	0,4	10,2	0,8	13,6	0,4	0,8	—	—	7,9	
14.		0,2 —0,32	18,8	3,0	24,0	1,7	3,0	10,9	—	0,4	—	—	3,0	—	0,4	0,4	8,3	—	8,3	0,4	0,4	0,4	0,4	16,2	
15.		0,32—0,63	2,7	1,4	12,9	0,7	1,4	25,2	2,0	—	—	—	19,7	—	—	—	2,0	—	—	—	0,7	—	2,7	28,6	
16.	5 (Deszk)	0,06—0,1	11,4	2,6	14,3	4,8	4,0	26,5	4,4	0,7	0,7	—	5,5	0,4	1,1	—	7,0	0,7	8,5	—	—	1,5	1,5	4,4	0,34
17.		0,1 —0,2	11,2	2,1	21,3	3,8	9‘6	13,3	1,7	0,8	0,4	—	7,5	0,4	0,8	—	5,8	1,3	4,6	0,4	—	1,3	0,8	12,9	
18.		0,2 —0,32	7,7	—	9,8	0,5	3,6	19,2	7,2	0,5	—	—	12,4	—	—	—	6,2	1,0	1,0	—	1,5	1,0	0,5	27,9	
19.		0,32—0,63	6,1	—	6,1	1,7	0,9	24,3	13,9	—	—	—	20,8	0,9	—	—	3,5	—	0,9	—	0,9	0,9	—	19,1	
20.	6 (Deszk)	0,06—0,1	14,8	2,3	11,7	3,4	6,8	18,5	1,1	1,5	2,3	0,8	2,7	1,5	1,1	0,4	9,1	0,8	15,9	—	0,8	1,5	1,1	1,9	0,25
21.		0,1 —0,2	15,2	1,9	21,3	1,9	8,8	11,5	0,8	1,9	0,4	—	5,7	—	0,4	0,4	7,6	2,3	5,7	1,2	0,8	1,9	0,4	9,9	
22.		0,2 —0,32	5,0	3,0	21,2	1,0	7,5	12,6	7,0	0,5	0,5	—	6,5	1,0	—	—	7,0	1,0	1,5	—	—	2,5	1,5	20,7	
23.		0,32—0,63	6,3	2,4	10,1	—	4,8	12,6	10,6	0,5	—	—	14,5	0,5	—	—	8,7	—	2,4	—	0,5	0,5	2,4	23,2	
24.	7 (Deszk)	0,06—0,1	12,1	3,3	15,2	4,2	5,1	16,2	0,5	2,8	0,5	—	0,5	1,4	0,9	0,5	7,4	1,9	15,3	0,5	—	0,5	2,8	8,4	0,18
25.		0,1 —0,2	10,1	1,6	17,0	3,6	11,7	8,9	3,2	1,6	0,8	—	8,5	0,4	—	—	9,3	2,4	2,8	0,4	0,4	1,2	0,8	15,3	
26.		0,2 —0,32	2,9	0,4	7,8	0,8	4,5	14,3	11,1	—	—	—	15,2	—	—	0,4	6,1	0,4	0,4	—	—	0,4	2,0	33,3	
27.		0,32—0,63	1,6	—	3,1	1,6	1,6	7,8	32,8	—	—	—	42,1	—	—	—	3,9	0,8	0,8	—	—	—	—	3,9	
28.	8 (Deszk)	0,06—0,1	9,3	4,0	20,8	4,4	3,5	16,7	4,0	2,6	2,2	—	2,2	0,9	1,3	1,3	5,7	1,3	11,0	—	0,4	1,8	1,8	4,8	0,12
29.		0,1 —0,2	11,2	2,4	14,7	2,8	9,7	14,4	3,2	0,8	0,8	—	5,6	0,4	0,4	0,4	11,2	2,0	6,0	—	0,4	2,4	0,8	10,4	
30.		0,2 —0,32	4,5	0,5	4,5	0,5	4,5	20,7	31,3	0,5	—	—	23,0	—	—	—	2,8	1,7	—	—	—	0,5	—	5,0	
31.		0,32—0,63	1,4	—	—	—	4,1	4,1	62,1	—	—	—	21,5	—	—	—	6,8	—	—	—	—	—	—	—	
32.	9 (Deszk)	0,06—0,1	12,7	2,5	16,6	0,5	6,4	16,2	2,9	3,4	2,9	—	2,5	0,5	—	1,5	5,4	1,0	12,7	0,5	1,0	1,0	2,0	7,8	0,073
33.		0,1 —0,2	11,0	1,8	13,9	2,2	10,1	13,1	4,4	0,9	0,4	—	7,5	0,9	0,4	—	8,8	1,3	6,1	—	0,4	1,8	1,8	13,2	
34.		0,2 —0,32	0,5	—	5,9	0,5	4,5	17,6	30,2	—	0,5	—	25,7	—	—	—	7,2	0,9	0,5	—	0,5	0,5	0,5	4,5	
35.		0,32—0,63	—	—	1,9	—	—	7,5	66,1	—	—	—	13,2	—	—	—	3,8	—	—	—	—	—	—	7,5	

The selected fractions were separated in bromoform into minerals of a specific gravity higher than 2,88 and into one of a lower specific gravity. The separated heavy minerals were put on an object plate and studied under a mineralogical microscope.

According to W. A. P. GRAHAM, [1930], in a heavy mineral analysis it is enough to determine 100 grains to obtain satisfactory result. This statement is wrong, as at least 150 grains have to be examined, as found earlier by the author [B. MOLNÁR, 1959], in order that the question of origin may be answered. The determination of 100 grains may prove sufficient in the case when only a few species of heavy minerals are present in the sample. Should this be the case, so even the determination of fewer grains will give correct values as to the percentage distribution of the mineral grains. W. A. P. GRAHAM, [1930] too found a total of nine mineral species in the sample examined.

According to A. L. DRYDEN, [1931] the accuracy of the results will increase with the square root of the number of grains counted. This author has stated, however, that potential errors will markedly decrease, if the number of counted grains is higher than 300. Therefore, the author determined nearly 300 grains in his own studies.

Another requirement is to examine at least two size fractions of the sample when heavy minerals are considered. W. W. RUBEY, [1933] has suggested to keep one of the two constant in all of the samples and to select the other fraction so that it may have the same relative position within the total size range (e. g. smaller than the median) in all samples.

The resultant values of the heavy minerals indicate the rations of the mineral grains counted. In other words, the percentage frequencies of the minerals, rather than their volume or weight percentage composition, will be obtained. *Nota bene,* there is a difference in the specific gravity of the individual minerals; (for instance, it is only as to the number of occurrence that the same percentage of two minerals of different specific gravity in the sample agree with each other).

The actual heavy mineral content of Maros River sands, i. e. the gravity of the heavy minerals as compared to the rest of the minerals, is already known from earlier studies: 1 to 5% in dependence on the grain composition. If considered in one and the same sample, this figure increases from the coarser fractions towards the finer ones, varying between 1 and 20% [J. MEZŐSI and E. DONÁTH, 1951; B. MOLNÁR 1963, 1964/a, 1964/b, 1965/a, 1965/b, 1966, 1968].

However, this is not necessarily true for all types of sediment. G. WOLETZ, [1958] discussed a sand in which the heavy minerals exhibit the highest abundance in a fraction other than the finest.

With the exception of Sample 2 — in which the 0,06 to 0,1 mm fraction was absent — the heavy mineral composition of four fractions (still examinable under the mineralogical microscope) were examined in each sample on the basis of the determination of nearly 300 grains, as mentioned above (Table II). The maximum of the mineral species identified was 21. Because of the knowledge of the lithological composition of the source area, the minerals could be classed according to their source, too. Out of the 21 minerals, the number of minerals of more than 5% ratio was as low as 7. The unidentifiable, altered,

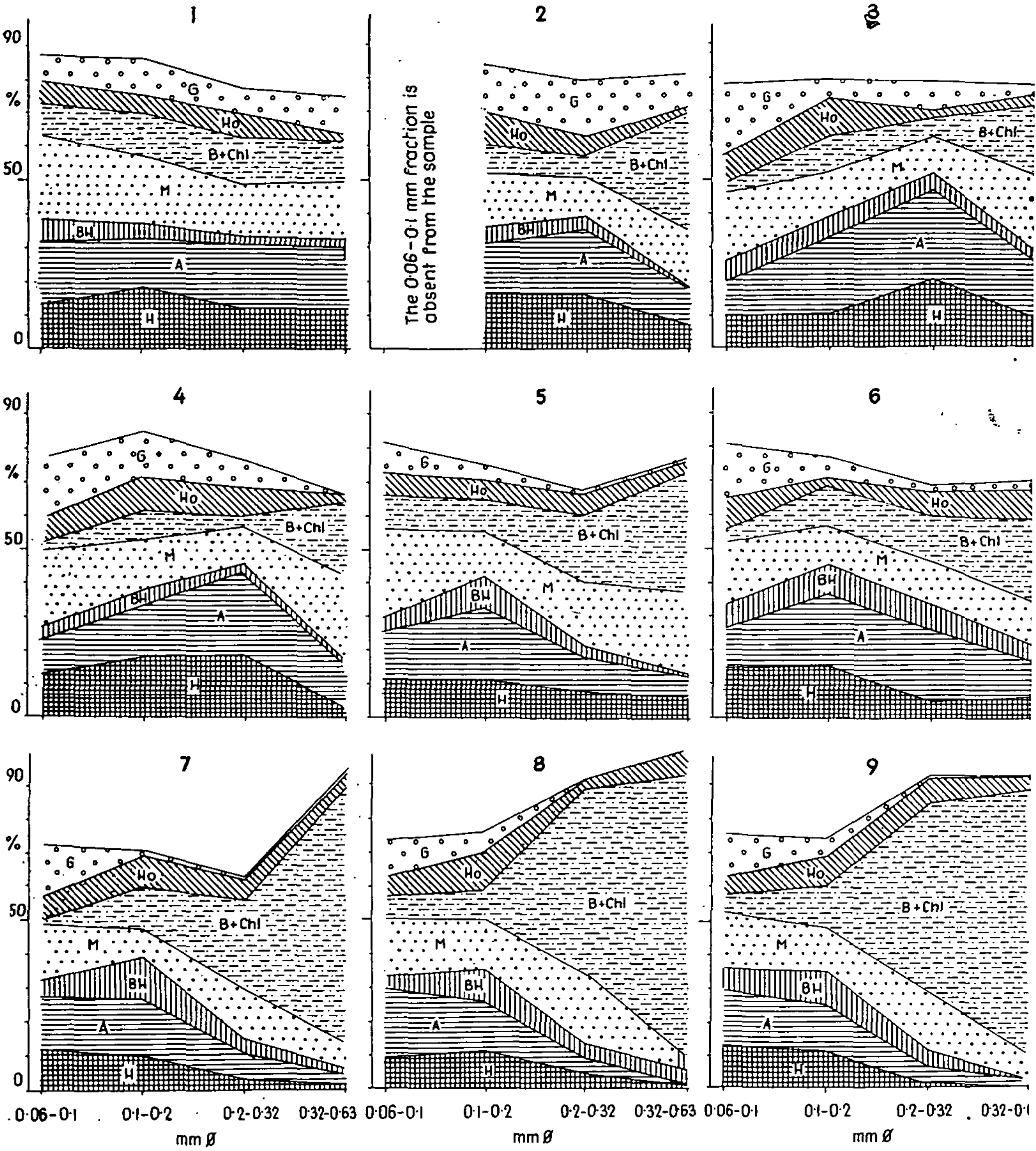

Fig. 3. Percentage distribution of heavy minerals predominant in the various fractions of Samples *1* to *9*

H: *Hypersthene*
A: Augite
BH: Basaltic Hornblende
M: Magnetite
B + Chl: Biotite + Chlorite
Ho: Hornblende
G: Garnet

minerals were, of course, disregarded during the determination of the origin.

1) The quantitative distribution of the 7 most important heavy minerals by samples and fractions is shown in *Fig. 3.* In Sample *1,* representing a sediment of coarsest grain composition, it is evident that the 7 minerals show the same percentage ratio in the various fractions. In Samples *2* to *6,* representing coarse to medium sands, there are, however, marked fluctuations in the correlative percentage rations of the same minerals in the various fractions. Magnetite and garnet rise slightly above the average as compared to the samples of finer grain composition. In Samples *7* to *9* (fine to finest sands)

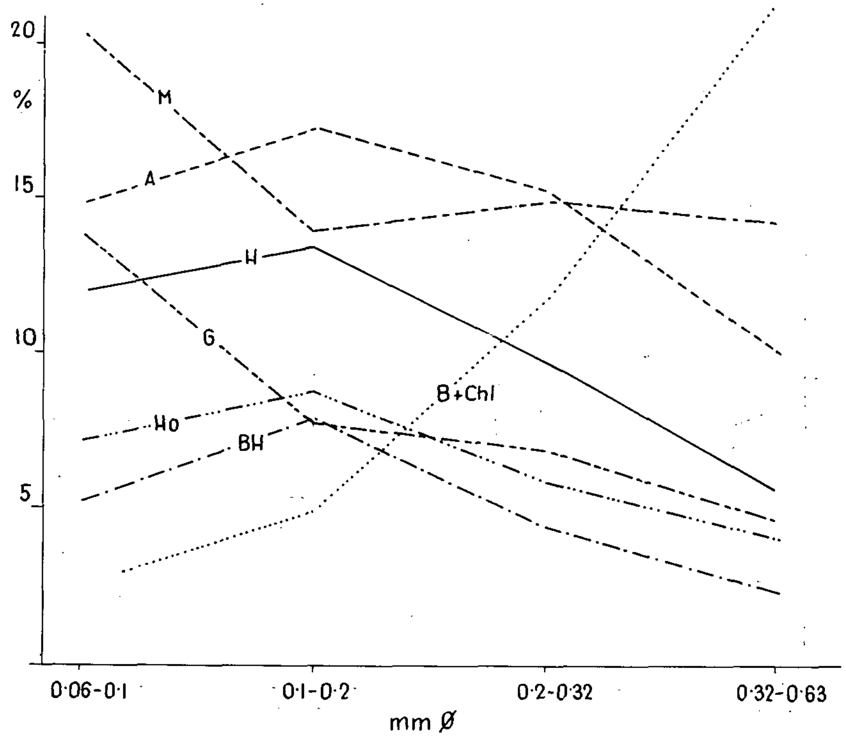

Fig. 4. Percentage values of heavy mineral averages as found in the various fractions of Samples *1* to *9* (for legend, see Fig. *3*)

these differences become further accentuated. The coarser fractions of these samples have a composition other than the finer fractions have. The difference is due, in the first place, to the high percentage of biotite and chlorite.

Hence, whichever fraction of a coarse sand should be examined, the results will be the same; in case of medium sands they are still acceptable, but the finer fractions of both coarse and medium sands are characterized by a slight rise of the abundance of magnetite and particularly of garnet, exceeding the average. In case of small and fine sands, it is only the 0,06 to 0,2 mm fractions that yield evaluable results.

2) Fig. 4 shows the average values of the 7 most frequent minerals, as counted in the various fractions of the nine examined samples. Proceeding from the finer fractions towards the coarser ones, one can see a break in the average of every mineral at the 0,1 to 0,2 mm fraction. The average of magnetite and garnet shows a strong increase as compared to the average of the rest of the minerals in the finer fractions. In fractions coarser than 0,1 to 0,2 mm, magnetite does not exhibit any essential change, the averages of the other minerals diminish, while mica is multiplied: in the 0,2 to 0,32 mm fraction it is close to 12% (in contrast wit the 5% found in the previous fraction), to become as high as 22% in the 0,32 to 0,63 mm fraction.

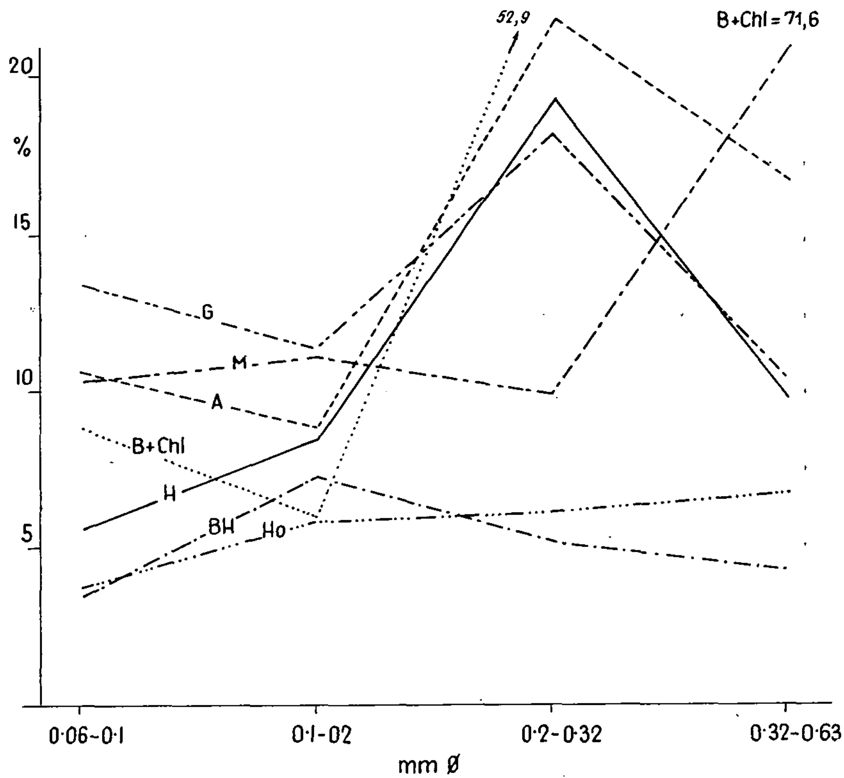

Fig. 5. Divergences between the lowest and the highest percentage abundances of the heavy mineral grains abundant in the various fractions of Samples *1* to *9* (for legend, see Fig. *3*)

3) Fig. 5 illustrates the differences of the frequencies of the same *7* minerals, as reflected by the contrast between the smallest and the largest mineral percentage in the different fractions and mineral types. For instance, the lowest hypersthene percentage of the 0,06 to 0,1 mm fraction is in Sample *8* (9,3%), the highest (14,8) in Sample *6*; hence, the difference between the two equals 5,5%.

These differences are not insignificant in the 0,06 to 0,1 and 0,1 to 0,2 mm fractions, either; but here they may remain subconstant for particular minerals. The higher the percentage of a mineral (in terms of grain number) in the various samples, the more striking the difference between the extreme values of occurrence. For instance, hypersthene is present in all samples and in most of the fractions in a higher percentage than this is the case with basaltic hornblende; hence, the divergence between the highest and lowest percentage values of the hypersthene grains is also higher, even as distributed among the various fractions, than that of basaltic hornblende.

From the fraction 0,2 to 0,32 mm towards the coarser fractions, however, the divergence of extreme values will show a sudden increase and become rather unsteady for the minerals other than basaltic hornblende, hornblende and a part of magnetite. Out of the rest of the minerals it is biotite and chlorite that is prominent, being characterized by a particularly marked increase of abundance: to above 71% in the 0,32 to 0,63 mm fraction as contrasted against the figure as low as 6% in the 0,1 to 0,2 mm fraction and as high as 53% in the 0,2 to 0,32 mm fraction. Consequently, it is only one of the finer fractions that can come into consideration in heavy mineral analyses.

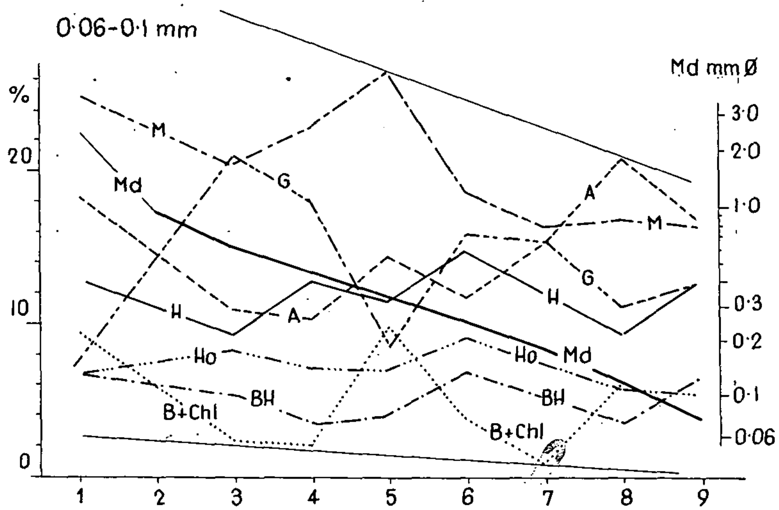

Fig. 6. Percentage abundances of predominant heavy mineral types in the 0,06 to 0,1 mm fractions of the examined samples (for legend, see Fig. *3*)

4) The minor minerals may in many a case be very important for the determination of the mineralogical composition of the sediment, as they may serve as indicators of certain characteristics geological features. During the present study these minerals were found to be mainly confined to the finer fractions (Table II), though occasionally they were absent even here, a fact due to the lower frequency of their occurrence. In the coarser fractions they were totally absent in most cases.

The abundance of altered minerals is often dependent on dia- and epigenetic processes, providing no information as to the proper origin of the sediment. In case of the correlation of two sequences, however, it may prove a useful tool for strata identification, if there are layers differing altered mineralization from the rest of the sequence.

Accordingly, in the first 6 samples (Samples *1* to *6*) examined, i. e. in coarse and medium sands, the amount of altered minerals usually increases from the finer towards the coarser fractions. In small and fine sands (Samples *7* and *8*) the examined finest and coarsest fractions are characterized by a lower, the intermediate fractions by a higher, abundance of altered minerals.

Consequently, the results hitherto presented testify that the actual heavy minerals composition of the individual samples can be approximated in the case, when one of the finer fractions of the sample is examined.

5) Figs. 6 to *8* indicate the variation of the heavy mineral conent of a single fraction of each analysed sample. In the following discussion the percentage occurrence of grains of the predominant heavy mineral species in single fractions of samples of different grain composition will be considered. *Nota bene*, what is commonly of interest is not the heavy minerals composition of an individual sample, but to find out – by analysing one and the same fraction of several samples by the aid of serial analysis – wether the results to be obtained in case of identical origin are the same or (should the origin happen to be doubtful) the data can be intercorrelated.

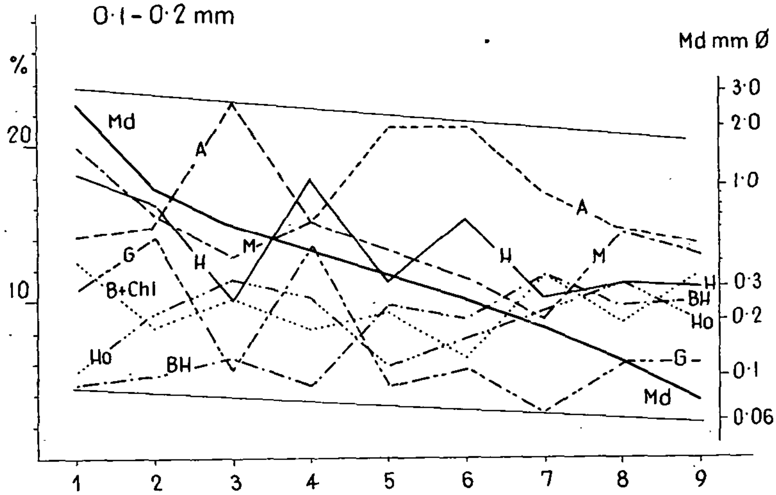

Fig. 7. Percentage abundances of predominant heavy mineral types in the 0,1 to 0,2 mm fractions of the examined samples (for legend, see Fig. *3*)

Fig. 6 shows the percentage distribution of the heavy mineral grains predominating in the 0,06 to 0,1 mm fraction of the 9 samples as well as the median diameter values obtained for the individual samples *(Md)*. The area of the percentage plots of mineral grains has been delimited by two straight lines. These are divergent towards the coarser fractions, touching the magnetite and augite curves at the top and the garnet curve at the bottom.

On *Fig 7* the percentage distribution of the heavy mineral grains of the 0,1 to 0,2 mm fraction has been represented in the same way. Here the two tangent lines are subparallel, embracing a belt substantially narrower than in the former fraction. This means that in this fraction the fluctuations of the indvidual mineral percentages are less marked. The slight growth of area observed towards the coarser samples is an evidence of the increasing abundance of the predominant minerals.

In *Fig. 8* the percentage occurrences of heavy mineral grains in the grain size range of 0,2 to 0,32 mm have been represented. The tangent straight lines here converge towards the finer samples (in contrast with the fraction of 0,06 to 0,1 mm), delimiting a considerably larger area than those shown in the previous figures, a fact due to fluctuations in the abundances of the predominant minerals.

Thus, the values of the coarsest fraction, 0,32 to 0,63 mm, could not be represented. It should be noted that in this fraction even the 7 predominant minerals were not fully represented in many cases. Therefore this fraction cannot come into consideration.

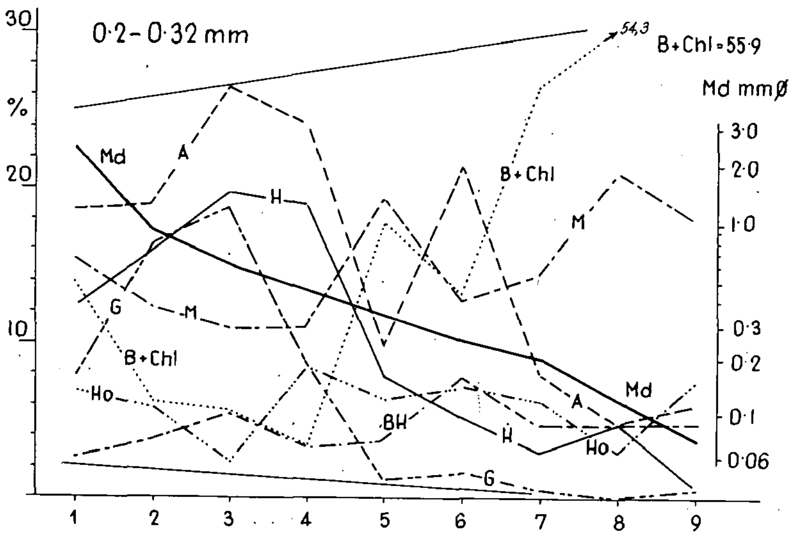

Fig. 8. Percentage abundances of predominant heavy mineral types in the 0,2 to 0,32 mm fractions of the examined samples (for legend, see Fig. *3*)

CONCLUSIONS

As suggested by a comparison of Samples *6* to *8*, finer fractions are characterized by a divergence of the percentage of mineral grains towards the coarser samples, the coarser fractions are so towards the finer samples when the heavy mineral composition of sediments of different grain composition are examined. The intermediary, 0,1 to 0,2 mm, fraction yields the most favourable averages. The peak of garnet and magnetite, observable in the finer fractions, (0,06 to 0,1 mm) cannot yet be observed here. On the other hand, the increase of the abundance of mica, characteristic of the coarser fractions, cannot be observed, either.

It can be stated that the results obtained for the 0,1 to 0,2 mm fraction of samples of different grain sizes are readily comparable with one another and that the problem of source of the sediment can be settled on the basis of these data.

The results of the present study are in complete agreement, with respect to magnetite, with those calculated theoretically by W. RUBEY, [1933]. Here too, the abundance of magnetite showed an increase towards the finer fractions. The enrichment of mica in the coarsed fractions is also due to deposition in the liquid. Having a very large surface as compared to their specific gravities, the mica grains remain suspended for a long time and are more easily kept in motion by the river. This is the reason why they will settle with the coarser sand fraction.

In contrast with the results of L. HAWKES and A. J. SMYTHE, [1931], the abundance of garnet showed an increase towards the finer fractions and such an increase has been common for all the Hungarian results of heavy mineral analyses. Beside the fairly high specific gravity (3,5—4,5), this phenomenon is also connected with the resistance to weathering of the garnet grains.

Consequently, the results of heavy minerals determinations can be best correlated when the predominant grain diameter of the examined sediment is within the 0,15 to 0,25 mm range. Grain composition implies some limitation to the method. Therefore, it is not advisable to use it mechanically. For instance, it would be unreasonable to analyse and correlate, in a sedimentary sequence, every fine-grained sample containing the 0,1 to 0,2 mm fraction in a few per cent only.

Should the method be used under such conditions, so e. g. the coarser, transgressive member of a sedimentary sequence would show a completely different composition than the later deposited, finer-grained member, even if the source area did not change in the meantime. Hence, the only solution is to select layers of subequal grain diameter for analysis. If this is impossible and if there is little difference in grain composition among the samples (e. g. fine-grained and medium-grained sands), one has first to scrutinize the percentage variation of the minerals present. Conclusions can be drawn after this has been done. However, it is by no means reasonable to compare the composition of a differently grained sediment — the less so a fine-grained one (slightly sandy silt) — with the composition of a coarse sand or of a sediment of even coarser fraction; nor is so to infer any actual difference therefrom.

SUMMARY

If the heavy minerals composition of a coarse-grained material with a median of > 0,5 mm is examined, any of its grain-size fractions will yield results corresponding exactly to the composition of the entire sample. Although medium sands (0,2 to 0,5 mm) exhibit some slight fluctuation of mineral percentages in the various size fractions, the values are acceptable. In case of small to fine sands (predominant grain diameter: from 0,06 to 0,2 mm), however, it is merely the fractions of the 0,06 to 0,2 mm range that yield evaluable data.

Should a sediment comprising a wide range of grain size from fine sand to granules, be analysed for heavy minerals, the results cannot be compared with one another unless the fractions of the 0,06 to 0,2 mm range are considered.

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