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A COMPARISON OF TWO METHODS FOR CONVERTING GRAIN COUNTS TO WEIGHT PERCENT COMPOSITION*

By

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By R. C. Kellagher and F. J. Flanagan

ABSTRACT

Differences in experimental weight percent composition obtained in a recent study of sampling methods, when compared to the known composition of the original sample, have led to the reassessment of the method of computing weight percent composition from grain counts. The concept of average weight per grain of each mineral was used in place of the frequently used specific gravity factor method. The differences in the results calculated by specific gravity factors and by average weights per grain are shown to be statistically significant. Comparison of the mean percentages of the minerals shows that the results obtained using the concept of average weight per grain are the best estimates of the known weight percent composition.

INTRODUCTION

In connection with recent studies of monazite sands of the southeastern United States a large number of samples was collected for grain count analysis by the U. S. Geological Survey on behalf of the U. S. Atomic Energy Commission. An investigation of sample splitting methods (Flanagan and Kellagher, 1955) used in this monazite program provided grain counts of prepared test samples. Comparison of the weight percent composition of these test samples as calculated from the grain counts with the actual sample compositions showed serious discrepancies and indicated that substantial errors might be caused by the method of calculating weight percent composition from grain counts.

For expediency in the majority of geologic investigations the weight percent composition of sized, mixed, mineral aggregates is obtained from a grain count of small portions of the sample. This grain count is used as a measure of the volumes of the minerals contained in the sample and is converted to weight by multiplying by the respective mineral densities according to the relation, weight = volume x density.

It is apparent that the accuracy of these weight determinations depends upon the assumption that all of the mineral grains are of equal volume. However, differences in volume due to shape, degree of roundness, and relative size among minerals cannot be ignored and attempts have been made to evaluate their effects and to apply correction factors which would yield more accurate results.

Grout (1937) determined the effect of fragment shape in a test in which sized garnet and biotite were compared by weight percent composition and grain frequency, and he concluded that perhaps the platy minerals should be separated and weighed instead of counted. He also directed attention to the importance of the relative grain size of the minerals in computations of this type and concluded that procedures for this work should be standardized.

Chayes (1946), following the suggestion of Grout that flaky minerals be separated and weighed, has prepared a table showing average specific weights of some 15 mineral specimens compared to a specimen of beryl (from Acworth, N. H.) with an assumed value of 1. He also computed, using -100+200 mesh material, apparent or average grain weights of calcite and muscovite in a series of mixtures of these two minerals.

Inspection of the sized samples used in the sample-splitting tests showed differences in the average size and shape of the three minerals. In view of these differences we have extended the idea of apparent grain weight proposed by Chayes using calcite and muscovite to granular minerals to minimize errors due to unknown shape and size factors.

SAMPLES AND SAMPLING

Three samples weighing 5, 10, and 20 grams were used in the sample splitting tests. They were prepared mixtures of quartz (Q), ilmenite (I), and monazite (M) in a weight ratio of 1:2:2. All of the minerals in the samples were sized to -80+100 mesh and weighed to the required amount before mixing. The three methods of sample splitting were the microsplit, the cone splitter (Kellagher, 1953), and hand-quartering.

To obtain a grain count the sample was reduced to counting size (approximately 700 grains) by the three methods of sample splitting and each final split counted in its entirety using a binocular microscope. A split was taken from each sample by each method three times and the splits counted by one operator A, the grain count checked by operator B, and the split returned to the original sample before resplitting. The grain counts are shown in table 1.

The procedure for obtaining the grain frequencies may vary depending on the mesh size and the amount of sample to be counted, but in most cases it consists of counting for reasonable precision a minimum of approximately 300 grains (Dryden, 1931) from a randomly selected field of a mounted specimen. The specific gravity values assigned to each of the minerals are usually obtained from tables which list the specific gravity as an upper and lower limit.

To obtain the weight percent composition grain counts on frequencies and densities are substituted in the equation,

$$(\text{Weight percent})_n = \frac{F_n d_n}{\sum_{i=1}^{n} (F_i d_i)} \times 100$$

where F is the grain frequency and d is the specific gravity of the minerals.

GRAIN CHARACTERISTICS

Serious differences are possible between the actual mineral volume and the volume represented by the grain frequency. As the grain counts cannot be altered, correction for these differences must be made in the density factor of the equation and must include correction for specific gravity as well as for those mineral properties that influence volume. Another factor of importance affecting the volume is the size distribution of the minerals within a mesh size. An inspection of the mineral grains shows that there are differences in shape and roundness, from one mineral to another that would seriously

Table 1.--Grain counts of splits of three samples.

Method	Split	Operator	5 g				10 g				20 g			
			Q	I	M	Total	Q	I	M	Total	Q	I	M	Total
Microsplit	1	A	219	145	243	607	157	326	190	673	311	233	299	843
		B	223	144	243	610	174	328	190	692	310	232	292	834
	2	A	321	315	224	860	216	377	272	865	186	195	160	541
		B	340	330	230	900	198	374	268	840	180	209	149	538
	3	A	162	180	107	449	139	185	135	459	322	328	205	855
		B	166	183	108	457	133	185	132	450	310	328	209	847
Cone splitter	1	A	357	339	219	915	401	436	239	1076	249	217	138	604
		B	356	336	222	914	390	430	242	1062	240	216	135	591
	2	A	226	206	144	576	338	280	204	822	254	155	84	493
		B	219	208	141	568	324	269	210	803	243	158	83	484
	3	A	231	215	151	597	248	268	163	679	434	295	219	948
		B	236	214	151	601	242	247	169	658	420	288	227	935
Hand-quartering	1	A	201	217	178	596	238	240	150	628	219	257	149	625
		B	181	218	194	593	223	232	149	604	204	238	144	686
	2	A	418	308	248	974	237	250	169	656	270	180	121	571
		B	396	308	247	951	211	240	152	603	251	178	128	557
	3	A	262	248	187	697	233	197	110	540	347	189	132	668
		B	260	255	187	702	230	203	112	545	352	201	132	685

Average grain count = 695

Q = Quartz   I = Ilmenite   M = Monazite influence any calculations based on the assumption of equal grain volume. The relative size, shape, and surface characteristics of the mineral grains used in the experiment are shown in the photomicrographs (figs. 1, 2, 3, and 4). Although the minerals were all sized to -80+100 mesh, it is apparent from photographs that quartz displays embayments, ilemenite angularity, and the monazite grains are well rounded.

The size distributions of the quartz and ilmenite seem much wider than that of monazite and the average grain size of the latter appears much larger. It is incorrect, therefore, to assume that the minerals have equal grain volumes.

WEIGHTS PER GRAIN

To obviate the use of specific gravity and obtain the true weight relationship from the grain frequency data, the average weight per grain for each mineral was determined experimentally and substituted for d in the equation.

$$(\text{Weight percent})_n = \frac{F_n d_n}{\sum_{i=1}^{n} (F_i d_i)} \times 100$$

These values were obtained by counting and weighing approximately 700 grains of each mineral and dividing the weight by the grain count. Means and standard deviations of six such weighings for each mineral are shown in table 2. Weight percent compositions, using both the specific gravity factor and the concept of average weight per grain (W/G), are shown in table 3.

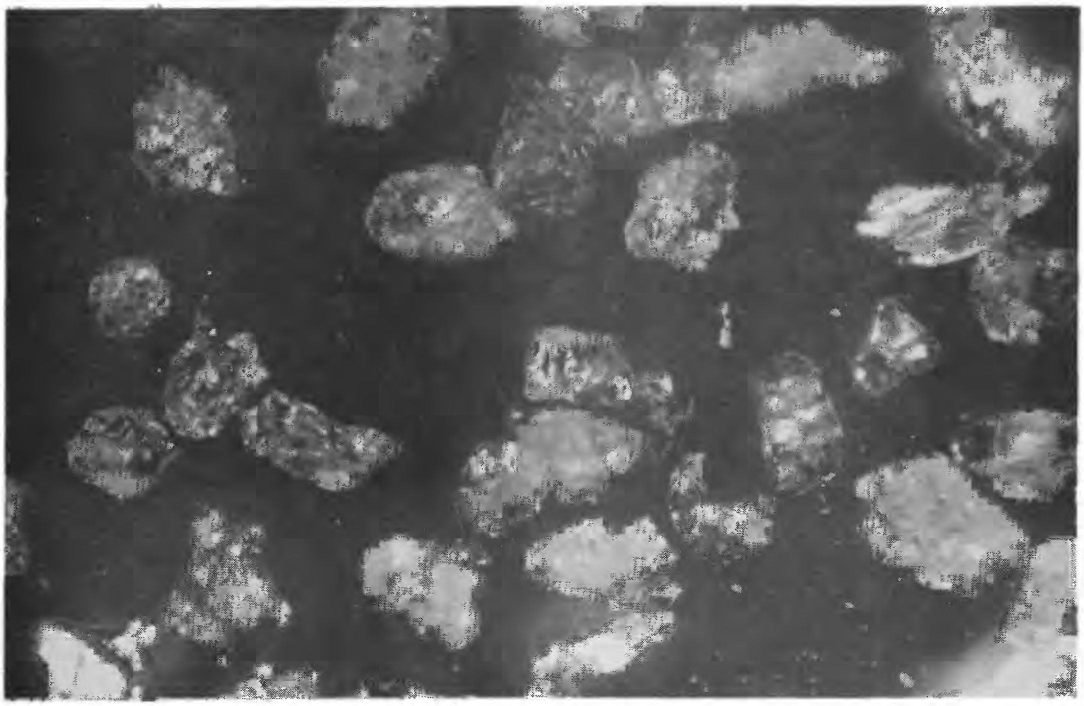

Figure 1. QUARTZ (60X)

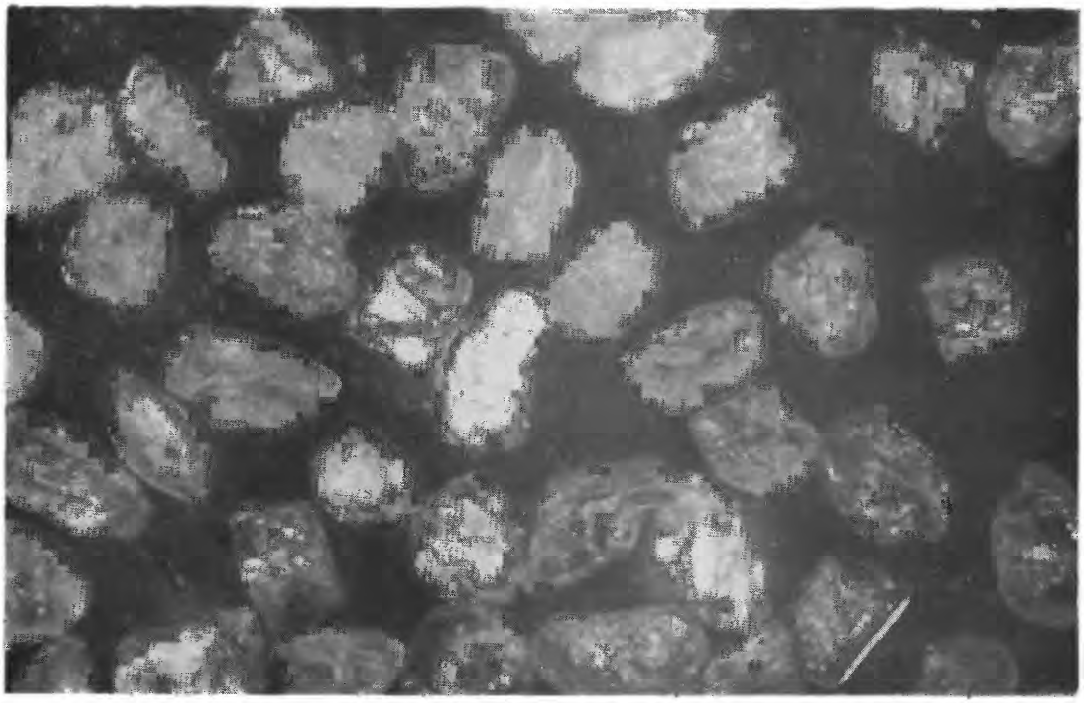

Figure 2. MONAZITE (60X)

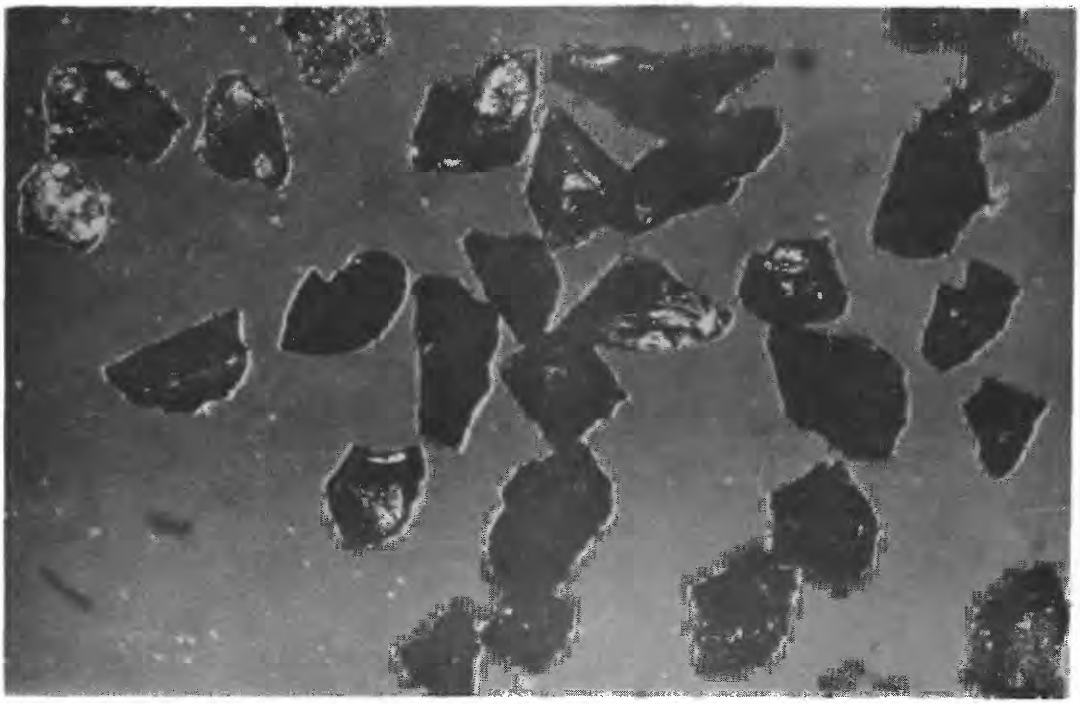

Figure 3. ILMENITE (60X)

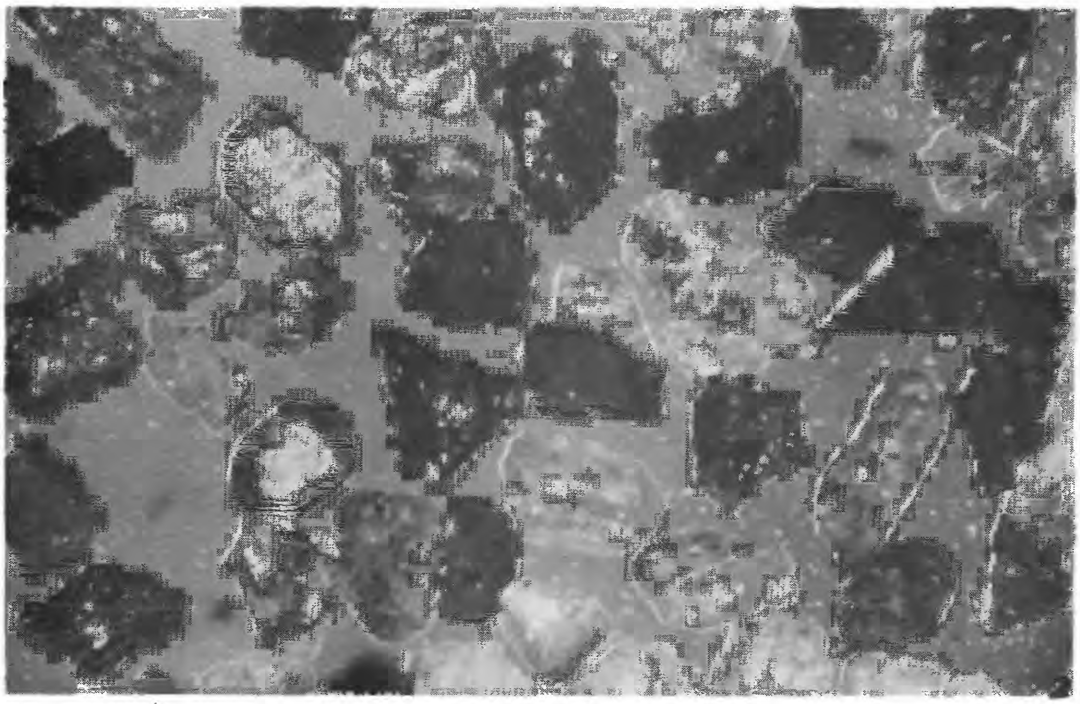

Figure 4. MIXTURE (60X)

Table 2.--Average weights per grain of the test minerals.

Mineral	Means (micrograms)	Standard deviation (micrograms)
Quartz	8.46	1.66
Ilmenite	17.36	0.83
Monazite	27.13	0.60

Inspection of the weight percent compositions listed in table 3 shows substantial differences in many cases between the values listed for the two methods. That the two methods of calculation are significantly different may be easily demonstrated. Using the data in table 3 we may calculate for each of the minerals the average difference between the two methods of calculation and the standard deviation of these differences. By means of Students t test we may then determine if a significant difference exists between the methods by substituting the appropriate values in the equation

$$t = \frac{\bar{d}}{s_d/\sqrt{n}}$$

where $\bar{d}$ is the average difference, s_d the standard deviation of the differences, and n the number of pairs of observations, in this case, 54. The calculated values are shown in table 4. A comparison of the t values obtained with a table value of 2.93 for 53 degrees of freedom at the 99.5 percent confidence level shows that all calculated values are much greater than the table value and hence extremely significant.

Table 4.--Statistics of the differences between the two methods of calculation.

	Quartz	Ilmenite	Monazite
$\bar{d}$	4.57	3.40	8.06
s_d	0.80	1.21	0.45
n	54	54	54
t	42	20	131

It may then be said that the two methods of calculation of weight percent are significantly different for each of the minerals.

Inspection of the weight percents obtained by both methods of calculation (table 3) shows that for any mineral the value obtained by the average-weight-per-grain method is normally closer to the known composition by weight. This is better demonstrated by the grand means of each of the minerals by both methods as shown in table 5.

Table 5.--Comparison of means of weight percent composition.

Mineral	Known composition	Calculated by S.G.	W/G	Difference S.G. - W/G
Quartz	20	24.70	20.13	4.57
Ilmenite	40	42.03	38.63	3.40
Monazite	40	33.22	41.28	8.06
	100	99.95	100.04	

Table 3.--Weight percent composition of raw data (table 1) calculated by both methods.

Weight	Split	Counter	Microsplit						Cone splitter						Hand-quartering					
			Q		I		M		Q		I		M		Q		I		M	
			S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G	S.G.	W/G
5 g	1	A	22.7	17.4	27.0	23.4	50.3	59.2	25.4	20.9	43.4	40.4	31.2	39.3	21.2	16.9	41.2	37.1	37.6	45.9
		B	23.0	17.7	26.8	23.2	50.2	59.1	25.3	20.7	43.0	39.7	31.4	39.6	18.8	14.8	40.8	36.4	40.4	48.8
	2	A	24.0	19.4	42.4	38.9	33.5	41.7	25.5	20.8	41.9	38.6	32.6	40.6	28.4	23.2	37.7	34.7	33.8	42.1
		B	24.4	19.8	42.6	39.1	33.0	41.1	24.7	20.1	42.3	38.8	33.0	41.1	27.4	22.2	38.4	35.2	34.2	42.6
	3	A	23.1	18.9	46.3	42.8	30.6	38.3	25.1	20.4	42.1	38.7	32.8	40.9	24.2	19.6	41.2	37.7	34.6	42.7
		B	23.3	19.1	46.3	42.8	30.4	38.1	25.6	20.8	41.7	38.4	32.7	40.8	23.8	19.3	42.0	38.3	34.2	42.4
10 g	1	A	14.0	11.2	52.2	47.3	33.8	41.5	24.1	19.9	47.2	43.9	26.9	36.2	24.5	20.0	44.5	41.2	30.9	38.7
		B	15.2	12.2	51.5	46.9	33.2	40.9	23.7	19.4	47.0	43.6	29.4	37.0	23.8	19.3	44.5	41.0	31.7	39.7
	2	A	15.0	11.9	47.4	42.2	37.6	45.9	27.0	22.0	40.3	37.2	37.6	40.8	23.1	19.6	43.9	39.8	33.0	40.6
		B	14.1	11.1	47.9	42.7	38.0	46.2	26.4	21.4	39.4	36.2	34.2	42.4	22.3	20.1	45.6	40.9	32.1	39.0
	3	A	18.7	14.9	44.9	40.5	36.4	44.6	23.5	19.2	45.6	42.2	30.9	38.6	28.8	21.0	43.9	42.9	27.3	36.1
		B	18.3	14.6	45.4	41.2	36.3	44.2	23.6	19.2	43.4	39.8	33.0	41.0	28.1	21.2	44.6	43.0	27.4	35.8
20 g	1	A	23.4	18.3	34.6	27.9	45.0	53.8	27.2	22.4	42.6	39.6	30.2	38.0	22.4	18.3	47.2	43.6	30.4	38.1
		B	23.6	18.5	31.9	28.1	44.5	53.4	26.7	21.9	43.2	40.2	30.1	37.8	22.2	18.0	46.5	42.9	31.3	39.1
	2	A	21.7	17.4	41.0	37.0	37.3	45.6	36.2	30.8	39.8	30.1	24.0	31.1	32.3	29.9	38.8	36.4	28.9	36.8
		B	21.1	16.9	44.0	40.0	34.9	43.1	35.1	29.7	41.0	39.2	23.9	31.1	30.3	25.0	38.7	36.0	31.0	39.0
	3	A	24.4	19.9	44.6	41.2	31.0	38.9	30.9	25.4	37.8	35.2	31.2	39.4	36.5	30.5	35.6	33.8	27.9	35.6
		B	23.5	19.2	44.8	41.2	31.7	39.6	30.2	24.6	37.2	35.5	32.6	40.9	36.0	30.2	37.0	35.1	27.0	34.3

The method of calculating weight percents from grain frequency data using average weights per grain results in a 24 percent increase in the reported weight percents for monazite compared to calculations using specific gravity factors. If we may assume that similar, although equally unknown size distributions are true for the recently completed monazite study mentioned previously, then we may infer that weight percents of monazite reported for that study may be 24 percent low. This study has been conducted using mineral grains in the size range -80+100 mesh. It would be logical to assume that weight percents calculated by both methods might differ to a greater degree if a wider size range were used.

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