# GRAIN SIZES AND SHAPES OF VARIOUS MINERALS IN IGNEOUS ROCKS

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Abstract

Conflicting statements are found in geological literature regarding grain sizes of various minerals in igneous rocks. The writer has found no general information on the subject. A series of 200 rocks involving 40,000 to 50,000 measurements were studied in thin sections at the University of Minnesota. Results of this study are used to arrive at some general conclusions.

Average grain size for a mineral differs in different granitoid rocks. Any one mineral in a series of several hundred granitoid igneous rocks shows an average grain size which differs widely from the average grain size of another mineral in the same series of rocks. Different minerals vary in average shape as well as average area. There is some suggestion that difference in grain size is due largely to abundance or scarcity of corresponding material in the parent magma.

Workers in petrography seem to have no generalized data concerning relative grain sizes of various minerals in igneous rocks. Rubey[1] says he "is aware of no common or at any rate no generally recognized, relationships of crystal sizes that result in marked differences in the grain size of the various mineral species present in igneous or metamorphic rocks." On the other hand, Martens[2] writes that he "can not agree with Rubey in his statement that the assumption of a homogeneous size-distribution of the heavy mineral grains at the source seems justifiable, but, rather, believes that differences in size-distribution of different minerals at the source may be as important as any of the other factors causing sands of different coarseness, derived from the same source, to have different relative amounts of heavy minerals."

Neither statement is supported by quantitative data. The writer has found no general study of relationships of grain sizes of minerals. In the present study two hundred granitoid igneous rocks were examined in the hope that these would furnish a basis for at least preliminary generalizations with respect to relative grain sizes of a few common minerals. A few slightly metamorphosed equivalents of igneous rocks, where there is no evidence of crushing or recrystallization, were included in the study.

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[1] Rubey, W. W., Size-distribution of heavy minerals within a water-laid sandstone: *Jour. Sed. Petr.*, **3, 4,** 23 (1933–34).

[2] Martens, J. H. C., Beach sands between Charleston, South Carolina, and Miami, Florida: *Bull. Geol. Soc. Am.*, **46,** 1586 (1935).

"Grain size," as used throughout this paper is measured in thin sections in two dimensions and computed as an area. Where the outline of grains was irregular or rounded, for the purpose of consistency, maximum length and width were recorded in each case. Strictly, grain size involves three dimensions or volumes, but since most mineral grains would be difficult or impossible to isolate from fresh igneous rocks, and since areal ratios approximately correspond to volume ratios,[3] it was decided that best results could be obtained for a variety of minerals by measuring grain sizes in thin section under a microscope.

It is noteworthy that grain sizes in thin section are not always maximum cross-sections of the grains. Many of them will be so oriented and cut as to give areas smaller than the maximum, but results will be about as much affected for one mineral as for others, and will give a basis for comparison of a series of minerals even if not the actual sizes. Calculated results represent grain size in a specimen but not necessarily in a large rock body where locality is given, since a single thin section may not be representative of that rock body.

Only minerals believed to be primary were measured for comparison. For a pseudomorph the original mineral was recorded if there was evidence of its nature. An average of over 100 grains per slide was measured, or a total of from 40,000 to 50,000 measurements in all.

All granitoid and coarse diabasic rocks in the petrography laboratory at the University of Minnesota were made available to the writer. They were collected from many states of the United States and at least a dozen other countries, some being from type localities.

The study involved compilation of a mass of data and then arrangement and calculation of results. The primary minerals in a slide were listed on a sheet (Table 1 is an example). The rock number, classification, and location were recorded at the top. Measurements were made by a micrometer ocular consecutively without arbitrary selection for each mineral. Where less than six grains of a mineral were found, the measurements were not considered representative and, therefore, not used in computing average grain sizes for that mineral. Traverses at close intervals were made parallel to the length of the slide. Many rocks were represented by one slide, but where several slides were available most or all of these were used to obtain measurements.

[3] Holmes, A., *Petrographic Methods and Calculations:* Thos. Murby and Co., London 310–312 **(1930).**

TABLE 1. EXAMPLE OF AN ORIGINAL SHEET SHOWING HOW MEASUREMENTS WERE TABULATED

Rock Number: GP. 397-6 (Biotite Granite)
Ascutney Mountain, Vermont

| Readings in $\frac{mm}{20}$ | | | Readings in $\frac{mm}{65}$ | | | | | |
|---|---|---|---|---|---|---|---|---|
| Quartz | Ortho-clase | Plagio-clase N<CB | Biotite | Magne-tite | Sphene | Apatite | Allanite | Zircon |
| 20×15 | 65×58 | 25×20 | 10× 4 | 9×9 | 9× 5 | 5×2 | 13×13 | 2×2 |
| 10× 9 | 15× 9 | 9× 7 | 31×29 | 9×5 | 10× 6 | 3×2 | 11×10 | 2×1 |
| 13×12 | 16×16 | 4× 2 | 14× 8 | 9×9 | 19× 8 | 5×4 | 7× 3 | 2×1 |
| 9× 7 | 30×19 | 8× 3 | 18×18 | 8×4 | 7× 5 | 2×2 | 11× 4 | 1×0.5 |
| 13× 9 | 11× 6 | 10× 7 | 17× 8 | 1×1 | 5× 2 | 5×4 | 25×12 | 3×2 |
| 10× 5 | 7× 3 | 35×13 | 15×15 | 2×1 | 9× 6 | 5×1 | 6× 4 | 3×1 |
| 20×15 | 94×52 | 27×17 | 20×12 | 5×4 | 15×10 | 4×4 | 35×11 | 2×1 |
| 16×15 | 35×30 | 11× 7 | 14× 8 | 15×9 | 14× 4 | 12×5 | 30× 7 | 4×3 |
| 13×10 | 26×21 | 12× 8 | 9× 9 | 4×4 | 29× 9 | 6×4 | 6× 3 | |
| 14× 8 | 67×25 | 11× 7 | 4× 3 | 9×7 | 14× 4 | 4×1 | | |
| 6× 4 | 28×20 | 49×16 | 17× 8 | 7×7 | 8× 4 | 6×2 | | |
| 8× 7 | 24×13 | 18×10 | 16×10 | 6×6 | 11× 5 | 12×6 | | |
| 6× 5 | 72×55 | 5× 3 | 16× 7 | 1×1 | 28× 9 | 9×5 | | |
| 6× 4 | 42×22 | 30× 9 | 25×11 | 8×6 | 55×14 | 1×1 | | |
| 4× 3 | 29×19 | 20×15 | 25×15 | 8×5 | | | | |
| 8× 8 | 44×40 | | 64×50 | 8×8 | | | | |
| 1× 1 | 103×50 | | | | | | | |
| 22×17 | | | | | | | | |

Some difficulty was encountered in determining boundaries of opaque or isotropic grains where these occurred in clusters. Wherever possible such clusters were avoided, but where measurements could not be obtained otherwise an attempt was made to determine boundaries by differences in lustre under reflected light when the stage was rotated.

From the data sheets a maximum and minimum area* for each mineral were found and the average grain size was calculated; all being listed as in Table 2.

* For this maximum and minimum, *lengths* were chosen. In 19 out of 20 cases which were checked, maximum lengths corresponded to maximum *areas*. On the basis of this finding, lengths were considered reasonable indications of size.

TABLE 2. MAXIMUM, MINIMUM, AND AVERAGE GRAIN SIZES OBTAINED FROM DATA IN TABLE 1

Rock Number: GP. 397-6 (Biotite Granite)
Ascutney Mountain, Vermont

| | Readings in $\frac{mm}{20}$ | | | Readings in $\frac{mm}{65}$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quartz (18)* | Orthoclase (17) | Plagioclase N<CB. (16) | Biotite (16) | Magnetite (16) | Sphene (14) | Apatite (15) | Allanite (9) | Zircon (8) |
| Maximum grain size | 22×17 | 103×50 | 49×16 | 64×50 | 15×9 | 55×14 | 12×6 | 35×11 | 4×3 |
| Minimum grain size | 1× 1 | 7× 3 | 4× 2 | 4× 3 | 1×1 | 5× 2 | 1×1 | 6× 3 | 1×0.5 |
| Average grain size | 11× 8.5 | 42×27 | 19×11 | 20×13 | 6.8×5.4 | 17× 6.5 | 5.4×3 | 16×7.4 | 2.4×1.4 |

* Represents number of grains measured.

The rocks were divided into three groups:

I. Silicic, to include granites and syenites except nepheline (or other feldspathoid) syenites.
II. Medium, to include feldspathoid syenites, monzonites, and diorites.
III. Basic, to include gabbros, and ultra-basic rocks.

On this basis 92 of the rocks were found to be in group I, 55 in group II, and 53 in group III.

Minerals as determined in slides were listed under each group, and the average grain size of the minerals for the whole group determined. These averages for all the minerals in each group, together with the number of rocks used in obtaining the average, are listed in Table 3.

TABLE 3. AVERAGE GRAIN SIZES OF VARIOUS MINERALS IN ROCKS

(Areas are in sq. mm.; figures in parentheses following areas, indicate number of rocks from which average is derived.)

| Mineral | Silicic | Medium | Basic |
|---|---|---|---|
| Plagioclase | 1.3 ×0.75 =0.975 (87) | 1.1 ×0.60 =0.66 (48) | 1.3 ×0.60 =0.78 (43) |
| Microcline | 1.15 ×0.75 =0.87 (49) | 2.05 ×1.15 =2.36 ( 4) | ( 0) |
| Orthoclase | 1.25 ×0.80 =1.0 (76) | 1.4 ×0.75 =1.05 (21) | 1.6 ×0.90 =1.44 ( 5) |
| Microperthite | 1.8 ×1.05 =1.89 ( 7) | 1.95 ×0.75 =1.46 ( 2) | ( 0) |
| Quartz | 0.85 ×0.55 =0.468 (88) | 0.49 ×0.34 =0.166 (26) | 0.39 ×0.26 =0.101 ( 4) |
| Hornblende | 0.80 ×0.48 =0.384 (38) | 0.85 ×0.50 =0.425 (27) | 0.95 ×0.55 =0.525 ( 9) |
| Pyroxene | 0.77 ×0.44 =0.339 ( 3) | 0.824×0.421=0.347 (27) | 1.114×0.696=0.697 (35) |
| Biotite | 0.70 ×0.31 =0.217 (62) | 0.70 ×0.375=0.262 (36) | 0.70 ×0.38 =0.266 (16) |
| Olivine | ( 0) | 0.50 ×0.37 =0.185 ( 2) | 0.9 ×0.6 =0.54 (26) |
| Nepheline | ( 0) | 1.1 ×0.85 =0.935 (10) | 0.80 ×0.45 =0.36 ( 2) |
| Allanite | 0.20 ×0.108=0.0216 ( 6) | 0.43 ×0.29 =0.125 ( 3) | 0.335×0.195=0.065 ( 1) |
| Sphene | 0.23 ×0.114=0.0262 (20) | 0.31 ×0.154=0.048 (20) | 0.20 ×0.132=0.0264 ( 2) |
| Fluorite | 0.35 ×0.22 =0.077 ( 5) | 0.17 ×0.085=0.0145 ( 1) | ( 0) |
| Apatite | 0.12 ×0.05 =0.006 (58) | 0.17 ×0.07 =0.012 (51) | 0.23 ×0.10 =0.023 (27) |
| Zircon | 0.063×0.042=0.0026 (43) | 0.066×0.046=0.003 ( 7) | 0.057×0.035=0.002 ( 4) |
| Magnetite | 0.185×0.123=0.023 (66) | 0.185×0.14 =0.026 (42) | 0.37 ×0.28 =0.103 (47) |
| Muscovite | 0.445×0.23 =0.103 (11) | 0.26 ×0.103=0.027 ( 2) | ( 0) |
| Pyrite | 0.137×0.088=0.012 ( 3) | 0.23 ×0.17 =0.039 ( 6) | 0.20 ×0.132=0.026 ( 8) |

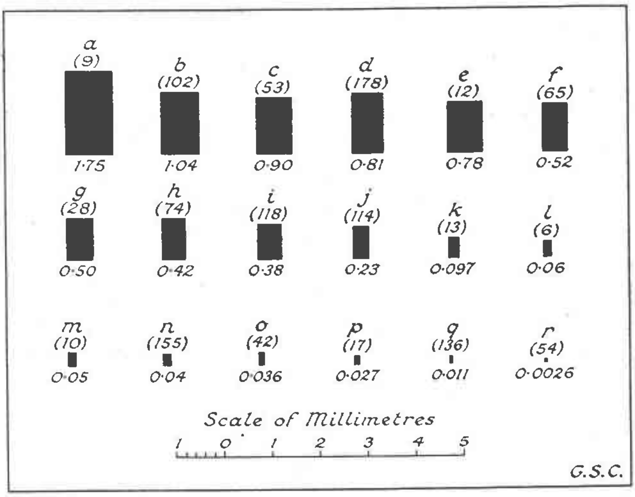


FIG. 1. Average shapes and areas of minerals in 200 thin sections of medium granitoid igneous rocks. Numbers above blocks indicate number of rocks in which the mineral was studied. Numbers below blocks indicate areas in square millimeters.

| | | |
|---|---|---|
| a—Microperthite | g—Olivine | m—Allanite |
| b—Orthoclase | h—Hornblende | n—Magnetite |
| c—Microcline | i—Quartz | o—Sphene |
| d—Plagioclase | j—Biotite | p—Pyrite |
| e—Nepheline | k—Muscovite | q—Apatite |
| f—Pyroxene | l—Fluorite | r—Zircon |

Members of isomorphous series and similar groups were combined and listed under group names.

Average grain sizes, shapes, and areas are shown in Fig. 1 where minerals are arranged in descending order of size. Available data for garnet, tourmaline, pyrrhotite, hematitie, carbonate, epidote and chlorite are so meager that they have been omitted from Table 3 and Fig. 1. The results would not modify the general conclusions.

It is clear from Table 3 that grain sizes of some minerals differ considerably with composition of the rock in which they occur. Average quartz grains in silicic rocks are more than 4 times as large as those in basic rocks, and average magnetite and apatite grains in basic rocks are approximately 4 times as large as those in silicic rocks. Average pyroxene grains in basic rocks are twice as large as those in silicic rocks. This may mean that grain size is related to abundance of a mineral in igneous rocks. Essential and varietal minerals all have a larger average grain size than accessory minerals. However, there are many exceptions to this trend. Orthoclase and hornblende, for instance, have larger average grain sizes in basic rocks than in silicic rocks. Many more rocks would have to be carefully studied before generalizations could be made.

In Fig. 1 it is evident that differences in grain sizes of different minerals are pronounced. The average orthoclase area is 400 times as large as the average zircon area. Minerals in rocks have differences in shape as well as size. Average pyrite and magnetite grains are nearly equidimensional, while average apatite, zircon, and sphene grains are elongated. Average acmite-augite grains are more elongated than augite grains.*

There is a wider range between maximum and average grain size for large grained minerals than for small grained ones; but the ratio of maximum grain size/average grain size is generally smaller in the large grained minerals.

From the two hundred rocks which were studied, several general conclusions are drawn:

1. Average grain size for a mineral differs in different granitoid igneous rocks.
2. Any one mineral in a series of several hundred granitoid igneous rocks shows an average grain size which differs widely from the average grain size of other minerals in the same series of rocks.
3. Different minerals in thin sections of granitoid igneous rocks differ in average shape as well as average area.

* Each member of the pyroxene group was determined and measured separately but all have been listed under the group name in final tabulations.

4. The characteristic essential and varietal minerals are strikingly larger than the usual accessory minerals. There is a suggestion that this difference may be due largely to the abundance or scarcity of the corresponding material in the parent magma, but data are rather meager for this last suggestion.