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The Accessory Minerals of some Granitic Rocks of the Boulder Batholith

Robert T. Donahue

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THE ACCESSORY MINERALS OF SOME GRANITIC ROCKS OF THE BOULDER BATHOLITH

by
Robert T. Donahue

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
Butte, Montana
May 17, 1952

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by

Robert T. Donahue

INTRODUCTION

Although the position of the Boulder batholith in space and time is well known, the modes of occurrence of various rock types and the inter-relationships between the petrographic types are not known in detail. The heavy accessory minerals and the percentage distribution of accessory minerals are mineralogical features which might be expected to aid in "finger printing" the different rock types, especially if significant differences in mineralogical assemblages are found.

The purpose of this investigation was to gather preliminary data from different megascopic rock types from two different localities within the batholith and to determine (1) the similarities or dissimilarities of the accessory mineral suites and (2) to determine if the percentage distribution of accessory minerals correlate with the detailed petrographic analyses. The results show similar suites for all rocks with magnetite, sphene, and apatite in all samples and zircon commonly found. No obvious correlation with petrographic types was determined.

On the basis of previous work, accessory minerals known to be present in the rocks of the Boulder batholith include magnetite, sphene, apatite, zircon, monazite, ilmenite and rutile. However, the

PLATE I

Geologic Map of the Boulder Batholith

The localities from which samples were obtained are indicated by numbers as follows:

(1) 32 - 3 - 2

(2) 22 - 9 - 1

(3) 29 - 15 - 2

(4) 29 - 43 - 1

(5) 28 - 142 - 2

(6) 22 - 14 - 11

(7) 22 - 14 - 10

(8) 22 - 14 - 9

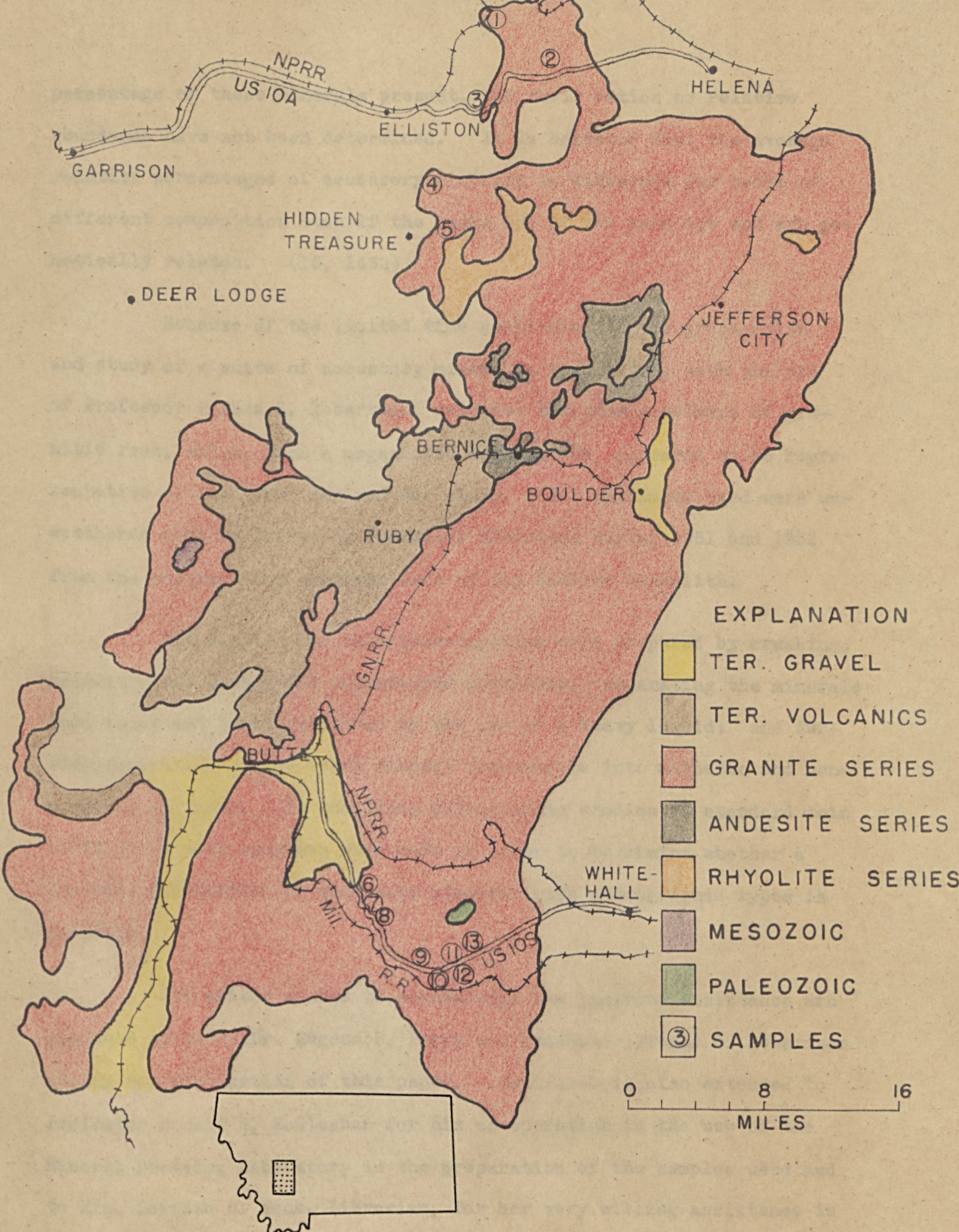
(9) 22 - 13 - 1

(10) 22 - 13 - 4

(11) 22 - 14 - 6

(12) 22 - 14 - 7

(13) 22 - 14 - 8



GEOLOGIC MAP OF THE BOULDER BATHOLITH

After Billingsley, AIME Trans. Vol. 51

percentage of these minerals present, and their ratios or relative abundance have not been determined. It is believed that the average relative percentages of accessory minerals is different for rocks of different composition even if the rocks are of the same age and are genetically related. (16, 1432)

Because of the limited time available for the preparation and study of a suite of accessory minerals, the writer, with the aid of Professor Forbes S. Robertson, selected thirteen specimens of granitic rock, which, from a megascopic examination, appeared to be representative of the types desired for study. All specimens used were unweathered rock collected by Professor Robertson during 1951 and 1952 from the northern and southern ends of the Boulder batholith.

The samples for this investigation were prepared by crushing, grinding, and sizing the unweathered specimens; separating the minerals into heavy and light fractions by the use of a heavy liquid; and further separation of the heavy mineral concentrate into magnetic and nonmagnetic portions. In addition, petrographic studies of standard thin sections of each specimen were made in order to determine whether a possible correlation of accessory minerals with petrographic types is possible.

The writer wishes to acknowledge the generous assistance and guidance given by Dr. Eugene S. Perry and Professor Forbes S. Robertson during the preparation of this paper. Gratitude is also extended to Professor Donald R. McGlashan for his co-operation in the use of the Mineral Dressing Laboratory in the preparation of the samples used and to Mrs. Loretta B. Peck, Librarian, for her very willing assistance in the library.

PREVIOUS WORK

Because of its size, extent of exposure, numerous mineral deposits, and accessibility, the Boulder batholith has received considerable attention from geologists for many years. Billingsley, Barrell, Grout, Knopf, Weed, and others have written much about the rocks and mineral deposits of the batholith. Barrell's petrographic studies (1) were confined to the Elkhorn mining district, and although Billingsley (2) mentions that more than three hundred thin sections were prepared and examined in his studies of the batholith, the results of the petrographic study were not published in detail. Studies by these authors seem to have led to generalized conclusions concerning the batholith, rather than detailed petrographic descriptions of the different rock types comprising the batholith.

White (18) studied samples of black stream sands collected from different localities in Montana, including the area of the Boulder batholith. The heavy accessory minerals found include only those which are resistant to chemical weathering, and do not represent the type or amount of accessory minerals originally present in the rocks. If other heavy mineral and petrographic studies of the rocks of the batholith have been made, the results of such studies have not been published, to the writer's knowledge.

PREPARATION OF HEAVY MINERAL CONCENTRATE

A review of the methods of preparing and studying heavy mineral suites from igneous and sedimentary rocks led the writer to follow, in a general way, the method employed by Tolman and Koch (15) in their study of the heavy accessory minerals of the granites of Missouri.

Sampling of Rocks

Samples of granitic rocks were collected from fresh exposures in two localities in the Boulder batholith. Eight samples from the southern end were collected along highway 10S, and five samples were collected from the northern end as indicated on PLATE I. Care was taken to select specimens that were representative of the general type of rock at each exposure. Xenoliths and sulfide deposits along joints were carefully avoided.

Comminution

In order to produce about 50 grams of material between 65 and 100 mesh, suitable for study, approximately 500 grams of sample were crushed in a jaw crusher, further reduced in size in a roll mill, and pulverized in a Braun pulverizer. After each operation, the material was screened to eliminate the fines, and to prevent overgrinding. Two pulverizing operations were necessary, in most cases, to produce the desired amount of crushed and sized sample. A size range of 65 mesh to 100 mesh was selected to permit easier identification of the accessory minerals. However, the writer believes that a size range of approximately 120 mesh to 150 mesh would be more practical because of the greater liberation of mineral particles which would have been achieved. Some difficulty was had in separating grains in which two minerals were attached to one another. A sketch of some mixed grains, the result of insufficient liberation, is shown in Fig. 1.

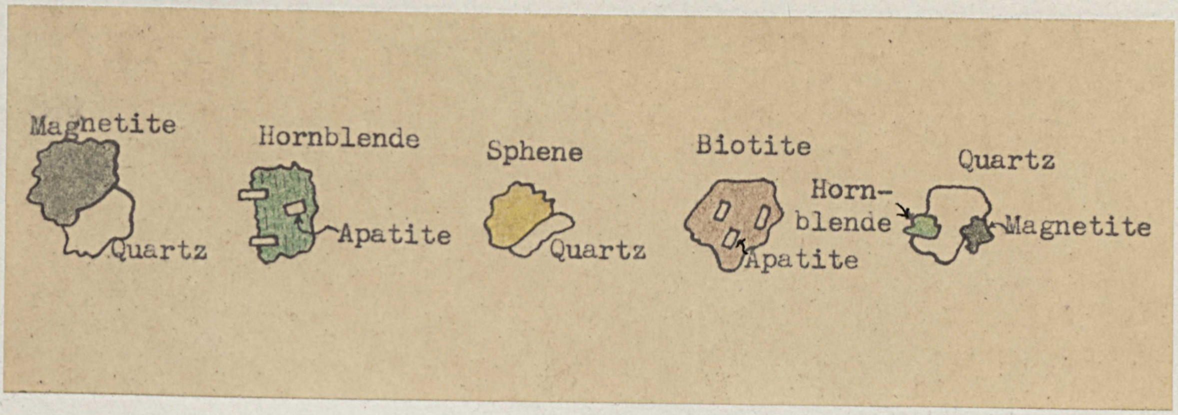


Fig. 1. Sketches of Various Mixed Mineral Grains Showing Incomplete Liberation.

Tolman and Koch (15) state that samples which were crushed to various sizes and separated showed an increase in heavies with an increase in the fineness of crushing. However, probably because of air bubbles which cause adhesion of the mineral particles in the heavy liquid, suitable separation of powders finer than 200 mesh was found impractical.

To prevent contamination of the samples, each machine was carefully cleaned by compressed air before the introduction of a new sample. In this manner, the desired amount of powder can be obtained from each sample in about 20 minutes.

Sizing

The Tyler Ro-Tap testing sieve shaker was employed in the sizing operation to provide a standard screening of each sample. Two sets of trays, each consisting of a 65 mesh sieve, a 100 mesh sieve, and a bottom pan, were used to permit the sizing of two samples simultaneously. Each operation was carried on for 10 minutes, and if the desired amount of crushed and sized sample was not obtained, a second pulverizing and sizing operation of the coarse product (plus 65 mesh) was performed.

In addition to the desired sample of crushed material, the plus 65 mesh and the minus 100 mesh products were packaged and labeled for possible future study. Again, careful cleaning of the sieves by the use of compressed air after each operation was necessary to prevent contamination of the remaining samples.

<u>Separation of Samples</u>

After each sample was weighed and the weight recorded, separation of the sample into heavy and light fractions was carried out by the use of the heavy liquid, bromoform (sp. gr. 2.884). This particular heavy liquid was selected because of its suitably high specific gravity, its availability, and its ability of being washed easily. The used bromoform was washed with alcohol, and then cleaned and recovered in a large separatory funnel by shaking the mixture with water, which absorbs the alcohol and floats on the bromoform. After a period of time, usually several hours, the clear bromoform was drawn off from below the water-alcohol mixture.

Although many types of apparatus may be used to carry out heavy liquid separations, the ordinary closed, pear-shaped, separatory funnel was selected. The use of this type of funnel allows a minimum loss of the heavy liquid by evaporation. To reduce evaporation, it was necessary to clean and re-grease the ground glass stopcocks and stoppers after each operation. Since some of the light minerals could have been carried down with the heavy minerals, a second separation was performed to obtain a clean product. This separation was carried out by running the heavy constituents out of one funnel directly into a smaller one as shown in Fig. 2.

In the first separation, the funnel was filled to within about two inches of the top with bromoform, and the crushed and sized sample was introduced slowly so that only the heavies sunk to the bottom of the funnel. The float material was agitated four or five times with a glass rod during each separating operation to allow a more complete separation of the heavy constituents from the light constituents. Since only a limited amount of time during the day was available for each separation, the mixture was prepared in the afternoon and allowed to stand until the following morning.

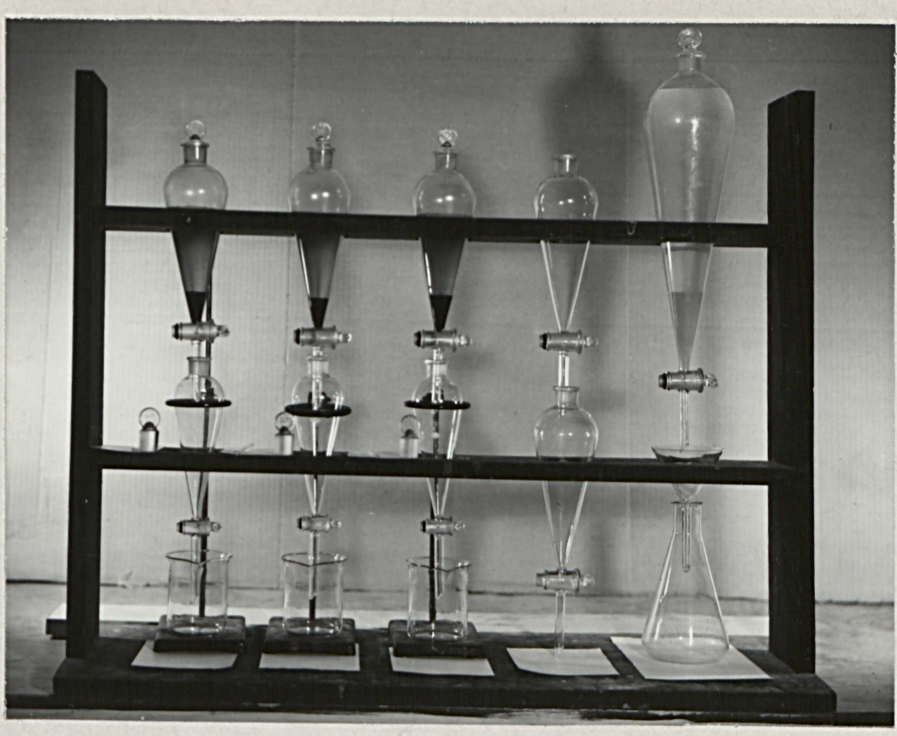


Fig. 2. Apparatus Used in the Separation of Heavy Minerals from Light Minerals.

The second separation was carried out by running the heavies and about one half of the bromoform from the first funnel directly into a smaller separatory funnel, which contained only a small amount of bromoform. After several hours of settling, the heavies were filtered and washed with alcohol and allowed to dry. The light fraction also was thoroughly washed, filtered, dried, and saved for further study.

To prevent the heavies from adhering to the sides of the funnel, it was necessary to have the glass thoroughly clean and dry before the bromoform was admitted. The funnels can be easily cleaned in a few moments with alcohol, water, and a rubber "policeman".

HEAVY MINERAL CONCENTRATE

Separation of Heavy Constituents

After the heavy mineral concentrate was obtained, it was weighed and further separated into magnetic and nonmagnetic portions. This separation was carried out by the use of a strong Alnico hand magnet covered with tissue paper to permit easy removal of the adhering magnetic particles. Five separations were made to ensure the removal of high and intermediate magnetic particles. The magnetic portion was weighed and placed in small bottles for future reference and possible study.

Sampling of Heavy Constituents

In order to make a reliable quantitative determination of the minerals in the heavy concentrates, either the total amount must be mounted or a small portion truly representative of the total amount must be selected for mounting. Since a relatively small amount of concentrate was available for study, a microsplitter was used to split the concentrate down to about 250 mineral grains. It is believed that this method is much more reliable than the use of a knife blade for the division of the samples.

Mounting for Microscopic Study

Canada balsam (index 1.53 - 1.54) was used as a mounting medium. Two mounts of approximately 250 grains each were prepared on glass slides. The balsam was melted on the glass slides and cooked slowly to eliminate most of the air bubbles. The mineral grains were fairly evenly distributed by carefully shaking them onto the melted balsam and placing a cover plate over them before the balsam began to cool.

Study of the Concentrate

Each mount was carefully studied with the petrographic microscope, and the writer, to the best of his ability, determined the kind of accessory minerals present in each mount. A description and the particular identifying features of each mineral were recorded for each mount before a particle count was made of the minerals to determine quantitatively the minerals present.

Unfortunately, neither the apparatus nor the time was available to separate the ferromagnesian minerals from the nonmagnetic portion. Such minerals, because of their relatively greater amount, tended to obscure the distinctive features of the remaining nonmagnetic assemblage. For this reason Tolman and Koch (15, 23) state, "It is highly important that the separation of the ferromagnesian minerals from the non-magnetic minerals be made."

Unmounted grains were selected and examined in oils to determine their index, relief, optical characteristics, etc. Some difficulty was found in selecting unmounted grains, because of their difference in appearance in the mounts.

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The particle count of the accessory minerals was facilitated by the use of a grid eyepiece placed in the ocular, and a Wentworth traveling stage. Only those minerals definitely identified were counted, with the exception of one mineral X, found only in one mount.

DESCRIPTION OF ACCESSORY MINERALS

Accessory minerals found to be present in the suite of granitic rocks from the Boulder batholith include magnetite, sphene, apatite, zircon, rutile, epidote, and an unidentified mineral X. The "index" figure, that is, the percentage of the rock mass exceeding the specific gravity of bromoform, was calculated for each sample and used as a basis for placing the data obtained from the heavy mineral and petrographic studies on Table I.

Magnetite

Magnetite is the most persistent and abundant accessory mineral. It is present in all samples in amounts ranging from 0.60 percent to 3.40 percent of the original rock mass. The magnetic portion of the heavy mineral concentrate consisted primarily of magnetite, but also included unliberated essential minerals; that is, fragments of rock-forming minerals adhering to magnetic particles.

Sphene

Sphene, the second most persistent and abundant accessory mineral, is also present in all samples. It is distinguished by its very high relief, honey yellow to brownish color, strong pleochrism, and commonly wedge-shaped crystals. Excluding magnetite, sphene comprises from 55 percent to 90 percent of the accessory minerals present in the samples.

Apatite

Apatite, though not always abundant, is present in all samples. It is distinguished by its moderate relief, weak birefringence, parallel extinction, and prismatic, barrel-shaped crystals. It comprises from 10 percent to 35 percent of the heavy minerals present in the samples.

Zircon

Zircon, present in only one sample from the northern part of the batholith, is present in all but one sample from the southern part of the batholith. In one sample where only 29 grains of accessory minerals were counted, it comprised 35 percent of the minerals, otherwise the zircon content ranged between 7 percent and 10 percent. It is distinguished by its very high relief, strong birefringence, parallel extinction, and often doubly-terminated crystals, which may show inclusions or zoning.

Epidote

Grains of epidote were present in many samples. However, the grains were difficult to distinguish in the mounts during the particle count. To eliminate the possibility of errors in the final results, the identified grains of epidote were not counted.

Rutile

A mineral, included in several grains of biotite in one sample, in the form of hairlike crystals was believed to be rutile. The crystals were terminated within the grains of biotite.

Mineral X

An unidentified mineral found in one sample had the following optical properties:

1. Clear
2. Low Relief
3. Biaxial (-)
4. $2V = 25^{\circ}$
5. $r < v$

PETROGRAPHY

Thin sections of each sample were prepared by a skilled technician, from chips supplied by the writer. Although a complete petrographic study of the thin sections was not made, it was noted that the accessory minerals present in the nonmagnetic portion of the heavy mineral concentrates were also present in the thin sections in every instance.

Six traverses of each thin section were made with the use of a Wentworth traveling stage to determine the percentages of the various minerals present in the rock as a whole. The minerals used in classification include quartz, orthoclase, plagioclase, biotite, hornblende, and magnetite. Table I shows the relative percentages of these minerals in each sample.

ANALYSIS OF DATA

All data compiled in this project were recorded on 5-inch by 7-inch file cards for easy reference. Localities from which samples were obtained are shown on PLATE I; each sample is identified by a number such as 22-14-10. The number 22 refers to the Geology Department field notebook, in which specimen number 10 is recorded on page 14.

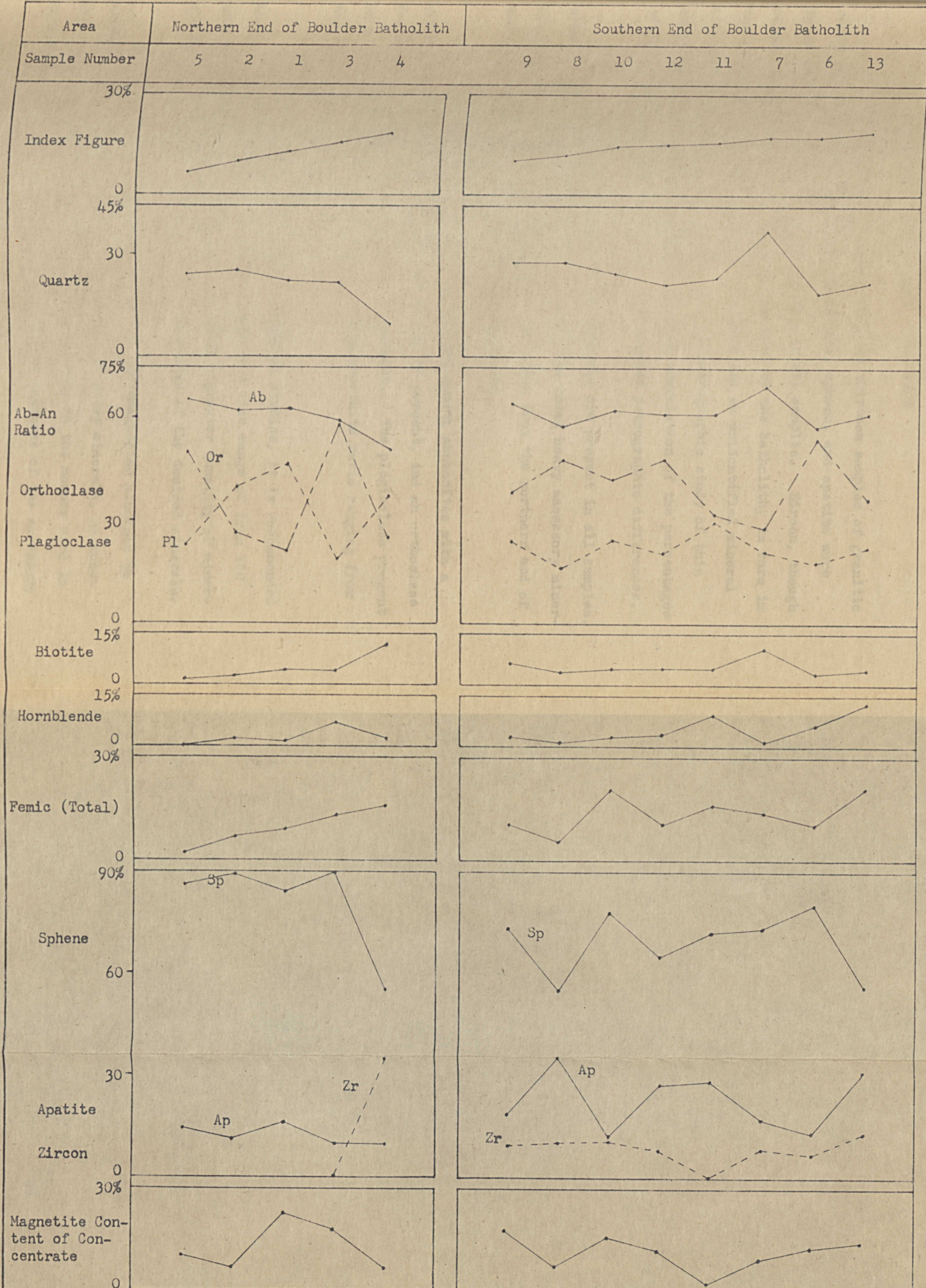
"Index figures (percentage of heavy constituents) for the suite of rocks studied varies between 6.28 and 21.56 with an average of 14.16. However, the average index figure of rocks from the northern end of the batholith is 12.3, whereas that for the southern end is 15.3. An increase in "index" figure in the northern area shows a corresponding increase in the biotite and total ferromagnesian mineral content, and a decrease in the quartz content of the rocks. A similar correlation cannot be made for the rocks from the southern area, since the variation in the amount of minerals is too erratic.

The ratios of the accessory minerals -- sphene, apatite, and zircon -- in the nonmagnetic portion of the heavy mineral concentrate were calculated, and these ratios show that sphene is the most abundant and persistent mineral, followed by apatite which is persistent but not as abundant. Zircon is present in only one sample from the northern area and absent in only one sample from the southern area of the batholith.

The particle count of these minerals shows that they comprise less of the heavy mineral concentrate in the northern area than in the southern area. Correlation of any or all of the heavy accessories with different petrographic types of rocks was attempted, but it did not meet with any success. The graphs on PLATE II show the relationship of the heavy accessory minerals with the essential minerals.

	Northern End of Boulder Batholith					Southern End of Boulder Batholith							
Sample Number (Shown on Plate I)	5	2	1	3	4	9	8	10	12	11	7	6	13
Index Figure (See page 11)	6.28	9.60	12.38	15.08	18.15	9.70	11.96	14.41	15.34	15.55	16.98	17.06	21.56
Quartz	25.0	26.8	23.1	10.4	21.6	27.8	31.0	25.2	21.5	23.6	37.4	18.7	21.8
Orthoclase	50.1	26.6	21.4	58.2	25.0	37.8	47.8	42.1	48.1	31.6	28.0	53.5	36.4
Plagioclase	22.7	40.0	46.5	18.7	37.4	24.0	15.8	24.1	20.5	29.3	21.0	17.7	21.8
Biotite	1.6	2.6	4.2	3.9	11.7	6.2	3.8	4.7	4.8	4.6	10.4	3.2	4.5
Hornblende	--	3.9	1.4	6.8	2.8	2.6	0.94	2.8	3.6	9.2	1.6	5.9	12.7
Magnetite	0.6		3.4	2.0	1.5	1.6	0.68	1.1	1.5	1.7	1.6	1.0	2.8
Femic (Total)	2.2	6.5	9.0	12.7	16.0	10.4	5.4	20.0	9.9	15.5	13.6	10.1	20.0
Magnetic Content of Concentrate	30.0	26.4	42.7	38.2	26.7	38.2	27.3	36.3	32.3	22.4	29.0	32.8	34.4
Magnetic Content of Sample	1.9	3.6	5.3	5.8	4.8	3.7	3.3	5.2	5.0	3.5	4.9	5.5	7.4
Particle Count (no. of grains)	22	28	63	28	29	56	46	87	48	72	75	31	32
Sphene	86	89	84	90	55	73	55	78	65	72	73	80	56
Apatite	14	11	16	10	10	18	35	11.5	27	28	19	13	31
Zircon	--	--	--	--	35	9	10	10.5	8	--	8	7	13

TABLE I. Percentages of Rock Constituents of Samples Studied



RELATIONSHIP OF THE HEAVY ACCESSORY MINERALS WITH THE ESSENTIAL MINERALS

SUMMARY AND CONCLUSION

Through a heavy mineral study of thirteen samples of granitic rocks of the Boulder batholith, magnetite, sphene, and apatite were found to be present in varying amounts in all samples. Zircon, though common in the rocks from the southern area of the batholith, is rare in the rocks of the northern area. Epidote and an unidentified mineral of minor importance were recognized. A petrographic study of thin sections of each sample showed no obvious correlation of the percentages of these heavy accessory minerals to detailed petrographic differences.

In general, the same heavy minerals are present in all samples, with the exception of zircon. However, the total heavy accessory minerals comprise a smaller percentage of the rocks from the northern end of the batholith than those from the southern end.

The samples used are granites and quartz monzonites with a quartz content ranging from 10 percent to 37 percent, and an orthoclase content ranging from 21 percent to 58 percent. The plagioclase present in all samples is andesine with an albite-anorthite ratio ranging from Ab_{51}-An_{49} to Ab_{69}-An_{31}.

For future heavy accessory mineral studies, it is recommended that at least 100 grams of powder ground to a size range of from 120 mesh to 150 mesh be used to make available a greater quantity of minerals for study and to ensure greater liberation of the desired minerals.

It is also recommended that the ferromagnesian minerals be separated from the nonmagnetic assemblage of heavy minerals, because their presence, in a relatively greater amount, in the mounts used in this study tended to obscure the distinctive features of the accessory minerals. Furthermore, fewer grains of accessory minerals were present in each mount because of the predominance of the ferromagnesian minerals in the concentrate.

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