Geology and Mineralogy

This document consists of 16 pages.
Series A.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

THE RADIOACTIVITY OF THE CONWAY GRANITE AT REDSTONE, CARROLL COUNTY, NEW HAMPSHIRE*

By

W. L. Smith and F. J. Flanagan

January 1955

Trace Elements Investigations Report 493

*This report concerns work done on behalf of the Division of Research of the U. S. Atomic Energy Commission.

USGS - TEI-493

GEOLOGY AND MINERALOGY

Distribution (Series A)	No. of copies
Argonne National Laboratory	1
Atomic Energy Commission, Washington	2
Division of Raw Materials, Albuquerque	1
Division of Raw Materials, Butte	1
Division of Raw Materials, Denver	1
Division of Raw Materials, Douglas	1
Division of Raw Materials, Hot Springs	1
Division of Raw Materials, Ishpeming	1
Division of Raw Materials, Phoenix	1
Division of Raw Materials, Richfield	1
Division of Raw Materials, Salt Lake City	1
Division of Raw Materials, Washington	3
Division of Research, Washington	1
Exploration Division, Grand Junction Operations Office	1
Grand Junction Operations Office	1
Technical Information Service, Oak Ridge	6
Tennessee Valley Authority, Wilson Dam	1
U. S. Geological Survey:	
Fuels Branch, Washington	1
Geochemistry and Petrology Branch, Washington	15
Geophysics Branch, Washington	1
Mineral Deposits Branch, Washington	1
E. H. Bailey, Menlo Park	1
A. L. Brokaw, Grand Junction	1
J. R. Cooper, Denver	1
N. M. Denson, Denver	1
C. E. Dutton, Madison	1
W. L. Emerick, Plant City	1
L. S. Gardner, Albuquerque	1
M. R. Klepper, Spokane	1
A. H. Koschmann, Denver	1
R. A. Laurence, Knoxville	1
D. M. Lemmon, Washington	1
J. D. Love, Laramie	1
P. C. Patton, Denver	1
J. F. Powers, Salt Lake City	1
Q. D. Singewald, Beltsville	2
J. F. Smith, Jr., Denver	1
A. E. Weissenborn, Spokane	1
TEPCO, Denver	3
TEPCO, RPS, Washington, (Including master)	2
	66

CONTENTS

	Page
Abstract	4
Introduction	4
Acknowledgments	5
The Conway granite	6
Collecting method	8
Methods of measurement	8
Data and calculation	9
Summary	14
Appendix I	15
Literature cited	16

TABLES

		Page
Table 1.	Minerals of Conway granite at Redstone, N. H.	7
2.	Chemical analyses	7
3.	Radioactivity of Redstone Quarry samples	10
4.	Comparison of variances	11

THE RADIOACTIVITY OF THE CONWAY GRANITE AT REDSTONE, CARROLL COUNTY, NEW HAMPSHIRE

By W. L. Smith and F. J. Flanagan

ABSTRACT

Forty-four samples of Conway granite were collected from the red and green phases of the rock at Redstone, N. H. Sampling was done over a pattern which should aid in the statistical interpretation of the variations in radioactivity in each phase, weathered and fresh, and between the two phases.

A large variation in radioactivity is shown between individual samples. Inspection of the means of the four subsets of samples shows that the red phase is higher in radioactivity than the green, that the weathered green is higher than the fresh green, and that the fresh red is slightly higher than the weathered red. Calculation of F ratios of different combinations of variances of the four subsets of material shows that only the fresh and weathered red phases may be considered as the same population in regard to radioactivity. Inferences are made that factors such as variations in mineralogic composition or differential leaching or absorption may be responsible for the variations of the radioactivity.

INTRODUCTION

A study of the radioactivity and the distribution of uranium in the rocks and minerals of the Conway granite of New Hampshire has been undertaken under the direction of A. P. Butler, Jr., of the Geological

Survey. As a part of this study William L. Smith, Rachel M. Barker, and Regina L. Wack, of the Geological Survey, collected a number of samples of granite at the Redstone, Carroll County, N. H., quarries, along patterns which should aid in the statistical interpretation of the information derived from the analysis of the samples.

The samples were collected for the immediate purposes of (1) determining the degree of variation of the radioactivity in the two phases of the Conway granite, (2) determining the effect of weathering upon the radioactivity of the rocks, and (3) comparing statistically the radioactivity of the two phases.

The Conway granite is relatively high in uranium content and contains proportionately large amounts of accessory minerals, thus minimizing possible sampling errors and providing material which, within the limitations of the size of sample used for analysis, should be typical of the whole sample.

ACKNOWLEDGMENTS

We wish to acknowledge the assistance of B. A. McCall and P. Moore, of the Geological Survey, who made the radioactivity determinations, and to thank W. J. Youden of the National Bureau of Standards for his advice on statistical problems. This work is part of a program undertaken by the U. S. Geological Survey on behalf of the Division of Research of the U. S. Atomic Energy Commission.

THE CONWAY GRANITE

The Conway granite is one of a series of the alkaline rocks which comprise the White Mountain batholith. The White Mountain batholith is of Carboniferous age and includes both intrusive and extrusive phases. At Redstone, N. H., a red phase and a green phase of the Conway granite have been mined by the Maine and New Hampshire Granite Corp. from adjacent quarries since 1889. The two phases are separated by a fault contact which is at the west end of the Redstone Red quarry. The distribution of the Conway granite in this area has been described by Billings (1928) and the petrography has been described by Billings (1928) and by Dale (1908).

The red phase of the Conway granite is a coarse even-grained biotite granite containing microperthite, smoky quartz, biotite, hastingsite, and accessory minerals in the amounts shown in table 1.

The green phase of the Conway granite is a coarse-grained yellow-green granite composed mainly of green microperthite, smoky quartz, hastingsite, and biotite. Billings (1928) describes the green phase as a segregation from the red phase. Comparison of the mineral compositions in table 1 shows a marked difference between the fresh red and fresh green rock.

Table 1.--Minerals of Conway granite at Redstone, N. H.

Mineral	Red phase	Green phase
	Major components	
Feldspar	70	75
Quartz	25	20
Biotite	3.0	0.2
Hastingsite	0.2	3.
	Accessory minerals (in order of abundance)	
	Magnetite	Magnetite
	Fluorite	Fluorite
	Allanite	Allanite
	Zircon	Zircon
	Apatite	Ilmenite
	Ilmenite	Pyrite
	Pyrite	Thorite

Analyses of the two phases by W. H. Herdsman (Billings, 1928) are shown in table 2.

Table 2.--Chemical analyses.

	Red phase	Green phase
SiO_2	70.45	69.85
Al_2O_3	14.87	14.44
Fe_2O_3	1.07	0.94
FeO	1.54	2.37
MgO	0.35	0.24
CaO	1.28	1.25
Na_2O	4.28	3.93
K_2O	4.16	5.04
H_2O+	0.65	0.66
H_2O-	0.50	0.35
TiO_2	0.69	0.74
P_2O_5	0.04	0.03
MnO	0.00	tr
Total	99.88	99.84
Sp. gr.	2.63	2.65

Weathering has altered the Conway granite near the glaciated surface of Redstone Ridge producing a greater amount of iron oxide staining toward the top of the quarries. Billings (1928) describes completely disintegrated glacial boulders of the red phase 1 foot in diameter and concludes that the breakdown of the rock has occurred since Wisconsin time. Dale (1908) describes limonite, kaolinite, calcite, and epidote as secondary minerals in the green phase; and hematite, kaolinite, leucoxene, chlorite, and calcite as secondary minerals in the red phase.

COLLECTING METHOD

Forty-four samples of the Conway granite were collected from both quarries. In the Redstone Green quarry a rock face 200 ft long by 50 ft deep is exposed; the Redstone Red quarry exposes 500 feet of granite to depths ranging from 30 to 80 ft. The samples were collected at regular intervals along the quarry faces in both the fresh rock at lower levels and in the weathered zone. The samples of weathered rock, which is not gruss, were collected approximately vertically above the fresh samples.

METHODS OF MEASUREMENT

All samples were ground to pass an 80-mesh screen and measured for their radioactivity by a routine β-γ method. The apparatus consists of a glass tube-and-sample holder made of a complete ground-glass joint into the bottom half of which is sealed securely in a coaxial position a 30 mg/cm^2 thin-walled Geiger tube. The outer half of the joint, when secured in proper position on the inner half, surrounds the Geiger tube so that the powdered samples may be held in a reproducible position. The unshielded tube-and-sample holder is held vertically by a ring stand and clamp and is connected to a conventional sealer. Background determinations are made using a radioactively inert salt such as sodium sulfate, and standardization is accomplished by comparison with counted chemically analyzed standards.

The usual assumptions are made that (1) all the radioactivity of the samples is due to uranium and its daughter products, and (2) the uranium is in secular equilibrium with its daughter products. Although these two assumptions may not be true, they allow us to calculate radioactivity measurements in terms of the percent equivalent uranium (eU), that is, the radioactivity which is equivalent to that shown by a specified percentage of uranium in equilibrium with its daughter products. This method of calculation has the advantage that intra-laboratory comparisons may be made without the laboratories specifying their exact counting conditions.

DATA AND CALCULATION

Radioactivity determinations were made on the samples and the results, expressed as net β-γ counts per 5-minute counting period, are shown in table 3.

Preliminary inspection of the data shows that: (1) a radioactivity count, for sample 136, of 1418 is about twice the value of the mean of all others in its class, and (2) the weathered green phase is higher in radioactivity, with one exception, than the fresh green, whereas the high and low values for the red phase are about equally distributed between the weathered and the fresh rocks. Although the value of 1418

Table 3.--Radioactivity of Redstone Quarry samples.

Green phase				Red phase			
Weathered		Fresh		Weathered		Fresh	
Sample	Counts*	Sample	Counts*	Sample	Counts*	Sample	Counts*
135	907	113	710	123	836	101	942
136	(1418)**	114	754	124	768	102	887
137	799	115	712	125	904	103	1041
138	831	116	750	126	1044	104	933
139	742	117	713	127	1143	105	969
140	716	118	767	128	953	106	1023
141	801	119	715	129	1030	107	1126
142	760	120	700	130	924	108	776
143	806	121	724	131	996	109	980
144	821	122	716	132	893	110	1051
				133	1100	111	1081
				134	873	112	1060
Number	9		10		12		12
Mean	798.1		726.1		955.3		989.1
Variance	3109.		507.		12260.		9234.
Standard deviation	55.8		22.5		110.7		96.1

* Net β-γ counts in 5 minutes.
**This value omitted from calculations. (See discussion above.)

counts above may be rejected upon inspection alone, it may be strongly rejected from a calculated "t" value of approximately 33, calculated using the mean and the standard deviation of the other nine samples in the weathered green phase group. The table "t" value for the 95 percent confidence level for eight degrees of freedom is 2.31.

It seems from the pattern of sample collecting at regular intervals that the data could be treated by an analysis of variance in a 2 X 2 classification design where color would be one classification and the condition of the rock the other. One of the prerequisites for the analysis of variance is that the variances of the subsets be homogeneous, and it may be seen by inspection of table 3 that one standard deviation, that of the weathered red phase, is about five times that of the fresh green phase. The squares of the standard deviations--the variances--vary by a factor of about 5^2, and hence are even more heterogeneous. The data, therefore, cannot be treated by an analysis of variance.

We may, however, compare the four subsets of data by testing certain hypotheses concerning the variances of pairs. If the variances of two sets of random samples are not significantly different, then it may be inferred that the samples from which the variances are calculated are not significantly different. The statistic used for this test is the F ratio, $F = \frac{s_1^2}{s_2^2}$, where s_1^2 is the larger of the two variances. The hypothesis we wish to test is that the variances σ^2 of the different populations, from which samples with variances s^2 were drawn, are equal. The 95 percent confidence level, i.e., one chance out of twenty being wrong, has been chosen. The sample pairs whose variances are being tested, the F ratios at the 95 percent confidence level, and the calculated F ratios are shown in table 4.

Table 4.--Comparison of variances.

Variance ratio s_1^2/s_2^2	$F_{95}(N_1-1, N_2-1)$	F (calculated)	Conclusion
Weathered green/fresh green	3.23	$\frac{3109}{507} = 6.13$	Significant
Weathered red/fresh red	2.82	$\frac{12260}{9234} = 1.33$	Not significant
Weathered red/weathered green	3.32	$\frac{12260}{3109} = 3.94$	Significant
Fresh red/fresh green	3.10	$\frac{9234}{507} = 18.21$	Significant

There is therefore only one set of variances that may be considered as having come from the same populations and that set is the weathered red-fresh red pair. All other combinations have variances significantly different; the fresh red-fresh green pair are significant.

Consideration of the data in table 3 shows that a considerable variation exists in the radioactivity of the red-phase samples as compared to the green. The alternating high and low values of radioactivity in the red phase, and to a much lesser extent in the green, lead one to suspect that one or more unknown factors are influencing the radioactivity. This effect might be due to several causes, for example, different mineralogic composition, differential leaching, or absorption of radioelements.

The theory of different mineralogic composition is further strengthened by data obtained in the laboratory. Radioactivity measurements made during an internal standardization of a shale sample with the same counting intervals showed that this shale sample had a mean radioactivity of 0.0058 percent eU with a standard deviation of $\pm$ 0.00016 percent eU or a coefficient of variation of $(\frac{0.00016}{0.0058} \times 100)$ 2.8 percent. Uranium is believed to be the main source of radioactivity in this shale and it is generally believed to be uniformly distributed horizontally. The standard deviation above obtained from 100 randomly selected portions of the same sample, counted on two different counters and by two different operators, may then be called the expected value of the population standard deviation. As the 100 portions were merely replicate determinations of the same shale sample, we may also call this estimate the expected standard deviation, σ_m, of the method where the counting rate is about 1000 counts per five-minute counting period.

This now gives a basis for comparison. If the samples of the red phase are homogeneous with respect to the source of radioactivity, a standard deviation of 28 counts would be expected. This is obtained by multiplying the mean of the counts of the red phase, 989, by the known coefficient of variation, 2.8 percent. We shall assume that the variance, σ^2, shown by the fresh red phase samples, for which s^2 of the samples is an estimate, was obtained from a random sample of the population from which our method variance, σ^2_m, was derived. To test this hypothesis we shall use the statistic $\chi^2/\text{d.f.} = \frac{s^2}{\sigma_m^2}$ which has a $\chi^2/\text{d.f.}(N-1)$ distribution where the degrees of freedom (d.f.) are equal to (N-1), N being the number of observations in the sample. The upper value of $\chi^2/\text{d.f.}$ (11) at the 95 percent confidence interval is 1.79. The calculated $\chi^2/\text{d.f.}$ (11) is equal to $\frac{9234}{(28)^2}$ or 11.78, which is extremely significant.

As the same method of measurement was used for both the shale and the granite, the observed differences must be due, not to the method, but to variations in the samples themselves. Similar calculations involving the observed variances of the other three groups of samples show that only the variance for fresh green phase samples may be considered as being the same as the methods variance, σ_m^2. It must be pointed out that, whereas the significant values of $\chi^2/\text{d.f.}$ may indicate a possible difference in mineralogic composition, the nonsignificance of $\chi^2/\text{d.f.}$ for the fresh green phase does not indicate that small differences in the samples may not exist.

The sample data with radioactivity values calculated to percent equivalent uranium (eU) are attached as appendix 1.

SUMMARY

The radioactivity of fresh and weathered sectionsof the green and red phases of the Conway granite has been measured on forty-four samples from the Redstone quarries, N. H. Inspection of the means of the four subsets of samples shows that the red phase is higher in radioactivity than the green, that the weathered green is higher than the fresh green, and that the fresh red is slightly higher than the weathered red. Calculation of F ratios of different combinations of variances of the four subsets of material shows that only the variances of the fresh red and weathered red phases may be considered equal and, hence, that the two types of the red phase may be considered as the same population insofar as radioactivity is concerned. Inferences may be made, supported by a comparison of the obtained variance of the fresh red phase to an expected variance known from previous work, that variations in mineralogic composition or differential absorption or leaching may be responsible for the greater-than-expected differences in the radioactivity of the fresh red phase. Similar conclusions may also be drawn for the weathered green and the weathered red phases.

APPENDIX I

Radioactivity of the Conway granite, Redstone quarries, New Hampshire.

Green phase				Red phase			
Weathered		Fresh		Weathered		Fresh	
Sample	eUx10^4	Sample	eUx10^4	Sample	eUx10^4	Sample	eUx10^4
135	52	113	41	123	48	101	55
136	82	114	44	124	45	102	51
137	46	115	41	125	52	103	60
138	48	116	46	126	61	104	54
139	43	117	41	127	66	105	56
140	41	118	44	128	55	106	59
141	47	119	41	129	60	107	65
142	44	120	40	130	54	108	45
143	47	121	42	131	58	109	57
144	48	122	41	132	52	110	61
				133	64	111	63
				134	51	112	61

LITERATURE CITED

Billings, M., 1928, The petrology of the North Conway quadrangle in the White Mountains of New Hampshire: Am. Acad. Arts Sci. Proc., v. 63, p. 67-137.

Dale, T. N., 1908, The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island: U. S. Geol. Survey Bull. 354, 228 p.