HELIUM INDEXES FOR SEVERAL MINERALS AND ROCKS.

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ABSTRACT. Helium indexes of a series of crystalline basic rocks are found to be fairly consistent with expected geological sequence, probably because of the high helium retentivities of the mafic constituents. Results for pre- and post-ore dikes in southern Quebec and Newfoundland suggest contemporaneous mineralization in these two widely separated deposits. Poor results were obtained with minerals at Franklin, New Jersey, possibly due to their complex geological history, but on the average the results agree with geological indications of a late pre-Cambrian age. Variable results were obtained with other minerals, including magnetite, and some of these are ascribed to crystal imperfections. As noted previously, rocks having glassy groundmasses are of no use in geological correlation by the helium method.

THE production and storage of radiogenic helium in rocks and minerals has been the subject of intensive investigation for several years. It has become apparent that, while the radioactive mechanism is suitable for clocking geological time, the reliability of the helium index is uncertain because the helium retentivity differs from rock to rock and from mineral to mineral. This problem has been explored in a series of papers on "*The Distribution of Helium and Radioactivity in Rocks*" published in this Journal,[1] where the results for helium, radioactivity, and helium index have been given for several rocks and their constituent minerals. It is the purpose of this paper to present data for rocks and minerals not generally a part of the above investigation.* Suggestions for profitable continuation of helium studies are given, active work in this field having been discontinued for the present.

[1] Keevil, N. B.: 1938, Amer. Jour. Sci.; I. *36*, 406-416; II. 1942, *240*, 13-21; III. 1942, *240*, 204-215; IV. 1942, *240*, 831-846; V. 1943, *241*, 277-306; VI. 1944, (Chelmsford migmatite, in preparation with E. S. Larsen).

* Where overlapping has occurred, the results are included in the tables for sake of completeness. Preliminary reports of some of the data have been made already[2,3], and results for a series of samples from Red Lake, Ontario, have been published elsewhere.[4]

[2] Keevil, N. B.: 1938, Trans. Roy. Soc. 32, pp. 123-150.

[3] Keevil, N. B.: 1941, Univ. of Toronto Studies, 46, pp. 39-67.

[4] Horwood, H. C., and Keevil, N. B.: 1943, Jour. Geol. 51, pp. 17-32.

Results of co-operative studies on rocks and minerals from Massachusetts, Colorado, British Columbia, and the Northwest Territories will appear later.

TABLE I.

Helium Index Data for Rocks and Minerals from Franklin (F) and Sterling Hill (SH), New Jersey.†

No.	Specimen	Helium‡ x10⁻⁵cc./g.	Activity‡ Alphas/ mg./hr.	I	I/A
243	Trap dike (F)	11.0	2.25	150	0.60
227	Magnetite (F)	14.3	2.45	180	0.29
245	Franklinite (F)	0.62	0.09	212	0.35
261	Franklinite (F)	0.83	0.07	365*	0.61
283	Franklinite (F)	0.85	0.15	174	0.28
284	Franklinite (SH)	0.63	0.10	194	0.32
282	Zincite (SH)	0.13	0.03	133*	0.22
283	Willemite (SH)	0.27	0.37	224	0.36
280	Willemite (SH)	0.57	0.07	250*	0.40
281	Willemite (F)	0.20	0.05	123*	0.20
278	Hancockite (F) 30% Franklinite	8.60	2.8	94	0.16
245	Fowlerite (F)	2.07	0.28	227	0.36
282	Fowlerite (SH)	0.50	0.03(5)	438*	0.70
244	Impure barysilite (F)	1.61	0.64	77	0.12
277	Calcium larsenite (F)	0.32	0.05	196*	0.33
276	Roepperite (SH)	1.66	0.21	242	0.39
279	Friedelite (SH)	4.7	0.15	96	0.15
275	Schefferite (F)	6.38	0.09	2,200	3.68
296	Garnet (F)	7.33	1.17	193	0.31
295	Vesuvianite (F)	51.9	4.63	344	0.55
297	Biotite (some cyprine) (F)	1.00	0.06	510*	0.85
291	Plagioclase (F)	1.37	0.29	147	0.25
292	Amazonite (F)	0.08	0.19	13*	0.02
237	Crystal of manganiferous fluorescent calcite (white) (SH)	1.66	0.005	10,200*	17.0
239	Same pink crystal (F)	0.99	0.15	202	0.34
242	Aggregate of white non-fluorescent calcite crystals (SH)	4.19	0.21	615	0.98
245	Calcite sep'd from fowlerite (F)	3.66	0.07	1,600*	2.57
261	Calcite (F)	1.00	0.013	2,360*	3.93
227	Siderite with iron olivine (F)	65.5	7.2	280	0.47
293	Barite (F)	30.5	0.82	1,140	1.83
290	Sussexite (F)	0.81	<0.007	>3,550*	5.9
296	Apatite (F)	41.5	3.96	322	0.51
294	Pochuck gneiss	1.71	0.46	114	0.07

† Material furnished by Mr. Hans Lundberg or from the University of Toronto collections.

‡ Most of the values reported in this table represent an average of two or more determinations.

* Appreciable error due to low concentrations.

MINERALS FROM FRANKLIN, NEW JERSEY.

A group of minerals from Franklin and Sterling Hill, New Jersey, consisting of silicate, oxides, carbonates, sulphate, phosphate, and borate was investigated. The results summarized in Table I show a wide range of values for the helium index. The age of these minerals is between that of the pre-Cambrian

Pochuck gneiss, which shows an unusually high loss of helium, and the Paleozoic trap dike, which shows average helium retention. The minerals occurring in the pre-Cambrian Franklin limestone were apparently formed largely by replacement. Some are believed to be primary, some to have been introduced by the pegmatites of possible pre-Cambrian age, and others by contemporaneous or later hydrothermal processes. This complex mineralogical history of the deposits may account in part for the variations in helium index.

The earlier minerals subjected to changes in temperatures by later igneous fluids, and possibly partly recrystallized, show the greatest loss of helium from their crystal structures. The wide range of helium indexes found for the hydrothermal minerals and products of secondary metamorphism due to the intrusions of pegmatite dikes is probably due to differences in composition, crystal structure, and origin. Their average helium retentivity is probably less than 50 per cent and greater than 25 per cent, indicating an age greater than 500 million years and probably late pre-Cambrian. Assuming an age of 600 m.y., the helium retentivities, I/A, are given in the last column of Table I.

An attempt has been made to group the results according to the classification of Palache:

Primary Minerals		Skarn		and Pneumatolytic Minerals		Hydrothermal Minerals	
Franklinite	174,194	Magnetite	180	Schefferite	2,200*	Calcite	1,600*
Willemite,	224, 250,	Siderite	280	Calcium		Franklinite	212
123		Roepperite	242	Larsenite	196	Fowlerite	227
Average,	193	Friedelite	96	Garnet	193	Calcite	2,360*
		Hancockite	94	Apatite	322	Franklinite	365
		Barysilite	77	Vesuvianite	344	Fowlerite	438
				Bio.+		Zincite	133(?)
				cyprine	510	Calcite	10,200*
				Average,	230	Calcite	202
						Calcite	615*
						Barite	1,140*
						Sussexite	3,550*
						Average,	263

* High values of helium index omitted in averaging.

Considerable uncertainty admittedly exists in the assignment of the minerals and results in these groups; unfortunately information on the origin of most of the specimens was lacking, but examination of the minerals, the usual mode of origin, and the mineral associations in the samples gave some indication as to their correct classification. It may be noted that six minerals of probable hydrothermal origin—carbonates, sulphate and borate—show evidence of extraneous helium, possibly from trapped gases present in the hydrothermal fluid.

The relationship of helium retentivity to structure is not clear, interpretation of the results for later minerals with more open structures being complicated by the presence of excess helium. However, a group of minerals having close-packed prismatic structures formed late in the period of mineralization show good retentivity, with helium indexes as follows: Apatite, 322, fowlerite 330, roepperite, 242, and vesuvianite 344. The helium retentivity is probably between one-half and one for this group, and if one assumes the average retentivity to be seventy-five per cent, a helium age of 550 m.y. is obtained for these Franklin minerals, consistent with the average result estimated above. One might expect the close-packed oxide structures to be highly retentive also, but as already suggested these may be imperfect due to metamorphism by later hydrothermal processes. In the case of the zincite mixed with fowlerite, the former was present as a narrow band of finely crystalline material.

On the whole, the results suggest that one must exercise caution in interpreting data on minerals from highly mineralized areas, at least to the degree in which they influence the assignment of geological age.

MINERALS FROM VARIOUS SOURCES.

Magnetite obtained from museums, University collections, and various sources have been found by Hurley and Goodman[5] to possess a retentivity of 1. This high retentivity does not appear to be generally true (Table II), however, a sample of pre-Cambrian magnetite from Port Henry, New York, obtained from the University of Toronto collections having been found to have a helium index of 228, which indicates a retentivity one-third of Hurley's value. Hedenbergite separated from the same sample has retained only one-fifth of the helium produced during its geological history. In a sample

[5] Hurley, P. M., and Goodman, C.: 1941, Bull. Geol. Soc. Am., 52, pp. 545-560.

TABLE II.

Helium Index Data from Minerals from Various Sources.

Mineral	Source	He x10⁵ cc./g.	a Alphas/ mg./hr.	I	I/A
	1. Port Henry, New York.				
Magnetite	U. of T. Collection	9.7	1.24 1.39 Ave. 1.31	228	0.38
Hedenbergite	do., separated from magnetite	336.0	82	126	0.21
	2. Digby Neck, Nova Scotia.				
Magnetite Crystals	Royal Ontario Museum Collection	0.48	0.06	246	1.(8)
	3. Chu Chua, B. C.				
Magnetite from partly oxidized ore	Royal Ontario Museum Collection	0.09	0.12	23	0.66
	4. Magnet Cove, Arkansas				
Magnetite	Royal Ontario Museum Collection	0.57	0.41	43	0.29
Quartz crystals*	Harvard Univ. Collection	0.47	0.14	103	0.41
	5. Hot Springs, Arkansas.				
Garnet crystals	Ward's Minerals	2.33	0.29	247	0.99
	6. Fort Wrangel, Alaska.				
1st Crystal Garnet	Ward's Minerals	0.51	0.12	130±40	1.00
2nd Crystal Garnet	Ward's Minerals	0.24	0.13	57±15	0.44
3rd Crystal Garnet	Ward's Minerals	1.27	0.11	350±35	2.69
	7. Moose Mt., Ontario.				
Titaniferous Magnetite	U. of T. Collection	1.13	0.06	580	0.28
Tremolite	Separated from magnetite	1.65	0.033	1,600	0.78
	8. Lake St. John, Quebec.				
Titaniferous Magnetite	Royal Ontario Museum Collection	1.07	0.03	1,100	0.94

* Location in Arkansas not known.

from Moose Mountain, Ontario, however, tremolite associated with magnetite has retained most of the helium with titaniferous magnetite retained less than one-third. A titaniferous magnetite from Lake St. John, Quebec, gave a result consistent with its geological age and nearly complete retentivity, but magnetite with titanium minerals separated from a Yellowknife diabase (ref. 1, paper IV) contained considerable excess of helium from a source other than its constituent radioactivity. Good crystals from Digby Neck, Nova Scotia, yielded uncertain results due to the difficulty in determining the small quantity of radioactive elements present.

Some escape of helium during exposure to surface forces undoubtedly plays a part in variable and low retentivities; for example, magnetite from a partly oxidized ore from Chu Chua, British Columbia, has retained only two-thirds of its radiogenic helium.

Quartz has been found to have poor retentive properties, but garnet sometimes gives a helium index close to the expected helium age, as with crystals from Hot Springs, Arkansas. Some rather surprising results in three red garnet crystals from one locality at Fort Wrangel, Alaska, are at least partly explained by imperfect crystal structure. Although externally the crystals appeared to be perfect, examination of thin sections showed the garnets to be quite impure, irregular blebs of quartz being present to varying extents in three sections cut at different directions through a crystal. It is clear that any hope of success in using helium indexes in geological correlation must rest on the study of unaltered and microscopically perfect crystals.

ROCKS AND MINERALS FROM BUCHANS, NEWFOUNDLAND.

It has been shown[1, 3] that porphyries and lavas are of no use in the helium method of estimating geological age, a fact confirmed by the results for such rocks of Paleozoic age from Newfoundland (Table III). Quartz porphyries and feldspar porphyries of probable Ordovician or Silurian age gave helium indexes of 11, 17, 18, 20, 29, and 39, and associated lavas 10, 11, 11, 22, 22, 30, and 54. Quartz-carbonate stringers yielded a higher helium index, 101, but the results for Franklin carbonates suggest that this may be due to the presence of extraneous helium.

TABLE III.

Helium Index Data for Rocks and Minerals from Buchans, Newfoundland.

Sample	Helium x 10^5 cc./g.	Activity alphas/ mg./hr.	I	I/A
Post-ore diabase	0.58	0.30		
53-12 Stope Buchans Mine ..	0.52	0.33	53	0.41
		Ave. 0.315		
Barite with ore, Lucky Strike,		0.11		
north orebody	0.36	0.15		
		0.14	83	0.55
		Ave. 0.133		
Pre-ore diabase, Hanging wall,		0.54		
Lucky Strike orebody	0.93	0.36		
		0.43	65	0.36
		Ave. 0.44		
Fine grained red Granite (1) North of R. R. bridge				
over Little Sandy River (2)	5.3	2.44		
		2.18	70.5	0.29
		Ave. 2.31		
	7.9	2.24		
		2.06	113	0.47
		Ave. 2.15		
Coarse gray granite, E. side Stag Ridge in bed of Victory Brook	1.31	0.29*	139	0.50
Same, quartz concentrate	0.78	0.23*	104	0.38
Same, biotite and hornblende..	4.85	0.51*	292	1.06
Quartz, porphyry and rhyolite		0.92		
from drill core	0.80	1.49		
		1.75		
		1.54	17	0.05
		Ave. 1.42		
Quartz, porphyry, large quartz	0.71	0.92		
eyes, drill core	0.50	1.12	18	0.05
		Ave. 1.02		
Same, outcrop south of mill...	0.87	0.9*	29	0.09
Quartz porphyry veinlets near ore body	0.41	0.64*	20	0.06
Quartz-carbonate stringers in quartz porphyry veinlets ...	0.28	0.085*	101	0.31
Amphibolite from drill core ...	4.18	0.48		
		0.42		
		0.31	321	0.96
		Ave. 0.40		

TABLE III (*Continued*).

Sample	Helium x 10^5 cc./g.	Activity alphas/ mg./hr.	I	I/A
Dacite, N. side, Buchans R., between bridge and Old Buchans	0.58	2.00		
		1.92	9	0.03
		1.96		
		2.11		
	0.69	Ave. 1.85		
		Ave. 1.98	10.5	0.03
Lava from drill core	0.61	0.59		
		0.64	30	0.09
		Ave. 0.615		
"Chocolate" lava, Lava breccia	0.43	0.66		
		0.52	22	0.06
		Ave. 0.59		
Lava breccia, Laycock's Lookout	1.13	0.69		
		0.61	54	0.15
		Ave. 0.65		
Trachyte intersected by epidote veinlets, drill core	0.98	1.34		
		1.04		
		1.20		
		1.93	22	0.06
		Ave. 1.38		
Feldspar porphyry, 800 ft. S. of Mary March Bridge, Newfoundland R. R.	3.25	2.17		
		3.01		
		2.44	39	0.11
		Ave. 2.54		
Quartz porphyry fragments in arkose, W. of Arkose Hillock North of Oriental orebody..	0.50	1.79		
		1.36		
		1.11	11	0.03
		Ave. 1.42		
Same, Red glass fragments in arkose	0.42	1.56		
	0.51	1.29		
		1.22	11	0.03
		Ave. 1.36		

* Average of several values.

Helium retentivity, I/A, is estimated from geological information and an age A, obtained from an assumed time scale.[3]

Helium index results for crystalline basic rocks or for granitic rocks frequently give results consistent with expected geological sequence. In the Buchans suite these rocks in order of increasing age gave helium indexes of 53, 65, 92, 139 and 321, the last four being all within a single geological period (Paleozoic).

Application of average helium retentivities obtained from several hundred comparisons of helium index with geological data[3] provides a guide for estimating the helium age. When the corrections are made, the results are consistent with geological sequence. As a matter of fact, the errors for geological and calculated ages may be approximately equal in the last two columns of Table IV.

It is interesting to note that the pre- and post-ore basic dikes at the Eustis mine, Quebec, and at the Lucky Strike Mine, Newfoundland, show the expected sequence,

Helium Ages	Eustis Mine, Quebec	Lucky Strike Mine, Newfoundland
Post-Ore Dike	140	130
Ore	—	165
Pre-Ore Dike	185	165

suggesting that the lead-zinc ores in these widely separated deposits are of the same age.

TABLE IV.

Helium Ages Calculated from Average Retentivities.

Sample	I	Average Retentivity	Helium Age	Geological Age
Post-ore diabase	53	0.4	130	Triassic
Orebody (barite)	83	0.5	165	Carboniferous?
Pre-ore diabase	65	0.4	165	Carboniferous?
Younger Granite	92	0.3	300	Devonian
Older Granite	139	0.3		Early Devonian
Quartz	104	0.3	425	Early Devonian
Biotite & Hornblende	292	0.6		Early Devonian
Amphibotite	321	0.6	530	Ordovician

HELIUM INDEXES FOR SOME NORTH AMERICAN BASIC ROCKS.

Results for a number of basic rocks from Yellowstone National Park, Michigan, New Jersey, and Quebec are given in Table V. Helium retentivities in the last column were estimated from geological information and the assumed time scale.[3] Most of these rocks are reasonably well dated geologically and the sequence of helium indexes is found to be in good accord with that deduced from field investigations. These data suggest that results for basic rocks are more reliable than those for other rocks a conclusion first reached by Lane and Urry.[6, 7]

In this connection it should be pointed out that basic rocks are usually better dated geologically than are acidic intrusives or ore-bodies, which raises the question whether many variations in helium retentivities and many discrepancies in the sequences of helium indexes may not be due to errors in the assignment of *geological age.*

TABLE V.

Diabases and Basic Rocks from Yellowstone National Park, Michigan, New Jersey, and Quebec.

Rock	He $\times 10^5$ cc./g.	Ra $\times 10^{13}$ g./g.	Th $\times 10^6$ g./g.	a alphas/ mg./hr.	I	I/A
Basalt, overhanging Cliff, Yellowstone Park	0.32	4.16	4.30	0.81	12	0.60
Trap rocks, Long Lake, Wyoming, border of dike..	6.4	4.56	5.15	0.93	211	0.37
Same, 2 ft. from margin of 100 ft. dike	5.8	4.62 4.95	4.08	0.94	190	0.33
Quad Creek, Wyo.	16.6	1.4 1.6	1.6 2.6	0.28 0.40	1810 1275	1.0
Trap rock, Gogebic Range, Mich. ...	1.82	1.40	1.72	0.30	186	0.31
Diabase, Horne Mine, Noranda, Que.	4.9	4.85	2.43	0.71	210	0.37
Post-ore Lamprophyre, Eustis Mine, Que.	1.5	4.7	2.93	0.75	61	0.47
Pre-ore Lamprophyre, Eustis Mine, Que.	0.99	2.3	1.61	0.38	80	0.45
Basalt flow, Watchung Mts., N. J.	0.82	...	...	0.37	68	0.45
Palisades sill, New York	0.99	...	...	0.34	89	0.59
Basalt, Oldwick, N. J.	0.99	2.3	2.26	0.44	69	0.46

[6] Lane, A. C., and Urry, W. D.: 1935, Bull. Geol. Soc. Am., *46*, pp. 1101-1120.

[7] Urry, W. D.: 1936, Bull. Geol. Soc. Am., *47*, pp. 1217-1234.

The agreement between geological age and helium age (corrected by applying average helium retentivities) for several basic rocks is shown in Table VI, and the results suggest that helium age determinations may prove useful when geological information is obscure. For example, Table VI indicates that rocks of Miocene (20), Triassic (150), Carboniferous (250), Keweenawan (575), and Archean (3000) age could be distinguished by the helium method. However, since feldspar comprises about one-half of these rocks, and its retentive properties are low (0.20), it seems more desirable to use the mafic portions of basic rocks, which on the basis of the above figures

TABLE VI.

Comparison of Helium and Geological Ages for Several Basic Rocks.

Location	Helium Index	Helium Age (1)*	Helium Age (2)*	Geological Age
Overhanging Cliff, Yellowstone Park	12	25	21	Miocene
Buchans, Newfoundl'd	53	120	105	Triassic
Eustis Mine, Que. ...	61	140	120	Triassic
Watchung Mts., N. J.	68	155	135	Triassic
Oldwick, N. J.	69	155	140	Triassic
Palisades, N. Y.	89	200	175	Triassic
Buchans, Newfoundl'd	65	150	150	Pre-Triassic?
Eustis Mine, Que. ...	80	185	185	Carboniferous?
Kilchattan, Scotland..	80	185	185	Post-Devonian
Reasg Buidhe, Scotland	109	250	250	Post-Devonian
Franklin, N. J.	150	340	340	Post-Ordovician
Buchans, Newfoundl'd (Amphibolite)	321	530	530	Ordovician
Long Lake, Wyoming	200	450	575	Keweenawan
Gogebic Range, Mich.	186	425	530	Keweenawan
Noranda, Que.	210	475	600	Keweenawan
Quad Creek, Wyoming	1550	2875†	...	Pre-Cambrian
Huron Claim, Manitoba	1800	3200†	...	Early pre-Cambrian

* (1) from average I/A=0.44; (2) from retentivity–age relationship.[3]
† Corrected for decay of parent elements.

possess an average retentivity of about 0.7; such a procedure should give even better agreement of helium age and geological age than is evident in Table VI. Results obtained thus far on separated minerals have been by no means perfect, although those obtained as pure minerals separated from carefully selected rocks are encouraging.

It is worthy of mention that there seems to be a change of retentivity with time, the older rocks showing greater loss of helium than the younger. Referring to the last columns of Table V and part of Table III the helium retentivities are Miocene (0.60), Triassic (0.45), and pre-Cambrian (0.34). A relationship between helium retentivity and degree of alteration has been noted elsewhere.[4, 8]

TABLE VII.

Lavas and Monchiquites from England and Scotland.

Specimen	He $\times 10^5$ cc./g.	Ra $\times 10^{13}$ g./g.	Th $\times 10^6$ g./g.	a alphas/ mg./hr.	I	I/A
Basic Andesite Lava, Mosedale, Cumberland, England	0.59	...	...	0.59	30.7	0.09
Basic Andesite Lava, Keswick, Cumberland, England	0.73	...	...	1.45	15.5	0.05
Rhyolite, Long Sleddale, Westmoreland, England	0.45	...	...	2.83	5	0.01
Monchiquite dike, Riasg Buidhe, Is. of Colonsay, Scotland	4.05	7.18	2.04	1.13	109	0.44
Monchiquite dike, Kilchattan Is. of Colonsay, Scotland	1.71	4.03 3.2	3.42	0.72	80	0.32

LAVAS AND MONCHIQUITES FROM ENGLAND AND SCOTLAND.

Although helium indexes for basic rocks of the monchiquite type from Scotland fit reasonably well in the sequence of results for other crystalline basic rocks (Tables VI and VII), the results for lavas show no relationship to geological age and indicate variable and pronounced loss of helium, typical of lavas and porphyries having glassy groundmasses.

Data for the three lavas from the Lake District, England,

[8] Keevil, N. B.: 1941, Trans. Am. Geophys. Union, pp. 501-503.

are especially convincing because these rocks are well dated, being unquestionably of Ordovician age. It was hoped, in the earlier stages of these investigations, that results for these rocks could be used as fixed points on a helium-time scale and every precaution was taken to obtain the best possible material. The writer is indebted to Dr. S. E. Hollingworth and to the Great Britain Geological Survey for their painstaking work in supplying material together with complete descriptive details. It is most regrettable that this research has shown the material to be unsuitable, but at least it has helped to establish the limits of application of the helium method to geological materials.

LAVAS FROM SOUTHERN MASSACHUSETTS.

Two specimens of lavas were taken near North Attleboro, Massachusetts, from opposite sides of Route I near the Rhode Island State line. Although the writer has received conflicting opinions regarding the exact age from different geologists, there is no question that these rocks are late Paleozoic. Consistent with other results on lavas, the helium indexes and the retentivities are low (Table VIII). The red rhyolite is somewhat fresher in appearance than the gray-colored basalt, but both were jointed and slightly weathered along joint planes, and both had the same geological history. The result for the rhyolite, which is actually somewhat higher than usual for lavas, may be due to the relatively higher retentivities of the feldspar phenocrysts and quartz veinlets present in the specimen used for this investigation.

TABLE VIII.

Rhyolite and Basalt from N. Attleboro, Mass.

Specimen	He $\times 10^5$ cc./g.	Ra $\times 10^{13}$ g./g.	Th $\times 10^6$ g./g.	a alphas mg./hr.	I	I/A
Rhyolite	1.57	6.50	9.0	1.47		
				1.21		
				1.42	35	0.15
				Ave. 1.37		
Basalt	0.11	2.75	3.22	0.57	6	0.03

DISCUSSION.

While porphyries, most lavas, and minerals in deposits that have been altered or reworked are shown to be generally unsuitable for helium-age work, some degree of success has been obtained with unaltered crystalline igneous intrusives, the best results having been obtained with basic members of this group.

In important problems of correlation where geological criteria of age are lacking, helium-age determinations on rocks may be warranted. Because of the low helium retentivities of quartz and feldspar, however, it has been recommended that iron minerals separated from carefuly selected specimens be studied. The results obtained with such minerals thus far suggest that samples be as free as possible from any geological influences that may have distorted crystal structure or have caused chemical alteration. Even so, there is some question whether one mineral or type of mineral, by any standard of selection, is wholly reliable for geological correlation by the helium method.

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