PROCEEDINGS OF THE THIRTY-THIRD ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA AT BOSTON, MASSACHUSETTS

C. S. HURLBUT, JR., *Secretary.*

The thirty-third annual meeting of the Society, which was held on November 13–15, 1952, at the Hotel Statler, Boston, Massachusetts, was attended by 244 Fellows and Members. Scientific sessions were held on the morning and afternoon of November 13 and 15, and on the afternoon of November 14. The Program of the Mineralogical Society carried titles and abstracts of 86 papers, 81 of which were presented orally.

The annual luncheon of the Society on November 14 was attended by 171 Fellows, Members and guests. Following the luncheon the eleventh presentation of the Roebling Medal was made to Fred. E. Wright and the second presentation of the Mineralogical Society of America Award was made to Frederick H. Stewart. The Society was addressed by the Retiring President, Michael Fleischer, on *Some Problems of Chemical Mineralogy.*

The 1952 Council of the Society met for 13 hours during November 12 and 14, 1952, and discussed 24 items of business. The 1953 Council met briefly on November 15. Much of the business of the 1952 Council was of a routine nature, but some items that are of interest to the general membership are mentioned below.

1. *Revision of the By-Laws.* It has been felt by a group of Fellows of the Society that the ballot for officers should carry two names for each office. Accordingly, the Council debated this question at length but decided against such action. However, the Council felt that, if it were made easier for nominations to be made by Fellows and Members at large, somewhat the same end would be accomplished. To achieve this purpose the Council voted to approve the following change in Article IV, Section 1 of the By-Laws and to present it to the membership at the time of the election of officers for 1954:

From

Nominations for office shall be made by the Council. The list shall be published in the Journal of the Society at least three months before the annual meeting. Any ten (10) fellows or members may forward to the secretary other nominations for any or all offices. All such nominations reaching the secretary not later than three months prior to the annual meeting shall be printed, together with the names of the nominators, as special ballots. The regular and special ballots shall then be mailed to the general membership. The results shall be announced at the annual meeting, and the officers thus elected shall enter upon duty at the adjournment of the meeting.

To

Nominations for office shall be made by the Council. The list shall be published in the Journal of the Society at least three months before the annual meeting. Any ten (10) fellows or members may forward to the secretary other nominations for any or all offices. All such nominations reaching the secretary not later than three months prior to the annual meeting shall also be printed on the ballots to be mailed to the general membership. The results shall be announced at the annual meeting, and the officers thus elected shall enter upon duty at the adjournment of the meeting.

This change would enable 10 Fellows or Members to propose nominations which would be printed on the regular ballot together with nominations made by the Council without differentiating between the two slates.

2. *Committee on Committees.* The 1951 Council appointed a committee to review the committee structure of the Society and to report to the Council at the 1952 meeting. The report of this Committee as accepted by the Council is as follows:

1. *Nominating Committee for Fellows*

It shall be the duty of this Committee to examine the qualifications of persons nominated for Fellowship in the Society and of others, qualified but not nominated, and to report each year to the Council for election. The Committee shall consist of six Fellows, appointed by the Council to serve three-year terms, two appointments to expire each year. The Chairman shall be designated by the Council.

2. *Nominating Committee for Officers*

It shall be the duty of this Committee to recommend to the Council candidates for the position of President, Vice-President, Secretary, Treasurer, Editor, and Council or Councilor (4-year term). The Committee shall consist of five Fellows to be appointed by the Council to serve one-year terms. The Chairman shall be one who has served on the Committee during the previous year.

3. *Roebling Medal Committee*

It shall be the duty of this Committee to recommend to the Council whether an award of the Roebling Medal shall be made in the following year and to recommend the recipient, if any. The Committee shall consist of three Fellows to be appointed by the Council to serve one-year terms. The Chairman shall be one who has served on the Committee during the preceding year.

4. *Mineralogical Society of America Award Committee*

It shall be the duty of this Committee to recommend to the Council whether an award shall be made during the following year and to recommend the recipient of the Award, if any. The Committee shall consist of five Fellows to be appointed by the Council to serve one-year terms. The Chairman shall be one who has served on the Committee during the preceding year.

5. *Financial Advisory Committee*

It shall be the duty of this Committee to serve as advisers to the Treasurer on matters pertaining to the investment of the Society's funds. The Committee shall consist of three Fellows or Members to be appointed by the Council to serve three-year terms. The Chairman shall be designated by the Council; he shall be one who has served on the Committee during the preceding year.

6. *Auditing Committee*

It shall be the duty of this Committee to inspect and verify the books of the Treasurer as of August 1 and to report its findings to the Council. The Committee shall consist of three Fellows or Members to be appointed by the President to serve one year. The Chairman shall be one who has served on the Committee during the preceding year.

7. *Committee on Nomenclature*

It shall be the duty of this Committee to consider problems of mineralogical nomenclature, to maintain contact with other societies or their committees, and to conduct correspondence and conferences with them aimed at reaching international agreement on such problems, and to recommend action by the Council on matters of nomenclature. The Committee shall consist of six Fellows to be appointed by the Council for three-year terms. The Chairman, designated by the Council, shall be one who has served during the preceding year. If necessary, the Council may appoint, with the advice of the Chairman, subcommittees to serve for specified times to deal with special problems.

8. *Program Committee*

It shall be the duty of the Program Committee to consider the types of program to be presented at the annual meeting of the Society, to suggest suitable subjects for Symposia at these meetings, and to make recommendations to the Council if changes in programs are deemed desirable. The Chairman shall serve as representative of the Society on the Program Committee of the Geological Society of America; the Secretary is ex officio a consultant of this Committee. The Committee shall consist of three Fellows appointed by the Council for three-year terms; the Secretary shall be a member ex officio.

9. *Editorial Board, The American Mineralogist (Board of Associate Editors)*

It shall be the duty of the Board to serve as advisers to the Editor on matters of policy pertaining to the conduct of the Society's Journal, *The American Mineralogist.* The Board shall consist of six Fellows, two to be appointed each year by the Council for a term of three years.

10. *Special Publications Editorial Board*

It shall be the duty of this Board to consider manuscripts suitable for publication in the Mineralogical Society of America Special Publications Series, to oversee their editing, and to make recommendations to the Council as to their publication. The Board shall consist of six Fellows to be appointed by the Council for three-year terms.

11. *Representative to National Research Council*

One, to serve three years, appointed by the Council.

12. *Representative to American Geological Institute*

Two, one appointed each year by the Council, to serve two years.

13. *Executive Committee*

There shall be an Executive Committee of three (President, Secretary and Treasurer) to handle matters that arise during the year and require prompt action.

14. *Committee on Committees*

There shall be a Committee on Committees composed of five Fellows. This Committee is to be appointed by the Vice-President and is to report to the incoming Council at its first meeting.

Committees of the Mineralogical Society of America

Roebling Medal Committee

H. H. Hess, *Chairman*
H. E. Merwin
J. D. H. Donnay

Mineralogical Society of America Award Committee

V. T. Allen, *Chairman*
T. F. W. Barth
W. F. Bradley
J. W. Gruner
R. S. Cannon, Jr.

Nominating Committee for Officers

E. W. Nuffield, *Chairman*
B. Stringham
J. R. Goldsmith
H. Winchell
J. F. Schairer

The above committees reported to the 1952 Council. It should be pointed out that these committees make recommendations, but the Council is responsible for final choice. In order to have a larger participation in the affairs of the Society, Fellows and Members are requested to send to the Secretary suggestions for candidates for Awards and for officers.

Nominating Committee for Fellows

W. Parrish and S. Zerfoss 1953
A. Buddington, *Chairman*, and H. Insley 1953–54
J. T. Lonsdale and R. B. Ferguson 1953–55

Financial Advisory Chairman

R. E. Fuller 1953
J. P. Marble 1953–54
E. P. Henderson, *Chairman*, 1953–55

Auditing Committee

H. S. Yoder, Jr., *Chairman*
(The remaining members are to be appointed later by the President.)

Nomenclature Committee

M. Fleischer and B. H. Mason 1953
C. Frondel, *Chairman*, and W. F. Bradley 1953–54
A. L. Howland and E. W. Nuffield 1953–55

Program Committee

G. T. Faust, *Chairman*, 1953
R. A. Rowland 1953–54
J. T. Goldsmith 1953–55

Special Publications Editorial Board

C. Frondel, *Chairman*, and M. Fleischer 1953
A. F. Buddington and L. S. Ramsdell 1953–54
F. A. Bannister and A. Pabst 1953–55

Board of Associate Editors
E. S. Larsen, Jr. and A. F. Rogers 1953
M. Fleischer and G. Tunell 1953–54
A. Pabst and E. F. Osborn 1953–55

Representatives
National Research Council
E. Ingerson
American Geological Institute
J. P. Marble 1953
W. T. Pecora 1953–54

REPORT OF THE SECRETARY

To the Council of the Mineralogical Society of America:

ELECTION OF OFFICERS AND FELLOWS

Five hundred ballots were cast in the election of officers: 148 by Fellows and 352 by Members of the Society. The officers elected to serve in 1953 are:

President: J. D. H. Donnay, The Johns Hopkins University, Baltimore, Maryland
Vice-President: H. V. Ellsworth, Canada Geological Survey, Ottawa, Canada
Secretary: C. S. Hurlbut, Jr., Harvard University, Cambridge, Massachusetts
Treasurer: Earl Ingerson, U. S. Geological Survey, Washington, D. C.
Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan
Councilor (1953–56) C. Osborne Hutton, Stanford University, Palo Alto, California

Dr. H. V. Ellsworth's untimely death in October 1952 left a vacancy in the office of Vice-President for 1953. To fill this vacancy the Council appointed Sterling B. Hendricks Acting Vice-President for 1953.

According to the provisions of the Constitution, the following have been elected to fellowship:

Louis Herman Ahrens, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Ciro Andreatta, Universita di Bologna, Bologna, Italy.
W(illiam) M(ortimer) D(rein) Bryant, E. I. duPont de Nemours and Company, Wilmington, Delaware.
Margaret Dorothy Foster, U. S. Geological Survey, Washington, D. C.
Kenneth T(itsworth) Greene, U. S. Bureau of Reclamation, Denver, Colorado.
Anna Martta Hietanen-Makela, U. S. Geological Survey, Washington, D. C.
Harry William Trudell, Abington, Pennsylvania.
Orville Frank Tuttle, Geophysical Laboratory, Washington, D. C.
Hatten Schuyler Yoder, Jr., Geophysical Laboratory, Washington, D. C.
(Frederik) William Houlder Zachariasen, University of Chicago, Chicago, Illinois.
Peter Zodac, Peekskill, New York.

MEMBERSHIP STATISTICS

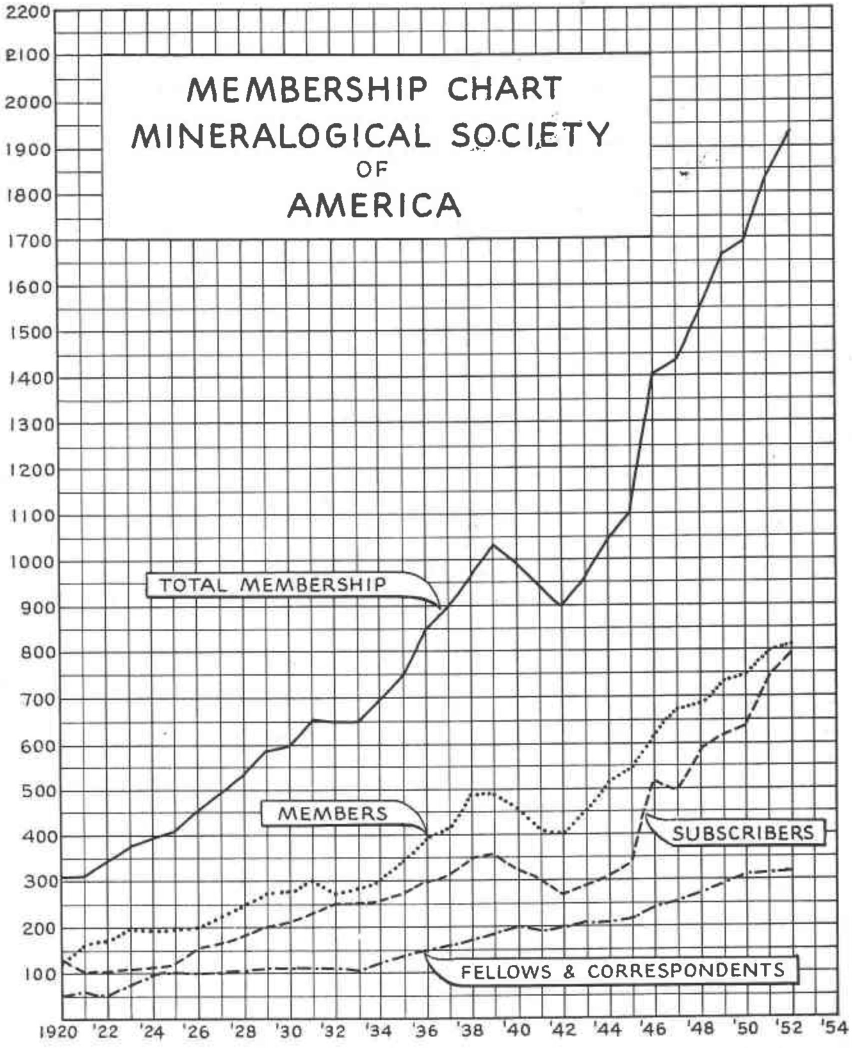
November 1, 1952

	1951	*1952*	*Gain*	*Loss*
Correspondents	5	5	0	0
Fellows	309	315	11	5
Members	797	814	143	126
Subscribers	735	799	130	66
	1846	1933	284	197

The above figures show a net gain of 6 fellows, 17 members and 64 subscribers. Considering the four groups together, there is a gain of 87, giving a total of 1933.

The Society lost through death four fellows: H. V. Ellsworth of the Canada Geological Survey, Ottawa, Canada; Samuel G. Gordon of the Atomic Energy Commission Laboratory, Los Alamos, New Mexico; Max N. Short of the University of Arizona, Tucson, Arizona; and Charles R. Toothaker of the Commercial Museum, Philadelphia, Pennsylvania.

Respectfully submitted,
C. S. Hurlbut, Jr., *Secretary*



REPORT OF THE TREASURER FOR 1952

To the Council of the Mineralogical Society of America:

Your treasurer submits herewith his report for the fiscal period beginning November 1, 1951, and ending July 31, 1952:

RECEIPTS

Dues and subscriptions	$ 7,726.07
Sale of back numbers	731.04
Authors' charges on reprints	830.58
Interest and dividends from endowment	3,675.10
Geological Society of America aid for printing the Journal	4,914.37
Advertising	966.17
Sale of Index, volumes 21–30	54.30
Sale of Index, volumes 1–20	4.70
Securities called and sold	1,318.75
Balance from Detroit luncheon	18.50
Contribution	1.00
	$20,240.58
Cash on hand, November 1, 1951	5,601.87
	$25,842.45

DISBURSEMENTS

Printing and distribution of the Journal (5 issues)	$12,784.61
Printing and distribution of reprints	1,016.68
To the Editor	375.00
Clerical assistance	426.00
Postage and express	318.33
Printing and stationery	230.88
Office supplies and equipment	156.09
1951 program and abstracts	425.00
New securities purchased	6,350.00
Commission on securities	63.66
Taxes on securities	3.23
Committee expenses	27.78
Expenses of officers to 1951 annual meeting	98.98
Safety deposit box	7.80
Refunds	32.21
Checks returned	8.00
Exchange charges on checks	1.72
Telephone and telegraph	4.16
M. S. A. Award certificates	146.00
	$22,476.08
Cash balance, July 31, 1952	3,366.37
	$25,842.45

The endowment funds of the Society as of July 31, 1952, consist of the following securities:

BONDS

6M Atlantic Coast Line, 4½	$5,257.50	
5M New York Central, 5	4,300.00	
5M Southern Railway	5,743.75	
		$15,301.25

PREFERRED STOCKS

200 shares, Southern California Edison, 4.88	$5,250.00	
100 shares, Union Pacific, 4	4,570.25	
60 shares, Jones and Laughlin, A, 5	4,987.50	
55 shares, United States Steel, 7	6,946.20	
50 shares, Virginia Electric & Power Co., 5	5,942.50	
24 shares, Public Service Electric & Gas Co	728.40	
10 shares, Consolidated Edison, 5	1,066.64	
		$29,491.49

COMMON STOCKS

288 shares, Potomac Electric Power Co	$3,871.00	
200 shares, Greyhound Corp	2,300.00	
150 shares, Spencer Kellog	3,775.00	
100 shares, Columbus & Southern Ohio Electric	2,087.50	
80 shares, Kroger Co	1,990.00	
60 shares, United Fruit Co	3,067.50	
56 shares, Standard Oil of New Jersey	1,444.84	
50 shares, Chesapeake & Ohio Railway	2,368.75	
50 shares, Phelps Dodge	1,975.00	
47 shares, American Telephone & Telegraph	6,427.32	
A. T. & T. Convertible Debentures	600.00	
40 shares, Plymouth Cordage	2,050.00	
30 shares, U. S. Playing Card	2,411.25	
		$34,368.16
		$79,160.00

Respectfully submitted,
EARL INGERSON, *Treasurer*

DANA FUND

Disbursements are made to needy mineralogists in war areas and to families of deceased mineralogists in war areas.

RECEIPTS

Available balance, November 1, 1951	$170.96
Interest	2.45
	$173.41

DISBURSEMENTS

Disbursed	$ 25.00
Available balance, July 31, 1952	148.41
	$173.41

Respectfully submitted,
EARL INGERSON, *Treasurer*

REPORT OF THE AUDITING COMMITTEE

To the President of the Mineralogical Society of America:

The Auditing Committee has examined and verified the accounts of the Treasurer of the Mineralogical Society of America for the fiscal period beginning November 1, 1951, and ending July 31, 1952. The securities listed in the Treasurer's report, with all future coupons on the coupon bonds attached, are in the safety deposit box at the West End Branch of the Washington Loan and Trust Company in Washington, D. C.

Respectfully submitted,
HOWARD W. JAFFE
HATTEN S. YODER, JR.
MARIE L. LINDBERG, *Chairman*

REPORT OF THE EDITOR FOR 1952

To the Council of the Mineralogical Society of America:

In presenting the annual editorial report for 1952 at this time, the same general policy will be followed as that used in recent years. With five issues published and distributed and the November-December number in press, sufficient data are now available to give a fairly accurate general survey of the year's activity. When the editor's report appears in print in the March-April issue certain details incomplete or not available at present will be incorporated so that the final printed report in April can be compared with those given for previous years.

If the success of a year's activity can be judged by the number of articles published and by the total pagination, then the accomplishments for 1952 can be considered well above the average. The current volume will run close to 1090 pages, an increase of approximately 150 pages, or 16%, above the figures achieved last year.

Aside from the five regular issues, one special number, authorized by the Council, and sponsored by the Walker Mineralogical Club, appeared as the May-June number. This particular issue continued the series of Contributions to Canadian Mineralogy under the able editorship of L. G. Berry of Kingston, Ontario. In this number the guest editor assembled 17 interesting papers on varied mineralogical subjects and assumed full responsibility in seeing these contributions through the press. This policy, followed for the past four years, of devoting one issue each year exclusively to Canadian Mineralogy and Canadian authors seems to have won general approval, and by Council action will be continued in 1953.

Attention should also be called to a colored plate (2 figures) appearing in the November-December number on the "Effect of heavy charged particle and fast neutron irradiation on diamonds." One of the authors was so anxious to have this effect reproduced in color that he personally will assume the entire cost of these colored reproductions.

The current volume will run, as indicated above, about 1090 pages and contain 77 leading articles. Twenty-three additional short papers, appearing under Notes and News, give an overall total of 100 published manuscripts for the year. These contributions were re-

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOLUME 37

Subjects	Articles	Pages	Per Cent of Total
Leading articles*			
Descriptive mineralogy	14		
Geochemistry	23		
Structural crystallography	20		
Petrography	5		
Optical crystallography	4		
Mineralography	2		
Geometrical crystallography	1		
Memorials	4		
Miscellaneous	4		
	77	892	83.0
Shorter articles	23	55½	17.0
Notes and news	35	13½	
Proceedings of Societies	4	65	
Abstracts of new mineral names	39	11	
Book reviews	34	37	
Total entries	212	1074	100.0
Illustrations	291		
Index, Title page, Table of contents		20	
Grand total		1094	

* Leading articles averaged 11.6 printed pages each.

ceived from 127 authors associated with 57 different Universities, research bureaus, and technical laboratories. Thirty-four critical book reviews, thirty-nine abstracts of new mineral names, and four new minerals described in detail for the first time—bystromite, aurostibite, robinsonite, and hurlbutite—are a few of the other items of general mineralogical interest.

It should be a matter of considerable pride to the Society to note that the service rendered by the Journal is world wide in its scope. As an indication of this fact, during the past year 31 contributions (out of 100) were received from contributors residing outside of the States; 17 from Canada; three each from Australia, South Africa, and Japan; and one each from England, Formosa, New Zealand, India, and Venezuela.

While it is impossible at this early date to state with any degree of extreme accuracy the printing demands that will be made on the Journal in 1953, it would seem from present indications that no depression is in sight, and that the volume for 1953 conservatively speaking might easily reach the 1200 page level. This estimate is based on the fact that as of November 1 the files contain 31 articles of various lengths aggregating about 700 typed pages. This estimate does not include one or more special numbers that are contemplated, whose lengths cannot be estimated at this time.

This report would not be complete without an expression of appreciation for the liberal and substantial financial support received from the Geological Society of America toward defraying a sizeable portion of the printing costs of the Journal. For this assistance the Society is indeed very grateful for without such aid expansion would be impossible and services of necessity would have to be curtailed.

The accompanying Table 1 summarizes in more detail the distribution of subject matter in volume 37.

Respectfully submitted
WALTER F. HUNT, *Editor*

BIBLIOGRAPHY ON URANIUM IN ARIZONA, NEVADA, AND NEW MEXICO

The Geological Society of America published the following article in the February, 1953, issue of its Bulletin: "Bibliography and Index of Published Literature on Uranium and Thorium and Radioactive Occurrences in the United States. Part 1: Arizona, Nevada, and New Mexico," by Margaret Cooper of the Division of Raw Materials, U. S. Atomic Energy Commission. Since this 38-page bibliography may prove helpful to both geologists and laymen interested in uranium prospecting, the Society has prepared reprints for public sale at 25 cents per copy. Remittance must accompany orders, which should be sent to:

The Geological Society of America
419 West 117 Street, New York 27, New York

OPENING FOR ASSISTANT PROFESSOR OF MINERALOGY

The Ohio State University has a vacancy in the Department of Mineralogy for an Assistant Professor. In order to be considered, applications should be submitted prior to June 1, 1953, to Professor Duncan McConnell, *Chairman.*

Dr. Edward Steidle, Dean of the School of Mineral Industries at the Pennsylvania State College since 1928, will retire with emeritus rank on June 30. He will be succeeded by Dr. Elburt F. Osborn, associate dean of the School. Dr. O. F. Tuttle has been named professor of geochemistry and Head of the Department of Earth Sciences, effective July 1, 1953. Dr. John A. Hipple, Chief of the Atomic Section, National Bureau of Standards, Washington, D. C., has been named Director of the Mineral Industries Experiment Station.

Erratum

Am. Mineral., **37** (1952) p. 598 last line: read *Fig. 2* instead of *Fig. 1.*

ABSTRACTS OF PAPERS PRESENTED AT THE THIRTY-THIRD ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA, NOV. 13–15, 1952

COMPARISON OF THE CHEMICAL ANALYSES OF SEDIMENTARY AND METAMORPHIC ROCKS

ARDEN L. ALBEE
Montpelier, Vermont

The composition of a metamorphic rock is commonly compared with that of the supposed parent rock to determine if chemical changes have taken place during metamorphism. Chemical analyses of metamorphic rocks supposedly derived from sedimentary rocks are frequently compared with composite analyses of sedimentary rocks (commonly Clarke's), and certain compositional features are compared with those that have come to be accepted as generally characteristic of sediments. E. S. Bastin has cited the dominance of MgO over CaO, the dominance of K_2O over Na_2O, an excess of Al_2O_3 over the amount necessary for feldspars, and a high SiO_2 content as characteristic of pelitic sediments. These generalizations concerning pelitic sediments have come to be regarded by many geologists as applicable to sediments in general, and some recent textbooks have so treated them.

Complete analyses of individual argillaceous and arenaceous rocks are presented graphically to show the range of variation from the composite analyses. The graphs also show the departure of various rock types from the compositional features mentioned above.

Comparison of an analysis of a metamorphic rock with composite or averaged analyses of sedimentary rocks is shown to be an unreliable basis for hypothesizing chemical change during metamorphism. Comparison should instead be made with individual analyses of sedimentary rock, taking into account the geologic setting of the rocks to be compared.

Some of the important factors involved in the comparison of a sedimentary rock and its metamorphic equivalent are discussed.

MINERAL AGE MEASUREMENT: MASS SPECTROMETRIC DETERMINATIONS OF Rb^{87} AND Sr^{87} IN LEPIDOLITES

L. T. ALDRICH, J. B. DOAK AND G. L. DAVIS
Department of Terrestrial Magnetism and Geophysical Laboratory, Carnegie Institution, Washington, D. C.

Isotopic determinations of Rb^{87} and Sr^{87} in lepidolites have been made using stable isotope dilution and mass spectrometric techniques. Chemical procedures outlined in the paper by Davis and Aldrich yielded sufficient Sr for this analysis if 2 grams of the lepidolite were available and it was as old as 10^7 years. Rb from 100 mg of lepidolite could be separated from the K with sufficient purity for isotopic analysis with a single recrystallization of the perchlorates. In the analysis of each mineral sample 50 micrograms of Sr containing 64 per cent Sr^{84} and 180 micrograms of Rb containing 89 per cent Rb^{87} were added when the sample was first put in solution. The ratio of Sr^{87}/Rb^{87} can be determined with a precision of 3 per cent under the least favorable conditions.

Ages have been determined in this manner for five lepidolites. They range from $158 \pm 10 \times 10^6$ years for a Pala, California, sample to $3300 \pm 300 \times 10^6$ years for a specimen from Southern Rhodesia. The absolute ages depend on the decay constant of Rb^{87}, the latest published value for which is $1.09 \pm .03 \times 10^{-11}$ $year^{-1}$.

X-RAY EVIDENCE OF THE NATURE OF CARBONATE-APATITE

Z. S. ALTSCHULER, E. A. CISNEY, AND I. H. BARLOW
U. S. Geological Survey, Washington, D. C.

The existence of carbonate-fluorapatite as a distinct variety of apatite rather than a mixture of a carbonate phase and fluorapatite has been tested by the following *x*-ray experiments: (1) Several samples each of fluorapatite and hydroxyl-apatite, of approximately end-member composition, and of carbonate-fluorapatite (having 2 to 4 per cent CO_2) were *x*-rayed by powder-film methods under identical conditions of instrumentation and sample preparation. The resultant film patterns are distinctive and can be correlated visually with the above chemical types by reference to the (231) and (004) lines. (2) Mixtures of these several varieties were *x*-rayed and line duplication resulted. (3) Mixtures of two samples of the same variety were *x*-rayed and line duplication did not occur. (4) Unit-cell constants, computed from *x*-ray spectrometer patterns with an accuracy and precision of ±0.002 Å, offer proof that carbonate-fluorapatite is sufficiently different from fluorapatite and hydroxyl-apatite to be considered another variety of apatite. The cell constants follow:

	a_0 (A)	c_0 (A)	c/a
Hydroxyl-apatite, Holly Springs, Ga., U.S.A.	9.413	6.875	0.730
Fluorapatite, Durango, Mexico	9.386	6.878	0.733
Carbonate-fluorapatite, Staffel, Germany	9.344	6.881	0.736

The apatite in the marine phosphorites of Khouribga, French Morocco, of Florida and Idaho, U.S.A., and many other areas is carbonate-fluorapatite.

MAGMATIC AND GRANITIZED ROCKS IN THE YELLOWJACKET DISTRICT, LEMHI COUNTY, IDAHO

ALFRED L. ANDERSON
Cornell University, Ithaca, New York

The pre-Cambrian Belt strata in the Yellowjacket district, Idaho, have been invaded by three unrelated groups of intrusive rocks, one of which has induced local granitization. The earliest group (pre-Cretaceous) is represented by small bodies of considerably altered gabbro; the second (late Cretaceous or early Tertiary), by dikes and stocks of diabase, olivine gabbro, augite-hornblende-biotite diorite, hornblende-biotite diorite, pegmatite, and lamprophyre, and marginal masses of biotite diorite and syenite about the body of hornblende-biotite diorite and a small dike of pulaskite remote from the diorite; and the third (Miocene), by dikes and less regular bodies of granophyre, granite porphyry, and vitrophyre.

Except for the biotite diorite, syenite, and pulaskite, the rocks have all the textural and structural characteristics of more or less quickly cooled hypabyssal intrusives, complete with various reaction phenomena and in part with micrographic and microspherulitic intergrowths. The exceptions are products of alkali-rich granitizing fluids from the hornblende-biotite diorite magma, with the biotite diorite and syenite formed by replacement of the bordering Belt rocks and the pulaskite by consolidation of the fluids along more distant channelways. Metallization accompanied the second group of intrusives, with ore deposition just ahead of the injection of lamprophyres, which brought the magmatic cycle to a close. The two earlier groups of intrusives apparently had their sources in the basic subcrust; the younger in magma that had reached a higher level in the crust. None of the intrusives is related to the deeply underlying Idaho batholith.

PITCHBLENDE DEPOSITS ON QUARTZ HILL, CENTRAL CITY DISTRICT, GILPIN COUNTY, COLORADO

F. C. ARMSTRONG
Denver, Colorado

The Central City district, in the northern half of the Colorado Front Range mineral belt, has been the principal domestic source of pitchblende. A recorded 110,757 pounds of U_3O_8 has come from Quartz Hill—more than 98 per cent from the Wood and Kirk mines.

Quartz Hill is underlain by a folded sequence of pre-Cambrian biotite granite gneiss, amphibolite, quartz-biotite schist, granulite, and skarn intruded by pegmatite, metagabbro, and Upper Cretaceous bostonite. These rocks are cut by steeply dipping, east-trending faults that contain metalliferous veins. The Central City district is zoned with pyritic gold ores in the center and lead-zinc-silver ores on the periphery. Quartz Hill is on the west side of the district, and is in a transition zone where the mineralogy of the veins changes from quartz-pyrite-gold on the east to quartz-pyrite-sphalerite-chalcopyrite-galena-gold-silver on the west. Pitchblende occurs with chalcopyrite in this transition zone. Gold ore bodies are grossly controlled by the intersection of faults with brittle granitic layers, and pitchblende ore bodies probably have a similar control. Mineralogically and structurally the veins are of xenothermal type.

Ore produced from the Wood and Kirk mines had an estimated average grade of 0.2 per cent U_3O_8. It is probable that unmined parts of the Wood and Kirk veins within the transition zone contain ore of similar grade.

RADON LEAKAGE FROM RADIOACTIVE MINERALS

GEORGE L. BATE, BRUNO J. GILETTI, AND J. LAURENCE KULP
Lamont Geological Observatory, Palisades, New York

The rate of radon leakage from selected radioactive minerals and ores has been measured as a function of particle size and temperature. The results suggest that this factor is a significant correction for certain types of minerals used in uranium-lead age measurement. For disseminated types of ores such as occur at the Sunshine Mine, Idaho, the correction may be as large as 20% of the Pb^{206} content. Certain massive ores or clean crystals show leakage rates on the order of 1% or less. The leakage rate is not largely affected by temperature until several hundred degrees are reached. This suggests that an integrated radon leakage for the entire history of the mineral can be calculated with adequate precision for the age measurement. The method by which such a calculation is made and the error involved in the final age value by this procedure will be discussed for a particular case.

PLEONASTE FROM CABALLO MOUNTAINS, NEW MEXICO

CARL W. BECK AND CHARLES H. MAXWELL
University of New Mexico, Albuquerque, New Mexico

Pleonaste crystals occur as large phenocrysts in several nepheline olivine basalt flows at the north end of the Caballo Mountains, New Mexico. These Quaternary (?) flows overlie Cretaceous and Permian strata and are separated from them by an angular unconformity.

The pleonastic spinels from this area range in size from microscopic up to 15 mm. Most of the pleonaste crystals are anhedrons or malformed octahedrons. Good octahedrons, or octahedrons truncated by dodecahedrons, are not uncommon, and one cubic truncation has been noted. The octahedron faces are usually pitted. The color is dark green to brownish green, nearly opaque; fracture, conchoidal; luster, dull on external surfaces, vitreous to splendent on fractures; hardness, 8; parting, cubic. The measured specific gravity ranges from 3.83 to 3.88; calculated specific gravity is 3.91. The space group is *Fd3m*, $a_0=8.12$ Å. The index of refraction ranges from 1.788 to 1.789. The empirical formula, as determined from a chemical analysis of 4.025 gm, is: $(Fe_{.35}Mg_{.65})O\cdot(Fe_{.02}Al_{.98})_2O_3$.

From petrographic studies it is concluded that the original mafic magma, before eruption, cooled and remained uniform long enough to allow large crystals of pleonaste and olivine to form, then was ejected and cooled too quickly for the liquid to resorb these early-formed crystals.

STUDIES OF METAMICT MINERALS (II): RE-EXAMINATION OF FERGUSONITE

JOSEPH BERMAN
U. S. Bureau of Mines, College Park, Maryland

With one possible exception all descriptions of fergusonite found by the author indicate that the mineral occurs only in the metamict state.

Fergusonite was investigated by T. F. W. Barth in 1926. He concluded that the mineral crystallizes at about 400° C. but the crystallized particles are too small for good *x*-ray diffraction unless heated to a temperature between 800° C. and 900° C.

My investigation shows that fergusonite is dimorphic. At approximately 450° C. metamict fergusonite crystallizes and can be indexed with orthorhombic axes. At higher temperatures (ranging from about 850° C. to 1050° C., depending on the kind of sample and the length of heating time) it crystallizes in a form identical with that of synthetic "fergusonite." Barth has indexed this synthetic "fergusonite" with a tetragonal lattice.

It is believed that the structure of the low-temperature dimorph of fergusonite is equivalent to the structure of the original crystalline material.

NEW DATA ON LEAD SULPHARSENIDES FROM BINNENTAL, SWITZERLAND

L. G. BERRY
Queen's University, Kingston, Ontario

Weissenberg and precession camera studies on baumhauerite, dufrenoysite and rathite, lead to the following new structural data:

Baumhauerite is triclinic (pseudomonoclinic) with $a=22.74$, $b=8.33$, $c=7.89$ A, $\alpha=90°$, $\beta=97°25'$, $\gamma=90°$. The unit cell contains $4[3PbS\cdot 2As_2S_3]$.

Dufrenoysite is monoclinic, probable space group $P2_1/m$; $a=8.41$, $b=25.85$, $c=7.88$ A, $\beta=90°30'$. The unit cell contains $8[2PbS\cdot As_3S_3]$ with specific gravity 5.53 (measured), 5.61 (calculated). The axial ratio of the unit cell, $a:b:c=0.326:1:0.306$ agrees closely with the morphological ratio given by Palache in Dana (1944).

Rathite-II is monoclinic, probable space group $P2_1/m$; $a=8.32$, $b=70.9$, $c=7.91$ A, $\beta=90°$. The unit cell probably contains $2[19PbS\cdot 13As_2S_3]$ with specific gravity 5.42 (measured, Jackson), 5.52 (calculated). The unit cell dimensions do not agree with previous structural or morphological data on rathite, although they were obtained on a fragment of the original material analyzed by Jackson (analysis 3, Dana, 1944) which was kindly supplied by Dr. Bannister from the British Museum (Natural History).

RELATIONSHIP BETWEEN LIGHT ABSORPTION AND COMPOSITION IN A SOLID SOLUTION SERIES

F. DONALD BLOSS
University of Chicago, Chicago, Illinois

Using a spectrophotometer improvised from a monochromator, polarizing microscope, and a photomultiplier tube, light absorbance measurements were made for the γ' direction on a (110) face for crystals of varying nickel content in the solid solution series between $Ni(NH_4)_2(SO_4)_2 \cdot 6H_2O$ and $Mg(NH_4)_2(SO_4)_2 \cdot 6H_2O$. Measured absorbance values were found to confirm the Beer-Lambert law within the limits of measurement. On the basis of this law, compositions predicted from absorbance per centimeter values of different crystals were, on the average, accurate to within 2.5 mol per cent (of the compositions predicted from density values).

Calculations to obviate the effects of opaque inclusions and internal cleavages in the measured crystals when predicting composition from absorbance measurements are discussed.

CHARACTER AND ORIGIN OF THE ROAN AND CAROLINA GNEISSES IN THE SPRUCE PINE PEGMATITE DISTRICT, NORTH CAROLINA

DONALD A. BROBST
Spruce Pine, North Carolina

A belt of upper-middle-grade metamorphic rocks that have long been divided into Roan gneiss (essentially hornblende gneiss and schist) and the Carolina gneiss (essentially mica gneiss and schist) constitute a part of the Spruce Pine pegmatite district in the Blue Ridge of western North Carolina. Detailed field mapping of 250 square miles in that district indicates that these two rocks are interlayered and the individual layers range from an inch or less to several tens of feet in thickness. The hornblende and mica rocks merge laterally and vertically.

All the metamorphic rocks have been plastically deformed into complexly folded structures. Foliation is parallel to the layers. No crosscutting relationships have been found between the Roan and Carolina gneisses.

The mica rocks include mainly biotite and muscovite gneiss and schist. The feldspar is generally oligoclase; orthoclase and microcline are rare. The schists typically have more mica, with muscovite dominating over biotite; they also have more garnet and are more distorted than the gneisses. Typical accessory minerals in the Carolina gneiss are garnet, staurolite, kyanite, epidote, allanite, apatite, zircon, and magnetite-ilmenite.

The hornblende rocks are chiefly gneiss and schist which, in addition to the hornblende, contain quartz, andesine, epidote, and magnetite-ilmenite. Associated rocks include layers rich in actinolite, epidote, zoisite, garnet, diopside, and rarely dolomite.

Field evidence and laboratory studies suggest that the Roan-Carolina complex of this area is of sedimentary origin. The Roan gneiss may have been derived from ferruginous carbonated shales and dolomitic limestones. The Carolina gneiss may have been derived from clayey to sandy shales and sandstones.

SOME ASPECTS OF THE GEOCHEMISTRY OF POTASSIUM, RUBIDIUM, CESIUM, AND THALLIUM IN SEDIMENTS

FRANK C. CANNEY
Massachusetts Institute of Technology, Cambridge, Massachusetts

Determinations of the rubidium, cesium, and thallium contents of 323 samples from 10 sedimentary geological formations have been made by spectrochemical methods. Potassium, present as a structure constituent in a known concentration, was used as a variable internal standard. The precision of the spectrochemical methods employed, expressed as standard deviations, was ±4.5% for rubidium, ±8.2% for cesium, and ±8.8% for thallium. Average abundance values for these elements in argillaceous sediments are: Rb_2O—0.031%, Cs_2O—0.00081%, and Tl_2O—0.000038%. Thallium is usually enriched in highly organic sediments.

The average % K_2O/% Rb_2O, % K_2O/% Cs_2O, % K_2O/% Tl_2O, and % Rb_2O/% Tl_2O abundance ratios in the various classes of sedimentary materials will be given and their significance discussed. A comparison of these values with the average values of corresponding ratios in igneous rocks shows that the order of relative enrichment of these elements in sediments is normally: $Cs>Rb>K>Tl$.

The conclusion is reached that the order of relative enrichment found is in excellent agreement with the theory that the adsorption affinity of a cation from aqueous solutions is [believed to be] proportional to the value of the positive electrostatic potential existing at the surface of the hydrated ion.

ORIGIN OF GRANITIC GNEISS DOMES OF WESTERN NEW HAMPSHIRE

CARLETON A. CHAPMAN
University of Illinois, Urbana, Illinois

At least twelve domical structures lying within a narrow belt in western New Hampshire have been mapped and described by different investigators. Each dome consists of a central elliptical core of weakly foliated gneiss, mantled by concentric belts of metamorphosed sedimentary and volcanic rocks. The foliation of the gneissic core is most pronounced near the borders where it parallels the contact and the bedding-plane schistosity of the adjacent metamorphic rocks.

Various magmatic origins have been proposed for these Oliverian domes including the laccolithic, phacolithic, and sill theories. Virtually no consideration, however, has been given to other possible origins for these plutonic features. That metamorphic and metasomatic phenomena may have played dominant roles in the formation of these gneissic domes seems highly probable and warrants special attention. This possibility is discussed and evidence for replacement in the dome rocks is given. The time and space relation of the Oliverian domes to the general sequence of tectonic and petrologic events in central New England is considered to have a most significant bearing on the origin of the domes themselves.

It is concluded, tentatively at least, that, whereas many observations may be interpreted as indicating a magmatic origin for the gneissic cores of the Oliverian domes, our present knowledge of these plutons may be explained more logically by the metamorphic-metasomatic theory.

ISOTOPIC CONSTITUTION OF RADIOGENIC LEADS AND THE MEASUREMENT OF GEOLOGICAL TIME

C. B. COLLINS, R. M. FARQUHAR AND R. D. RUSSELL
University of Toronto, Toronto, Canada

A review of all the age determinations carried out by the authors is described. Isotopic abundances and ages are listed for over 70 radiogenic leads extracted from uranium-bearing samples from different localities. Chemical analyses are given for some of the samples. Ages have been calculated from ratios of radiogenic Pb^{207}/Pb^{206}, and from the ratio of Pb^{206}/U^{238} for chemically analyzed samples.

The reliability of the chemical and isotopic ages is discussed. It is pointed out that discrepancies between the ages by the two methods may be explained by the loss of uranium or lead in recent time which may occur by partial dissolution or alteration of the sample. Evidence is presented showing that the loss of radon is small or does not occur at all, and that therefore the isotopic age values are the most reliable as was pointed out by Nier.

From age determinations combined with mineralogical evidence the behavior of hydrothermal pitchblende deposits is discussed. Evidence is given of the dissolution and redeposition of such deposits. Ages of uraninites, and of a few pitchblendes are considered useful in dating orogenies, but many pitchblendes give younger dates for that reason.

The preparation and analysis of samples is described. Quantities of lead as small as 5 mg. have proved sufficient for the preparation of adequate samples of lead tetramethyl for analysis in a mass spectrometer.

ISOTOPIC CONSTITUTION OF ORE LEADS AND THEIR RELATION TO GEOLOGICAL TIME

C. B. COLLINS, R. D. RUSSELL, AND R. M. FARQUHAR
University of Toronto, Toronto, Canada

Since the publication of Nier's determinations of the isotopic constitution of leads from lead ores of different ages, his data have been the basis for several estimates of the age of the earth's crust and of the maximum time of formation of the elements. All these investigators have pointed out the need for more isotopic analyses of naturally occurring leads of known age. The authors report the isotopic constitution of 14 samples of lead ores, 12 of which were collected from Precambrian areas. A number of these leads have been dated, by isotopic analyses of associated radiogenic leads by the authors, by isotopic analyses of radiogenic leads by Nier, and by Ahren's ages from the Rb-Sr method. These new values for the isotopic constitution of ordinary leads have been combined with those of Nier and used to calculate the time of solidification of the earth's crust, for which the authors report a value of 3.5 ± 0.2 billion years. This value agrees with estimates reported by Holmes, and by Bullard and Stanley within the limits assigned. A new estimate of 5.50 ± 0.2 billion years is given as a maximum limit for the time of formation of the elements.

The authors discuss the dating of ore leads from their isotopic constitution, and point out that while no general criterion may be used for all samples, it is usually possible to approximately date the separation of the ore from the parent magma.

MINERAL AGE MEASUREMENT: CHEMICAL SEPARATIONS OF Rb AND Sr BY MEANS OF ION-EXCHANGE COLUMNS

G. L. DAVIS AND L. T. ALDRICH
Geophysical Laboratory and Department of Terrestrial Magnetism, Carnegie Institution, Washington, D. C.

The chemical separation of trace amounts of any element, in pure form, from minerals is a formidable problem by conventional analytical procedures. For mineral age measurements by mass-spectroscopic analyses it is particularly important to obtain strontium, rubidium, and calcium from micas, feldspars and accessory minerals from granites. The strontium must be completely separated from rubidium and usually partially separated from calcium.

Ion-exchange resin columns have been adapted to this separation and procedures developed in which, first, the alkali metals and alkaline earths are completely separated from the aluminum, iron, zirconium and other elements in the mineral, with complete recovery. Next, the alkalis are removed from the column, separated partially from each other and completely from the calcium and strontium. Finally the alkaline earths are removed with at least a partial separation.

TEXTURAL RELATIONSHIPS IN THE SALINA SALT OF MICHIGAN

LOUIS F. DELLWIG AND LOUIS I. BRIGGS
University of Michigan, Ann Arbor, Michigan

Petrographic examination of the salt bed at the base of the Salina was directed toward the study of the textural relationship between halite, anhydrite and dolomite and related pyrite, sylvite, celestite, quartz and carbonaceous material. The core examined was taken from Newago County, Michigan, the base of the salt being intersected at 5147 feet. Study of these relationships was facilitated by the frequent interbedding of dolomite and anhydrite with salt in the lower portion of the section.

Some of the particularly significant relationships are (1) variations in grain size and shape of dolomite and anhydrite, both tending toward increased size and euhedral shape in the presence of halite, (2) reversal of the normal sequence of deposition with changes upward progressing from salt to anhydrite to dolomite to salt, (3) concentration of pyrite and carbonaceous material along the contact between halite and the overlying anhydrite, (4) brecciation of anhydrite layers, the fragments being contained in a matrix of dolomite, and (5) development of a chevron structure in halite due to the orientation and concentration of liquid inclusions in the form of negative crystals.

DIRECTIONAL GRINDING HARDNESS IN DIAMOND

REYNOLDS M. DENNING
University of Michigan, Ann Arbor, Michigan

In order to measure the relative variation of grinding hardness in single diamond crystals, two mechanisms have been constructed. One, which might be called a hardness comparator, permits the simultaneous cutting of two crystals. One crystal is oriented in an arbitrarily chosen unit hardness direction. The cutting rate of the second crystal is compared with the cutting rate of the reference crystal.

To facilitate the measurements a second apparatus has been designed to prepare spherical surfaces of predetermined radii on the diamonds. This apparatus was used in connection with hardness variation measurements on the cube face. The remainder of the planes investigated were studied on pyramidally faceted stones, because of the very slow operation of the sphere grinder.

Hardness curves were plotted, hardness against grinding azimuth, for the cube, dodecahedron, and octahedron, and for intermediate planes in the zones containing these three planes.

Hexoctahedral symmetry was assumed since no evidence of lower symmetry has been obtained from hardness measurements.

Errors inherent in the method are discussed.

COMPOSITIONAL CONTROL OF THE DIMENSIONAL PROPERTIES OF CRYSTALS

GEORGE W. DEVORE
University of Chicago, Chicago, Illinois

The compositional control of crystal dimensions is illustrated by the Ca-containing amphiboles. The dimensions as expressed by the ratio of $\frac{\text{length in the } b \text{ direction}}{\text{length in the } c \text{ direction}}$ varies in the crystals measured from 0.09 for tremolite to 0.78 for Fe-rich hastingsite. These ratios are interpreted as being the crystallographic (or growth) expressions of the changes in bond forces as the composition changes from Al, Fe-poor tremolites to Al, Fe-rich hastingsites.

Al which substitutes for Si weakens the Si-O bonds in the *c* direction and strengthens the Metal-O bonds in the directions of the *a* and *b* axes. Fe which substitutes for Mg, and Al which substitutes for Fe and Mg further strengthen the bonds in the *a* and *b* directions and thus influence the development of the crystal in these directions.

The presence and development of the 010 face seems to be correlated with the substitution of Fe and/or Al for Mg.

Compositional control of crystal dimensions of other amphiboles and of pyroxenes is discussed. Implications of the dimensional ratios on grain size and the tendency to recrystallize are indicated.

SEISMIC REFRACTION MEASUREMENTS IN THE GULF OF MAINE

CHARLES L. DRAKE, J. LAMAR WORZEL, AND WALTER BECKMANN
Lamont Geological Observatory, Palisades, New York

Seismic refraction measurements were made in the Gulf of Maine in 1948 and 1952 as a continuation of the program of geophysical exploration of the continental margins. Sections from Portland, Maine, to the northwest edge of Georges Banks, from Matinicus Rock, Maine, to Cultivator Shoal, and from Cape Ann, Mass., to Yarmouth, Nova Scotia, were observed.

Sediments of 5,025 to 6,800 ft/sec varied erratically in thickness from 0 to 2,000 ft. To the north and east of Ammon Rock consolidated sediments of 12,000 to 13,000 ft/sec were detected with thicknesses up to 1,600 ft. These are tentatively identified as Triassic and possibly represent a continuation of the Fundy Basin. Basement rocks with velocities of 16,500 to 18,000 ft/sec were observed to pinch out rapidly away from shore on all sections. Sub-basement rocks with velocities of 19,000 to 21,000 ft/sec were found to underlie the entire Gulf of Maine.

PURIFICATION AND PROPERTIES OF MONTMORILLONITE

J. W. EARLEY, B. B. OSTHAUS, AND I. H. MILNE
Gulf Research & Development Company, Pittsburgh, Pennsylvania

Descriptive mineralogical data have been obtained on ten montmorillonites from bentonite deposits located in the United States and Canada using thermal, *x*-ray, electron, and chemical methods.

The montmorillonites were hand-picked and subsequently mechanically purified by settling and supercentrifugation. After purification cristobalite was detected in four of the ten samples. Lepidocroite and hydrous mica were present in one sample. The differential thermal analysis curves show endothermic peaks at (140–160° C.), (650–715° C.), and (820–885° C.) followed by an exothermic reaction above 870° C. *X*-ray powder photographs show basal spacings up to the tenth order yielding $d_{(001)} = 17.9$ to 18.0 A for glycerol treated specimens. The electron micrographs reveal small, irregular thin plates. One sample showed some of the plates curled into tubes. The base-exchange capacity varies from 66 to 128 milliequivalents per 100 grams of sample depending on impurities and chemical composition of the montmorollonite, but independent of particle size. Formulae calculated from the chemical analyses show a fairly wide range of isomorphism. The peak temperatures of the thermal reactions, the "*a*" and "*b*" dimensions of the unit cell and base-exchange capacities are correlated with the substitution of magnesium and iron for aluminum in the octahedral layer and aluminum for silicon in the tetrahedral layer as determined from chemical analyses.

THERMAL, DEHYDRATION, AND X-RAY STUDIES ON MONTMORILLONITE

J. W. EARLEY AND I. H. MILNE
Gulf Research & Development Company, Pittsburgh, Pennsylvania

The thermal reactions, water loss and changes in crystal structure have been investigated between 500° C. and 950° C. for five montmorillonite samples with varying chemical composition.

The water loss during the first high temperature endotherm accounts for the water proposed by the Hogmann-Endell-Wilm structure. This reaction involves changes in the spacings of the *x*-ray diffraction lines which probably reflect symmetry differences. There is some additional water loss which takes place slowly over the entire range between the first and second high temperature endotherms with a gradual change in the spacings of the *x*-ray diffraction lines but no loss in the intensity of the pattern. Crystal water is essentially completely removed by the end of the second high temperature endotherm. Water loss during this endotherm may well contribute to the thermal reaction but cannot fully account for it. During this endotherm the intensity of the *x*-ray powder pattern decreases rapidly indicating breakdown of the crystal structure and the formation of a disordered state which results in an increase in entropy. Thermodynamically the effect of increased entropy can be expressed by the general equation of third law, $dS=q/T$, where S is entropy; T, temperature; and q heat absorbed. Thus q increases with S and manifests itself as an endothermal reaction accounting for the second high temperature endotherm. The exothermic reaction which follows is attributed to the formation of spinel and partial return to an ordered state. Silica is not present as a crystalline phase in this temperature range.

ORIGIN OF LISTWÄNITES OF THE CAUCASUS AND URALS

NICHOLAS EFREMOV
New York, New York

Listwänites are widely distributed in Eastern Europe and particularly in the Caucasus and Urals. At least three different types of listwänites have been observed: serpentinitic, gabbroic and porphritic. Here I shall present some findings concerning the serpentinitic listwänites investigated by me in those regions.

The term "serpentinitic listwänite" identifies a metamorphic rock composed chiefly of different carbonates (ankerite, dolomite, breunnerite, magnesite, calcite) with varying quantities of quartz (from 25–30% to 70%) and accessories, such as antigorite, chlorite, magnetite, chromite and others.

Contrary to the views of academician Karpinsky and Professor Lodschnikov, I have shown that the serpentinitic listwänites are products of hydrothermal alterations of serpentinites and that they cannot be considered as metamorphosed limestones as was originally supposed by those two scientists. Listwänites occur in the contact zones of the serpentinite bodies and its formation and composition appear to be independent of the chemical composition of the enveloping country rock. These rocks are formed as a result of a replacement of the serpentinitic rocks by silicon-bearing carbonic hydrothermal solutions.

Deposition of commercial quantities of gold (on berezites) during this replacement process was observed as an interesting side-light. In fact, listwänites were frequently used as ore-indicators by gold prospectors.

The comparatively high content of CaO and SiO_2 on the listwänites is a good illustration of Larsen's polarity law.

RECENT RESULTS FROM EARTHQUAKE SURFACE WAVE INVESTIGATIONS

MAURICE EWING AND FRANK PRESS
Lamont Geological Observatory, Palisades, New York

The dispersion and absorption of mantle Rayleigh waves with periods of 70–400 sec. have been investigated. The observed dispersion may be accounted for by the known increase of shear wave velocity with depth in the mantle. A value of .000018 km^{-1} was deduced for the absorption coefficient of waves with periods of 230 sec. The internal friction in the upper mantle corresponding to this absorption is $1/Q = 590\times 10^{-5}$, a value surprisingly similar to that reported from audio frequency vibration studies on crystalline rocks at atmospheric pressure.

Investigation of the short period surface shear wave Lg, which propagates a cross continental path only with a velocity of 3.51 km/sec. suggests that the large amplitudes and long duration of this phase can only be accounted for by wave guide transmission through a remarkably homogeneous sialic plate which ends abruptly at the continental margins.

Investigation of Rayleigh waves traversing oceanic paths with periods from 16–40 sec. reveals that crustal structure beneath the Atlantic and Pacific oceans is characterized by the absence of any significant thickness of granitic rock and the occurrence of the Mohorovician continuity at a depth of about 10 km below the sea surface.

RELATION BETWEEN IONIC SUBSTITUTION AND SWELLING IN MONTMORILLONITES

MARGARET D. FOSTER
U. S. Geological Survey, Washington, D. C.

The swelling of samples of Na-saturated montmorillonite from 12 localities was determined after separation of the clays from associated minerals. The degrees of swelling, which ranged between 21 and 66 ml per gram of sample, showed no correlation with cation-exchange capacity or with tetrahedral charge; but it did show a correlation with octahedral substitution, in the direction of decrease in swelling with increase in octahedral substitution. Substituted Fe^{+2} has a greater depressing effect on swelling than Fe^{+3}, which in turn appears to have about the same depressing effect as Mg^{+2}.

Swelling, being an osmotic property of montmorillonite, is affected by degree of ionization. The more complete the ionization, the greater the number of silicate sheets carrying a negative charge, the greater the tendency for the sheets to repel one another, and the greater the swelling; and vice versa. It is suggested that just as substitutions in acetic acid affect the strength and degree of ionization of the acid, so substitutions in the montmorillonite structure affect its degree of ionization and its swelling. The substitution of the more electropositive Fe^{+3} and Mg^{+2} ions for Al^{+3} would tend to alter the surface energy of the montmorillonite structure with the result that, when the mineral is dispersed in water, the degree of ionization is less and the consequent swelling is less.

PETROGRAPHIC EVIDENCE INDICATING POSSIBLE PATHS ALONG WHICH MATTER HAS MOVED IN AND AROUND QUARTZ AND FELDSPARS IN SOME METAMORPHIC ROCKS

A. F. FREDERICKSON
Washington University, St. Louis, Missouri

By appropriately adjusting the illumination in an ordinary petrographic microscope, a considerable amount of detail, commonly overlooked, can be seen. Great relief differences can be produced enabling one to distinguish with ease quartz and K-feldspars by inspection in plain light. "Channels," outlined by a Becke line, occur in and around the edges of certain minerals. Zoisite, clinozoisite, sericite, and other minerals develop along the channels and in plagioclases where the channels leave quartz grains. The color of biotite has changed where the channels cross it indicating compositional changes. The materials, added and subtracted, are thought to have moved along the channels.

No birefringence difference exists in quartz between the material in the channels (which has the lower index of refraction) and that on either side. This has tentatively been interpreted to mean that "chunks" of quartz (fragments of the lattice or particles of colloid size) have been removed and "porous," channel zones produced. A possible mechanism for this process is mentioned. H_2O molecules, H^+ or OH^- ions now occupying these zones produce the lower index of refraction noted in the channels.

Photomicrographs illustrating these phenomena and laboratory experimental results are presented to support the above conclusions.

PETROLOGY OF THE OLIVINE AMPHIBOLITE OF PARRY SOUND, ONTARIO, CANADA

GERALD M. FRIEDMAN
University of Cincinnati, Cincinnati, Ohio

An island, approximately 260 by 150 feet, made up of olivine amphibolite is located in Blackstone Lake 15 miles southeast of Parry Sound. The rocks of the western part of the island show curvi-columnar structure.

The amphibolite consists of cummingtonite, olivine and serpentine with small amounts of spinel, magnetite and chlorite; chlorite is locally abundant. A colorless amphibole, perhaps gedrite, forms coronas between olivine and the amphibole.

With the exception of olivine the minerals of the amphibolite are of secondary origin and have probably formed from olivine and pyroxene, while serpentine and chlorite also formed from amphibole. The chemical composition of the rock comes closest to that of a picrite.

Pegmatite dikes are abundant in the area and diorite dikes cut the amphibolite. The formation of the olivine amphibolite from an original peridotite is probably due to metasomatic metamorphism caused by the dikes. The amphibole is believed to have formed at the expense of pyroxene; Mg, Fe and Al ions in excess of those required for amphibole formation aided the formation of spinel. Near the dikes the rock is essentially a spinel amphibolite, and olivine is absent; the introduction of Al appears to have converted the olivine into amphibole and spinel.

DEUTERIUM CONTENT OF NATURAL WATERS

IRVING FRIEDMAN AND HAROLD C. UREY
U. S. Geological Survey, Washington, D. C.

A mass spectrometric method for the accurate determination of the hydrogen deuterium ratio has been developed. It is possible to determine the ratio of ±0.10% using material of "normal abundance" i.e. 1 part D in 6,700 parts H. Samples as small as 0.1 mg. H_2 (0.001 ml. H_2O) can be run. Natural evaporation and condensation that have been shown to fractionate the oxygen isotopes, also fractionate the hydrogen isotopes. The ratio of these two fractionation processes is equal to the ratio of the ratios of the H_2O/HDO and the H_2O^{16}/H_2O^{18} vapor pressures.

Ocean waters vary from $+3.25$ to $+5.65$ mole % deuterium, while fresh waters of the U. S. range from -10.1 to $+4.3$ mole % deuterium, both relative to an arbitrary standard. An explanation of these variations based upon the measured fractionation coefficient between liquid water and vapor will be given.

STUDIES OF URANIUM MINERALS (XI): GUMMITE

CLIFFORD FRONDEL
Harvard University, Cambridge, Massachusetts

The name gummite has been applied in a generic sense to designate fine-grained, pseudomorphic alteration products of uraninite whose true identity is unknown. It is similar in usage to limonite and wad. Study of a suite of gummite pseudomorphs from 35 localities has shown that the true identity of the mineral phases present can be established in most instances by *x*-ray powder methods. The alteration of the parent uraninite is in general sequential: (1) oxidation of U^4 in large part of U^6 with preservation of the uraninite structure, color usually black, brownish black or greenish black; (2) complete oxidation to U^6 with the formation of new anhydrous or slightly hydrated oxide phases, chiefly clarkeite and "green uraninite," color brown to green; (3) formation of new, relatively highly hydrated oxide phases, chiefly fourmarierite and "Mineral X" of Palache and Berman (1933), rarely schoepite, color yellow, orange or red; (4) formation of uranium silicates, chiefly uranophane and kasolite, less commonly beta-uranophane, rarely soddyite, color greenish yellow to straw yellow. The minerals of (2), (3) and (4) comprise gummite proper; mixtures are common. Clarkeite is a valid species, apparently one of the polymorphs of UO_3. "Tetragonal uraninite" and U_3O_8 were not observed in the course of the work.

STUDIES OF URANIUM MINERALS (XII): BILLIETITE AND BECQUERELITE

JUDITH W. FRONDEL AND FRANK CUTTITTA
U. S. Geological Survey and Harvard University, Cambridge, Mass.

Billietite ($BaO\cdot 6UO_3\cdot 11H_2O$), originally described from Katanga by Vaes (1949), is a valid mineral species isostructural with becquerelite ("$2UO_3\cdot 3H_2O$"). New chemical analyses and Weissenberg *x*-ray studies on two specimens of billietite from Katanga gave: (1) $a_0=12.04$ Å, $b_0=14.24$, $c_0=15.06$; $nX=1.730$, $nY=1.810$, $nZ=1.815$; $BaO=6.88$, $UO_3=82.76$, $H_2O=8.97$, $SiO_2=0.76$, $CaO=0.30$, total$=99.76$; S.G.$=5.57$ (meas.), 5.33 (calc.); (2) $a_0=12.08$ Å, $b_0=13.98$, $c_0=15.06$; $nX=1.725$, $nY=1.780$, $nZ=1.790$; $BaO=7.41$, $UO_3=84.39$, $H_2O=8.68$, total$=100.48$; S.G.$=5.15$ (meas.), 5.40 (calc.). Billietite is orthothombic ($2V(-)\sim 35°$; X pale yellow, Y and Z deep golden yellow. There are $4(BaO\cdot 6UO_3\cdot 11H_2O)$ per unit cell. The unit cell differs from that of Brasseur (1949) in that the *a*- and *b*-axes are interchanged and the *b*-axis is doubled. Brassuer has $a_0=7.11$ Å, $b_0=12.08$, $c_0=15.09$; $nX=1.730$, $nY=1.822$, $nZ=1.829$; $BaO=6.95$, $UO_3=83.36$, ign. loss$=10.49$, total$=101.30$.

A new analysis and *x*-ray study of becquerelite from Katanga gave: $a_0=12.45$ Å, $b_0=13.92$, $c_0=15.09$; $nX=1.770$, $nY=1.805$, $nZ=1.820$; $UO_3=89.53$, $H_2O=8.95$, $SiO_2=1.82$, total 100.30; S.G.$=5.3$ (meas.), 5.56 (calc.). Becquerelite is orthorhombic, $2V(-)$ 30°; X yellow, Y and Z deep golden yellow. There are 14 ($2UO_3\cdot 3H_2O$) in the unit cell.

The near coincidence in dimensions and intensities of the single crystal and powder photographs of billietite and becquerelite indicate that these minerals are isostructural. From the new analysis a formula ($7UO_3\cdot 11H_2O$, with S.G. calc.$=5.60$) for becquerelite can be written analogous to that of billietite. The unit cell contains four formula units. A substitution of one Ba for one U^6 is presumed. If the role of water in the structure were understood, it might be possible to explain the necessary valence compensation for such a substitution by the O to (OH) ratio in each mineral.

EXTENSION OF THE "DIFFERENCE PATTERSON" TO FACILITATE THE SOLUTION OF ORDER-DISORDER PROBLEMS IN MINERALOGY

ALFRED J. FRUEH, JR.
University of Chicago, Chicago, Illinois

Great difficulty is encountered in attempts to locate the specific metal positions from among the symmetrically distributed possible positions in those minerals based upon close packed sulfur atoms (chalcopyrite, bornite, stannite, etc.). Because of the identity of many interatomic distance vectors the Patterson projections, or sections, of such structures cannot be readily solved, even by modern techniques.

If it can be shown, or assumed, that the non-superstructure *x*-ray reflections do not change in intensity when these structures are disordered then Patterson projections or sections made using the superstructure reflections alone represent vector maps where all vectors are suppressed except those between like atoms that change position during the disordering process. Positive peaks represent vectors between sites that have either both gained or both lost in atomic number through disordering. Negative peaks take on a significance; they represent vectors between two sites one having gained and the other having lost in atomic number, hence represent the vectors between unlike atoms that change position during disordering. Chalcopyrite is used as a known example to show the advantages and shortcomings of the method. The method is being applied to the bornite problem.

URANIUM DEPOSITS IN THE BLACK HAWK DISTRICT, GRANT COUNTY NEW MEXICO

ELLIOT GILLERMAN
U. S. Geological Survey, Silver City, New Mexico

Pitchblende occurs in association with native silver and with nickel and cobalt arsenides and sulfides in the old Black Hawk district, 14 miles west of Silver City, New Mexico. The geologic setting is similar to that of the high-grade uranium deposits at Great Bear Lake, Canada, and at Joachimsthal, Czechoslovakia; and the mineralogical associations in the three localities are almost identical. In geologic setting and in mineralogical associations the Black Hawk deposits are unique in the United States. The Black Hawk district produced high-grade silver from 1881 to 1893, but the mines have been idle since that time and are at present inaccessible.

The ore is in fissures with a carbonate gangue in pre-Cambrian quartz diorite gneiss. The veins trend north to northeast; and the deposits that contain radioactive minerals form a northeast-trending belt about 2 miles long. This belt parallels the elongation of a nearby monzonite porphyry stock. Most of the major deposits are along faults in the gneiss, adjacent to where the faults cut monzonite porphyry dikes or apophyses of the main stock. Diamond drilling to test the area for commercial deposits of uranium, nickel, and cobalt is in progress.

MICROCLINE-SANIDINE STABILITY RELATIONS

JULIAN R. GOLDSMITH AND FRITZ LAVES
University of Chicago, Chicago, Illinois

Natural potash feldspars that are crystallographically intermediate between microcline and sanidine are described. It is not yet known whether the intermediate states represent stable configurations of a disordering transition as a function of temperature, or whether they are non-equilibrium states.

Conversion of microcline to monoclinic $KAlSi_3O_8$ can be induced by hydrothermal treatment, but the reverse (i.e., "synthesis" of microcline) has not been accomplished and probably will not take place in times available for experimentation. *X*-ray patterns show that a small percentage of finely powdered microcline is converted when held several days at 550° C. (8,000 psi H_2O pressure). Conversion is apparently complete in this time at 800° C.

Hydrothermal treatment at 800° C. of small microcline fragments used for single-crystal *x*-ray analysis show the development of tiny oriented overgrowths of monoclinic feldspar on the microcline. This phenomenon, coupled with the fact that fine powder is converted to the monoclinic form relatively rapidly whereas the small fragments (0.2 mm.) take very much longer indicates that the conversion is brought about by surface recrystallization abetted by the hydrothermal environment. The fact that hydrothermal recrystallization to a monoclinic phase (that may be metastable at the temperature of crystallization) probably takes place in considerably less time than does stable internal readjustment in microcline, makes experimental interpretation of the transition temperature or temperature range somewhat uncertain.

THEORETICAL CONSIDERATIONS IN GAMMA-RAY WELL LOGGING

CLARK GOODMAN
Massachusetts Institute of Technology, Cambridge, Massachusetts

Gamma-ray logs are useful in determining subsurface stratigraphy in uncased and cased oil field drill holes. Logs of diamond drill holes may also be used to evaluate uranium reserves. A theoretical treatment of the problem indicates practical conclusions that have been overlooked in the usual empirical applications. Statistical fluctuations in the emission of gamma rays limit the resolution and logging speed. The use of scintillation counters affords some improvement. The theory allows corrections to be made for the increased apparent thickness of beds and the depth displacement caused by the finite length of the detector and the time constant of the circuitry. The effect of multiple strings of casing, eccentric location of detector, shielding around the detector and radioactivity of mud and mud cake can be evaluated individually. The theory also is useful in evaluating the efficiency of radioactive tracers, the depth of penetration of radioactive bullets, and the radial weighting function in neutron-gamma logs. Limitations in the present treatment are: (1) a purely exponential and inverse square attenuation is assumed, (2) a uniform horizontal distribution of radioactive material in the formations is assumed, (3) the dip is assumed zero and (4) the counting rate of the detector is assumed to be directly proportional to the gamma flux on the drill-hole axis.

CHEMICAL VARIATIONS IN THE PRE-TERTIARY ROCKS OF CORNUCOPIA, OREGON

G. E. GOODSPEED
University of Washington, Seattle, Washington

The Pre-Tertiary rocks of the Cornucopia area, in the southeastern part of the rugged Wallow Mountains of northeastern Oregon, are chiefly metamorphosed sedimentary rocks of Paleozoic and Mesozoic age, and granitic rocks of varying composition. Hornfelses derived from argillaceous sedimentary rocks are dominantly of mesozonal grade.

The contacts of the granitic rocks with the metamorphic rocks are gradational. For example a granitic mass 232 feet wide cut by a lower adit, has transitional zones 30 and 38 feet respectively. Chemical variations across this zone include about 10 per cent increase in SiO_2 in the granitic rock with a corresponding decrease of nearly 5 per cent in Fe_2O_3+FeO

and over 2 per cent MgO but with little change in CaO and Na_2O. Crystalloblastic textures prevail in the granitic rock as well as in the transitional zones.

From the 31 analyses afforded by a G.S.A. grant, several variation diagrams have been made and these diagrams are quite different from those of magmatic rocks. It is the opinion of the writer that the chemical variations can best be explained by the hypothesis of granitization rather than magmatic differentiation.

STABILITY OF MAGNESIAN CALCITES

D. L. GRAF AND J. R. GOLDSMITH
Illinois State Geological Survey, Urbana, Illinois and University of Chicago,
Chicago, Illinois

The geologic stability at earth surface conditions of calcite solid solutions with at least 1 or 2 mole per cent $MgCO_3$ is suggested by the occurrence of such material in the Quaternary and Tertiary of Florida, and elsewhere.

However, it is also a commonly held view that the difference of size of Ca^{++} and Mg^{++} precludes the formation of stable magnesian calcites. In order to evaluate these matters, the stability of the hard parts of certain present-day algae and echnoids containing as much as 20 mole per cent $MgCO_3$ in solid solution has been studied. Ten day runs at 300° C. in the presence of water expel little or none of the Mg, but similar runs at 400° C. produce a pure calcite and brucite. The presence of moderate CO_2 pressure appears to inhibit the breakdown of the solid solution.

Magnesian calcites containing at least 20 mole per cent $MgCO_3$ in solid solution have been produced synthetically both at room temperature and at elevated temperatures and pressures, but these products may be metastable. In the former case, in particular, the conditions under which crystal growth begins are critical; a high concentration of NaCl decreases the rate of growth and favors greater content of Mg in the carbonate solid solution.

SYNTHESES OF URANIUM MINERALS AT ROOM AND ELEVATED TEMPERATURES*

JOHN W. GRUNER
University of Minnesota, Minneapolis, Minnesota

Syntheses of uranium-minerals is probably the best way of solving some of the problems accompanying the mineralogy of the several scores of natural uranium-compounds. Uranyl minerals, that is, so-called secondary ones, were synthesized at room and elevated temperatures in solutions that usually had a terminal pH of 1 to 5. Zippeite ($5UO_3 \cdot 3SO_3 \cdot 10H_2O$) and becquerelite ($5UO_3 \cdot 10\text{–}12H_2O$) were made at room temperature. Fourmarierite ($3PbO \cdot 6UO_3 \cdot 5H_2O$) formed easily at 100° C. Curite ($3PbO \cdot 7UO_3 \cdot 4.5H_2O$), kasolite ($PbO \cdot UO_3 \cdot SiO_2 \cdot H_2O$) and soddyite ($5UO_3 \cdot 2SiO_2 \cdot 6H_2O$) readily formed at 180° C. and higher. The silica in kasolite and soddyite came from the glass containers of the experiments. Clarkeite ($UO_3 \cdot nH_2O$) is the only mineral recognized in solutions with a pH higher than 7 at 258° C. In many experiments one or two unknown compounds were found. Pitchblende (uraninite) was made at 50° to 212° C. by reduction of uranyl ions with H_2S or ferrous ions. Reactions below 50° C. are extremely slow. In some experiments at 212° C. hematite was a by-product of the pitchblende which could explain the common hematitic staining in hydrothermal veins. Organic liquids are able to reduce uranyl ions to pitchblende at room temperature. Whether these organic reactions take place in the complete absence of light is not yet known. That they occur in ultraviolet radiation has been known for 50 years.

* This investigation is a part of a contract with the Raw Materials Offices of the Atomic Energy Commission and is published with their permission.

INTRUSIVE TUFF-BRECCIA

RICHARD L. HAY
Goshen, Indiana

Andesitic tuff-breccia of intrusive origin is widely exposed over an area of at least 100 square miles in northwest Wyoming in the east-central part of the Absaroka Range, a dissected volcanic plateau consisting mainly of Eocene deposits. The tuff-breccia occurs as one or more essentially horizontal sheets, an unusual feature for intrusive pyroclastic rock. The intrusive sheet(s) range in thickness from a maximum of about 650 feet to a minimum of 50 feet or less. Included blocks from the overlying beds, some as much as several hundred feet in diameter, are a characteristic feature of the tuff-breccia. There is contact alteration of both these inclusions and the country rock beds.

Stratigraphic evidence suggests that the tuff-breccia was emplaced at relatively shallow depth (probably between 600 and 1900 feet); locally it probably reached the surface. The beds into which the pyroclastic rock was intruded were probably poorly consolidated and water-saturated. The occurrence of foreign material unlike nearby country rock and beds of the underlying sequence suggests underground lateral movement of several miles.

The temperature at the time of emplacement is unknown, although petrographic evidence suggests that the tuff-breccia did not contain liquid magma at the time of emplacement. Some heat (and volatiles) was probably required, however, for the contact alteration, characterized by chlorite(?) and hardening (silicification ?).

No satisfactory explanation can now be given for the mode of origin and emplacement, but evidence seems to suggest the relatively non-explosive subcrustal formation of tuff-breccia and its injection under pressure.

CHEMICAL DIFFERENTIATION OF MULTI-GENERATION PEGMATITE MINERALS

E. WM. HEINRICH
University of Michigan, Ann Arbor, Michigan

Differentiated pegmatities, consisting of zones or combined zones and younger hydrothermal units, can contain more than one generation of a mineral species. Compositional variation of successive generations of a species is systematic and is a function of paragenetic position. Decreasing relative age of formation is accompanied, in plagioclase, by increasing Na_2O; in microcline by decreasing amounts of sodic plagioclase as exsolution perthite and by increasing Rb_2O. Alkalies, except K_2O, also increase in lepidolite, tourmaline, beryl and some phosphates, with younger generations of each. In garnet, tourmaline, columbite-tantalite, triphylite-lithiophilite, muscovite and probably lepidolite the Fe:Mn ratio decreases with decreasing relative age. Likewise in columbite-tantalite Ta_2O_5 increases in younger members. Other multigeneration species that reveal compositional differences are amblygonite (in the F-OH ratio and in Na_2O), apatite (in the F-OH ratio and MnO), cassiterite, biotite, spodumene, quartz and topaz. The small-scale, sequential changes in the composition of succeeding generations of pegmatite minerals reflect, in a general way, the large-scale variations in the magmatic differentiation series, gabbro to granite, and thus constitute an argument for the origin of structurally complex pegmatites through fractional crystallization.

METASOMATISM BY APOPHYSAL DIKES IN THE CRAWFORD NOTCH REGION, NEW HAMPSHIRE

DONALD M. HENDERSON
University of Illinois, Urbana, Illinois

On the northwest side of Crawford Notch in the White Mountains of New Hampshire, a large ring-dike of Albany porphyritic quartz syenite fingers out into many apophysal dikes where it meets a body of fine-grained gneiss of the Littleton formation. The rock in the ring-dike proper is porphyritic quartz syenite which is composed of approximately equal amounts of euhedral phenocrysts of feldspar 1 cm. across, and of 0.5 mm. grained groundmass. The rock of the apophysal dikes ranges from quartz syenite porphyry to granite porphyry. The groundmass is dark-gray to black, aphanitic, and composes two-thirds of the rock. The phenocrysts are similar to those in the porphyritic quartz syenite.

The apophysal dikes are enclosed in thick to thin bedded, fine-grained biotite gneiss and hornfels which are locally andalusite bearing. The dikes range from a few feet to 300 feet wide and from a few tens of feet to several hundred feet long. Most of the apophysal dikes are bordered by transitional zones ranging from a few inches to 25 feet wide which grade into fine-grained gneiss and hornfels. The most striking feature of the border zones is the occurrence in gneissic matrix of abundant feldspar "phenocrysts" like those of the dikes proper. The groundmass of the transitional zone is chiefly fine-grained gneissic material with abundant added tourmaline and intermixed constituents of the groundmass of the dikes.

It is concluded that significant amounts of rock-forming minerals as well as "mineralization products" such as tourmaline, sulfides and silicification can be produced by metasomatic action of magmatic dikes even as fine-grained as porphyries.

STRUCTURE AND METASOMATISM OF THE BELT SERIES NORTHWEST OF THE IDAHO BATHOLITH*

ANNA HIETANEN
U. S. Geological Survey, Washington, D. C.

The older rocks around the northwestern corner of the Idaho batholith belong to the pre-Cambrian Belt series.

The area is structurally complex, situated at the junction of two arcuate segments of Nevadan folding and also on the western border of the Laramide orogenic belt. The major fold axis parallels the trend of the northern arcuate segment of Nevadan folding (N. 70°–80° W.). The lineation and axis of small folds parallel the trend of the southern arcuate segment (N. 50° E.). Both sets of folds are locally overturned to the south and are accompanied by low-angle thrusts. The gentle north trending folds may be of Laramide age. The block faulting continued to Miocene time.

The main folding was accompanied by small intrusions of gabbro, diorite, and tonalite, intense metamorphism, and metasomatic introduction of hornblende, biotite, andesine, and accessories. Locally, a second period of metasomatism obliterated the folded structures and is interpreted as having caused the formation of monomineralic rocks like hornblendites and anorthosites. This second period of metasomatism may be contemporaneous with the emplacement of the quartz dioritic border zone of the batholith. Small intrusions of tonalite west of the batholith and the rocks of the quartz monzonite series in the center and north of the batholith were emplaced after the second period of metasomatism.

Chemical analyses show that mainly silica was expelled and Fe, Mg, Al, Ca, and Ti were introduced during the metasomatism.

---

* Publication authorized by the Director, U. S. Geological Survey.

RADIATION DAMAGE IN ZIRCON: A POSSIBLE AGE METHOD

PATRICK M. HURLEY AND HAROLD W. FAIRBAIRN
Massachusetts Institute of Technology, Cambridge, Massachusetts

The relationship has been studied between crystal structure damage and total alpha particle irradiation in zircon. The total irradiation was based on estimated or measured age times alpha activity, and the damage was determined by the change of the *x*-ray diffraction angle from the (112) plane as measured to .01° by *x*-ray spectrometer. The angle was found to be 35.635° (2θ) for completely undamaged material and it approached 35.1° asymptotically as the zircon had suffered increasing dosages of alpha irradiation and become metamict. The difference between the measured angle and 35.635° was found to equal $0.535e^{-2.31\times 10^{-16}\alpha}$ degrees, where α = total irradiation in alphas/mg. The results have been interpreted to indicate that 4.5×10^3 atoms are displaced per alpha disintegration and that the annealing rate is essentially zero at earth's surface temperature. The process appears to be useable for age measurement but generally limited to zircons of less than 500 alphas/mg./hr. activity.

It was further found that the zircon became "half-metamict" after a radioactive energy release of 685,000 cal./gm., indicating that only a fraction of a per cent of the energy is stored in the structure as disordered atoms, the remainder being lost as heat. Observations on the high annealing rate of common rock minerals show that the amount of energy capable of being stored in a rock by alpha damage is negligible in questions relating to petrogenesis and volcanism.

HEAT PRODUCTION IN BASALTS AND THEIR ORIGIN

PATRICK M. HURLEY
Massachusetts Institute of Technology, Cambridge, Massachusetts

Progress is being made on the measurement of the radioactivity of crustal rocks (including potassium) for the determination of heat generation. Present averages show 2.2×10^{-6} cal./gm.yr. for the basalts of the Columbia Plateau, Oregon, 1.0×10^{-6} for the intrusive diabase dikes of the Canadian Shield area, and 1.0×10^{-6} for the Deccan basalts of India.

The objective is a clearer definition of conditions limiting the origin of certain basic volcanic rocks, particularly those of a tholeiitic flood type, those associated with stable Shield areas, and those of an oceanic type. At the present time it appears that the thermal gradient in large, low-lying areas of old crystalline rocks, even allowing for a low average radioactivity to the depth of the Mohorovicic discontinuity, will not permit the temperatures needed for the production of basic magmas at depths less than 100 km under equilibrium conductive conditions, and at the same time the existence of a layer of material of basaltic composition at these depths for any great time is not permitted on the basis of its heat generation.

It therefore seems necessary to think in terms of at least local, transient, thermal columns caused by convected material in the mantle. If the convected material is of a peridotitic composition it would be necessary that a gravitational separation of a basalt-like extract be effected at some time during the history of the column. This extract could not represent more than one part in 10^{-2} of the original mantle material.

STATISTICAL STUDY OF TEXTURE OF ENCHANTED ROCK PLUTON, SOUTHWESTERN LLANO COUNTY, TEXAS

ROBERT M. HUTCHINSON
University of Texas, Austin, Texas

Enchanted Rock pluton, one of Stenzel's Town Mountain Series of plutons, covers 100 square miles, is of pear-shaped outline, and intrudes tightly folded Precambrian metamorphics.

Tectonic features within the mass and structural attitude of wallrocks indicate the northern third is phacolithic, but the remainder is probably discordant batholithic. The phacolithic part occupies a synclinal trough plunging 16–20° southeast.

Density of the granite varies 2.62–2.68. Biotite-rich schlieren vary 2.93–3.02. Xenoliths run commonly 2.71–2.74 and may strike 15–30° transverse to surrounding platy flow structure.

Seven traverses were run from center to margin of the pluton normal to platy flow structure. Number and dimensions of microcline phenocrysts were recorded for a 100 square centimeter area at each station. Chi-square values were calculated for their long dimension. On horizontal cross section crystals are rectangular. Brachy- and macropinacoids predominate.

Variation diagrams showing number of crystals per 100 square centimeters and average area of these crystals have characteristic curves. Chi-square values show only probability that deviations from the hypothesis of independence are caused by chance.

Characteristic curves indicate textural changes and aid in determining cooling history and structure of the pluton. Judging from chi-square values, probability that curves obtained are due to chance is small. Chi-square values are especially significant when comparing dimensions of crystals occurring in chill zones with those in which chilling was weak to absent. Where chilling occurred values are low; where crystallization proceeded uninterrupted values are high.

OCCURRENCE OF OPTICALLY NEGATIVE FORSTERITE IN THE SYSTEM Na_2O-MgO-Al_2O_3-SiO_2

ROBERT H. INSLEY
Champion Spark Plug Co., Detroit, Michigan

Biaxial negative forsterite was crystallized from melts containing Na_2O, MgO, Al_2O_3 and SiO_2. The crystals show inclined extinction up to 10° and prominent embayments. Optic axis interference figures indicate an optic angle lower than that reported in the literature for pure forsterite. *X*-ray diffraction patterns are identical with that reported in the literature for pure synthetic forsterite.

Although the ionic radii of both Na^+ and Al^{3+} differ radically from Mg^{2+}, the sum of the radii of Na^+ and $Al^{3+}=2Mg^{2+}$. It is postulated that atomic substitution takes place on a limited scale to account for the change in optical properties and morphology of the crystals.

RATIO OF OXYGEN ISOTOPES IN QUARTZ OF CONTRASTED ORIGIN

M. L. KEITH, M. A. TUVE, G. L. DAVIS, AND J. B. DOAK
Pennsylvania State College, State College, Pennsylvania and
Carnegie Institution, Washington, D. C.

Measurements of the $O^{18}:O^{16}$ ratio in carbon dioxide produced by reaction of quartz with carbon in a vacuum furnace show that samples of quartz from a geological environment indicative of relatively low temperature of quartz growth, have a higher content of

O^{18} than do quartz samples formed at higher temperature. Differences are small but readily measurable with the mass spectrometer. Results indicate that the oxygen isotope ratio of quartz, taken in conjunction with other data, including data on the high-low inversion, may provide a useful clue to geologic temperatures in a relatively low range.

ALTERATION AND URANIUM MINERALIZATION, MARYSVALE, UTAH

PAUL F. KERR, GERALD P. BROPHY, HARRY M. DAHL, JACK GREEN, AND LOUIS E. WOOLARD
Columbia University, New York, N. Y.

Alteration zones containing a sequence of clay minerals, silicification, alunitization or pyritization occur in a variety of rock types in an area some fifty square miles in extent at Marysvale, Utah. Two field seasons with an intervening period of laboratory study have been devoted to an analysis of the relationship between the alteration and uranium mineralization. More significant channels of alteration have been mapped.

The area has been mapped geologically in order to establish correlation between the alteration and rock types. It has been found desirable to subdivide the major geologic units, such as the Bullion Canyon volcanic series, the Mount Belknap volcanics and the intrusives for greater clarity in structural interpretation, interpretation of the alteration and the delineation of host rocks presumably favorable to the deposition of uranium.

Alteration appears to diminish in the Mount Belknap red facies. Minor bleached areas occur along faults and shear zones. These are characterized by the development of adularia but contain few clay minerals. Such zones traced into bordering rocks of the Bullion Canyon volcanic series or intrusives may show enlargement and the development of argillic alteration.

Uranium bearing veins contain both oxidized uranium minerals and uraninite. Fluorite is a common associate becoming more darkly colored near ore zones. Jordisite and ilsemannite are associated vein minerals. Montmorillonite, hydromica and kaolinite are common clay mineral constituents of the uranium vein walls. Localized hematitic alteration may be observed. Biotite may develop as an alteration mineral. Brecciated thin quartz veins, pyritic and chloritic zones and occasionally magnetite zones occur in the uraninite area.

Uranium minerals have been found in several units of the Bullion Canyon series accompanied by zones of argillic alteration. The principal veins found to date, however, are in quartz monzonite or fine-grained granite. The Mount Belknap has not yet yielded more than migratory secondary mineralization along fractures. Alunitic zones are generally free from uranium, but uranium mineralization is occasionally found nearby.

Conclusions presented constitute a progress report on the Marysvale Alteration Study jointly sponsored by the Division of Raw Materials, Atomic Energy Commission and the Department of Geology, Columbia University.

CARBON 14 MEASUREMENTS ON GEOLOGICAL SAMPLES

J. LAURENCE KULP, LANSING E. TRYON AND WILLIAM A. SNELL
Lamont Geological Observatory, Palisades, New York

Carbon 14 age measurements on various types of geological samples which have been made during the last year will be reported. Wood specimens from cores taken in the Mississippi delta region show that the last major sea level lowering (on the order of 400 feet) occurred more than 30,000 years ago and that the rise has been more or less continuous since then. The time of a certain sea level in the Mississippi delta region is very close to the same level on Bermuda. A survey of the carbon 14 content of the atmosphere indicates that it is essentially constant and corresponds closely to that for living wood. The carbon 14 concentration in ocean carbonate is much less for deep water than for surface water suggesting that the rate of ocean turnover is on the order of thousands of years. There is evidence for a variation in the carbon 14 concentration of the surface ocean water. This is important in the evaluation of ages derived from shellmaterial.

PETROGENESIS OF A GABBRO-GRANOPHYRE COMPLEX IN NORTHERN WISCONSIN

MORRIS W. LEIGHTON
Tulsa, Oklahoma

A gabbro-granophyre complex is exposed in northern Wisconsin on the steeply dipping south limb of the Lake Superior geosyncline. The complex consists of two distinct belts of middle Keweenawan gabbro and granophyre split by a narrow belt of lower Keweenawan extrusives. Younger basic dikes cut the area.

The gabbro was intruded along zones of weakness developed between certain flow units during the formation of the geosyncline. In the gabbro two apparently unrelated structures are found. The first, fluxion structure, is believed to be due to shear or flow as the mass crystallized. The second, rhythmic layering, appears to be related to crystal settling. Gabbroic mineral compositions reveal simultaneous soda enrichment in plagioclase and iron enrichment in coexisting pyroxenes and olivines.

Between the gabbro and granophyre is a narrow zone of "intermediate rock" which exhibits peculiar mineralogical and textural characters. Fourteen features of this zone indicate that it originated as an alteration product of gabbro through contact action of a granophyric melt. For the granophyre, criteria of a replacement origin are inconclusive. Eleven facts strongly support a magmatic origin. The granitic magma may have developed through partial refusion in the lower reaches of the geosyncline or through fractional crystallization at depth. The resulting granophyric texture is unrelated to eutectic crystallization.

As a result of the contact action of granophyre magma on solidified gabbro, geochemical culminations of TiO_2, FeO, MnO, and P_2O_5 occur in the "intermediate zone." Variations in isotopic compositions of oxygen also resulted from this contact metasomatism.

RELATION OF PITCHBLENDE DEPOSITS TO HYPOGENE ZONING IN THE FRONT RANGE MINERAL BELT, COLORADO

B. F. LEONARD
U. S. Geological Survey, Denver, Colorado

The distribution of pitchblende deposits in several Front Range mining districts shows a distinctive relation to the pattern of hypogene zoning. The deposits appear to be restricted to an intermediate or transitional zone between central areas of pyritic gold veins and peripheral areas of silver-lead-zinc veins. At present we do not know whether pitchblende is more common in inner or the outer part of the intermediate zone. In at least one district (Central City) significant quantities of copper in the form of chalcopyrite have been produced from the intermediate zone. The position of uranium in an intermediate zone between gold and zinc was tentatively implied by W. H. Emmons (1926) in his generalized treatment of hypogene zoning.

At least seven local geologic factors must be considered in interpreting the zonal distribution of Front Range pitchblende deposits. These factors are: bostonite intrusives, fault patterns, multiple stages of uranium mineralization, differences between paragenetic sequence and position of minerals in successive zones, correlation of pitchblende with copper sulfides (and sulfosalts?), scale and complexity of zoning in plan and in section, and effective depth of mineralization. The significance of some of these factors can already be evaluated.

The concept of the position of pitchblende in hypogene zoning is developed to stimulate and guide the systematic search for pitchblende deposits. Though the zonal position of pitchblende deposits is best known for areas of complex base-metal mineralization dominantly of mesothermal (possibly xenothermal) character, knowledge of the zonal position of uranium deposits in widely different geologic environments might be similarly useful in a search for ore.

RELATIONSHIP BETWEEN POLYMORPHISM AND COMPOSITION IN THE MUSCOVITE-LEPIDOLITE SERIES

ALFRED A. LEVINSON
University of Michigan, Ann Arbor, Michigan

A determination of the crystal structures of 500 muscovites and lepidolites, approximately 50 of which are of known composition has demonstrated the existence of a complete series between muscovite and lepidolite. The polymorphic variation in this series can be correlated with chemical composition, particularly with Li_2O content. A new variant of the muscovite structure has been discovered for which the term lithium muscovite is proposed. This modification crystallizes with a structure very similar to that of normal muscovite and apparently links heptaphyllite muscovite with octophyllite lepidolite. Micas with 3.2–4.0% Li_2O are generally characterized by poor crystal development and anomalous optical properties owing to their transitional structures. Lepidolites with 4.0–5.1% Li_2O generally crystallize as the 6-layer monoclinic polymorph whereas those with more than 5.1% Li_2O have usually crystallized as the 1-layer monoclinic polymorph. Rhombohedral lepidolite is commonly associated with the 1-layer monoclinic polymorph, and both have essentially identical compositions. Twinning may be responsible for the rhombohedral form. Polymorphic modifications of lepidolite may occur across sheets and also along the c axis directions in single books.

MINERALS OF THE SAPUCAIA PEGMATITE MINE: FAHEYITE, A NEW BERYLLIUM PHOSPHATE*

MARIE LOUISE LINDBERG AND K. J. MURATA
U. S. Geological Survey, Washington, D. C.

Faheyite, a new mineral from the Sapucaia pegmatite mine, Minas Gerais, Brazil, has the composition $(Mn, Mg, Na)Be_2Fe_2(PO_4)_4 \cdot 6H_2O$. It occurs as white, bluish-white, or brownish-white minute fibers that coat minerals in vugs. Evidences for a late-stage phosphate mineralization include the occurrence of faheyite as tufts of fibers on altered muscovite, as flat rosettes between muscovite sheets, and as fiber-coating on euhedral crystals of quartz and variscite. The variscite crystals are unusual in that they are raspberry red and contain up to 2.46 per cent MnO. Crystals of roscherite, childrenite, amblygonite, and apatite and botryoidal masses of frondelite also occur in the vugs.

The powder pattern has been completely indexed on the basis of a primitive hexagonal cell with dimensions $a_0=9.43$ Å, $c_0=16.00$ Å; the cell contents are $Z=3$. The powder film was compared with a rotation picture of a fiber taken in the powder camera, as an aid to indexing the powder film. X-ray powder data show strong lines at 5.72, 7.28, 3.243, 3.087, 3.031, and 3.958 Å. The specific gravity is 2.660 (obs.) and 2.670 (calc.). The indices of refraction are $\omega 1.631$ and $\epsilon 1.652$.

---

* Publication authorized by the Director, U. S. Geological Survey.

The analysis shows the following percentages: insoluble 9.44, P_2O_5 38.11, Fe_2O_3 21.42, Al_2O_3 0.10, Mn_2O_3 none, FeO none, BeO 7.26, MnO 5.99, MgO 1.14, Na_2O 0.84, K_2O trace, F trace, H_2O 14.90, total 99.20.

The mineral is named in honor of Joseph J. Fahey, geochemist of the U. S. Geological Survey.

NATIVE LEAD, PRESIDIO COUNTY, TEXAS

JOHN T. LONSDALE AND KATHRYN O. DICKSON
University of Texas, Austin, Texas

Approximately 3,000 pounds of ore containing native lead was recovered from three small tabular ore bodies in the western part of the Shafter District, Presidio County, Texas. Two of the ore bodies were vein-like in limestone with clay gouge walls. The metallic lead was localized at the centers of the veins. The third ore body was flat lying disk-shaped about 4 feet thick with a surface area of 1,600 square feet. The native lead occurred along a part of the margin of the ore body in a zone about 9 inches thick separated from the wall rock by clay gouge.

The ore generally was argentiferous steel galena partly or completely altered to cerussite and anglesite with minor minerals including wulfenite, litharge (?), quartz and limonite. The native lead occurred as threads, sheets to one-half inch thick and pods up to 4×7×2.5 inches.

The native lead appears to have been derived from the secondary minerals. Microscopic, chemical and spectrographic data are presented, and the paragenesis of the mineral suite discussed.

GEOLOGY OF THE GYPSUM DEPOSITS NEAR SUN CITY, BARBER COUNTY, KANSAS

DUNCAN J. MCGREGOR
University of Michigan, Ann Arbor, Michigan

An area of approximately four square miles, in the vicinity of the Pioneer Mine, Sun City, Kansas, was mapped to ascertain the relationship between the Medicine Lodge gypsum and anhydrite. Samples were studied petrographically.

The Medicine Lodge gypsum is lower Permian in age and forms the cap rock in the area. The regional dip is about 11 feet per mile to the southwest. Structural contours on the base of the gypsum show local irregularities which may represent initial dip.

Anhydrite is not generally present on surface outcrop, but is exposed in the mine. It occurs as lenticular deposits about 10 feet above the base of the gypsum. The thickness of the gypsum is about 30 feet in the mine. Where anhydrite is absent, solution channels generally are present. These channels are zones of brecciation in which the gypsum is soft, porous, and sugary, and coated with some clay. Drilling has encountered water in these channels.

Petrographic studies show (1) gradation of anhydrite to gypsum; (2) gypsum fracture filling in the anhydrite; (3) absence of anhydrite in the upper and lower part of the gypsum; and (4) no evidence of distortion.

Hydration of this anhydrite may have taken place subsequent to the sedimentary anhydrite-gypsum deposition.

INSHORE MARINE MAGNETIC INVESTIGATIONS: THE AREA FROM NEW JERSEY TO CAPE COD, MASSACHUSETTS

EDWARD TITUS MILLER
Lamont Geological Observatory, Palisades, New York

The total intensity of the earth's magnetic field was measured from a ship along various tracks from New Jersey to Cape Cod to a distance about 30 miles from shore. The measurements were made with a continuously recording airborne magnetometer which had been modified to be towed about 30 feet under water 200 or more feet astern the survey vessel. This survey shows that there is no magnetic anomaly associated with the inshore end of the Hudson Canyon. It found major anomalies of several hundred gammas magnitude covering large areas 10 miles east of Sandy Hook, N. J., south of Fire Island and SSW and NNE of Block Island. A non-anomalous region was found south of Narragansett Bay. The half widths of smaller anomalies are the order of fractions of a mile at the Cape Cod end of the area, while in the area south of Long Island they had half-widths of the order of miles. It is concluded that there is no major structure at the surface of the crystalline rock under the Hudson Canyon near shore. The Narragansett Basin is shown to extend south under water at least 10 miles. Several hypotheses concerning the subsurface crystalline rock in the area are proposed.

URANIUM ORE CONTROLS IN THE HAPPY JACK MINE AND VICINITY, WHITE CANYON, UTAH

LEO J. MILLER
Atomic Energy Commission, Grand Junction, Colorado

Channels within the Triassic Shinarump formation are thought to be the primary uranium ore control in White Canyon, southeastern Utah. This has been demonstrated in the Happy Jack Mine and on the Sunrise and Gonaway claims. In addition, there are important intra-channel controls; the most conspicuous being carbonaceous matter and lithologic changes.

Shinarump stream channels were first mapped in White Canyon during 1951, on the basis of outcrop mapping alone. Three of these channels, the Happy Jack, Sunrise and Gonaway were later explored and extended by drilling. Detailed geologic mapping of the Happy Jack Mine and drill hole information supplemented each other.

A structural contour map of the base of the Shinarump, corrected for regional dip, was the most important tool in locating ore. Each drill site was located only after the preceding diamond drill core information had been evaluated and placed on the contour map. Forty-five per cent of the holes drilled were situated in ore, resting on or near the bottom of channels. No ore was found in this area outside of channels. Correlations among diamond drill holes and outcrops reveal that the ore is characteristically in a porous carbonaceous sandstone on top of Shinarump siltstone.

Cross sections of the Happy Jack Mine show, in addition to the above features, horizontal bedding plane control for pitchblende and sulfide mineralization. There is no evidence for vertical control of primary ore.

SOME SPECIAL CRITERIA FOR GRANITIZATION

PETER MISCH
University of Washington, Seattle, Washington

In addition to textures, replacement features, structural and stratigraphic continuity with, and chemical relationships to country rocks, etc., the following criteria appear useful.

Early epidote often occurs in amphibolitic-derived granitized rocks; either inherited, or formed by early-metasomatic partial biotitization of hornblende. It antedates part of the plagioclase and all of the late K-feldspar. Its preservation indicates temperatures below those of any silicate melt. Microscopic relations between early epidote and feldspar greatly differ from those between feldspar and secondary epidote.

Early epidote and other minerals assign a considerable part of the granitized rocks to temperatures lower than those of the high-grade zone. Mapping of progressive zones leads to the concept of *external and internal zoning*, some isograds being outside and others inside the granitized body. At igneous contacts, all progressive zones are external.

Some relict minerals in granitized rocks are also chemical indicators of non-magmatic origin. *Al-silicates* have been previously discussed. Sometimes *lime-silicate minerals* survive. Chemical incompatibility of certain minerals with the bulk rock composition suggests granitization.

Many granitic rocks have unequivocally crystalloblastic, some indubitably igneous textures. *If crystalloblastic and igneous appearing features are combined, time analysis* is decisive. If igneous textures are older, an igneous rock has been altered autometamorphically or metamorphically. If crystalloblastic textures are older, a granitized rock has eventually developed certain igneous features. Final liquefication destroys all crystalloblastic and creates new igneous textures. Intrusive emplacement does not prove liquefication.

Chemical similarity of advanced granitized and igneous granitic rocks indicates close genetic connection, rather than two geologically unrelated origins. Probably the quantitatively apparently subordinate, true igneous granitic rocks mostly form by liquefication of granitized rocks. Granitization converges toward a chemical equilibrium in the crust.

PITCHBLENDE DEPOSIT AT THE CARIBOU MINE, BOULDER COUNTY, COLORADO

F. B. MOORE AND W. S. CAVENDER
U. S. Geological Survey, Denver, Colorado

Pitchblende occurs at the Caribou mine in a mesothermal carbonate vein that contains silver, lead, and zinc minerals. Unlike most of the large, well-known pitchblende deposits of the world, it does not contain nickel- and cobalt-bearing minerals. The deposit is believed to be unique in that the host rock is a Tertiary monzonite. The pitchblende is in a tension fracture (the Radium vein) of an inter-connecting vein system, at vertical depths between 875 and 1075 feet. Two pitchblende ore shoots are known; the largest one has a vertical dimension of 200 feet and a horizontal dimension of 70 feet. Within the ore shoots, pitchblende forms a discontinuous seam as much as 6 inches thick along the side of sulfide veins. The sulfides and the pitchblende are not intergrown. There is no apparent difference in mineralogy, other than the presence of pitchblende, between the pitchblende-bearing vein and the other veins in the system. The pitchblende is predominantly a soft, sooty variety, but the larger masses also contain a hard, botryoidal variety. The soft pitchblende is believed to have been deposited later and at a lower temperature than the hard pitchblende.

BRANCHING RATIO OF K^{40} RADIOACTIVE DECAY AND ITS APPLICATION TO GEOLOGICAL AGE DETERMINATIONS

A. K. MOUSUF
University of Toronto, Toronto, Ontario

The ratio of K-capture to beta-emission for the naturally occurring radioactive isotope K^{40} has been determined by extracting, purifying and measuring the volume of argon extracted from four different samples of microcline. The amount of radiogenic A^{40} was ascertained by mass spectrometric analysis. The potassium contents of the samples of microcline were determined by chemical analysis. The argon was extracted by heating with metallic sodium in vacuum, and it was purified by treating the gas in a calcium furnace to constant volume. Isotopic analysis of argon thus obtained showed that the different samples contained from 93 to 100 per cent of radiogenic argon.

All the samples of microcline used in this investigation were from the Grenville area where ages ranging from about 850 to 1050 m.y. had been determined by uranium-lead methods. As the localities from which these samples were collected are not precisely dated, they have been assumed to be of the same age as Wilberforce (1030 m.y.). Using the total half life for K^{40} of 12.7×10^8 years as obtained by Sawyer and Wiedenbeck, the values of branching found were from 0.053 to 0.066. These are in good agreement with the low range of values obtained by counting experiments and also with those obtained by Aldrich and Nier. But if any of the sample had a younger age (for example 850 m.y.) then the values for the branching ratio would be raised and would still be within the range of other physical determinations.

Work upon more precisely dated material is being continued in the hope that the branching ratio can be more precisely fixed and a useful method of determining ages established.

α-EUCRYPTITE PROBLEM

MARY E. MROSE
State Teachers College, Salem, Massachusetts, and Harvard University,
Cambridge, Massachusetts

Massive granular α-eucryptite is reported from two new pegmatite localities, Center Strafford, New Hampshire, and the Harding mine, Dixon, New Mexico. The Center Strafford material is an intergrowth of α-eucryptite and albite, identical with that described by Brush and Dana (1880) from Branchville, Connecticut. The Harding material is white to pale gray with a waxy luster. Hardness $6\frac{1}{2}$. Specific gravity 2.64. Optically uniaxial positive (+) with $n\text{O}=1.573$ and $n\text{E}=1.583$. Analysis gave: Li_2O 8.36, CaO 0.19, Na_2O 0.62, K_2O 0.38, Al_2O_3 35.76, SiO_2 54.64, total 99.95; measured cell contents: $Li_{4.5}Al_{5.3}Si_{6.9}O_{24}$. The strongest x-ray powder lines: 3.35 (10), 3.93 (9), 1.37 (9), 2.74 (8).

Crystals of synthetic α-eucryptite, averaging 5 to 8 mm. in length and 0.5 to 1.0 mm. in width were made hydrothermally (by G. C. Kennedy). Hardness ~6. Hexagonal-R; hexagonal scalenohedral. Observed forms: $c\{0001\}$, $m\{10\bar{1}0\}$, $a\{11\bar{2}0\}$, $r\{10\bar{1}1\}$, $e\{01\bar{1}2\}$, $f(02\bar{2}1\}$, $v\{21\bar{3}1\}$. Unit cell dimensions: $a_0=13.54$ Å, $c_0=9.01$ ($a_0{:}c_0=1{:}0.6654$); space group: $D^5{}_{3d}-R\bar{3}m$. The optical and x-ray powder data are identical with those of the Harding material. Analysis gave: Li_2O 9.65, Al_2O_3 43.75, SiO_2 46.70, total 100.10; measured cell contents: $Li_{4.9}Al_{6.5}Si_{5.9}O_{24}$. Treating the composition as derivative from SiO_2 (or $Si_{12}O_{24}$), the general formula can be written $(Si_{12-x}, Al_x)(Li_{x-y}Al_{y/3})O_{24}$, where $x=5.1$ and $y=0.6$ in the Harding material, and $x=6.1$ and $y=1.2$ in the synthetic material. The mechanism of compositional variation is interesting in that there is a coupled interstitial entrance of 3Li+Al to provide valence compensation for Si=Al instead of alkali alone as in the tridymite-christiansenite and high-cristobalite—alpha-carnegieite series.

Both natural and synthetic α-eucryptite fluoresce begonia rose (Ridgway) in shortwave ultraviolet radiation. In the direct x-ray beam the natural material fluoresces pale shrimp pink; the synthetic, begonia rose. When irradiated, both become pale smoky.

PALERMOITE AND GOYAZITE, TWO STRONTIUM MINERALS FROM THE PALERMO MINE, NORTH GROTON, NEW HAMPSHIRE

MARY E. MROSE
State Teachers College, Salem, Massachusetts and Harvard University,
Cambridge, Massachusetts

Palermoite, a new species having the composition $(Li, Na)_4SrAl_9(PO_4)_8(OH)_9$, and goyazite, $SrAl_3(PO_4)_5H_2O$, occur as late hydrothermal products in open cavities at the Palermo pegmatite, North Groton, New Hampshire.

Palermoite is orthorhombic, long prismatic in habit with {001}, {010}, {011}, {130} and {110}. The prism zone is vertically striated. Unit cell dimensions: $a_0 = 7.31$ Å, $b_0 = 15.79$, $c_0 = 11.53$ ($a_0:b_0:c_0 = 0.4630:1:0.7320$) with the space group D_{2h}^{25}-*Imm*. Cleavage {100} perfect, {001} fair. Fracture fibrous to subconchoidal. Brittle. Hardness 5½. Specific gravity 3.22 (meas.), 3.20 (calc. for two formula-units per cell with Li:Na = 4.9:1). Colorless to white. Luster vitreous to subadamantine. Streak white. Fluoresces white in direct *x*-ray beam. Optically biaxial negative (−) with $nX = 1.627$, $nY = 1.642$, $nZ = 1.644$; $2V = \sim 20°$; $r < v$, moderate; $X = c$ (elongation), $Y = a$, $Z = b$. Analysis gave: Li_2O 3.70, Na_2O 1.56, K_2O 0.10, CaO 0.88, SrO 9.20, Al_2O_3 33.85, P_2O_5 44.64, H_2O 5.97, total 99.90. The strongest *x*-ray powder lines are 3.11 (10), 4.38 (9), 2.44 (8).

Small colorless to white rhombohedral crystals of goyazite, pseudocubic {10$\bar{1}$2} terminated by {0001} and truncated by {20$\bar{2}$1} and {11$\bar{2}$0} occur in association with palermoite. Unit cell dimensions on Palermo crystal: $a_0 = 6.98$ Å, $c_0 = 16.54$ ($a_0:c_0 = 1:2.3696$). Specific gravity 3.15. Optically uniaxial positive (+) with $nO = 1.640$ and $nE = 1.651$, showing anomalous biaxial character with 2V up to 20°. The strongest *x*-ray powder lines: 2.97 (10), 2.20 (8), 1.89 (7).

The mineral association includes siderite, childrenite-eosphorite, green fibrous beraunite, crandallite-deltaite (?), whitlockite, brazilianite, tiny white hexagonal prisms of apatite, and small quartz crystals. Palermoite and goyazite appear in the sequence after siderite, but before apatite and quartz.

X-RAY STUDY OF RENIÉRITE, GERMANITE, AND COLUSITE

JOSEPH MURDOCH
University of California at Los Angeles, Los Angeles, Calif.

X-ray powder photographs of reniérite, germanite, and colusite show them to be essentially isostructural. There are slight but consistent differences in the edge of the unit cells, and reniérite further shows some divergence from a true isometric pattern, accounting for the strong anisotropism observed in polished section. The average values of a_0, using both CuK_α and CoK_α filtered radiation, are as follows:

Colusite 10.62 ± Å, germanite and reniérite 10.57 ± Å. The value for germanite is twice the published figure (5.299 Å), and that for reniérite is new.

Intensities for all three correspond very closely, with the exception of one group of lines, where there is a consistent difference.

		Intensity	
Form	Colusite	Germanite	Reniérite
{002}	2	1	1
{012}	2	½	1
{112}	2	2	2

All lines can be satisfactorily indexed except in reniérite, where members of definitely resolved doublets at 1.33±Å, 1.08±Å, and .9390±Å cannot be so indexed, and suggest strongly that the mineral is pseudo-isometric.

MINERALOGY OF THE SERPENTINE GROUP

BARTHOLOMEW NAGY AND THOMAS F. BATES
The Pennsylvania State College, State College, Pennsylvania

An investigation of the stability, morphology and structure of a number of serpentine and serpentine-like minerals has resulted in a more critical evaluation of the fundamental properties of the end members chrysotile and antigorite, and in more information as to the nature of certain related minerals.

Chrysotile asbestos is less stable than antigorite as shown by treatment with HCl and analysis of the results by *x*-ray and differential thermal patterns, electron micrographs, and solubility data. Since nitrogen adsorption measurements reveal no significant difference in the surface area of the test samples, it is believed that the difference in solubility may be the result of greater strain in the outer layers of chrysotile tubes than is present in the flat antigorite plates. Hydrothermal treatment of finely ground chrysotile fibers produces a flaky substance resembling antigorite in its properties.

Using the effect of 1N HCl treatment upon the 001 *x*-ray reflection, a method was devised statistically which provides a means of evaluating the percentage of chrysotile and antigorite present in mixtures. With the aid of this method it has been shown that serpentines other than chrysotile and antigorite are usually mixtures of these two minerals.

A fibrous form of bementite has been found to be a manganese mineral analogous with chrysotile and ectropite may be a similar analog of antigorite.

Deweylite seems to consist of a crystalline serpentine phase plus an amorphous complex of alumina, silica, and water.

GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED ATLANTIC COASTAL PLAIN. PART VII, THE CONTINENTAL SHELF, CONTINENTAL SLOPE, AND CONTINENTAL RISE SOUTH OF NOVA SCOTIA

CHARLES B. OFFICER, JR. AND MAURICE EWING
Lamont Geological Observatory, Palisades, New York

The results of a series of twenty-five refraction profiles made over the continental shelf south of Nova Scotia and extending down to the adjacent deep basin are reported. The shelf profiles are similar to those obtained elsewhere along the Atlantic Coastal plain, showing an unconsolidated sediment, a semiconsolidated sediment and a crystalline basement. The sediments gradually increase in thickness seaward up to 2.0 km (6500 ft.). On the continental shelf southeast of Halifax, Nova Scotia, a lens of higher velocity sediment is present below the semi-consolidated sediment with a maximum thickness of 2.7 km (9000 ft.). There is a downbuckle in the basement under the continental slope and a corresponding increase in the total thickness of sediments up to 5.0 km (16,000 ft.) on the continental rise. The sediments then thin further seaward with the younger sediments overlapping the older. On the profiles over the continental rise the intermediate layer of seismology was measured at an average depth of 10 km (33,000 ft.) and an average velocity of 6.9 km/sec (23,000 ft/sec), and on one profile the Mohorovicic discontinuity was measured at a depth of 16 km (52,000 ft.).

EOCENE MAGMA SERIES OF THE BEARPAW MOUNTAINS, MONTANA*

W. T. PECORA
U. S. Geological Survey, Washington, D. C.

In the Bearpaw Mountains region of north-central Montana, early Eocene deposition of terrestrial sediments, probably equivalent to the Wasatch formation, was halted by uplift due to irruption of magma that continued intermittently through the rest of Eocene time. Four major volcanic formations and a great variety of intrusive rocks are provisionally assigned to two magma series. One of these series is represented by igneous rocks related to a monzonitic petrographic suite and the other by igneous rocks related to a hyperalkalic shonkinitic petrographic suite. Metalliferous deposits and inclusions of pre-Cambrian basement rocks occur in rocks of the monzonitic series. Rocks of both series occur also in neighboring mountains and can be correlated with those in the Bearpaw Mountains. Evidence supports the thesis that the undersaturated shonkinitic magma, through assimilation of basement rocks, gave rise to the magma series that formed the rocks of the monzonitic suite.

NOTES ON THE DIFFERENTIAL LEACHING OF URANIUM, RADIUM, AND LEAD FROM PITCHBLENDE IN H_2SO_4 SOLUTIONS

GEORGE PHAIR AND HARRY LEVINE
U. S. Geological Survey, Washington, D. C.

Two 5-pound samples from the "hot spot" of the pyritic dump of the Wood mine, a past producer of pitchblende near Central City, Colo., showed Ra/U ratios that were abnormally high but nearly constant at about 150 times the equilibrium value for both samples in spite of a seven fold difference in uranium contents. Analyses of oxidized but still black Katanga pitchblende before and after leaching in very dilute, dilute, and concentrated sulfuric acid solutions showed that: (1) UO_3 is preferentially leached with respect to UO_2, Ra, and Pb in all three solutions, (2) the resulting residual concentration of both radium and lead effected in the process is proportional to the total amount of uranium leached except in concentrated H_2SO_4, and (3) after leaching in concentrated H_2SO_4 the resulting residual concentration of radium relative to lead is much lower, as might be expected from data published by Lind, Underwood, and Whittemore in 1918 for the solubility of $RaSO_4$. Under similar leaching conditions unaltered pitchblende from Great Bear Lake lost only 1/10 to 1/15 as much uranium as the UO_3-rich Kantanga ore. Both laboratory and field results point to the same conclusion: in an oxidizing, highly acid environment uranium is rapidly leached and both radium and lead tend to be fixed approximately proportionally in the process. These results help to explain (1) why UO_3-rich uranium minerals tend to give *maximal* Pb/U ages and (2) why the search for high-grade uranium ore, in and around abandoned sulfide mines known to have produced pitchblende in the past has been consistently disappointing.

ABUNDANCE OF Ba, Sr, Sc AND Zr IN CHONDRITES AND ULTRAMAFIC ROCKS

W. H. PINSON AND L. H. AHRENS
Harvard University and Massachusetts Institute of Technology,
Cambridge, Massachusetts

Twenty-one chondritic meteorites and a number of mineralogically related ultramafic rocks have been analyzed by the optical spectrograph for some elements believed to be

---

* Publication authorized by the Director, U. S. Geological Survey.

restricted largely to the silicate phase of meteorites. The concentration of each of these elements remains remarkably uniform in chondrites, lending evidence to the theory that meteorites had a common origin in both space and time. Analytical results and their implications in the Shattered Planet Hypothesis of the origin of meteorites are discussed.

In chondrites the following abundance values were obtained: Ba 0.0008%, Sr 0.0007%, Sc 0.0007% and Zr 0.005%. The validity and accuracy of these results is discussed in some detail.

Some preliminary observations have been made on the abundance of lithium in chondrites and ultramafic rocks. This element shows a strikingly large abundance difference in these two materials and its concentration in chondrites is more than twenty times greater than that in ultramafics. Ba, Sr, Sc and Zr do not show such extremely large abundance differences.

SEISMIC REFRACTION MEASUREMENTS ON THE GRAND BANKS AND ADJACENT SHELVES

FRANK PRESS AND WALTER BECKMANN
Lamont Geological Observatory, Palisades, New York

A reconnaissance refraction survey of the Grand Banks, St. Pierre Banks, and Banquereau was conducted in the first two weeks of September 1951. Three partially reversed profiles on the Grand Banks indicate sedimentary layers ranging in total thickness from 2000–4500 feet, underlain by crystalline rocks with velocities of 16,000–18,000 ft./sec. On St. Pierre Bank a single partially reversed profile showed 8000 feet of sediment underlain by crystalline rocks with a velocity of 17,500 ft/sec. Similar results were obtained on Banquereau where 9000 feet of sediments were found overlying crystalline rock with a velocity of 15,500 ft/sec. A partially reversed profile in the channel between St. Pierre Bank and Banquereau indicates 15,000 feet of sediment overlying crystalline rock with a velocity of 20,500 ft/sec. These results suggest that the channel is structural in origin.

WIDESPREAD OCCURRENCE AND CHARACTER OF PITCHBLENDE IN THE TRIASSIC AND JURASSIC SEDIMENTS OF THE COLORADO PLATEAU

A. ROSENZWEIG, J. W. GRUNER, AND LYNN GARDINER
Grand Junction Exploration Branch, Grand Junction, Colorado, and University of Minnesota, Minneapolis, Minnesota

During the last three years numerous uranium deposits in the sedimentary rocks of the Colorado Plateau have been shown to contain pitchblende. Although this mineral is not restricted to any one formation, the majority of its occurrences are in the lower Chinle and Shinarump formations of Triassic age. There are two principal modes of occurrence of pitchblende, one with sulfides of copper, the other in asphaltic bodies. In both types, the association with fossil plants or the occurrence in beds rich in organic debris is generally the rule. Fossil plants replaced by pitchblende and sulfides show a remarkable preservation of the organic structures. Pitchblende generally replaces cell walls, while the copper sulfides fill the cells, as is shown particularly well at White Canyon, Utah. Under these conditions the hardness and reflectivity of the pitchblende may differ considerably from that of hydrothermal vein pitchblende. At Seven Mile Canyon, Utah, pitchblende is found as rims on quartz and limestone pebbles as well as replacing wood. The ores of Temple Mountain, Utah, contain pitchblende as minute grains, one to ten microns in diameter, arranged in ribbon or ellipsoid-like aggregates in asphaltite. It is likely that not all of the uranium occurs as pitchblende, a portion being combined with the organic matter. The paragenesis of the minerals is complex and somewhat obscure, but a formation of the

pitchblende contemporaneous with, or shortly followed by, copper sulfides is suggested. In the asphaltite deposits a polymerization by alpha particles of light hydrocarbons may be involved.

STUDIES IN THE SYSTEM MgO-Al_2O_3-SiO_2-H_2O

DELLA M. ROY AND RUSTUM ROY
Pennsylvania State College, State College, Pennsylvania

Continuing earlier hydrothermal studies of the systems MgO-Al_2O_3-H_2O and Al_2O_3-SiO_2-H_2O, the influence of silica and magnesia on these respective ternary systems was studied. Magnesian serpentine is shown to admit about 10 mol. per cent Al_2O_3 into solid solution, thereby raising its temperature of stability at least 15° and changing its habit from tubular to platy. The preparation of various serpentines including nickel serpentine (slightly fibrous) and magnesia-germania serpentine (good hexagonal plates) lend support to the concept that size of ions controls the morphology. Pure aluminous montmorillonite admits magnesia into its structure, giving rise to a large primary phase volume of quaternary solid solutions. The decomposition temperature of magnesian montmorillonite is greater than that of the pure aluminian end member, attaining a maximum temperature of about 500° C. An "X-phase" is also encountered.

Phase equilibria in the high-alumina corner of the system indicate stability of the corundum-cordierite join above 500° C. and 5,000 psi. Apparent disagreement with earlier work in other parts of the system and the effect of the nature of the starting material on the attainment of equilibrium are discussed.

MINERALOGY OF THE RESIDUAL KAOLINS OF THE SOUTHERN APPALACHIANS

L. B. SAND AND T. F. BATES
Pennsylvania State College, State College, Pennsylvania

An investigation was made of the residual kaolins of the Southern Appalachian region to evaluate conditions giving rise to halloysite and kaolinite.

A new differential thermal analysis technique was developed to determine quantitatively the relative amounts of endellite versus kaolinite and/or halloysite in a sample. This was used along with other analytical methods to make quantitative mineralogical analyses of the residual clays.

The mineralogical analyses and thin section studies formed the basis for determining the sequence of weathering in the granites and pegmatities. Halloysite is formed only from the weathering of feldspars, and under conditions of intense leaching is formed from both the plagioclase and potash feldspars. The primary muscovite always alters to vermicular kaolinite. Where leaching is less intense, vermicular kaolinite is formed from the potash feldspars through the intermediate stage of secondary mica of the muscovite type and halloysite is formed from the plagioclase feldspars. Where acid leaching conditions obtain but are least intense, vermicular kaolinite is formed from the weathering of feldspars through the intermediate stage of secondary mica with minor amounts of halloysite forming directly from feldspar. Once secondary mica is formed, vermicular kaolinite is the next weathering product.

PROBLEM OF TRACE-ELEMENT DISTRIBUTION IN MAGMATIC MINERALS

DENIS M. SHAW
Hamilton College, McMaster University, Hamilton, Ontario

Goldschmidt and his associates showed that the distribution of trace-elements in magmatic minerals depends on the camouflage principle, whereby a minor element replaces a major element of similar size. It was also claimed that where there is a difference in size the larger element (cation) is concentrated in later fractions of the mineral. Evidence is presented to show that this latter statement is not a general rule and has no theoretical or experimental basis. Camouflage may also occur where there is a valency difference, but again it cannot be predicted from valency and size alone, whether the minor element is concentrated or dispersed during magmatic crystallization.

Theory shows that where a minor element, e.g., Tl^{+1} replaces K^{+1} in the potash feldspars (continuous solid solutions assumed), then the M.P. of the hypothetical feldspar $TlAlSi_3O_8$ determines whether thallium is enriched or impoverished during crystallization. Melting-points have no direct relation to ionic size. Collected data on the M.P.s of end-members in binary solid solution series confirm that there is in fact no regular relation between M.P. and ionic size or charge of the cation. If conditions are assumed to be more complex than the simple binary solid solutions, ionic size and charge matter even less. Wickman's activation energies are of little assistance, because they are closely related to lattice-energies, which do not determine melting-points.

The camouflage, capture and admission principles were established on the basis of spectrographic data on minor element abundances. Review of the more recent literature shows again that these principles are incapable of general application. Where they seem to apply (e.g., Li and Mg, Tl and K) this must be regarded as coincidental. In conclusion, it is at present impossible to predict the behaviour of a minor element during magmatic evolution from ionic properties alone, beyond indicating generally where it will be camouflaged.

LEAD-URANIUM AGES OF SOME URANINITES FROM TRIASSIC AND JURASSIC SEDIMENTARY ROCKS OF THE COLORADO PLATEAU

L. R. STIEFF AND T. W. STERN
U. S. Geological Survey, Washington, D.C.

In the course of a study on the origin of the uranium deposits in the Triassic and Jurassic sedimentary rocks of the Colorado Plateau, 13 samples of uraninite from nine deposits were collected for Pb^{206}/U^{238} and Pb^{207}/U^{235} age determinations. These uraninites are believed to be the most reliable of more than 100 samples from the Plateau on which age determinations have been made. The 13 uraninites have a mean Pb^{206}/U^{238} age of approximately 70 million years when corrected only for common lead.

Chemical and mass spectrometric errors change the mean Pb^{206}/U^{238} age by approximately ±4 million years. Uncertainties resulting from the correction for common lead and from the possible presence of old radiogenic lead in the ores will decrease the mean Pb^{206}/U^{238} age by approximately 3 million years. Corrections for the selective loss of uranium will decrease the mean Pb^{206}/U^{238} age, whereas selective loss of daughter products will increase the mean Pb^{206}/U^{238} age by approximately 10 million years.

Holmes gives 130 and 160 million years as the close of the Jurassic and Triassic periods, respectively. If the ages calculated for the samples of uraninite are close to the true ages of the ores, then the uranium was introduced into the sedimentary rocks in late Mesozoic or early Tertiary time (60 to 70 million years ago). This conclusion differs markedly from conclusions based on other evidence that the uranium ores were formed in the Triassic and Jurassic sedimentary rocks of the Colorado Plateau during or soon after the deposition of the rocks.

PORPHYRY INTRUSIONS IN THE BEARTOOTH RANGE, NEAR RED LODGE, MONTANA

HELEN STOBBE
Smith College, Northampton, Massachusetts

Porphyry intrusions are exposed for a vertical distance of about 4,000 feet, at approximate elevations between 6,000 and 10,000 feet along the Red Lodge–Cooke City Highway into Yellowstone Park. As it is unusual to find such fresh and deeply cut exposures, the the present study has been begun to see if mineral or textural change occurs with depth. This may aid in understanding the method of intrusion or the relationship of the porphyry to the cover rock.

The porphyries form concordant sheets or sills, ranging from 50 to several hundred feet thick. Their attitude varies from almost horizontal to about 30° dip. Jointing is pronounced. Faulting occurred within the sheets, and some contacts with pre-Cambrian rocks are faults marked by gouge and mylonite zones.

The rock composition is quartz monzonite. The fine-grained ground mass is either brown, gray or light gray with phenocrysts of feldspar (abundant), quartz and hornblende. In the limited section studied along the highway and on Line Creek Plateau, the porphyries are in contact with pre-Cambrian granites, gneisses and amphibolites. The field survey shows no mineral or textural change in the rock with depth. A petrographic examination is in progress to see whether a variation occurs. The work also will be extended to examine porphyry bodies which have intruded sediments in nearby areas.

The porphyries examined are younger than the pre-Cambrian rocks. Similar porphyries in associated areas, which have intruded sediments, have been dated by others as late Cretaceous or very early Tertiary in age.

INTRUSION BRECCIAS OF MAJUBA HILL, NEVADA

RALPH H. THURSTON AND ALBERT F. TRITES, JR.
U. S. Geological Survey, Denver, Colorado

Majuba Hill, in the Antelope Range, Pershing County, Nevada, is a complex, roughly elliptical plug that has a maximum diameter of 5,000 feet. Shale, limestone, and sandstone of Triassic (?) age was first invaded by Tertiary (?) dikes and sills of andesite, dacite, latite, and diorite, and later by the plug of rhyolite prophyry, quartz porphyry, and porphyritic rhyolite.

Dikes and irregular bodies of breccias cut all rocks within the plug except the porphyritic rhyolite and cut the metamorphosed shales along the borders. More than 20 lithologic types of intrusion breccias are recognized. Rhyolite porphyry, quartz porphyry, or a mixture of quartz and tourmaline commonly forms the groundmass of the breccias; and copper, tin, and uranium minerals occur in the intrusion breccias that contain a matrix of quartz and tourmaline.

The intrusion breccias are believed to have been formed by: (1) incorporation and incomplete assimilation along the edges of rhyolite porphyry and quartz porphyry dikes, (2) autobrecciation of rhyolite porphyry and quartz porphyry dikes and masses as they were injected into the plug, and (3) minor explosive action resulting from the rapid release of gases emanating from the magma.

MASS SPECTROMETRIC DETERMINATION OF THORIUM

G. R. Tilton, Claire Patterson, and M. G. Inghram
Dept. of Terrestrial Magnetism, Carnegie Inst. of Washington; University of Chicago, Chicago, Ill.; Argonne National Laboratory

Thorium possessing a Th^{230} to Th^{232} ratio of four has been isolated in milligram amounts from a Colorado Plateau uranium ore. This carrier has been used in conjunction with a mass spectrometer equipped with an electron multiplier which permitted isotopic analysis of amounts of thorium as low as one microgram. Under these conditions it was possible to determine 0.01 microgram of thorium with an accuracy of $\pm 10\%$ and amounts of 0.1 microgram or more to $\pm 1\%$.

The method has been applied to zircon in a granite from the Haliburton Area of the Canadian Shield. Three analyses of separate powder fractions gave results of 2012, 2033 and 2058 parts per million of thorium with an analytical error of $\pm 1\%$ for each determination.

On the basis of previously determined uranium and lead data the age of the mineral is believed to be 1050 ± 20 million years. The newly calculated thorium-lead age is 420 ± 10 million years. A sufficient number of uranium, thorium and lead analyses have been made to establish that the sampling was representative. Since the zircon has metamict and unaltered zones the data may be explained by an accumulation of thorium relative to uranium in the metamict phase, which could allow Pb^{208} to be lost more easily than Pb^{206} or Pb^{207}. Further investigation of the problem is under way.

THERMAL TRANSFORMATIONS IN SOME LAYER SILICATE MINERALS

EDWIN W. TOOKER
University of Illinois, Urbana, Illinois

Single crystals of muscovite, biotite, and chlorite and sedimented flakes of illite were subjected to progressive, stepwise heat treatment by two methods: (1) conventional air quench procedure, and (2) high temperature method with furnace mounted on an *x*-ray spectrometer. Comparisons of the *x*-ray data indicate marked differences in the high temperature region (800–1100° C.) depending on variations in experimental procedure, particle size, and perhaps other factors. The high temperature furnace procedure was found to be the more rapid and accurate method.

Visual images of the structure (electron density along *c*-axis) were calculated by Fourier syntheses. The close relationship between the specific layer structure, the amount of dehydration, the gradation (or lack of it) to an anhydride, and the early appearance of new phases were observed.

Precise evaluation of thermal transformations requires careful consideration of the time factor with respect to particle size and degree of crystallinity, approach to equilibrium, and decomposition temperature.

SIGNIFICANCE OF THE VARIATION IN NORMATIVE vs. MODAL FELDSPAR OF GRANITES

O. F. TUTTLE
Geophysical Laboratory, Washington, D. C.

Granites having identical normative amounts of "plagioclase" and "orthoclase" may contain equivalent quantities of these constituents or they may consist of "one" feldspar (perthite) and quartz. Modal analyses of a series of specimens collected along the contacts of tertiary granites from the Island of Skye, Scotland, show a variation in modal plagioclase from 0 to 20 per cent. Chemical analyses of the granites indicate that the normative feldspar composition is approximately 30 per cent "plagioclase" and 30 per cent "orthoclase." Such variations in modal feldspar suggest, (1) that the granites crystallized at different temperatures, or, (2) that the plagioclase unmixed from the potash-bearing feldspar subsequent to primary crystallization. Evidence will be presented for and against each of these possibilities.

PETROLOGY OF THE JUDITH MOUNTAINS, MONTANA

STEWART R. WALLACE
University of Michigan, Ann Arbor, Michigan

The Judith Mountains are a group of Tertiary porphyry stocks and related intrusives that have domed and cut a thick series of sedimentary rocks ranging in age from Cambrian to Upper Cretaceous. Quartz monzonite intrusions mark the beginning of intrusive activity and form the major stocks in all parts of the mountains. Later igneous rocks represent two lines of descent: (1) more siliceous types exemplified by rhyolite, (2) rocks relatively poor in silica and high in the alkalies, best exemplified by tinguaite. The youngest rock in the area, the alkali granite porphyry of Judith Peak, is rich in both silica and the alkalies, and is believed to represent a union of the two separate lineages.

The area is bisected by a strong but irregular east-west fault that divides the mountains into two structural units, each with a distinct assemblage of igneous rocks. The southern unit is characterized by calc-alkaline rocks containing perhaps 50 per cent of highly siliceous rocks, i.e., the rhyolites. The northern unit is characterized by both calc-alkaline and alkaline rocks. Only a small percentage, probably less than 1 per cent, of the calc-alkaline rocks is rich in silica.

Pre-intrusive structural and erosional events have influenced the mechanism of emplacement of the initial quartz monzonite intrusions. Detailed mapping shows large-scale magmatic sloping of the Madison limestone north of the strong east-west fault but not south of it. This suggests that limestone syntexis has desilicated the magma at depth to yield tinguaites, according to Daly's hypothesis. The alkali granite is believed to represent a late siliceous differentiate of the calc-alkaline series, contaminated by alkaline fluids generated by resurgent carbon dioxide released from the assimilated limestone.

MINERALOGIC STUDIES ON THE COLORADO PLATEAU

ALICE DOWSE WEEKS
U. S. Geological Survey, Washington, D.C.

The primary studies on the mineralogy of the Colorado Plateau, such as the establishment of standards for *x*-ray identification of uranium and associated minerals, techniques for separating and studying radioactive minerals, and acquaintance with Colorado Plateau minerals and mineral assemblages, have reached the stage where the mineralogic study of the Plateau uranium ores is progressing rapidly. About 20 uranium minerals and several uranium-bearing minerals or organic materials have been identified, as well as many associated minerals. The principal uranium minerals are uraninite and pitch-blende, hydrous oxides, carbonates, sulfates, phosphates, arsenates, vanadates, and silicates. The chief metals associated with the uranium are vanadium and/or copper. The minor metals are lead, zinc, cobalt, nickel, manganese, silver, molybdenum, gold, arsenic, and selenium. Hummerite and montroseite, two new vanadium minerals, have been described. A possible new uranium mineral and several other possible new vanadium minerals are being investigated.

Recent work suggests that carnotite ore is restricted to near-surface deposits in the zone of oxidation. Black uranium-vanadium ore occurs in scattered surface deposits and in the few deep deposits so far known in western Colorado. It is less oxidized and contains more sulfides than the carnotite ore. Present study of several new minerals from the black ore is concerned with the paragenesis of the uranium-vanadium ores. The minerals of areas containing copper, of which the White Canyon district, San Juan County, Utah, has been most thoroughly studied, are uraninite, copper and iron sulfides (with minor amounts of galena), sphalerite, cobalt and nickel minerals, and many secondary hydrous oxides, carbonates, and sulfates of uranium and other metals. Altered wall rock in the White Canyon district contains jarosite, alunite, kaolinite, allophane, and gibbsite.

FLUID INCLUSIONS IN CERTAIN MINERALS FROM THE ZONED PEGMATITES OF THE BLACK HILLS, SOUTH DAKOTA, AND THEIR SIGNIFICANCE

PAUL L. WEIS
University of Virginia, Charlottesville, Virginia

A study of fluid inclusions in minerals from zoned pegmatites was undertaken as a check on the theory of zonal development through fractional crystallization in a restricted system. Beryl, spodumene and garnet gave results that showed general agreement; the most extensive results were obtained from beryl.

Temperature determinations were made by heating polished mineral sections under the microscope and recording the temperature of disappearance of the vapor phases of the fluid inclusions.

Beryl from outer zones of the Highland Lode and Bob Ingersoll No. 1 pegmatites yielded higher temperatures than beryl from inner zones. Results from the Peerless and Bob Ingersoll No. 2 pegmatites were inconclusive or contradictory. No other pegmatites yielded enough data to allow establishment of any temperature trends.

Temperatures observed in beryl ranged from 216° to 515° C. Results from individual crystals showed a range of 9° to nearly 200° C., and individual zones gave ranges of 65° to 230° C.

Data were too meager to permit presentation of conclusions, but results give tentative support to the hypothesis of fractional crystallization. Estimates of pressures prevalent at the time of crystallization imply temperatures of crystallization in excess of 800° C. for a few of the early-forming beryl crystals.

PRACTICAL NOTATION AND ARRANGEMENT OF THE CRYSTAL CLASSES

C. D. WEST
Polaroid Corporation, Cambridge, Massachusetts

The notations and arrangements of the 32 crystal classes adopted in current reference works can be criticised as inadequate in practical respects. They are not easy to remember, nor convenient to write and print, nor yet suited for consideration of macroscopic physical properties. We show a notation for the classes, based on modified international symbols for 13 kinds of macroscopic symmetry axes, and put into a 4 by 12 tabular arrangement, which we have found to be more practical in several respects. Some physical properties of interest in crystallography include for both isotropic and monocrystalline solids the following:

Voigt—Bhagavantam	Jahn	Constants	Examples
	Centric Phenomena		
vector-vector	$[V^2]$	16	Dielectric susceptibility, crystal optics, etc.
scalar-tensor	$[V^2]$	1–6	Thermal expansion.
tensor-tensor	$[[V^2]^2]$	2–21	Elasticity.
tensor-tensor	$[[V^2]^2]$	2–36	Photoelasticity.
	Acentric Phenomena		
scalar-vector	V	1–3	Hydrostatic piezoelectricity, etc.
pseudoscalar-tensor	$E[V^2]$	1–6	Optical rotation.
vector-tensor	$V[V^2]$	1–18	Piezoelectricity, electro-optics.

THREE-DIMENSIONAL PICTURE OF STEAMBOAT SPRINGS, NEVADA

DONALD E. WHITE
Carson City, Nevada

Diamond drilling by the Geological Survey has added immeasurably to an understanding of the structure, mineral deposition, rock alteration, temperature relations, and migration of water at Steamboat Springs.

The thermal history is long and involved, perhaps extending throughout Quaternary time. The dominant structure appears to be a west-dipping thrust fault, with springs emerging from east-dipping normal faults in the hanging wall of the thrust.

Six drill holes 400 to 686 feet deep indicate a maximum or near-maximum temperature for each hole at depths of 200 to 360 feet below water level; maximum temperatures are 318 to 342° F. At greater depths temperatures level off, or decrease slightly below main structures serving as channelways. The most satisfactory interpretation of these relations is: At considerably greater depths, a volcanic component (probably steam with dissolved substances) and meteoric water mix with proportions and temperatures such that a single liquid phase results, with a temperature probably little above 342° F. This water rises with minor loss of temperature by conduction, except on margins of the thermal area, until it is within several hundred feet of the surface. With further rise and decrease of pressure, a vapor phase forms. The high near-surface geothermal gradient is largely due to boiling. Dissolved gases tend to lower the boiling range below that of pure water, whereas dissolved solids have an opposite effect.

Near the surface some meteoric water mixes with thermal water on margins of the area. Hydrodynamic head and density, which is a function of temperature, are controlling factors.

SUTTER BUTTES RESTUDIED

HOWELL WILLIAMS AND GARNISS CURTIS
University of California, Berkeley, California

Since the work of Williams on the Marysville Buttes (1929—now officially called Sutter Buttes) evidence has been found modifying some of the ideas then expressed concerning their evolution.

It is no longer believed that they are a denuded laccolith, result of a single andesite intrusion, but a complex of andesite intrusions of at least three different ages which form a stock-like core 4 miles in diameter. Rhyolite plugs surrounding this core are not the last intrusive phase, though they are later than some of the andesite intrusions. Rhyolite tuff, however, found at the base of associated volcanic sediments surrounding the central core, marked the initial explosive phase and was erupted before appreciable deformation of pre-volcanic sedimentary rocks had occurred. The buttes themselves are andesite plugs of later age than the rhyolite plugs and probably later than the central vent-tuff, formerly thought to have been the final phase of activity. They protruded through earlier intrusions and sedimentary cover to form great spines from which originated the youngest, very coarse lahars. Andesite block-lava flows, originating at vents in the peripheral sedimentary ring, closed the volcanic epoch.

The slow accretion of the central core caused progressive deformation of pre-volcanic and volcanic sedimentary beds, resulting in an unconformity which transgresses all but the final deposits of volcanic debris.

PSEUDOSYMMETRY AND ATOMIC PATTERNS OF CRYSTALS

DOROTHY WRINCH
Smith College, Northampton, Massachusetts

One set of cases in which it can be demonstrated that the pseudosymmetry of a crystal of known composition provides a pointer to the general nature of the atomic pattern is exemplified by orthorhombic staurolite $H_2FeAl_4Si_2O_{12}$, for which $a:b:c=0.4734:1:0.3414 \sim\sqrt{2}:3:1=2:3\sqrt{2}:\sqrt{2}$. Here the companion cell (with vertices actually on a cubic lattice) has displacements z[002], s[330], s′[$\bar{1}$10] and volume 12, all in the scale of some metric k in the range $a/2$, $b/3\sqrt{2}$, $c/\sqrt{2}$. Another set is exemplified by orthorhombic chrysoberyl $BeAl_2O_4$ for which $a:b:c=0.470:1:0.580\sim\sqrt{2}:3:\sqrt{3}=\frac{2}{3}\sqrt{3}:\sqrt{6}:\sqrt{2}$, with the corresponding displacements $\frac{2}{3}$t[111], r[11$\bar{2}$], s[$\bar{1}$10] and volume 4, in the scale of a metric k in the range $\frac{1}{2}a\sqrt{3}$, $b/\sqrt{6}$, $c/\sqrt{2}$. Two interesting conclusions follow. (1) For staurolite, $12k^3$ provides $48=12\times4$ close-packed sites, suggesting that $Z=4$: for chrysoberyl, $4k^3$ provides $16=4\times4$ such sites, suggesting that here too $Z=4$. (2) That the close-packed sites for staurolite are cubic (i.e. fcc) is shown by the z, s, s′ displacements of the companion cell, since the required symmetry elements for this orthorhombic crystal associated with each of these directions (2, m, or 2/m) lie within the cubic system. On the other hand, such symmetry elements associated with r and t displacements do not lie within the cubic system. We infer from the r, s, t nature of the displacements for chrysoberyl that the close-packed sites in this crystal are of double cubic, not of cubic type.

DIOPSIDE-WATER SYSTEM

HATTEN S. YODER, JR.
Geophysical Laboratory, Washington, D.C.

The diopside-water system has been investigated up to 6500 bars by means of sealed platinum tubes held in an internally heated, high-pressure vessel. The melting point of diopside is lowered from 1391°C. at atmospheric pressure to 1289° C. at the maximum pressure of water vapor applied. This lowering is considerably less than the measured lowering(∼400°) of the melting point of albite under the same vapor pressure of water.

It was not feasible to quench the melt to a glass under the conditions of most of the experiments, hence a quantitative measure of the water content of the liquid could not be obtained. However, the preliminary experiments support the view that a basaltic magma contains much less water than a granitic magma.

LIST OF FORMER OFFICERS AND MEETING PLACES

By recommendation of the Council, a complete list of past officers is printed in the proceedings of the annual meeting of the Society:

	Presidents	Vice-Presidents
1920	Edward H. Kraus	Thomas L. Walker
1921	Charles Palache	Waldemar T. Schaller
1922	Thomas L. Walker	Frederick A. Canfield
1923	Edgar T. Wherry	George F. Kunz
1924	Henry S. Washington	Washington A. Roebling
1925	Arthur S. Eakle	Herbert P. Whitlock
1926	Waldemar T. Schaller	George Vaux, Jr.
1927	Austin F. Rogers	George L. English
1928	Esper S. Larsen	Lazard Cahn
1929	Arthur L. Parsons	Edward Wigglesworth
1930	Herbert E. Merwin	John E. Wolff
1931	Alexander H. Phillips	William F. Foshag
1932	Alexander N. Winchell	Joseph L. Gillson
1933	Herbert P. Whitlock	Frank N. Guild
1934	John E. Wolff	William A. Tarr
1935	Clarence S. Ross	Ellis Thomson
1936	William S. Bayley	Harold L. Alling
1937	Norman L. Bowen	H. V. Ellsworth
1938	Ellis Thomson	Kenneth K. Landes
1939	Max N. Short	Burnham S. Colburn
1940	William F. Foshag	Ian Campbell
1941	Frederick E. Wright	William J. McCaughey
1942	Arthur F. Buddington	Martin J. Buerger
1943	John F. Schairer	John W. Gruner
1944	W. C. Emmons	Harry Berman
1945	Kenneth K. Landes	George Tunell
1946	Paul F. Kerr	S. B. Hendricks
1947	M. J. Buerger	Carl Tolman
1948	M. A. Peacock	Adolf Pabst
1949	John W. Gruner	J. D. H. Donnay
1950	George Tunell	Ralph E. Grim
1951	A. Pabst	Michael Fleischer
1952	Michael Fleischer	J. D. H. Donnay

	Secretaries
1920–1922	Herbert P. Whitlock
1923–1933	Frank R. Van Horn
1933–1934	Albert B. Peck
1934–1944	Paul F. Kerr
1944–	C. S. Hurlbut, Jr.

	Treasurers
1920–1923	Albert B. Peck
1924–1929	Alexander H. Phillips
1929–1930	Albert B. Peck
1931–1940	Waldemar T. Schaller
1941–	Earl Ingerson

	Editors
1920–1921	Edgar T. Wherry
1922–	Walter F. Hunt

Councilors

1920 Arthur S. Eakle, Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips.
1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.
1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.
1923 Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.
1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.
1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.
1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.
1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.
1928 William F. Foshag, William A. Tarr, Alexander N. Winchell, Ellis Thomson.
1929 William A. Tarr, Alexander N. Winchell, Ellis Thomson, Clarence S. Ross.
1930 Alexander N. Winchell, Ellis Thomson, Clarence S. Ross, Paul F. Kerr.
1931 Ellis Thomson, Clarence S. Ross, Paul F. Kerr, William S. Bayley.
1932 Clarence S. Ross, Paul F. Kerr, William S. Bayley, William J. McCaughey.
1933 Paul F. Kerr, William S. Bayley, William J. McCaughey, Kenneth K. Landes.
1934 William S. Bayley, William J. McCaughey, Kenneth K. Landes, E. P. Henderson.
1935 William J. McCaughey, Kenneth K. Landes, E. P. Henderson, J. F. Schairer.
1936 Kenneth K. Landes, E. P. Henderson, J. F. Schairer, Arthur F. Buddington.
1937 E. P. Henderson, J. F. Schairer, Arthur F. Buddington, Arthur P. Honess.
1938 J. F. Schairer, Arthur F. Buddington, Arthur P. Honess, R. C. Emmons.
1939 Arthur F. Buddington, Arthur P. Honess, R. C. Emmons, Carl Tolman.
1940 Arthur P. Honess, R. C. Emmons, Carl Tolman, D. Jerome Fisher.
1941 R. C. Emmons, Carl Tolman, D. Jerome Fisher, Martin A. Peacock.
1942 Carl Tolman, D. Jerome Fisher, Martin A. Peacock, Adolf Pabst.
1943 D. Jerome Fisher, Martin A. Peacock, Adolf Pabst, C. S. Hurlbut, Jr.
1944 Martin A. Peacock, Adolf Pabst, Michael Fleischer, S. J. Shand.
1945 Adolf Pabst, Michael Fleischer, S. J. Shand, R. E. Grim.
1946 Michael Fleischer, S. J. Shand, R. E. Grim, Joseph Murdoch.
1947 S. J. Shand, R. E. Grim, Joseph Murdoch, H. H. Hess.
1948 R. E. Grim, Joseph Murdoch, H. H. Hess, Clifford Frondel.
1949 Joseph Murdoch, H. H. Hess, Clifford Frondel, Lewis S. Ramsdell.
1950 H. H. Hess, Clifford Frondel, Lewis S. Ramsdell, E. F. Osborn.
1951 Clifford Frondel, Lewis S. Ramsdell, E. F. Osborn, George T. Faust.
1952 Lewis S. Ramsdell, E. F. Osborn, George T. Faust, Victor T. Allen.

Annual Meeting Places

1920 Chicago, Illinois
1921 Amherst, Massachusetts
1922 Ann Arbor, Michigan
1923 Washington, D. C.
1924 Ithaca, New York
1925 New Haven, Connecticut
1926 Madison, Wisconsin
1927 Cleveland, Ohio
1928 New York, N. Y.
1929 Washington, D. C.
1930 Toronto, Canada
1931 Tulsa, Oklahoma
1932 Cambridge, Massachusetts
1933 Chicago, Illinois
1934 Rochester, New York
1935 New York, N. Y.
1936 Cincinnati, Ohio
1937 Washington, D. C.
1938 New York, N. Y.
1939 Minneapolis, Minnesota
1940 Austin, Texas
1941 Boston, Massachusetts
1942 No meeting held
1943 No meeting held
1944 No meeting held
1945 Pittsburgh, Pennsylvania

1946 Chicago, Illinois
1947 Ottawa, Canada
1948 New York, N. Y.
1949 El Paso, Texas
1950 Washington, D. C.
1951 Detroit, Michigan
1952 Boston, Mass.

RECIPIENTS OF THE ROEBLING MEDAL

Charles Palache, December 1937
Waldemar T. Schaller, December 1938
Leonard James Spencer, December 1940
Esper S. Larsen, Jr., December 1941
Edward H. Kraus, February 1945
Clarence S. Ross, December 1946
Paul Niggli, December 1947
William Lawrence Bragg, November 1948
Herbert E. Merwin, November 1949
Norman L. Bowen, November 1950
Fred E. Wright, November 1952

RECIPIENT OF THE MINERALOGICAL SOCIETY OF AMERICA AWARD

Orville Frank Tuttle, November 1951
Frederick H. Stewart, November 1952