

PROCEEDINGS OF THE THIRTY-FIFTH ANNUAL
MEETING OF THE MINERALOGICAL SOCIETY OF
AMERICA AT LOS ANGELES, CALIFORNIA

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

The thirty-fifth annual meeting of the Society held on November 1-3, 1954, at the Statler and Biltmore Hotels, Los Angeles, California, was attended by 185 fellows and members. Six scientific sessions were held, at which 63 papers were presented orally and 8 by title.

The annual luncheon of the Society held at the Biltmore Hotel on November 2d was attended by 152 fellows, members and guests. Following the luncheon the thirteenth presentation of the Roebling Medal was made to Cecil E. Tilley and the fourth presentation of the Mineralogical Society of America Award was made to Hatten S. Yoder, Jr.

Before the business meeting on the afternoon of November 2d the Society was addressed by the Retiring President, Sterling B. Hendricks, on *Polytypism and Screw Dislocation. An Appreciation of the Work on Crystal Growth of S. Amelinckx and W. Dekeyser*.

The 1954 Council of the Society met for seven hours on October 31st and discussed 25 items of business. The 1955 Council met for three hours on November 3d.

Of grave concern to the Council is the large backlog of manuscripts of papers held by the Editor to be published in *The American Mineralogist*. At the time of the meeting the Editor reported that he had on hand enough manuscripts for five issues of *The American Mineralogist* for 1955. With the May-June issue devoted to *Contributions to Canadian Mineralogy*, over a year elapses between the time of the receipt of a manuscript and the time of its publication. In order to have more space for scientific papers, the Council voted that beginning in 1956 the publication of abstracts of papers presented at the annual meeting will be discontinued. For the same reason the Council voted to publish the list of fellows and members only every other year.

During the past few years the Mineralogical Society of America has printed its own program for the annual meeting with abstracts of papers to be presented there. The general program printed by the Geological Society of America duplicates this material. As an economy measure, the Council voted to discontinue printing a separate program beginning in 1955 so that more money will be available for the publication of scientific papers. The program of the Geological Society of America will be sent to all fellows and members. The titles of papers presented at the annual meeting will be printed in the March-April issue of *The American Mineralogist* and reference will be given to the Bulletin of the Geological Society of America, where the abstracts may be found.

COMMITTEES OF THE MINERALOGICAL SOCIETY OF AMERICA FOR 1955

Financial Advisory Committee

E. P. Henderson, *Chairman* '54-'55
J. P. Marble '54-'55
R. E. Fuller '54-'56

Auditing Committee

H. F. McMurdie, *Chairman*
J. C. Rabbitt
C. L. Christ

Nominating Committee for Officers

W. T. Pecora, *Chairman*
V. T. Allen
A. Pabst
J. Gruner
J. S. Stevenson

Nominating Committee for Fellows

R. B. Ferguson, *Chairman* '55
 J. T. Lonsdale '55
 T. F. Bates '55-'56
 J. J. Runner '55-'56
 A. E. J. Engel '55-'57
 R. J. Holmes '55-'57

Roebling Medal Committee

L. G. Berry, *Chairman*
 G. Tunell
 M. Fleischer

Mineralogical Society of America Award Committee

H. W. Fairbairn, *Chairman*
 J. J. Glass
 R. H. Jahns
 T. S. Lovering
 D. McConnell

Nomenclature Committee

G. T. Faust, *Chairman* '55-'56
 A. L. Howland '55
 E. W. Nuffield '55
 G. Tunell '55-'56
 C. O. Hutton '55-'57
 E. E. Wahlstrom '55-'57

Publications Committee

O. F. Tuttle, *Chairman* '55-'56
 N. L. Bowen '55-'56
 A. Pabst '55
 F. A. Bannister '55
 L. S. Ramsdell '55-'57
 R. S. Cannon '55-'57

Board of Associate Editors

A. Pabst, *Chairman* '55
 E. F. Osborn '55
 Ian Campbell '55-'56
 Brian Mason '55-'56
 W. F. Bradley '55-'57
 F. J. Turner '55-'57

*Representatives**National Research Council*

J. D. H. Donnay

American Geological Institute

E. Ingerson '55
 A. Montgomery '55-'56

American Association for Advancement of Science

A. Knopf

REPORT OF THE SECRETARY

To the Council of the Mineralogical Society of America:

ELECTION OF OFFICERS AND FELLOWS

Four hundred and sixty-eight ballots were cast in the election of officers, 163 by fellows and 305 by members of the Society. The officers elected to serve in 1955 are:

President: Harry H. Hess, Princeton University, Princeton, New Jersey.

Vice-President: Clifford Frondel, Harvard University, Cambridge, Massachusetts.

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 (1955-58): Leonard G. Berry, Queen's University, Kingston, Ontario, Canada.

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

Stuart Olaf Agrell, Department of Mineralogy and Petrology, Cambridge, England.

Edgar H. Bailey, U. S. Geological Survey, Washington, D. C.

Robert M. Garrels, U. S. Geological Survey, Washington, D. C.

Hisashi Kuno, Tokyo University, Tokyo, Japan.

Fritz Laves, University of Chicago, Chicago, Illinois.

William Nunn Lipscomb, University of Minnesota, Minneapolis, Minnesota.

Charles Meyer, University of California, Berkeley, California.

John Drew Ridge, The Pennsylvania State College, State College, Pennsylvania.
 Edwin C. Roedder, University of Utah, Salt Lake City, Utah.
 Ogden Linne Tweto, U. S. Geological Survey, Denver, Colorado.

CHANGE IN THE CONSTITUTION

On the recent ballot, fellows were asked to vote on the following proposed change in Article III, Section 1 of the Constitution (deletions are indicated by brackets and additions by italics):

The officers of the Society shall be a president, a vice-president, a treasurer, a secretary, and an editor, who shall be elected annually. There shall be an executive council consisting of the above officers, the retiring president and [four] fellows at large, *two* to be elected each year for terms of [four] *three* years each.

This change was approved by a vote of 149 in the affirmative with 3 in the negative.

MEMBERSHIP STATISTICS

November 1, 1954

	1953	1954	Gain	Loss
Correspondents	4	4	0	0
Fellows	326	329	10	7
Members	857	931	149	75
Subscribers	856	934	136	58
	<u>2043</u>	<u>2198</u>	<u>295</u>	<u>140</u>

The above figures show a net gain of 3 fellows, 74 members and 78 subscribers. Considering the four groups together, there is a gain of 155, giving a total of 2198.

The Society lost through death four fellows: Lawson H. Bauer of the New Jersey Zinc Company, Franklin, New Jersey; Alton Gabriel of the Bureau of Mines, University, Alabama; A. C. Hawkins of Plainfield, New Jersey; and M. Vonsen of Petaluma, California.

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

REPORT OF THE TREASURER FOR 1954

To the Council of the Mineralogical Society of America:

Your Treasurer submits herewith his report for the fiscal year beginning August 1, 1953, and ending July 31, 1954.

RECEIPTS

Dues and subscriptions	\$ 9,121.51
Sale of back numbers	832.17
Authors' charges on reprints	2,251.86
Interest and dividends from endowment	4,484.60
Geological Society of America aid for printing the Journal	8,464.14
Advertising	1,353.69
Sale of Index, volumes 21-30	18.80
Sale of Index, volumes 1-20	5.80
Aid on expense of a long paper	270.00
National Science Foundation grant to aid printing a special issue	1,100.00
Contributions toward Ross-Schaller volume	627.84
	<u>\$28,530.41</u>
Cash on hand, August 1, 1953	7,076.27
	<u>\$35,606.68</u>

DISBURSEMENTS

Printing and distribution of the Journal (5 issues)	\$17,400.44
Printing and distribution of reprints	1,407.31
Honorariums to Editor, Secretary, and Treasurer	1,062.50
Clerical Assistance	767.76
Postage and express	336.02
Printing and stationery	364.55
Office supplies and equipment	268.25
Program and abstracts (1953)	681.85
Roebbling Medal	141.90
New securities purchased	952.00
Committee expenses	4.84
Expenses of officers to 1953 meetings	83.87
Safety deposit box	7.80
Refunds	47.07
Checks returned	27.48
Mineralogical Society of America Award certificate	7.50
Reprinting back issues in microtext	654.42
Pamphlet on mineralogy	30.25
Mineralogical Society of America luncheon	8.25
Dividend adjustment	7.88
Service charge on check25
	<u>\$25,062.10</u>
Cash on hand, July 31, 1954	10,544.58
	<u>\$35,606.68</u>

The endowment funds of the Society as of July 31, 1954, 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	<u>5,743.75</u>
	\$15,301.25

PREFERRED STOCKS

200 Southern California Edison, 4.88	\$5,250.00
100 Union Pacific, 4	4,570.25
60 Jones and Laughlin, A, 5	4,987.50
55 United States Steel, 7	6,946.20
50 Virginia Electric and Power, 5	5,942.50
10 Consolidated Edison, 5	<u>1,066.64</u>
	\$28,763.09

COMMON STOCKS

300 Potomac Electric Power	\$4,057.73
200 Greyhound Corporation	2,300.00
150 Spencer Kellogg	3,775.00
100 Columbus and Southern Ohio Electric	2,087.50
80 Kroger Co.	1,990.00
60 United Fruit	3,067.50
56 Standard Oil of New Jersey	1,444.84

60 American Telephone and Telegraph	8,195.32	
50 Chesapeake and Ohio	2,368.75	
50 Phelps Dodge	1,975.00	
40 Plymouth Cordage	2,050.00	
30 U. S. Playing Card	2,411.25	
24 Public Service Electric and Gas	728.30	
		\$36,451.29
		\$80,515.63
	Respectfully submitted, EARL INGERSON, <i>Treasurer</i>	

DANA FUND

No disbursements were made during the fiscal year.

Available balance, July 31, 1954		\$99.13
	Respectfully submitted, EARL INGERSON, <i>Treasurer</i>	

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 year beginning August 1, 1953, and ending July 31, 1954. 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,
WILLIAM L. HILL
HOWARD F. MCMURDIE
J. J. FAHEY, *Chairman*

REPORT OF THE EDITOR FOR 1954

To the Council of the Mineralogical Society of America:

In presenting an editorial report for 1954 at this time, the same general procedure will be followed as in previous years. With five issues published and distributed and the November-December issue in galley form, sufficient data are now available to give a reasonably accurate general survey of the year's activity. When the editor's report appears in print in the March-April issue certain details incomplete and not available at the present time will be included so that the final printed report in April can be compared directly with those given in previous years.

In general, it may be stated that the accomplishments represent what might be termed the work of a good normal year with a volume of approximately 1050 pages. While this volume in size does not equal the one of last year that contained the exceedingly large November-December number dedicated to Ross and Schaller, still the 1954 volume may be regarded a very creditable accomplishment as each issue averaged about 175 pages.

By Council action one issue (May-June number) was set aside for "Contributions to Canadian Mineralogy." This policy begun in 1949 was continued in 1954 under the able editorship of Dr. L. G. Berry of Queen's University, Kingston, Ontario, and sponsored by the Walker Mineralogical Club. In this number the guest editor assembled 16 interesting papers on varied mineralogical subjects and assumed responsibility for their selection and

in seeing these contributions through the press. Aside from this single issue no other number was earmarked for a specific purpose.

The current volume as indicated will run about 1050 pages and contain 70 leading articles. Thirty-four additional short papers, appearing under Notes and News, give an overall total of 104 published manuscripts for the year. These contributions were received from 125 authors associated with 61 different universities, research bureaus and technical laboratories. Twenty-six critical book reviews, four new minerals described in detail for the first time and eighty-eight abstracts of new mineral names are a few of the other items of special mineralogical interest. One colored plate was employed to display the true color of the new mineral callaghanite.

As in previous years our service during 1954 has extended far beyond our own borders. During the current year 33 manuscripts (out of 104) came from 10 countries: Australia, Brazil, Canada, Denmark, England, Japan, Holland, Scotland, South Africa and Switzerland. These foreign contributions, although highly desirable in extending the influence of the Society's publication in distant lands, naturally reduce the space available and delay publication of American contributions.

As in the past the Geological Society of America has continued and increased its liberal financial support toward defraying a substantial portion of the printing costs of the Journal. For this assistance the Society is indeed very grateful and expresses its deep appreciation.

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOLUME 39

Subjects	Articles	Pages	Per Cent of Total
Leading articles*			
Descriptive mineralogy and paragenesis	6		
Chemical mineralogy and geochemistry	21		
Structural crystallography	25		
Petrography	7		
Memorials	4		
Geometrical crystallography	2		
Miscellaneous	5		
	70	818	78.7
Shorter articles	34	81½	21.3
Notes and news	36	9½	
Proceedings of societies	5	85	
Book reviews	26	25½	
Abstracts of new mineral names	88	20½	
Total entries	259	1040	100.0
Illustrations	235		
Index, Title Page, Table of Contents		24	
Grand total		1064	

* Leading articles averaged 11.7 printed pages each.

Respectfully submitted,
WALTER F. HUNT, *Editor*

And finally a word as to the prospects for 1955. The January-February manuscripts containing 10 main articles and 5 shorter contributions are in the hands of the printer. In addition at the present writing there are on file 42 major and 24 shorter contributions, or a total of 66 papers aggregating about 900 typed pages; approximately enough for 4 issues, exclusive of the January-February number.

The accompanying Table 1 summarizes in more detail the distribution of subject matter in volume 39.

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:

HONORARY PRESIDENTS

Edward S. Dana 1925-1935
 Charles Palache 1949-1954
 Edward H. Kraus 1955-

PRESIDENTS

1920 Edward H. Kraus
 1921 Charles Palache
 1922 Thomas L. Walker
 1923 Edgar T. Wherry
 1924 Henry S. Washington
 1925 Arthur S. Eakle
 1926 Waldemar T. Schaller
 1927 Austin F. Rogers
 1928 Esper S. Larsen
 1929 Arthur L. Parsons
 1930 Herbert E. Merwin
 1931 Alexander H. Phillips
 1932 Alexander N. Winchell
 1933 Herbert P. Whitlock
 1934 John W. Wolff
 1935 Clarence S. Ross
 1936 William S. Bayley
 1937 Norman L. Bowen
 1938 Ellis Thomson
 1939 Max N. Short
 1940 William F. Foshag
 1941 Frederick E. Wright
 1942 Arthur F. Buddington
 1943 John F. Schairer
 1944 R. C. Emmons
 1945 Kenneth K. Landes
 1946 Paul F. Kerr
 1947 M. J. Buerger
 1948 M. A. Peacock
 1949 John W. Gruner
 1950 George Tunell

1951 A. Pabst
 1952 Michael Fleischer
 1953 J. D. H. Donnay
 1954 Sterling B. Hendricks

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.

VICE-PRESIDENTS

1920 Thomas L. Walker
 1921 Waldemar T. Schaller
 1922 Frederick A. Canfield
 1923 George F. Kunz
 1924 Washington A. Roebbling
 1925 Herbert P. Whitlock
 1926 George Vaux, Jr.
 1927 George L. English
 1928 Lazard Cahn
 1929 Edward Wigglesworth
 1930 John E. Wolff
 1931 William F. Foshag
 1932 Joseph L. Gillson
 1933 Frank B. Guild
 1934 William A. Tarr
 1935 Ellis Thomson
 1936 Harold L. Alling
 1937 H. V. Ellsworth
 1938 Kenneth K. Landes

1939 Burnham S. Colburn
 1940 Ian Campbell
 1941 William J. McCaughey
 1942 Martin J. Buerger
 1943 John W. Gruner
 1944 Harry Berman
 1945 George Tunell
 1946 S. B. Hendricks
 1947 Carl Tolman
 1948 Adolf Pabst
 1949 J. D. H. Donnay
 1950 Ralph E. Grim

1951 Michael Fleischer
 1952 J. D. H. Donnay
 1953 Sterling B. Hendricks
 1954 Harry H. Hess

TREASURERS

1920-1923 Albert B. Peck
 1924-1929 Alexander H. Phillips
 1929-1930 Albert B. Peck
 1930-1940 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

- 1953 E. F. Osborn, George T. Faust, Victor T. Allen, C. Osborne Hutton.
 1954 George T. Faust, Victor T. Allen, C. Osborne Hutton, Felix Chayes

ANNUAL MEETING PLACES

- | | |
|-------------------------------|-------------------------------|
| 1920 Chicago, Illinois | 1938 New York, N. Y. |
| 1921 Amherst, Massachusetts | 1939 Minneapolis, Minnesota |
| 1922 Ann Arbor, Michigan | 1940 Austin, Texas |
| 1923 Washington, D. C. | 1941 Boston, Massachusetts |
| 1924 Ithaca, New York | 1942 No meeting held |
| 1925 New Haven, Connecticut | 1943 No meeting held |
| 1926 Madison, Wisconsin | 1944 No meeting held |
| 1927 Cleveland, Ohio | 1945 Pittsburgh, Pennsylvania |
| 1928 New York, N. Y. | 1946 Chicago, Illinois |
| 1929 Washington, D. C. | 1947 Ottawa, Canada |
| 1930 Toronto, Canada | 1948 New York, N. Y. |
| 1931 Tulsa, Oklahoma | 1949 El Paso, Texas |
| 1932 Cambridge, Massachusetts | 1950 Washington, D. C. |
| 1933 Chicago, Illinois | 1951 Detroit, Michigan |
| 1934 Rochester, New York | 1952 Boston, Mass. |
| 1935 New York, N. Y. | 1953 Toronto, Canada |
| 1936 Cincinnati, Ohio | 1954 Los Angeles, California |
| 1937 Washington, D. C. | |

RECIPIENTS OF THE ROEBLING MEDAL

- | | |
|--------------------------------------|---------------------------------------|
| Charles Palache, December 1937 | William Lawrence Bragg, November 1948 |
| Waldemar T. Schaller, December 1938 | Herbert E. Merwin, November 1949 |
| Leonard James Spencer, December 1940 | Norman L. Bowen, November 1950 |
| Esper S. Larsen, Jr., December 1941 | Fred E. Wright, November 1952 |
| Edward H. Kraus, February 1945 | William F. Foshag, November 1953 |
| Clarence S. Ross, December 1946 | Cecil Edgar Tilley, November 1954 |
| Paul Niggli, December 1947 | |

RECIPIENTS OF THE MINERALOGICAL SOCIETY OF AMERICA AWARD

- | | |
|-------------------------------------|-------------------------------------|
| Orville Frank Tuttle, November 1951 | L. H. Ahrens, November 1953 |
| Frederick H. Stewart, November 1952 | Hatten S. Yoder, Jr., November 1954 |

ABSTRACTS OF PAPERS PRESENTED AT THE THIRTY-FIFTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA, NOVEMBER 1-3, 1954

URANIUM IN APATITE*

Z. S. ALTSCHULER, R. S. CLARKE, JR., AND E. J. YOUNG
U. S. Geological Survey, Washington, D. C.

Apatite contains only traces of uranium, yet as apatite is a minor constituent in most rocks and the major constituent of a few very large deposits it accounts, paradoxically, for both dispersal and concentration of uranium in nature.

Uranium is typically 0.00X per cent of primary igneous apatite and 0.00X to 0.01X per cent of sedimentary marine apatite. End-stage igneous apatite may contain 0.0X per cent uranium. Analogously, marine reworked apatite becomes enriched in uranium from 0.00X to 0.0X per cent. This is demonstrated by the greater uranium contents of the texturally more complex phases within a single deposit.

Uranium can be secondarily leached from or introduced into apatite by ground water. These secondary changes are indicated by the existence of pronounced concentration gradients within single pebbles of apatite as well as by the redistribution of uranium among different mineral hosts in leached and altered sections of phosphorite.

It is proposed that uranium replaces calcium in the apatite structure. This is signified by several lines of investigation. Uranium and calcium contents parallel one another in sections of leached and altered phosphorite. Ionic radii of tetravalent uranium (1.05 Å) and divalent calcium (1.06 Å) are virtually identical, and most of the uranium in igneous, sedimentary, and bone apatite is found to be tetravalent. Petrographic and chemical analyses and nuclear emulsion studies have shown that uranium in apatite is disseminated rather than locally concentrated. In addition, phosphate deposits are essentially devoid of uranium minerals.

OCCURRENCE OF CHARNOCKITE SERIES IN BUNGER LAKE AREA, ANTARCTICA

E. T. APFEL AND W. T. HUANG

Syracuse University, Syracuse, New York, and
University of Oklahoma, Norman, Oklahoma

The Bunger Lake area lying between 66°7' S. latitude and 100°56' E. longitude [of the Antarctica] covers approximately 30 by 15 miles.

The rocks collected represent a wide variety of Precambrian igneous and metamorphic types. The outstanding ones are represented by the charnockite series. The acid and intermediate members of the series consist of erratics which have no clear relation with the basic member. The basic member is found at the northern end of the area. Its geologic setting is known.

The charnockite series is represented by hypersthene granite, hypersthene tonalite, and members designated as norite and noritic charnockite, respectively. Contamination of some basic charnockites by granitic emanations provides a clue to the origin of the erratics, in which hypersthene may have been derived from the basic charnockites.

The mineralogical features of petrogenic significance are: (1) the paucity of water in the charnockites is indicated by mineral species, (2) an increase in the FeO/MgO ratio as evidenced by the character of the hypersthene in the more acid charnockite is in accord with

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

the trend of crystallization in mafic magmas, (3) strong development of microperthites and myrmekite, (4) garnet occurs in hypersthene granite while augite is confined to noritic charnockites.

In view of the similarity of occurrence, mineralogy, chemical characters, and textural features of the Bungler Lake charnockites to those of other Antarctic charnockites, it appears that these rocks were originally a differentiated series of basic igneous intrusions, and have subsequently undergone metamorphism during a period of granitization. The discovery of the charnockites in this area has added a fourth distinct province to Antarctica.

PARTICLE SIZES OF CLAY MINERALS BY SMALL-ANGLE X-RAY SCATTERING

RONALD J. ARNOTT

The Texas Company Research Laboratory, Bellaire, Texas

A review of the present methods of particle size determination of clay minerals indicates that none are entirely adequate. Electron microscopy has provided the first reliable measure of clay sizes but gives poor results with montmorillonite and illite. This paper describes an investigation of small-angle x-ray scattering as a possible technique in the study of clay minerals. The interpretation used is that of Shull and Roess involving a graphical comparison of experimental scattering curves with theoretical scattering curves. In theory, both the distribution of particle sizes and the shape of the particles should be obtainable, but in practice outside evidence of the shape is required.

A two-crystal spectrometer was used to collect data for two carbon black samples and twenty-eight clay samples. The carbon blacks and most of the clays gave scattering curves from which particle size information could be extracted. The scattering curves for the halloysites and attapulgites could not be interpreted, probably because of their fibrous or tubular character. Of five purified samples of illite and montmorillonite, four gave uninterpretable scattering curves, possibly due to extreme orientation during treatment. Because of the scarcity of similar data in the literature it is difficult to verify the particle size information derived. However, it is believed that the small-angle x-ray scattering technique will fill the need for a relatively simple method of determining clay sizes.

MINERALOGY AND PETROGRAPHY OF THE CHATTANOOGA SHALE

T. F. BATES, E. O. STRAHL, N. M. SHORT, E. N. SILVERMAN, AND E. CAMILLI

Pennsylvania State University, State College, Pennsylvania

Detailed mineralogical and petrographic analysis of a drill core of the Chattanooga formation has resulted in a clearer picture of the relationship of uranium with the composition and texture of the black shale from the Highland Rim area of Tennessee.

Thin-section point counts, alpha-track counts and quantitative mineralogical and chemical analyses of sixty samples from thirty-five feet of core have yielded statistically significant correlations between uranium and some of the shale constituents. The correlation is positive with respect to "blackness" of the sample, total carbon, pyrite, and total sulfur, and negative with quartz, feldspar and clay and with Fe_2O_3 . The absence of high correlation coefficients indicates that the uranium is not specific to any single constituent that was measured. On the other hand certain relationships between uranium content and composition are apparent.

The upper member of the formation is darkest in color, shows the least mineralogical and petrographic variation and contains the highest concentration of uranium. The four lower members are more heterogeneous and consist of alternating gray and black beds. The gray beds are finer in grain size and contain more quartz, feldspar, and clay and less pyrite and organic matter than the black layers.

Autoradiographic studies demonstrate that the alpha particle source material is localized about concentrations of organic matter and pyrite.

X-RAY IDENTIFICATION OF CHLORITE SPECIES

G. W. BRINDLEY AND F. G. GILLERY

The Pennsylvania State University, State College, Pennsylvania

The identification of chlorites by x -rays has advantages over other methods for fine grained and impure materials. Since all chlorites have the same general structural scheme, and since particular species differ only in chemical composition, it is essential to consider the finer details of the x -ray pattern in any attempt to identify species by x -ray data alone. The principal isomorphous replacements are Al for Si in tetrahedral positions and Fe, Al . . . for Mg in octahedral positions. Simplifying assumptions reduce the problem for most chlorites to the determination of (1) the proportion of octahedral sites occupied by Fe, (2) the proportion of tetrahedral sites occupied by Al; i.e., two parameters are involved and these can be determined by consideration of (1) the intensities of the basal reflections, (2) the basal spacing. The use of the b lattice parameter is considered inadvisable. Examples are given of the identification of three chlorites by the x -ray method prior to chemical analysis. Subsequent chemical analysis showed that the x -ray data had given a reasonably accurate estimate of their compositions. While most chlorites are trioctahedral minerals, there is the possibility that dioctahedral types and mixed di-tri types may exist. Their recognition from x -ray data is considered. Some precautions which are necessary when measuring and interpreting basal intensities with a counter spectrometer are discussed.

CARBON 14 AGE RESEARCH

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Recent developments at the Lamont Observatory have involved extension of the C^{14} age method to 45,000 years by the utilization of large volume acetylene proportional counters with consequent increase in precision for modern samples. New measurements of geological and archeological samples supply information on a number of current problems. The rate of rise in sea level in the Mississippi Delta region over the past 30-40,000 years has been studied by the aid of wood and shell material taken from cores. The rate appears to be about a foot per century. Both the Robson and Malaspina glaciers show evidence of advance followed by retreat during the past 500 years. Samples of peat from the James Bay area, Canada, suggest that the end of the continental glacier in that area occurred only some 3,000 years ago.

Fossil organic muck appears to give reliable ages which agree with wood in the same horizon. The first dates from the Neolithic archeological sites in southeastern China (HongKong area) indicate 3,000 years. The alleged Norse ship at Follins Pond, Mass., is found to be from the Colonial period. A layer of dirt several feet from the surface of one of the ice islands shows an apparent age of less than 500 years, indicating relatively rapid accumulation. A "sea biscuit" from the top of the Atlantic seamount shows an age of 12,000 years. These and other results will be interpreted in terms of their geological significance.

RELATIONSHIP BETWEEN DENSITY AND COMPOSITION IN THE COLUMBITE-TANTALITE SERIES

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A study was undertaken to determine if the Nb_2O_5/Ta_2O_5 ratio in members of the

columbite-tantalite series could be evaluated from the relationship of density to composition.

A number of samples in this series were analyzed by means of fluorescent *x*-ray spectrography. The samples were checked by *x*-ray diffraction on a wide range goniometer. Densities were measured with a precision of ± 0.02 by application of a double pycnometer technique.

The theoretical relationship between density and $\text{Nb}_2\text{O}_5/\text{Ta}_2\text{O}_5$ ratio indicates that density is a linear function of the *atomic* per cent Ta_2O_5 . The *x*-ray diffraction studies show a small decrease in unit cell size with increasing FeO/MnO ratio but independent of the $\text{Nb}_2\text{O}_5/\text{Ta}_2\text{O}_5$ ratio. The following equation was obtained:

$$\rho = (A + B \text{ atomic } \% \text{ Ta}_2\text{O}_5)(1 + C \text{ atomic } \% \text{ FeO})$$

in which A, B, and C are empirically determined constants.

It is concluded that application of the above expression permits evaluation of the $\text{Nb}_2\text{O}_5/\text{Ta}_2\text{O}_5$ ratio with an accuracy equal to that obtained by conventional chemical techniques.

CONTEMPORANEOUS SLUMPING AND SLIDING IN THE BANDED GABBROS OF THE ISLE OF SKYE, SCOTLAND

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Structures attributed to slumping and sliding of stratified crystal-mush occasionally affect gabbroic rocks at the heart of the Cuillin complex. The rocks are at differing horizons of a Skaergaard-type layered series that formed by the bottom accumulation of discrete crystals on inclined surfaces. The observed dip of undisturbed layers varies between 35° and 50° . Blocky xenoliths of layered gabbro have been emplaced by gravity-sliding over the sloping surface of the parent-layer, sometimes with the formation of a slide-breccia. Lack of disturbance in overlying layers indicates that sliding occurred whilst the host-layer was still accumulating. Fracturing and separation of blocks was generally confined to layers which possessed an igneous lamination. Accompanying massive-textured layers, formed of mush with a greater liquid content, have flowed rather than fractured. The variable fluidity of the interlayered mush seems to explain earlier erroneous views on the age-relations of the Cuillin banded gabbros. The preponderant stability of the unconsolidated material, which was often deposited on slopes excessively steep by subaqueous standards, is attributed chiefly to the high viscosity possessed by magma.

PRECISION DETERMINATION OF LATTICE CONSTANTS OF SINGLE CRYSTALS USING THE CONVENTIONAL WEISSENBERG CAMERA

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The well-known graphical extrapolation method of Bradley and Jay [*Proc. Phys. Soc.*, 44, 563 (1932)] is a very powerful means of obtaining precise lattice constants of crystals. However, to apply this method it is necessary that the spacing data derived from film measurements be relatively free from errors due to film shrinkage and incomplete knowledge of the camera radius. In the present method a powder pattern of finely divided, annealed silver is recorded on the Weissenberg pattern of the crystal under study. From measurements of the silver pattern a film constant as a function of 2θ is derived. This is used to convert linear measurements of the Weissenberg spots to the corresponding 2θ values. With a conventional Weissenberg camera and a relatively crude commercial measuring device a precision of lattice constant of 3 to 4 parts in 10,000 may be obtained routinely from a single crystal.

CRYSTAL STRUCTURE OF COLEMANITE, $\text{CaB}_3\text{O}_4(\text{OH}) \cdot \text{H}_2\text{O}$

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Colemanite is monoclinic $P2_1/a$, $a = 8.743 \pm 0.004$, $b = 11.264 \pm 0.002$, $c = 6.102 \pm 0.003$ Å, $\beta = 110^\circ 07' \pm 05'$, $Z = 4$ [Christ, *Am. Mineral.*, 38, 411 (1953).]

From extensive 3-dimensional intensity data the phases of 944 observed structure amplitudes were calculated by the method of Hauptman and Karle (ACA Monograph #3, The Letter Press, Wilmington, Del., 1953). These results were used to calculate electron density sections over the xz plane at intervals along y of $1/60$, for $y = 0$ to $y = \frac{1}{2}$. Analysis of the electron-density sections shows that there are infinite boron-oxygen chains running parallel to the a -axis. The chain element has the composition $[\text{B}_3\text{O}_4(\text{OH})_3]^{-2}$ and consists of a BO_3 triangle and two BO_4 tetrahedra. The average B-O bond length in the tetrahedra is 1.4_3 and in the triangle is 1.3_7 Å. Ca^{++} has as nearest neighbors 5 oxygens and 1 water molecule at an average distance of 2.4_4 Å. The structure is being refined at the present time.

APPLICATION OF ELECTRON DIFFRACTION TO THE STUDY OF METAMICT MINERALS

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Metamict minerals, whose structures have been distorted by bombardment by the emanations from radioactive elements, yield poor or no x -ray diffraction patterns and optically are birefringent or isotropic. It has been found that at least some of these metamict minerals give sharp electron diffraction patterns. Apparently, sufficient relict crystallinity is retained so that the relatively short wavelength electrons ($\lambda = 0.055$ Å at 50 KV) will yield resolved patterns.

Electron diffraction studies have been started on various metamict minerals. Zoned zircon from Oklahoma was examined and both fresh and highly metamict portions of a given zircon yielded numerous diffraction rings. X-ray diffraction patterns of these same samples were sharp and with measurable lines in the case of fresh zircon, but they were poor and with no measurable lines in the case of the metamict zircon. Similarly, good electron diffraction patterns of metamict samarskite and polycrase have been obtained.

OPTICAL AND CHEMICAL STUDY OF JADEITE FROM CALIFORNIA

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The green to white jadeite from Clear Creek, San Benito County, California, described by Chesterman and Yoder, has been further investigated as part of a mineralogic and petrologic study of the New Idria district. The jadeite is found in small veins cutting albite-glaucophane-acmite schist and as larger lens-shaped pods within serpentine. The vein jadeite is associated with albite, analcime, natrolite, and thomsonite. Prehnite, hydrogrossular, thomsonite, and minor sphene are found associated with the jadeite pods. A chemical analysis, in per cent, shows the white vein material to be almost pure jadeite: SiO_2 59.38, Al_2O_3 25.82, FeO traces, Fe_2O_3 0.45, TiO_2 0.04, NnO nil, CaO 0.13, MgO 0.12, K_2O 0.02, Na_2O 13.40, $\text{H}_2\text{O} +$ 0.22, $\text{H}_2\text{O} -$ 0.16, Cr_2O_3 0.01, total 99.75. Optical data: $\alpha = 1.654$, $\beta = 1.657$, $\gamma = 1.666$, $\gamma - \alpha = 0.012$, $2V = 70^\circ \pm$, $Z \wedge c = 34^\circ$, $X = Z = Y$ colorless. Density: 3.43 ± 0.01 . Chemical analysis of the green jadeite shows that it carries about 10 per cent of the diopside molecule and 14 per cent of the acmite molecule. The mineral association suggests that the jadeite has formed under low temperature and pressure conditions, and that there are several possible modes of origin.

ISOTOPIC GEOCHEMISTRY OF THERMAL WATERS

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The relationships between volcanic and hot spring waters and local meteoric waters are being studied by "natural" isotopic tracer techniques utilizing both deuterium and oxygen 18. The isotopic "labelling" is provided by multiple stage fractional distillation processes over the oceans which produce large variations in the isotopic composition of meteoric waters in different regions of the earth. Thermal waters in areas of widely different surface water composition are then studied in detail for seasonal variations in isotopic and chemical composition.

The lightest thermal waters so far encountered occur at Yellowstone Park, while the heaviest occur in New Zealand; these differences are matched by the meteoric waters. The thermal waters in these localities differ in deuterium and oxygen 18 content by as much as 20% and 3% respectively, yet the isotopic relationships between surface waters, alkaline hot springs, and acid springs are the same in these and in areas of intermediate meteoric water composition. These relationships, correlated with experimental evidence, show that the acid hot springs in all areas examined are of secondary origin, derived from near-neutral and alkaline ground waters by non-equilibrium evaporation—condensation processes in which the waters become enriched in the heavy isotopes and in sulfuric acid. The alkaline springs are of direct meteoric origin; small amounts of juvenile or "recycled" water may be present and detailed studies are being made on the maximum percentages of these constituents.

CRYSTAL STRUCTURE OF SANBORNITE, BaSi_2O_6

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Sanbornite, previously described as triclinic, is apparently orthorhombic; space group $Pcmm$. The unit cell, $a=4.63$, $b=7.69$, $c=13.53 \text{ \AA}$, contains $4\text{BaSi}_2\text{O}_6$.

A structure with thirteen parameters has been found with the aid of Patterson and Fourier projections. It is a silicate sheet structure with two parallel, identical $\text{Si}_4\text{O}_{10}^{-4}$ sheets per unit cell lying in $x, y, \frac{1}{2}$ and $x, y, \frac{3}{4}$, and two Ba^{+2} lying roughly half way between each successive pair of sheets. Each $\text{Si}_4\text{O}_{10}^{-4}$ sheet may be regarded as made up of continuously linked, distorted six-membered rings of SiO_4 tetrahedra. The tetrahedra are arranged in pairs, one tetrahedron lying on either side of the m plane in $x, \frac{1}{4}, z$ or $x, \frac{3}{4}, z$. Pairs of tetrahedra within one sheet are related by glide reflection on the n plane in $x, y, \frac{1}{4}$ or $x, y, \frac{3}{4}$, so that unshared vertices of alternate pairs point up, the others down. Each sheet is derivable from the other by glide reflection on the c plane in $\frac{1}{4}, y, z$ or $\frac{3}{4}, y, z$. Each barium atom is surrounded by seven nearest oxygen atoms.

STUDIES IN THE URANIUM-LEAD METHOD OF AGE DETERMINATION

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During the past year several dozen complete age analyses have been made on samples of pitchblende, uraninites and samarskites from a number of important localities. Isotopic

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ratios of Pb^{206}/U^{238} , Pb^{207}/U^{235} , Pb^{206}/Pb^{210} , Pb^{208}/Th^{232} and Pb^{207}/Pb^{206} have been obtained for all samples where concentrations permitted. Radon leakage has been measured and corrected for as well as the common lead contamination. Several localities which have had age determinations made previously are included for comparison. Wilberforce, Ontario, remains at about 1040 m.y., Gilpin Co., Colo. at 50–60 m.y., and the Besner Mine, Ont., at about 820 m.y. New values include the Spruce Pine, N. C., pegmatite district at about 320 m.y., Joachimsthal at about 200 m.y., and Baden, Germany, at about 110 m.y.

A large number of pitchblende samples from the Lake Athabasca region were analyzed chemically and isotopically. Apparent ages from the various isotopic ratios differ considerably. It appears possible to interpret these results in terms of radon leakage, the preferential leaching of lead during recent geologic time, and several periods of pitchblende deposition or redeposition. The oldest pegmatite deposit in the area appears to be about 1700 m.y. The oldest pitchblende which has not been subjected to later chemical effects appears to be about 1670 m.y. More recent deposition or redeposition appears at approximately 350 m.y. The data include apparent ages from specimens taken from the same level, from different levels of the same mine, and from several widely separated mines in the Athabasca district.

STABILITY AND OCCURRENCE OF PARAGONITE

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Two modifications of paragonite have been synthesized: a 1-layer monoclinic (1M) and a two-layer monoclinic (2M) form. The univariant curve for the reaction paragonite \rightleftharpoons albite + 2 corundum + 2 water passes through the points 660° C.–30,000 psi water vapor pressure, 625° C.–15,000 psi, 610° C.–10,000 psi and 580° C.–5,000 psi. The point for 1 atm. was calculated and found to be 395° C.

The two forms can readily be distinguished in powder x -ray diffraction patterns. At temperatures above 400° C. the 2M paragonite is the more stable form. All natural paragonites studied so far show a powder pattern identical with the 2M form.

X -ray studies of many natural paragonites showed that in mica schists paragonites are usually accompanied by muscovite. In these cases the powder patterns are those of mechanical mixtures of the two micas and suggest that the solid solution between muscovite and paragonite is limited. The c_0 for synthetic paragonite is 19.27 Å, and for natural paragonites an extrapolation to the end member gives $c_0 = 19.15$ Å. The maximum displacement of the basal spacing for a natural paragonite associated with muscovite was found to be 22% of the total difference between paragonite and muscovite.

Of 90 mica-bearing schists from the Lincoln Mtn. and Hyde Park Quadrangles (Vt.) 33 samples contained paragonite in amounts up to 60% of the total mica content. Paragonite mainly appears in albite-free assemblages with kyanite, chloritoid, or chlorite. Staining for potassium was helpful in distinguishing paragonite from muscovite in thin sections.

CONSTITUTION OF THE NATURAL AND ARTIFICIAL DECAVANADATES

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When an alkaline solution of V_2O_5 is brought to a pH of about 6.5, it suddenly turns orange, and when concentrated, yields a variety of crystalline products. These products are very similar to the minerals, pascoite and hummerite, which are leached out of the vanadium oxide ores in the Colorado Plateaus area by surface waters. New x -ray data have

been accumulated which relates these minerals to the artificial system and throws light on their basic constitution. All data were measured on artificial crystals.

- (I) $K_8V_{10}O_{28} \cdot 10H_2O$: triclinic, space group, $P\bar{1}$ (pseudo-monoclinic, $I2/m$), $a=17.78 \text{ \AA}$, $b=11.28$, $c=17.48$, $\beta=130^\circ 15'$, $Z=4$.
- (II) $K_8V_{10}O_{28} \cdot 10H_2O$: monoclinic, space group, $P2_1/n$, $a=18.34 \text{ \AA}$, $b=17.42$, $c=10.56$, $\beta=94^\circ 20'$, $Z=4$.
- (III) $Ca_3V_{10}O_{28} \cdot 16H_2O$ (pascoite): monoclinic, space group $C2/M$, $a=16.89 \text{ \AA}$, $b=10.20$, $c=10.91$, $\beta=93^\circ 20'$, $Z=2$.
- (IV) $K_2Mg_2V_{10}O_{28} \cdot 16H_2O$ (hammerite; see A. D. Weeks, E. A. Cisney and A. M. Sherwood, *Am. Min.*, 36, 326, 1951): triclinic space group $P\bar{1}$, $a=10.81 \text{ \AA}$, $b=11.01$, $c=8.85$, $\alpha=106^\circ 04'$, $\beta=107^\circ 49'$, $\gamma=65^\circ 40'$, $Z=1$.
- (V) $K_2Zn_2V_{10}O_{28} \cdot 16H_2O$: triclinic, space group $P\bar{1}$, $a=10.76 \text{ \AA}$, $b=11.17$, $c=8.77$, $\alpha=104^\circ 50'$, $\beta=109^\circ 29'$, $\gamma=65^\circ 05'$, $Z=1$.

The crystal structure analysis of IV and V is in progress.

CONCENTRATION OF HEAVY ACCESSORIES FROM LARGE ROCK SAMPLES

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Concentration of heavy accessories from large rock samples (circa 50 lb.) requires, in the interest of efficiency, some modification of standard techniques currently used for small samples. The Carpcu induced roll separator will remove the magnetic fraction. The non-magnetic residue is then passed through a continuous flow heavy-liquid separator which reduces handling and economizes on time. It consists of an assembly of two stainless steel beakers mounted above one another. The upper beaker contains a thin, thoroughly mixed sludge of heavy liquid and sized sand. This is fed slowly through a conical valve into the beaker underneath, where fractionation into float and sink occurs. The float is continuously removed by a jiggling device and the sink is collected after completion of the run. An improved method of washing the float consists of adding water to the sand after removal of the excess heavy liquid. This gives much greater recovery of undiluted heavy liquid than is otherwise possible and reduces the volume of diluted acetone washings which comprises the final stage.

DIFFERENTIATION TRENDS IN THE LORING INTRUSIVES OF CANADA

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Two basic complexes, the Caribou and Memesagamasing intrusives, lie in the Canadian shield near the village of Loring. They are composed of norites with local picrites, pyroxenites and olivine norites. The feldspars vary in composition from An_{68} to An_{61} in the ultrabasics and olivine norites, and from about An_{63} to An_{48} in the norites. Orthopyroxenes vary from near En_{90} to En_{76} in the ultrabasics and olivine norites and from about En_{79} to En_{64} in the norites. The composition of the clinopyroxene in picrite is near $Wo_{38}En_{55}Fs_8$ and in pyroxenite near $Wo_{38}En_{52}Fs_{10}$. In the norite it varies from near $Wo_{39}En_{51}Fs_{10}$ to about $Wo_{41}En_{42}Fs_{37}$. The composition of the olivine is near Fo_{84} in picrite and near Fo_{88} in olivine norite. The picrite contains both ortho- and clinopyroxenes, but the early norite lacks the latter. As the orthopyroxene of the norite reaches a molar percentage of En_{76} augite appears and with continued crystallization it attains prominence.

A plot of the enstatite content of orthopyroxene against anorthite content of the plagioclase indicates a straight-line soda and iron enrichment relationship resulting from fractional crystallization and reflecting a temperature control. This linear relationship suggests

an approach towards equilibrium conditions. A plot of coexisting ortho- and clinopyroxenes indicates a linear increase of iron with progressive crystallization and suggests equilibrium conditions. In the (K_2O+Na_2O) -MgO-FeO diagram two trends distinguish themselves, magmatic and metasomatic. The former is one of iron enrichment and parallels the Mg-FeO side, The latter was caused by later granite pegmatites and parallels the calc-alkaline trend.

ISOTOPIC ANALYSIS APPLIED TO A CLIMATOLOGICAL PROBLEM

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A study of the Lake Maracaibo, Venezuela, region was undertaken with the object of determining the water balance of the lake.

Hydrographic data indicate salinity in the lake is uniform and is about 1/25-1/30 that of sea water. The lake is well mixed and outflow data show that 1/10 to 1/15 of the lake flows out to the sea each year. ($22.0 \times 10^9 m^3$) Inflow is about $0.7 \times 10^9 m^3/1$ year.

Using Thornthwaites' method, the upland runoff and rainfall of the lake were determined as $32.2 \times 10^9 m^3$ and $22.0 \times 10^9 m^3$ respectively. Deuterium determinations were made on the lake, river, and ocean waters. The deuterium balance requires that $33.5 \times 10^9 m^3/yr$ of water evaporate from the lake. This compares with $32.9 \times 10^9 m^3$ calculated from climatology data.

KUTNAHORITE: A MANGANESE DOLOMITE, $CaMn(CO_3)_2$

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A re-examination of type material has shown that the kutnahorite of Bukovsky (1901) from Kutná Hora, Czechoslovakia, is a valid member of the dolomite group with the composition $Ca(Mn, Fe, Mg)(CO_3)_2$. The material of Žák (1949) from Chvaletice, Czechoslovakia, is shown to be similar. A third occurrence is described from Franklin, New Jersey: $CaCO_3$ 51.50, $MnCO_3$ 42.00, $MgCO_3$ 5.77, $FeCO_3$ 0.73 (mol per cent); nO 1.728, nE 1.535; a_0 4.85, c_0 16.34 Å; S : G. 3.12. The DTA graph and x-ray powder pattern are very similar to those of ankerite, $CaFe(CO_3)_2$. Study of 46 specimens in the calcite-rhodochrosite series from Franklin, N. J., indicates that the series is incomplete under the particular genetic conditions at this locality, with a central gap extending from about 40 up to about 75 weight per cent $MnCO_3$.

A survey of the disordered calcite-type carbonates, olivine-type nesosilicates and NaCl-type oxides of Ca, Mn, Fe and Mg show that in the binary systems increasing similarity in ionic size is accompanied by increasing solid solution and decreasing tendency to form ordered phases. Further, in the binary series with a central gap, $(A,B)X - (B,A)X$, the smaller ion B substitutes to a larger extent for A in $(A,B)X$. An ordered dolomite-type phase $MnMg(CO_3)_2$ is predicted, and a possible example is cited. The ordered phase $FeMg(CO_3)_2$ is less likely, and three specimens found with essentially this composition proved to be of the disordered calcite-type, $(Fe,Mg)(CO)_3$.

INVESTIGATION OF DOMAINS IN REORDERED MINERALS

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In many compounds that have ordered after existing in the disordered state, the basic structure is essentially a single crystal, while the super structure is divided into small do-

mains whose orientations, although bearing a rational relation to the more highly symmetric basic structure, are dissimilar.

In bornite (Cu_5FeS_4) where little or no change occurs in the dimensions of the basic structure during disordering, the domains are of less than 1000 \AA in size as evidenced by diffuse super structure spots. In chalcopyrite (CuFeS_2) where a pronounced dimensional change occurs during disordering, the domains are larger.

The existence of anti-phase domains has been observed in natural occurring chalcopyrites in rocks where cubanite unmixing has occurred and in accessory chalcopyrite in metamorphic rocks of granulite facies.

THE THERMODYNAMIC RELATIONS AMONG THE URANIUM OXIDES, AND THEIR RELATION TO THE OXIDATION STATES OF THE URANIUM ORES OF THE COLORADO PLATEAUS

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Fields of stability of uranyl hydroxide and uranous hydroxide in water solution at 25°C . and one atmosphere pressure have been calculated as functions of Eh and pH. Equilibrium values of the activity of uranyl ion and of uranous ion also have been calculated and are shown as contours on the stability fields. Thermodynamic relations among the uranyl hydroxides, oxides, and hydrated oxides indicate that the free energy differences among the various species are small. The data are interpreted to mean that a variety of such uranium (VI) compounds may form and even co-exist. Similar studies of the uranium (IV) hydroxide indicates that it is unstable relative to the oxide and might well be expected to invert to the oxide at a finite rate. Uranium (V) compounds probably have a transitory existence because of the instability of the UO_2^+ ion; uranium (III) oxides and hydroxides would not be expected to occur naturally because the uranium (III) ion would decompose water. A comparison of the behavior of the low-valence vanadium hydroxides (III and IV) with uranium (IV) and (VI) hydroxides indicates that vanadium (III) hydroxide should oxidize to the vanadium (IV) hydroxide at a slightly lower potential than that required for the uranous to uranyl hydroxide pair. A speculative diagram showing probable fields of stability of many of the major minerals of the Colorado Plateaus is presented and the suggestion made that a consistent picture results if one assumes that the ores represent the superimposition of a weathering environment on a mineral assemblage formed in a primary reducing environment.

ABUNDANCE OF Sr^{87} DURING GEOLOGIC TIME

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The isotopic composition of "common" strontium from limestones and marbles of different ages has been determined. Samples include early Precambrian South African marble, middle Precambrian Grenville marble, Ordovician and Devonian limestones, and modern sea water. The change in the abundance of Sr^{87} relative to the stable Sr^{86} isotope is less than one-third of that expected (4.5% per billion years) from (a) the presently accepted abundances of Rb and Sr (Rankama and Sahama, 1951) in the upper crust, (b) the decay constant of Rb^{87} , and, (c) the assumption that the isotopic composition of strontium in the ocean is the same as the average isotopic composition of the strontium in the crust at any given time.

From this anomaly it is clear that one or more of the above assumptions is incorrect. A

critical examination of the geochemical cycle of radiogenic strontium, suggests that the mixing of radiogenic and common strontium is not complete during weathering and transport to the ocean. Such an effect is in the right direction to explain the anomaly. Another possibility is that the abundance of strontium relative to rubidium is greater than the value generally accepted in the literature.

GEOLOGY OF THE ENGER TOWER AREA, DULUTH, MINNESOTA

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In connection with studies of the Duluth gabbro that are being conducted by the Minnesota Geological Survey, the Enger Tower area in the City of Duluth has been mapped in detail. This area is considered to be representative of the upper part of the gabbro exposed in the Duluth region.

At least three periods of basaltic magma intrusion are recorded in the Enger Tower area. Anorthositic gabbro, the principal rock type, was derived in an early period. A second period of intrusion produced a zone of mixed rock types—quartz gabbro, granodiorite, and adamellite. A still later period resulted in basalt dikes.

Mesocratic uralite gabbro is a roof phase of the anorthositic gabbro contaminated with fragments of basalt flows. Inclusions of anorthosite of the Beaver Bay type may represent an older period of differentiation.

Younger rocks that intrude the anorthositic gabbro are small bodies of granodiorite and hedenbergite granophyre and dikes of granite. These rocks constitute a series the origin of which is attributed to differentiation by fractional crystallization of basaltic magma. The line of descent is gabbro→granodiorite→calcic-granophyre→granite.

The effects of assimilation and of contamination are considered to be quantitatively unimportant in producing this rock series. Inclusions have been altered to hornfels, and marginal to the main granodiorite-granophyre intrusion, quartz and alkali-feldspar were introduced in the anorthositic gabbro.

Na CONTENT OF MICROCLINE

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The amount of $\text{NaAlSi}_3\text{O}_8$ in solid solution in microcline (triclinic KAlSi_3O_8) can be determined by *x*-ray techniques. The *a*-axis spacing of microcline is the most sensitive to variation in the Na-content, analogous to the relation in monoclinic KAlSi_3O_8 . It is convenient to measure the (400) spacing by comparison with a simultaneously irradiated standard. The standard used here is a single phase, highly triclinic authigenic microcline, containing not more than 1% $\text{NaAlSi}_3\text{O}_8$. Microcline has not been synthesized, so the authigenic material is invaluable for establishing the lattice constants of the pure triclinic end-member.

If one assumes that the effect of Na on the *a*-axis of microcline is the same as its effect on sanidine, the data of Donnay and Donnay for the high temperature series can be used to construct a curve between microcline and albite. The validity of this assumption has been checked by plotting *a*-axis values of authigenic microclines with known quantities of Na introduced. Inasmuch as the *a*-axis of triclinic KAlSi_3O_8 differs slightly from that of monoclinic KAlSi_3O_8 , a correction for triclinicity must be made. The correction for "fully triclinic" microcline is approximately 9% for pure KAlSi_3O_8 , and varies with Na-content. Correction for microclines with intermediate triclinicity is also easily made.

Sizeable amounts of Rb in some microclines can lead to erroneous values. The data on

hand indicate that most microclines have exsolved virtually all of their albite; the common microclines appear to have 5% or less $\text{NaAlSi}_3\text{O}_8$ in solid solution.

DETAILED STRUCTURE OF NEPHELINE

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The detailed refinement has been made of the nepheline structure. This has been based on new single-crystal Geiger counter measurements of $F^2(hk \cdot 0)$ and $F^2(hh \cdot l)$. With these new data, two successive electron density projections $\rho(xy)$ and $\rho(xz)$, and difference syntheses, $\Delta\rho(xy)$ and $\Delta\rho(xz)$ were made. The second difference syntheses displayed an appreciable improvement in the relief, and corresponded to an improvement of the R factor. Because of overlapping in some of the atoms, no further improvement could be attained by refinement of projections. Accordingly, strategically located sections were prepared through the 3-dimensional electron density function. These syntheses made use of all new Geiger counter intensities plus additional upper-level intensities from the earlier photographic determination. The sections were synthesized on *X-RAC* with the kind permission of Professor Ray Pepinsky.

With these sections, the x , y , and z parameters of all atoms could be determined and some interesting and unsuspected features of the nepheline structure were revealed: The oxygen atom, ideally on the 3-fold positions, is off the axis and statistically occupies at least two nearby sets of 3-fold positions. The sodium atom too is distributed between two positions. Another oxygen atom in the general position also appears to occupy statistically two different locations. All other atoms are substantially fixed since sections through the electron density function show these atoms to be essentially spherical.

STUDIES IN THE SYSTEM CaO-MgO-CO_2

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Apparatus has been constructed to generate and apply a high pressure (100,000 psi) of CO_2 to cold-seal quenching units.

The p - T curve for the dissociation of dolomite, represented by the equation $(\text{CaMg}(\text{CO}_3)_2 = \text{CaCO}_3 + \text{MgO} + \text{CO}_2)$; passes through the points at 940° C. and 40,000 psi, 900° C. and 30,000 psi, 850° C. and 20,000 psi and at 800° C. and 10,000 psi. The corresponding curve for magnesite ($\text{MgCO}_3 = \text{MgO} + \text{CO}_2$) follows very nearly parallel to the dolomite curve between 40,000 and 10,000 psi but at about 50° C. below it. Some runs have been made to locate the calcite curve ($\text{CaCO}_3 = \text{CaO} + \text{CO}_2$) which is thought to be at somewhat lower temperatures than those previously determined by Smyth and Adams.

The sub-solidus relations in the system $\text{CaCO}_3\text{-MgCO}_3$ have been examined between 500 and 900° C. and it is found that solid solutions containing up to 51 per cent dolomite in calcite are stable at 900° C. and at pressures sufficiently high to prevent the dissociation of dolomite. Metastable solid solutions between calcite and dolomite have been synthesized and found to contain 64, 77 and 86 per cent of the dolomite component suggesting that complete solid solution may be found to be stable at higher temperatures. There is evidence of slight solid solution of calcite in dolomite and of dolomite in magnesite but the amount of magnesite in solid solution in dolomite was found to be negligible in the 500 to 900° C. range.

ISOTOPIC COMPOSITION OF Sr IN THE HOMESTEAD METEORITE

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The Homestead meteorite is a typical chondrite, containing 11% metal phase. Sr and Rb contents, determined by optical spectrographic analysis are: Sr = $0.0020 \pm 0.0006\%$; Rb = $0.0013 \pm 0.0004\%$, indicating precision of analysis only. The relative abundances of the Sr isotopes have been determined with a solid-source mass spectrometer and are the averages of 148 individual magnet-sweep, single collector determinations. The relative abundances are: $87/86 = 0.740 \pm 0.003$; $87/88 = 0.0881 \pm 0.0003$; $86/88 = 0.1192 \pm 0.0002$; $84/88 = 0.0058 \pm 0.0008$. A single double-collector measurement agrees with these measurements. The 86/88 ratio is identical with that of standard terrestrial Sr, while the 87/88 ratio is 5% greater.

Calculation of the age requires knowledge of the initial ^{87}Sr relative abundance. If this abundance was no greater than 0.0690 (the lowest value found in terrestrial rocks or minerals by our analyses) the minimum age would be 1 to 3×10^9 years, within the limits of uncertainty in the Sr and Rb measurements stated above. Other reasonable assumptions yield greater ages.

Analysis of a second meteorite (Pasamonte), with a considerably higher Sr/Rb ratio is in progress, and may provide knowledge of the initial ^{87}Sr abundance. The Sr/Rb ratio will be determined by isotope dilution analysis.

AGE DETERMINATIONS ON ZIRCON BASED ON RADIATION-DAMAGE MEASUREMENTS

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Age determinations based on measurements of the ratio of radiation damage to present alpha activity have been carried out on zircons from northern New Jersey, North Carolina, Southern Ontario, and the Adirondacks. The increase in the *c*-dimension of the unit cell of zircon has been used as a measure of radiation damage. The results are in good agreement with other age measurements on material of probably equivalent age and with ages found for the same materials by the lead-alpha activity method. It is concluded that radiation damage measurements in zircon can serve as the basis for a reliable method of age determination, and that the method will be particularly useful for homogeneous zircons which have received a radiation dosage between 50×10^{13} and 300×10^{13} alpha disintegrations per mg.

RELATIONS OF REGIONAL AND THERMAL METAMORPHISM NEAR THE BASE OF THE STILLWATER COMPLEX, MONTANA

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Precambrian granite and metamorphosed sedimentary rocks form the main core of the Beartooth Mountains in south-central Montana. A study of the relationship of these rocks to the Stillwater igneous complex along the northern border of the range has been made by the U. S. Geological Survey. In the western part of the Stillwater complex the metamorphosed sedimentary rocks, consisting largely of a pelitic series, but containing some quartzite and iron-formation, are adjacent to the base of the complex and extend several miles southward from it. To the east, granite is in contact with the base of the complex except where small patches of sedimentary rocks are preserved at the base or as masses within the granite. Thermal metamorphism by the complex precedes the regional meta-

morphism and the emplacement of the granite as shown by the following: (1) Close to the base of the Stillwater complex high-temperature thermal metamorphism, associated with the intrusion of the complex, has altered the pelitic rocks, presumably originally of low-grade regional metamorphic facies, to cordierite-hypersthene-biotite-quartz hornfels and the iron-formation to quartz-magnetite-fayalite-pyroxene hornfels. (2) Away from the influence of the complex the sedimentary rocks are regionally metamorphosed to garnet-quartz-mica schist and partly granitized. (3) The granite, where it lies near the thermally metamorphosed zone, has partly converted hornfels to schist. The alteration of cordierite to sericite is the first sign of nearness of the granite.

ROLE OF WATER IN METAMORPHISM OF ROCKS IN THE CUCAMONGA CANYON AREA, CALIFORNIA

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The rocks of the Cucamonga Canyon area, California, have been subjected to two periods of metamorphism. Metamorphic rocks of the granulite facies were converted to amphibolites and mylonites in belts of intense fracturing during a post-granulite metamorphism. Mineral assemblages of the granulite facies in belts that were little deformed, however, were not altered to minerals of the amphibolite facies.

As the temperature and confining pressure during the second period of metamorphism were probably uniform over the small area about Cucamonga Canyon, the intimate association of granulite and amphibolite facies minerals suggests that local differences in vapor pressure of H_2O may have played an important role in determining the equilibrium assemblage. Thus Eskola's concept of metamorphic facies should be modified as the equilibrium assemblage of a rock of given bulk composition depends not only upon temperature and hydrostatic pressure, but also upon vapour pressure of H_2O in equilibrium with anhydrous and hydrated minerals (P_{H_2O}), and possibly upon some other factors. This conclusion can be reached independently from thermodynamic considerations.

Water was introduced during the second period of metamorphism preferentially into the pyroxene-rich rocks, probably because P_{H_2O} is lower for such rocks than for felsic rocks which are interbedded. Consequently, active syntectonic neomineralization (involving hydration of granulite minerals) was possible in mafic rocks, forming granoblastic amphibolites, while the felsic rocks underwent cataclastic deformation, forming mylonites.

MAGMATIC TRENDS AND AGE DETERMINATIONS OF PRECAMBRIAN INTRUSIVES OF CENTRAL TEXAS

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Harker variation diagrams have been plotted for 17 intrusions: 8 Town Mountain type with 1 associated aplite; 1 Oatman type; 2 Sixmile type; 5 aplogranites, and 1 granite porphyry (llanite).

Town Mountain type granites occupy positions of lower and intermediate silica content. Aplogranites are restricted to high-silica positions. The aplite falls within the aplogranite range suggesting the aplogranites may be late stage differentiates of Town Mountain type granites. Llanite falls within the more acid of the Town Mountain type granites and probably is the approximate aphanitic equivalent.

Oatman type granite is intermediate between aplogranites and Town Mountain granites. Sixmile type granites fail to fit the curves suggesting a separate line of magmatic descent.

Age determinations are as follows:

Town Mountain type intrusions:	Wolf Mountain phacolith	917 million years
	Legion Creek mass	893 million years (av.)
	Enchanted Rock pluton	815 million years (av.)
Sixmile type:	Sixmile mass	822 million years
Oatman type:	Sharp Mountain mass	857 million years (av.)

Zircon samples from Wolf Mountain phacolith and Legion Creek mass gave low alpha counts compared with those from Enchanted Rock pluton and suggest a different period of intrusion or possibly fractionation with the uranium and thorium having concentrated in the younger fraction. High alpha counts of zircon from Sixmile mass and Sharp Mountain mass also indicate possible fractionation. The Town Mountain type granites probably had a common magma source, with different periods of intrusion.

Field relations confirm the age determinations. Sixmile mass crosscuts and contains xenoliths of Wolf Mountain phacolith. Enchanted Rock pluton contains xenoliths of schist recrystallized by intrusion of the Legion Creek mass.

PRELIMINARY REPORT ON INVESTIGATIONS OF MINERALS OF COLUMBIUM AND TANTALUM AND OF CERTAIN ASSOCIATED MINERALS

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The rotation properties of the columbite-tantalite series have been determined in detail and the results and their application to identification are discussed in the report on the investigation. The optical properties of some other columbium-tantalum minerals in reflected light, including ytrotantalite, bismutotantalite, stibiotantalite, tapiolite and ilmenorutile, have been determined. The relationship between the orthorhombic columbite-tantalite series and the tetragonal mossite-tapiolite series is critically examined. It is suggested that there is, in nature, only a single series with composition $(\text{Fe}, \text{Mn})\text{Cb}_2\text{O}_6$ - $(\text{Fe}, \text{Mn})\text{Ta}_2\text{O}_6$ and that this series includes the minerals columbite, tantalite and tapiolite with a change from orthorhombic to tetragonal symmetry in the tantalum-rich range. A disordered variety of the mineral tapiolite has been recognized and has a crystal structure of the rutile type. All specimens of ilmenorutile so far studied were found to be intergrowths of two minerals, columbite and rutile.

TEXTURAL RELATIONS OF CRYSTAL ACCUMULATES IN THE ULTRAMAFIC ZONE OF THE STILLWATER COMPLEX, MONTANA

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The igneous Stillwater complex is a differentiated layered intrusion at least 18,000 feet thick exposed for 30 miles along the front of the Beartooth Mountains, Montana. The lower 3,500 feet of the complex is composed of rhythmically stratified ultramafic rocks that exhibit both igneous and sedimentary textures. Mineral grains in the rocks can be divided into two types: individual euhedral crystals and negative-shaped grains interstitial to these crystals. Variations in size, shape, and composition of the well-formed grains are related to, and in many instances define, the layering. The interstitial material occurs in single grains or oikocrysts that are independent of the layering. The euhedral grains crystallized from the main magma and settled to the floor of the magma chamber; the interstitial grains crystallized in place from magma surrounding the settled crystals. The composition of the settled minerals is peridotitic: only olivine, orthopyroxene, and chromite occur as

ehedral individuals. The composition of the interstitial material is gabbroic: plagioclase, orthopyroxene, and clinopyroxene are the principal minerals. Where settled crystals were "cemented" by interstitial material belonging to a different reaction series, the original porosity of the crystal mush can be determined to have ranged from 20 to 40 per cent. Where settled crystals were secondarily enlarged or resorbed after accumulation by interstitial material belonging to the same reaction series, the rocks developed xenomorphic and hypautomorphic textures.

IGNIMBRITES IN SOUTHERN PERU

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Ignimbrites near Arequipa were described in 1948 by Fenner and by Jenks. The ignimbrite (sillar) outcrops in 12% of the Arequipa quadrangle. It also occurs extensively in the Departments of Moquegua, Puno, Cusco, and Abancay, southern Peru.

Many tuff flows are related to an early phase of the present stream pattern. Single flows have been traced down valleys for 30 km.: in the headwaters they occupy valley bottoms; in the lower reaches valleys have been incised as much as 700 m. below the base of the tuff flows, leaving the flows on remnants of a mature surface. Thus these eruptions are related to the Chacra mature valley erosional stage, and were the last events before the rejuvenation which produced the present deep canyons.

Whereas the bulk of the Tertiary to Recent volcanics is andesitic, the sillar is rhyolitic. The sillar appears to have been a near-terminal phase of a long history of andesitic eruptive activity. The sillar in turn is locally covered by dominantly andesitic rocks of the latest cycle of vulcanism.

The sillar was erupted from diverse, dominantly andesitic volcanic massifs, but specific vents have not been found.

Ignimbrites of the Arequipa region are not welded. The hardness of those which are largely devitrified was attained by crystallization and cementation while the tuff flows were still hot, with the production of textures like those of previously described ignimbrites. Initial toughness of the ignimbrites is attested by their permanent displacement of major streams.

CORRELATION OF BASALT FLOWS IN CENTRAL NEW MEXICO BY FUSION TECHNIQUE*

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Late Tertiary and Quaternary basalt flows of at least five different ages from seven vents lie upon various surfaces in the Cerro Verde quadrangle, 50 miles northwest of Socorro New Mexico. The flows consist of olivine, augite, labradorite, magnetite, and glass and average about 48 per cent silica.

Powdered samples were fused in a carbon arc according to the method of Matthews, and refractive indices of glasses thus formed were determined to 0.001. Indices of 50 samples determined in the study range from 1.608 to 1.583. Duplicate fusions show that indices are reproducible to 0.002.

* Published by permission of the Director, New Mexico Bureau of Mines and Mineral Resources.

It was found that each flow has a specific range of refractive index not exceeding 0.015. Where these ranges do not overlap markedly, isolated flow remnants can be correlated on the basis of five or less samples. Vent rocks may also be correlated with flows derived from them.

The indices for three superposed flows from one vent are significantly different; each succeeding flow is more silicic. Statistical analysis shows that the probability of obtaining such variations from one population is less than 0.004.

The rapid fusion technique furnishes adequate basis for local correlation of basalt flow remnants as well as for correlation with filled vents. In all these samples compositional differences do not appear to be large enough to be revealed significantly by chemical analysis.

VARIATION IN THE ISOTOPIC COMPOSITION OF COMMON LEAD

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New measurements of the isotopic composition of lead from some 120 lead minerals are reported. Some of these samples have been measured in several laboratories using Pb^{210} from PbI_2 , Pb^{210} from $Pb(CH_3)_4$ and $Pb(CH_3)_3^+$. In general the agreement is excellent indicating the absence of appreciable systematic error in any of the techniques.

This large increase in the data on common lead makes it possible to begin to predict the range in isotopic composition of lead from various geological settings. This is important for age determination and for the understanding of the mechanism of emplacement of lead ores. In the Joplin District the range in 207/206 is at least 4%, in the Wisconsin-Illinois-Iowa District at least 9%, and in S. E. Missouri 15%, although samples from opposite ends of a single crystal of galena showed no differences. The precision of measurement is 0.1 to 0.2%. These data strongly suggest that these leads were not derived from the mantle.

Variations in the isotopic composition of common lead from pegmatites in well-defined geological provinces such as New England or the Southern Appalachians appear much smaller. A few interesting exceptions to the regional pattern appear. One such exception occurs at Franklin, New Jersey.

The rough correlation of the isotopic composition with age persists. The new data do not greatly affect the calculation of the age of the earth, but do help delimit the area of application of the "galena age method."

VERTICAL CHANGES IN CHEMICAL COMPOSITION OF A PARTIALLY WEATHERED ILLINOIAN TILL

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Indiana, and Mineralogisk-Geologisk Museum, Oslo, Norway

The high wall of an abandoned strip coal mine in Clay County, Indiana, has provided a section including 40 feet of Illinoian till. Sixty-five channel samples were obtained; each sample represented 6 inches of section. Tests with dilute HCl and color differences indicated three distinct zones: (a) lower—unleached and unoxidized; (b) middle—unleached and oxidized; (c) upper—leached and oxidized.

This paper deals with the results of chemical and spectrographic analyses of the minus 200 mesh material and of water solutions obtained with the fine fraction of each sample. A concurrent investigation of the vertical changes in mineral composition is the subject of another paper.

Preliminary qualitative analyses proved unsatisfactory in the study because of the apparent similarity of the samples. Quantitative data for pH, Li, Na, K, Rb, Be, Mg, Ca,

Sr, Ba, B, Al, Y, Ti, Zr, V, Cr, Mn, Fe, Ni, Cu, Ga, C, Si, Pb, P, S, and F have shown some remarkable ranges of composition. For example, sulfur in the minus 200 mesh material increases from 0.3 per cent (as S) at the base to 0.6 per cent and decreases to 0.2 per cent in zone (a); it decreases further through zone (b) to a minimum of 0.005 per cent at the boundary of zones (d) and (c).

SANIDINE- AND ORTHOCLASE PERTHITES

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A new rapid x-ray method for determining accurately the reciprocal lattice angles α^* and γ^* of the soda phase of perthites has been developed. Using this method the lamellar structure of a number of sanidine- and orthoclase perthites has been investigated in detail. Measurements of the reciprocal lattice angles α^* and γ^* of the soda phase give results which indicate that the composition of this phase may be determined from these angles.

The orthoclase micropertthites generally have a monoclinic potash phase and a soda phase corresponding to low-temperature albite or oligoclase. Specimens which have in addition a triclinic potash phase are found and these have values of optic axial angle greater than would be expected from their bulk chemical composition.

Sanidine cryptopertthites have a monoclinic potash phase and a soda phase which is not pure high-temperature albite but has a considerable amount of orthoclase in solid solution.

No perthites have been found having a soda phase which gives evidence of states transitional between high- and low-temperature soda feldspar although such forms have been postulated by other workers for single phase soda feldspar from both optical and x-ray studies.

DEVITRIFICATION IN PERLITE

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Perlites from many localities scattered throughout the western United States have been studied in thin section. The microcrystalline phase of perlites may be divided into two parts. One phase, consisting of crystallites and microlites is characteristic of all hypohyaline rocks and apparently reflects the composition and cooling history of the magma. It may be considered primary. The other phase, which may be considered secondary, consists of devitrified films on both sides of the perlitic cracks which are commonly filled with a secondary mineral. The devitrification bordering the cracks typically is highly irregular in outline and diffusely birefringent. This phase appears to have developed in many cases after cooling of the perlite. Photomicrographs illustrate the greater abundance of this secondary phase in the older perlites among the specimens examined. Thus, in an Eocene perlite, the film of devitrificatoin is 7 microns thick; in a Pliocene perlite, less than 1 micron thick.

To explain the transformation of the metastable glass phase into crystalline material, a mechanism involving the diffusion of water is introduced. Calculations indicate that the upper limit for the diffusion constant of water into natural glass in the neighborhood of 25° C. is $10^{-8}\text{cm.}^2/\text{M yr.}$

Hydrothermal alteration causes considerable variation in the penetration of devitrification inward from the numerous internal interfaces. This process and the presumed distribution of water in the perlites are correlated to explain the greater water content of the older perlites.

CaO-V₂O₅-H₂O SYSTEM

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As an aid in determining environmental conditions of naturally occurring hydrous calcium vanadates, an investigation was made of the CaO-V₂O₅-H₂O system. The variables of the system, in the order of their importance, are pH, temperature, and concentration. pH values ranged from 0 to 12; temperature from 25 to 90° C.; and the V₂O₅:CaO ratio from 0.5 to 10. The stability areas of eight crystalline phases were delineated. These phases can be divided into two major groups: the colorless phases, which are stable above pH 6.5; and the colored phases, which are stable below 6.5. According to the phase diagram, the stable phase below pH 2.2 at 25° C. (pH 3.0 at 90° C.) is hydrous vanadium pentoxide. Between 2.2 and 6.5 two naturally occurring minerals, hewettite and pascoite, are stable.

The stability field of pascoite is large at ordinary temperatures but gradually diminishes as the temperature rises and disappears at about 70° C.; at the same time the stability field of hewettite increases at the expense of the pascoite field. In the pH range from 6.5 to 7.5 and at temperatures less than 40° C., rossite is the stable phase. At higher temperatures several unnamed phases appear. At pH 7.5 to 10.0 two hydrous pyrovanadates(?) occur. Their stability range is influenced both by pH and by the V₂O₅:CaO ratio. Above pH 10, Ca(OH)₂ rapidly precipitates, and calcite forms if the solution is exposed to the atmosphere. Those phases whose stability field is near pH 7 seem to be the most soluble.

RADIOACTIVITY OF SOME RECENT BOTTOM SAMPLES FROM LAKE PONTCHARTRAIN, LOUISIANA

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An examination by means of a scintillation detector and a scaling circuit of some recent bottom samples taken from Lake Pontchartrain has been carried out under carefully controlled conditions. Considerable variation has been found in the disintegration rates. The data collected have been compared with both mechanical and chemical analyses of similar samples taken from the area and a correlation has been made. The areas of finer textures show the higher counts and the area of low organic content likewise have higher counts than the areas of higher organic matter. The detrimental factors due to background count have been removed by heavy shielding and by the determination of the residual background before and after sample counting. In order to insure accuracy with such low counting rates as exhibited here, a counting time of five hours has been utilized.

NEW MINERALS, REEDMERGNERITE (Na₂O·B₂O₃·6SiO₂) AND EITELITE (Na₂O·MgO·2CO₂) ASSOCIATED WITH LEUCOSPHEENITE, SHORTITE, SEARLESITE, AND CROCIDOLITE IN THE GREEN RIVER FORMATION, UTAH*

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Cores and cuttings from the Green River formation in Utah contain two new minerals, reedmergnerite and eitelite, with leucospheenite, searlesite, crocidolite, and shortite, in dolomitic shale. Reedmergnerite (Na₂O·B₂O₃·6SiO₂) occurs in many wells in Duchesne and Uintah counties as crystals rarely more than a millimeter long, colorless, triclinic, space group *P1* or *P1̄* forms (100)(001)(102)(101) in one zone, and (010)(100) and (210)

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

another; habit stubby prismatic; $D=2.69$; indices of refraction: $\alpha=1.560$, $\beta=1.564$, and $\gamma=1.572$. The name honors Frank S. Reed and John L. Mergner, technicians of the Geological Survey, whose skill has served petrological science for more than 40 years. Reedmergnerite and $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3 \cdot 2\text{SiO}_2$ are the only known ternary phases of the system $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3 \cdot \text{SiO}_2$, and apparently both must form hydrothermally under relatively low temperature and pressure.

Searlesite ($\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) occurs sparingly with eitelite, etc., the fourth reported occurrence and the first in Utah; however, J. J. Fahey, who described this mineral from Wyoming in 1950, also noted its presence in cores from the Green River formation in Utah in 1952.

Eitelite ($\text{Na}_2\text{O} \cdot \text{MgO} \cdot 2\text{CO}_2$) has been found only in the Carter Oil Company Kermit Poulson No. 1 around 2850 feet, in crystals a few millimeters in diameter. Indices of refraction: $\epsilon=1.450$ and $\omega=1.605$; good basal cleavage; agrees with hexagonal symmetry reported by Eitel and Skaliks, who synthesized it in 1929. This is the second of the alkali-alkali earth carbonates synthesized by Eitel and Skaliks found in nature, the other being fairchildite, $\text{K}_2\text{O} \cdot \text{CaO} \cdot 2\text{CO}_2$.

Eitelite is named to honor Wilhelm Eitel, Director, Institute of Silicate Research, University of Toledo, Ohio.

IGNEOUS PETROLOGY OF PARAGUAY*

CHARLES MILTON AND EDWIN B. ECKEL

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A collection of igneous rocks made by E. B. Eckel in southern and east-central Paraguay as representative of the principal rock types of the region has been studied. Eight new analyses are given of granite, aplite, rhyolite, and quartz porphyry, two of basalt, and two of alkalic rocks—nepheline syenite and shonkinite. Each analysis is supplemented by spectrographic determination of 19 minor and trace elements. A widespread series of granitic, rhyolitic, and porphyritic rocks has been variously ascribed to ages ranging from Precambrian to Tertiary; however, all of these rocks have a notably consistent petrographic character, chemical composition, and suite of trace elements, suggesting that all of these rocks may be co-magmatic and essentially contemporaneous. No evidence of a stratigraphic nature opposed to this suggestion is known to the writers. The presence of boulders of such rock in conglomerate of Permian age indicates Paleozoic or older age for these silicic rocks. Among basaltic rocks and diabase is one occurrence containing well-developed pseudobrookite. A heretofore unrecognized suite of alkalic rocks, ranges from nepheline syenite to shonkinite; the latter contains an unusual type of kataphorite, similar to an amphibole previously known only from Wyoming and Western Australia.

The silicic rocks are presumably the southern extension of the Brazilian basement complex; the basaltic rocks are part of the vast Parana basalt of Triassic-Jurassic age of southeastern Brazil and eastern Paraguay; the alkalic rocks represent a group of magmas of relatively local extent but sporadically widespread; they may be younger than Precambrian. But no closer age designation can be made now.

ZONED PLAGIOCLASE IN METAMORPHIC ROCKS

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Since metamorphic plagioclase is often stated to lack normal, and especially recurrent, zoning, and since the presence of such zoning in a granitic rock is widely accepted as proof

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

of an igneous origin, the plagioclase was examined in a large number of varied, non-granitic, and unquestionably metamorphic rocks from different areas. Zoning, though on the whole less common than in certain igneous rocks, was found to be widely present, with normal more frequent than reverse zoning. Recurrent zoning was also observed, for instance in mica schist and calc-silicate granulite. Zoning varies from highly gradational to rather sharp, and from anhedral to euhedral. A low metamorphic grade, as well as strong syncrystalline deformation, are unfavorable for zoning. Petrographic features suggest different causes of zoning. (1) Thermal control may produce normal, reverse, or recurrent zoning in rocks containing "anorthite substitutes" (epidote, zoisite, calcite plus mica, Cascapolite, etc.), the ability of the plagioclase to incorporate anorthite molecule changing with the temperature, and a supply of potential anorthite being available. (2) Slow, very small-scale diffusion of Ca from more into less calcareous bands in higher grade rocks may cause reverse zoning. (3) Introduction of Na may produce normal zoning. (4) Contrasted to these cases of growth-zoning, passive or secondary normal zoning may occur if plagioclase is partially replaced by (a) Ca-rich minerals (epidote, hornblende), or (b) K-feldspar; preservation of the original plagioclase lattice in the more sodic secondary rims indicates microscopic lattice diffusion. In other cases, the causes of zoning remain obscure.

ORIGIN OF CALCAREOUS OÖLITHS

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Laboratory studies were undertaken to discover mechanisms which might explain the origin of calcareous oöoliths in nature.

Calcium carbonate was precipitated from sea water by evaporation, by addition of precipitating agents, and by the growth of sulfate-reducing bacteria.

The effect of the major ions in sea water on the form of the calcium carbonate precipitate was studied.

From these studies the following conclusions may be drawn:

(1) Calcareous oöoliths or spherulites can be chemically precipitated from sea water if the carbonate ion concentration at the time of precipitation is greater than 0.002 mol per liter. This is a higher concentration than is found in normal sea water.

(2) Calcareous oöoliths may also be formed through the growth of sulfate-reducing bacteria in sea waters.

(3) The presence of the magnesium ion in sea water causes calcium carbonate to precipitate as aragonite rather than calcite.

(4) The laboratory conditions necessary for the chemical precipitation of calcareous oöoliths might be reproduced by an environment in which fresh waters high in carbonate ion flow into a shallow sea. Such a mechanism does not appear to be responsible for any large present day deposits.

(5) Environments where sulfate-reducing bacteria might be important in the origin of calcareous oöoliths should be characterized by deficiency of oxygen, increased pH, and presence of hydrogen sulfide or sulfide salts. Such environments might be highly localized.

VERTICAL CHANGES IN MINERALOGICAL COMPOSITION OF A PARTIALLY WEATHERED ILLINOIAN TILL

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Mineralogisk-Geologisk Museum, Oslo, Norway

This study gives the vertical changes in mineral composition of a partially weathered Illinoian till section described in a paper by the same authors concerning the vertical

changes in chemical composition. The minerals were identified using the petrographic microscope, x-ray diffraction, and differential thermal analysis. The minerals in the minus 20 to plus 200 mesh range were examined in some twenty samples, but the major work was done on the minus 200 mesh fractions of sixty-five samples.

The minus 200 mesh fractions in the lower, unoxidized, unleached zone (assumed to be unaltered till) contain mostly quartz, calcite, dolomite, feldspar, kaolinite, illite, chlorite, and a small amount of montmorillonite. The same fractions in the middle, oxidized, unleached zone contain the same minerals; however, the crystallinity of the clay minerals, illite and chlorite, decreases, presumably because of oxidation of iron, and the amount of montmorillonite increases slightly. In the minus 200 mesh fractions of the upper, oxidized leached zone, primary calcite and dolomite disappear; kaolinite, illite, and chlorite either disappear or are present in very small amounts. The amount of montmorillonite increases markedly in the upper, highly weathered zone; this fact is contrary to expectations because kaolinite is usually considered to be the most stable clay mineral. Organic material is present in the unoxidized zone, but disappears almost completely in the oxidized zones.

THE STRUCTURAL SCHEME OF SEPIOLITE

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An idealized structural scheme for sepiolite is deduced from the observed x-ray diffraction effects in the zero layer line of diagrams obtained from several natural fibres. The structure consists of a centered array of linked chains of composition $H_6Mg_8Si_{12}O_{30}(OH)_{10} + Aq$ somewhat similar to those found in attapulgite, the chains serving to enclose a second centered array of channels in which molecular water is disposed.

The $hk0$ projection is orthogonal with $a=13.4\text{\AA}$ and $b=27\text{\AA}$. The skeletal chains are centered about $0, 0, Z$ and $\frac{1}{2}, \frac{1}{2}, Z$. Mg sites for each chain are at $x=0$ and $y=0, \pm 1/18, \pm 2/18, \pm 3/18$, and $\pm 4/18$. Oxygen and hydroxyl, silicon, and oxygen, in layers, fill out each chain coordinated as in a mica or a chlorite, and the eight oxygens at $\frac{1}{4}, \frac{1}{4}, Z$ are each links common to two chains. The water channels are centered about $\frac{1}{2}, 0, Z$, and $0, \frac{1}{2}, Z$.

The disposition of the eight octahedral ions (mainly Mg) indicated by chemical analysis among the nine positions available in the schematic chain is not specified.

The quality of agreement between calculated and observed $hk0$ type intensities is illustrated. It is considered to adequately confirm the idealized section. It seems probable that the entire structure is in $C 2/m$.

MANGANESE CONTENT OF GARNETS FROM THE FRANCISCAN SCHISTS

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Many years ago Pabst described "The garnets in the glaucophane schists of California" (*Am. Mineralogist*, 16: 327-333, 1931) reporting a very low manganese content. In summarizing, the range of the spessartite content was given as "0-1%."

Several years ago, at the suggestion of Dr. Max D. Crittenden, some of these garnets were reexamined. New determinations indicated that the 1931 report of manganese content was seriously in error.

Nearly two years ago, in response to an inquiry, the writer informed Dr. Schürmann of the Hague of this error and indicated the correction. In spite of this Dr. Schürmann (*Neues Jahrb. f. Min.*, 85: 303-394, 1953) has recently cited my old erroneous figures without comment.

Recently a full analysis of a garnet from eclogite associated with glaucophane schist near Healdsburg, California, has been reported by Dr. Iris Borg. This also shows a more than negligible amount of MnO.

Thanks to the courtesy of Drs. Borg and Crittenden it is now possible to make the corrected statement in the following table:

Garnet	MnO	S. G.	N_{Na}	a_0
	wt.			
Hilton Gulch, Santa Clara Co., Calif., "A" of Pabst, 1931.	2.03%	3.95 ± 0.04	1.795 ± 0.002	$11.62 \pm 0.01 \text{ \AA}$
South of Calaveras Valley, Santa Clara Co., Calif., Crittenden, 1951.	4.63	4.00 ± 0.05	1.795 ± 0.002	11.61 ± 0.01
Near Junction School, Healdsburg Quad., Calif., Borg, 1954.	0.92	4.08 ± 0.02	1.795 ± 0.003	11.62 ± 0.01

The last column of table III in Pabst (1931) should be revised to read "range of grossularite 8-30%, andradite 4-24%, almandite 48-56%, pyrope 16-20%, spessartite 1-10%." The order remains as before even though the spessartite limit is raised by a factor of 10.

PETROLOGY OF SPODUMENE-BEARING PEGMATITES

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The wide variety of petrologic types of spodumene-bearing pegmatities is the result of differences in the initial composition of magmas, mode of emplacement, crystallization history, and simultaneous deformation of the wall rocks. An individual body may have formed by cooling of single or multiple masses of magma, with or without metasomatic replacement. Each body is composed of at least two distinct mineralogic and structural units; some bodies are composed of as many as 13 units. Spodumene-perthite, spodumene-perthite-amblygonite-albite-quartz, spodumene-albite-quartz, and spodumene-quartz are the most common mineral assemblages in lithium-rich units. The long axes of spodumene crystals—either fresh or altered—may be oriented parallel or at right angles to the wall-rock contacts, at right angles to the zonal contacts, parallel to pre-existing gneissoid banding, or at random.

Spodumene is commonly the first mineral to form in the pegmatite unit and acts as a locus for crystallization of albite. The early-formed spodumene crystals may react completely with rest liquids to yield pseudomorphs composed of clay, mica, and other minerals; less complete reaction commonly results in corroded and rounded crystals.

Flow structures, broken crystals, and deformed wall rocks indicate forceful intrusion of initial viscous lithium-bearing magmas; other orientations of spodumene within the units are the result of crystallization during regional deformation or under static conditions. Replacement units rich in spodumene form as the result of abrupt changes in physical conditions during crystallization.

VARIATION DIAGRAMS ON TRIANGULAR COORDINATES OF ORTHOMAGMATIC AND METASOMATIC SUITES

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Suites of chemical analyses of orthomagmatic rocks exhibit distinctive symmetrical patterns which are considered to represent different modes of magmatic differentiation. Metasomatic granitic rock suites, on the other hand, show erratic patterns. Mobilized feldspathized rocks show a tendency towards symmetrical patterns.

The diagrams are a modification of Larsen's triangular diagrams. Norms are computed from chemical analyses after the C.I.P.W. system and adjusted to 100 per cent. Feldspars, mafics, and quartz are plotted. (Silica deficiency is plotted below the zero quartz line.) The Or-Ab-An ratios are superimposed respectively. Lines connect the two points obtained from a single analysis and serve to emphasize the symmetrical or erratic characteristics of the diagrams.

Orthomagmatic suites include: volcanic rocks from several localities; rocks from layered intrusions; and rocks from igneous granitic bodies of batholithic dimensions.

Metasomatic suites include rocks from localities where the interpretation of granitization has been advanced and also from localities where the field and petrographic evidence suggests granitization.

VERTICAL DIFFERENTIATION IN THE WHITE TANK QUARTZ MONZONITE

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The White Tank quartz monzonite, of possible Jurassic age, forms four distinct plutons in Joshua Tree National Monument just south of Twentynine Palms, Calif. The largest of these plutons (seven miles in diameter), shows a variation of composition and texture through a vertical range of 1000 feet from the actual roof to the lowest exposed rock (probably not the true base).

The principal upward changes in the pluton are: potash feldspar increases from 20% to 50%; grain size of potash feldspar changes from three to eight millimeters, and color changes from pink to gray; biotite decreases from 10% to 3%; composition of the principal plagioclase changes from $Ab_{70}An_{30}$ to $Ab_{85}An_{15}$; the amount of myrmekite and "vein" perthite increases. The ratio between the amounts of quartz and plagioclase is roughly the same throughout the pluton, and the sizes of quartz and plagioclase are constant. The upper part of the pluton contains irregular intergrowths between microcline and sodic oligoclase, distinct albitic borders on some plagioclase laths where they contact potash feldspar, and rare graphic texture. The myrmekite is largely restricted to the albitic rims.

It is believed that the compositional and textural variations may be explained by simple crystallization differentiation of an intruded melt and enrichment of the later fluids in water. All of the observed textural features may logically form by primary crystallization.

GOLDICHITE, A NEW HYDROUS POTASSIUM FERRIC SULFATE FROM THE SAN RAFAEL SWELL, UTAH

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Goldichite, a new hydrous potassium ferric sulfate from the Dexter No. 7 Mine, Calif Mesa, San Rafael Swell, Utah, has the composition $KFe(SO_4)_2 \cdot 4H_2O$. It occurs as radiating

clusters of pale-green crystals or fine-grained crystalline encrustations. It is associated with coquimbite, halotrichite, roemerite, alunogen, copiapite, fibroferrite, melanterite and other sulfates, which comprise the cementing material of a talus slope below a small, pyrite-rich uranium deposit in the Triassic Shinarump conglomerate. Crystals are commonly singly terminated, monoclinic-prismatic laths parallel {100} with forms {100}, {110}, and {011}. The space group is $P2_1/c$ and the cell constants are: $a_0=10.45 \text{ \AA}$, $b_0=10.55 \text{ \AA}$, $c_0=9.15 \text{ \AA}$, $\beta=101^\circ 49'$. The cell contains 4 molecules; the density is 2.43 (observed) and 2.419 (calculated). The mineral is biaxial positive, with $2V=82^\circ$ (calculated), $\alpha=1.582$, $\beta=1.602$, $\gamma=1.629$; $X=b$, $Z \wedge c=11^\circ$.

The mineral is named in honor of Samuel S. Goldich, Professor of Geology at the University of Minnesota.

LAYERED BASIC INTRUSIVE, FAIRWEATHER RANGE, SOUTHEASTERN ALASKA

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In 1952 the U. S. Geological Survey examined one of three known layered basic intrusive bodies in the Fairweather Range, southeastern Alaska. The body is roughly elliptical in plan, about 16 miles long and 8 miles wide. It is distinctly layered. The layers form a bowl-shaped structure similar to that of the Skaergaard complex, but this body differs in that the contacts are essentially vertical. About 32,000 feet of layered rock is exposed, but neither the top nor the bottom is visible. The structure, metamorphism of enclosing rocks, and contact relations suggest that the body is intrusive.

The rock-forming minerals, plagioclase and clino- and ortho-pyroxene, do not show significant change in composition throughout the entire sequence. The ratio of light to dark minerals within a layer or groups of layers suggests that the layers are genetically related and were formed by the same precisely repeated mechanism. A plot of the specific gravities of about 600 rock specimens fails to show any recognizable trend within the exposed portion. The relation of observed structures within layers to the genesis of the body is discussed.

SYNTHETIC ALKALINE EARTH GERMANATES ISOSTRUCTURAL WITH ENSTATITE AND PSEUDOWOLLASTONITE

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Germanium dioxide, of the α -quartz structure, when heated with equi-molar per cents of MgO, CaO, SrO, and BaO, at $1,235^\circ \text{ C}$. for one hour, was found to form ABO_3 -type compounds. The MgGeO_3 compound was found, by x -ray diffraction, to be isostructural with enstatite (MgSiO_3). This Ge-enstatite is orthorhombic with $a=18.661 \text{ \AA}$, $b=8.954 \text{ \AA}$ and $c=5.346 \text{ \AA}$. SrGeO_3 and BaGeO_3 were found to have structures similar to pseudowollastonite (α - CaSiO_3). However the structure of CaGeO_3 was not definitely established to be of this form. X -ray patterns of the pseudowollastonite-type structures indicate that larger A and/or B ions tend to increase the symmetry of the structure. α - CaSiO_3 itself is only pseudo-hexagonal but BaGeO_3 appears to be truly hexagonal.

As GeO_2 is known to have a rutile-type polymorph, with Ge^{+4} ions in octahedral coordination, it was thought possible that these silicate-type structures might have titanate-type polymorphs. GeO_2 can be readily formed in the rutile-type structure by heating the quartz-type polymorph at 700° C . and 20,000 psi. However, the pseudowollastonite-type BaGeO_3 , when heated under 20,000 psi at 700° C . showed no change in crystal structure. Differential thermal analysis of BaGeO_3 indicates a phase transformation at about 340° C . A 1% addition of Fe_2O_3 to BaGeO_3 causes an entirely different x -ray pattern which may represent the stabilized form of high temperature BaGeO_3 .

RECONNAISSANCE OF THE SYSTEM $\text{Na}_2\text{O}-\text{FeO}-\text{SiO}_2$

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More than seventy separate compositions in this system have been prepared and studied by the method of quenching. The fields of fayalite, wüstite, tridymite, quartz, sodium metasilicate and sodium disilicate have been delineated. There are many new ternary compounds whose compositions, fields of stability, and mutual melting relations are very difficult to determine because of the change in composition of melts by reaction with the container, an iron crucible, and because of the crowding of the fields of many of these compounds into a very small portion of the phase diagram. A preliminary diagram for this system is presented at this time.

Phase data on this system and its analog $\text{Na}_2\text{O}-\text{MgO}-\text{SiO}_2$ are necessary before proceeding to studies of more complex systems which may help us to determine the relationships between alkaline pyroxenes and amphiboles which are important constituents of some of the alkaline rocks and minor mineral constituents of many igneous rocks.

VOLCANIC ROCKS OF SAIPAN, MARIANA ISLANDS*

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The Mariana Islands are divisible into two separate chains—the Southern Marianas, which include Saipan, aligned along an eastern arc and consisting of Tertiary volcanic rocks and limestones; and the northern Marianas, forming a western arc of Quaternary volcanoes.

The volcanic rocks of Saipan consist of dacitic and andesitic flows and pyroclastic rock of Eocene and probable Oligocene age. The dacites are composed primarily of silicic glass, oligoclase, silica minerals, and magnetite. The andesites are composed principally of labradorite, hypersthene, augite, magnetite, silica minerals, and anorthoclase. Chemically, the rocks are characterized by a high content of silica and alumina and a low content of potash. Quartz is universally present in the norm, attaining as much as 49 per cent in the dacites. The andesites are extremely calcic and contain a large excess of lime over alkalis.

The andesites and dacites of Saipan generally bear a close compositional resemblance to volcanic rocks of other islands in the system of arcs extending from Japan to Palau. Apparently the bulk of the volcanic rocks in this region form a well-defined petrographic province.

It is difficult to reconcile the andesitic and dacitic rocks with simple differentiation of a primary basaltic magma. Providing they are related to ancestral basaltic rocks, it seems necessary to assume assimilation of important amounts of siliceous and aluminous crustal material to account for their composition. The absence of basalts on Saipan and the wide compositional gap between the andesites and dacites may indicate that the andesitic and dacitic magmas originated independently.

MINERALOGICAL MAGIC NUMBERS

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Axial ratios c/a in the proportions 2, 3, 4, 15, 6, 21, 8, . . . , recorded for one dimensional isomorphous series such as the rare earth carbonates and iron sulfate hydrates, and

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

for one dimensional polymorphs such as silicon carbide and zinc sulfide, can be explained by a superlattice principle of general applicability. Each of the axial ratio numbers represents the number of layers in the unit cell of a particular phase. The smaller layer numbers of the isomorphs occur at simple stoichiometric ratios of the end-member components. The smaller layer numbers of the polymorphs occur at simple stoichiometric ratios of the end-member structural arrangements. Choice of stoichiometric ratio is a function of temperature. Given a fixed stoichiometric ratio, summation of interaction potentials between layers shows that an orderly distribution of the two types of layers minimizes the potential. Superlattices result from ordering. The "magic numbers" remain, even with compositional departure from simple stoichiometric proportions, because of the higher entropy of the simple ratios. From this point of view, complete isomorphism or a continuous series is possible only with disequilibrium. At equilibrium, the stable phases form a discontinuous or discrete series.

**CHEMICAL EVIDENCE OF POSSIBLE GRANITIZATION OF THE FORDHAM GNEISS,
NEW YORK**

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Evidence of a possible granitization origin for the Poundridge granite, Westchester County, New York, is afforded by calculations of Barth's standard rock cell. Since there is no evidence of any expansion in the migmatite, a comparison of the standard cells of the Fordham gneiss and the migmatite gives an accurate picture of the exchange of cations which produced the migmatite by metasomatism of the gneiss.

Cations added	Cations subtracted
4.3 Si	.1 Ti
2.8 K	1.5 Al
<hr style="width: 20%; margin-left: 0;"/>	1.2 Fe ³⁺
7.1 Cations representing	2.0 Fe ²⁺
20 valences	1.0 Mg
	2.1 Ca
	.6 Na
	.6 H
	<hr style="width: 20%; margin-left: 0;"/>
	9.1 Cations representing
	20 valences

A similar comparison of the migmatite and Poundridge granite indicates that the following exchange could have produced the granite.

Cations added	Cations subtracted
5.6 Si	.2 Ti
.1 Fe ³⁺	4.4 Al
1.1 K	.9 Fe ²⁺
<hr style="width: 20%; margin-left: 0;"/>	1.3 Mg
6.8 Cations representing	1.3 Ca
23.4 valences	1.3 Na
	1.2 H
	<hr style="width: 20%; margin-left: 0;"/>
	10.6 Cations representing
	23.5 valences

The very similar pattern of the two exchanges shows that the granite could well have been a product of the same metasomatic process which produced the migmatite. The difficulty in assuming the migmatite to be the result of the simple addition of silicon and potassium from a granite magma lies in accounting for the lost ions removed from the gneiss. There is nothing inconsistent in the composition of the Fordham gneiss to destroy the possibility that these ions were displaced outward into the surrounding gneiss. It is also possible that they became concentrated in the ubiquitous amphibolite layers which characterize the gneiss.

SYNTHESIS AND ATOMIC STRUCTURE OF LORENZENITE

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Lorenzenite is the name of the naturally occurring compound $\text{Na}_2\text{Ti}_2\text{Si}_2\text{O}_3$ in which ZrO_2 may substitute for TiO_2 to the extent of nearly 12% ZrO_2 by weight.

Synthesis of lorenzenite has been previously reported. This synthesis cannot be repeated and it is shown here that rutile was mistaken for lorenzenite in this early report. A successful and reproducible synthesis from systems containing fluorine is described in this paper. The indices of refraction and the x-ray diffraction pattern of the synthetic lorenzenite confirm the synthesis.

The space group of lorenzenite has been reported as $D_{2h}^{14}\text{-Pbcn}$ with a_0 —14.51 Å, b_0 —8.73 Å, and c_0 —5.22 Å. This space group has been redetermined and confirmed using Weissenberg photographs. However, the orientation is found to be a_0 —8.66 Å, b_0 —5.18 Å, and c_0 —14.42 Å. There are four molecules of composition $\text{Na}_2\text{Ti}_2\text{Si}_2\text{O}_3$ in the unit cell.

The atomic coordination scheme of lorenzenite has been deduced with sufficient accuracy that refinement by the use of Fourier or Patterson series would be relatively easy should such refinement become desirable. The structure consists of chains of titanium octahedra, similar to those in brookite, in parallel coordination with chains of silicon tetrahedra, similar to those in the pyroxenes. The growth habits, physical properties and diffraction intensities are in accord with this preliminary structure for lorenzenite.

ISOTOPIC COMPOSITION OF CARBON IN PETROLEUMS AND OTHER ORGANIC CONSTITUENTS OF SEDIMENTS

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$\text{C}^{13}/\text{C}^{12}$ ratios of petroleum and other organic sedimentary constituents vary by more than three per cent. C^{13} content of organic carbon occurring in nonmarine deposits is appreciably lower than that of organic carbon associated with marine sediments. This difference may be due to inherent differences in source materials because fresh water plants and land plants contain less C^{13} than do marine plants and animals.

Variations in carbon isotope abundances in petroleum are related also to petroleum composition. Paraffinic and naphthenic constituents separated in the laboratory from a California crude oil are low in C^{13} content, whereas aromatic constituents are enriched in C^{13} relative to the C^{13} content of the total crude oil.

FORM AND MODE OF EMPLACEMENT OF SILLS IN THE ELKHORN MOUNTAINS, MONTANA

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Sills are abundant in the Late Cretaceous, pre-Boulder Batholith intrusive sequence in the Elkhorn Mountains in west central Montana. They comprise basalt, lamprophyre, andesite, diorite, and granodiorite—with andesite and basalt prevailing—and are as much as 2,000 feet thick.

In strata of Belt and Paleozoic age, true sills are most abundant; injection dilation is the important mechanism of emplacement and enclosing shales are often contorted. In Cretaceous sedimentary rocks, intrusives tend to have concordant bases but partly discordant tops with irregular upwellings and dike offshoots. Injection dilation was accompanied or followed by stoping and assimilation along the top.

In Upper Cretaceous volcanic rocks, sills occur largely as apophyses of larger plutons, are wedge shaped and commonly divergent by forking or changing intrusion horizon. Depth of cover was slight.

In pre-volcanic rock strata, argillaceous horizons were preferred; in the volcanic rocks, true sills abound in bedded water-laid volcanic mudstones and siltstones, and welded tuffs. In coarser, poorly bedded pyroclastics, diverging sills prevail; in volcanic breccias, sills have gradational, ill-defined contacts masked by country-rock recrystallization and local assimilation.

A unique sill type in some water-laid bedded volcanic sedimentary rocks exhibits intimate mixing of country-rock with thick marginal zones of amygdaloidal igneous rock, each retaining its own characteristics even on a microscopic scale. Observations of dike offshoots from the basal amygdaloidal zone cutting through the sill support the hypothesis that these zones acquired water from moist semi-consolidated sediments, enabling them to remain mobile. Assimilation was very slight and the roof gently deformed.

ORIGINAL RADIOGENIC LEAD, AN ADDITIONAL CORRECTION FOR LEAD-URANIUM AND LEAD-LEAD AGE CALCULATIONS

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The age of uranium ore minerals can be determined from the Pb^{206}/U^{238} , Pb^{207}/U^{235} , and Pb^{207}/Pb^{206} ratios. In general the following sequence of ages results: Pb^{206}/U^{238} youngest, Pb^{207}/U^{235} slightly older, and Pb^{207}/Pb^{206} much older than both lead-uranium ages. Wickman has attributed this sequence of ages to the much greater loss of radon compared to actinon, gaseous daughter products in the U^{238} and U^{235} series, respectively. Some investigators prefer the Pb^{207}/U^{235} age because it is essentially unaffected by loss of actinon.

Possible alteration and the loss of uranium or lead, or both, have led some recent investigators to choose the Pb^{207}/Pb^{206} age. This age calculation should be satisfactory if corrections for radon loss, original lead, and mass spectrometric errors are small.

Kovarik and others have mentioned that the absence of original radiogenic lead is a necessary condition for satisfactory age determinations. Recent studies on lead minerals and uranium ores from the Colorado Plateau province have shown that these uranium ores contain at least two generations of radiogenic lead: original radiogenic lead deposited with the uranium and radiogenic lead formed after deposition by the decay of the uranium. The correction of Plateau uranium ores with the average isotopic composition of Plateau lead minerals still results in a large discrepancy between Pb^{206}/U^{238} and Pb^{207}/Pb^{206} ages. Added corrections for the isotopic composition of the original radiogenic lead, which has also been

found in certain Colorado Plateau province lead minerals, bring the Pb^{206}/U^{238} , Pb^{207}/U^{235} , and Pb^{207}/Pb^{206} ages into agreement within limits of experimental error.

RADIOCARBON MEASUREMENTS AT THE U. S. GEOLOGICAL SURVEY

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During the past year a method for C^{14} determination has been developed and applied at the Geological Survey in Washington. Employing acetylene as a counting gas, the method extends the age limit for radiocarbon dates to almost 40,000 years. So far, about 100 dates have been obtained by this method. Our main object has been the dating of pre-Mankato material and the establishing of an absolute time scale for glacial events in the later part of the Wisconsin age. The results show for example that a major glacial advance took place in North America about 20,000 years ago, penetrating in certain areas farther south than any previous glacier in the Wisconsin age.

Further investigations were made on general questions such as the suitability of carbonate samples for dating.

GEOCHEMICAL ASPECT OF THE VOLCANIC ROCKS OF CIENEGA, NEW MEXICO*

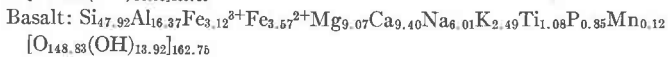
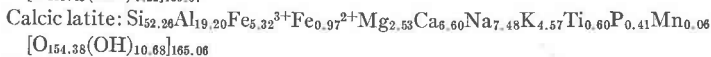
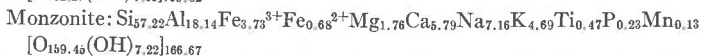
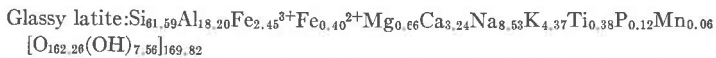
MING-SHAN SUN AND BREWSTER BALDWIN

New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico

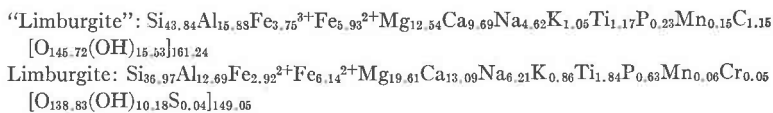
Six main volcanic units occur at Cienega, 15 miles southwest of Santa Fe, N. M. Andesite breccia, resting on late Eocene Galisteo formation, was domed by monzonite, which in turn was eroded and buried by calcic and glassy latite breccia and Cieneguilla limburgite. Pleistocene gravel and basalt bevel this sequence.

Refractive indices of 80 fused samples, ranging from 1.525 to 1.646, reflect the silica content, ranging from 69.04% to 38.99%. Spectrographic analyses show that nickel, vanadium, and chromium vary inversely with silica content.

The rock standard cells, derived from complete chemical analyses by methods of Barth and Eskola, are presented in the following modified Holmquist chemical formulae:



* Publication authorized by the Director, New Mexico Bureau of Mines and Mineral Resources.



The total number of anions, including hydroxyl and non-oxygenous anions such as sulphur, is directly proportional to cation number of Si. The number of Ti increases with decrease of Si.

ARDENNITE FROM THE GRANTS URANIUM DISTRICT, NEW MEXICO*

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Ardennite, a hydrous silicate of manganese, aluminum, and vanadium, has been found as a rare associate of Plateau-type uranium minerals about 20 miles northwest of Grants, New Mexico. The mineral occurs as rosettes of tapered, acicular crystals that coat a nearly vertical joint surface in Jurassic Todilto limestone. Recrystallized calcite underlies, and is partly intergrown with the ardennite rosettes. Cuprosklodowskite occurs as sparse, small flecks on ardennite.

Rosettes about 2.8 mm. in diameter consist of radially disposed prismatic crystals approximately 0.3 mm. (*a*-axis) \times 0.07 (*b*-axis) \times 1.3 mm. (*c*-axis). *b*-faces are especially prominent in a few crystals. Cleavage is 010 perfect, and 110 distinct. Color black. Streak brown. Luster subadamantine. Very brittle. Pleochroism dark reddish brown to yellowish brown, with absorption $X > Y > Z$. $X = c$. $\alpha = 2.01$ by immersion method. Dispersion distinct. Readily fusible in alcohol flame to a dull black bead.

X-ray analyses by both Laue and rotation methods indicate an orthorhombic symmetry, with cell dimensions: $a_0 = 9.201 \text{ \AA}$, $b_0 = 30.023 \text{ \AA}$, $c_0 = 6.280 \text{ \AA}$. Previous data by Gossner and Strunz gave: $a = 18.56 \text{ \AA}$, $b = 5.83 \text{ \AA}$, $c = 8.72 \text{ \AA}$.

Major constituents, determined by spectrographic methods, are Mn, Al, V, Fe, and Si. Minor constituents are Ca 0.1–1.0%, Na trace, Co 200 ppm, Ni 20 ppm, Ba 100 ppm, Sr 300 ppm, and Pb 100 ppm.

ISOTOPIC COMPOSITION OF LEAD IN OLIVINE BOMBS

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Two laboratories have conducted independent studies of the isotopic composition of lead in three olivine bombs of Quaternary age. Diopside separated from a bomb from Dreiser Weiher, Germany, contained 2 parts per million lead with an isotopic composition of $206/204 = 19.5$, $207/204 = 15.5$, $208/204 = 39.7$. The uranium content of the diopside was determined by isotope dilution to be 0.0067 parts per million. Lead in the diopside of

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a second bomb from San Bernardino, California, had a concentration of 2 parts per million and an isotopic composition almost identical with that of the Dreiser Weiher bomb. An olivine bomb from the western branch of the 1800 flow, Hualalai Volcano, Hawaii, contained 1 part per million lead in the composite bomb with an isotopic composition of $206/204=19.29$, $207/204=15.45$, $208/204=37.95$.

These data indicate that the lead in the bombs has spent most of its past history in an environment with a much higher ratio of uranium to lead than that found in the bombs today. The uranium now in the diopside of the Dreiser Weiher bomb would have changed the 206/204 ratio of its lead by only 0.7 per cent in the past 4.5 billion years. Because of this evidence of extreme differentiation, we believe that the bombs may not be representative of the chemical composition of their source materials.

The leads in all three bombs show abnormally high 206/204 ratios relative to their respective 207/204 ratios when compared to the average young ore lead. This could be explained as contamination by young, or lately formed radiogenic lead, although it is difficult to envisage a mechanism for such a process.

SYNTHESIS OF THE HUMITES

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The humites are neosilicates of magnesium containing fluorine and hydroxyls. Their general formula is expressed as $n\text{Mg}_2\text{SiO}_4 \cdot \text{Mg}(\text{F}, \text{OH})_2$ in which $n=1$, norbergite, 2 chondrodite, 3 humite and 4, clinohumite. Fluorine end members have been synthesized from melts and solid state reactions. No success was obtained in synthesizing compositions where n was greater than 4 or less than 1. The humite synthesis using hydrothermal techniques has been accomplished and partial substitution of OH for F has been achieved. No completely hydroxyl end member of the series has been synthesized and it is concluded that none exists. Data based on phase determinations using quench techniques indicate the fluorine end members are an incongruent melting series. The optical constants of the fluorine end members are:

	α	β	γ	2V
Norbergite	1.548	1.552	1.570	33°
Chondrodite	1.582	1.594	1.612	50°
Humite	1.598	1.606	1.630	59°
Clinohumite	1.608	1.618	1.636	76°

The x-ray powder data of the synthetic humites agrees well with the recent published work on natural humites by T. G. Sahama.

WALLROCK ALTERATION IN THE BROKEN HILLS RANGE, NEVADA

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Investigation of a "talc" deposit which gave high Al_2O_3 analyses showed considerable quantities of associated sericite and chlorite. The deposit occurs north of Gabbs, Nevada, in the Broken Hills range, and is the result of wallrock alteration of a rhyolite porphyry along a vertical fissure.

Chemical analyses show an increase of MgO and a correlative decrease of SiO_2 , Al_2O_3 , K_2O and Na_2O across the alteration zone towards the fissure. Thin section study shows an

orderly selective replacement of biotite, feldspars and quartz in the host rhyolite. Introduced minerals are sericite, green chlorite flakes, sericite (second stage), talc, tourmaline and chlorite in fine-grained aggregates.

Alteration was the result of MgO-bearing hydrothermal solutions moving upwards along the fissure and outwards into the wallrock. With the exception of tourmaline, the alteration minerals are built up of certain layer type lattice units. The formation of any of the above alteration minerals reflects the availability of the proper basic layer lattice unit at that particular time. Some of the necessary basic layer lattice units became available during the process of destruction of the host minerals; others, particularly the brucite lattice were formed from components introduced in solution. The more mobile elements (Na_2O , K_2O) were removed in solution.

POSSIBLE REACTION AND EUTECTIC RELATIONS BETWEEN NATURALLY OCCURRING FELDSPARS FROM THE JUDITH MOUNTAINS, MONTANA*

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Rocks containing two primary alkali feldspars are rare. Recent investigations by Bowen and Tuttle of the system $\text{NaAlSi}_3\text{O}_8$ - KAlSi_3O_8 - H_2O indicate that the alkali feldspars form mixed crystals at high temperatures (in anhydrous melts), but that a sufficient pressure of water vapor will depress the solidus-liquidus curves below the solvus and result in the formation of two feldspars, first by a reaction relation, and, at still higher pressures and lower temperatures, by a eutectic relation.

Vesicular and brecciated textures of intrusive alkali syenite, alkali rhyolite, and tinguaitite breccia suggest that their corresponding magmas contained abundant volatiles. Albite, An_5 , phenocrysts with reaction rims of potash feldspar suggest that the volatile content depressed the crystallization temperature of the feldspars to the reaction point.

Exceptionally large doubly-terminated crystals of quartz in an alkali granite porphyry stock on Judith Peak are, in spite of their habit, probably low quartz and suggest growth in a fluid magma at a relatively low temperature. Silicification of the wall rock and granitization of sedimentary rock inclusions indicate an exceptionally high concentration of volatiles. Textural and size relationships of both sanidine and albite, An_3 , crystals in an early fine-grained facies of the alkali granite and a later coarse-grained facies suggest simultaneous growth of both feldspars and implies a eutectic relation.

The relationship of these feldspars may illustrate in magmas both the reaction and eutectic relations between the alkali feldspars postulated by Bowen and Tuttle on the basis of their laboratory investigation of hydrous melts.

$\text{A}^{40}\text{-K}^{40}$ DATING METHOD

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The radiogenic argon content of several potassium feldspars of known lead-uranium age has been determined using an isotopic dilution technique. Using a branching ratio of 0.085 and a decay constant of $\lambda = 0.55 \times 10^{-9} \text{y}^{-1}$, it was found that the calculated $\text{A}^{40}/\text{K}^{40}$ ages could be brought into agreement with the Pb-U ages within 6%. The good agreement

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

which was obtained for different samples ranging in age from 260 million to 1,000 million years indicates no serious loss of argon by diffusion in feldspars.

The A^{40}/K^{40} age of a sample of Beardsley meteorite, a gray chondrite, has been determined. The value obtained was 4.8×10^9 years using the above listed constants. The determination of potassium in Beardsley was made using an isotopic dilution technique with K^{41} tracer obtained from Oak Ridge. The material was analyzed using a surface ionization technique.

X-RAY DIFFRACTOMETER THERMAL STUDIES OF CLAY-MINERAL DEHYDROXYLATION

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With an oscillation-heating x-ray diffraction technique the position and intensity of an x-ray diffraction maximum may be followed continuously while a powdered sample is heated at a regular rate of temperature rise (5° C. per minute). The sample is sedimented on a platinum slide mounted in a furnace designed to fit the horizontal shaft of the North American Phillips x-ray Diffractometer. The diffractometer is set with the maximum to be followed at the center of a one-half degree 2θ oscillation. After heating and oscillating the tops of the recorded series of peaks indicate position and intensity. The bottoms represent the background which is very sensitive to position changes.

Typical oscillation-heating patterns of basal spacing maxima for Georgia kaolinite, a Vermont chlorite, a clinochlore, and sheridanite are presented. The kaolinite (001) remains constant at 12.5 2θ until it collapses at 525° C. The chlorites (002) shift from 12.51° 2θ to 12.47° 2θ and begin to collapse simultaneously with the intensity increase of the (001).

Sheridanite (001) increases abruptly at 525° C. and collapses at 750° C. after shifting from 6.28° to 6.49° 2θ . Clinochlore follows a similar pattern. The (002) collapses abruptly at 525° C. Vermont chlorite (001) begins the intensity increase at 500° C., is greatest at 640° C., begins to collapse at 740° C. and is collapsed at 810° C. after shifting from 6.28° 2θ to 6.52° 2θ . The (002) collapse begins at 500° C. and is complete at 810° C. These differences may be related to the iron content of the brucite layer.

HARDNESS DETERMINATIONS ON SILICON, GERMANIUM, AND THE III-V COMPOUNDS

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Micro-indentation hardness measurements have been made on certain substances with diamond and sphalerite type structures using a Knoop type diamond indenter. The investigation, performed mainly on {111} planes (or $\{1\bar{1}1\}$ planes), showed differences in hardness for different directions and, to a lesser extent, for different areas. Since the hardness varied slightly for identical crystallographic directions and localized areas, the data were evaluated statistically. The plots of the indentation values for all substances investigated gave straight lines on probability paper. This indicates a normal Gaussian distribution of the data. The Knoop hardness values, derived from $H = CL/l^2$ (C-constant, L-load applied to indenter, l-length of indentation), range from 83 to 190 (Mohs values from $2\frac{1}{2}$ to 5) for the III-V compounds (InSb, InAs, InP, GaSb, GaAs, GaP, AlSb, AlAs), and from 268 to 547 (Mohs values from $4\frac{1}{2}$ to 6) for germanium and silicon. These values are roughly proportional to r^{-8} , where r is the inter-atomic distance.

ALMANDITE GARNET STABILITY RANGE

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The upper thermal stability limit of almandite garnet, $\text{Fe}_3\text{Al}_2\text{Si}_3\text{O}_{12}$, has been determined up to 10,000 bars water vapor pressure. The univariant equilibrium curve for the reaction



passes through the points 1030° C.—10,000 bars; 980° C.—8000 bars; 930° C.—6000 bars; 880° C.—4000 bars; and 830° C.—2000 bars. A projection of this curve indicates that almandite would be stable below 785° C. at atmospheric pressure.

The synthetic almandite crystals are cinnamon brown in color and exhibit the dodecahedral and icositetrahedral forms usually, and the cube and octahedron rarely. They are optically isotropic with $n = 1.830 \pm 0.003$ in sodium light. The powder x -ray diffraction pattern is identical with that of a natural almandite close to the ideal composition and has $a_c = 11.53 \pm 0.01 \text{ \AA}$.

Growth is obtained from glass ($n = 1.662$) of the requisite composition and a mix consisting of ferrous oxalate dihydrate, gamma alumina, and silica glass. Complete reaction is obtained in less than two hours at the highest pressures and temperatures, and the rate of reaction falls off rapidly below 7000 bars to nil at 1000 bars. Oxidation of the breakdown products to magnetite+quartz+hercynite, magnetite+iron—cordierite+hercynite, or to magnetite+quartz+corundum is common.

The occurrence of almandite in the metamorphic rocks as well as in some igneous rocks is accounted for by the character of the stability curve. The behavior of these garnets in the "wet" and "dry" contact aureoles can also be interpreted from the experimental data.

FACTORS INFLUENCING THE ARTIFICIAL PRECIPITATION OF CALCIUM CARBONATE

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Aragonite, calcite, and vaterite have been precipitated under conditions of controlled temperature, pH, and impurity ion concentration. Results from x -ray diffraction studies, spectrographic analysis, microscopic examination, and thermoluminescence studies have provided information regarding the extent to which these three factors effect the formation of the various crystalline forms. CaCO_3 precipitates were made from dilute solutions of $\text{Ca}(\text{NO}_3)_2$ by the controlled addition of dilute Na_2CO_3 .

Employing this method of precipitation, high pH, high concentrations of Pb^{++} , Sr^{++} , Ba^{++} , low concentrations of Mg^{++} , and a temperature range from 50° to 65° C. appear to favor aragonite formation. However, aragonite was produced at temperatures outside this favorable range when conditions of high pH and favorable impurity concentration existed. Calcite and vaterite have been obtained throughout a wide temperature range. Calcite formation is favored by a lower pH, low concentrations of Pb^{++} , Sr^{++} , Ba^{++} , and high concentrations of Mg^{++} . pH and impurity effects cannot easily be correlated directly with the synthesis of vaterite.

pH and impurity effects are closely related and appear to be significant factors influencing the crystalline form of CaCO_3 . Temperature influences the crystalline form of the precipitate primarily through its effects upon pH and the solubility of the impurity ions. The conclusion that impurities are the controlling factors determining the crystalline form of CaCO_3 under conditions of constant temperature is supported by evidence obtained from spectrographic studies of natural cave formations.