PROCEEDINGS OF THE THIRTY-FOURTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA AT TORONTO, CANADA

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

The thirty-fourth annual meeting of the Society was held on November 9–11, 1953, at the Royal York Hotel, Toronto, Canada. Scientific sessions were held in the morning and afternoon of November 9th and 11th, and in the afternoon of November 10th, at which 83 papers were presented orally. In order to accommodate such a large number of papers two concurrent sessions were held on two occasions.

The annual luncheon of the Society on November 10th was attended by 185 fellows, members and guests. Following the luncheon the twelfth presentation of the Roebling Medal was made to William F. Foshag, and the third presentation of the Mineralogical Society of America Award was made to Louis H. Ahrens. This time was also the occasion of the presentation of the November-December issue of *The American Mineralogist* to Dr. Waldemar T. Schaller and Dr. Clarence S. Ross. This enlarged issue was dedicated to Drs. Schaller and Ross and contained 34 scientific papers written by their friends and colleagues on the U. S. Geological Survey.

Before the beginning of the scientific session on the afternoon of November 10th the Society was addressed by the Retiring President, J. D. H. Donnay, on *Edifices of Periodic Matter.*

The 1953 Council of the Society met for 8 hours during November 8th and 9th and discussed 20 items of business. The 1954 Council met for 4 hours on November 10th and 11th.

Recommended Amendment to the Constitution. When the Constitution was adopted in 1920 there were 48 fellows of the Society. Thus with 6 officers and 4 councilors at large a high percentage of the fellowship was represented on the Council. Through the years the fellowship has gradually increased until in 1953 there were 326 fellows, but the number on the Council has remained the same. In order to bring about a larger representation, the 1954 Council recommends the following amendment to the Constitution of the Society:

ARTICLE III, SECTION 1*

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.

* Deletions are indicated by brackets and additions by italics.

COMMITTEES OF THE MINERALOGICAL SOCIETY OF AMERICA FOR 1954

Financial Advisory Committee
J. P. Marble '54
E. P. Henderson, *Chairman* '54–'55
R. E. Fuller '54–'56

Auditing Committee
J. J. Fahey, *Chairman*
H. F. McMurdie
W. L. Hill

Nominating Committee for Officers
V. T. Allen, *Chairman*
R. C. Emmons
E. H. Kraus

T. N. McVay
J. R. Goldsmith

Nominating Committee for Fellows
A. F. Buddington '54
H. Insley '54
J. T. Lonsdale, *Chairman* '54–'55
R. B. Ferguson '54–'55
T. F. Bates '54–'56
J. J. Runner '54–'56

Roebling Medal Committee
J. W. Gruner, *Chairman*
R. E. Grim
L. G. Berry

Mineralogical Society of America
 Award Committee

F. J. Turner, *Chairman*
D. J. Fisher
J. E. Hawley
H. W. Fairbairn
J. Murdoch

Nomenclature Committee

C. Frondel, *Chairman* '54
W. F. Bradley '54
A. L. Howland '54–'55
E. W. Nuffield '54–'55
G. T. Faust '54–'56
G. Tunell '54–'56

Publications Committee

A. F. Buddington, *Chairman* '54
L. S. Ramsdell '54
F. A. Bannister '54–'55
A. Pabst '54–'55

N. L. Bowen '54–'56
O. F. Tuttle '54–'56

Board of Associate Editors

M. Fleischer '54
G. Tunell '54
A. Pabst '54–'55
E. F. Osborn '54–'55
Ian Campbell '54–'56
Brian Mason '54–'56

Representatives

National Research Council
 J. W. Peoples
American Geological Institute
 J. P. Marble '54
 E. Ingerson '54–'55
American Association for the Advancement of Science
 C. S. Hurlbut, Jr.

It should be pointed out that the Roebling Medal Committee, the Mineralogical Society of America Award Committee, the Nominating Committee for Officers, and the Nomination Committee for Fellows make recommendations, but the Council is responsible for final choice. In order to have a larger participation in the affairs of the Society, fellows and members are requested to send to the Secretary suggestions for candidates for Awards and for officers and fellows.

REPORT OF THE SECRETARY

To the Council of the Mineralogical Society of America:

ELECTION OF OFFICERS AND FELLOWS

Five hundred and fourteen ballots were cast in the election of officers: 156 by fellows and 358 by members of the Society. The officers elected to serve in 1954 are:

President: Sterling B. Hendricks, Bureau of Plant Industry, U. S. Department of Agriculture, Beltsville, Maryland.

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

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 (1954–57): Felix Chayes, Geophysical Laboratory, Washington, D.C.

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

Carl Wellington Beck, University of New Mexico, Albuquerque, New Mexico.

Conrad Burri, Swiss Federal Institute of Technology, Zürich, Switzerland.

Charles Louis Christ, U. S. Geological Survey, Washington, D.C.

Ludmila M. M. Dolar-Mantuani, Hydro Electrical Power Commission of Ontario, Toronto, Canada.

Alfred Joseph Frueh, Jr., University of Chicago, Chicago, Illinois.

Paolo Gallitelli, Istituto di Mineralogia della Università, Modena, Italy.

John Cedric Griffiths, Pennsylvania State College, State College, Pennsylvania.

Norman Fordyce McKerron Henry, University of Cambridge, Cambridge, England.

Riad A. Higazy, University of Cambridge, Cambridge, England.

S. Benedict Levin, Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey.

Dan McLachlan, Jr., University of Utah, Salt Lake City, Utah.
Heinz Meixner, Bergdirektion Hüttenberg, Knappenberg, Kärnten, Austria.
Mary E. Mrose, U. S. Geological Survey, Washington, D.C.
Hans Ramberg, Prinsensgata 6a, Trondheim, Norway.
Arthur James Cochran Wilson, University College, Cardiff, Wales

CHANGE IN THE BY-LAWS

On the recent ballot, fellows and members were asked to vote on the following proposed change in Article IV, Section 1 of the By-Laws of the Society:

From

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

To

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

This change was approved by a vote of 454 in the affirmative with 31 in the negative. It should be pointed out that nominations made by any 10 fellows or members will be indistinguishable on the ballot from nominations made by the Council. However, only *fellows* can be nominated for office.

MEMBERSHIP STATISTICS
November 1, 1953

	1952	1953	Gain	Loss
Correspondents	5	4	0	1
Fellows	315	326	15	4
Members	814	857	87	44
Subscribers	799	856	108	51
	1933	2043	210	100

The above figures show a net gain of 11 fellows, 43 members, and 57 subscribers, with a loss of 1 correspondent. Considering the four groups together, there is a gain of 110, giving a total of 2043.

The Society lost through death one of its five correspondents, Paul Niggli of Zürich, Switzerland, the 1947 recipient of the Roebling Medal, and four fellows: Albert A. Klein of the Norton Company, Worcester, Massachusetts; O. Ivan Lee of Jersey City, New Jersey; Ralph L. Rutherford of the University of Alberta, Alberta, Canada; and Frederick E. Wright of Washington, D. C., the 1952 recipient of the Roebling Medal.

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

REPORT OF THE TREASURER FOR 1953

To the Council of the Mineralogical Society of America:

Your Treasurer submits herewith his report for the fiscal year beginning August 1, 1952, and ending July 31, 1953.

RECEIPTS

Dues and subscriptions	$ 8,323.52
Sale of back numbers	1,886.63
Authors' charges on reprints	1,190.12
Interest and dividends from endowment	4,612.76
Geological Society of America aid for printing the Journal	7,845.07
Advertising	1,278.18
Sale of Index, volumes 21–30	43.10
Sale of Index, volumes 1–20	7.00
Aid by author on expense of a paper	305.54
Contribution	2.63
Contributions toward Ross-Schaller volume	1,133.00
	$26,627.55
Cash on hand, August 1, 1952	3,366.37
	$29,993.92

DISBURSEMENTS

Printing and distribution of the Journal (6 issues)	$16,871.99
Printing and distribution of reprints	1,407.31
To the Editor, Secretary, and Treasurer	1,437.50
Clerical assistance	751.25
Postage and express	326.39
Printing and stationery	252.55
Office supplies and equipment	12.90
1952 program and abstracts	611.39
Roebling Medal	139.32
New securities purchased	402.73
Committee expenses	5.41
Expenses of officers to 1952 meetings	111.30
Safety deposit box	7.80
Refunds	49.55
Check returned	4.00
Telephone and telegraph	.81
M. S. A. Award certificate	7.50
Reprinting back issue	517.95
	$22,917.65
Cash on hand, July 31, 1953	7,076.27
	$29,993.92

The endowment funds of the Society as of July 31, 1953, 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	5,743.75

$15,301.25

PREFERRED STOCKS

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

$29,491.49

COMMON STOCKS

300 shares, Potomac Electric Power	$4,057.73
200 shares, Greyhound Corporation	2,300.00
150 shares, Spencer Kellog	3,775.00
100 shares, Columbus & Southern Ohio Electric	2,087.50
80 shares, Kroger	1,990.00
60 shares, United Fruit	3,067.50
56 shares, Standard Oil of New Jersey	1,444.84
53 shares, American Telephone & Telegraph	7,243.32
50 shares, Chesapeake & Ohio	2,368.75
50 shares, Phelps Dodge	1,975.00
40 shares, Plymouth Cordage	2,050.00
30 shares, U. S. Playing Card	2,411.25

$34,770.89

$79,563.63

Respectfully submitted,
EARL INGERSON, *Treasurer*

DANA FUND

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

RECEIPTS

Available balance, August 1, 1952	$148.41
Interest	.72

$149.13

DISBURSEMENTS

Disbursed..	$ 50.00
Available balance, July 31, 1953.....................................	$ 99.13

$149.13

Respectfully submitted,
EARL INGERSON, *Treasurer*

REPORT OF THE AUDITING COMMITTEE

To the President of the Mineralogical Society of America:

The Auditing Committee has examined and verified the accounts of the Treasurer of the Mineralogical Society of America for the fiscal year beginning August 1, 1952, and ending July 31, 1953. 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,
ALVIN VAN VALKENBERG, JR.
SAMUEL ZERFOSS
HATTEN S. YODER, JR., *Chairman*

REPORT OF THE EDITOR FOR 1953

To the Council of the Mineralogical Society of America:

In presenting the annual editorial report for 1953 at this time, the same general policy will be followed as that used in recent years. With five issues published and distributed and the November-December number emerging from the press, 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 or not available at the present time will be incorporated so that the final printed report in April can be compared with those given for previous years.

As some of you may have surmised the volume this year will establish a new high level as far as size is concerned. This is due largely to the November-December issue now in press (Ross-Schaller number which contains 34 articles and will run slightly over 400 pages in length; making a total for the year of approximately 1285 pages. This exceeds the previous high mark of 1937 by nearly 100 pages. That volume as you may recall included the very large Palache number, appearing in May 1937. This accomplishment is a matter of great pride to all of us and especial credit is due to Dr. Earl Ingerson and his coworkers for assembling the papers for this special issue, reading proof and looking after many of the details connected with the printing of this number.

Beginning with 1949, by Council action, one issue (May-June number) was set aside for "Contributions to Canadian Mineralogy." This policy was continued in 1953 under the able editorship of Dr. L. G. Berry of 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 full responsibility for their selection and in seeing these contributions through the press. Also it should be recalled that the January-February issue was designated as a "Michigan number."

Thus by Council action 3 of the 6 issues for 1953 were earmarked for specific purposes. Naturally this has caused unusual delay of all papers, long and short, that did not fall within the framework of the purposes designated. I am aware that this may have caused

some slight irritation in certain quarters as the elapsed time between receipt and printing has increased to about a year, instead of the usual six to eight months.

However, it should be stated that the circumstances that caused the delay this year are not apt to occur again in the near future, at least not to the same extent. It is hoped that next year we will be able to return to a more normal and rational printing schedule. And in connection with the printing of our Journal, I believe the Banta Publishing Co. should be commended for their whole-hearted cooperation and their careful, efficient and prompt service in printing our publication. As an indication of this performance, recall the present November-December number which is more than twice the normal size and will be ready for distribution about 30 days before its regular printed schedule.

In summarizing the current volume, as indicated previously, the volume will run about 1285 pages (without index) and contain 93 leading articles. Twenty-three additional short papers, appearing under Notes and News, give an over-all total of 116 published manuscripts for the year. These contributions were received from 135 authors associated with 42 different Universities, research bureaus and technical laboratories. Twenty-three critical book reviews and 13 new minerals described in detail for the first time—faheyite, lipscombite, manganpyrosmaltite, hydrohausmannite, woodruffite, sahamalite, roentgenite, faustite, moraesite, burbankite, calkinsite, hidalgoite and montroseite—are a few of the other items of special mineralogical interest.

As in previous years our contributions were not confined to authors residing in the States. During the current year 22 manuscripts (out of 116) came from 6 countries: Australia, Brazil, Canada, Egypt, England and South Africa, indicating a continued broad service rendered by the Journal.

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOLUME 38

Subjects	Articles	Pages	Per Cent of Total
Leading articles*			
Descriptive mineralogy and paragenesis...	28		
Chemical mineralogy and geochemistry....	21		
Structural crystallography...............	21		
Petrography...........................	8		
Memorials.............................	4		
Miscellaneous.........................	11		
	93	1087	84.7
Shorter articles.........................	23	67	
Notes and news.........................	41	21	
Proceedings of Societies.................	5	88	15.3
Abstracts of new mineral names...........	2	1	
Book reviews...........................	23	20	
Total entries...........................	187	1284	100.0
Illustrations...........................	318		
Index, Title page, Table of contents........		25	
Grand total.............................		1309	

* Leading articles averaged 11.7 printed pages each.

This report would not be complete without an expression of deep appreciation for the liberal financial support received from the Geological Society of America toward defraying a substantial portion of the printing costs of the journal. Also the National Science Foundation made a liberal contribution to assist with the printing of the large Ross-Schaller number. For this assistance the Society is indeed grateful for without such aid services of necessity would have to be curtailed.

Following the favorable action by this Council, the editor has written the secretaries of the Mineralogical Societies of Great Britain, France, Switzerland, Germany and Italy suggesting an exchange of advertisements with the thought of stimulating greater interest and possibly resulting in an increase in membership. Sufficient time has not yet elapsed for replies to this suggestion.

And finally a word as to the prospects for 1954. From present indications no depression is in sight, although some recession from this year's top level may be expected. The January-February manuscripts containing 11 main articles and 6 shorter contributions are in the hands of the printer. In addition at the present writing there are on file 51 manuscripts aggregating an estimated 775 pages of typed material, 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 38.

Respectfully submitted,
W. F. HUNT, *Editor*

LIST OF FORMER OFFICERS AND MEETING PLACES

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

PRESIDENTS

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 E. 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

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. Roebling
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

TREASURERS

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

EDITORS

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

COUNCILORS

1920 Arthur S. Eakle, Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips.
1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.
1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.
1923 Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.
1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.
1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.
1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.
1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.
1928 William F. Foshag, William A. Tarr, Alexander N. Winchell, Ellis Thomson.
1929 William A. Tarr, Alexander N. Winchell, Ellis Thomson, Clarence S. Ross.
1930 Alexander N. Winchell, Ellis Thomson, Clarence S. Ross, Paul F. Kerr.
1931 Ellis Thomson, Clarence S. Ross, Paul F. Kerr, William S. Bayley.
1932 Clarence S. Ross, Paul F. Kerr, William S. Bayley, William J. McCaughey.
1933 Paul F. Kerr, William S. Bayley, William J. McCaughey, Kenneth K. Landes.
1934 William S. Bayley, William J. McCaughey, Kenneth K. Landes, E. P. Henderson.
1935 William J. McCaughey, Kenneth K. Landes, E. P. Henderson, J. F. Schairer.
1936 Kenneth K. Landes, E. P. Henderson, J. F. Schairer, Arthur F. Buddington.
1937 E. P. Henderson, J. F. Schairer, Arthur F. Buddington, Arthur P. Honess.
1938 J. F. Schairer, Arthur F. Buddington, Arthur P. Honess, R. C. Emmons.
1939 Arthur F. Buddington, Arthur P. Honess, R. C. Emmons, Carl Tolman.
1940 Arthur P. Honess, R. C. Emmons, Carl Tolman, D. Jerome Fisher.
1941 R. C. Emmons, Carl Tolman, D. Jerome Fisher, Martin A. Peacock.
1942 Carl Tolman, D. Jerome Fisher, Martin A. Peacock, Adolf Pabst.
1943 D. Jerome Fisher, Martin A. Peacock, Adolf Pabst, C. S. Hurlbut, Jr.

1944 Martin A. Peacock, Adolf Pabst, Michael Fleischer, S. J. Shand.
1945 Adolf Pabst, Michael Fleischer, S. J. Shand, R. E Grim.
1946 Michael Fleischer, S J. Shand, R. E. Grim, Joseph Murdoch.
1947 S. J. Shand, R. E. Grim, Joseph Murdoch, H. H. Hess.
1948 R. E. Grim, Joseph Murdoch, H. H. Hess, Clifford Frondel.
1949 Joseph Murdoch, H. H. Hess, Clifford Frondel, Lewis S. Ramsdell.
1950 H. H. Hess, Clifford Frondel, Lewis S. Ramsdell, E. F. Osborn.
1951 Clifford Frondel, Lewis S. Ramsdell, E. F. Osborn, George T. Faust.
1952 Lewis S. Ramsdell, E. F. Osborn, George T. Faust, Victor T. Allen.
1953 E. F. Osborn, George T. Faust, Victor T. Allen, C. Osborne Hutton

ANNUAL MEETING PLACES

1920 Chicago, Illinois
1921 Amherst, Massachusetts
1922 Ann Arbor, Michigan
1923 Washington, D. C.
1924 Ithaca, New York
1925 New Haven, Connecticut
1926 Madison, Wisconsin
1927 Cleveland, Ohio
1928 New York, N. Y.
1929 Washington, D. C.
1930 Toronto, Canada
1931 Tulsa, Oklahoma
1932 Cambridge, Massachusetts
1933 Chicago, Illinois
1934 Rochester, New York
1935 New York, N. Y.
1936 Cincinnati, Ohio

1937 Washington, D. C.
1938 New York, N. Y.
1939 Minneapolis, Minnesota
1940 Austin, Texas
1941 Boston, Massachusetts
1942 No meeting held
1943 No meeting held
1944 No meeting held
1945 Pittsburgh, Pennsylvania
1946 Chicago, Illinois
1947 Ottawa, Canada
1948 New York, N. Y.
1949 El Paso, Texas
1950 Washington, D. C.
1951 Detroit, Michigan
1952 Boston, Mass.
1953 Toronto, Canada

RECIPIENTS OF THE ROEBLING MEDAL

Charles Palache, December 1937
Waldemar T. Schaller, December 1938
Leonard James Spencer, December 1940
Esper S. Larsen, Jr., December 1941
Edward H. Kraus, February 1945
Clarence S. Ross, December 1946

Paul Niggli, December 1947
William Lawrence Bragg, November 1948
Herbert E. Merwin, November 1949
Norman L. Bowen, November 1950
Fred E. Wright, November 1952
William F. Foshag, November 1953

RECIPIENTS OF THE MINERALOGICAL SOCIETY OF AMERICA AWARD

Orville Frank Tuttle, November 1951   Frederick H. Stewart, November 1952
L. H. Ahrens, November 1953

ABSTRACTS OF PAPERS PRESENTED AT THE THIRTY-FOURTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA, NOV. 9-11, 1953

URANIUM CONTENT OF THE LAVAS OF LASSEN VOLCANIC NATIONAL PARK, WASHINGTON

JOHN A. S. ADAMS AND DONALD F. SAUNDERS

University of Wisconsin, Madison, Wisconsin

Nineteen samples of volcanic rocks from Lassen Volcanic National Park have been analyzed for U, Na, K and Ca. In addition, the alpha activities were measured with scintillometers. U and K correlate positively, indicating that both tend to be enriched as differentiation proceeded toward more silicious lavas. In the samples studied the U is enriched about four fold while the K is enriched about three fold. The correlations with Ca, Na, and total K + Na are less well defined than the K correlation. The correlation between K and alpha particle activity under standard conditions is rather well defined.

The correlation between alpha particle activity and U is not well defined when all samples are included. However, the samples that are furthest from the main trend may be considered special cases, e.g. mud flows and rocks that were probably partially weathered and thus leached of part of their U. The main trend in the U content vs. alpha particle activity indicates that the Th/U ratio did not shift significantly during the differentiation of the Lassen lavas.

URANIUM CONTENT, ALPHA PARTICLE ACTIVITY, AND K_2O, Na_2O, CaO ANALYSIS OF OBSIDIANS, PITCHSTONES, AND TEKTITES

JOHN A. S. ADAMS, DONALD F. SAUNDERS AND EDWARD J. ZELLER

University of Wisconsin, Madison, Wisconsin

Seventy-four glassy rocks, including obsidians, pitchstones, tektites, and possible tektites have been analyzed for uranium fluorimetrically. Alpha activities have been measured with scintillometers. K_2O, Na_2O, and CaO have been determined on the flame photometer. The indices of refraction have also been measured. About half of the samples are from the United States. The thermoluminescence of several samples was also measured, but no thermoluminescence was detected except in one obsidian from Ascension Island.

The uranium contents range from 0.77 ppm in an obsidian from Shizuoka Prefecture, Japan, to 16 ppm in an obsidian from Liparii, Italy. Few of these obsidians have as much as 0.50% CaO. A plot of alpha particle activity under standard conditions vs. uranium content has little scattering from linearity. This linearity indicates that the Th/U ratio is rather constant in the obsidians measured. Several geochemical interpretations of this linearity are advanced.

LOGNORMAL DISTRIBUTION OF THE ELEMENTS

L. H. AHRENS

Massachusetts Institute of Technology, Cambridge, Massachusetts

The statistical nature of the distribution of Li, K, Rb, Cs, Ga, Sc, V, Co, Cr, Cu, F, Pb, La and Zr in many specimens of two specific rock types, granite (New England

and Canada) and diabase (Ontario, Canada) has been examined. Distribution *appears* to be normal only when dispersion is small, as in the examples of Ga (granite and diabase) and Sc, V and Co (diabase only). Skewness, however, increases regularly with increase in the amount of dispersion and is extreme for Cr (granite and diabase) and Sc, V and Pb (granite only). All elements, irrespective of whether they have a small or large dispersion, show a distribution which is *lognormal*, or at least closely approaches it. An assumption of normal distribution leads to completely erroneous predictions about the prevalence of various concentrations of an element, if its dispersion is large—in fact, the occurrence of some granite with negative concentrations of V, Sc, Pb and Cr is predicted on the basis of such an assumption.

An element may show a totally different degree of dispersion in granite and diabase. For example, dispersion of Sc and V is small in diabase but extreme in granite; on the other hand dispersion of Rb and K is small in granite but moderately large in diabase.

These conclusions are based on quantitative spectrochemical determinations, each calibrated with standard rocks.

PHACOLITH OF CHARNOCKITIC ADAMELLITE PORPHYRY AT KEIMOES, CAPE PROVINCE, SOUTH AFRICA

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The charnockitic cycle separates the earlier Kheis orogeny from the numerous pegmatites found throughout the Archean of the northwest Cape, dated at 1,200 million years. The phacolith occupies 225 square miles and similar bodies are found elsewhere in the region. Slightly earlier dikes are basaltic and contain labradorite and bronzite phenocrysts and quartzitic xenoliths. Upon emplacement the charnockitic magma contained phenocrysts of andesine and orthopyroxene, blue quartz xenocrysts, and metasedimentary xenoliths. After emplacement augite, hornblende, biotite, clear quartz, titanomagnetite, and potash-soda feldspar crystallized. The magma apparently originated by deep seated contamination of a basaltic magma. Country rocks are psammitic metasediments with minor pelitic and cafemic intercalations, lenses of orthoamphibolite and metagabbro, and syntectonic lenses of tonalitic to granodioritic gneiss. Contacts with the charnockite are sharp when parallel to the foliation of the country rocks and the charnockite becomes finer grained toward such contacts. Crosscutting contacts are gradational. Migmatitic rocks are adamellite hybrids with charnockitic textures, permeation gneisses, and mixed rocks produced by intermingling of hybrid magma and mobilized country rocks. The magma was emplaced during compression of rigid folded strata, plastically deformed during the Kheis orogeny. After emplacement compression persisted, resulting in the production of compression joints in the charnockite. Differential movements along joints produced cataclastic deformation in adjacent charnockites. Solutions ascended through the joints and altered neighboring charnockite to quartz-epidote rocks. Constituents removed in this process were concentrated below the roof of the phacolith, where the rocks were changed to syenites of pneumatolytic origin.

FURTHER DATA ON THE ISOTOPIC COMPOSITION OF COMMON LEAD

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The isotopic composition of about 50 lead minerals of world-wide distribution has been obtained by mass spectrometric analysis. The range in composition lies within the

extremes reported in the literature for common lead. The results indicate a maximum variation of about 4% in the Pb^{207}/Pb^{206} ratio for minerals from the same metallogenic province.

It appears that in most areas a few isotopic analyses of common lead samples will be sufficient to define the abundances to use in correcting a radiogenic lead for contamination by common lead. This in turn virtually eliminates this source of uncertainty in uranium-lead age measurements.

In order to define the age of the earth more accurately, it is necessary to obtain a still larger number of isotopic analyses of common lead from dated localities.

CALLAGHANITE, A NEW MINERAL

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Studies of small, azure-blue crystals from the working pits of the Gabbs Refractories, Inc., Gabbs, Nevada lead to the description of a new hydrated basic copper, magnesium, calcium carbonate, $Cu_4Mg_4Ca(OH)_{14}(CO_3)_2 \cdot 2H_2O$. The mineral is named callaghanite after Dr. Eugene Callaghan, Director, New Mexico Bureau of Mines and Mineral Resources, in recognition of his geological work on magnesite desposits. The mineral occurs near peridotite dikes intrusive into magnesite and dolomite.

X-ray studies by Weissenberg and precession methods showed callaghanite to be monoclinic; space group either $C_s^4 - Aa$ or $C_{2h}^6 - A2/a$; and cell dimensions $a_0 = 8.24$ Å, $b_0 = 11.80$ Å, $c_0 = 10.06$ Å, $\beta = 107°18'$. Elements calculated from x-ray data are: $a : b : c = 0.6983 : 1 : 0.8525$; $p_0 : q_0 : r_0 = 1.2209 : 0.8140 : 1$; $\mu = 72°42'$; $p'_0 = 1.2788$, $q'_0 = 0.8525$, $x'_0 = 0.3115$. The unit cell content is 2.

Crystal forms present are {111}, {$\bar{1}$11}, {221}, and {$\bar{2}$21}. Elements calculated from goniometric data are: $a : b : c = 0.7252 : 1 : 0.8504$; $p_0 : q_0 : r_0 = 1.2168 : 0.8092 : 1$; $\mu = 72°5'$; $p'_0 = 1.2788$, $q'_0 = 0.8504$, $x'_0 = 0.3094$.

Optical data are: $\alpha = 1.559$, $\beta = 1.653$, $\gamma = 1.680$; $2V = 55°$; optically $(-)$; $Z \wedge c = 18°$; pleochroic in blue with absorption $Z > Y > X$; $r > v$, strong.

Cleavages are {111} and {$\bar{1}$11}, perfect; brittle; hardness is 3-3½; transparent; habit, pyramidal. Calculated specific gravity is 2.78; measured 2.71.

NATURE OF CRYSTALLIZATION OF METAMICT MINERALS

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In recent years there has been an increasing interest in the study of metamict minerals with regard to their origin, identification, and possible use as geologic age indicators.

Many of these non-crystalline minerals have been crystallized by heating to comparatively high temperatures and various workers index the x-ray powder patterns of these heated specimens under the assumption that this crystalline material is a reformation of the mineral as originally deposited or crystallized in the rock.

It is the intention of this paper to point out that recrystallization to the original structure of the metamict minerals is the exception rather than the rule. Likewise, data will be presented to show that the temperature, and type, of crystallization of some of these minerals are dependent upon their present state of metamictization and upon the present composition which may or may not be their original composition.

It also will be shown that certain related "stable" minerals will dissociate when subjected to the temperatures at which some metamict minerals crystallize.

ISOTOPIC ABUNDANCES IN ROCKS AND METEORITES

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Hydrogen, nitrogen, and carbon isotopes were studied in a number of rocks and meteorites to clarify some aspects of the problem of the loss of volatiles from the planetary system and of the origin and formation of the atmosphere.

Hydrogen isotopes were analyzed in the water contained in stony meteorites and igneous rocks: the abundance of deuterium in these samples is explainable with single-stage fractionation processes. No nuclear or multiple fractionation processes seem to be involved, and therefore one can conclude that the abundance of hydrogen isotopes does not change remarkably through the planetary system, except for the sun where the deuterium was consumed by nuclear reactions. Particularly interesting are the carbonaceous chondrites, which contain up to 10 per cent of water and show a minimum of contamination by terrestrial water. The percentage difference in the D/H ratio in these meteorites ranges from -5% to $+20\%$ as referred to the average ocean water. Carbon isotopes were also analyzed in these meteorites, showing a high C^{13} content with respect to the average on the earth and to the ordinary chondrites. Nitrogen isotope ratios have been measured in rocks. Amounts of nitrogen of 0.1 cc are easily extracted and analyzed with the developed technique. N^{15}/N^{14} variations of some per cent with respect to the atmospheric nitrogen were found.

MAFIC INTRUSIONS AS A CLUE TO THE METAMORPHIC HISTORY OF THE SPRUCE PINE DISTRICT, NORTH CAROLINA

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The geologic history of the Spruce Pine district of North Carolina can be traced from the sediments that formed the pre-Cambrian rocks through two periods of regional metamorphism to the intrusion of basaltic dikes, of Triassic (?) age. The sedimentary rocks were recrystallized and plastically deformed during a late Ordovician or early Silurian metamorphic cycle. Ultramafic bodies were intruded early; alaskite and associated pegmatites were emplaced late. Uranium-lead measurements indicate that pegmatites formed 350 ± 20 million years ago. An interval of crustal tension, with brecciation of the rocks, culminated in a Devonian (?) invasion by the gabbro stock and dike swarm now cropping out near Bakersville. In a second period of regional metamorphism (Appalachian ?), both gabbro and cementing material of the breccia were recrystallized. Minerals of the altered gabbro include garnet, hornblende, intermediate plagioclase, and cloudy pyroxene. The older, already recrystallized rocks were essentially unaffected by this period of metamorphism, although chlorite formed in shear zones. Intense plastic deformation was absent in the second cycle. Tension cracks following this cycle were filled by diabasic dikes during the Triassic (?) period.

The first metamorphic cycle was probably characterized by moderate to high temperatures, high water concentration, and relatively high rates of metamorphic reaction, effecting plastic behavior of the rocks. During the second cycle, temperatures were probably the same or slightly higher; but lower water concentration retarded metamorphic reaction, effecting brittle behavior of the rocks. Because of differences in water concentration evidence of two periods of high-temperature metamorphism is not only preserved, but distinguishable.

GEOCHEMICAL ASPECTS OF INTERSTITIAL MATERIAL IN IGNEOUS ROCKS

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The chemical composition and lability of "interstitial" material in four rocks have been studied. The Bonsall tonalite from the Southern California batholith yields upon leaching with dilute acid 0.55% leachable material; a granite from Elberton, Georgia, yields 0.39%; a granite from Essonville, Ontario, yields 0.13%; an aplite from the Boulder batholith (Montana) yields 0.091%. The compositions of the material leached from the four rocks with respect to major constituents are remarkably similar. Silica in all cases is low, ranging from 2% to 6%. Major constituents are CaO (15% to 45%), Fe_2O_3 (11% to 46%) and Al_2O_3 (20% to 32%). The levels of minor constituents in interstitial material vary widely and are related to the trace element levels in the original rocks and to the chemical natures of the elements.

The rate of removal of interstitial material is dependent upon the hydrogen ion concentration. In 1M acid the interstitial material of the Bonsall tonalite is taken into solution at a rate of 16 per cent per minute; in 0.1M acid the rate of removal is 4.3 per cent per minute at room temperature. Acid is consumed in the solution process and preliminary experiments indicate that the hydrogen ion consumption amounts to 0.01 moles per gram of interstitial material removed.

Experiments have been run for the purpose of determining the effects of particle size distribution upon the liberation of interstitial material.

TRIMORPHISM IN ZINC SULFIDE

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Experimental evidence was found for the existence of a third polymorphic modification of zinc sulfide. In addition to β zinc sulfide (zincblende or sphalerite) and α zinc sulfide (wurtzite) structures, a three-layer rhombohedral structure was found to occur in the temperature range of approximately 600° C. to 1020° C. This structure is similar to the zincblende structure referred to hexagonal axes wherein the c and a interatomic distances are slightly altered. In conformity with conventional nomenclature it is designated γ-zinc sulfide.

The experimental evidence for the existence of rhombohedral zinc sulfide is the fine structure of cubic (111) x-ray reflections as observed with high resolution spectrometer studies on pure zinc sulfide heated to various temperatures and quenched.

The role of the rhombohedral phase in the sphalerite-to-rhombohedral-to-wurtzite transformation has been studied.

IRON AND TITANIUM OXIDE MINERALS OF ADIRONDACK ROCKS

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In igneous rocks of the Adirondack region the amount of TiO_2 in ilmenomagnetite (magnetite with exsolved ilmenite) is greatest in some ore segregations in gabbro and anorthosite (12 to 14 per cent), less in hornblende microperthite granite (5 to 6.7 per cent), and least in microperthite alaskite (3.0 to 4.3 per cent). The titanium variation

in the ilmenomagnetite of these plutonic rocks parallels that found by Japanese geologists in magnetite of basaltic, andesitic, and rhyolitic volcanic rocks in Japan; it is a function of temperature of formation and affords a wide-range temperature scale. The composition of the ilmenomagnetite, both that accessory in granite and that in ore concentrations in gabbro and anorthosite, leads to an inference of formation at *magmatic* temperatures.

The magnetite of microcline-rich *granitized* rocks, formed at temperatures lower than magmatic, has about 2.2 to 3.1 per cent TiO_2. The TiO_2 in magnetite of gneisses reconstituted in the upper temperature range of granulite-amphibolite facies is 3.1 to 4.1 per cent; in the lower range of amphibolite facies it is only 1 to 2 per cent. Free ilmenite is present in all samples.

Six different oxide assemblages that were analyzed have the *same* ratio of iron to titanium but differ largely in degree of oxidation. The least oxidized combination (magnetite, ilmenite, and (?) ferrous orthotitanate) occurs in olivine gabbro, and the most oxidized facies (rutilohematite and rutile) in a microcline-rich granite gneiss formed from metasediments by potash-rich fluids. The Fe_2O_3 in solid solution in magnetite in granite and gneiss decreases with temperature of formation.

CRYSTAL STRUCTURE OF BERTHIERITE, FeSb₂S₄

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The unit cell, space group, and approximate structure of berthierite were reported in earlier communications. The rough structure has now been refined. The observed amplitudes $|F_{hko}|$ were first put on an absolute basis by Wilson's method which also determined the temperature coefficient, $B = 1.05$. The refinement was carried out by using successive Fourier syntheses, $(F_o - F_c)$ syntheses, and by fitting the Patterson of the proposed structure to the details of the observed Patterson. The final structure has the following parameters: Fe [.314, .335, ¼]; Sb₁ [.145, .064, ¼]; Sb₂ [.036, .385, —¼]; S₁ [.197, .272, —¼]; S₂ [.428, .186, ¼]; S₃ [.229, .494, ¼]; and S₄ [.452, .405, —¼]. The new parameters are within a few thousandths of the values determined directly by minimum-function methods. Using these final parameters, a refined absolute F_{obs} scale and temperature coefficient were computed. The residual error, $R = (||F_o| - F_c||)/|F_o|$, is .142 for hk0 and .126 for h0l.

Each antimony atom is bonded to three sulfur atoms at distances of about 2.5Å and these SbS₃ groups share sulfur atoms to form chains running parallel to the c axis. The iron atoms are surrounded by six sulfur atoms in approximately octahedral arrangement. These octahedra share edges to form chains parallel to the c axis. The Fe—S distance, however, is about 2.5Å, which is considerably in excess of that found in structures where the bonds are recognized as covalent (pyrite, 2.26Å, marcasite, 2.24Å). The distance is about what would be expected for ionic Fe—S bonds. The structure can therefore probably be regarded as $Fe^{++}(SbS_2)_2^-$.

CRYSTAL STRUCTURE OF LIVINGSTONITE, HgSb₄S₇

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The unit cell and space group of livingstonite were investigated by Gorman. His triclinic cell has the following dimensions:

$$a = 7.650\text{Å} \quad \alpha = 99°12\frac{1}{2}'$$
$$b = 10.817 \quad \beta = 102°01'$$
$$c = 3.990 \quad \gamma = 73°48'$$

This cell contains 1 HgSb₄S₇. Because of the shortness of the c axis, we thought it might be relatively easy to determine the structure as projected parallel to c. F^2 ($hk0$) intensity data were obtained from a c axis Weissenberg photograph processed by the M.I.T. modification of the Dawton method. With these data a Patterson map was prepared. The one Hg atom can be taken as located at the origin of Gorman's cell. A quantitative interpretation of the peak heights of the Patterson map located the Sb atoms. An M_5 minimum-function map confirmed these locations and delimited areas available for sulfur atoms.

The structure was approached by successive Fourier syntheses. Phases for the F_{obs} ($hk0$)'s were approximated by assuming that the Hg and Sb's determined the phases provided that they accounted for at least $\frac{1}{3}$ of the full amplitude. Each successive Fourier synthesis revealed one or more sulfur atoms, which were then taken into account when new phases for a next Fourier synthesis were computed.

One of the seven S atoms should occupy an inversion center provided that livingstonite is centrosymmetrical and provided that the formula is correct. We found no S atom in such a position, but did find a somewhat weak pair of peaks in a general position.

The xy coordinates found are as follows:

	x	y
Hg	0	0
2 Sb$_I$	.473	.146
2 Sb$_{II}$	.164	.428
2 S$_I$	.243	.180
2 S$_{II}$	.929	.364
2 S$_{III}$	.694	.087
2 S$_{IV}$	.598	.444

This structure investigation is being continued.

C¹⁴ CONCENTRATION IN MODERN CARBON

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The accuracy of the absolute age of a sample dated by the C¹⁴ method depends on the specific activity of modern carbon.

Measurements have been made on the following contemporary materials: (1) twelve different woods collected on the Lamont grounds; (2) twenty-six air samples selected to show possible variation with physiography, climate, altitude, humidity and time of day; (3) twenty-four shell or associated meat samples; and (4) a number of surface sea water samples.

Previous results indicated that the specific activity was constant for modern wood. A comparison of these data with that obtained in other laboratories shows that within the present assumed 5% error the C¹⁴ concentration in wood, air, surface ocean carbonate, shell and clam or oyster meat is the same (i.e. about 15 dpm/gm.).

If the C^{14} produced in the upper atmosphere is well mixed within a century, variations in the rate of production with latitude will not affect the C^{14} ages. The results reported above lend substantial support to this underlying assumption of the method.

CRYSTAL CHEMICAL STUDIES OF BORATE MINERALS

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For the known members of the series $2CaO \cdot 3B_2O_3 \cdot xH_2O$, $x = 13$, 9, 7, and 5. The $2CaO \cdot 3B_2O_3 \cdot 9H_2O$ is known only as a synthetic mineral. X-ray studies yield the following data:

Mineral	Inyoite	Artificial	Meyerhofferite	Colemanite
Composition	$2CaO \cdot 3B_2O_3 \cdot 13H_2O$	$2CaO \cdot 3B_2O_3 \cdot 9H_2O$	$2CaO \cdot 3B_2O_3 \cdot 7H_2O$	$2CaO \cdot 3B_2O_3 \cdot 5H_2O$
System	Monoclinic	Triclinic	Triclinic	Monoclinic
Space group	$P2_{1/a}$ (C_{2h}^5)	$P\bar{1}-$ (C_i^1)	$P\bar{1}-$ (C_i^1)	$P2_{1/a}$ (C_{2h}^5)
Z	2	1	1	2
a_0	10.63 Å	7.04_6 Å	6.61 Å	8.743 Å
b_0	12.06	9.45_2	8.35	11.264
c_0	8.40_5	6.41_2	6.49	6.102
α	(90°00′)	101°21′	91°00′	(90°00′)
β	114°02′	101°19′	101°31′	110°07′
γ	(90°00′)	99°49′	86°55′	(90°00′)
Volume	984.1 Å³	400.7 Å³	350.5 Å³	564.2 Å³
Vol./O-atom	20.5 Å³	20.0 Å³	19.5 Å³	17.6 Å³

Colemanite seems to contain sheets of oxygen ions linked by boron ions, parallel to the perfect cleavage plane (010). The study of this structure and its relationship to the structures of the other members of the series is being continued.

CRYSTAL STRUCTURE OF MURDOCHITE

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The crystal structure of the new Cu-Pb-O mineral murdochite has been established. It is an ordered NaCl type, approximate formula Cu_6PbO_8, space group *Fm3m* (O_h^5) with atomic parameters

(000; 0 ½ ½; ½ 0 ½; ½ ½ 0)+
4Pb : (a) 000
8 O_I : (c) ¼ ¼ ¼; ¾ ¾ ¾
24 O_{II} : (e) x00; 0x0; 00x; $\bar{x}$00; 0$\bar{x}$0; 00$\bar{x}$ with x $\doteq$ ¼

The 24 Cu atoms of the cell are distributed statistically over the 28 sites given by:

4Cu_{II} : (b) ½ ½ ½
24Cu_I : (d) 0 ¼ ¼; ¼ 0 ¼; ¼ ¼ 0; 0 ¼ ¾; ¾ 0 ¼; ¼ ¾ 0

CONTACT METAMORPHISM IN THE CHRISTMAS MOUNTAINS, BREWSTER COUNTY, TEXAS

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Spurrite, gehlenite, wollastonite, and other high-temperature contact metamorphic minerals occur in a well defined skarn zone at the contact between Lower Cretaceous limestone and gabbro in the central part of the Christmas Mountains. Superimposed

on the high-temperature mineralization is hydrothermal contact metamorphism associated with small, irregular apophyses of pyroxene syenite and nepheline syenite. Irregular stringers of aplitic nepheline analcime syenite in fractures in the upper part of the gabbro appear to be local differentiates of the gabbro. Clinozoisite and zeolites are associated with the nepheline syenite, and syenite projections into the skarn are rich in sphene, strongly pleochroic titanaugite, and schorlomite. Trachyte and rhyolite porphyry dikes cut the gabbro, and larger intrusive masses of porphyry are numerous around the periphery of the gabbro. A few small replacement bodies of fluorite occur in limestone adjacent to some of the larger rhyolite masses.

ISOTOPIC GEOCHEMISTRY OF HOT SPRINGS

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Many geochemical and geological problems require data on the rate of transfer of volatile materials from the interior to the surface of the earth; it is difficult to discuss the mechanisms involved without some estimate of the amounts of juvenile material being added to the surface at the present time. An attack on this problem has been begun by the method of isotopic analyses of carbon, oxygen, hydrogen, and nitrogen in the gases, waters, and deposits of thermal areas, and in igneous rocks.

Five areas have been studied: Yellowstone Park; Steamboat Springs, Nev.; Lassen Park, Calif.; The Geysers, Calif.; and Larderello, Italy. Yellowstone Park appears to contain the smallest proportion of magmatic components; the isotopic composition of the various phases is entirely in accord with a limestone origin for the carbon and a meteoric supply for the waters. In other areas the isotopic analyses indicate varying proportions of magmatic constituents which appear to be greatest at The Geysers. It appears that such areas can be used as successive approximations to determine whether juvenile carbon has the composition of carbon in igneous rocks or of mean surface carbon; this determination is important because an estimate of the degree of constancy of the rate of supply through geologic time can be derived from it. The data indicate that diamonds do not have the isotopic composition of primary terrestrial carbon.

QUANTITATIVE SPECTROGRAPHIC ANALYSIS OF ROCKS USING A METHOD OF MUTUAL STANDARDIZATION

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The mutual standard method is based on the assumption that the intensity ratio of two spectral lines is a function only of the concentration ratio of the two emitting elements. Since the major elements compose essentially 100 per cent of common rocks, the formula

$$\%Al_2O_3 = \cfrac{100}{1 + \cfrac{\%SiO_2}{\%Al_2O_3} + \cfrac{\%TiO_2}{\%Al_2O_3} + \cfrac{\%Fe_2O_3}{\%Al_2O_3} \cdots\cdots\cdots\cdots \cfrac{\%K_2O}{\%Al_2O}}$$

is used for the determination of alumina and thence the remaining oxides. Oxide ratios are found by plots (working curves) of $\dfrac{\text{Intensity, analysis line}}{\text{Intensity, Al 2652}}$ vs $\dfrac{\%\text{ analysis oxide}}{\%Al_2O_3}$.

The lines used are Al 2652, Mg 2779, Mn 2801, Fe 2929, Si 2987, Ti 3088, Ca 3170, Na 3302, and K 4044 Å.

Analysis by this method may be performed on untreated powders in the d.c. arc, and all elements are determined simultaneously. Working curves prepared from chemically analyzed rocks allow determinations to be made over a wide concentration range, and use of standards of a similar nature to the analysis material ensures good accuracy. The relative deviation (%σ) of the method is 10 per cent.

A number of minor elements, notably Cu, Co, Mo, Ni, Pb, and Zr may also be determined with the major elements.

Analytical time is less than two hours per triplicate analysis of an unknown rock.

TEMPERATURE AND THE DISTRIBUTION OF TRACE ELEMENTS

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The trace element composition of a mineral can be considered as an equilibrium condition controlled by the major composition of the mineral, P-T conditions of formation, and the availability of trace elements.

Preliminary investigations have demonstrated that the hornblende, biotite, garnet, and chlorite Cu, Cr, Ni, and V contents decrease with increasing temperature. The major decreases of these elements—several thousand ppm for Cr and Ni, and several hundred ppm for Cu and V—seem to occur at the rock transformation from epidote-amphibolite to amphibolite facies. The hornblende and biotite Ti and Mn content increases with increasing temperature; however, these minerals are volumetrically small in the granulite and magmatic facies and may release Ti and Mn from the area. Zinc content, in the few samples analyzed for zinc, is uniformly low and may indicate release of Zn before epidote-amphibolite facies. Therefore, these facies changes and mineral reactions may be related to certain ore deposits of the indicated elements.

The anorthosite plagioclases may be the source of titanium in titaniferrous iron ores associated with anorthosite. Anorthosite plagioclases are notably high in Ti, Fe, and Mg, most of which occurs as minute, opaque, exsolved, rod-like inclusions in the plagioclase. Granulation and recrystallization of the plagioclases are accompanied by notable decreases in Ti and often Fe and Mg in the four anorthosite areas studied.

Work on the trace element behavior in pyroxenes, olivines, muscovites, epidotes, feldspars and on other trace elements is in progress and will be discussed.

TYUYAMUNITE, CARNOTITE, AND SENGIERITE

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The following data were obtained by Weissenberg and precession methods; all lengths given in Å to ± 0.3 per cent.

Tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 6-8H_2O$, from Mesa County, Colorado: orthorhombic, $a = 10.63$ A, $b = 8.36$ A, $c = 16.96$ A; aspect $Pna*$; pseudo $Pnan$ (D_{2h}^6); $Z = 4$; $G = 3.92$ (obs.). Potassium replaces calcium; the Ca/K atomic ratio is 1.57.

Carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 2/3H_2O$, from Cane Spring Pass, near Moab, Utah: monoclinic, $a = 10.47$ A, $b = 8.41$ A, $c = 6.91$ A, $\beta = 103°40' \pm 10'$; $P2_1/a$ (C_{2h}^5); $Z = 2$; $G = 4.70$ (obs.). The cell dimensions of synthetic anhydrous carnotite reported by Sundberg and Sillén, are similar, except $c = 6.59$ A. The water of hydration should therefore be located between the structural layers (001). Carnotite twins by reticular pseudo-merohedry (index 3, obliquity ca 1°); twin and composition plane (001).

Sengierite, $Cu(UO_2)_2(VO_4)_2 \cdot 8-10H_2O(?)$, from Haut Katanga, Belgian Congo, pre-

viously reported by Vaes and Kerr as orthorhombic: monoclinic, $a = 10.62$ A, $b = 8.10$ A, $c = 10.11$ A, $\beta = 103°40' \pm 5'$ (gon.); $P2_1/a$ (C_{2h}^5); $Z = 2$; $G = 4.41$ (obs.).

Sengierite gives sharp x-ray reflections, whereas tyuyamunite and carnotite give streaky reflections indicating disorder in their crystal structures—the normal to the uranyl-vanadate layers describes a small-angle cone around the normal to the cleavage (001). This is ascribed to the weak bonding of Ca^{++} and K^+, a hypothesis supported by similar observations on the analogous phosphates: sharp spots from meta-torbernite from Cornwall, England; streaky reflections from meta-autunite from Lauter, Saxony.

Pb²¹⁰ METHOD OF AGE DETERMINATION

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The age of uranium-bearing mineral can be determined by measuring the ratio of Pb^{206} to Pb^{210}. The Pb^{206} concentration is determined with the mass spectrometer. The Pb^{210}(RaD) concentration is measured by scintillation alpha counting the daughter Po^{210}(RaF). Calibration of the alpha counting system is achieved by counting the Po^{216} derived from known aliquots of radon. The method has several important advantages. The ratio Pb^{206}/Pb^{210} is insensitive to both radon leakage and uranium leaching. Pb^{210} ages on minerals from classical uranium localities are in good agreement with the "best" ages derived from other isotopic data.

SEDIMENTARY ORIGIN AND STRATIGRAPHIC EQUIVALENCE OF THE SO-CALLED CRANBERRY AND HENDERSON GRANITES IN WESTERN NORTH CAROLINA

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The rocks that have been called Cranberry granite and Henderson granite in the metamorphic complex of western North Carolina have been found to be largely sedimentary in origin. There are four specific field relations that favor this conclusion: (1) At least 75 per cent of the outcrops of these rocks show primary compositional banding, (2) these rocks are interbedded with rocks of known sedimentary origin (e.g., Carolina gneiss), (3) intrusive relations between the Henderson or Cranberry and the Carolina are absent, (4) the regional distribution suggests that the Cranberry and Henderson rock is the lower unit in the southwest-plunging synclinorium. This field evidence is supported by a microscopic study of zircons from these rocks that shows the common phases of the Cranberry and Henderson to be mostly sedimentary. Detailed mapping in the northwest corner of the Morganton quadrangle where the Cranberry and Henderson come together shows that along strike they grade from one into the other. The two formations therefore seem to be stratigraphically equivalent and the minor differences in their composition may be attributed to facies changes in the original sedimentary sequence. The Cranberry and Henderson rock apparently underlies the Roan and Carolina complex in the Spruce Pine District and thus is older than that complex rather than younger as previously believed.

CHEMICAL CONSTITUTION OF PALYGORSKITES AND PILOLITES

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Sepiolite minerals which might be considered as end members of the palygorskite and pilolite series are characterized by significant variations of their chemical com-

position. This may be expressed by the coefficient K corresponding to the varying ratio of MgO : SiO₂ in the chemical formulae of sepiolites. In the sepiolites studied by the author and other investigators the coefficient K covers the range from 1.0 to 0.60, i.e. from $MgO \cdot SiO_2 \cdot 2H_2O$ to $6MgO \cdot 10SiO_2 \cdot 10H_2O$. Consequently the composition of the sepiolite minerals can be expressed by a series of formulae having the following MgO:SiO₂ ratios: 1.0, 0.88, 0.75, 0.66, 0.60, 0.50. An end member of the sepiolite series, $MgO \cdot 2SiO_2 \cdot 2H_2O$ (K = 0.50) was originally (1939) assumed by the author to be a hypothetical mineral and was actually discovered in 1949 in the Urals (Gerasimov, Grushko, Chirvinsky). These formulae of the sepiolite series make it possible to explain the chemical constitution of palygorskites and pilolites. These minerals may be considered as products of an isomorphic isovalent replacement

$$Mg\overset{\cdot\,\cdot}{\,}_3 \; - \; Al\overset{\cdot\,\cdot\,\cdot}{\,}_2$$

in the molecules of sepiolite minerals with different K values. The recalculation of molecular quantities in the analyses of palygorskites and pilolites after the replacement

of $Al\overset{\cdot\,\cdot\,\cdot}{\,}_2$ through $Mg\overset{\cdot\,\cdot}{\,}_3$ enables us to demonstrate that the empirical chemical formulae of these minerals correspond quite exactly to the formulae of the sepiolite series. This point of view has been corroborated by x-ray investigations and by the thermal analysis data.

COMPOSITIONAL EVOLUTION OF A MAJOR MARBLE UNIT, GRENVILLE SERIES, NORTHWEST ADIRONDACK MOUNTAINS, NEW YORK

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Marble in the Balmat-Edwards area is at least 1800 feet thick and represents about one-sixth of the marble in and one-ninth of the thickness of the exposed Grenville series. A weighted average composition of marble inferred to be least altered includes 50 minerals, chiefly (volume per cent) dolomite, 42; calcite, 18; quartz, 16; diopside, 8; tremolite, 7; serpentine, 4; talc, 2. As oxides this represents (weight per cent) SiO₂, 28; MgO, 17; CaO, 25; CO₂, 27; other, 3.

Field studies suggest that pre-metamorphic (sedimentary?) amounts of MgO and CaO approximated present values, but that the mineral composition was (weight per cent) quartz, 15; dolomite, 80; other, 5. Major chemical changes during metamorphism were, therefore, doubling of SiO₂ and appreciable decarbonation. Most calcite probably formed during the (incongruent?) solution of dolomite by water-rich, alkali-silicate, magmatic fluids. These fluids deposited quartz and widely redistributed magnesia, concentrating it into zones of tremolite, anthophyllite, talc, and serpentine. Principal premetamorphic accessories postulated are calcite, clay minerals, gypsum, and conceivably pyrite, H₂S, and methane.

Trace elements in least-altered dolomite beds include (modes of 40 analyses, in ppm) Sr, 200; Mn, 700; Ti, 20; Ba, 4; B, 20; Cu, 2. Comparison with other dolomites —some equally, some less metamorphosed, some roughly contemporary, some much younger—suggest that appreciable strontium diffused out of the dolomite during metamorphism about one billion years ago. One analysis for lead, by Patterson, showed a concentration of 2.14 ppm with an isotopic composition exceptionally high in Pb[207]. A possible explanation of the values is that both amount and composition of lead were modified during metamorphism by interchange of constituents in the dolomite with those in associated carbonaceous shales.

SYNTHESES AND STABILITY OF THE PHLOGOPITES

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A one-layer monoclinic (1M) or a three-layer trigonal (3T) hydroxyl-bearing phlogopite has been synthesized. A curve through the points 840° C.—1,000 psi water vapor pressure, 995°—5,000 psi, 1025°—10,000 psi, 1050°—15,000 psi, 1080°—30,000 psi, and 1105°—75,000 psi mark the upper limit of stability of phlogopite. Above this curve the stable phases are forsterite + leucite + orthorhombic $KAlSiO_4$ + vapor. These same phases form metastably at temperatures immediately below the curve, particularly at low pressures.

The phlogopite forms quickly at the higher temperatures, and grows very slowly at the lower temperatures. At the lowest temperatures a completely disordered mica (1Md) grows which is believed to be equivalent to the trioctahedral clay micas. It is not possible to distinguish the 1M and 3T polymorphs on the basis of powder x-ray diffraction patterns; however, the synthetic phlogopite is not 2M. A natural 2M can be transformed to a 1M or a 3T at high temperatures. The phlogopites from lavas are one-layer monoclinic (1M); however, 1M phlogopites are also formed in metamorphosed limestones. No clear relationship between the temperature of formation and the type of stacking in natural phlogopites has been observed. It has not been ascertained whether the polymorphs are related by a univariant curve of equilibrium or are dependent on growth factors.

Eastonite was synthesized, and its decomposition products are forsterite + leucite + orthorhombic $KAlSiO_4$ + spinel + vapor. Mahadevite (1M) is close to eastonite in composition and does not lie midway on the phlogopite-muscovite join.

Phlogopite appears on the liquidus in the synthetic "haplogranite." The formation of phlogopite (and biotite) and the absence of muscovite in lavas are accounted for by their stability curves.

Data have also been obtained on the phlogopite-muscovite, phlogopite-eastonite, and phlogopite-annite joins.

CRYSTAL STRUCTURE OF KVO₃

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Anhydrous potassium metavanadate, KVO_3, forms colorless crystals on precipitation from a water solution containing KOH and V_2O_5 in the mol ratio of 2 to 1, at a pH of 7 to 8. The crystals are orthorhombic, space group *Pmab,* with $a = 5.69$ A, $b = 10.82$, $c = 5.20$, the unit cell containing $4KVO_3$. The structure contains infinite chains stretched along the a axis, with VO_4 tetrahedra linked by corners in a manner similar to the silicate tetrahedra in diopside. The structure is analogous to that proposed for NH_4VO_3 by Lukesh. The chain linkage is contrasted with the fivefold coordinated chain linkage found in $KVO_3 \cdot H_2O$, which forms under the same conditions as KVO_3.

ALTERATION PROCESSES IN MONTROSEITE

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Montroseite, $(V,Fe)O(OH)$, has been shown to have a structure analogous to that of diaspore, $AlO(OH)$. Crystals of montroseite give multiple x-ray patterns, showing one sharp orthorhombic lattice corresponding to the host crystal, and a pair of diffuse

lattices of similar symmetry and dimensions in parallel orientation. The more prominent of the diffuse phases is interpreted as a metastable form of VO_2, resulting from oxidation of the host crystal. The concept of an alteration process involving a migration of ions and electrons through an undisturbed oxygen framework is supported by a Fourier analysis of x-ray intensities of the sharp and diffuse lattices, and by chemical information. The postulated alteration mechanism is illustrated by certain other examples, notably the alteration of lepidocrocite to maghemite, and goethite to hematite.

MURDOCHITE, A NEW COPPER LEAD OXIDE

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Chemical analysis and x-ray structural studies (see abstract by C. L. Christ and J. R. Clark in this issue) establish as a new species, a copper lead oxide from the Mammoth Mine, Tiger, Arizona. The percentage composition, 67.24 CuO, 30.53 PbO_2, 0.17 Fe_2O_3, 0.05 SiO_2 and 1.11 Insol. yields the formula Cu_6PbO_8. The specific gravity is 6.465 at 4° C. The mineral forms in tiny lustrous black octahedra associated with wulfenite, dioptase, willemite and fluorite.

The new mineral was found by Percy W. Porter, now deceased, of Cavecreek, Arizona and at his request is named in honor of Professor Joseph Murdoch of the University of California at Los Angeles.

RADIOACTIVITY OF THE HELIUM-BEARING FORMATIONS OF THE TEXAS PANHANDLE REGION

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The discovery of radon in some of the helium-bearing natural gas in the Texas Panhandle gas field points out the desirability of determining the distribution and occurrence of radon and associated radium, uranium, and helium in formations containing natural gas. The radon content of about 1,200 producing gas wells has been measured, mostly in the Panhandle field. Concentrations from less than 1 to about 700×10^{-12} curies of radon per liter (S.T.P.) have been observed. The highest concentration of radon usually occurs along the fringes of structural highs. Theoretical analysis of radon measurements under conditions of transient gas flow indicates that the measured radon may originate in the immediate vicinity of the bore in most wells. This result is tentatively confirmed by gamma-ray logs in two wells, but so far it has not been possible to obtain adequate samples of the gas-producing beds to determine the radon source. Samples of spent liquor from the acidizing of one well show great excess of radium over uranium. Small grains of uraniferous asphaltite and radioactive petroleum residues are disseminated in drill samples of dolomite from beds well above and within the gas-producing formations. Radon concentration in the gas is not enough to account for the high helium content. The research is being continued, and comprehensive studies of subsurface geology of this and several other gas fields are in progress.

ABUNDANCE OF S^{32} AND S^{34} IN SOME NATURAL SOURCES OF SULFUR

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An investigation of the abundance of S^{32} and S^{34} in natural sulfur compounds has been undertaken as part of a study of the origin of Gulf Coast Sulfur desposits.

The abundance expressed as S^{32}/S^{34} was measured on sulfur dioxide in a Nier type, single collector, mass spectrometer.

A suite of about 25 samples from the Newgulf Salt dome showed that the S^{32}/S^{34} ratio for the sulfur from the sulfate was about 1.4% lower than that from elemental sulfur. It has also shown that the ratio S^{32}/S^{34} is not constant in either the sulfate or the native sulfur, variations of as much as 4% having been found in both forms. The S^{32}/S^{34} from sulfate in the caprock appears slightly lower than in the salt mass suggesting preferential leaching. At the Newgulf Salt dome the S^{32}/S^{34} in the H_2S of the bleedwater, in the pyrite of the caprock and in the native sulfur fell within the same range. This suggests that the last step in the formation of the native sulfur is the oxidation of the H_2S.

A core from near Barreno, Mexico in which elemental sulfur and gypsum were closely associated showed the S^{32}/S^{34} ratio from the gypsum to be only 6% lower than the elemental sulfur. Laboratory experiments with the sulfur oxidizing bacteria *Thiobacillus Thiooxidans* showed no fractionation effects.

In sea water sulfate samples from the same location the sulfur isotope ratio is the same at the surface as at a depth of 7,600 feet.

THE SYSTEM FeO-SiO₂-H₂O

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Phase equilibrium relationships are presented for the system $FeO-SiO_2-H_2O$. Syntheses are reported for wustite, magnetite, fayalite, greenalite, minnesotaite, grunerite, and hydrated ferro-ferrisilicates of the chlorite and mica families. In a non-oxidizing hydrothermal environment fayalite undergoes serpentinization to form greenalite below 250° C. Greenalite thermally decomposes to fayalite and minnesotaite above 470° C. The upper limit of stability for minnesotaite is placed at 480° C., minnesotaite decomposing to fayalite and quartz with grunerite appearing as a metastable intermediate phase. Fayalite and silica coexist from 480° C. to the limits of experimentation at 925° C. The iron pyroxene, "ferrosilite," was not identified. Distinction is made between the stability relationships observed in a closed, non-oxidizing hydrothermal environment and those to be expected in an open or circulating hydrothermal system.

CLASSIFICATION AND CORRELATION OF DIOCTAHEDRAL MICAS AND HYDROUS MICAS

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The method for calculating formulas for montmorillonites from analyses, suggested by Marshall, and the fractional notation used by Ross and Hendricks for writing formulas for montmorillonites is extended to the dioctahedral micas and hydrous micas, which have the same 2-1 layer structure. From formulas so calculated the charges on the tetrahedral and octahedral layers can be calculated. The sum of these charges should agree closely with the sum of the external cations and provide an internal check on the purity of the sample and the accuracy of the analysis.

Such formulas, with a notation of charge on tetrahedral and octahedral layers, provide a means for comparing the composition of micas and hydrous micas and reveal relationships not otherwise evident. From the muscovites and sericites, in which

almost all the charge is on the tetrahedral layer, there is a continuous shift in the relationship between tetrahedral and octahedral charge through the phengites and glauconites to the celadonites, in which the charge is almost wholly octahedral. The micas and hydrous micas can be classified, therefore, according to their tetrahedral-octahedral charge relationship. Such a scheme of classification permits the correlation of specimens containing unusual constituents, such as manganese, vanadium, chromium, etc. And many specimens that have been given specific mineral names are shown to be merely steps in the shifting of the seat of the charge or in the degree of hydration.

SIMPLE METHOD FOR THE DETERMINATION OF THE PLAGIOCLASE FELDSPARS

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Precise refractive index data on synthetic plagioclase feldspar glasses have been available for over forty years. However, no routine method based upon these data has come into general use for the determination of the natural feldspars. Such a method possesses certain advantages over the many other procedures presently followed. Its theoretical accuracy is about twice that obtainable with established refractive index methods. Index determinations, involving no particular refinements of technique, were made on the glasses of eight chemically analyzed natural plagioclase feldspars. The anorthite contents derived from these data agreed with those calculated from the chemical analyses within about two per cent. The method is simple and rapid, and calls for no costly equipment. It is therefore recommended for inclusion among the standard methods for the determination of the plagioclase feldspars.

CARIBOU ERUPTIVE COMPLEX, AN INTERPRETATION IN TIME AND SPACE

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The Caribou complex is located in the Canadian shield two miles west of Loring, Ontario, where it intrudes granite-gneisses. Its shape is that of a lopolith, the map picture presenting a funnel tilted to the west and planed off by erosion. Structural, geophysical and petrographic evidence indicates that the magma was emplaced from the east. The complex is mostly composed of norite with local peridotite and pyroxenite facies; granodiorite forms the upper facies of the intrusive. Throughout, the feldspars and pyroxenes of the norite show granulation and mortar structure. They show extensive replacement by hornblende and biotite which are locally intergrown with pyrite, pyrrhotite and titaniferous magnetite. Garnet and quartz form reaction-rims separating feldspar and pyroxene in the norite; in the olivine-bearing rocks hypersthene, spinel and a diopside-spinel symplectite separate the olivine from the feldspar. The intrusive shows cryptic layering with gradual Fe and Na-Si enrichment toward the west on which is superimposed a rhythmic layering of pyroxene and feldspar.

Consolidation of the intrusive was followed by extensive jointing, and granite-pegmatites ascended many of the fractures. Metasomatism of the norite by the pegmatites gave rise to quartz-diorite with a diablastic texture in areas adjoining the pegmatites and may be responsible for the extensive biotite, hornblende and reaction rim formation in the complex. Late-stage faulting broke up the complex into seven blocks. Some of these faults bear nickeliferous pyrrhotite, mineralization thus post-dating the main igneous activity.

USE OF ZONE OR BAND THEORY IN PROBLEMS OF SULFIDE MINERALOGY

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The metallic or semi-metallic characteristics of many sulfide minerals, demonstrated by such properties as ductility, metallic luster and low electrical resistivity, are evidence of the metallic nature of their chemical bonds. This justifies a limited application of the modern electronic theories of the metallic state to problems involving these minerals.

Brillouin zones of the minerals in the iron-copper-sulfur system have been determined. The volume of these zones and the electron to atom ratios required to fill these zones have been calculated. These minerals exhibit the properties of semi-conductors (increased conductivity with increased temperature) and therefore it is assumed that free electron states exactly fill one of the zones, with a small energy gap between the filled zone and the next higher zone. Use is made of a modification of the electron theory of H. Jones to explain why, as we go from compounds richer in iron and sulfur to compounds richer in copper, we form structures whose corresponding Brillouin zones, when filled, have lower electron to atom ratios.

THERMODYNAMIC RELATIONS AMONG THE VANADIUM OXIDES, AND IMPLICATIONS OF THE COLORADO PLATEAU URANIUM-VANADIUM DEPOSITS

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Fields of stability of the low-valence vanadium oxides V_2O_2, V_2O_3(VOOH), and V_2O_4 in water solution have been calculated as functions of pH and oxidation potential. The theoretical equilibrium relations indicate that V_2O_2 should not occur naturally; water would decompose, releasing hydrogen, before a sufficiently reducing environment could be attained. The field of V_2O_3 is essentially coexistent with that of $Fe(OH)_2$; V_2O_4 is stable down to approximately the same lower limits of oxidation potential as Fe_2O_3 [$Fe(OH)_3$]. The field of V_2O_3 also is essentially coexistent with the common metal sulfides over a wide range of total sulfur concentration. An implication from the theoretical relations is that the so-called black ores of the Colorado Plateau that contain low-valence uranium and vanadium compounds and metal sulfides (in addition to many other minerals) may be primary and the carnotite-roscoelite ores are derived from them by oxidation.

EQUILIBRIUM THERMAL DECOMPOSITION OF DOLOMITE

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The experimentally determined P_{CO_2}-temperature stability curve of dolomite rises in an exponential fashion from approximately 400° C. in air to approximately 640° C. at 65 atm. CO_2 pressure. The 400° value is in good agreement with the observed decomposition of dolomite under CO_2-free hydrothermal conditions.

The calcites formed by the decomposition contain Mg in solid solution. The similar occurrence of Mg in the calcites of numerous unweathered carbonate metamorphic rocks suggests that such solid solutions are stable under proper conditions of temperature, CO_2 pressure, and Mg^{++} activity.

This equilibrium curve has been further verified using magnesian calcite algal material, from which dolomite may be synthesized by solid state reaction. Inasmuch as dolomite is formed from the algal material within the dolomite stability field and MgO by exsolution outside the field, the curve may be delineated particularly well by this technique.

PSEUDOMORPHOUS ILLITE AFTER BIOTITE

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Near Marysvale, Utah, hydrothermal alteration of the lowest unit of Bullion Canyon latite has produced unusually well-formed illite pseudomorphs after biotite. A series is described which goes from biotite to illite with intermixed chlorite to a final almost pure illite. In the weathered zones a pseudomorphous series from biotite to mixed illite-chlorite and calcite is developed. Pseudomorphs range from 1-4 millimeters in diameter. Early exsolution of iron and late development of epidote occurs. Optical, stain, thermal, and x-ray data support the interpretation given. The paragenesis of hydrothermal clays in alkali-rich volcanic rocks is believed to be from mafic constituents to a mixture of chlorite and illite to illite. On crystal chemical grounds the extension of the sequence to pinite or sericite seems likely.

ELECTROMAGNETIC SURVEYING OF DRILL HOLES FOR THE DETECTION OF CONDUCTING SULFIDES

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A diamond drill hole will sample only the diameter of the hole and many ore bodies present can be missed readily. In a manner analogous to surface electromagnetic surveying the region up to a radius of about 400 feet about the hole can be surveyed for conducting sulfides by use of special apparatus. The direction in which these sulfides lie as well as some indication of their size can be inferred from the results. The method of testing vertical drill holes is described showing how it is possible to allow for the departure of the hole from the vertical. Testing of angle holes is outlined although field tests have not been made with this method.

Results of field tests in the Sudbury basin in drill holes passing through barren areas and in holes collared in areas of known sulfides are discussed.

The method is useful in reducing the number of drill holes required to explore an area and in indicating the direction that further drilling should be done.

KYANITE, ANDALUSITE, AND SILLIMANITE IN THE SCHISTS IN BOEHL'S BUTTE QUADRANGLE, IDAHO

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Kyanite, andalusite, and sillimanite are found together in the cordierite-bearing mica schists of the Prichard formation of the pre-Cambrian Belt series exposed in the Boehl's Butte quadrangle in the southern part of the Idaho "panhandle." Microscopic studies of these schists suggest that the following inversions took place: (1) sillimanite $\rightarrow$ kyanite, (2) kyanite $\rightarrow$ andalusite, (3) kyanite $\rightarrow$ sillimanite, (4) andalusite $\rightarrow$ sillimanite. These inversions are probably related to the fluctuation of tempera-

ture and stresses during the complex regional and thermal metamorphism to which the schists were subjected. In some thin sections all three crystal forms occur side by side, suggesting that the minerals may have crystallized under physical-chemical conditions in which all three can exist in equilibrium. The association epidote-plagioclase (An_{86}) in the calcium-rich beds of the same area suggests that the temperature during the crystallization was close to 400° C.

STUDIES OF RADIOACTIVE COMPOUNDS: VII—PHOSPHURANYLITE AND DEWINDTITE

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Phosphuranylite from Urgeirica, Portugal, with indices α 1.669, β 1.710 (Na) shows only a trace of lead spectrographically. Rotation and Weissenberg films gave the data: Orthorhombic, *Bmmb;* $a = 15.85$, $b = 17.42$, $c = 13.76$ A.

Dewindtite from Kasolo gave a practically identical powder pattern confirming Frondel's (1950) statement that the two minerals are isostructural. The indexed powder pattern of dewindtite gave the cell constants: $a = 16.00$, $b = 17.62$, $c = 13.66$ A. Schoep's analysis and measured density (5.03) are in better agreement with the formula $Pb_3(UO_2)_6(PO_4)_4(OH)_6 \cdot 9H_2O$ (calc. G. 4.95; Z = 4) than the hitherto accepted formula $Pb_3(UO_2)_5(PO_4)_4(OH)_4 \cdot 10H_2O$ (calc. G. 4.46; Z = 4).

The analyses of phosphuranylite in Frondel (1950) do not lead to rational cell contents. The formula $Ca_3(UO_2)_6(PO_4)_4(OH)_6 \cdot 9H_2O$ which is to be expected if the new formula for dewindtite represents the chemistry of that mineral, requires more calcium than is indicated by the analyses in Frondel (1950). It is concluded that the chemistry of the two minerals is uncertain.

RECRYSTALLIZATION OF METAMICT ZIRCON

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The recrystallization of metamict zircons has been studied by observing the heat emission and changes in the density and structure during annealing. It has been found: (1) that the heat energy liberated during recrystallization is proportional to the degree of structure damage, (2) that the effect of heat treatment at constant temperature on the density of metamict zircons can not be explained in terms of a single stage reaction, and (3) that during annealing the unit cell dimensions approach those of undamaged zircon more rapidly than the density approaches that of undamaged zircon.

GRANULITES, AMPHIBOLITES, MYLONITES, AND ASSOCIATED ROCKS OF THE CUCAMONGA CANYON AREA, SOUTHEASTERN SAN GABRIEL MOUNTAINS, CALIFORNIA

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The oldest rocks of the Cucamonga Canyon area, California, are granulites that have been folded in an apparently homoclinal sequence, striking N. and dipping almost vertically. The granulites, comprising mineral associations characteristic of the granulite facies, are probably sedimentary and volcanic rocks that have been dynamothermally metamorphosed.

The granulites have been altered to amphibolites and mylonites along NNW. dipping thrust planes. In Aurela Ridge belt, the granulite structures remain almost intact and only minor amounts of polymetamorphic rocks are present. South of Aurela Ridge belt, ENE. trending structures prevail, yet relic granulite structures and minerals are recognizable. In a belt hundreds of feet wide north of Aurela Ridge belt, the mylonites and amphibolites strike ENE. and granulite structures are obliterated, although relic granulite minerals are plentiful. Farther north, ENE. trending mylonites and minor amphibolites occur in Sarac Ridge belt ½ mile wide; traces of granulite minerals present suggest these rocks may have been derived from the granulites.

The amphibolites and mylonites are syngenetic. While the felsic granulites were being deformed cataclastically to form mylonites, the mafic granulites were deformed through neomineralization to form amphibolites. Mineral associations indicate that these polymetamorphic rocks were probably formed by the metamorphism of the granulites under the amphibolite facies conditions complemented by intense shearing stress.

Gneissose quartz diorite north of Sarac Ridge, probably emplaced synkinematically, may represent mobilized "quartz-dioritized" granulites. Small quartz monzonite intrusives in the quartz diorite pluton, emplaced post-kinematically, may have promoted recrystallization of the mylonites.

DEMONSTRATION POLARISCOPE

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The demonstration polariscope is constructed of two crossed Polaroids four inches apart and four inches square. An ordinary 60-watt lamp beneath the lower Polaroid serves as a light source. Above the lower polarizer is a stage on which cleavage fragments or mineral slices can be placed and rotated to demonstrate extinction angles, twinning, interference and other phenomena observed in plane polarized light. By inserting polished spheres of crystals between the Polaroids one can observe interference figures as described by Professor Horace Winchell in 1947.

This polariscope has the additional advantage of permitting demonstration of interference figures produced by thin slices of minerals. A three-inch plastic sphere can be slid into position between the polarizers; and, if a suitably oriented slice is placed on the stage, an interference figure is observed to fill the sphere. A mirror placed over the upper Polaroid at 45° enables one to demonstrate interference figures to a class of twenty or more at one time.

PETROLOGY OF ENCHANTED ROCK PLUTON, LLANO AND GILLESPIE COUNTIES, TEXAS

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The Precambrian pluton consists of four concentric zones: outer zone (1), medium to coarse leucogranite and granite; intermediate zone (2), medium to coarse granite and quartz monzonite; intermediate central zone (3), coarse quartz monzonite and alkalic granodiorite; and the core (4), fine to medium leuco-quartz monzonite and leucogranite. Seriate porphyritic texture prevails. Rapakivi texture is most abundant in zone (3) and magmatic origin for it is indicated by lack of negative correlation between normative quartz and orthoclase + albite.

The magma was probably uniform prior to emplacement, and concentric zones were

developed during emplacement. Crystallization-differentiation accompanied by filter-pressing of a crystal mesh in which microcline separated as the first stable crystalline phase are responsible for rock types and their distribution. The finer grain of the core is believed due to partial escape of volatiles and loss of heat, the latter due mainly to depletion of the magma reservoir.

Microcline phenocrysts, despite size, maintain a mean length-width ratio of 2:1 throughout all rock zones. Standard deviation of mean length for zones (1) and (2) is abnormally low and for zone (3) is large. Values for the latter zone are probably due to presence of the filter-pressed fraction and late stage magmatic and deuteric activity.

Forces that produced steep regional folds may have been sufficient to draw the magma into the chamber. Arcuation of schlieren in zone (1) suggests the magma rose with a spiral motion.

DISTRIBUTION OF RARE ELEMENTS WITHIN GRANITES AND GRANITIC PEGMATITES

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The distribution and mode of occurrence of rare elements in a given igneous rock are governed by several well-known factors, chiefly: (1) composition of the magma, including concentrations of the rare-element ions; (2) pressure-temperature conditions during crystallization of the magma; and (3) size, charge, polarizability, and other properties of the rare-element ions.

During crystallization of a magma under a given set of conditions, a rare-element ion may enter the structure of a common mineral (Ga in feldspar) or a rarer mineral (Cs in beryl); it may enter, or be trapped by, a much less appropriate mineral structure (Sn in muscovite), followed in some instances by transfer to an exsolved mineral; it may be concentrated in the residual fluid until it forms a mineral of its own (Cs in pollucite); or it may remain dispersed in the residual fluid until ultimately it is bound to the surface of the nearest crystal lattice.

The first three mechanisms seem to account satisfactorily for the distribution of Be, Cs, Rb, Tl, Li, Nb, Ta, the rare earths, Sn, Ti, W, Mo, U, Th, and other rare elements in granitic pegmatites and some granites. The fourth mechanism evidently becomes prominent during crystallization of other granitic rocks, especially those formed from magmas of relatively high viscosity. It results in end-stage attachment of numerous rare-element ions to the crystal surfaces of common silicate minerals. The binding is relatively weak, and these ions are readily mobilized if the host granites are altered or weathered. Despite their low concentrations, enormous quantities of rare elements might thus be leached from a single large body of granitic rock.

ZONES OF REGIONAL METAMORPHISM IN THE PRE-CAMBRIAN OF NORTHERN MICHIGAN

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Pre-Cambrian rocks are exposed throughout an area of about 7,500 square miles in northern Michigan. Of this area, approximately 3,300 square miles is underlain by

unmetamorphosed upper pre-Cambrian (Keweenawan), about 2,700 square miles by metamorphosed middle pre-Cambrian (Huronian), and about 1,500 square miles by metamorphosed lower pre-Cambrian ("Archean"). Flat-lying or low-dipping strata of Paleozoic age overlap the pre-Cambrian along the east margin of the area.

The degree of metamorphism is most clearly shown by mineralogic changes in the middle pre-Cambrian sedimentary rocks, especially the iron-formations and the gray-wackes and slates, and in the late middle pre-Cambrian basic intrusive rocks. These rocks were metamorphosed during the Killarney interval of orogeny and minor granite intrusions. At least one earlier period of major metamorphism (Algoman) is recognized and, in nearby areas of Wisconsin and Minnesota, later but areally more restricted metamorphism is related to the intrusion of the upper pre-Cambrian Duluth gabbro and equivalent masses.

Zones of metamorphic intensity delineated by sillimanite, staurolite, garnet, biotite, and chlorite isograds or their equivalents are completely or partly developed around four nodes, two of which lie in immediately adjacent parts of Wisconsin. The zones range in width from less than a mile to about 30 miles, with metamorphism of low grade being areally dominant over that of intermediate or high grade. Retrograde metamorphism, not accompanied by shearing, is widespread.

Granite dikes and small stocks are fairly common in the areas of higher grade metamorphism. Though doubtless both the metamorphism and the granite intrusions were part of the same orogenic cycle, the granite exposed in most areas is clearly later than the regional metamorphism.

EXPERIMENTAL STUDIES OF RHEOMORPHISM

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In order to study the successive melting of natural rocks, specimens of granite, syenite, gabbro, diabase, and peridotite were heated to the melting temperature of minerals present. The rock was kept at constant temperature for periods ranging from a few hours to ten days. After quenching, the rock was studied in thin section. Tests were run in air, CO, CO_2, H_2O and city gas.

In all tests the ferromagnesian minerals started to melt earlier than feldspar and quartz. In the thin sections the mafic components could be seen converted into glass. At the same temperature the felsic components were unaffected, if we disregard optical changes. Biotite and chlorite seem to be the first minerals to melt.

In a gas furnace the melting starts 200-300° earlier than in an electric furnace and air. In an electric furnace an atmosphere of H_2O and (or) CO did lower the melting temperature. A reducing atmosphere seems to cause an early melting of minerals containing iron and magnesium. The time of heating did not affect the temperature of melting. The grain size may have a considerable effect.

The sequence of melting in natural rocks thus does not under all conditions correspond to the sequence of crystallization found in artificial melts. The experiments seem to throw some doubts on the theory that aplitic and granitic material is formed by means of partial anatexis. They explain certain structural features in volcanic and plutonic rocks.

PETROLOGY OF THE ROUND LAKE BATHOLITH AND ITS ASSOCIATED INTRUSIVES

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The Round Lake batholith is a composite, elliptical intrusive extending from Round Lake, south of Kirkland Lake to Matachewan. It is composed of two main phases, a southeastern leucocratic quartz dioritic or trondhjemitic phase and a northwestern granitic phase which is the younger. Both phases are remarkably uniform, massive and structureless except near contacts with older Keewatin rocks. These features together with local chilled contacts and contact breccias are best explained by assuming a magmatic origin for the batholith.

To the north of the batholith lie a series of syenitic stocks of which the Otto Stock, northwest and north of Round Lake has been most completely studied by the author. The core of this stock is very similar in composition and appearance to the granitic phase of the batholith. The major portion of the stock is syenitic, with local marginal phases of coarse pegmatitic texture, and locally, of altered nepheline syenite.

OPTICAL AND X-RAY STUDIES OF NATURAL HIGH-TEMPERATURE ALKALI FELDSPARS

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Accurate optic axial angle measurements have been made on members of the sanidine-anorthoclase series both in their natural state and after heating at 900° C. for 24 hours. The mean value of the optic angle of feldspars in the compositional range Or_{100}-Or_{60} decreases and, in the compositional range Or_{60}-Or_{37}, increases as a result of this heat treatment. Those feldspars which are triclinic at room temperature (anorthoclases) show only a very slight increase in the mean value of the optic angle. X-ray studies show that these changes are related neither to unmixing nor to the variation in optic angle of crystals from the same specimen.

The change in the effect of heat treatment on the optic angle at a composition of Or_{60} is correlated with the ease with which the change from sanidine to high-sanidine can be accomplished and, at a composition of Or_{37}, with the change from monoclinic to triclinic symmetry.

GEOCHEMICAL STUDY OF CHERT AND RELATED DEPOSITS

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Chemical analyses of 24 samples of high-silica sedimentary materials indicate surprisingly similar bulk compositions. Thirteen of the samples are chert; the remainder are novaculite, flint, siliceous oolite, silicified wood, melikaria, and a chalcedony ball from a bauxite deposit. The samples range from Pre-Cambrian to Recent and have a wide geographic distribution.

The narrow range of silica, 95.00-99.95 per cent, shows a facility of sedimentary differentiation to produce pure chemical types. Differences in the minor and trace constituents, however, may reflect different environments and geologic processes.

The following ranges in weight per cent were found for major constituents: SiO_2, 95.00-99.95; Al_2O_3, 0.00-1.95; Fe_2O_3, 0.04-0.90; MgO, 0.00-0.49; CaO, 0.00-1.54; Na_2O,

0.00-0.09; K_2O, 0.00-0.33; H_2O, 0.01-1.03; and CO_2, 0.00-1.20. TiO_2, P_2O_5, MnO and Li_2O are minor constituents. As and Mo range from less than 1 to 10 p.p.m. Ge is more variable, with an average of about 40 p.p.m. for the 24 samples. The average Ba content is about 350 p.p.m.; Be, Cu, Cr and Sr range from less than 1 to 500 p.p.m. Co, Ga, Ni, Sc, Sn and V are present as traces but Bi, Pb and Zr could not be detected in any of the samples.

NEW OCCURRENCE OF LEUCOSPHENITE, IN OIL SHALE FROM UTAH

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Leucosphenite, previously known only from the Narsarssuak, Greenland, pegmatite, is a widespread mineral in the Green River formation of Tertiary age in northeastern Utah. It has been found in several cores from oil wells in Duchesne and Uintah counties, and well cuttings indicate a vertical range of several thousand feet. It occurs in brown oil shale as well-formed crystals several millimeters in length, commonly associated with shortite $Na_2Ca_2(CO_3)_3$. It also occurs with analcime-bearing layers in beds of the Green River formation like those described by W. H. Bradley in 1930. The formula of leucosphenite, on the basis of chemical analysis of the Utah mineral and spectrographic analysis of the type Greenland crystals is revised to include 3% B_2O_3 (previously missed) and to omit 3% ZrO_2 (previously reported). The formula tentatively proposed is $CaBaNa_3BTi_3Si_9O_{29}$. Morphological and x-ray studies are in progress. The formation of the leucosphenite is believed related to the reaction of volcanic ash with strongly saline solutions as suggested by Bradley for the analcime.

SIGNIFICANCE OF ACCESSORY MINERALS IN IGNEOUS ROCKS

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Contrary to the expressed opinion of many petrologists, most of the common accessory minerals (apatite, zircon, sphene, rutile, iron oxides, pyrite) may be expected to crystallize late in igneous rocks. This conclusion is based on the known association of accessory minerals with pegmatites, on the physical-chemical premise that, other things being equal, constituents in small amount should crystallize late in a complex system, and on evidence from ore deposits of apatite, rutile and oxides of iron and titanium.

Studies of the frequency of association of accessory minerals with the various essential constituents of igneous rocks, particularly the basic to intermediate varieties, indicate a marked association with minerals, such as biotite and hornblende, which are low in the reaction series of Bowen. In all types of plutonic igneous rocks, the accessory minerals occur most abundantly along grain boundaries, near fractures and cleavages, or with alteration patches in the essential minerals. These relationships, occasional replacement criteria, and the erratic distribution of accessory minerals in thin sections, bear out the conclusion that most if not all have crystallized in a late (deuteric) stage of the cooling magma.

Conversely, the association of the accessory minerals with biotite and related minerals in acid rocks implies a late origin for this mineral even in these rocks. The more equal distribution of accessory minerals among the essential constituents of paragneisses as compared with igneous rocks offers a criterion for distinguishing paragneisses from those of magmatic origin.

DISORDER IN THE SUPER-LATTICE OF EKMANITE

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The chemical composition and differential thermal analysis data of ekmanite suggest that this flaky, hydrous-iron-manganese silicate mineral is related to the layer lattice silicates. The results of single crystal x-ray investigations indicate that ekmanite possesses a structure that is essentially a packing of talc-type sheets and interleaved cations and that the orthohexagonal cell is a multiple of a sub-unit of the following dimensions: $a = 5.54$ A, $b = 9.60$ A and $c = 12.08$ A. The multiplicity of this sub-unit is present along all three axes, resulting in a super-lattice. The distribution of diffuse reflections indicates the presence of a disordered lattice related to random and irregular displacements of the structural layers along the a and b axes. This effect can be inferred from the rotation diagrams of ekmanite taken by rotating the crystal around the b axis which show diffuse streaks along all of the layer lines, and also from normal-beam equatorial Weissenberg photographs taken by rotation around the b axis which show that the $h0l$ reflections are spread out along curves of constant h and continuously varying l indices.

The chemical composition, DTA curves and the results of the x-ray investigations suggest a relationship between ekmanite and stilpnomelane.

STRUCTURAL-CHEMICAL CLASSIFICATION OF THE CHLORITES: MAGNESIAN CHLORITES

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As a result of the extension of previous hydrothermal studies in the system $MgO\text{-}Al_2O_3\text{-}SiO_2\text{-}H_2O$ single homogeneous crystalline phases have been synthesized along the chrysotile-amesite join as far as the amesite composition. At lower temperatures phases with the 7 Å antigorite structure are formed. X-ray data that show the change in unit cell dimensions accompanying the addition of alumina along the join are given. A single phase of the amesite composition is formed only above 300° C., while below this temperature boehmite $+$ an aluminous serpentine form. Above 450° C. all compositions more aluminous that chrysotile yield a more stable 14 Å phase, presumably with the chlorite structure. The equilibrium decomposition temperatures of the 14 Å phases have been determined. Experiments with natural materials indicate that these, too, probably undergo the antigorite-chlorite dimorphism.

These results substantiate Tschermak's concept of an isomorphous series between serpentine and amesite. The dimorphism between the antigorite and chlorite structures suggests a new structural-chemical classification for at least the magnesian chlorites.

STUDIES OF MINERAL SULPHO-SALTS: XVIII—PAVONITE, A NEW MINERAL

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Alaskaite (Koenig, 1881) from the Alaska Mine, Colorado which was said to be a Bi sulphide of Pb, Ag and Cu was shown by Thompson (1950) to be a mixture of several minerals including aikinite ($PbCuBiS_3$) and matildite ($AgBiS_2$). A second occurrence in Sur-Lipez province, Bolivia (Ahlfeld with an analysis by Herzenberg, 1926) Thompson identified as benjaminite by x-ray powder patterns.

Single crystal studies of more favorable material show that despite a marked similarity between the powder patterns of type benjaminite from Nevada and the Bolivian mineral, the two are distinct species:

Nevada	a' 13.34	b' 4.06	c' 20.25 A	β 104°
Bolivia	a 13.35	b 4.03	c 16.34 A	β 94½°

An x-ray fluorescence analysis and fusion experiments indicate the composition $AgBi_3S_5$ ($Ag_2S \cdot 3Bi_2S_3$) which is different from that of known sulpho-salts. The Pb and Cu of Herzenberg's analysis are accounted for by the presence of aikinite and chalcopyrite.

Since the type alaskaite has been discredited and its name and supposed composition are not applicable to the Bolivian mineral, it is proposed to name the new species pavonite from the Latin pavo for peacock, in honor of the late Professor M. A. Peacock.

ABUNDANCE OF URANIUM AND THE ISOTOPES OF LEAD IN THE EARTH'S CRUST AND METEORITES

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Data have been obtained for the abundances of uranium and the isotopes of lead in basaltic and oceanic materials. The isotopic compositions of lead from the Columbia River basalt and of recent lead from the Pacific Ocean are 206/204 = 18.12, 207/204 = 15.45, 208/204 = 38.08, and 206/204 = 19.04, 207/204 = 15.69, 208/204 = 39.00 respectively. A study of uranium and lead in meteorites has been reported by Patterson, Inghram, Tilton and Brown. The cosmic abundances of uranium and lead are estimated to be 1 x 10^{-4} atoms and 8 x 10^{-3} atoms per 10^4 atoms of silicon respectively. The composition of primordial lead, if it can be inferred from that in an iron meteorite, is 206/204 = 9.41, 207/204 = 10.27, 208/204 = 28.16. It is possible to make the following interpretations from the above data: nearly all of the uranium in the earth is concentrated in the outermost layer of the crust; this concentration was established when the earth was formed; the U^{238}/Pb^{206}, Pb^{207}/Pb^{206}, and Th^{232}/Pb^{208} ages for the earth's crust have values greater than 4 billion years; basalt may originate from a material from which, during the life of the earth, some uranium has been removed.

METAMORPHISM RELATED TO PEGMATITES IN THE GRENVILLE

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Study of wall rocks of pegmatite intrusives near Bancroft, Ontario, indicates the presence of at least two stages of metamorphism:

(1) An older, regional type which produced diopside pyroxenites and amphibolites in lime-magnesium sediments and hornblende-plagioclase gneisses from argillites.

(2) A younger local effect associated with swarms of pegmatite intrusives, appearing as zones of alteration extending to as much as 2 miles from the pegmatite. The alteration appears as metasomatic replacement with the gradual appearance of scapolite, oligoclase, and microcline in the pyroxenites and amphibolites and microcline and quartz in the gneisses.

A general study of pink gneisses in the Grenville indicates that their association with pegmatites is constant; it is concluded that the effects seen near Bancroft are typical.

STRUCTURE OF MONTMORILLONITE IN RELATION TO THE PHYSICAL PROPERTIES OF BENTONITES

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Properties of bentonites vary with the nature of the montmorillonite mineral and are dependent upon the proportion of exchangeable Na^+ and Ca^{++} ions as well as types of isomorphous substitutions, which, in turn, may be partially related to weathering and near surface alterations in the bentonite deposit.

Theoretical intensity calculations were made for montmorillonite using a multiplicity factor for *three* possible phase shifts. *X*-ray analyses and theoretical calculations show that naturally occurring, air-dried bentonites contain "intimate mixtures" of three kinds of montmorillonite. One kind has two molecular layers of water, the second only one molecular layer of water, and the third no water at all adsorbed on the layers. "Double water layer particles" contain Ca^{++} as the exchangeable base; "single water layer particles" contain Na^+ as the exchangeable base and "zero water layer particles" are probably electrostatically neutral.

Drilling mud yield values of bentonite samples are correlated with data obtained from the (001) diffraction lines. Best yield values come from bentonite samples with a (001) 'd' value between 12.85 Å and 12.5 Å and with asymmetry values between .4 and .8. Samples with very symmetrical (001) peaks are very pure in one component and show poor yields. A certain amount of exchangeable Ca^{++} is needed in a clay-water system to produce a good drilling mud because a few "double water layer particles" create enough disorder in the system to allow dispersion to take place more easily.

SYNTHESIS, STABILITY AND PROPERTIES OF LAYER SILICATE STRUCTURES. I—SERPENTINE-KAOLINITE FAMILY

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Minerals with the serpentine structure have been prepared from the following compositions: $Mg_6Si_4O_{10}(OH)_8$, $Mg_5Al \cdot AlSi_3O_{10}(OH)_8$, $Mg_6Ge_4O_{10}(OH)_8$, $Ni_6Ge_4O_{10}(OH)_8$ and $Ni_6Si_4O_{10}(OH)_8$. The appropriate compositions in the following systems do not yield any serpentine (or 1:1 layer) structure: $ZnO-SiO_2$, $CoO-SiO_2$, $MnO-SiO_2$, $Ga_2O_3-SiO_2$, $MnO-GeO_2$ and $Ga_2O_3-GeO_2$. A comparison of the morphologies of the serpentine minerals formed supports the thesis that in structures of this type a "misfit" between the layers is the basic cause for the formation of cylindrical crystals. Other data show the secondary importance of the presence of foreign ions, temperature of formation and duration of run in conditioning this basic requirement.

A large number of other new phases has also been synthesized, including talc structures from the following systems, $MgO-GeO_2$, $NiO-GeO_2$ and $NiO-SiO_2$, an anthophyllite from the $MgO-GeO_2$ system, and a gallia-silica montmorillonite. A value of 8.16% has been determined for the volume expansion accompanying the spinel-olivine structure inversion occurring at 1005° C. in Mg_2GeO_4.

Phase equilibria in the systems $MgO-GeO_2-H_2O$ and $NiO-SiO_2-H_2O$ are presented as a set of pressure-temperature curves for the various reactions, and are compared with those for $MgO-SiO_2-H_2O$. Comparative data for the various reactions show some unexpected results; thus the stability limits at 10,000 psi water pressure for the serpentines is as follows: (Mg-Si), 490° C.; (Mg-Ge), 520° C.; (Ni-Si), 530° C.; (Ni-Ge), 360° C.

STABILITY RELATIONS OF SOME MINERALS IN THE SYSTEM $Na_2O-Al_2O_3-SiO_2-H_2O$

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A study has been made of the synthesis of minerals in the low soda portion of the system $Na_2O-Al_2O_3-SiO_2-H_2O$ and of the phase equilibria relating these phases with temperature and pressure. Analcime, albite, paragonite, Na-montmorillonite, sodalite, cancrinite, nepheline and a hydrated nepheline phase were the minerals synthesized and studied. The maximum temperature stability of analcime has been located at $525 \pm 5°$ C. (from 500 to 20,000 psi) and the minimum temperature of formation of nepheline located at $460°$ C. A maximum decomposition temperature for Na-montmorillonite has been found at $450°$ C. and for paragonite at $635°$ C.

Phase equilibria are shown in a series of pressure-temperature curves separating areas of stability of various phase assemblages.

PRELIMINARY REPORT ON THE SYSTEM $Na_2O-MgO-SiO_2$

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More than two hundred separate compositions in this system have been prepared and studied by the method of quenching. So far, eight ternary compounds have been recognized, all of which melt incongruently. Several of the new compounds are difficult to identify under the microscope from optical properties, particularly when they are present as tiny crystals which are suitable for rapid attainment of equilibrium between crystals and liquid. All of them are easy to identify by their characteristic x-ray powder patterns. A phase equilibrium diagram is given showing the fields of the several primary phases and the temperatures and compositions of the ternary invariant points.

A knowledge of the crystalline phases and melting relations in this ternary system is prerequisite to studies of more complex hydrous systems which may elucidate the compositions and relationships between alkaline pyroxenes and amphiboles which are major constituents of certain alkaline rocks and minor mineral constituents of many igneous rocks.

POLYMORPHISM IN ONE DIMENSION

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Lattices of layers of nets of equilateral triangles stacked with the nodes of each net above the centers of the triangles of the net below form an infinite set. Layers are distinguished by their immediate environments as cubic (c) and hexagonal (h). The zinc sulfide structures are examples. An admissible lattice as defined above is described by a linear series as; hcchc. . . . To remove one layer (h) requires energy V_1; to remove one layer (c) requires energy V_2. At equilibrium, V, $V = V_2 - V_1$, is related to the absolute temperature and the number of layers of each type; $n_h/n_c = f(exp -V/kT)$. For every value n_h/n_c, there is a subset of admissible lattices. Each member of the subset is distinguished by a unique value of a parameter σ; $\sigma = [n_{pq} - (n_{pp} + n_{qq})]/[n_{pq} + (n_{pp} + n_{qq})]$; p and q, q = p—l, are the two possible distances from h to h in a series and n_{pq} is the number of contacts of blocks of layers of unlike distance and n_{pp} and n_{qq} are the numbers of contacts of like blocks. If v_{pq}, v_{pp}, and v_{qq}, are the energies associated with each kind of contact, $v = v_{pq} - \frac{1}{2}(v_{pp} + v_{qq})$; v is unit

energy of change of σ, σ = f(exp −v/kT). Admissible lattices fill equal volumes; therefore no volume discontinuities accompany polymorphism in the admissible set and, since no latent heats are observed, these transitions must be of higher order than first.

EFFECT OF DIFFUSION ON THE NATURAL ISOTOPIC ABUNDANCE RATIOS

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Some processes of formation and alteration of rocks may have altered the isotopic abundance ratios of the elements in the earth's crust. Although exchange reactions have been used to explain these variations to a great extent, it would appear that isotopic fractionation due to a diffusion process might also explain, at least in part, some of the observed data. The degree of fractionation which can be expected from diffusion is shown from a theoretical study of solid-state and solute-diffusion processes. Solid-state diffusion across a boundary or within a crystal can account for a fractionation of several per cent under certain high-temperature conditions, but under the more usual geological conditions diffusion will cause a fractionation of about 1 per cent or less. Solute diffusion can account for fractionation of about the same order of magnitude. These theoretical results are in qualitative agreement with experimental data in a number of cases.

These studies also show that special sampling precautions should be taken for isotopic-abundance measurements which ultimately will be used to interpret geological processes or age measurements; very small crystals or material leached from crystals might display isotopic abundances which have been altered by diffusion processes.

TRACE-ELEMENT BEHAVIOR IN REGIONAL METAMORPHISM

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Sixty-three rocks of the pelitic Devonian Littleton formation of New Hampshire have been analyzed spectrographically for trace elements. The samples represent all grades of metamorphism from shales to sillimanite schists and gneisses. The average concentrations and standard deviations are given as follows in ppm: Ga, 19, 6.3; Cr, 110, 33; V, 120, 39; Li, 110, 104; Ni, 64, 26; Co, 18, 6.6; Cu, 18, 18; Sc, 14, 7.4; Zr, 200, 73; Y, 45, 20; Sr, 710, 310; Pb, 24, 12. In addition, Be, Mo, Sn, La, Ag were sought, but were usually below the sensitivity limits of 30, 10, 20, 100, 1 ppm, respectively. Ba almost always exceeds 1000 ppm.

Figures for individual analyses were grouped according to low, medium, or high grade of metamorphism. Statistical tests show a rather wide range in original composition, which suggests that it is unwise to deduce composition changes from a few analyses. Consideration of the averages, however, shows that the concentration of most elements remained constant during regional metamorphism. Ni and Cu show a slight decrease, and Li and Pb a well-defined increase of the order of 100%, accompanying the metamorphism. This increase is a metasomatism at the trace-element level which probably accompanies the potash-metasomatism encountered by Billings in the same formation.

POTASSIUM ARGON STUDIES AT THE UNIVERSITY OF TORONTO— A PROGRESS REPORT

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In 1951-52 the University of Toronto began studies of the radiogenic argon content of potassium minerals in order to obtain a value for the branching ratio of potassium 40, and to investigate the possibility of geological age determinations based on the radioactive decay of potassium. Preliminary results of these studies were sufficiently promising that the project was continued and expanded in the following year. Measurements of the potassium and radiogenic argon content of a number of potassium feldspars differing in age by as much as a factor of five were found to be consistent with a branching ratio of $0.060 \pm .006$.

Two new argon measuring apparatuses have been built and the number of research workers has been increased. Present indications are that satisfactory age determinations can be made from argon and potassium measurements in feldspars and micas.

SODIC PLAGIOCLASES: (A) LATTICE PARAMETERS OF THE NATURAL HIGH- AND LOW-TEMPERATURE SERIES AND OF SYNTHETIC CRYSTALS, AND (B) REVISED DETERMINATIVE CHARTS FOR THE NATURAL LOW-TEMPERATURE SERIES

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Natural low-temperature sodic plagioclases are converted into the high-temperature form by prolonged heating near the melting point. Synthetic sodic plagioclases have been crystallized only in the high-temperature form. Accurate measurements of the six (triclinic) lattice parameters have been made on the Philips powder spectrometer of all three types of material from An_0 to An_{36} using a method similar to that of Donnay and Donnay on the synthetic alkali feldspars. A matrix method giving a least-squares solution for the lattice parameters was used.

The lattice parameters (especially γ^*) of the low-temperature sodic feldspars vary considerably with composition, thus providing a sensitive method for determining composition by x-rays (sensitivity $\sim 0.5\%$ An). For the high-temperature sodic plagioclases only β^* varies appreciably with composition. This parameter is sensitive to a change of 3% An. The difference between the lattice parameters of the two series decreases rapidly as the An content increase to An_{35}.

A revised determinative chart for the low-temperature sodic plagioclases using the angle between the (131) and (1$\bar{3}$1) reflections has been prepared. Poor resolution of the (1$\bar{3}$1) reflection for compositions in the vicinity of An_7 seriously reduced the precision of the measurement. The angle between (24$\bar{1}$) and (132) is almost as sensitive to differences of composition, however, and has the further advantage of uniformly good resolution over the entire range. A determinative chart has therefore been prepared for these reflections.

THEORETICAL AND X-RAY STUDY OF THE MICA POLYMORPHS

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Th two factors which allow polymorphism in the micas are: (1) the pseudo-hexagonal rings of oxygen atoms around the potassium atoms which link the layers

together, and (2) the staggering of the two silicon sheets which form each layer. There are four possible ways of stacking two adjacent layers. A simple way of depicting the stacking is to give only the positions of the potassium atoms, for the complete structure can be built from this knowledge. Completely random stacking gives a one-layer, monoclinic, disordered structure (1Md). With only one stacking fault in an ordered sequence twin crystals are produced. For ordered stacking an infinity of structures can be built, but the simpler ones are 1M, 2M, 2O (Orthorhombic), 6M, 3T (Trigonal), and 6H (Hexagonal). The theoretical structures have all been found in nature except for the 2O and 6H. Random arrangements of blocks of ordered layers give mixed-layer structures.

Interaxial angles measured on a precession camera agree within the experimental error (± 5′) with the values for exact geometry for a 1M mahadevite, 2M muscovite (USNM 96460), 3T muscovite from Sultan Basin, Washington, and a 3T phlogopite (USNM R4463). Although bending and absorption make intensity comparisons uncertain, those intensities observed were always consistent with exact symmetry. The same Sultan Basin material had been previously described as 3M on the basis of a finite 2V and an apparent lack of symmetry between equivalent diffuse streaks.

A new twin plane (001) was found in a 1M mahadevite crystal close to eastonite in composition. The (001) twin as well as the previously described [110] twin is demonstrated theoretically. A re-examination of a six-layer, triclinic biotite of Hendricks and Jefferson indicates that this is a 2M mica described on different axes.

OCCURRENCE OF ALUNITE AND PYROPHYLLITE IN PUERTO RICO

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An alunite-pyrophyllite deposit between the towns of Comerio and Aguas Buenas approximately 20 miles southwest of San Juan, Puerto Rico, has been mapped and studied in detail. The work is being carried on cooperatively by the U. S. Geological Survey and the Puerto Rico Economic Development Administration. The area mapped embraces about 12 square miles, but the principal deposit is limited to an area about 4 miles long and a mile wide along the crest and part way down the flanks of east-west trending Cerro La Tiza Mountain. The alunite is represented principally by finely banded alunite-quartz boulders whose relationship to their source is not definitely understood. It seems probable that some of the boulders, especially the larger ones near the crest are the result of local weathering and have not moved far from their place of origin. The flanks of the mountain below the deposit are composed of deeply weathered greenish-brown volcanic agglomerates most probably of Late Cretaceous age.

Pyrophyllite occurs in foliated outcrops, some as much as 70 feet wide. Small patchy bodies of kaolin group minerals, sericite and alunitic clays occur in exposures along small roads and foot trails through a heavy cover of foliage. Preliminary chemical analyses show that the alunite contains about 6 per cent K_2O and 2 per cent Na_2O.

The deposit is believed to be of hydrothermal origin, the solutions having come from quartz diorite batholiths of Eocene age south and southeast of the deposit. The hydrothermal solutions are believed to have come up along a general east-west trending line of weakness. Other smaller deposits of a similar nature have been found at intervals as far as 25 miles eastward along this trend and are being studied.

PROGRESS IN AIRBORNE RADIOACTIVITY SURVEYING

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Further development of airborne radioactivity surveying by the U. S. Geological Survey and the Oak Ridge National Laboratory during the last 2 years has improved greatly the technique both for prospecting and for geologic reconnaissance. In prospecting for new occurrences of uranium and thorium, local concentrations of radioactive materials of possible economic significance can be detected satisfactorily 500 feet above the ground. For maximum efficiency when using multi-engine aircraft a unit area of at least 50 square miles should be surveyed. Selection of areas for survey should be based on the best geologic inferences drawn from general knowledge of where uranium and thorium are most likely to occur. Promising results have been obtained in areas so selected.

Airborne surveys in North Carolina, Florida, California, and Arizona show that radiation intensity is related to the areal distribution of various rock types; thus such surveys provide a reconnaissance technique for delineating major geologic features with rapidity and at low cost. In geologic reconnaissance, rock types can be distinguished both where rock outcrops occur and where residual soils blanket the bedrock.

Empirical measurements of gamma radiation intensity have been made at various distances over point sources of different gamma radiation energies and over simulated ore outcrops; these data accord with and confirm theoretical analyses of the absorption and scattering of gamma radiation in various media and geometric configurations.

ISOTOPIC COMPOSITION OF LEAD IN LEAD MINERALS FROM THE COLORADO PLATEAUS

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Approximately 45 specimens of lead minerals have been collected from the Colorado Plateaus and adjacent areas. The isotopic composition of the lead in these minerals has been determined. This work is part of a detailed study of the lead-uranium ages of the uranium ores from the Upper Triassic and Upper Jurassic rocks of the plateaus.

The Pb^{206} content of essentially uranium- and thorium-free lead minerals ranges from approximately 24 to 60 per cent. The absence of thorium from the plateaus sediments is reflected by the relatively constant Pb^{204}/Pb^{208} ratio. Systematic changes in the Pb^{206} and Pb^{207} contents suggest the addition of small amounts of old radiogenic lead whose age is approximately one billion years.

The systematic variations in the isotopic compositions of the lead minerals from the uranium deposits of the plateaus and the Tertiary deposits adjacent to the Colorado Plateaus strongly suggest a common or similar source for the original lead as well as the added radiogenic lead. The apparent relationship of the lead in the plateaus and adjacent ore deposits in Upper Triassic, Upper Jurassic, and Tertiary rocks is supported by the Tertiary lead-uranium ages which have been determined for these uranium ores.

In addition to the application of the regional variation in the lead isotope abundances to certain problems of ore deposition, the isotopic data on the Plateaus leads may also be used to evaluate the current estimates of the Pb^{207}/Pb^{206} age of the earth using ore leads. Some of the assumptions required by the Pb^{207}/Pb^{206} method do not appear to be supported by these new isotopic analyses.

SYNTHETIC ZINC SULFIDE POLYTYPE CRYSTALS

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X-ray examination of zinc sulfide crystals grown from the vapor phase show them to consist of mixed polymorphic structures in the majority of cases, regardless of their external morphology. In addition to intimate mixtures (on atomic scale) of 2- and 3- layer structures—wurtzite and zincblende (or rhombohedral, Buck and Strock) they also show Frondel and Palache polytypes of 4- and 6- layer structures. Crystals containing 2, 3, 4, 5, 6, 7, 8, 9 and 11 layer structures have been observed. Many crystals show very intense diffuse x-ray reflections from certain hkl zones of constant hk values, not reported for the natural polymorphs. The role of impurities in determining the structure and growth habit of the crystals has been studied.

ORDOÑEZITE, ZINC ANTIMONATE, A NEW MINERAL FROM GUANAJUATO, MEXICO*

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Tin ores from the Santin mine, Guanajuato, Mexico, contain a new mineral having the chemical composition $ZnSb_2O_6$. The mineral is in small pale to dark brown crystals associated with cassiterite. It is tetragonal, $a = 4.66$, $c = 9.24$ A, space group $P4/mnm;$ specific gravity $= 6.64$. The structure is the trirutile type, and the mineral is isostructural with tapiolite ($FeTa_2O_6$), bystromite ($MgSb_2O_6$) and many other artificial antimonates and tantalates. The name ordoñezite is proposed for the mineral after the late Ezequiel Ordoñez, outstanding Mexican geologist.

USE OF ISOTOPE DILUTION IN DETERMINATION OF GEOLOGIC AGE OF MINERALS

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The method of isotope dilution along with the mass spectrometer for determination of radiogenic Sr^{87} and Rb^{87} reported by Aldrich, has been greatly extended so that 0.01% of rubidium and 0.0001% of radiogenic Sr^{87} have been estimated accurately using only 100 mg. of mineral sample.

For each age determination 0.5 μg of Sr^{90} and 0.01 μg of fission rubidium containing 70.2% Rb^{87} were used. The possibility of working with such small quantities has greatly simplified chemical separation of strontium and has made separation unnecessary for rubidium. The use of Sr^{90}, a readily available fission product absent in natural strontium, makes the interpretation of the mass spectrograms simpler. The radioactivity of Sr^{90} and of its daughter isotope Y^{90} greatly facilitate chemical manipulation. Determination of ages for minerals containing many times as much normal strontium as radiogenic Sr^{87} have been carried out.

Ages are presented for one lepidolite and two biotite minerals. The ages obtained were found to be considerably greater than those found by other methods. Since incorrect ages would result if fractionation of rubidium and strontium had occurred due to weathering, this possibility was studied by determining ages of one biotite after washing with hydrochloric acid and aqua regia. These treatments did not materially affect the value of the ages.

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DETERMINATION OF POLAR AXIAL ANGLES AND POLAR AXIAL RATIOS FROM INTERFACIAL ANGLES

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A simple method of calculation of crystallographic axial ratios and axial angles, and a simple method of determination of Miller indices from measurements of interfacial angles with the one-circle goniometer or with the contact goniometer, are especially needed by mineralogists and geologists whose principal interests are in branches of geologic science other than crystallography but who wish to make some use of crystallographic data in mineral determination.

In all crystal systems the polar axial angles are defined as the angles between the edges of a parallelepiped constructed with its edges perpendicular to the faces 100, 010, and 001, and with its body diagonal perpendicular to the face 111, and the polar axial ratios are defined as the ratios of the lengths of the edges of this parallelepiped. The edge perpendicular to the face 100 is designated p_o', the edge perpendicular to the face 010 is designated q_o', and the edge perpendicular to the face 001 is designated r_o'; the angle between q_o' and r_o' is designated λ, the angle between p_o' and r_o' is designated μ, and the angle between p_o' and q_o' is designated ν. The polar axial angle λ is thus by definition the angle between the normals to the faces 010 and 001. Likewise the polar axial angle μ is by definition the angle between the normals to the faces 100 and 001, and the polar axial angle ν is by definition the angle between the normals to the faces 100 and 010. The polar axial angles of some triclinic minerals can thus be obtained as measured interfacial angles or as the sums of measured interfacial angles.

The polar axial ratios of a triclinic crystal can be calculated by means of the equations:

$$\frac{p_o'}{r_o'} = \frac{l \, \sin \, (001 \wedge h0l)}{h \, \sin \, (100 \wedge h0l)}, \tag{1}$$

$$\frac{q_o'}{r_o'} = \frac{l \, \sin \, (001 \wedge 0kl)}{k \, \sin \, (010 \wedge 0kl)}, \quad \text{and} \tag{2}$$

$$\frac{p_o'}{q_o'} = \frac{k \, \sin \, (010 \wedge hk0)}{h \, \sin \, (100 \wedge hk0)}. \tag{3}$$

The polar axial ratios of some triclinic minerals can thus be obtained as the ratios of the sines of measured interfacial angles.

In the other crystal systems the calculation of the polar elements from interfacial angles is even more simple.

MAGMATIC ORIGIN OF A TERTIARY GRANITE FROM THE ISLAND OF SKYE, SCOTLAND

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Recent detailed study of the properties of quartz and feldspar show that both may yield information as to the conditions under which they crystallized. The inversion temperature of quartz can be used as an indicator of relative temperatures of crystallization; high-temperature and low-temperature feldspars can be distinguished by determinations of composition and optic angle.

Previous investigation showed that quartz samples from a group of granites invert at higher temperatures than do quartz samples from a group of rhyolites, and it was suggested that the observed difference between "rhyolite quartz" and most "granite

quartz" probably results from late-stage recrystallization of granite minerals at low temperature. A small pluton on the Island of Skye was selected for study as a type of occurrence which might yield granite which had not recrystallized completely. Quartz was separated from 25 specimens and the inversion in every case was found to be similar to that of quartz from rhyolites previously studied. The alkali feldspar holds up to 45% albite in solid solution and has properties characteristic of sanidine which has changed partially to orthoclase cryptoperthite. The plagioclase feldspar is high-temperature oligoclase. The granite has the textural features of a granite together with the mineralogical features more commonly found in rhyolite. The evidence thus points to a magmatic origin of the granite.

APPLICATIONS AND LIMITATIONS OF GEOPHYSICAL PROSPECTING IN NEW BRUNSWICK

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Employment of a combination of two geophysical methods, the airborne magnetic and the ground electromagnetic, has led to the discovery of two important new ore-bodies in the Bathurst area of New Brunswick. Several other geophysical methods are currently in use in New Brunswick, notably resistivity, ground magnetic and geochemical soil testing. The part which each of the five methods noted above has played in the discovery of sulfide mineralization is noted. The applicability and limitations of each method are described particularly with reference to the problem of distinguishing between sulfide mineralization, graphitic sediments (which are abundant in the area) and magnetite deposits.

The airborne magnetometer maps structure by virtue of its response to magnetite content in rocks and ores. The electrical methods map electrically-conducting bodies such as sulfide mineralization and graphitic sediments. Geochemical soil testing, in the limited number of cases in which it has been applied, has been successful in separating those zones of good electrical conductivity which contain quantities of such metals as copper and zinc from those which do not contain these metals.

MINERAL ASSOCIATIONS AND TYPES OF URANIUM ORES ON THE COLORADO PLATEAUS

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Uranium ores from the Colorado Plateaus are classified in two main types: (1) uranium with vanadium, (2) uranium with copper and other metals. Each type is subdivided into highly oxidized or relatively unoxidized ore.

The vanadium-uranium ratio of the vanadiferous ores ranges from about 30:1 at Placerville and Rifle, Colo., to about 1:1 at Temple Mountain, San Rafael district, Utah. The chief uranium minerals of the highly oxidized ore are the uranyl vanadates: carnotite, tyuyamunite, and metatyuyamunite. The other vanadium minerals include roscoelite, vanadium hydromica, corvusite, fernandinite, and hewettite, with small amounts of pascoite, hummerite, rossite, metarossite, steigerite, fervanite, hydrated vanadium pentoxide, and the sodium analogue of hewettite, the last two being new minerals whose descriptions will be published soon.

The unoxidized vanadiferous ores are black and contain a new black uranium mineral found in 9 mines, pitchblende, and montroseite and at least 2 other low-valence

vanadium oxides. They are associated with pyrite and small amounts of sulfides (or selenides) of lead, copper, zinc, cobalt, nickel, molybdenum, and silver. Melanovanadite, corvusite, and fernandinite may represent a transition to oxidized ore.

The oxidized nonvanadiferous ore is characterized by bright-colored secondary minerals: about 18 yellow, orange, or green uranium minerals, including hydrated oxides, carbonates, sulfates, phosphates, arsenates, and silicates, as well as many secondary blue or green copper minerals, 5 different pink cobalt "blooms," and traces of molybdenum, lead, zinc, nickel, and silver.

The unoxidized nonvanadiferous ore is also black and contains pitchblende, the new uranium mineral mentioned above, chalcopyrite, pyrite, bornite, chalcocite, sphalerite, galena, and traces of cobalt, nickel, molybdenum, and silver.

EQUILIBRIA RELATIONS DURING THERMAL METAMORPHISM OF CARBONATE ROCKS

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By the use of thermo-chemical data and by approximating certain unknown heat capacity and entropy values, the equilibrium relations ($\Delta F = 0$), under ideal conditions and ignoring pressures, have been calculated for fourteen different reactions occurring during progressive thermal metamorphism of siliceous carbonates. The reactions considered involved the following minerals: calcite, dolomite, magnesite, α and β quartz, forsterite, enstatite, diopside, wollastonite, periclase, monticellite, α and β larnite, lime and carbon dioxide.

The calculated equilibrium temperatures at one atmosphere CO_2 pressure vary from 92° C. for the reaction $MgCO_3 + SiO_2 \rightleftharpoons MgSiO_3 + CO_2$ to 877° C. for the reaction $CaCO_3 \rightleftharpoons CaO + CO_2$. These equilibrium temperatures are found to be in fairly good agreement with known experimentally determined reaction temperatures. However, the consistent deviation of the experimentally determined reaction points in the lower temperature reactions from the theoretical values show that the speed at which equilibrium is attained is already strongly retarded considerably before equilibrium is reached. Due to the large time factor involved in metamorphism, the natural occurring reactions are believed to take place much closer to the theoretical than to the experimental values.

The effect of rock pressure on the equilibria temperatures at one atmosphere CO_2 pressure is calculated using the Clapeyron equation by assuming that the CO_2 is squeezed out of the system. In this case rock pressures of 4,000 atmospheres will cause a lowering of the equilibrium temperatures between 40 and 80° C. depending on the change in the mole volume of the solids during the reaction.

GRAVITY OBSERVATIONS AT SEA, PART I: THE BAHAMAS ISLANDS REGION

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Simple Bouguer and free air anomalies for 234 new gravity observations in the deep water of the Bahamas Islands region are reported. Bouguer gravity anomalies for 326 points in the shallow water areas of the Bahama Islands have been provided by oil companies and oil prospecting companies. Anomaly maps are presented combining all available data. Predominantly the anomalies can be explained by simple erosion of the deep-water portions without compensation, or alternately construction of the shallow

water-portions with regional compensation. This is superimposed on a small seaward increase of gravity. A negative free-air anomaly of about 110 milligals follows the eastern boundary of the Bahamas and the southern part of the Blake Plateau. The greatest part of this anomaly can be explained by the above process, possibly complicated by boundary effects of the isostatic compensation.

ZIRCONS AS PROVENANCE INDICATORS

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A recent study of a Scottish granite intruded into Moine "granulites" showed that while the greater part of the granite was clearly magmatic, there was considerable granitization near the contact in some areas. The magmatic origin of the granite was shown by field evidence, and by microscopic, chemical and trace-element studies; the granitized Moine could be differentiated from the normal granite without difficulty. The accessory zircons in these rocks were studied, and it was found that zircons from the granite are idiomorphic, while those from the Moines are well rounded. Furthermore, zircons from contaminated granite are similar to those from the normal granite, but they are very elongated; and zircons from the granitized Moines are recrystallized and idiomorphic, but quite distinct from those in the granite. It is suggested that this technique may have wider uses in similar studies.

SYNTHESES AND STABILITY OF THE MUSCOVITES

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The syntheses of randomly stacked one-layer monoclinic muscovite (1Md = illite), one-layer monoclinic muscovite (1M), and two-layer monoclinic muscovite (2M) have been accomplished. The upper stability limits of muscovite are represented by a curve passing through the points 625°C.-5,000 psi water vapor pressure, 665°-15,000 psi, and 715°-30,000 psi. Above this curve sanidine + corundum + vapor are the stable phases.

The stability ranges of the muscovite polymorphs named could not be fixed accurately because of the sluggish nature of the transformations. However, the following transformations were effected: $1Md \rightarrow 1M \rightarrow 2M$. It is believed this sequence obtains in the progressive metamorphism of sediments. The first transformation is probably dependent on factors affecting reaction rate. The second transformation may be related to a univariant curve of equilibrium (i.e., an isograd). The three-layer trigonal muscovite (3T) was obtained in only one run with 2M muscovite and its synthesis is therefore not substantiated.

Experiments on reactions alleged to represent a biotite isograd indicate that the muscovite-chlorite-quartz schists undergo the following reaction: muscovite + 2 clinochlore + 4 quartz $\rightleftharpoons$ phlogopite + 2 cordierite + 8 water. The growth of biotite according to this reaction in low-grade metamorphic rocks must be accompanied by another phase (i.e., cordierite). Growth of biotite as a result of other reactions will not be of equivalent grade. The upper stability curve of muscovite marks the conditions of the second sillimanite (or orthoclase) isograd.

A comparison of the upper stability curve of muscovite with the minimum melting curve of the "granite" system suggests that muscovite may form in granitic magmas above approximately 25,000 psi water vapor pressure and in the solid state below that

pressure in granitic rocks. These relations may account for the apparent two generations of muscovite in some granites.

Data have also been obtained on the muscovite-leucophyllite, muscovite-paragonite, and muscovite-quartz joins.

THERMOLUMINESCENCE OF ARTIFICIALLY PRECIPITATED CALCITE

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A number of experiments have been performed in which calcite has been precipitated from solutions containing varying concentrations of impurity ions. Some of the impurities such as manganese and strontium appear to serve as activators for thermoluminescence. Iron generally inhibits the thermoluminescence of calcite. In some instances, specific electron trapping centers appear to be assignable to specific impurities.

A second series of experiments has been carried out in which limestones containing their natural impurities have been dissolved in acid and reprecipitated under conditions of increasing pH. These experiments indicate that certain impurities are included in the crystal lattice of calcite precipitated under specific pH conditions, since the thermoluminescence glow-curves change markedly with changing pH. It is hoped that detailed examination of these changes will yield information about the pH of the solutions from which natural calcites have been precipitated.

In order to attempt to simulate geological conditions to a small degree, some of the precipitates have been subjected to high pressures and attempts have been made to recrystallize some of the samples. Pressure effects are complex, but there appears to be a general reduction in low temperature thermoluminescence of precipitates which have been subjected to high pressure.