

PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL
MEETING OF THE MINERALOGICAL SOCIETY OF
AMERICA AT OTTAWA, CANADA

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

The twenty-eighth annual meeting of the Society was held at the Chateau Laurier, Ottawa, Canada, on December 29–31, 1947. The registration figures show that 165 fellows and members attended. The scientific sessions were held in the afternoon on December 29th and 30th and in the morning of December 31st, at which forty-five papers were presented orally and eleven by title. The annual luncheon of the Society, which was held on December 30th, was attended by 140 fellows, members, and guests. This is not only the largest number who have ever attended an annual luncheon but many others were turned away because of lack of space. Following the luncheon Edward H. Kraus presented the Roebling medal to Paul Niggli of Zürich, Switzerland. Professor Niggli is the seventh recipient of the medal and the second European to receive this award. The retiring President, Martin J. Buerger, addressed the Society on the *Rôle of Temperature in Mineralogy*.

On the following pages are given the reports of the officers for the year 1947 as read before the Council at its meeting on December 28, 1947.

ELECTION OF OFFICERS AND FELLOWS FOR 1948

The secretary reported that 378 ballots were cast in the election of officers for 1948: 253 by members and 125 by fellows of the Society. The officers as nominated by the Council were elected and are:

President: Martin A. Peacock, University of Toronto, Toronto, Canada.

Vice-President: A. Pabst, University of California, Berkeley, California.

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 (1948–1951): Clifford Frondel, Harvard University, Cambridge, Massachusetts.

The secretary reports that according to the provisions of the constitution the following have been elected to fellowship:

Julian Devereau Barksdale, University of Washington, Seattle, Washington.

Harold E. Buckley, University of Manchester, Manchester, England.

Felix Chayes, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Theodore Ayrault Dodge, Tucson, Arizona.

Harry von Eckermann, University of Stockholm, Stockholm, Sweden.

Reuben B. Ellestad, Metalloy Corporation, Minneapolis, Minnesota.

Antoine Marc Gaudin, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Eberhardt William Heinrich, University of Michigan, Ann Arbor, Michigan.

Ralph Jerome Holmes, Columbia University, New York, N. Y.

George Clayton Kennedy, Harvard University, Cambridge, Massachusetts.

Charles Edmund Marshall, University of Missouri, Columbia, Missouri.

Edward Wilfrid Nuffield, University of Toronto, Toronto, Canada.

Lincoln Ridler Page, U. S. Geological Survey, Custer, South Dakota.

Percy Dudgeon Quensel, University of Stockholm, Stockholm, Sweden.

Kalervo Rankama, University of Helsinki, Helsinki, Finland.

Richard Atwell Rowland, Shell Oil Company, Houston, Texas.

Ward Conwell Smith, U. S. Geological Survey, San Francisco, California.

Bronson Ferrin Stringham, University of Utah, Salt Lake City, Utah.
 Charles Joseph Vitaliano, Indiana University, Bloomington, Indiana.
 Elizabeth Armstrong Wood, Bell Telephone Laboratories, Murray Hill, New Jersey.

ACTION BY THE COUNCIL

It was voted by the Council to continue in the future the practice of holding the Annual Meeting at the same time and place as the Annual Meeting of the Geological Society. Therefore, the meeting in 1948 will be held in New York City on November 11-13. Because of this change, it will be necessary that the Secretary have abstracts of papers to be presented at the meeting by *September 1, 1948*. The Council also voted that in the future no papers be accepted for presentation by title only.

REPORT OF THE SECRETARY FOR 1947

MEMBERSHIP STATISTICS

To the Council of the Mineralogical Society of America:

	1946	1947	Gain	Loss
Correspondents	6	6	0	0
Fellows	237	254	20	3
Members	625	677	205	153
Subscribers	535	501	115	149
	<hr/>	<hr/>	<hr/>	<hr/>
	1403	1438	340	305

The above figures show a net gain of 17 fellows and 52 members and a net loss of 34 subscribers. Considering fellows, members and subscribers together, this shows a total gain of 35. The loss in subscribers over 1946 was due to the cancellation of 95 Russian subscriptions in March of 1947. Although the number of subscribers has been substantially reduced, the number of subscriptions in the Soviet Union has not been reduced a comparable amount, for several institutions are now receiving more than one copy of *The American Mineralogist* and one as many as 25 copies.

The Society lost through death three fellows in 1947: Gregori Aminoff, Joseph P. Connolly, and Terence T. Quirke.

Respectfully submitted.

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

REPORT OF THE EDITOR FOR 1947

To the Council of The Mineralogical Society of America:

In making an overall report on, and appraisal of, the publication activities of the Society for the current year, two related items should be included: (1) the bimonthly publication, the *Journal*, and (2) the decennial index for the years 1936-1945. The latter, a 200-page author-subject index, is now available for distribution and represents a carefully prepared and complete table of references for volumes 21-30. For the completion of this valuable and indispensable reference volume we are indebted to Drs. Ingerson and Fleischer who have labored long and faithfully in its preparation. An edition of 1300 copies has been printed and this number should be sufficient to meet both the present and future demands. The index is being offered for sale at a price of \$2.00 to members and subscribers, and \$3.00 to non-members.

The *Journal* has likewise experienced a very satisfactory year. The current volume of slightly over 700 pages represents an increase of 100 pages over the previous year. If to the

700 pages we add the 200 pages represented by the decennial index, the over-all total exceeds 900 printed pages which the Society has made available this year to those interested in our science. This grand total of 900 printed pages has been equalled but once and exceeded on only one other occasion in the entire history of the Society.

This increased volume of printing, together with rising costs of labor and materials, is naturally reflected in marked increased printing expenditures. However, this tendency of ascending prices seems to be the order of the day and is not restricted to any one locality or printer. We have enjoyed over a long period of years very efficient service, promptness of publication combined with the use of an excellent quality of coated paper making possible a clarity of reproduction of graphs, diagrams, and photographs that has been the envy of other publications and a "joy to see," as recently expressed in a personal communication from a colleague in an English University. I hope no action will be taken, under the guise of economy, that might in any way retard efficiency or cheapen the character of the Journal through a change in the quality of materials now being used.

The Geological Society has continued its generous financial support for defraying a substantial portion of the publication costs. This past year this aid amounted to \$3000 with an additional appropriation of \$500 for the cost of colored plates if and when such illustrations were deemed necessary or highly desirable. Likewise, some additional financial assistance was received from the Geological Society for the printing of the decennial index. Recognition and deep appreciation is here expressed for this generous and timely assistance, by virtue of which it was possible to include two articles requiring colored insertions.

There has been no back log of accumulated manuscripts under our present bimonthly system. If the Journal had appeared monthly this past year, the total number of pages would have been exactly the same; only each issue would have been half the size while a substantial increase in the over-all cost for the volume would have resulted. The cost of covers, for binding and for mailing would have been doubled, and there would have been a further percentage increase resulting from the doubling up of change-overs in the typesetting department, press room, and folding division. Aside from the additional cost involved in a change-over to a monthly magazine, printing difficulties would arise, as the new typesetting equipment that has been on order for some time has not yet been delivered. Therefore, considered from all angles it would seem necessary, at least for the present, to continue as a bimonthly, since all material thus far received has been adequately taken care of without undue delay and at a minimum cost.

In a detailed analysis of the Journal for 1947, we find that volume 32 contains 702 pages, exclusive of index. Leading articles, which number 57, occupy 79.3% of the total space. Table 1, which accompanies this report, indicates the distribution of the leading articles in the various fields listed. It might be of some interest to note that the average length of each of the main articles was slightly less than 10 printed pages.

If to the 57 leading articles we add 20 shorter papers appearing under the heading of "Notes and News," we obtain a total of 77 published manuscripts for the calendar year. These contributions were obtained from 83 contributors associated with 48 different universities, research bureaus, and technical laboratories.

The Journal for 1947 carries detailed descriptions of five new minerals: paraschoepite, epiianthinite, fairchildite, buetschliite, and groutite. Two hundred and sixty-seven illustrations of various types assist in clarifying the descriptive portions of the text.

In one respect, at least, volume 32 is quite unique, namely, in the number of papers submitted and printed from contributors residing outside of the States. Sixteen such manuscripts were received representing the following 11 countries: Australia, Belgium, Canada, England, Finland, Germany, Italy, Japan, New Zealand, Norway, and South Africa.

The accompanying Table 1 summarizes in detail the distribution of subject matter in volume 32.

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOL. 32

<i>Subjects</i>	<i>Articles</i>	<i>Pages</i>	<i>Per Cent of Total</i>
Leading articles*			
Descriptive Mineralogy	9		
Chemical Mineralogy	17		
Structural Mineralogy	12		
Geometrical Mineralogy	1		
Petrography	8		
Optical Mineralogy	4		
Mineralography	1		
Memorials } Miscellaneous }	5		
	57	557	79.3
Shorter articles	20	33½	20.7
Notes and news	19	8	
Proceedings of societies	11	78½	
Book reviews	11	14	
New mineral names	35	11	
Total entries	153	702	100.0
Illustrations	267		
Index, Title page, Table of contents		16	
Grand total		718	

* Leading articles average 9.8 printed pages each.

Respectfully submitted

WALTER F. HUNT, *Editor*

REPORT OF THE TREASURER FOR 1947

To the Council of the Mineralogical Society of America:

Your treasurer submits herewith his annual report for the year beginning December 1, 1946, and ending November 30, 1947.

RECEIPTS

Cash on hand December 1, 1947	\$ 7,392.92
Dues and subscriptions	4,289.31
Sale of back numbers	878.26
Authors' charges on separates	549.16
Interest and dividends from endowment	3,139.95
Payments on principal of Trenton Mortgage stock	273.11
Geological Society of America aid for printing the Journal	4,059.77
Geological Society of America aid for printing new Index	1,000.00
Advertising	209.89
Sale of 20-volume Index	2.00
Sale of Index to volumes 21-30	53.00
	<hr/>
	\$21,847.27

DISBURSEMENTS

Printing and distribution of the Journal (6 issues)	\$ 7,225.76
Reprinting two out-of-print issues	918.50
Printing and distribution of separates	740.34
To the Editor, Secretary, and Treasurer	1,250.00
Postage	123.09
Clerical help	434.25
Office equipment	60.98
Printing and stationery	215.55
Safety deposit box	9.60
Telephone and telegraph	8.75
Committee expenses	17.37
Society luncheon (1946)	4.94
Roebing Medal	132.34
Exchange charges on checks75
Returned check	3.60
Refund of dues	3.00
Travel expenses of Editor and Secretary to Annual Meeting	111.55
Preparation of Index to volumes 21-30	1,353.50
Printing of Index to volumes 21-30	2,035.93
New securities purchased	5,050.00
Commission on new securities	13.50
Accrued interest on bonds purchased	81.95
Program and abstracts (1946)	265.85
Back numbers of the Journal purchased	38.00
	<hr/>
Cash balance November 30, 1947	\$20,095.10
	1,752.17
	<hr/>
	\$21,847.27

The endowment funds of the Society as of November 30, 1947, consist of the following securities:

BONDS

5M U. S. Treasury, 2½%	\$ 5,190.63
5M Illinois Central, 4%	3,887.50
5M Southern Railway, 5%	5,743.75
5M Cleveland Union Terminal, 5%	5,068.75
6M Atlantic Coast Line, 4½%	5,257.50
5M New York Central, 5%	4,300.00
4C Great Northern, 5½%	400.00

PREFERRED STOCKS

50 shares, Virginia Electric & Power Co., 5%	\$ 5,942.50
55 shares, U. S. Steel, 7%	6,946.20
50 shares, Union Pacific, 4%	4,570.25
60 shares, Jones and Laughlin, A, 5%	4,987.50
10 shares, Consolidated Edison	1,066.64
5 shares, Public Service of New Jersey	702.00
37 514/1000 shares, Trenton Mortgage Service	1,481.37*

COMMON STOCKS

50 shares, Chesapeake and Ohio Railway	\$ 2,368.75
50 shares, Pennsylvania Railroad	1,468.75
25 shares, Standard Oil of New Jersey	1,356.25
30 shares, American Telephone and Telegraph	4,119.32
1 share, New York, Chicago & St. Louis Railroad	37.00
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	\$64,894.66

Respectfully submitted,

EARL INGERTON, *Treasurer*

* Residual value.

DANA FUND

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

RECEIPTS

Available balance, November 30, 1946	\$615.73
Interest	5.52
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	\$621.26

DISBURSEMENTS

Disbursed	\$150.00
Available balance, November 30, 1947	\$471.25
	<hr/>
	\$621.25

Respectfully submitted,

EARL INGERTON, *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 ending November 30, 1947. 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 Friendship Branch of the Riggs National Bank of Washington, D. C.

Respectfully submitted,

STERLING B. HENDRICKS

K. J. MURATA

ALTON GABRIEL, *Chairman*

**This book belongs to
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ABSTRACTS OF PAPERS PRESENTED AT THE TWENTY-
EIGHTH ANNUAL MEETING OF THE MINERALOGICAL
SOCIETY OF AMERICA, OTTAWA, CANADA,
DECEMBER 29-31, 1947

UNIQUE ASSOCIATION OF THALLIUM AND RUBIDIUM IN MINERALS

L. H. AHRENS

Massachusetts Institute of Technology, Cambridge, Massachusetts

Spectrochemical analyses of various minerals have shown that "alkali metal" thallium and rubidium are found only in potassium minerals and the cesium mineral pollucite, and that in these minerals the Tl:Rb association is very close. Altogether 167 specimens have been analyzed quantitatively, the selection comprising lepidolite, amazonite, hydrothermal pegmatitic microcline, primary pegmatitic microcline, zinnwaldite, biotite, muscovite, phlogopite, pollucite, rhodizite, and cesium beryl. The mean weight ratio $\%Rb_2O/\%Tl_2O$ was determined as 100, and the vast majority of the ratios fall within the limits of 35-300; the extreme limits are 10 and 650. A plot of $\log \%Rb_2O$ vs. $\log \%Tl_2O$ produced a curve of unit slope over the thousand fold range of concentration that could be investigated. There appears thus to be no shift in the ratio Rb/Tl throughout the selective crystallization of minerals and the ratio seems to be independent of the type of host mineral: the ratio does, however, vary to some extent from area to area, and it seems likely that the cause for this variation is a chemical one. The reasons for the close association of "alkali metal" thallium and rubidium are that the radii of their ions are identical and that in certain pertinent respects, their chemical properties are very similar.

With the possible exception of the pair Zr:Hi, which elements are very closely associated in minerals, "alkali metal" thallium and rubidium are perhaps the most closely associated pair of elements in the earth's crust, and their association is made more unique because thallium is a Group 3b element, whereas rubidium is an alkali metal (Group 1a).

The abundance of thallium in the earth's crust has been estimated as 0.0003% Tl, by weight.

WEATHERING OF PLAGIOCLASE FELDSPARS TO BAUXITE*

VICTOR T. ALLEN

Institute of Geophysical Technology, Saint Louis University, Saint Louis, Missouri

In Oregon plagioclase feldspars weathered to kaolinite-halloysite or to beidellite-nonttronite; then, gibbsite and bauxite formed from these clay minerals by the removal of silica. Contrary statements in four recent publications subordinate this two-stage process: "that calcium feldspar gives free aluminum hydroxide," "that gibbsite precedes kaolin in the weathering of all but the most silicic igneous rocks," "that under tropical conditions laterite is developed from basic igneous rocks and clay from granitic rocks," and "that kaolinite is an insoluble hydrated silicate and the change ends with its formation."

A hole drilled by Alcoa into one Oregon ferruginous bauxite deposit indicates that weathering penetrated downward more than 175 feet with alumina, iron, titanium, and water increasing progressively but not regularly at the expense of silica. Alumina ranges from 47-25 per cent in the upper 50 feet to 35-24 in the underlying 100 feet, ferric oxide from 49-18 per cent to 32-15, titania from 8-3 per cent to 7-3; water from 25-13 per cent

* Published by permission of the Director, U. S. Geological Survey, Department of the Interior.

to 13-9, and silica increases from 2-23 per cent to 21-26. A transitional layer of clay over 100 feet thick separates the bauxite at the top of the profile of weathering from the underlying parent basaltic materials of Miocene age. Irregularities within the weathered zone reflect original differences in chemical composition. Detrital sands and basaltic lava with a glassy groundmass that weathered easily to nontronite provided zones of increased permeability and susceptibility to alteration; differentiation of the basaltic lavas caused notable differences in the original silica and titania of certain horizons.

INFRA-RED LIGHT FOR MINERAL DETERMINATION

RENÉ BAILLY

Washington University, Saint Louis, Missouri

Many minerals which are opaque in visible light are transparent in the infra-red. By substituting a photo-electric ocular, sensitive in the infra-red, for the ordinary eye-piece, it is possible to study their optical properties just as for nonopaque minerals. Oriented thin sections can be studied with the polarizing microscope. By means of the universal stage, the optical characters, including optic sign, birefringence, axial angle, etc., can be determined. Photography with infra-red sensitive plates is useful.

The best method for determining the refractive index generally is the prism method with normal incidence. The indices of many opaque minerals are too high to be determined with the total reflection refractometer. An adjustable slit before the photo-cell takes the place of the cross-hair in the visual eyepiece of the goniometer's telescope. In many cases, the photo-electrical method is more precise than the visual one. The photo-electric current is very variable, according to the character of minerals. It is hardly possible to use a galvanometer without previous current amplification. The amplifier must be very sensitive and stable. The infra-red light (8,000-10,000 Å) is produced by a filament bulb or metallic arc lamp with adequate filters.

The properties of the following minerals have been determined: molybdenite, stibnite, bournonite, stephanite, enargite, tetrahedrite, tennantite, ferberite, wolframite, hübnerite, chromite, hematite, goethite, hauerite, thoreaulite, sphalerite. The variation of index with the chemical composition has been studied for several species. The correlation is especially good for wolframite. Curves are presented showing the dispersion of hübnerite, hematite, goethite, thoreaulite, sphalerite, calcite, up to 10,000 Å.

METAMORPHIC ROCKS OF THE LOWER METHOW VALLEY, WASHINGTON

JULIAN D. BARKSDALE

University of Washington, Seattle, Washington

A series of paragneisses composed of hornblende-chlorite-epidote-albite schist, hornblende schist, biotite-hornblende-quartz-feldspar gneiss, biotite quartzite, and calcite-epidote-garnet-rock was intruded by a remarkably uniform granitic rock now cataclastically metamorphosed to a distinctive biotite granite gneiss. The gneissic structure of the latter parallels that of the paragneiss near their mutual contacts. The metamorphic rocks outcrop over an area of approximately 125 square miles in the lower reaches of the Methow Valley. Migmatites formed from the paragneisses by the intrusion of hornblende granodiorite and quartz monzonite of the Chelan batholith extend south and west from the Methow along the Columbia River to the vicinity of Lake Chelan. In contrast the granitic rocks of the Okanogan batholithic complex invade the metamorphic rocks with but minor contact effects.

DISTRIBUTION OF OXYGEN IN THE LITHOSPHERE

TOM. F. W. BARTH

University of Chicago, Chicago, Illinois

Oxygen, which makes up more than 90 per cent by volume of the total lithosphere, shows the highest concentration in the outer shell. The regular decrease with depth represents an approximation to thermodynamic equilibrium. When highly oxidized surface rocks are brought down to great depths, oxygen will be squeezed out of the mineral lattices and returned to the surface. Therefore the deeper parts of our globe are not able to become oxidized.

TYROLITE, HIGGINSITE AND CORNWALLITE

L. G. BERRY

Queen's University, Kingston, Ontario

X-ray and optical studies on numerous specimens of hydrated basic copper arsenates yield the following data:

Tyrolite: orthorhombic; probable space group $Pmma$; the unit cell with $a=10.50$, $b=54.71$, $c=5.59$ Å, $a:b:c=0.1919:1:0.1022$, contains $4[\text{Cu}_9\text{Ca}_2(\text{AsO}_4)_4(\text{OH})_{10}\cdot 10\text{H}_2\text{O}]$. Specific gravity, measured 3.27 (Hillebrand); calculated, 3.27. Optical characters; biaxial, negative, $X=b$, optic plane $\parallel (001)$. Crystals from Schwartz, Tyrol, are lath-like and elongated $\parallel a$; they contain microscopic spherical inclusions with a radiating structure. Crystals from Centennial Eureka Mine, Tintic, Utah, are elongated $\parallel c$. The unit cell dimensions, $a=10.34$, $b=26.9$, $c=5.57$ Å, given by Wolfe for "trichalcite" from Turginsk, suggest probable identity of "trichalcite" with tyrolite.

Higginsite: several specimens labelled "conichalcite" and "erinite" from Utah, Nevada, and Cornwall give identical x-ray powder patterns which prove to be identical with the pattern of higginsite from Bisbee, Arizona. A crystal of "erinite" from Utah is orthorhombic with probable space group $Pnam$ and unit cell, $a=7.40$, $b=9.26$, $c=5.87$ Å. These elements agree well with the elements for higginsite given by Strunz (1939) and Richmond (1940).

Cornwallite: the identical x-ray powder patterns given by cornwallite from Cornwall and several specimens of "erinite" from Utah indicate probable isomorphous relationship of this mineral with pseudomalachite. The name cornwallite is retained for this mineral.

THE SYSTEM $\text{MgO-SiO}_2\text{-H}_2\text{O}$

N. L. BOWEN AND O. F. TUTTLE

Geophysical Laboratory, Washington, D. C.

The system has been investigated up to 900°C. and 30,000 lbs./in.² Four-phase P-T curves have been determined showing equilibrium relations between the vapor (or fluid) phase and the crystalline phases serpentine, talc, forsterite, enstatite, and silica. No liquid phase has been encountered, a fact that is suggestive in connection with the problem of the existence of "serpentine magma" in the pressure-temperature range investigated.

ROLE OF TEMPERATURE IN MINERALOGY

M. J. BUERGER

Massachusetts Institute of Technology, Cambridge, Massachusetts

Temperature endows a mineral with energy beyond that of its static crystal structure. This excess energy is the cause of many well-known mineralogical relationships, which can be comprehended as transformations.

Three different structural changes may occur in the transformation of one crystalline

phase to another (polymorphism). High-low transformations may be called *displacive* from a structural viewpoint since they correspond with slight displacements of the atoms. Forms connected by displacive transformations always have related symmetries, the high-temperature form having the higher symmetry. Sluggish transformations may be called *reconstructive* since they correspond structurally to destruction of one structure and construction of a new structure from the same units. Gradual transitions correspond structurally with disordering of the atoms in the structure. Forms connected by gradual transition also have related symmetries. The disorder is the cause of solid solution. Falling temperature requires an ordering transition. If the crystal which must become ordered is a solid solution, it is necessary for one phase to transform into two; in other words, the transition causes unmixing. Many common minerals, for example, chalcopyrite and feldspar, have hitherto unrecognized high-temperature forms due to a disorder transition.

Another kind of transformation develops when an energy increase can disrupt *part* of the structural unit. When the character of the structure permits this, a reaction series results. Thus, Bowen's reaction series is merely a series of increasingly fragmented silicate units.

When a wave of temperature energy reaches the surface of a crystal, it is in a position to snap off surface units provided that the energy exceeds the bonding energy of the units. This temperature corresponds with the critical temperature of recrystallization, and the surface transformation provides the mechanism of metamorphism.

A PETROGRAPHIC REFRACTIVE INDEX METHOD

NELSON B. DODGE

Bausch and Lomb Optical Co., Rochester, New York

With dark-field illumination, color criteria provide an alternative to the usual methods for comparing index of crushed grains with immersion media. Since organic immersion liquids have steeper dispersion curves than inorganic solids, spectrum colors are produced from white light by refraction at interfaces of grains and liquid. With ordinary illumination when the dispersion curves intersect in the yellow, the oblique illumination test produces colored grain borders as explained by F. E. Wright and others. Dark-field colors appear in bright contrast to a dark background, affect grains everywhere in the microscope field, and require no changing of focus.

Most microscopes can be adapted for dark-field illumination, which requires a hollow cone of light from the condenser, focused on the preparation, having a greater aperture than the objective. The field of view is dark, except where refraction and reflection in the preparation send light to the eye. When solid and liquid indices differ widely, grains appear white against a dark background. When indices differ by a few units in the second decimal place, or less, grains are yellow if higher and blue if lower in index than liquid. At equality of sodium index, $\pm .001$, grains appear purplish blue with a scattering of deep red borders.

The colors can be explained as a result of the Christiansen effect. They are due to the subtraction of the lost transmitted wavelengths from white light.

KLOCKMANNITE AND ARTIFICIAL CuSe

J. W. EARLEY

University of Toronto, Toronto, Canada

In the course of a study of natural and artificial copper selenides now in progress, the compound CuSe was prepared by dry fusion and by hydrosynthesis, and the crystalline products were found to be physically and structurally identical with klockmannite from Sierra de Umango, Argentina. The pyrosynthetic material has the specific gravity 5.99.

The minute greenish black hexagonal plates of hydrosynthetic CuSe show $c(0001)$ (perfect cleavage), $n(10\bar{1}2)$, $r(10\bar{1}1)$, $m(10\bar{1}0)$, and the unit cell with space-group $C6/mmc$, $a=3.93$, $c=17.22$ kX, contains $6[\text{CuSe}]$, and has the calculated density 6.12. A superstructure has $a'=12a$. Klockmannite is clearly isostructural with covellite.

LOUGHLINITE, A NEW HYDROUS MAGNESIUM SILICATE*

JOSEPH J. FAHEY WITH x -RAY ANALYSIS BY JOSEPH M. AXELROD
U. S. Geological Survey, Washington, D. C.

The name loughlinite, in honor of the late Dr. Gerald F. Loughlin, former Chief Geologist of the United States Geological Survey, is given to a new mineral from the Green River formation of southwestern Wyoming.

This mineral was first found in 1940 in the drill core of the John Hay, Jr., Well No. 1, and again in 1946 in the drill core of the Union Pacific Well No. 4, both in quantities too small for adequate investigative work. In the summer of 1947 many excellent samples were obtained from material excavated during the sinking of the shaft of the Westvaco Chlorine Products Corporation, drilled for the purpose of mining trona. These three locations are between eighteen and twenty miles west of Green River, Sweetwater County, Wyoming.

Loughlinite occurs in veins in low-grade oil shale that contains crystals of shortite. It has an asbestos-like appearance, a silica-magnesia ratio of two to one, and gives an x -ray powder picture unlike any known magnesium silicate.

* Published by permission of the Director, U. S. Geological Survey, Department of the Interior.

OBSERVATIONS ON WEBERITE AND JARLITE

R. B. FERGUSON
University of Manitoba, Winnipeg, Canada

Fragments of weberite, oriented optically, gave the unit cell with space-group $Ibmm$ or $Ibm2$, $a=7.30$, $b=7.05$, $c=9.97$ kX, containing $4[\text{Na}_2\text{MgAlF}_7]$; $X=a$, $Y=b$. Poor crystals of jarlite (sp. grav. 3.87), also oriented optically, gave the unit cell with space-group $C2/m$ or $C2$ or Cm , $a=15.99$, $b=10.82$, $c=7.24$ kX, $\beta=101^\circ 49'$; $Y=b$, $Z:c=+84^\circ \pm 2'$; $\alpha=1.430$, $\beta=1.435$, $\gamma=1.437$, $2V=90^\circ \pm 10'$. "Meta-jarlite" (sp. grav. 3.65, with inclusions) gave $\alpha=1.429$, $\beta=1.431$, $\gamma=1.434$, and an x -ray powder pattern hardly distinguishable from that of jarlite. Sharp powder photographs of ralstonite show indications of non-cubic symmetry, and the yellow ochre "hagemannite" is mainly ralstonite rather than thomsenolite. These results were found to confirm and add to published results by C. Broset (Diss. Stockholm, 1942—M.A. 10-16).

AQUEOUS EMANATION FROM PARÍCUTIN VOLCANO

W. F. FOSHAG
U. S. National Museum, Washington, D. C.

Large quantities of water vapor are emitted from the crater of Parícutin volcano. An estimate based on observations on May 27, 1945, gives 16,000 tons per day, compared to 100,000 tons of lava emitted. The characteristics of the vapors emitted from the crater vent differ from those emitted directly from the lava vents, suggesting considerable dilution of magmatic emanations by groundwaters. It is suggested the rock alteration in many ore deposits is due in part to activated groundwaters.

USEFUL ASPECTS OF THE FLUORESCENCE OF ACCESSORY-MINERAL ZIRCON

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The mineral zircon has long been known to exhibit fluorescence when exposed to ultraviolet radiation. Hitherto little practical use appears to have been made of this phenomenon. Its application is here recommended in the inspection of commercial concentrates of zircon, and of other minerals containing zircon as an impurity. Comparison of the fluorescent behavior of grains of zircon from igneous rocks of different ages, and from igneous as compared to sedimentary sources, reveals certain contrasts. The possible usefulness of such contrasts in the solution of a number of petrological problems is discussed. Reference is also made to the fluorescence of accessory-mineral apatite, and of certain other minerals found in association with zircon.

ENGINEERING GEOLOGIC STUDIES OF THE UPPER MISSOURI RIVER BASIN

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Extensive geologic studies and foundation explorations have been conducted by the Bureau of Reclamation on twenty dam sites on the upper Missouri River and tributaries during the past three years. A wide variety of foundation problems have been encountered at these sites and the need and value of a complete geologic investigation and interpretation has been demonstrated at each dam site. Approximately half of the twenty dam sites are located in the Northern Great Plains on soft to semi-hard, unconsolidated, compacted Upper Cretaceous and Tertiary sediments. In addition to the low compressive and shear strengths of the unconsolidated sediments, they contain numerous interbedded layers of bentonite and bentonitic-like clays.

The dam sites located on the Paleozoic and pre-Cambrian rocks on the east slopes of the northern and middle Rocky Mountains generally present less serious foundation problems, but wide zones of fault gouge and limestone cavities are common problems.

The proposed construction of numerous large dams on the upper Missouri River and tributaries on unconsolidated sediments present many difficult foundation, design, and construction problems.

A SECOND OCCURRENCE OF BRAZILIANITE*

CLIFFORD FRONDEL AND MARIE LOUISE LINDBERG

Harvard University and U. S. Geological Survey

A second occurrence is recorded for brazilianite, at the Palermo mine, near North Grafton, Grafton Co., New Hampshire. The mineral occurs as a late hydrothermal product in a granite pegmatite of the quartz-core type, in the following association and sequence:

quartz—brazilianite—apatite—whitlockite—quartz (last).

The crystallographic, optical and physical properties conform closely to those of the Brazilian crystals. Observed forms: $a\{100\}$, $b\{010\}$, $n\{011\}$, $o\{111\}$, $g\{\bar{1}11\}$, $s\{211\}$, $x\{101\}$, $v\{301\}$, $q\{\bar{1}21\}$. The crystals have an elongate, four-sided appearance due to the relatively large development of $n\{011\}$ and $g\{\bar{1}11\}$ and the near suppression of the prism zone. The crystals range in size up to about three-fourths inch along $[100]$. Color chartreuse-yellow. Specific gravity 2.985 ± 0.005 . Optically positive, $n(Na):X=1.602$, $Y=b=1.609$,

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$Z=1.623$, $X \wedge c = -20^\circ$, $2V=71^\circ$ (calc.); dispersion $r < v$, faint. A redetermination of the gravity and refractive indices for the Brazilian crystals gave $G=2.980 \pm .005$; $X=1.601$, $Y=1.608$, $Z=1.620$. A chemical analysis of the Palermo crystals (by M.L.L.) gave: Na_2O 8.29, K_2O 0.20, Al_2O_3 42.85, Fe_2O_3 0.03, TiO_2 0.05, P_2O_5 38.79, H_2O — 0.04, $\text{H}_2\text{O}+$ 9.91, total 100.16. The analysis conforms closely to the established formula, $\text{NaAl}_3(\text{PO}_4)_2 \cdot (\text{OH})_8$.

ISOMORPHIC PHENOMENA IN THE MELILITES

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Experimental determinations have shown that $\text{CaO} \cdot 2\text{Al}_2\text{O}_3$ forms a partial solid solution series with $\text{Ca}_2\text{Al}_2\text{SiO}_7$ (artificial gehlenite). A substitution of Al for Ca is here involved, which was hitherto unknown in silicates and has been considered unlikely because of the rather large size difference of the two ions.

The soda content of melilites was also investigated, it being found that 15 per cent of the hypothetical "molecule" $\text{Na}_2\text{Si}_3\text{O}_7$ can be taken into solid solution with gehlenite. There is no solid solution of this soda member with akermanite ($\text{Ca}_2\text{MgSi}_2\text{O}_7$); thus the artificial melilites contain less than 15 per cent $\text{Na}_2\text{Si}_3\text{O}_7$, the absolute amount decreasing with an increase in the akermanite content of the mix crystals. The fact that some published analyses of natural melilites show more soda (up to 5.44% Na_2O) than can be accounted for by the determined maximum of 15 per cent $\text{Na}_2\text{Si}_3\text{O}_7$ (3.85% Na_2O) would indicate that more careful work on natural melilites should be done.

A PART OF THE SYSTEM $\text{H}_2\text{O}-\text{H}_3\text{PO}_4-\text{AlPO}_4$

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This work is being done in connection with the growing of crystals of AlPO_4 and is sponsored by the Squier Signal Laboratories, U. S. Signal Corps, Fort Monmouth, N. J. Only the part of the system is being investigated which contains only solution at room temperature. Crystals form in these solutions on raising the temperatures. Hydrates of AlPO_4 have been found to about 140°C . depending upon concentrations. Above this temperature anhydrous αAlPO_4 (berlinite) crystallizes. The pressures accompanying each concentration at given temperatures are also being measured. Anhydrous AlPO_4 grown under these conditions has an inversion point from α to β within 5°C . of that of quartz (573°C .). It also resembles quartz very closely in many other respects.

SOME ASPECTS OF REGIONAL METAMORPHISM IN NORTHERN MANITOBA

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Argillite, greywacke, arkose, and basic volcanic rocks of the Snow group in northern Manitoba grade into Kisseynew schists and gneisses. Isograds of regional metamorphism trend east-west and intensity of metamorphism increases from south to north. However, the isograds in arenaceous and volcanic rocks occur at a more northerly latitude than those in argillaceous members. Consequently it is inferred that these finer grained rocks are more sensitive to effects of regional metamorphism than are the coarser grained varieties, and this sensitivity persists to rocks of the highest grades of metamorphism. The zones of regional metamorphism characterized by the presence of staurolite and sillimanite are well developed in sedimentary rocks of appropriate composition and grade into one another, but no kyanite was found anywhere in the area studied. It is concluded that the staurolite zone

extends into the zone normally distinguished by kyanite. Explanations are sought for the lag in degree of regional metamorphism of arenaceous and volcanic rocks as compared with fine-grained sedimentary rocks, and for the lack of diagnostic kyanite.

**PSEUDO-EXSOLUTION INTERGROWTHS DUE TO PERITECTIC REACTIONS
INVOLVING PARTIAL DISSOCIATION**

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In a partial study of the NiAs-NiSb system, experimental results show that these substances form a complete solid solution series after fusion in vacuo. On heating, however, NiAs partially breaks down above 850°C. and slowly at 500°C to form Ni₃As₂ (artificial maucherite) according to the peritectic reaction as noted by Friedrich:



On addition of antimony to the nickel arsenide lattice, the structure is stabilized and this dissociation does not occur to any marked extent when between thirty and forty atomic percent of NiSb is present.

Intergrowths produced from both artificial and natural niccolite consist of both a blade and a net type resembling textures usually ascribed to unmixing of solid solutions. A very similar natural net type of intergrowth of niccolite and maucherite found in a specimen of ore from the Studbury district, Ontario, is hence interpreted as due to a partial dissociation of niccolite. The dissociation is due either to a post-niccolite heat effect, or to a reduction of confining pressures while high temperatures still prevailed. Although the reaction involves a rearrangement of Ni and As atoms to form the lattice of "maucherite," and since the original pure niccolite is in no sense a solid solution the prefix is necessary in describing the resulting intergrowths as a pseudo-exsolution type.

Work on artificial pyrrhotite-pentlandite intergrowths suggests that at least some of these may be similarly related to a peritectic reaction involving the partial loss of sulphur from nickeliferous pyrrhotite solid solutions. However, since the original host is a solid solution and migration of nickel atoms to the pentlandite segregations occurs during heating, the resulting intergrowths must be regarded as true exsolution effects.

PEGMATITES OF THE EIGHT MILE PARK AREA, COLORADO

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The Eight Mile Park area, just west of Canon City in Fremont County, Colorado, is a plateau of 30 square miles roughly bisected by the Royal Gorge of the Arkansas River. The underlying rocks consist of three units whose contacts strike northeast-southwest. The northwestern batholith of Pikes Peak granite is separated by a narrow belt of Idaho springs schists from the southeastern body of injection gneiss. Large pegmatite bodies, many of which have been mined for feldspar and mica, occur in both the granite and the schists along the batholith margins. Those bodies in the granite are flat-lying sheet-like masses that transect the granitic flow structure. Those in the schist are moderately to steeply dipping sills along the metamorphic foliation. The latter are characterized by a well-developed zonal structure consisting of border, wall, intermediate, and central zones. Hydrothermal replacement units, which are also strongly developed in this type of body, characteristically lie along the footwall contacts between central and intermediate zones, and replace parts of both. The sheet-like bodies are marked by less definite zoning and weakly developed hydrothermal units. The total number of mineral species found is 35. Among the rarer species, which occur only in the replacement units, are fremontite (the type locality), and beyerite.

THE TURRET CORUNDUM DEPOSITS, CHAFFEE COUNTY, COLORADO

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University of Michigan and University of Colorado

The corundum deposits near Turret, in Chaffee County, Colorado, have been known since about 1890. The best known occurrences are near the abandoned Calumet Iron mine in a thin horizon of sillimanite- and graphite-bearing schist of Pennsylvanian age, which lies near the contact between garnet-bearing marble (metamorphosed Leadville limestone) and a mafic igneous rock. The corundum crystals, some of which attain a diameter of $\frac{1}{4}$ inch, are deep blue in color. A few contain fracture-free parts.

In a less well-known deposit, which is just south of Turret, corundum is disseminated throughout the central part of a 50-foot zone of chlorite rock that lies within pre-Cambrian muscovite-garnet and quartz-biotite schists. Much of the coarse chlorite occurs in veins and appears to be hydrothermal in origin. At the southeast end of the deposit a marked zonal structure is developed by the alternation of coarse chlorite layers with layers of garnet and actinolite rock. Other minerals are: quartz, plagioclase, biotite, anthophyllite, hoegbomite, spinel, and magnetite.

It is noteworthy that in the first deposit corundum occurs as thin basal plates whereas in the second the grayish blue crystals are barrel-shaped, tapering prisms.

OPTICAL PROPERTY CURVES FOR COMMON CLINOPYROXENES

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An improved set of optical property curves for common rock-forming clinopyroxenes has been prepared. The basis for drawing the curves was furnished by 35 new analyses, and from data taken from the work of Bowen, Schairer and others on synthetic end members of the series. A large portion of the clinopyroxene field is poorly represented or not represented at all in the available data so that further revision of the curves will be necessary as specimens to fill the gaps in the present data become available.

The effect of Al_2O_3 , Fe_2O_3 , Cr_2O_3 , MnO , and TiO_2 on optical properties is discussed as well as the effect of exsolution of lamellae of orthopyroxene.

The chemical analyses were financed by a grant from the Geological Society of America and by Princeton University.

MULTIPLE DIFFERENTIAL THERMAL ANALYSIS

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Considerable improvements in the equipment used for differential thermal analysis in recent years have resulted from work in various laboratories. As a consequence the method is finding a constantly broadening application.

In this paper, equipment is described which is designed to further increase the utility of thermal analysis in connection with statistical studies. Through the adaptation of standard recording devices and a program controller to a multiple specimen holder it has been arranged to secure six differential thermal curves at once. With this apparatus a large number of determinations may be made in a relatively short period, as many as twenty-four curves being obtainable in a day.

The qualitative and quantitative application of this equipment to a variety of minerals are shown by a considerable number of selected curves. As an illustration a differential thermal study of artificial mixtures of kaolinite with various other minerals shows the change in kaolinite percentage to be essentially independent of the chemical nature of the other

components. A "calibration curve" of kaolinite peak amplitude plotted against percent kaolinite in the sample may, therefore, be assumed valid in application to an unknown mixture containing kaolinite for rough quantitative analysis.

STORM KING GRANITE AT BEAR MOUNTAIN, NEW YORK

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The Storm King granite at Bear Mountain, New York, occupies the core of a syncline in the earlier crystalline complex of the Hudson Highlands. It is part of a larger synclinal pluton whose concordance with the NE-plunging structure is shown by conformable relations of contacts and parallel mineral alignment in both the granite and the country rocks.

Uniform composition, flow structures of early hornblende crystals and inclusions confined to the marginal portions of the granite indicate magmatic intrusion. Absence of secondary foliation and lack of tectonic fabric patterns in the granite suggest essentially post-tectonic emplacement. The concept of "exchange of space" between the rising magma and the country rocks subsiding into the emptying magmatic chamber is proposed to account for the lack of evidence indicating lifting of the overlying rocks by forcible injection of the granite.

In contrast to most fusion tectonites described in the literature, quartz *c*-axes do not have clearly preferred orientations. Anomalous relations between dimensional and lattice orientation of the larger quartz grains are tentatively explained by differential solution of quartz by hydrothermal end-stage products of magmatic (Storm King granite) origin.

Field and statistical studies of principal joint systems reveal significant concentrations of longitudinal, cross and diagonal fractures. Joint patterns in the Storm King granite and in the Highlands Complex are nearly identical. Several possible mechanisms are discussed to explain their development.

The tectonic history of the region is traced. Interpretation of faults in conjunction with other structural data is used to distinguish between the effects of pre-Cambrian and Paleozoic deformation intervals.

OXIDATION AND REDUCTION IN GEOCHEMISTRY

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The concept of oxidation-reduction potentials is capable of wide application in the study of geochemistry and mineral paragenesis. Many elements occur in different oxidation states in the earth's crust, and oxidation-reduction potentials give a quantitative expression for the conditions of stability of these different oxidation states. Reactions involving oxidation and reduction are particularly important in the formation of minerals from aqueous solutions at or near the earth's surface. The groundwater table often forms a sharp boundary between an upper zone of high oxidation potential and an underlying zone of relatively low oxidation potential.

The significance of oxidation-reduction potentials in geochemistry is particularly marked in the way in which rare elements are often concentrated and enriched in deposits formed under extreme oxidizing or reducing conditions.

CUSPIDINE IN THE SYSTEM $\text{CaO} \cdot \text{SiO}_2 \cdot \text{CaF}_2$

WM. J. MCCAUGHEY, KARL KAUTZ, AND RALPH G. WELLS

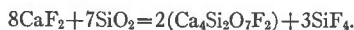
Ohio State University, Columbus, Ohio

The reported occurrence of cuspidine ($\text{Ca}_4\text{Si}_2\text{O}_7\text{F}_2$) in but three localities, two of which are in volcanic areas, would indicate it to be a rare mineral. Cuspidine, however, has been

identified as such in basic open hearth steel slags and in finishing slags from electric steel furnaces. In electric furnace slags, cuspidine is associated with larnite, merwinite, or with pseudo-wollastonite.

To determine the equilibrium relations of cuspidine, ten gram samples covering a wide range in composition of CaO, SiO₂ and CaF₂ were melted in platinum and in graphite crucibles. Cuspidine formed readily in these melts, being associated with the same minerals as in the slags. The actual mineral composition did not agree however with calculated compositions based on a simple chemical reaction between the three components. The actual mineral composition indicated a loss in silica.

Melts made from pulverized quartz and fluorite in graphite crucibles yielded well-crystallized cuspidine. The graphite crucibles in the muffle furnace were surrounded by a thick matt of fibrous silica which in some cases covered the crucible and the lid. The loss in weight of the original constituents was determined, and from the identification of the resultant phase this reaction follows:



The deposit of silica surrounding the crucible is caused by the reaction of the SiF₄ with the water vapor in the products of combustion.

Attempts to determine the melting point of pure cuspidine in a quenching furnace were unsuccessful, the cuspidine being converted to a mixture of dicalcium silicate and lime and sometimes tricalcium silicate.

The reaction



accounts for this phenomenon. Further evidence for this reaction lies in the abundant presence of gas bubbles imbedded within the dicalcium silicate crystal fragments.

The volatilization of silicon tetrafluoride accounts for the anomalous results obtained in a previous investigation.

CHARTING FIVE, SIX, AND SEVEN VARIABLES ON HYPERTETRAHEDRAL FACES*

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Three variables may be charted in a triangle by the use of trilinear coordinates, and four variables in a tetrahedron by means of quadrilinear coordinates. This unique property of the triangle and tetrahedron suggests that a similar property exists for hypertetrahedra of n dimensions.

By mathematical induction, it is possible to predict the number of vertices, edges, triangular faces, tetrahedra, and hypertetrahedra that bound an n -dimensional hypertetrahedron. A tabulation of these boundaries, up to the ninth dimension, is given. The number of vertices in each hypertetrahedron corresponds to the number of variables that may be charted within it. Hypertetrahedra of 4, 5, and 6 dimensions, having 5, 6, and 7 vertices are bounded respectively by 10, 20, and 35 triangular faces.

Two methods exist for charting 4 variables in a tetrahedron. From a number of sets, a surface may be geometrically constructed or analytically deduced; and a topographic map of this surface may then be drawn. A second method is to develop the tetrahedron onto a plane, and merely to plot the triads 123, 124, 134, and 234, each recomputed to 100 percent. The first method is inapplicable to hypertetrahedra, and the second method may not

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be exactly applied, as hypertetrahedra can not be developed. The triangles bounding the hypertetrahedra, however, may be arranged empirically, so as to constitute a compound system of trilinear coordinates for charting the triads $1, 2 \cdots (v-1), 3 \cdots v, 2, 3 \cdots (v-1), 4 \cdots v, 3, 4 \cdots (v-1), 5 \cdots v$, etc., where v means both vertices and variables.

Coordinate systems of this kind have been prepared for charting 5, 6, and 7 variables. Some choice exists in the arrangement of the triangles, but compactness and the preservation of developed tetrahedra are determining factors that practically eliminate alternative arrangements. Such coordinates may be given algebraic meanings within individual triangles, but not between them. The composite charts, however, afford geometrical pictures, which, if conventionalized, may be as effective as a true system of analytical coordinates.

FUSION OF SANDSTONE BY INTRUSIVE ANDESITE, PALISADES DAMSITE, IDAHO

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During pre-construction investigations at Palisades Damsite, on the Snake River, about 44 miles east of Idaho Falls, Idaho, an irregular sill-like body of hypersthene-augite andesite intrusive into sandstones, siltstones, and claystones at the left abutment has been explored extensively. The andesite is basic (57.9 percent SiO_2), containing microphenocrysts of hypersthene, augite, and labradorite in a groundmass of microcrystalline labradorite, augite, and magnetite with interstitial glass. Secondary clay minerals ranging from montmorillonite to nontronite occur in the groundmass, having formed from the primary minerals and glass, and in voids and fractures. Calcite veins $1\frac{1}{4}$ inches wide are present. Well-developed crystals of tridymite, possibly the variety of christensenite, occur in voids, and apparently formed later than associated nontronite.

As indicated by drill cores, the andesite-sediment contact is irregular, varying from highly contorted to relatively plane, typically transgressing stratification. In several places, sandstones at the contact have been partially fused and caused to flow. Particles of sediments enclosed by andesite are partially digested and surrounded by reaction products. In one occurrence volcanic glass penetrates sandstone more than 1 inch. Locally the sediments are affected through an 8-foot wide zone.

The partially fused sandstones are gray, vesicular, massive to flow-banded, and very hard. In one occurrence, the fused material is intruded upwardly into adjacent indurated sediments. Microscopically, the grains of sand are observed in an isotropic or cryptocrystalline matrix; minute prisms of secondary pyroxene are present. Vesicles are ellipsoidal, as large as 3.0 mm. in diameter, and are lined or partially filled with tridymite.

RELATION OF MINOR INTRUSIVES TO GRANITE IN THE BRYCE AREA, ONTARIO

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A petrographic and chemical study is presented of sodic porphyries, lamprophyres, and granitic rocks in the vicinity of Bryce township, Ontario. It is concluded that the minor intrusives crystallized from a late extract of the granite batholith, modified by reaction with the country rock. This conclusion is supported by field evidence and by the textures, chemistry, and mineralogy of the rocks involved. An attempt is made to correlate these results with the intrusives of the Kirkland Lake area which lies on the north side of the granite batholith in question.

ZONED METASOMATIC GNEISSES RELATED TO STRUCTURE AND TEMPERATURE,
LARAMIE RANGE, WYOMING*

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During geologic work in the Laramie Range, southeastern Wyoming, from 1945 to 1947, an area of pre-Cambrian metasomatic gneisses was mapped in detail. The gneisses, which are dioritic to granitic, replace metagabbro schist. A zonal variation of gneisses occurs along strike, with highest temperature facies in the most open structure and lowest in the tightest structure. This is indicated by percentage variations of plagioclase, anorthite content, potash feldspar, pyroxene, and biotite. Abrupt lithologic variations across strike reflect time intervals of shearing. Mineral zoning and relation to structure are analogous to these features in ore deposits.

Migration of K and other ions upward and laterally by diffusion through liquid in shear fractures, or by surface diffusion along planar structures and in the solid state, drove out Mg, Fe, and other elements from metagabbro schist. Numerous cordierite bodies formed by advancing metasomatism in metagabbro schist. Under certain conditions of similar metasomatism minor elements such as Zn, Pb, and other metals in host rock silicates, should be prohibited in part from entering the crystal lattice of newly-formed silicates, and move upward to form ore deposits. None is present here possibly because of high temperature, kind of silicates, and rapidity of crystal formation. Pegmatites, other than occasional small granites, are lacking—an absence related to the high thermal gradient.

Metasomatic gneisses which replace hornblende schist 25 miles northwest contain more potassic facies on more open parts of structure; tighter portions have facies higher in lime and soda.

The first example of zoning formed against relatively cool, the second against relatively hot, host rock.

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FRANCKEITE IN RELATION TO LENGENBACHITE

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The symmetry of franckeite was described as orthorhombic, pseudo-tetragonal (Ahlfeld, Himmel & Kleber, 1935) on the basis of goniometric measurements on poor crystals from the Porvenir vein, Huanuni, Bolivia. Rotation and Weissberg photographs of a crystal from this locality show monoclinic symmetry and lead to a cell with $a=46.85$, $b=11.62$, $c=17.28$ kX, $\beta=94^{\circ}48'$; cell content $16[5\text{PbS} \cdot 3\text{SnS}_2 \cdot \text{Sb}_2\text{S}_3]$.

The rotation photograph indicates the presence of a pseudo-period with $b'=b/2$. The Weissberg resolutions of the layers ($h0l$) and ($h2l$) show well-defined spots and continuous curves with h a multiple of 8. Hence there is a pronounced pseudo-cell with $a'=a/8$, $b'=b/2$, $c'=c$. The films bear a striking resemblance to those obtained on lengenbachite, $6\text{PbS} \cdot (\text{Ag, Cu})_2\text{S} \cdot 2\text{As}_2\text{S}_3$ (Nuffield, 1944), a mineral with similar habit and cleavage. Here, however the layering is a multiple of 6. Data for the pseudo-cells of the two minerals compare as follows:

	a'	b'	c'	β	Z	G(calc.)	G(meas.)
Franckeite	5.86	5.81	17.28	$94^{\circ}48'$	1	5.87	5.88
Lengenbachite	5.80	5.745	18.36	$94^{\circ}19'$	1	5.78	5.80

Obviously these two minerals are related structurally although quite different chemically.

CONDUCTIVITY OF DILUTE WATER SOLUTIONS NEAR THE CRITICAL TEMPERATURE

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Attempts to measure the conductivity of water and solutions of low concentration through the critical temperature are described. The methods employed include tubular stainless steel bombs with electrodes introduced through insulating connectors. Various frequencies from 60 to 10,000 cycles per second have been applied. The conductivity is measured with an impedance bridge. Results to date are reported showing increasing conductivity with rising temperature in the liquid state until the critical region is approached; a much lower order of conductivity for the vapor phase but increasing also. The two curves approach each other in the critical region, and appear to join in such a way as to indicate a transitional range of several degrees rather than a single critical temperature. Difficulties inherent in the method are presented and criticism and suggestions are invited.

The investigations are being conducted as part of a research contract with the Signal Corps Engineering Laboratories which calls for experimentation in the artificial crystallization of quartz of a size useful for piezoelectric purposes.

FELDSPAR INTRODUCTION IN THE RED RIVER DISTRICT, NEW MEXICO

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The border facies of the pre-Cambrian granite bodies in the Red River-Twining area of northern New Mexico show clearly the methods of introduction of potash feldspar into metamorphic rocks, especially into amphibole schists and gneisses. A few scattered grains of bright salmon-colored feldspar with quartz were first noted along narrow cracks, either parallel to or transverse to the foliation of the metamorphic rocks. The salmon-colored feldspar permeated the country rocks from such tiny fractures, and apparently replaced the pre-existing minerals. The process became more and more intense until the resulting rocks resembled a gneissic granite. The grains of the introduced feldspar range from microscopic in size to crystals more than three inches long; the average is probably about $\frac{1}{4}$ inch. Muscovite and albite feldspar are commonly introduced in small amounts with the potash feldspar, and locally black tourmaline is present. Deposition of the feldspars is thought to have taken place under a cover of several thousand feet. The potash-bearing fluids were not channelled along well-defined open fissures or faults, but rather soaked through all available openings in the metamorphic rocks. The extent of the feldspar introduction by replacement is hypothetical as evidence has been recognized only along the borders of the granite. Feldspars within the interior of the mass are, however, identical in composition and texture with those on the borders.

HEXAGONAL ZONAL EQUATIONS

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Two zonal equations are presented. The first uses Bravais indices where $p_0 = \frac{1}{3}$, c/a and $\pi_0 = \frac{1}{3}$, $c/\sqrt{3a}$, and $h+k+i=0$ and $(h+2k)+(2h+k)+(h-k)=0$. This requires simultaneous equations involving three sets of rectangular axes.

The second uses Klein indices where $p_0 = \frac{2}{3}$, c/a and $\pi_0 = \frac{2}{3}$, $c/\sqrt{3a}$, and $h+k+i=0$ and $(h+2k)+(2h+k)+(h-k)=0$, but $h+k+i+(h+2k)+(2h+k)+(h-k)=0$. This gives equations involving a vertical axis and two sets of three horizontal axes.

Both equations are heptaxial. In the gnomonic projection u/w and v/w are shown as ratios between p_0 and π_0 and the zonal intercepts. It is impossible to use Klein axes with Bravais indices or Bravais axes with Klein indices.

SCORZALITE AND SOUZALITE, TWO NEW PHOSPHATE MINERALS ASSOCIATED
WITH BRAZILIANITE, MINAS GERAIS, BRAZIL*

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

The paper describes two new phosphate minerals associated with brazilianite from the original brazilianite-bearing pegmatite near Divino, Minas Gerais, Brazil. The new minerals are named in honor of Dr. Evarista Scorza and Dr. Antonio José Alves de Souza, both of the Departamento Nacional da Produção Mineral, Rio de Janeiro, Brazil.

Scorzalite is a massive, blue hydrous iron magnesium aluminum phosphate with the formula $R_3O_3:RO:P_2O_5:H_2O$; chemical analysis: $Al_2O_3=30.87$; $Fe_2O_3=0.54$; $TiO_2=0.10$; $FeO=14.74$; $MgO=4.23$; $MnO=0.11$; $P_2O_5=42.90$; $H_2O+=5.86$. The x-ray powder pattern of scorzalite is identical with lazulite and the two minerals form a continuous series arbitrarily separated where the Mg-Fe molecular ratio is 1:1; Specific gravity is 3.33; Biaxial (-), 2V med-large; X near 1.637; Y near 1.663; Z near 1.673; Monoclinic; Cleavage (110); Twinned (100); $Z=b$; X near c ; no crystals available for study.

Souzalite is a fibrous, green hydrous iron-magnesium-aluminum phosphate with the formula $2R_2O_3:3RO:2P_2O_5:5H_2O$. The mineral is a hydrothermal alteration product of, and more abundant than, scorzalite in the pegmatite. Chemical analysis: $Al_2O_3=26.07$; $Fe_2O_3=2.65$; $TiO_2=0.07$; $FeO=11.49$; $MgO=9.62$; $MnO=0.31$; $P_2O_5=37.70$; $H_2O+=12.04$. The x-ray powder pattern is unlike any known phosphate. Specific gravity is 3.087; Biaxial (-); 2V medium; Dispersion, extreme; X near 1.623; Y (blue) near 1.640; Z near 1.652; Monoclinic (?), Cleavage (010); twinned (100); $X=b$ and Z near c . No crystals available for study.

The mineral assemblage includes albite, muscovite, quartz, apatite, zircon, and tapiolite, and the pegmatite can be subdivided into a central and border zone, each displaying characteristic texture, structure, and mineralogy.

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TELESCOPED, XENOTHERMAL MINERAL ASSOCIATION IN ALKALIC PEGMATITES AND
RELATED VEINS, VERMICULITE PROSPECT, BEARPAW MOUNTAINS, MONTANA*

W. T. PECORA

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

Pegmatites and veins genetically related to an early Tertiary, potash-rich syenitic magma, are intrusive into fractured syenitic porphyry and fine-grained alkalic monzonite in the Rocky Boy composite stock, at the site known as the Vermiculite Prospect, near the head of Big Sandy Creek, Bearpaw Mountains, Montana.

The complex mineral assortment of these deposits represents an alkalic counterpart of the quartz-rich deposits in other regions that have been called telescoped and xenothermal by Spurr, by Buddington, and by other writers. The pegmatites and related veins at the Vermiculite Prospect are believed to have formed at a depth of from 3,000 to 5,000 feet under conditions of rapid fall in temperature.

Silicate minerals include sanidine (in pegmatites) and adularia (in veins); aegirite, biotite, sphene, and zircon. Oxide minerals include magnetite, ilmenite, hematite, brookite, and perovskite. Sulfide minerals include pyrrhotite, pyrite, galena, chalcocopyrite, and sphal-

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erite. Calcite is abundant. Other minerals include apatite, chlorite, fluorite, barite, celestite, apophyllite, and analcime.

Under action of surface waters the biotite has been locally altered to vermiculite, especially in the vicinity of pyrrhotite, and in some places it has been leached of its bases to form brittle, white plates.

UNIT CELL OF MALACHITE

LEWIS S. RAMSDELL

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The unit cell data for malachite given in the literature are those of Brasseur (1932), and were obtained from rotation photographs. Weissenberg photographs confirm his cell dimensions, but indicate a considerable difference in the value of the angle β . Brasseur used the crystallographic value of $91^{\circ}03'$ (Goldschmidt setting), and apparently indexed his films on this basis.

Measurements on Weissenberg photographs, with rotation both about the c and b axes, give a value for β of $98^{\circ}45'$. Because of the large value of d_{100} and the small value of c_0 , this is nearly the maximum angle possible. An angle of about 100° would be equivalent to a B-centered orthorhombic cell, with a doubled value for d_{100} .

The cell dimensions as found are:

$$\begin{aligned} a_0 &= 9.42 \text{ \AA} \\ b_0 &= 11.87 \quad \beta = 98^{\circ}45' \\ c_0 &= 3.21 \end{aligned}$$

SYNTHESIS OF LEAD SULPHANTIMONIDES

S. C. ROBINSON

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Lead sulphantimonides were synthesized by dry fusion in vacuum and from various aqueous solutions in a closed system at temperatures up to 425°C . and at pressures up to 2000 bars, and the products were correlated with natural minerals by x -ray powder and Weissenberg photographs. Only two lead sulphantimonides were synthesized by dry fusion in vacuum: boulangerite and mineral 'X', a new mineral from the Red Bird mine, Nevada, which has not as yet been named. From aqueous solutions artificial equivalents of fulopite, plagionite, semseyite, zinkenite, and mineral 'X' were synthesized, together with two other lead sulphantimonides for which natural counterparts are unknown. Products of hydro-synthesis were sealed in vacuum and subjected to temperatures below their melting points (about 380°C .) for a period of two weeks. Outward crystal forms of these products remained unchanged, but in every case partial to complete alteration to boulangerite, mineral 'X' or galena, with deposition of a brown sublimate of stibnite, had occurred.

The minerals reproduced by hydrosynthesis are typical of the epithermal environment; minerals of mesothermal association were not obtained in this way. Sulpho-salts form most readily from alkaline and variably sulphurous solutions; acid solutions result in deposition of lead and antimony sulphides with, rarely, traces of lead sulphantimonides. Neutral chloride salts facilitate formation of these sulpho-salts; carbonates and bicarbonates repress such formation.

GARNET-IDOCRASE ROCK, A PSEUDO-JADE FROM PLACER COUNTY, CALIFORNIA

AUSTIN F. ROGERS

Stanford University, California

A massive rock occurring in connection with serpentine proves on optical examination to be an intimate mixture of grossularite and idocrase. The idocrase occurs in minute por-

phyroblasts disseminated through the granoblastic garnet and is apparently a product of retrogressive metamorphism.

The color of the rock varies from white and gray to greenish gray and has interesting brownish red mottlings. It is an attractive ornamental stone especially in thin slabs by transmitted light.

It is essentially different from californite although the latter term might be expanded to include it.

Attention is called to the variability of idocrase in various occurrences.

MINERALOGY OF THE BALLAST SANDS OF JAPANESE BALLOONS*

CLARENCE S. ROSS

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

The beach sands of the Japanese balloons dispatched to this country in great numbers were submitted to the Section of Military Geology of the U. S. Geological Survey. Detailed studies indicated that these showed such an unusual suite of minerals that it would be possible to indicate their probable source on the coast of Japan. The minerals of these sands and their characteristics will be described in detail.

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PRESENT STATUS OF LABORATORY STUDIES OF DRY SILICATE SYSTEMS

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Phase equilibrium studies of dry silicate systems, which are now in progress or have just been completed at Geophysical Laboratory, yield much information on the ranges in chemical composition and on the mutual stability relations at elevated temperatures of several groups of important rock-forming minerals—particularly the olivines, pyroxenes, pyroxenoids, melilites, feldspars, and feldspathoids. Progress on the following systems is reported: $\text{Na}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2$, $\text{K}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2$, nepheline-potash nepheline-silica, leucite-anorthite-silica, leucite-forsterite-silica, nepheline-diopside-silica, nepheline-anorthite-silica, $\text{CaO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$, $\text{CaO}-\text{MgO}-\text{FeO}-\text{SiO}_2$, $\text{K}_2\text{O}-\text{MgO}-\text{SiO}_2$ and $\text{K}_2\text{O}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$.

TEMPERATURE OF FORMATION FROM FLUID INCLUSIONS

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In collaboration with Dr. F. G. Smith a simple technique has been developed whereby primary liquid and gas inclusions in a mineral may be utilized to determine its approximate temperature of formation. The mineral is prepared by crushing and screening and is placed in an electric furnace whose temperature is steadily increased. The temperature at which the expanding liquid just fills the cavity is accepted as the temperature of formation and is usually determined visually with the microscope; in the present procedure, the frequency and volume of exploding inclusions is recorded, providing data from which the temperature is interpreted. By this means the temperature of formation of quartz in the Ivigtut (Greenland) cryolite deposit was determined as at least 320°C. The inversion temperatures of several minerals studied, including quartz and cryolite, have a marked influence on the audible effect, and inversion points may in some cases at least be predicted from this effect alone.

PARAGENESIS OF THE GARNET AND ASSOCIATED MINERALS OF THE BARTON
MINE NEAR NORTH CREEK, N. Y.

B. M. SHAUB

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During the spring and late summer, the writer made his first post-war visits to the Barton Garnet Mine on Gore Mt. near North Creek, N. Y., and during these visits a number of specimens of the garnet and associated minerals were collected for a paragenetic study which was suggested by the occurrence of hypersthene crystals up to four inches in length extending from their attachment in the hornblende rims into the garnet masses. These vary in size up to a foot in cross section. Other hypersthene crystals up to one and a half inches in length were completely inclosed within the garnet.

In addition to the usual rather thick envelope of hornblende surrounding the garnet a commonly occurring thin envelope of plagioclase feldspar appears between the hornblende and garnet. The feldspar sometimes produces envelopes or irregular masses up to an inch thick. Euhedral crystals of hypersthene and terminated crystals of hornblende are associated with the larger masses of feldspar. A number of other minerals occur at the contacts and/or wholly within the plagioclase or garnet.

The textural and structural relationships suggest that the direction and order of crystallization was centripetally from the surrounding mass of the inclosing gabbroic rock to the garnet which, except for the acid plagioclase, was the last mineral to crystallize.

USE OF FELDSPAR IN THE PETROFABRIC ANALYSIS OF IGNEOUS ROCKS

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Microscopic statistical analysis has not kept pace with granite tectonics as a tool in the structural study of igneous rocks. The methods of petrofabrics are rarely applied to igneous problems and when used rely chiefly on studies of quartz and the micas.

The omnipresent feldspars are readily oriented with the five-axis Universal Stage and are more useful in studies of igneous rocks than the more restricted quartz and mica. Although the elements in the feldspars suitable for measurement are limited by the variable relations of the indicatrix to crystallographic directions and by twin relationships, several elements give reliable data. Measurements of both lineation and foliation can be made on the same mineral.

Adaptations of the Fedorov plagioclase stereograms permit measurements to be made on an easily oriented crystallographic element while the plotting may be done for a more desirable element or section. Petrofabric data are more easily interpreted if included as a part of the structural map and sections.

Study of a granitic intrusive in north-central Wisconsin by both megascopic and microscopic methods indicates that the two methods complement each other and that microscopic data may be used where megascopic data are incomplete or lacking. Microscopic analysis frequently reveals several structural elements where only the dominant one may be visible in outcrop.

GOLD CRYSTALS FROM THE SOUTHERN APPALACHIANS

STEPHEN TABER

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Gold in well-formed rhombic dodecahedra is reported for the first time from the Southern Appalachians. The crystals were obtained from placer deposits in Greenville County, South Carolina. Poorly-developed octahedra, dendritic forms and wire gold have been re-

ported from Georgia. Euhedral gold crystals are extremely rare compared with the amount of the metal produced and very few have been preserved.

Euhedral crystals and filiform gold develop in open spaces, for gold is too soft and malleable to displace most other minerals. Also because of these properties crystalline structure is readily destroyed by impact or even by polishing, but the high mobility of the atoms makes recrystallization easy. Euhedral crystals are deposited from solutions occupying the cavities. Wire-like forms of the native metals result when the material for growth is available in only one direction, the wires being pushed out into the cavities by the addition of atoms at their base from solutions occupying small pore spaces in the walls.

RÔLE OF ALUMINUM IN THE ROCK-FORMING SILICATES

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In the rock-forming silicates aluminum may appear in either six-fold (octahedral) or four-fold (tetrahedral) coordination with oxygen. Octahedrally coordinated aluminum is structurally like magnesium or ferrous or ferric iron. Tetrahedrally coordinated aluminum is structurally like silicon.

A survey has been made of the geologic distribution of tetrahedrally and octahedrally coordinated aluminum. It has been found that minerals containing tetrahedrally coordinated aluminum are characteristic of igneous rocks, thermally metamorphosed rocks, high-grade regionally metamorphosed rocks and the products of artificial melts. Minerals containing octahedrally coordinated aluminum are characteristic of weathering products, sedimentary rocks, hydrothermal deposits, deuteric alterations, and low and middle grade regionally metamorphosed rocks (stress minerals). It is apparent that at high temperatures aluminum tends to be tetrahedrally coordinated and at low temperatures octahedrally coordinated. The effect of hydrostatic pressure is less obvious but octahedral coordination is more economical of space.

The presence of other ions in a mineral, particularly the alkalis, seems to be important. In potassium-aluminum silicates there is always at least one tetrahedrally coordinated aluminum ion for each potassium ion present. The same holds true for the sodium-aluminum silicates except in the pyroxene, jadeite, and the corresponding amphibole, glaucophane.

Rock and mineral relationships considered in the light of aluminum coordination include kyanite-andalusite-sillimanite-mullite, epidote-plagioclase, and gabbro-eclogite. On the assumption that the linking of silicon tetrahedra is favored by low temperature and low pressure, and that high aluminum coordination is favored by low temperature and high pressure it is possible to derive, theoretically, mineral facies essentially similar to those of Eskola.

PYROSYNTHESSES OF TELLURIDE MINERALS

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In connection with a comprehensive study of the telluride minerals an attempt was made to reproduce most of the established and reported species by fusing the powdered elements in the proper proportions in evacuated silica glass tubes. The following compositions gave practically homogeneous compounds which were proved to be identical with the corresponding minerals by microscopic and x -ray examination: AuTe_2 (calaverite), Ag_3AuTe_2 (petzite), Ag_2Te (hessite), Ag_5Te_3 or Ag_{2-x}Te (empressite), Cu_6Te_3 or Cu_{2-x}Te (weissite), Cu_4Te_3 or Cu_{2-y}Te (rickardite), NiTe_2 (melonite), FeTe_2 (frohbergite), PbTe (altaite), HgTe (coloradoite), Bi_2Te_3 (tellurbismuth), BiTe or $\text{Bi}_{2+x}\text{Te}_{3-x}$ (wehrlite). (Ag,

Au)+Te ("muthmannite") gave $\text{AuTe}_2 + \text{Ag}_3\text{AuTe}_2$. $\text{Ag}_4 + \text{Te}$ ("stuetzite") gave $\text{Ag}_2\text{Te} + \text{Ag}_3$. $\text{Pt} + \text{Te}_3$ ("nigglite") gave $\text{PtTe}_2 + \text{Te}$. Some natural tellurides dissociate on heating and cannot therefore be reproduced by fusion.

A NEW HYDROTHERMAL QUENCHING APPARATUS

O. F. TUTTLE AND N. L. BOWEN

Geophysical Laboratory, Washington, D. C.

A simple apparatus has been developed for the study of equilibrium relations at high temperatures and pressures in mineral systems including volatile components. Investigations have been carried to pressures of 30,000 lbs. per sq. in. (approximately 4.5 miles depth) at temperatures up to 900°C. Results on the system $\text{K}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}$ show that a water pressure of 15,000 lbs. per sq. in. lowers the liquidus about 100°C. in the orthoclase field. In compositions approaching the quartz-orthoclase join a pressure of 30,000 lbs. per sq. in. gave relatively insignificant additional lowering.

PARTLY VITRIFIED XENOLITHS IN PILLOW BASALT*

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Department of Mines, Victoria, Canada

Pillow basalt in the Tuya Range of northern British Columbia contains many xenoliths of granite and a few of quartzite. The feldspar and quartz of the granite inclusions are highly cracked and, together, have yielded abundant colourless glass with a refractive index of 1.495. Some of the feldspar grains which have been partly vitrified are cut by glass veinlets that form extremely fine meshworks. The ferromagnesian minerals have been converted almost completely to a dark brown glass containing scattered new crystals of clinopyroxene and black opaque minerals. A small proportion of the quartz contains tridymite in minute veinlets of glass. The quartzite inclusions show partial vitrification, some introduction of basic pale brown glass chiefly along grain boundaries, and the formation of sanidine, cordierite, hypersthene, and clinopyroxene. A fragment of granite in basaltic agglomerate is also partly vitrified and contains the new minerals: clinopyroxene and anorthoclase. The temperatures attained by the xenoliths did not exceed 1075°C but were probably greater than 900°C.

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ROCK ALTERATION ASSOCIATED WITH THERMAL SPRINGS*

DONALD E. WHITE

Carson City, Nevada

The study of rock alteration and its relation to ore-bearing solutions can be approached in a number of different ways. Each general method is examined briefly and the need for a close integration of all methods is emphasized.

The study of processes taking place in areas of thermal springs is one approach. In such areas there is opportunity to investigate several specific types of alteration as well as the physical state, temperature, composition, and concentration of each associated solution. General conditions at Steamboat Springs, Nevada, are described; rocks above the general

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water table are being altered by sulfuric acid resulting from the oxidation of H_2S , and rocks below the water table are being more slowly attacked by the saline spring waters. Outstanding studies by other men are summarized.

ISOTOPE RATIOS, A CLUE TO THE AGE OF CERTAIN MARINE SEDIMENTS

FRANS E. WICKMAN
Stockholm, Sweden

If an element A has a radiogenic isotope A_1 and a nonradiogenic A_2 , the ratio A_1/A_2 is an index of the age of marine chemical sediments, if the content of the isotope B* producing A_1 can be neglected. It is shown that the method can be used for strontium (and perhaps Pb^{208}) on limestones and anhydrites.

STABILITY RELATIONS OF GROSSULARITE

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Massachusetts Institute of Technology, Cambridge, Massachusetts

Experiments of an exploratory nature have been conducted to determine the range of stability of grossularite garnet, $Ca_3Al_2(SiO_4)_3$. The following techniques were applied: thermal and differential thermal analysis, high pressure and temperature bombs, hydrothermal bombs, and powder metallurgical sintering techniques. Natural grossularite decomposes in the solid state into gehlenite, wollastonite, and anorthite between 1000°C. and 1100°C. The three resulting minerals are essentially a eutectic mixture below 1265°C. Using both synthetic and natural materials, the decomposition products were found to be stable at least as low as 800°C. This result is dependent on the variables in the diffusion process. The P-T diagram indicating the range of stability of grossularite in the system $CaO-Al_2O_3-SiO_2$ has been derived theoretically and determined in part experimentally. The decomposition products are stable above 1028°C. at pressures up to 4100 atmospheres. The nature of the substitution solid solution series $Ca_3Al_2(OH)_{12}-Ca_3Al_2(SiO_4)_3$, in which the minerals grossularite, plazolite, hibschite, grossularoid, and hydrogrossular occur, is confirmed. An irreversible, endothermic reaction takes place in "pure" natural grossularites in the vicinity of 1000°C. This is thought to be the release of the hydroxyl groups as water, the more hydroxyl, the lower the temperature of release. It is recommended that all garnets be analyzed for H_2O_+ . Although grossularite may form at high pressures in dry systems, its hydrothermal nature should be emphasized.

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