

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

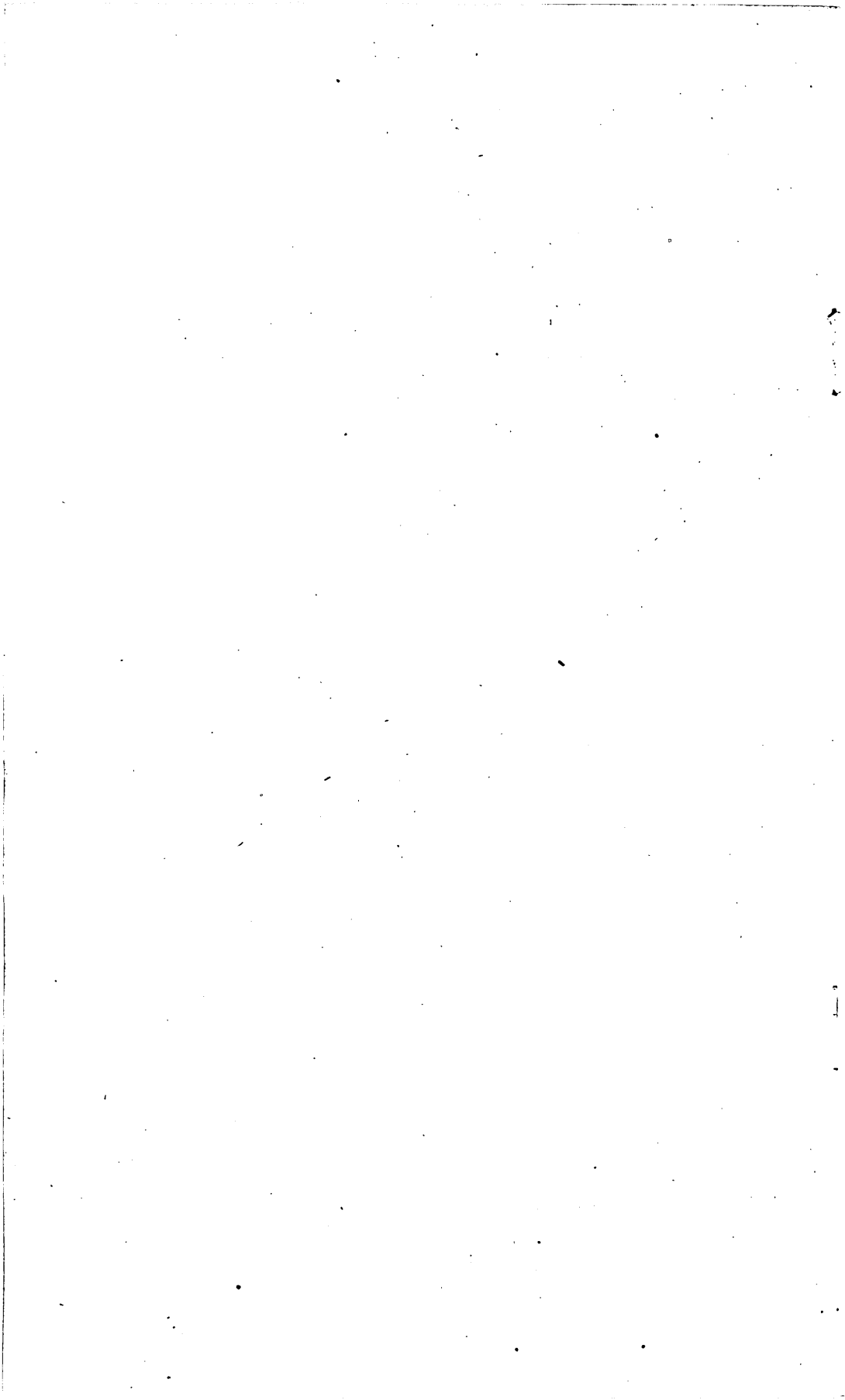
No. 148



WASHINGTON

GOVERNMENT PRINTING OFFICE

1897



UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

ANALYSES OF ROCKS

WITH A CHAPTER ON

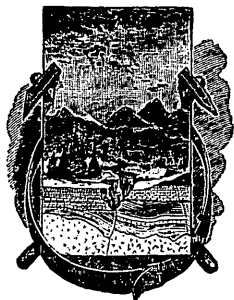
ANALYTICAL METHODS

LABORATORY OF THE UNITED STATES GEOLOGICAL SURVEY

1880 to 1896

BY

F. W. CLARKE AND W. F. HILLEBRAND



WASHINGTON

GOVERNMENT PRINTING OFFICE

1897

CONTENTS.

	Page
Introduction, by F. W. Clarke	9
Some principles and methods of analysis applied to silicate rocks, by W. F. Hillebrand.....	15
Part I.—Introduction	15
Scope of the present paper	20
Part II.—Discussion of methods	22
Preparation of sample.....	22
Specific gravity.....	23
Weights of sample to be employed for analysis.....	26
Water, hygroscopic	26
Water, total or combined.....	30
Silica, alumina, iron, etc.....	34
Manganese, nickel, cobalt, copper, zinc.....	41
Calcium and strontium.....	43
Magnesium	43
Barium and titanium.....	45
Zirconium	48
Rare earths other than zirconia	50
Chromium and phosphorus	51
Ferrous iron	52
Alkalies	54
Carbon dioxide.....	56
Chlorine.....	57
Fluorine.....	57
Sulphur	58
Boron	59
Nitrogen.....	59
Special operations	60
Estimation of minute traces of certain constituents	61
Preliminary qualitative analysis	62
Summation of analytical results.....	62
Quality of reagents	63
Analyses of rocks; arranged and tabulated by F. W. Clarke.....	65
Igneous and crystalline rocks	65
Maine	65
New Hampshire.....	67
Vermont.....	68
1. Rocks of Mount Ascutney.....	68
2. Miscellaneous rocks	71
Massachusetts	72
1. Rocks of the Connecticut Valley.....	72
2. Miscellaneous rocks	77

Analyses of rocks; arranged and tabulated by F. W. Clarke—Continued.	Page.
Igneous and crystalline rocks—Continued.	
Connecticut.....	79
New York.....	79
New Jersey.....	80
Pennsylvania.....	81
Delaware.....	82
Maryland and the District of Columbia.....	83
1. Peridotite and pyroxenite.....	83
2. Gabbro and diorite.....	85
3. Granite and gneiss.....	85
4. Miscellaneous rocks.....	90
Virginia.....	91
North Carolina.....	91
1. Rocks from Corundum Hill.....	91
2. Pyroxenite from Webster.....	92
Kentucky.....	92
1. The Elliott County dike.....	92
2. The Crittenden County dike.....	94
Missouri.....	95
Arkansas.....	96
Texas.....	96
The Lake Superior Region.....	97
1. The Marquette and Michigamme Region, Michigan.....	97
2. The Menominee River.....	100
First. The Sturgeon Falls gabbro.....	100
Second. Lower Quinnesec Falls.....	101
Third. Upper Quinnesec Falls.....	102
3. The Penokee-Gogebic Region.....	103
4. Rocks of Pigeon Point, Minnesota.....	104
5. Miscellaneous rocks from Minnesota.....	111
South Dakota.....	114
Wyoming.....	115
The Yellowstone National Park.....	117
1. Electric Peak.....	117
2. Sepulcher Mountain.....	120
3. The Crandall Basin.....	122
4. Absarokite-Shoshonite-Banakite series.....	125
5. Miscellaneous rocks.....	130
Montana.....	137
1. The Madison and Gallatin valleys.....	137
2. The Crazy Mountains.....	142
3. The Little Belt Mountains.....	146
4. The Castle Mountain district.....	150
5. The Highwood Mountains.....	152
6. The Little Rocky Mountains.....	155
7. The Bearpaw Mountains.....	156
Colorado.....	158
1. The Denver Basin.....	158
2. The Pikes Peak district.....	159
3. Silver Cliff and Rosita.....	165
4. The Buffalo Peaks.....	171
5. The Leadville region.....	172
6. The Ten Mile district.....	175
7. The Elk Mountains.....	177

Analyses of rocks; arranged and tabulated by F. W. Clarke—Continued.	Page.
Igneous and crystalline rocks—Continued.	
Colorado—Continued.	
8. The West Elk Mountains	178
9. Miscellaneous rocks	179
Utah	183
New Mexico	184
1. Basalts from Rio Grande Canyon	184
2. The Mount Taylor region	185
3. Miscellaneous	186
Arizona	187
Nevada	188
1. Rocks from Washoe	188
2. Rocks from Eureka	189
California	190
1. Mount Shasta	190
2. The Lassen Peak region	191
First. Rhyolites	192
Second. Dacites and andesites	193
Third. Basalts	198
3. Plumas County	201
4. Butte County	204
5. Sierra County	206
6. Nevada City and Grass Valley	208
7. Placer County	211
8. Eldorado County	213
9. Amador County	214
10. Calaveras County	216
11. Tuolumne County	217
12. Mariposa County	219
13. The Quicksilver region	222
14. Mount Diablo	224
15. Miscellaneous rocks	228
Oregon	230
1. Basalt, Mount Thielsen	230
2. Peridotite from Douglas County	231
3. Basalt, near Crater Lake	231
Alaska	232
Stony meteorites	234
Meteoric iron	244
Sandstones and cherts	247
Ohio	247
California	248
1. Mount Diablo	248
2. Shasta County	249
3. Sulphur Bank	250
Miscellaneous sandstones	251
Chert	252
The carbonate rocks	254
Vermont and Massachusetts	254
New York, Pennsylvania, Maryland	255
Virginia and West Virginia	256
Georgia	257
Tennessee, Alabama, Louisiana	258
Florida	259

Analyses of rocks; arranged and tabulated by F. W. Clarke—Continued.	Page.
The carbonate rocks—Continued.	
Ohio.....	260
Indiana.....	263
Missouri.....	264
Kansas.....	264
Michigan, Wisconsin, Minnesota, Canada.....	265
Montana.....	269
Colorado.....	270
1. The Denver Basin.....	270
2. The Leadville district.....	271
3. Fairplay, Park County.....	272
4. Pitkin County.....	272
5. Glenwood Springs.....	273
6. Ten Mile district.....	274
Utah.....	275
Nevada and California.....	275
Hawaiian Islands.....	276
Slates and shales.....	277
Vermont.....	277
New York.....	280
Kentucky, Georgia, Alabama.....	282
Ohio.....	283
Wisconsin.....	283
Colorado.....	284
California.....	285
Clays, soils, etc.....	287
Massachusetts.....	287
New York, Pennsylvania, Delaware.....	288
Virginia, North Carolina.....	289
South Carolina, Georgia.....	290
Florida.....	290
Alabama, Mississippi.....	292
Illinois, Iowa, Minnesota.....	293
Wisconsin.....	294
Missouri, Arkansas.....	295
Colorado.....	297
Wyoming, Utah, New Mexico.....	299
Nevada.....	300
California, Washington, Hawaiian Islands.....	301
Index to rocks.....	303

ANALYSES OF ROCKS, WITH A CHAPTER ON ANALYTICAL METHODS, LABORATORY OF THE UNITED STATES GEOLOGICAL SURVEY, 1880-1896.

By F. W. CLARKE and W. F. HILLEBRAND.

INTRODUCTION.

By F. W. CLARKE.

The present Geological Survey of the United States was organized in 1879. In 1880 a chemical laboratory was established at Denver, in connection with the Colorado work, in charge of Dr. W. F. Hillebrand, with whom were associated Mr. Antony Guyard and, later, Mr. L. G. Eakins. In 1882 Dr. W. H. Melville was placed in charge of a second laboratory at San Francisco, and in the autumn of 1883 the central laboratory was started in Washington, with myself as chief chemist. In November, 1885, Dr. Hillebrand was transferred to Washington; he was followed early in 1888 by Mr. Eakins, and the Denver laboratory was discontinued. Dr. Melville was also brought to Washington in the spring of 1890, and since then the chemical work of the Survey has been concentrated at headquarters.

Up to January 1, 1897, about 3,700 analyses have been made in the laboratory at Washington. These represent rocks, minerals, ores, waters, sediments, coals, metals, and so on through all the range of substances with which geology has to do. There were also some hundreds of analyses made in the laboratories at Denver and San Francisco, and a fair amount of research work upon mineralogical and analytical problems has also been done. In all of this work the following chemists have been employed: Charles Catlett, T. M. Chatard, F. W. Clarke, L. G. Eakins, F. A. Gooch, Antony Guyard, W. F. Hillebrand, W. H. Melville, R. B. Riggs, E. A. Schneider, George Steiger, H. N. Stokes,

and J. E. Whitfield. As many as eight of these have been at work simultaneously; at present only four are connected with the Survey. Other officers of the Survey have been occupied more or less with chemical questions; but the men named in this list were connected directly with the laboratory. Some work for the chemical division has also been done by chemists not regularly on the rolls of the Survey; but their analyses, with a single exception to be noted later, do not fall within the scope of this paper.

Quite naturally, on account of the activity of the petrographers, the dominant feature of the laboratory work has been the analysis of rocks. These have been studied in great numbers, and in the most thorough way. The results have appeared in widely scattered publications, official reports, monographs, bulletins, American and foreign journals, and so on. The object of this bulletin is to bring together this valuable material, together with such bibliographic and petrographic data as seems to be necessary in order to identify the specimens and to facilitate chemical discussion. Analyses of minerals have been included only when related to petrographic studies, appearing then in connection with the rocks to which they belong. Meteorites, of which twenty-seven have been analyzed, are brought into the work on account of their petrographic relations; and the groups of clays and soils have been admitted because of the bearing of these substances upon the study of slates and shales. The actual number of analyses given in the bulletin is as follows:

Igneous and crystalline rocks	692
Mineral separations	78
Meteorites, and separations from them	58
Sandstones and cherts	36
Carbonate rocks	183
Slates and shales	45
Clays, soils, etc.	93
Total	1,185

It may be observed that the classification thus indicated has not been rigorously followed. In a few instances the study of a sedimentary rock has been so related to that of its igneous neighbors that the analyses are best tabulated together; but these exceptional cases are few, and all are properly noted. The heading of "igneous and crystalline rocks" has been used in the broadest and most liberal way, and doubtless many of the analyses given under it might properly be otherwise classified. In such cases of uncertainty, convenience has furnished the rule to follow.

Within each division of the analyses the classification chosen has been geographic. The petrographic grouping of the rocks would doubtless be best, were petrographers agreed upon it; but their differences are many, and the chemist will do well to avoid them. The geographic method, moreover, has some advantages of its own; it facilitates the

study of areas, it simplifies the bibliographic references, and it brings together in great measure the work of each petrographer for whom analyses have been made. Thus, most of Diller's work has been in California, most of Cross's in Colorado, and most of Iddings's in the Yellowstone National Park; and in each case the analyses are massed and their discussion is practically uniform in character. As regards nomenclature, each rock has received the designation given it by its describer, and no liberties have been taken. This plan may cause some lack of uniformity; but no other procedure seemed to be practicable.

It will be noticed by anyone who uses this bulletin that the analyses vary as regards completeness. Among the sedimentary rocks, especially, partial analyses are common; but in the igneous group thoroughness is more general. In the early days of the chemical division many analyses were made along the older lines, just as they are still made in many laboratories to-day—that is, only the main constituents, those having direct petrographic significance, were determined. In such analyses the minor ingredients, like titanium, phosphorus, barium, strontium, chlorine, etc., were ignored; and, although the results are satisfactory in some respects, they leave much to be desired. Latterly, greater completeness has been sought for, the work done has been much fuller, and the data obtained can be discussed with much higher approaches to accuracy. The old form of "complete analysis" is to be discouraged; it leads too often to erroneous conclusions; and only the best modern methods of work and of statement should be tolerated. The fuller analyses, moreover, have brought some interesting points to light; titanium now appears to be one of the more abundant elements, and barium and strontium are found to be almost universally diffused in igneous rocks in quite perceptible quantities.

On general principles the analysis of a rock and its petrographic description should be two parts of the same investigation, matching each other completely. In practice, however, this rule does not always hold, and the departures from it are in two opposite directions. For example, an analysis of the older type says nothing of titanium and phosphorus, while the microscope reveals the presence of sphene and apatite. In this case the petrographer has been more thorough than the chemist. On the other hand, a full and perfect analysis may be given, accompanied by a petrographic description of the most general kind, in which only the main mineral constituents of the rock are noted. Here the analysis has been incompletely used, and the petrographic discussion is defective. It is hoped that the publication of this material may lead to a clearer recognition of the mutuality which should exist between the chemical and the microscopic researches, and so bring, in the future, both lines of investigation more into harmony. Hitherto the chemist and the petrographer have worked too much apart, and each has too often misunderstood the purpose of the other. If the study of the thin section could always precede the analysis, the

petrographic problems could be stated more clearly, and the chemical evidence might be rendered much more pertinent and satisfactory.

In a paper published some years ago,¹ on the relative abundance of the chemical elements, I computed the average composition of the primitive crust of the earth from 880 analyses of eruptive and crystalline rocks. Of these analyses only 207 were from the laboratories of the Survey, while 673 were collected from various other American and foreign sources. A large proportion of them were incomplete, regarded from a modern point of view, and yet the results obtained were fairly conclusive. The material now available for similar discussion is much better than that which was formerly used, and an average based upon it may not be out of place here.

In the bulletin now presented I have found 680 complete analyses of rocks which are suitable for my purpose. I have also taken from the partial analyses given in the laboratory records 180 additional determinations of silica, 90 of lime, and 130 of alkalis. In 340 of the analyses there is discrimination between the water lost below 110°C and that which is essential to the composition of the rocks; and this amounts to 0.40 per cent. Omitting this water, the average found may fairly represent the composition of the older crust of the earth, as deduced from a mass of data which are reasonably uniform in character and entitled to a high degree of credence. The mean for the more important constituents is as follows, with the old average given in a parallel column for comparison:

	New mean.	Old mean.
SiO ₂	59.77	58.59
Al ₂ O ₃	15.38	15.04
Fe ₂ O ₃	2.65	3.94
FeO.....	3.44	3.48
CaO.....	4.81	5.29
MgO.....	4.40	4.49
K ₂ O.....	2.83	2.90
Na ₂ O.....	3.61	3.20
H ₂ O.....	1.51	^a 1.96
TiO ₂.....	.53	.55
P ₂ O ₅.....	.21	.22
	99.14	99.66

^a Including hygroscopic water.

¹ Bull. U. S. Geol. Survey No. 78, 1891, p. 34.

If we reduce these figures to elementary form and include minor constituents, the two averages compare as follows:

	New mean.	Old mean.
Oxygen	47.13	47.29
Silicon	27.89	27.21
Aluminum.....	8.13	7.81
Iron.....	4.71	5.46
Calcium.....	3.53	3.77
Magnesium.....	2.64	2.68
Potassium.....	2.35	2.40
Sodium.....	2.68	2.36
Titanium.....	.32	.33
Hydrogen .....	.17	.21
Carbon.....	.13	.22
Phosphorus .....	.09	.10
Manganese.....	.07	.08
Sulphur.....	.06	.03
Barium .....	.04	.03
Chromium .....	.01	.01
Nickel .....	.01	.....
Strontium.....	.01	.....
Lithium.....	.01	.....
Chlorine .....	.01	.01
Fluorine .....	.01	.....
	100.00	100.00

As the old mean represents an attempt to measure the composition of the entire solid crust of the earth, and so includes an allowance for the carbon in the limestones, the two columns are not strictly comparable. They are, however, corroborative of each other, and show that within reasonable limits the statistical method is applicable to the problem under consideration. For the arguments upon which the discussion is based the original paper should be consulted. For the elements not in the table no estimates can now be made; but not one, probably, could reach 0.01 per cent in quantity. Their proportions may be regarded as small corrections to be applied at some time in the future.

During the preparation of this bulletin much assistance was rendered by the petrographers and geologists connected with the Survey, especially with reference to analyses hitherto unpublished. In each case credit has been given for the data thus added. Twenty-eight analyses of rocks from Montana, executed by or under the direction of Prof. L. V. Pirsson, of Yale University, and having been made in connection with regular Survey work, are included in the tabulations. With this

exception all of the analyses given were made in the Survey laboratories. To those executed in the laboratory at Washington "record numbers" are attached, which serve to identify them on the record books of the Division of Chemistry. Of the abbreviations used for bibliographic reference only three need explanation, and they refer to the official publications of the Survey. "Ann." for Annual Report, "Mon." for Monograph, and "Bull." for Bulletin are the three in question. The others relate to well-known journals, and are familiar to all geologists.

SOME PRINCIPLES AND METHODS OF ANALYSIS APPLIED TO SILICATE ROCKS.

By W. F. HILLEBRAND.

PART I.—INTRODUCTION.

The composition of the ultimate ingredients of the earth's crust—the different mineral species which are there found and of many of which its rocks are made up—was the favorite theme of the great workers in chemistry of the earlier half of this century, and for the painstaking care and accuracy of Berzelius, Wöhler, and others the mineralogists and geologists of to-day have need to be thankful. Considering the limited facilities at their disposal in the way of laboratory equipment and quality of reagents, the general excellence of their work is little short of marvelous. As an outgrowth of and closely associated with the analysis of minerals came that of the more or less complex mixtures of them—the rocks—to aid whose study by the petrographer and geologist a host of chemists have for many decades annually turned out hundreds of analyses of all grades of quality and completeness. With the growth and extraordinary development of the so-called organic chemistry inorganic chemistry gradually fell into a sort of disfavor. In many, even of the best, European laboratories the course in mineral analysis, while maintained as a part of the curriculum of study, became but a subordinate prelude to the ever-expanding study of the carbon compounds, whose rapid multiplication, offering an easy and convenient field for original research and possible profit, proved a more tempting opening to young chemists than the often-worked-over and apparently exhausted inorganic pasture. For one student devoting his time to higher research on inorganic lines were perhaps fifty engaged in erecting the present enormous structure of carbon chemistry. The instruction afforded the student in mineral analysis was confined to the ordinary separations of the commoner ingredients occurring in appreciable quantities, with little regard to supposed traces and with still less attempt to find out if the tabulated list really comprised all that the mineral or rock contained.

With the introduction of improved methods of examination by the petrographer, especially as applied to thin rock sections and the use of heavy solutions, whereby, on the one hand, the qualitative mineral composition of a rock could be preliminarily ascertained with considerable certainty, and on the other, chemical examination of the more or less perfectly separated ingredients was rendered possible, a great help

and incentive was afforded to the few chemists engaged in rock analysis. The microscope often obviated in part the necessity for tedious and time-wasting qualitative tests, and the heavy solutions, by permitting the concentration and separation of certain components, facilitated the detection of elements whose existence had long been overlooked.

Meanwhile in the progress of chemistry new methods and reagents for qualitative detection and quantitative separation and estimation were gradually being discovered and devised. The supposed adequacy of some well-established methods was shown to be unwarranted; some had to be discarded altogether; others were still utilizable after modification. In the light thus shed it became possible to explain many hitherto incomprehensible variations in the composition of some rock species or types, as shown in earlier analyses, and in not a few cases it appeared that the failure to report the presence of one or more elements had obscured relations and differences which more thorough examination showed to exist (see pp. 17-18). Consequently there arose a feeling of distrust of much of the older work in the minds of those chemists and petrographers best qualified to judge of its probable qualities. This, and the incompleteness of nearly all the earlier work (and much of that of to-day unfortunately), as shown by the largely increased list of those elements now known to enter into the normal composition of rocks, is rendering the old material less and less available to meet the increasing demands of the petrographer.

And yet these demands on his part are, with few exceptions, by no means so exacting as they should be. Often the analysis is intrusted to the hands of a student without other experience than that gained by the analysis of two or three artificial salts and as many comparatively simple natural minerals, and with a laboratory instructor as adviser whose experience in rock analysis may be little superior to his own. In other words, one of the most difficult tasks in practical analysis is expected to be solved by a tyro, and his results are complacently accepted and published broadcast without question. Even to those thoroughly familiar with the subject rock analysis is a complex and often trying problem. Although long practice may have enabled one to do certain parts of it almost mechanically, he is still from time to time confronted with perplexing questions which require trained judgment to properly meet and answer, and there is still room for important work in some of the supposedly simplest quantitative determinations. If the results are to be of any decided value for purposes of scientific interpretation and comparison, they should be the product of one competent to find his way through the intricacies of an analysis in which from fifteen to twenty-five different components are to be separated and estimated with close approach to accuracy, and this a beginner can not hope to do in the majority of cases. The conscientious chemist should have a live interest in this matter. He should work with a twofold purpose in view—that of lightening the labors of those who come after him by enabling them to use his work with less supplementary examination, and of thereby enhancing his own reputation by meriting encomiums on work that has stood the test of time.

The petrographer, again, should seek to have his analyses made as complete as possible, and not, as is so often the case, be content with determinations of silica, alumina, the oxides of iron, lime, magnesia, the alkalis and water. The latter, it is true, are entirely justifiable at times, and may serve the immediate purpose for which they were intended, but their incompleteness may, on the other hand, not only conceal points fruitful of suggestion to the attentive mind, but, what is of still greater importance, they may be actually misleading. Enough instances of totally inaccurate conclusions to be drawn from them have fallen under my own observation to fully justify this plea in favor of greater completeness in rock and mineral analyses made for purely scientific purposes.

This is shown by the difference between the following analyses:

	Earlier analysis.	Later analysis. ¹
SiO ₂	54.42	53.70
TiO ₂		1.92
Al ₂ O ₃	13.37	11.16
Cr ₂ O ₃.....		.04
Fe ₂ O ₃	² 61	3.10
FeO.....	² 3.52	1.21
MnO.....		.04
CaO.....	4.38	3.46
SrO.....		.19
BaO.....		.62
MgO.....	6.37	6.44
K ₂ O.....	10.73	11.16
Na ₂ O.....	1.60	1.67
Li ₂ O.....	Trace.	Trace.
H ₂ O below 110° C.....		.80
H ₂ O above 110° C.....	³ 2.76	2.61
CO ₂	1.82	
P ₂ O ₅		1.75
SO ₃.....		.06
F.....		.44
Cl.....		.03
	99.58	100.40
Less O for F.....		.19
		100.21

¹ A still more recent analysis of another of the series of rocks of which this is an example has shown that this "later analysis" is itself probably incomplete and incorrect in part—incomplete because of the probable presence of .2 per cent or more of ZrO₂, incorrect because of the error in Al₂O₃ resulting from having counted the ZrO₂ as Al₂O₃, and from the fact that titanium is not fully precipitable in presence of zirconium by Gooch's method (the one employed). This latter error involves both the TiO₂ and the Al₂O₃ (see p. 48).

² From the fact that repeated determinations of the iron oxides in this and related rocks from the same region show always a great preponderance of ferric oxide, it is not improbable that the figures given for the two oxides in the first analysis were accidentally transposed.

³ In the published analysis it does not appear whether this is total water or, as seems probable, only that remaining above 100° C.

The specimens were taken and analyzed at widely separated times and by different persons, it is true, but they were unquestionably from the same rock mass, in which, however much the relative proportions of the different mineral constituents might vary within certain limits, there can be no reason to doubt the general distribution of all the elements shown by the second analysis.

Another instance of similar kind is given below. Here, again, certain differences are explainable by natural variations in the proportions of the constituent minerals, but it can hardly be doubted that TiO_2 , BaO , SrO , P_2O_5 , and SO_3 were present in both specimens in approximately the same amounts. In the earlier analysis in this case determinations of some supposed unimportant constituents were purposely omitted or only made qualitatively, with results that can not be otherwise than fatal to a full comprehension of the mineralogical nature of the rock:

	Earlier analysis.	Later analysis.
SiO_2	44.31	44.65
TiO_2	Not est.	.95
Al_2O_3	17.20	13.87
Fe_2O_3	4.64	6.06
FeO	3.73	2.94
MnO}.....	.10	.17
CaO	10.40	9.57
SrO		1.37
BaO}.....		.76
MgO	6.57	5.15
K_2O	3.64	4.49
Na_2O	4.45	5.67
Li_2O		Trace.
H_2O below 110°C}.....	.77	.95
H_2O above 110°C		2.10
H_2O by ignition.....	3.30	
CO_2.....		.11
P_2O_5		1.50
Cl		Trace.
SO_3.....		.61
	99.11	99.92

¹ Not entirely free from CaO .

In order to more strongly emphasize the importance of completeness in analysis, one fact brought out by the hundreds of rock analyses made in this laboratory may be cited. It has been demonstrated most conclusively that barium and strontium are almost never-failing constituents

of the igneous rocks and many of their derivatives of the United States. These amounts are usually below 0.1 per cent for each of the oxides of those metals, but higher amounts are by no means uncommon. Furthermore, the weight of barium is almost without exception in excess of that of strontium. But a still more important point is that the igneous rocks of the Rocky Mountain region, so far as examined, show far higher average percentages of both metals than the rocks from the eastern and the more western portions of the United States. The following examples serve to illustrate certain types of Rocky Mountain igneous rocks: Of seven rocks forming a Colorado series, six held from 0.13 to 0.18 per cent of BaO, while in the seventh the percentage was 0.43. The SrO ranged from 0.07 to 0.13 per cent for six, and was 0.28 for that one highest in BaO. Of thirteen geologically related rocks from Montana, embracing basic as well as acid and intermediate types, the range of BaO was from 0.19 to 0.37 per cent, with an average of 0.30 per cent. Three others of the same series contained 0.10 per cent or less, while the seventeenth carried 0.76 per cent BaO. The SrO ranged from 0.37 per cent in the last instance to an average of 0.06 for the other sixteen. Certain peculiar rocks from Wyoming carry from 0.62 to 1.25 per cent BaO, and from 0.02 to 0.33 per cent SrO. Surely this concentration of certain chemical elements in certain geographic zones has a significance which future geologists will be able to interpret, if those of to-day are not.

While strongly upholding the necessity for more thorough work, necessarily somewhat at the expense of quantity, it is far from the writer's intention to demand that an amount of time altogether disproportionate to the immediate objects to be sought should be expended on every analysis. But it is maintained that in general the constituents which are likely to be present in sufficient amount to admit of determination in the weight of sample usually taken for analysis—say 1 gram for SiO_2 , Al_2O_3 , etc., to 2 grams for certain other constituents—should be sought for, qualitatively at least, in the ordinary course of quantitative work, and their presence or absence noted among the results. If present in little more than traces, that knowledge alone may suffice, for it is often more important to know whether or not an element is present than to be able to say that it is there in amount of exactly 0.02 or 0.06 per cent. In the tabulation of analyses a special note should be made in case of intentional or accidental neglect to look for substances which it is known are likely to be present. Failure to do this may subject the analyst to unfavorable criticism, when at some future time his work is reviewed and the omissions are discovered by new analyses.

Finally, whenever possible, a thorough microscopical examination of the rock in thin section should precede the chemical analysis. This may be of the greatest aid to the chemist in indicating the presence of

unusual constituents, or of more than customary amounts of certain constituents, whereby, possibly, necessary modifications in the analytical procedure may be employed without waste of time or labor.¹

SCOPE OF THE PRESENT PAPER.

The literature relating to analysis of silicates is extensive, but scattered; and the scheme given by Fresenius in his *Quantitative Analysis* answers well for the ordinary separations and is probably almost universally followed in all its essential features; but in no single article, to the writer's knowledge, is there to be found an exposition of the methods to be followed or the precautions to be observed in the search for some of the rarer constituents or those which, without being rare, have been of late years recognized as occurring persistently in small amounts. It is not the object of the writer to make this paper a treatise on mineral analysis; but it is believed that the experience gained by the chemists of this survey during the sixteen years since the establishment of its first chemical laboratory in Denver may be useful to most chemists interested in mineral and especially rock analysis. Lengthy descriptions of details of manipulation will be avoided so far as possible, and in general only an outline will be presented of the methods followed or recommended, since in the main they are familiar to all or easily accessible; but stress will be laid on those points meriting particular attention, and now and then a brief discussion of alternative methods may be attempted.

In the earlier years of the existence of the Washington laboratory opportunity was afforded for the testing of novel methods and the devising of new ones, with most excellent results, as shown especially by the methods for separation of titanium, of lithium, and of boron, due to Prof. F. A. Gooch, to whose inventive skill chemists owe likewise the perforated filtering crucible and the tubulated platinum crucible arrangement for the estimation of water. Of late years the press of routine work has been such as to fully fill up the time of the much-reduced chemical force, and as a consequence it has been found impossible to subject to critical trial several separation methods of recent origin, some of which seem to be full of promise, or to follow out certain lines of investigation which have been suggested by the observations made in this laboratory, one, at least, of which seems to be of high importance. This, then, must be offered in explanation if, in the following discussion, it may seem to some that any of the methods followed are too conservative or not sufficiently up to date. In general the discussion will be confined strictly to such separations as may be required in the analysis of an igneous, metamorphic, or sedimentary

¹ The foregoing tables and accompanying remarks, including several sentences preceding the tables, have been largely taken from the writer's paper entitled, "A plea for greater completeness in chemical rock analysis," published in the *Journal of the American Chemical Society*, Vol. XVI, pp. 90-93 1894; also in the *Chemical News*, Vol. LXIX, p. 163, 1894.

silicate rock of complex mineralogical composition, in which the majority of and possibly all the ingredients in the list given below may occur in weighable or readily discoverable quantities:

SiO ₂	TiO ₂	ZrO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO
NiO	CoO*	CuO	MnO	CaO	SrO	BaO
MgO	K ₂ O	Na ₂ O	Li ₂ O	H ₂ O	CO ₂	C†
SO ₃	S*	N.	Fl	Cl		

The special problems often arising in the analysis of rocks of extra-terrestrial origin—the more or less stony meteorites—will not be considered in this paper. An analysis of that kind should never be entrusted to the novice, but only to the chemist who has a knowledge of the composition and properties of the peculiar mineral constituents of those bodies, and a judgment fit to cope with the oftentimes difficult problems presented by them.

Thorium, cerium, and other rare earths are seldom encountered in quantities sufficient to warrant the expenditure of the time necessary for their isolation. A search for them qualitatively, even, is at present rarely justifiable unless there is microscopic or other evidence of the presence of minerals likely to contain them. Vanadium, tantalum, columbium, boron, and glucinum have never been certainly met with in the writer's experience, and yet they must be present in certain rocks, and doubtless traces have been overlooked at times. There is no reason to suppose that other elements may not be found by careful search, possibly all in the known category, and, indeed, Sandberger's researches have shown to what an extent this is true of a large number of those elements contributing to the filling of metalliferous veins. But those in the above list may usually be estimated with ease in weights of from one-half to 2 grams.

If the point be raised that many of the published analyses emanating from the Survey laboratories, even the earlier ones of the writer, are not in accord with the advocacy of completeness contained in the foregoing pages, it may be remarked that these ideas have been to a considerable degree evolved during a personal experience of sixteen years in this line of work, and that frequently the exigencies were such as to compel restriction in the examination. Where the latter has been the case subsequent developments have in some cases shown it to be bad policy in every respect. It is better, both for the geologist and the chemist, to turn out a limited amount of thorough work than a great deal of what may prove to be of more than doubtful utility in the end.

In this connection the question has often been put, "How long does it take to complete an analysis of this kind?" This will depend, of course, on the mineral complexity of the sample and on the personal factor of the individual worker. If there is a competent assistant to do the grinding, and specific-gravity determinations are not required,

* Usually as pyrite, not infrequently as pyrrhotite.

† As graphite or coal matter.

it is quite possible after long experience for a quick worker to learn to so economize every moment of time in a working day of seven hours, with an abundance of platinum utensils and continuous use of air and water baths through the night, as to finish every three days, after the completion of the first analysis, barring accidents and delays, one of a series of rocks of generally similar character, each containing from eighteen to twenty quantitatively determinable constituents, excluding, for instance, fluorine, carbon as such, nitrogen, metals of the hydrogen sulphide group, and cobalt. On one occasion a series of fourteen rocks, of comparatively simple composition, was completed in one month, with the help of an assistant who made the phosphorus and ferrous iron determinations. But such an output of work is more than exceptional and implies an unusual freedom from those occasional setbacks to which every chemist is exposed.

PART II.—DISCUSSION OF METHODS.

PREPARATION OF SAMPLE.

Although foreign to the above heading, a few words relative to the sample itself may be here appropriately inserted by way of introduction. In the great majority of cases a few chips from a hand specimen will well represent the average of the mass, but with rocks in which a porphyritic structure is strongly developed the case is different. Here a large sample should be provided, gauged according to the size of the crystals, and the whole of this should be crushed and quartered down for the final sample. Unless this is done, it is manifest that the analysis may represent anything but the true average composition of the rock.

Crushing.—Mechanical appliances for reducing samples to fine powder are much in use in technical laboratories, where they answer their purpose more or less admirably, and something similar is needed in those scientific laboratories where rock analysis is of daily occurrence and many samples must be reduced to fine powder in a short space of time. For accurate analyses the use of steel crushers and mortars is out of the question, because of the danger of contamination by particles of metal and the impossibility of cleansing the roughened surfaces after they have been in use a short time. Extraction of steel particles from the powder by aid of a magnet is quite inadmissible, since the rocks themselves, almost without exception, contain magnetic minerals. The method of rough crushing found to be most satisfactory in practice is to place each fragment as received on a hardened steel plate about $4\frac{1}{2}$ cm. thick and 10 cm. square, on which is likewise placed a steel ring 2 cm. high and of about 6 cm. inner diameter, to prevent undue flying of fragments when broken by a hardened hammer. In this way a considerable sample can soon be sufficiently reduced for transfer to the agate grinding mortar with a minimum of metallic contamination.

Grinding.—Of the various grinding arrangements on the market purporting to fulfill their purpose few, if any, observed have met the conditions required by the work in hand. Either the mechanical arrangement is complicated or cumbersome, requiring more power or space than is usually at disposal or causing too much noise, or thorough cleansing is difficult and troublesome, or there is likelihood of contamination from oil or grease or lack of facility for the removal of all powder from the mortar. These last defects are especially prominent in those forms in which the mortar is fixed in its setting.

All rock samples have therefore been reduced to powder by hand, involving a great expenditure of time and labor. Ordinarily an extremely fine state of division is unnecessary, except in the case of those portions in which alkalis and ferrous iron are to be estimated or where soluble constituents are to be removed by acids, etc., and in such cases the final grinding can be done at the balance table on a small portion slightly in excess of the quantity to be weighed off.

The process of sifting through fine cloth, the German "beuteln," is one not always to be commended, because of the time required and, more especially, because of the certainty of contamination by cloth fiber, which in the ferrous-iron portion might affect the result. Still less should metal sieves be used.

Weight of ground sample.—The sample when ground should weigh not less than 10 grams, and preferably 20 in case it should be necessary to repeat or advisable to employ unusually large portions for certain determinations, notably carbonic acid. Rock analysis has in this respect an advantage over mineral analysis, since material is almost always available in ample quantity and any desired number of separate portions may be used, whereas with a mineral the analyst is frequently compelled to determine many or all constituents in a single, often very small, portion of the powder. This course often involves delay and the employment of more complicated methods of separation than are usually necessary in rock analysis.

SPECIFIC GRAVITY.

By suspension in water.—This determination, when required, is best made upon one or several fragments weighing up to 20 grams. They are held together by a fine platinum wire ready for suspension from the balance, and thus held are placed in a small beaker to soak overnight in distilled water under the exhausted receiver of an air pump, side by side with a similar beaker of water. Boiling is of course a much less effective means of removing air than the air pump, and the boiling water may exert an undesirable solvent and abrading effect. In the morning the wire is attached to the balance arm, the rock fragments remaining immersed in the water; a thermometer is placed in the companion beaker of water, now likewise in the balance case, and the weight

is at once taken. Both vessels of water having precisely the same temperature, it is quite unnecessary to wait for the water to assume that of the balance should it not already possess it. The fragments are now lifted out, without touching the vessel, and carefully transferred to a tared crucible or dish; the wire is removed and at once reweighed, with the precaution that it dips just as far into the water now as when weighted. Hereby a special weighing of the wire out of water is avoided. The sample may now be dried on the water bath and then at 110° C. for some hours to certainly expel all absorbed water, and weighed after prolonged cooling in the desiccator. It is better to ascertain the weight of the dry rock after soaking in water than before in order to avoid the error due to possible breaking off of a few grains between the two weighings. Should the density of the rock in air-dry condition be required,¹ it may be left exposed to the air for a lengthy period after drying and before weighing; but the difference will only in exceptional cases affect the second decimal by more than a single unit. For instance, a rock of 2.79 specific gravity when dry will, if carrying the high percentage of 0.3 per cent hygroscopic moisture in the uncrushed state, have a density of 2.775; a rock of 3.00 specific gravity dry will have a density of 2.982 if 0.3 per cent of moisture is included.

Reasons for preferring suspension to pycnometer methods.—This method of ascertaining the specific gravity of rocks is certainly more convenient than, and for compact rocks is believed to be decidedly preferable to, that of the pycnometer, in which the fragments must be reduced to small size with consequent formation of more or less powder, which is subject to slight loss in the various manipulations. To exclude this powder and employ only small fragments would introduce a possible source of error, since it is apt to consist largely of the most easily abraded minerals and consequently not to have the average composition of the mass. By following the instructions given above, loss of material is absolutely avoided, a decided saving in time is effected, and considerable weights can be easily employed with consequent lower probable error in the results. To vesicular rocks, however, notably certain lavas, the above procedure is of course inapplicable, unless the datum is desired for certain considerations in which the relative density of large rock masses as they occur in nature is sought, as for the comparison of building stones or the calculation of large known or assumed areas of particular rocks.

Pycnometer methods.—If the pycnometer has to be used, as is generally the case when the density of any one of the mineral ingredients of

¹In view of the uncertainty as to what constitutes hygroscopic water (see p. 29), this course is perhaps more to be commended than the former, and seems imperative for certain zeolitic rocks. In such cases it is best to weigh the fragments before putting to soak, and afterward to collect on a Gooch crucible the grains which may have fallen off in the water. Should no crucible of this kind be available, a paper filter may unhesitatingly be used and incinerated with the powder, owing to the small amount of which the error due to loss of even all its water during ignition is quite negligible.

a rock is desired after separation by one of the approved methods, it being then in a more or less finely divided state, the most accurate procedure is that adopted in this laboratory by Mr. L. G. Eakins a number of years ago. The pycnometer used is one with a capillary stopper, provided with a millimeter scale etched in the glass, the divisions being numbered both ways from the center and calibrated by mercury so that the value of each one in weights of water is known. The capacity of the flask filled with water to the zero division is then calculated for every half degree of temperature from 0° C. to 30° C., by making a series of careful weighings, in which, knowing the capacity of the stem, it is quite immaterial at what level the water stands provided it is within the limits of the scale. The exact temperature is secured by an accurate thermometer placed in a companion vessel of similar shape to the pycnometer and containing a like amount of water, both being left in the balance case till its temperature has been nearly or quite assumed, as shown by a second thermometer. The weighing must of course be made before the thread of water has sunk beneath the lowest division, which it will do after a time, even though at first filling the bore to the top of the stopper; and the corrected weight full of water to the zero mark is found by adding or subtracting the needed amount, as shown by the height of the thread on the scale.

For each pycnometer in use, and these are of different sizes, is prepared a table showing its weight, the value of each scale division in grams of water, and the capacity of the flask at different temperatures, as indicated above. The preparation of such a series of flasks is time saved in the end, for the weighing of the flask full of water each time a density determination is made is rendered superfluous. All that is necessary is to look up in the table the weight corresponding to the temperature.

The density of the previously weighed substance in this case is now determined in much the same way, after the unstoppered pycnometer containing it and nearly filled with water has stood with its companion vessel of water under the air pump the necessary length of time. The water needed to fill the flask is taken from its companion.

All who have used the pycnometer method for fine substances know the difficulty experienced in preventing a portion from being held at the surface, despite all attempts at making it sink. Hence it often happens that a very small portion runs out around the sides of the stopper on inserting it. If the flask rests in a small tared dish the grains thus forced out may be washed down into it and weighed after evaporation in order to get the correct weight of that in the flask; or, after weighing, the contents of the flask may be emptied into a tared dish and the water slowly evaporated off in order to get the weight of the mineral. Usually this way is less to be recommended than the other.

Penfield's method for mineral fragments.—Penfield¹ recommends the following modification of the suspension method as more convenient than that by the pycnometer in many cases for small fragments of minerals.

After boiling in water, the substance is transferred with water to a small glass tube about 8 mm. by 35 mm., provided with a fine platinum wire for suspension. This is weighed full of water in another vessel of water, and again after the removal of the mineral, the weight of which is found after drying.

This method is, of course, more applicable to homogeneous minerals than to rock fragments, and will therefore be applied in rock analysis chiefly to the determination of the specific gravity of the mineral grains separated by heavy solutions or acids.

Heavy solutions not available in case of rocks.—Because of their roughness, porosity, and complex mineral composition the density of rock fragments can not be accurately determined by that of heavy solutions in which they may remain suspended.

WEIGHTS OF SAMPLE TO BE EMPLOYED FOR ANALYSIS.

With only occasional exceptions nearly all the constituents mentioned on p. 21 can be estimated, if present, in 1 gram of rock sample. This is a convenient weight to take for the main portion in which silica, alumina, etc., the alkaline earths, and magnesia are to be sought, but it should in general be a maximum, because if larger the precipitate of alumina, etc., is apt to be unwieldy. Its weight can not often be much reduced with safety if satisfactory determinations of manganese, nickel, and strontium are to be expected. For the alkali portion one-half gram is a very convenient weight. In general it may be made a rule not to use more than 2 grams for any portion which has to be fused with an alkaline carbonate, as for sulphur, fluorine, chlorine. For carbon dioxide the weight may rise to 5 grams or even more, if the amount of this constituent is very small, without expenditure of any more time than is required by 1 gram, and with correspondingly greater approach to correctness in the result.

WATER—HYGROSCOPIC.

Importance of not drying before weighing.—The time-honored custom of drying a powdered specimen before bottling and weighing has long seemed to the writer one that has no sound basis in reason. Its object is of course plain, namely, that of securing a uniform hygroscopic condition as a basis for convenient comparison of analytical results, since some rocks contain more hygroscopic moisture than others. Nothing, however, is more certain than that by the time the substance is weighed it has reabsorbed a certain amount of moisture, small, indeed, in most

¹ Am. Jour. Sci., 3d series, Vol. L, p. 448, 1895.

cases, but very appreciable in others; and further, with every opening of the tube moisture-laden air enters and is inclosed with the remainder of the dry powder. It therefore may very well happen that a powder at first dry will, after several openings of the tube, especially at considerable intervals, be nearly as moist as when first inclosed.

It is preferable to weigh the air-dry powder and to make a special determination of moisture at 100° or 110° C. If all the portions necessary for an analysis are weighed out one after another, or even at different times on the same day, the error due to difference of hygroscopicity in dry and moist weather, which for most of the separate portions is an entirely negligible quantity, is eliminated. Only in the main portion, in which silica and the majority of the bases are to be estimated, can it ever be an appreciable factor.

Temperature of drying.—As to the temperature to be adopted for drying in order to determine so-called hygroscopic moisture, the practice has varied at different times and with different workers, ranging from 100° to 110° C. For the great majority of rock specimens it is quite immaterial which of these temperatures is adopted, since no greater loss is experienced at the higher than at the lower temperature, given a sufficient time for the latter. Since the drying is accomplished more rapidly at 110° than at 100° , it is the present practice in this laboratory to employ the higher temperature. Should the results show a very unusually high loss, the powder is reheated at, say, 125° , in order to learn if the loss is progressive with increased temperature. In the affirmative case it may be well to repeat the drying at 100° , for a portion of the loss at 110° was probably due to combined water from a mineral or minerals in the rock; but in that case even the loss at 100° may sometimes very well include combined water, and a further drying over sulphuric acid alone may be desirable, or over dry sand.

Cautionary hints.—In this latter connection it is proper to point out certain pitfalls in the path of the unwary, which, however, are far more apt to be encountered in the analysis of minerals, where their influence may be of far-reaching consequence.

A mineral which loses a great deal of water over sulphuric acid—2 or 3 per cent, for instance—may need an exposure of several days or even weeks for its complete extraction. If the weighings are made from day to day, the apparent limit may be reached long before all water really removable has been taken up by the acid. Whenever the crucible, after weighing, is replaced in the desiccator, it is no longer in a dry, but a more or less moist atmosphere, and its contents, even when covered, sometimes absorb a part of this moisture and retain it so persistently that the acid is unable to bring the powder beyond its previous state of dryness in the next twenty-four hours. In fact, it may be unable even to reach it unless greater time is allowed. An experiment on 1 gram of tyrolite, made and published some years ago, seems to illustrate this point in part.

Hours exposed.	Loss.	Hours exposed.	Loss.
	<i>Gram.</i>		<i>Gram.</i>
18	.0231	24	.0002
26	.0083	24	.0003
23	.0029	48	.0006
24	.0012	24	.0002
23	.0008		
24	.0001	283	.0380
25	.0003		

The experiment might reasonably have been considered ended after the one hundred and fifty-eighth hour, when a loss of but 0.1 milligram was shown during twenty-four hours; but nevertheless a nearly steady loss of 0.3 milligram per day took place for six days more, and might have been longer observed but for the interruption of the experiment.

Again, it is sometimes desirable to determine the water given off by hydrous minerals in an air bath at temperatures far above 100° C. To insure accuracy this experiment should not be made in crucibles or dishes which must be cooled in a desiccator. One instance will suffice: A gram of a mineral mixture containing about 17 per cent of water, of which about 3 per cent was driven off at 100° and 8 or 9 per cent at 280° , was, after several hours' heating, placed in a desiccator over sulphuric acid and weighed as soon as cold, then replaced and again weighed the next day. It had gained $1\frac{1}{2}$ per cent of its original weight, although the desiccator was tightly closed and the crucible covered, showing apparently a drying power superior to that of the acid.

A specimen of tyrolite was found on one occasion to lose 10.34 per cent at 280° C., and on another occasion 14.33 per cent. In the latter case the drying and heating at progressive temperatures had continued during a period of 528 hours, the weighings being made usually from day to day; whereas in the former the duration of the experiment was much shorter and the intervals between weighings were but a few hours each.

Procedure in special cases.—For experiments of this nature the powder should be heated in a weighed tube, through which a current of dry air can be passed, and allowed to cool therein, or else the water given off should be collected and directly weighed in suitable absorption tubes,¹ even though the long time often required is an objection to this latter method, since the absorption tube may gain weight, other than that of the water from the mineral, sufficient to introduce an appreciable error.

The recent important research of Friedel² well shows what errors are

¹Jannasch and Locke, Zeitschr. für anorg. Chemie, Vol. VI, p. 174, 1894, describe and depict a form of apparatus adapted for either method of ascertaining hygroscopic water.

²Bull. Soc. Min., Vol. XIX, pp. 14, 94, 1896; Comptes Rendus, Vol. CXXII, p. 1006, 1896.

possible in the determination of this easily removable water, since he found that certain zeolites which had been largely dehydrated but not heated to the point of rupture of the molecular net, could then absorb, instead of water, various dry gases in which they might be placed, as carbon dioxide, ammonia, carbon disulphide, and others, even air in large quantities, and certain liquids. In the light of this observation the cause of the great increase of $1\frac{1}{2}$ per cent in weight of the partially dehydrated mineral mentioned on p. 28 may very possibly be attributed to air from the desiccator instead of moisture, as was at the time supposed. At any rate, as Friedel says, the danger of accepting a loss in weight as an index of the amount of water lost is clearly shown, and thus that method of determining water is for many cases fully discredited. Just what method to adopt must be largely left to the judgment of the operator, who will often be guided by the mineral composition of the rock as revealed by the unaided eye or the microscope.

Friedel (loc. cit.) indicates a means for determining the true weight of water lost by minerals behaving like the zeolites, even without collecting the water lost, namely, by driving out of the dehydrated and weighed mineral, under proper precautions, any air it may have absorbed in the process of drying and cooling, and collecting and measuring this air and thus finding its weight, which, added to the apparent loss, gives the true contents in water.

Argument in favor of including hygroscopic water in summation.—The question has been asked: "If the so-called hygroscopic water is not always such, but not infrequently includes combined water, why is not its determination and separate entry in the analysis entirely unnecessary? Why make a distinction which, after all, may not be a true one?" The question involves the further consideration of the advisability of including in the analysis at all the loss at 100° or 110° C. Many petrographers desire to have all analyses referred to a moisture-free basis, in order that they shall be strictly comparable, and therefore would omit the "hygroscopic" water from the list of constituents. This would be eminently proper were it always possible to be sure that the loss at 100° truly represents mechanically held water. Since it very often represents more, and the determination as to whether or not it does in each case is not always possible, and would add to the time required for the analysis, it seems necessary to include this water. What errors may arise from its exclusion the following rather extreme case well illustrates: Certain rocks of Wyoming in powder form lost from 1 to 2 per cent of moisture at 110° . That not even an appreciable fraction of this was truly hygroscopic the fact of the uncrushed rocks losing the same amount fully demonstrates; yet the rule followed by many chemists and petrographers would have involved the removal of all this water as a preliminary to beginning the analysis, and not only would a most important characteristic have passed unnoticed, but the analyst would have reported an incorrect analysis, inviting to false conclusions and possibly serious confusion.

Separate entry of hygroscopic and combined water.—To revert now to the primary question, it may be said that the estimation of the loss at 100° or 110° C. and its separate entry in the analysis is advisable as not infrequently affording at once to the lithologist an indication of the mineral character of one or more of the rock constituents, thus perhaps confirming the microscopical evidence or suggesting further examination in that line. An unusually high loss at 100° would be regarded as probable evidence of the presence of zeolites or other minerals carrying loosely combined water. It has been objected that the true hygroscopic moisture varies with the degree of comminution of the sample and with the condition of the air at the time of weighing, and that it is therefore improper to incorporate it in the analysis; but this variation is ordinarily not at all great. Perhaps the time may come when it will be the rule to ascertain by additional heating at a higher temperature whether the water lost at 100° is to be regarded as purely hygroscopic. In such case it would be proper to omit it, and a distinct advance would undoubtedly be scored.

Is all true hygroscopic water expelled at 100°?—It has been tacitly assumed in the foregoing that true hygroscopic water can all be expelled at 100°, which perhaps is not to be accepted as universally true. Eminent authority holds that it is impossible, in the cases of certain foliaceous minerals, notably the micas, to thus entirely remove it, but that a part is only driven off at higher temperatures. If this is true a further uncertainty is introduced in its determination, which not only strengthens the argument in favor of entering all water in the tabulation, but also serves to emphasize the difficulties of the situation.

WATER—TOTAL OR COMBINED.

Arguments against "loss on ignition" method.—In a few cases the simple loss on ignition of a rock will give the total water with accuracy, but in the great majority there are so many possible sources of error that this old-time method can rarely be used with safety. Only when the rock is free from fluorine, chlorine, sulphur, carbon, carbon dioxide, and fixed oxidizable constituents can the loss be accepted as the true index of the amount of water present, and it is rarely that a rock is met with fulfilling these conditions, especially as to the absence of ferrous iron. Blast ignition in presence of carbon dioxide alone of the above list may give a correct result, after separate estimation of the carbon dioxide, provided this emanates from carbonates of the earths and not from those of iron or manganese. The long-maintained and still upheld idea that in presence of ferrous iron a sufficiently correct result is obtainable by adding to the observed loss an amount needed for oxidizing all ferrous iron is not justifiable. There can be no certainty that the oxidation has been complete, especially in the case of readily fusible rocks, and at the high temperature of the blast a partial reduction of higher oxides is not only possible but sometimes certain. The inability

to insure complete oxidation by simple ignition is illustrated in the case of precipitated ferric hydroxide, which has been ignited together with its filter paper. If the quantity was in any degree large it is sometimes decidedly magnetic, presumably from presence of magnetic oxide, which no amount of heating wholly oxidizes, especially in the larger grains.

Brush and Penfield's method.—Direct weighing of the water evolved is, then, imperative in most cases, and if no other volatile constituents are present the beautifully simple method first used by Prof. G. J. Brush and extended by Prof. S. L. Penfield¹ leaves nothing to be desired for accuracy. It consists simply in heating the powder in a narrow tube of hard glass, enlarged at the closed end and provided with one or two further enlargements in the middle to hold the water and prevent its running back and cracking the hot glass. A capillary glass stopper, fitted in with rubber tubing, prevents the loss of water by circulating air currents. The tube being held horizontally, the bulb is heated to any required degree, either in the blast alone or the simple combination of blast with charcoal backing used by Penfield, which gives the white heat requisite for complete expulsion of water in some cases. Moistened filter paper or cloth wound about the cooler parts of the tube insures condensation of all water. The heated end being finally pulled off, the tube is weighed after cooling and external cleansing, and again after the water has been sucked out by aspiration. For most rocks, as they contain little water, central enlargements of the tube are hardly needed.

How this simple apparatus is made to afford entirely satisfactory results, even when carbonates are present, is fully set forth in the paper cited.

Few rocks, comparatively, are altogether free from other volatile constituents; hence for refined work the application of this apparatus in the simple manner above set forth is limited. It may, however, be used with the addition of a retainer for fluorine, sulphur, etc., in the shape of calcium, lead, or bismuth oxides, or even with sodium carbonate.

In whichever way used the water found is the total water, from which that found separately at 110° C. may be deducted if desired.

Gooch's apparatus.—Of more elaborate apparatus designed to be used with fluxes the tubulated platinum crucible invented by Dr. Gooch² is capable of affording most excellent service, and it is the one by which far the larger number of water determinations in this laboratory have been made. Since its manner of use is probably not generally known, some directions may not be amiss. A detailed description of the apparatus itself would not be clear without a figure, but it may be said that the form now used differs from that figured in Gooch's paper and his subsequent slight modification of it, in that the tubes for connecting

¹Am. Jour. Sci., 3d series, Vol. XLVIII, p. 31, 1894. Zeitsch. für anorg. Chemie., Vol. VII, p. 22, 1894.

²Am. Chem. Jour., Vol. II, p. 247, 1880.

with both the drying and absorption vessels are constructed wholly of platinum instead of lead glass, the vertical one being bent horizontally at right angles for convenient attachment to the drying towers, and the side one also bent at right angles, but downward, so as to admit of insertion in the rubber stopper of a U-shaped calcium chloride tube. The length of the vertical tube, including its horizontal part from top of cap, is $13\frac{1}{2}$ cm.; that of the side tube is 12 cm. The end of the latter is drawn in slightly, so as to enter the rubber stopper of the absorption tube without scraping it. With tubes of the lengths above given there is absolutely no danger of their ends becoming hot enough by conduction to scorch or soften the rubber stopper or other connection.

The extra first cost of the platinum extension to these tubes over the lead-glass ends of Gooch's original and modified forms need hardly enter as a factor in the question of employment of this apparatus. The glass ends often break, and only a rich lead glass, not easily obtainable, can be used, since it alone will not crack at the joint with the platinum after cooling. In its present form the whole apparatus weighs approximately 88 grams.

As an adjunct to its convenient use there is needed an ordinary upright iron ring-stand, with one small sliding ring, and above this a sliding ring-burner provided with entering ducts for gas and air blast. Still above this is another small ring, across which there is an arrangement of stout platinum wire, forming at the center of the ring a secure seat for the upturned flange of the crucible proper. Both rings and burner can be clamped firmly at any height.

The rock powder, having been placed in the cylindrical crucible, is there mixed with not more than 3 or 4 grams of fully dehydrated sodium carbonate,¹ or more of lead chromate if carbon is to be likewise determined, the crucible is sunk in its seat in the upper ring, and the tubulated cap is fitted on and attached to the calcium chloride drying towers on the one side and to a sulphuric acid bulb tube on the other. Powdered sodium tungstate—free from arsenic, which would soon ruin the crucible lips—is now poured into the flanged lip in which the cap rests, and a metal vessel of cold water having been raised up by the lower ring until the platinum crucible is sufficiently immersed, the blast-fed flame of the ring burner, or that of an ordinary blast lamp, if at hand, is turned on to melt the tungstate. As soon as this is fused the flame is removed and the salt solidifies and makes an air-tight joint, the test of which is the permanence of the column of sulphuric acid in the bulb tubes caused by the contraction of the air in the platinum apparatus as it cools.

After drying by a current of air at 110° C. for a couple of hours, more or less (see below), the absorption tube is interposed between the sulphuric acid bulbs and the apparatus, being fitted to the latter by its

¹ This has been heated for a length of time to near its fusing point over a free flame or in an air bath, to decompose the bicarbonate it usually contains, and then placed in a desiccator.

stopper, which is at other times closed by a glass plug, and while a slow current of air continues to pass the gradual heating and subsequent fusion of the flux is brought about by the blast-fed sliding ring-burner. When fusion is complete, as shown in the case of sodium-carbonate flux by the decided slackening of the gas current through the safety bulbs attached to the drying tube, the flame is extinguished and a current of air is allowed to continue until the apparatus is cold.

This apparatus suffers from the drawback of being slightly permeable to combustion gases at high temperature. The defect can be overcome by causing the flame to play upon an outer ordinary platinum crucible, kept permanently filled with sodium-potassium carbonate. This protective crucible, however, is soon ruined for other purposes, being distorted by the alternate expansion and contraction of the carbonate.

It has been found that if the operation is carried out expeditiously and the final full heat applied for but a few minutes the error due to penetrating water gases is inappreciable. This hastening may be rendered safer by using rather finely powdered calcium chloride in the central section of the U-shaped absorption tube to avoid large air channels. Through this, or any apparatus based on similar principles, the air current should always be forced, not drawn. A warm blast directed upon the exit tube near its entrance into the absorption tube greatly shortens the time required and is to be recommended.

In this apparatus only the water expelled above 100° to 110° should as a rule be determined, and to effect drying of the mixed mineral powder and sodium carbonate, after luting the tubulated cap on the cylindrical crucible with sodium tungstate, the tube is sunk through a round hole in the cover into a small cylindrical air bath, which can be heated from beneath by the same ring burner which is subsequently to fuse the flux. A slow current of air is then forced through and the drying satisfactorily accomplished.

The reason why it is unsafe to attempt estimation of "hygroscopic" moisture in this apparatus is, that the luting of the two parts must be done by direct application of a flame to the tungstate, and considerable water vapor may enter the apparatus and be in part retained by the dried sodium carbonate.

Chatard's apparatus.—The platinum apparatus, devised by Dr. Chatard¹ overcomes the permeability of the metal to gases and affords sharp results; moreover permitting of determining by direct absorption not only the hygroscopic water, but that which may be driven off at any desired temperature. It is, however, more costly than the Gooch apparatus, and the supposed nonliability to injury by warping, because of the protective layer of borax and asbestos, can hardly be considered as proved.

Penfield's second method.—Simplest of all, and permitting by the use of auxiliary arrangements such as shown in Chatard's paper of deter-

¹ Am. Chem. Journ., Vol. XIII, p. 110, 1891; Bull. U. S. Geol. Survey No: 78, p. 84, 1891.

mining the hygroscopic as well as any other fraction of the water, is the glass tube arrangement described on page 37 of Dr. Penfield's article cited on page 31.

All of these apparatus, except the first-mentioned glass tube, permit of the estimation of other constituents besides water in the same portion if necessary, and by the use of lead chromate or potassium chromate instead of sodium carbonate, graphite, or the carbon of organic matter, can be simultaneously determined with the water.

To one accustomed to its use, and with a drying and suspension attachment permanently set up, the Gooch apparatus, considering its limitations above set forth, offers perhaps the most handy and convenient means for the determination of water in rocks. Its high first cost, in comparison with the glass tube, is fully made up in time by its durability.

Jannasch's methods.—That most zealous deviser of improved methods in mineral analysis, Prof. P. Jannasch, has published in the *Zeitsch. für anorg. Chemie* and the *Ber. Deutsch. chem. Gesell.*, several papers dealing with the problem of water determination in minerals besides the one already cited. Beginning with lead oxide as a flux, he subsequently experimented with lead chromate, borax, and boric acid, finding all of these to give accurate results in most cases when his directions are carefully followed, but unfortunately not capable (with the exception, perhaps, of lead chromate), like sodium carbonate, of general applicability, since with certain minerals one or the other fails to effect complete decomposition or to retain all volatile constituents. Especially for these reasons, also because the methods have not been tested in this laboratory and because Professor Jannasch is still engaged in extending the boric-acid method, their use is not at present advocated for rock analysis. Moreover the rock must be in such an impalpable powder for the boric-acid decomposition that a half to one hour has to be expended in the grinding of one gram or less—a serious consideration for the busy chemist.

SILICA, ALUMINA, ETC.

Remarks on alternative methods of decomposition.—Various fluxes other than alkaline carbonates have been recommended for breaking up silicates insoluble in ordinary acids, such as lead and bismuth oxides, lead carbonate, borax, and boric acid. Prof. P. Jannasch and his pupils have been especially active of recent years in this line of work, as evidenced by their numerous published papers. One of the advantages these fluxes possess over the alkaline carbonates is their removability after serving their purpose, thus allowing the various separations to be made more perfectly and without the annoying interference of several grams of foreign fixed salts, which are most troublesome in that part of the analysis devoted to the separation of silica, alumina, iron, lime, and magnesia.

Another of their advantages is that with some of them it is possible to estimate in one portion the alkalies, in addition to those constituents usually determined in the silica portion. Where the material is limited, as it so often is in mineral analysis, this is a most important advantage, sufficient to outweigh all possible objections; but in rock analysis, where the supply of material is usually ample, it is rarely worth considering. A still further point in their favor is that it is probably more easy to obtain them entirely free from fixed impurities than an alkaline carbonate.

There are, however, objections to their use. With some of them an extraordinary amount of time must be devoted to grinding the mineral to an impalpable powder, and the flux itself may need considerable hand pulverization. Once introduced, they must be removed before the analysis can be proceeded with, and this removal takes much time and is always a possible source of error. The expulsion of boric acid and drying of the silica in the recent method of Jannasch and Heidenreich,¹ from their own account, requires the almost constant supervision of the chemist for several hours. In mineral analysis these objections are entitled to far less weight than in rock analysis, since the object sought—usually the deduction of a formula—warrants the expenditure of much time and painstaking care. Finally, it has been found that one or more of these fluxes are not available for altogether general use, since certain minerals do not fully succumb to their attack, as andalusite with boric acid and others with lead oxide (Jannasch). Therefore, however well adapted one or the other of these methods may be for the analysis of homogeneous minerals, it is very improbable that the vivid anticipations of Professor Jannasch,² to the effect that the boric-acid method will soon supersede the alkaline-carbonate-fusion method in rock as well as mineral analysis, will be speedily realized. Nor can the great saving in time of 50 per cent which is claimed be for a moment admitted. It may be that a chemist attending to only one analysis at a time will finish it somewhat sooner by following Professor Jannasch's procedure than the one here outlined; but it is quite possible, as intimated on page 22, for two, or even sometimes portions of three, analyses to be carried on in different stages of completion at the same time by the methods herein set forth.

The practice of separating alumina, etc., by the usual methods, after first attacking the rock powder by hydrofluoric and sulphuric acids—silica being estimated in a separate portion—while attractive in principle, was abandoned by the writer after fair trial, owing to the disturbance sometimes occasioned by incomplete expulsion of fluorine and to a less degree by the presence of sulphates instead of chlorides. With exception of the comparatively few analyses made thus, the sodium-carbonate method has always been employed. In the case of rocks rich in fluorine strict accuracy would require the separation of silica

¹ *Zeitsch. für anorg. Chemie*, Vol. XII, p. 208, 1896.

² *Loc. cit.*, p. 219.

to be made as in the Berzelian method for fluorine estimation, but in practice it is hardly ever necessary to resort to this tedious procedure, since the amount of fluorine is usually small and it can by no possibility cause a loss of much more than three-fourths its own weight of silica by volatilization as silicon fluoride when the sodium-carbonate fusion is evaporated directly with hydrochloric acid. Probably the loss is less, since some fluorine perhaps escapes as hydrofluoric acid. However this may be, the error is of comparatively slight importance, since it attaches to the constituent always present in greatest amount.

Purity of the sodium carbonate used as a flux.—Notwithstanding the most earnest efforts for years, it has been impossible to procure, either in the open market or by special arrangement with manufacturers, an article of sodium carbonate which can be called chemically pure. With special precautions small lots can be prepared in the laboratory that will contain less than 1 milligram total impurity in 10 grams; but such an article can not be purchased in the market, and rarely will the so-called chemically pure dry sodium carbonate contain as little as 1 milligram in 10 grams. The invariable contamination, aside from sand and straw, which have sometimes been found in large amount, is silica, alumina, iron, lime, and magnesia, all of these going into aqueous solution with the carbonate. The chief of these impurities are usually silica, alumina, and lime. An article of the above degree of purity is satisfactory in almost all imaginable cases, since the use of the usually extravagant amount of 10 grams for a fusion would introduce an error of but 0.1 per cent in the analysis, supposing 1 gram of mineral to be operated on. This error is undoubtedly fully equaled by the introduction of dust from the air in the various long evaporations.

Precautions in fusing.—Special directions with regard to the fusion and its first treatment are unnecessary, except to say that the flame should not be directed vertically against the bottom of the crucible, but at an angle against the side and bottom, nor should the flame be allowed to envelop the whole crucible. These precautions apply in all ignitions of reducible substances, and yet they are rarely observed. In neither case, if neglected, will there be the necessary oxidizing atmosphere within the crucible; on the contrary, reduction may occur fraught with serious consequences. This is especially true if the rock contains more than traces of pyrite or other sulphide, when, after cleansing and igniting the crucible, there may appear on its interior a darkening due to oxidation of reduced iron which had alloyed with the platinum. This may in exceptional cases amount to several milligrams in weight, and can be removed only by repeated ignitions, followed each time by scouring or treatment with hydrochloric acid. In order to avoid the use of niter in case of pyritiferous rocks, it is well to first roast the weighed powder in the crucible in which the fusion is to be made.

It sometimes happens that the cooled flux, and even its solution,

will indicate absence of manganese when it is really present in quantity to give normally a strong coloration. Two fusions made side by side or successively, under apparently similar conditions, may in one case show little or no manganese; in the other considerable. This observation has been frequently made, and therefore the absence of a bluish-green color in the fusion is not to be taken as proof of the absence of manganese. This difference of behavior I can ascribe to no other cause than that of a reducing atmosphere in one of the crucibles and an oxidizing one in the other, even though the conditions were apparently alike.

Drying and testing of silica.—As to the best way of rendering silica insoluble by evaporation, my own predilection is for a double evaporation instead of a single one on the water bath. By fusing with sodium carbonate in the forenoon, the silica is ready for the first filtration in the afternoon. It is quite unnecessary to carry the evaporation beyond approximate dryness. The filtrate is again evaporated, always in platinum, and is ready for final filtration the following morning, when approximately 1 per cent of silica is recovered and added to the main portion. My experience is that a better separation of silica is effected hereby, and in no more time than by a single long evaporation. That which is subsequently recovered from the ammonia precipitate rarely exceeds a half or, at the most, 1 milligram.

Drying in an air bath at 110° C. or higher, or on a hot plate or sand bath, or over a free flame, in order to render silica insoluble, offers no advantage unless much magnesium is present, and then the most favorable temperature, according to Gilbert,¹ is 120° C. The presence of much calcium chloride seems to facilitate dehydration of the silica, while magnesium chloride above 120° C., by decomposing, forms a silicate which dissolves in hydrochloric acid and increases the amount of silica carried into the filtrate. It does not appear from Gilbert's paper that the blast-furnace slags, on which he experimented, contained titanium, phosphorus, or iron in appreciable amounts. Basic magnesian rocks usually do, and in such cases it is doubtful if the employment of a drying temperature of 120° would not materially add to the large impurity always to be expected with the silica. In other cases he confirms the earlier belief that drying temperatures higher than that of the water bath increase the amount of insoluble impurity, chiefly alumina, in the silica, and that this amount can not be reduced by long digestion with hydrochloric acid. Further, he confirms Lindo's statement that evaporation with sulphuric acid till the appearance of white fumes gives a higher result in silica than with hydrochloric acid. But for general rock analysis the use of sulphuric acid at this stage must be rejected utterly.

Blasting for twenty to thirty minutes is necessary to expel all moist-

¹Technology Quarterly, Vol. III, p. 61, 1890. Abstract in Fresenius's Zeitschr. für anal. Chemie, Vol. XXIX, p. 688, 1890.

ure from the silica. Its weight should always be corrected for impurities, which are never absent, by evaporating with hydrofluoric and sulphuric acids and again blasting. If toward the end of evaporation with these acids, when the hydrofluoric acid has been driven off and the sulphates begin to appear in solid form, the residue has a peculiar milky or enamel-like appearance, it may be taken as evidence of much phosphorus and titanium.¹ This appearance is so unusual and striking that it is worth while calling attention to it. With basic rocks very rich in titanium and phosphorus the residue may amount to 2 or even 3 per cent of the rock.

The subsequent precipitate of alumina, etc., is usually ignited in the crucible containing the residue from the silica.

It might be supposed that this residue would contain most of the barium of those rocks carrying that element together with sulphur or sulphates, but the reverse is true as a rule. Only when there is a considerable excess of SO_3 over the BaO will much of the latter be found there, and usually there is none at all. Should some be present, its removal and estimation at this stage is not necessary, as it can be more conveniently recovered later, together with the silica accompanying the alumina, etc., precipitate.

The separation of silica in rocks containing fluorine has been touched upon in commenting on the sodium carbonate method of fusion (p. 35).

Platinum in filtrates.—The filtrates from the silica always contain notable amounts of platinum. This arises in very small degree from the crucible fusion, in a larger one from the action of hydrochloric acid on manganate and permanganate, sometimes chromate of sodium, and, if much iron is present, in no small degree from the reduction of ferric chloride to ferrous by the platinum of the dish. This reaction is little known, apparently, but is mentioned in Gmelin-Kraut² and can be readily demonstrated by evaporation of ferric chloride in platinum.

Metals of the hydrogen sulphide group.—The presence in appreciable amounts of metals precipitable by hydrogen sulphide, except perhaps copper, is of such infrequent occurrence in most rocks that discussion is unnecessary in their connection. In case it is necessary to precipitate them, however, it is always well to bear in mind that some titanium may be thrown down along with them. Separations of the silica should be made in porcelain, to eliminate platinum, or, better still, the quantitative estimation of any of these metals should be made in a separate portion of the rock broken up by the action of hydrofluoric and sulphuric acids.

Alumina, etc.—The removal of platinum from the filtrates before precipitating alumina and iron is quite unnecessary, and to do so would involve the reoxidation of all iron and subsequent boiling to remove

¹It is possible that this appearance is caused by zirconium with the phosphorus and titanium. (See p. 40, footnote.)

²Anorg. Chem., Vol. III, p. 359. Sixth revised edition.

or destroy the excess of oxidizing agent, together with the waste of much valuable time. The iron is already oxidized by the fusion, and needs no further help in that direction.

Two precipitations by ammonia are usually quite sufficient to separate iron, alumina, phosphoric acid, chromium, titanium, and zirconium, if all these are present, from nickel, manganese, the alkaline earths, and magnesium, provided ammoniacal salts are present in sufficient quantity. This last point is of special importance as regards magnesium, and failure to observe it is doubtless the reason why many old analyses and sometimes modern ones show utterly improbable percentages of alumina, especially as chemists were formerly often satisfied with a single precipitation. The necessary ammonium chloride is better obtained by the use of purified ammonia water and hydrochloric acid than by the addition of the solid salt, which is seldom pure.

Manganese not always separated by ammonia.—But it will occasionally happen that the separation from even very small amounts of manganese is altogether incomplete, and the uncertainty of insuring this separation has led the writer of late to employ the basic acetate method for the first precipitation in all cases where manganese is present—and the exceptions are few—even though the precipitation of alumina is sometimes less complete than by ammonia.¹ Not more than 2, or at most 3, grams of sodium acetate need be used. After slight washing the precipitate is redissolved in a sufficient excess of hydrochloric acid and reprecipitated by ammonia in slight excess. The complete boiling off of this excess is unnecessary, as pointed out by Genth and Penfield, since it is apparently the washing with pure water and not the free ammonia which carries small amounts of alumina into the filtrate. Penfield and Harper² recommend washing with a dilute solution of ammonium nitrate (20 c. c. nitric acid, neutralized by ammonia, to the liter), and also the solution of the first precipitate in nitric instead of hydrochloric acid, in order to shorten the washing, there being no chloride to remove.

The filtrates are strongly concentrated separately³ in platinum, a drop or two of ammonia being added toward the end to the second one, and filtered successively through the same small filter into a flask of 150 to 200 c. c. capacity, the ammoniacal filtrate serving as wash water for the first dish and containing enough ammoniacal salt to prevent precipita-

¹The fact must not be overlooked that certain of the rare earths may pass completely into the filtrate if the basic acetate method is followed. If then, later, on rendering the combined filtrates ammonical, an unexpectedly large precipitate appears, this should be carefully examined as to its nature. In an analysis of piedmontite from Maryland over 2 per cent of rare earths, including cerium and others not identified, were quantitatively separated in this way from iron, alumina, etc.

²Am. Jour. Sci., 3d series, Vol. XXXII, p. 112, 1886.

³If, instead of sodium acetate, ammonia alone has been used to precipitate alumina, etc., it has sometimes happened in the experience of others than the writer that on concentration of the first filtrate a pale straw-colored precipitate appeared which remained on the filter with the traces of alumina that may also separate, although it is slowly soluble in hot water. This is some compound of platinum, and attention is called to it here for the guidance of others who may notice it and be unaware of its character.

tion of magnesium in the first filtrate when mixed with it. If manganese has been deposited upon the surface of the dish it is removed by hydrochloric and a drop or two of sulphurous acids, which mixture is then passed hot through the filter. A reprecipitation by ammonia is then made, and the precipitate collected again on the filter and added to the main one, the filtrate passing into the flask containing the previous one. If much manganese is present, of course a second precipitation by ammonia, of the small precipitate, may be required. In these cases there is no difficulty in getting all the manganese into the filtrate.

Treatment of the alumina precipitate.—The combined alumina, etc., precipitates are ignited moist, in the paper, unless considerable iron is present, when the main one is dried, removed as far as possible from the paper, and the latter ignited separately to prevent partial reduction of a portion of the iron, which can not then be reoxidized by heating (see p. 31).

Alumina in the quantities ordinarily found can not be fully dehydrated by the full heat of the Bunsen burner. It must be blasted for five or ten minutes. If iron is present in large amount this last operation must be conducted so as to insure free access of air to the crucible (p. 36).

Estimation of silica and iron in the alumina precipitate.—The precipitate is dissolved by fusion with acid potassium sulphate, an operation which is accomplished without trouble in from two to four hours if the temperature is kept low and the acid salt has been properly made free from water and excess of acid. The melt is taken up with hot water and considerable dilute sulphuric acid, the residue collected, weighed, and corrected by hydrofluoric and sulphuric acids for silica, which, as said before, rarely amounts to 1 milligram in weight, and further examined for barium (see p. 38) by dissolving in hot, strong sulphuric acid and diluting with cold water.¹ The filtrate is reduced, hot, by hydrogen sulphide, boiled to collect the sulphur and platinum sulphide resulting from the bisulphate fusion, the hydrogen sulphide being allowed to pass for a short time after boiling.² It is then filtered³ hot into a

¹Some years ago, in a series of analyses of rocks from the Leucite Hills, in Wyoming, there was obtained at this stage, when it was customary to dissolve the melt in cold water only preliminary to precipitation of titanium by boiling the neutralized sulphuric solution in presence of sulphur dioxide, a white, more or less flocculent residue amounting to 1 to 3 per cent of the rock, which was at first taken to be a mixture of tantalic and columbic acids. Eventually it was found to consist apparently of nothing but TiO_2 and P_2O_5 , with perhaps a little ZrO_2 . By repeated fusion with acid potassium sulphate and leaching with cold water it could be gradually brought into solution. It was these rocks which furnished the most striking instance of the peculiar, milky, sulphate residues mentioned on p. 38, as derived from the ignited silica.

Knop (Zeitschr. für Kryst., Vol. X, p. 73, 1885) seems to have obtained a similar mixture in analyzing minerals from the Kaiserstuhl in Baden, but its nature was not ascertained, though suspected to be, if not silica, columbiferous titanic acid.

²It may be mentioned that the precipitation of platinum from a hot sulphate solution is far quicker and cleaner than from hydrochloric acid.

³Filtration is not necessary if only precipitated sulphur and no sulphides are in suspension, since this is without reducing action on cold permanganate solution, as Wells and Mitchell, and others before them, have pointed out. The above authors used this method of reducing ferric iron in titanic iron ores. (Jour. Am. Chem. Soc., Vol. XVII, p. 78, 1895; also Chemical News, Vol. LXXXIII, p. 123, 1896.)

flask attached to a carbonic acid apparatus, and brought to boiling to expel hydrogen sulphide. When this is fully effected the flask is cooled in water while the carbon dioxide still passes, and the solution is then titrated by potassium permanganate. The results are strictly accurate when care is taken with the reduction by hydrogen sulphide, and the method is altogether superior to that of reduction by zinc, since no foreign impurity affecting the result is introduced, and the ever-present titanium is not also reduced. If this latter element has not already been tested for, its relative amount can be conveniently ascertained by adding hydrogen peroxide to the titrated ferric solution.

Alumina found by difference.—In this laboratory titanium and phosphorus are estimated in separate portions, and likewise zirconium and chromium if present. The alumina is always found by difference after deducting their sum as oxides and the total iron as ferric oxide from the combined weights. This throws upon the alumina all errors involved in their separate determinations, but these may balance, and in any case the probable error can hardly be as high as that involved in the direct weighing of the alumina itself, considering the difficulty of effecting a satisfactory separation of it from all the other admixtures, an operation which would, moreover, immoderately extend the time required for each analysis.

Alternative method.—Should it be desirable for any reason to effect an actual further separation, this may best be done, up to a certain point, after the bisulphate fusion, by removal of the iron by ammonium sulphide in ammonium-tartrate solution, evaporation of the filtrate, ignition of the residue with sodium carbonate and nitrate, and extraction with water, whereby titanium and zirconium are left on the filter as sodium salts, and the chromium is carried into the filtrate as chromate. The further separation of Al_2O_3 and P_2O_5 from the chromium is outlined under the head of Chromium (p. 51). This is as far as the separation can well be carried, and the alumina must still be found by subtracting the P_2O_5 from the combined weights of the Al_2O_3 and P_2O_5 . The possibility of loss of some P_2O_5 by volatilization¹ during the bisulphate fusion must be borne in mind here, for if it takes place the final weight of Al_2O_3 and P_2O_5 will not contain all the P_2O_5 .

Some writers recommend dissolving the ignited alumina, etc., in hydrochloric acid, but when the precipitate has been heated over the blast, as it should be, this is very ineffective.

MANGANESE, NICKEL, COBALT, COPPER, ZINC.

Ammonia is added to the flask containing manganese, the earths, etc., and hydrogen sulphide gas is introduced, whereby manganese, nickel, copper, zinc, and a small part of the platinum from the dish are precipitated. The flask is set aside, corked, for at least twelve hours, and

¹ G. Rose speaks of such loss when volatilizing sulphuric acid in presence of phosphoric acid. *Handb. f. quant. Anal.*, Finkener edition, Vol. II, p. 575, and elsewhere.

preferably twenty-four, or even longer; the precipitate, collected and washed on a small filter with water containing ammonium chloride and sulphide, is extracted by hydrogen sulphide water acidified with one-fifth its volume of hydrochloric acid (sp. gr. 1.11), manganese and zinc, if present, going into solution.

Manganese.—The filtrate is evaporated to dryness, ammonium salts are destroyed by evaporation with a few drops of sodium carbonate solution, hydrochloric and a drop of sulphurous acids are added to decompose excess of carbonate and to dissolve precipitated manganese, and the latter is reprecipitated boiling by sodium carbonate after evaporation of the hydrochloric acid. If zinc is present it can be separated from the manganese after weighing. For the small quantities of manganese usually found the sodium carbonate method of precipitation is to be preferred to that by bromine or sodium phosphate, as equally accurate and a great time saver. No precipitations have as yet been made with hydrogen peroxide in alkaline solution, in the manner proposed by Jannasch and Cloedt,¹ but the method appears full of promise and extremely simple, affording also separation from zinc, if present, and it will be subjected to full trial at some future time.

The employment of ammonium sulphide instead of bromine for the separation of manganese from the alkaline earths and magnesia has the advantage that, by a single operation, nickel, copper, and zinc are likewise removed if present. There need be no fear of overlooking nickel or copper, for under the conditions of the precipitation they are not held in solution. Now and then a trace of alumina may be found in the precipitate, and magnesia, too, would contaminate it if ammonium salts were not present in sufficient quantity. Regard must therefore be had to these possibilities, and also to the rather remote possibility of the presence of rare earths which were not thrown out by the basic acetate precipitation (see footnote, p. 39).

Nickel, cobalt, copper.—The paper containing these is incinerated in porcelain, dissolved in a few drops of aqua regia, evaporated with hydrochloric acid, the copper and platinum thrown out warm by hydrogen sulphide, and nickel and cobalt thrown down from the ammoniacal filtrate by hydrogen sulphide. This is then rendered faintly acid by acetic acid and allowed to stand. The sulphide of nickel is simply burned and weighed as oxide, its weight being almost always very small, and then tested for cobalt in the borax bead.

It is somewhat unsafe to consider traces of copper found at this stage to belong to the rock if the evaporations have been conducted, as is usually the case, on a copper water bath, or if water has been used which has been boiled in a copper kettle, even if tinned inside. Therefore, and because of its contamination by a little platinum, it is better to determine copper in a separate portion if its presence is indicated with certainty.

¹ Zeitschr. für anorg. Chemie, Vol. X, p. 405, 1895.

CALCIUM AND STRONTIUM (BARIUM).

Precipitation and separation.—The platinum derived from the dish in the silica evaporation, except for the small portion precipitated with the manganese sulphide, is now wholly in the filtrate from the latter. Its filtration at this or any other stage is quite unnecessary; nor is the removal of ammonium chloride usually demanded, since there is no undue amount present in most cases, the first precipitation of alumina, etc., having been by sodium acetate.¹ Therefore, without destroying ammonium sulphide the calcium and strontium are thrown out by ammonium oxalate at boiling heat, the precipitate, often darkened by deposited platinum sulphide, is ignited and redissolved in hydrochloric acid, boiled with ammonia to throw out traces of alumina sometimes present and reprecipitated as before, but in a small bulk of solution. It is weighed as oxide, transferred to a small flask of 20 c. c. capacity, dissolved in nitric acid, evaporated to dryness at 150 to 160° C., and the separation of strontium from calcium effected by ether-alcohol² or amyl alcohol.³

Behavior of barium.—Barium will, after two ammonium oxalate precipitations, never be found with the ignited calcium and strontium in more than spectroscopic traces, unless originally present in excess of 3 or 4 milligrams, and very often only when in considerable excess.⁴ If present with them, however, it will be separated with the strontium by ether-alcohol or amyl alcohol, and these two must then be treated by the ammonium chromate method as prescribed by Fresenius,⁵ in order to arrive at the strontium. The barium is best estimated in a separate portion, (see Barium, p. 45).

Necessity of two precipitations by ammonium oxalate.—It may be said with regard to the separation of calcium from magnesium, that two precipitations by ammonium oxalate are essential to the attainment of correct results, not only for the complete removal of magnesium but of sodium as well, the retention of compounds of the latter element by calcium oxalate having been frequently observed here and elsewhere.

MAGNESIUM.

Platinum sulphide strongly contaminates the precipitate of magnesium phosphate in the first filtrate from the calcium oxalate, unless ammoniacal salts have been removed, as is advisable with very little magnesium; but this matters not, as it remains on the filter when the phosphate is redissolved in hydrochloric acid and added to the second

¹If two or three precipitations by ammonia alone are depended on, the second and third filtrates are evaporated rapidly to dryness and the ammonium salts removed by ignition.

²See Fresenius, *Zeitschr. für anal. Chemie*, Vol. XXXII, pp. 189, 312, 1893, for the latest improvements in this method.

³Browning, *Am. Jour. Sci.*, 3d series, Vol. XLIII, pp. 50, 314, 1892.

⁴W. F. Hillebrand, *Jour. Am. Chem. Soc.*, Vol. XVI, p. 83, 1894; *Chemical News*, Vol. LXIX, p. 147, 1894.

⁵*Zeitschr. für anal. Chemie*, Vol. XXIX, p. 428, 1890.

filtrate from calcium oxalate, where it is again precipitated. Barium phosphate will not contaminate the second precipitate unless there are notable amounts of barium in the rock, in which case it must be removed by sulphuric acid prior to the final precipitation of the magnesium. The magnesium-ammonium-phosphate may be collected in a Gooch crucible and weighed, or on a paper filter whence it may be washed into a tared crucible by nitric acid, evaporated,¹ ignited, and weighed therein as pyrophosphate. The latter way, though longer than that by the Gooch crucible, offers a certain advantage in facilitating the detection and estimation of the small amount of calcium which the magnesium always carries with it (see below), but it suffers from an objection which will appear shortly. In order to get the calcium which it carries the ignited pyrophosphate is dissolved in a few drops of hydrochloric acid, the solution is rendered just ammoniacal, the precipitate just redissolved by acetic acid, and a very small pinch of ammonium oxalate is added. In the cold solution, kept down to a few cubic centimeters in bulk, a turbidity appears shortly, which is almost invariably calcium oxalate, sometimes accompanied by magnesium oxalate. If necessary, it can be purified by re-solution and reprecipitation after ignition, and its weight, averaging one-half milligram, is then added to that of the lime already found, and subtracted as tricalcium phosphate from that of the magnesium pyrophosphate, in order to arrive at the true figure for magnesium. This separation, to be successful, must be done with care.

Now it has been often observed that the pyrophosphate obtained by evaporation with nitric acid in a platinum crucible does not always dissolve completely in hydrochloric acid after ignition, but that sometimes a white residue is left in light lumps which appear to be quite insoluble in acids. It contains no silica, but only phosphoric acid and magnesia, apparently, and is presumably a peculiar metaphosphate. The cause of its formation is probably this: In the evaporation with nitric acid magnesium nitrate and free phosphoric acid are formed, and crystallization partially takes place before the phosphoric acid has had a chance to expel the nitric acid, the consequence being that the complete molecular rearrangement, from which only pyrophosphate can result on ignition, can not take place, and the ignition product contains, in addition to pyrophosphate, other compounds, including, perhaps, metaphosphate and metaphosphoric acid. If the last, the weight found would be in error by the water retained by the metaphosphoric acid, even supposing none of the latter to be volatilized during ignition. Otherwise the weight would not differ from that of pyrophosphate alone. The uncertainty seems to be sufficient to condemn the method for accurate work, which is unfortunate, for it obviates the need of dissolving the phosphate

¹A pink color of varying intensity almost invariably becomes apparent as the mass approaches dryness, a most delicate test for the traces of manganese which always escape precipitation by ammonium sulphide or bromine.

off the felt of the Gooch crucible and subsequent concentration of the filtrate in order to look for contaminating lime.

BARIUM AND TITANIUM.

Barium.—It has been said above (p. 43) that only in very exceptional cases will barium be found with the calcium and strontium after two, or possibly three, precipitations of the latter as oxalate, since it passes into the filtrates with the magnesium, whence it may be obtained as sulphate after removal of ammoniacal salts. Addition of some alcohol insures also the recovery of traces of strontium if the rocks are very rich in it. But it is unsafe to regard the amount thus separated from the magnesium as representing the total amount of barium in the rock. It will almost always be found lower than the truth, probably for the reason that there are opportunities during the analysis for slight losses in the form of sulphate. It is best to estimate it in a separate portion, which may also serve with advantage for the estimation of titanium.

The powder is attacked by hydrofluoric and sulphuric acids, and every trace of the former then expelled by repeated evaporations with the latter. This expulsion of fluorine must be thorough, or else the titanium result will be low, and it is not always easy to effect this complete removal, though the time required seems to be in no slight degree dependent on the nature of the fluorides to be decomposed. Long after every trace of fluorine seems to be gone, the formation of a crust on the evaporating salts sometimes allows an accumulation of enough hydrofluoric acid gas to become plainly manifest to the smell on breaking the crust. Possibly fusion of the mixed sulphates and fluorides with boric acid, and removal of the latter by evaporations with methyl alcohol saturated with dry hydrochloric acid gas, as recommended by Jannasch¹ for the conversion of sulphates and possibly fluorides into soluble chlorides, would effect this expulsion of fluorine more certainly than mere evaporation with sulphuric acid; but these operations evidently require almost constant personal supervision, whereas repeated evaporations with sulphuric acid can be carried out on a radiator with almost no supervision. Moreover, the barium would have to be reprecipitated, whereas by the sulphuric-acid method it is already as sulphate.

The sulphate residue is digested for some time with dilute sulphuric acid of not less than 5 per cent strength. With acid rocks solution is very complete, but it can be made nearly so with even the most basic by transference to a small beaker and boiling. The filtrate is set aside, the residue ignited and fused with sodium carbonate, since zircon, andalusite, and a few other minerals are incompletely decomposed by hydrofluoric acid, and zircon, at least, is often present in appreciable amount. The melt is leached with water, washed, and extracted by a few drops of dilute hydrochloric acid, from which solution the barium is thrown

¹ Zeitschr. für anorg. Chemie, Vol. XII, p. 223, 1896.

out by a large excess of sulphuric acid. A single solution of the barium sulphate in concentrated sulphuric acid and reprecipitation by water suffices to remove traces of calcium which might contaminate it if the rock was one rich in calcium, and even strontium is seldom retained by it in quantity sufficient to be concerned about. Should this be the case, however, which will occur when the SrO and BaO are together in the rock in, roughly speaking, 0.2 and 0.4 per cent, respectively, the only satisfactory way is to convert the sulphates into chlorides and to apply to the mixture the ammonium-chromate method of separation (p. 43).

Barium and strontium sulphates can be brought into a condition for testing spectroscopically by reducing for a very few moments the whole or part of the precipitate on a platinum wire in the luminous tip of a Bunsen burner, and then moistening with hydrochloric acid. This should be known to everyone, but probably is not.

The procedure outlined in the foregoing paragraphs for the estimation of calcium, strontium, and barium in silicate rocks is the one which long experience has shown to be best adapted for securing the most satisfactory results with a minimum expenditure of time.¹ Even where no attempt is made to separate contaminating traces of SrO and BaO one from the other, the error is usually of no great consequence, for an absolute error of 25 per cent, even, in a substance constituting only one or two tenths per cent of a rock is ordinarily of small moment compared with the ability to certify to its presence with approximate correctness.

Separation of barium from calcium and magnesium by the method of Mar.—With such small amounts of barium as are usually found in rocks it is doubtful if Mar's² method for the separation of barium from calcium and magnesium, by the solvent action of concentrated hydrochloric acid mixed with 10 per cent of ether on the chlorides, could be conveniently applied here, although for larger amounts the method would seem to be accurate and easily executed. Moreover, it would probably not entirely remove contaminating strontium, and hence offers no advantage.

Titanium; colorimetric method.—The small hydrochloric filtrate from the barium sulphate, above mentioned, is evaporated to expulsion of the hydrochloric acid and added to the main solution containing the titanium, which is then oxidized by fluorine-free hydrogen peroxide³ and compared with a standard solution of titanium sulphate, similarly oxidized (Weller's method).⁴ Mere traces of hydrofluoric acid render the results inaccurate; hence the caution enjoined as to the first treatment of the rock powder and as to the character of the hydrogen peroxide, which, as sold in the market, often contains fluorine.

¹ For details consult W. F. Hillebrand, Jour. Am. Chem. Soc., Vol. XVI, p. 83, 1894; Chemical News, Vol. LXIX, p. 147, 1894.

² Am. Jour. Sci., 3d ser., Vol. XLIII, p. 521, 1892.

³ W. F. Hillebrand, Jour. Am. Chem. Soc., Vol. XVII, 1895; Chemical News, Vol. LXXXII, p. 158, 1895.

⁴ Ber. Deutsch. chem. Gesell., Vol. XV, p. 2593, 1882.

Dunnington¹ has pointed out the necessity for the presence of at least 5 per cent of sulphuric acid in solutions which are to be thus tested for titanium, in order, as he concludes, to prevent partial reversion to metatitanic acid, which does not give a color with hydrogen peroxide. The standard solution of titanium sulphate holding conveniently about 1 centigram TiO_2 in 10 c. c., equivalent to 1 per cent of TiO_2 in 1 gram of rock, contains, therefore, 5 per cent or more of sulphuric acid. Of this, 10 c. c. are mixed with a sufficiency of hydrogen peroxide (2 c. c. of most commercial brands is ample) and diluted to 100 c. c. in a measuring flask.

The solution to be tested, evaporated if necessary to less than 100 c. c., is now to be fully oxidized, and if the color is less intense than that of the standard, is made up to 100 c. c. with dilute sulphuric acid in a measuring flask, and mixed, otherwise in a flask of sufficient size to insure that its color shall be less intense. If rectangular cylinders are used for comparison, there should be a light box, blackened inside and provided with one ground-glass end against which the cylinders can be sunk from an opening above, the other end being open for the observer to look through. One cylinder being filled with the solution to be tested, 10 c. c. of the diluted standard are run into the other from a burette, and water is added from a second burette until there is no distinction as to color. A second and a third portion of the standard can be run in and diluted, and the mean of several determinations struck, when a simple calculation gives the percentage of TiO_2 in the rock.

If the convenient but expensive Soleil-Duboscq colorimeter is used, or the simple Nessler tubes, it is of course unnecessary to dilute the rock solution to the extent above required, should it be stronger than the standard. Experience has shown, however, that differences can not be sharply estimated in strongly colored solutions, and that the results are much more satisfactory when the color intensity is not much, if any, greater than that given by a standard of the above concentration. For the percentages of titanium found in rocks, clays, and soils, usually under 1 per cent, but rising to 2 or even 3 per cent or more occasionally, the colorimeter method gives results which are fully equal to those of the best gravimetric method, besides being a great time saver. The error introduced by iron, in consequence of the yellowish color of its sulphate solution, is practically negligible unless its percentage is very high; then either the iron must be removed prior to making the color test or, possibly better still, correction should be applied for known amounts of ferric sulphate in solutions of the requisite dilution.

The exact correction to be applied in such cases is difficult of determination because of the impossibility of matching the colors of titanium peroxide solutions with those of ferric sulphate; but tests made go to

¹Jour. Am. Chem. Soc., Vol. XIII, p. 210, 1891.

show that the coloring effect of 0.1 gram of Fe_2O_3 in 100 c. c. 5 per cent sulphuric acid solution is about equal to 0.2 milligram of TiO_2 in 100 c. c. when oxidized by hydrogen peroxide. This amounts to a correction of only 0.02 per cent on 1 gram of rock containing the unusual amount of 10 per cent Fe_2O_3 .

Gooch's method not readily applicable to rocks containing zirconium.—Prior to the adoption of this method, the excellent one of Dr. Gooch¹ was invariably used in this laboratory. Occasional inability to secure clean and complete precipitation by it was experienced, especially with a certain series of rocks rather poor in titanium. Long research showed the difficulty to be due to the presence of zirconium, which acts as a marked preventive of the precipitation of titanium by boiling in an acetic acid solution. The above rocks were found to contain up to 0.2 per cent of ZrO_2 , and this amount was able to prevent precipitation of 0.3 per cent of TiO_2 . The titanium which came down in excess of this amount did not settle out in flocculent condition, as happens when zirconium is not present, and it was difficult to filter. After the removal of the zirconium, however, no difficulty was experienced in precipitating all the titanium with the usual ease. In view of the good results obtainable by the colorimeter method in the presence, and by the Gooch method in the absence, of zirconium, it is incomprehensible that the old method of precipitation by many hours' boiling in a nearly neutral sulphate solution in presence of sulphurous acid should still find adherents in any part of the world.

Baskerville's method.—Baskerville² has proposed the separation of titanium from iron and aluminum by boiling the neutralized solution of the chlorides for a few minutes in presence of sulphurous acid. The test separations, as given by him, are sharp, and a single precipitation is said to suffice, the titanium being found free from iron and easily filterable. If it is desired to determine TiO_2 gravimetrically, this method seems admirably suited. Zirconium would probably be likewise precipitated (see p. 50), and phosphorus, perhaps, also, but this last point has not been investigated.

ZIRCONIUM.

This element is rarely looked for by chemists, though shown by the microscope to be one of the most constant rock constituents, usually in the form of zircon, in which occurrence its amount can be approximately judged of and a chemical test rendered almost unnecessary; but sometimes it occurs in other minerals, and is then unrecognizable under the microscope. It may rarely be present up to a few tenths of 1 per cent of the rock.

For its detection and estimation in such cases, or whenever a search for it seems called for, the following procedure has been devised, which

¹ Proc. Am. Acad. Arts Sci., n. s., Vol. XII, p. 435; Bull. U. S. Geol. Survey, No. 27, p. 16, 1886; Chemical News, Vol. LII, pp. 55 and 68, 1885.

² Jour. Am. Chem. Soc., Vol. XVI, p. 427, 1894.

serves, when carried out with care, to detect with certainty the merest trace—0.02 per cent, for instance—in 1 gram.

The powder is thoroughly fused with sodium carbonate, leached with water, the residue dissolved in a little hot dilute sulphuric acid, and filtered through the original filter, which is ignited, evaporated with hydrofluoric and sulphuric acids, and its solution added to the main one after filtration from any barium sulphate that may appear. To the solution, which should be in a small flask and contain not much above 1 per cent of pure sulphuric acid, is now added hydrogen peroxide to oxidize the titanium, and then a few drops of a soluble orthophosphate solution. The flask is set aside in the cold for twenty-four to forty-eight hours. If the color bleaches after a time, more hydrogen peroxide should be added. Under these circumstances the zirconium is thrown out as phosphate and collects as a flocculent precipitate, which, at this stage, is not always pure. No matter how small or insignificant, it is collected on a filter, ignited, fused with sodium carbonate, leached with water, the filter again ignited, fused with very little acid potassium sulphate, brought into solution in hot water with a few drops of dilute sulphuric acid, poured into a flask of about 20 c. c. capacity, a few drops of hydrogen peroxide and of sodium phosphate added, and the flask set aside. Titanium is now almost never present, and the zirconium appears after a time as a white flocculent precipitate, which can be collected and weighed as phosphate. For the small amounts usually met with it is safe to assume that it contains 50 per cent of ZrO_2 (51.8 by theory). If the amount is rather large, it may be fused with sodium carbonate, leached, ignited, fused with acid potassium sulphate, reprecipitated by ammonia, and weighed as ZrO_2 . Certainty as to its identity can be had by again bringing it into solution, precipitating by ammonia, dissolving in hydrochloric acid, evaporating to a drop or two, and testing with turmeric paper. With the very smallest amounts no color can be obtained by this turmeric-paper test, which, however, is readily available for as little as 1 milligram ZrO_2 , and with the proper care for as small an amount as 0.3 milligram (Dr. H. N. Stokes). No element other than thorium is ever likely to contaminate the ZrO_2 thus precipitated.

This separation of zirconium from titanium in presence of hydrogen peroxide is founded on a method by G. H. Bailey,¹ but in his experiments the precipitation was not made by addition of a phosphate but is said to be due solely to the hydrogen peroxide, the precipitate being a hydrated peroxide, Zr_2O_5 or ZrO_3 .² My own efforts to secure a precipitate in acid solutions of zirconium sulphate by hydrogen peroxide alone were unsuccessful, perhaps for lack of a sufficiently strong peroxide. The ability to obtain the zirconium free from phosphoric acid would certainly be a great improvement on the method described above.

¹ Jour Chem. Soc., Vol. XLIX, pp. 149, 481, 1886.

² Bailey, Chemical News, Vol. LX, p. 6, 1889.

Were it not for the necessity of working in a much too acid solution, the separation of zirconium could be made in the same portion in which the titanium is colorimetrically determined.

Davis¹ separates zirconium sharply from aluminum, but not from iron, by precipitation as an oxyiodate in a boiling neutralized solution of chlorides, but the method is hardly applicable for rock analysis.

Baskerville² has proposed a method for the separation of zirconium from iron and aluminum similar to his method for the separation of titanium from those elements (p. 48). It is based on the precipitability of ZrO_2 by boiling the neutralized chloride solution for two minutes in presence of sulphurous acid, and seems to be excellent. As titanium is always present and is presumably quantitatively thrown down also, the two would have to be separated by hydrogen peroxide. No tests as to the availability of the method for separating the small amounts met with in rock analysis have been made.

RARE EARTHS OTHER THAN ZIRCONIA.

For the few cases in which it may be necessary to look for rare earths other than zirconia, the following procedure is suggested as likely to prove satisfactory in many cases:

The rock powder is thoroughly decomposed by several partial evaporations with hydrofluoric acid, the fluorides of all earth metals except zirconium are collected on a platinum cone, washed with water acidulated by hydrofluoric acid, and the precipitate washed back into the dish or crucible and evaporated with enough sulphuric acid to expel all fluorine. The filter is burned and added. By careful heating the excess of sulphuric acid is removed and the sulphates are taken up by dilute hydrochloric acid. The rare earths, with perhaps some alumina, are then separated by ammonia, washed, redissolved in hydrochloric acid, and evaporated to dryness, then taken up with water and a drop of hydrochloric acid, and only enough ammonium acetate to neutralize the latter added, followed by oxalic acid. In this way as little as 0.03 per cent of rare earths have been found when working on not more than 2 grams of materials.

This method eliminates at once most of the aluminum, the iron, phosphorus, titanium, and zirconium, and has the further advantage of collecting with the earthy fluorides as UF_4 any uranous uranium that the rock might have held.

An alternative method would be to fuse with sodium carbonate, leach with water to get rid of phosphorus as far as possible, dissolve the residue in hydrochloric acid, separate silica as usual, precipitate alumina, etc., by ammonia, dissolve the precipitate again in hydrochloric acid, evaporate, and proceed as by the former method, which in most cases would undoubtedly give better results than this one.

¹ Am. Chem. Jour., Vol. XI, p. 27, 1889.

² Jour. Am. Chem. Soc., Vol. XVI, p. 475, 1894; Chemical News, Vol. LXX, p. 57, 1894.

CHROMIUM, PHOSPHORUS.

Silica is removed by hydrofluoric and sulphuric acids, excess of fluorine expelled, the residue brought into solution as far as possible with hydrochloric acid and hot water, filtered, the residue ignited, fused with sodium carbonate dissolved in hydrochloric acid, and the solution added to the main one, which is now precipitated by ammonia to get rid of the magnesium salts usually present and thus insure a cleaner subsequent fusion with sodium carbonate.

Separation of alumina and phosphoric acid.—The precipitated Al_2O_3 , P_2O_5 , Cr_2O_3 , Fe_2O_3 , and TiO_2 is dissolved in hot hydrochloric acid and filtered into a large platinum crucible, the filter burned and added, the solution evaporated to pastiness, a little water added to dissolve the salts, and dry sodium carbonate added in portions and stirred in thoroughly to prevent lumpiness in the fusion to follow, which is continued for half an hour. Addition of sodium nitrate is not necessary. The melt is boiled out with water, and to the filtrate containing all the chromium and phosphoric acid and most of the aluminum ammonium nitrate is added till no further precipitation ensues. All P_2O_5 is thus removed, but not quite all alumina. After decanting, the precipitate is washed with ammonium nitrate solution, dissolved in nitric acid, and the phosphoric acid thrown out by molybdate solution.

Chromium.—The previous filtrate is acidified, boiled, rendered ammoniacal, and hydrogen sulphide introduced or fresh ammonium sulphide added. The precipitate of alumina and chromic oxide is now treated according to Baubigny,¹ by dissolving in hot nitric acid, evaporating to near dryness, and heating with strong nitric acid and potassium chlorate, then evaporating to dryness to get rid of the acid. On dilution with cold water, acid sodium carbonate is added in slight excess, and after two or three hours the precipitated alumina is filtered off. From the filtrate the chromium is then thrown out by fresh ammonium sulphide, redissolved to remove alkali, reprecipitated, and weighed.

Probably the separation of aluminum from chromium by hydrogen peroxide in ammoniacal solution, as recommended by Jannasch and Cloedt,² would be preferable to the above if one has specially prepared hydrogen peroxide. The commercial brands are so impure that it is unsafe to employ them in most separations.

The above outline is from a paper by Dr. Chatard³ detailing a procedure devised in this laboratory for "the separation of titanium, chromium, aluminum, iron, barium, and phosphoric acid in rock analyses." If necessary, titanium, iron, and barium can be determined in the same portion, the reader being referred to the original paper for details.

¹ Bull. Soc. chimique (N. S.) Vol. XLII, p. 291, 1884; Chemical News, Vol. L, p. 18, 1885.

² Zeitschr. für anorg. Chemie, Vol. X, p. 402, 1895.

³ Am. Chem. Jour., Vol. XIII, p. 106, 1891; Bull. U. S. Geol. Survey No. 78, p. 87; Chemical News, Vol. LXIII, p. 267, 1891.

Phosphorus in rocks free from chromium.—If the rock contains no chromium the phosphorus is determined as follows: Fuse with sodium carbonate, dissolve in nitric acid, evaporate to dryness, take up with nitric acid, filter, ignite filter and treat with hydrofluoric and a drop of sulphuric acids, bring the small residue into solution by boiling with nitric acid and add to the main portion, in which, after addition of ammonium nitrate, precipitate by ammonium molybdate solution. The turbidity often observed on dissolving the precipitated phosphomolybdate in ammonia is due to a compound of phosphorus which should always be re-fused with sodium carbonate and treated as above, in order to recover the phosphorus in it, if the addition of a small fragment of a crystal of citric or tartaric acid fails to dissolve it.

It is sometimes possible to extract all phosphorus from a rock by simple digestion with nitric acid; but quite as often, if not more often, this fails, and hence the necessity for resorting to the longer method.

FERROUS IRON:

Comparison of sealed-tube and hydrofluoric-acid methods.—No point in rock analysis has been the cause of greater solicitude to the chemist, and especially to the mineralogist and petrographer, than the determination of iron in ferrous condition. The sealed-tube method with sulphuric acid, for a long time the only available one, is in theory perfect, since complete exclusion of oxygen is easily attainable. Its chief defect, however, lies in the inability to always secure complete decomposition of the iron-bearing minerals, and even to ascertain, oftentimes, whether or not the decomposition has been complete. The addition of hydrofluoric acid to the sulphuric in the tube, in order to insure this breaking up, is to be regarded as of very doubtful utility in most cases, since the glass may be so strongly attacked as to add an appreciable amount of iron to the solution, and the hydrofluoric acid may have exhausted itself in attacking the glass before the more refractory minerals succumb. Nevertheless, if decomposition can be effected by sulphuric acid alone the results obtained are sharp and concordant, and what is especially remarkable, and up to the present without a satisfactory explanation, they are in rock analyses invariably higher than when made by any of the modifications of the hydrofluoric-acid method now so extensively practiced. This difference is not very marked with rocks containing but 1 or 2 per cent of the ferrous iron, but it increases with rising percentage to such an extent that where the sealed-tube method will show 12 per cent FeO the other may indicate no more than 10 per cent. This is a fact of which the writer has long been cognizant, but it does not seem to be known to chemists or petrographers at large, and it is one well deserving of critical examination. Attempts have from time to time been made to get at a solution of the problem, but without effect. Experiments with soluble iron salts of known composition, like ferrous sulphate or ferrous ammonium sulphate, throw no light on the subject,

for both methods give the same sharp and accurate results with them. It is only when a silicate is taken that the difference appears. In titrating for ferrous iron the well-known rapid bleaching of the first permanent color—the supposed crucial test of complete oxidation—in hydrofluoric-acid solutions of silicates, even with sulphuric acid present, has been thought to be perhaps in some way connected therewith. This bleaching is so pronounced that several cubic centimeters of permanganate solution may be gradually added after the first so-called permanent coloration, without its being possible to obtain a persistent color; and yet in hydrofluoric-sulphuric solutions of ferrous salts free from silica the first coloration is persistent for a long time.

The question now arises, which of these methods gives the correct result. My own opinion is in favor of the sealed-tube method with sulphuric acid, simply for the reason that there seems no possible chance for obtaining too high results thereby. No suggestion ever advanced to account for their being too high seems tenable. It has been proved over and over again that the error is not due to iron from the glass or to impurities in the sulphuric acid; a reduction of sulphuric acid with corresponding oxidation of ferrous iron seems impossible; and yet, did it occur, the result could be in nowise affected, for the amount of permanganate needed would be the same.

Notwithstanding this predilection in favor of the tube method, the one in exclusive use in this laboratory is that by decomposition by means of hydrofluoric and sulphuric acids. The results obtained by it are at least comparable with those found by other workers, and the impossibility of being assured of complete decomposition in a sealed tube is sufficient to condemn that method for general use.

Cooke's method of decomposing by hydrofluoric and sulphuric acids.—The specially ground powder, in a capacious crucible, is placed, after stirring up with dilute sulphuric acid, on a small water bath of a single opening, and covered with a glass funnel which rests in a depression of the cover, into which water constantly drops from a tubulated bottle, thus securing a perfect water joint and serving to keep the bath full. Through a small metal pipe carbonic acid gas flows into the bath above the surface of the water, and rising through orifices in the cover fills the funnel and crucible.¹ The lamp under the bath is lighted and hydrofluoric acid is poured into the crucible through a platinum funnel, which is left in place to serve as an occasional stirrer, for which a rod or wire may be substituted. After boiling commences the rapid gas current can be safely interrupted, to be restored when the lamp is extinguished after one-half to one or more hours. A full stream of cold water is then caused to flow from the tubulated bottle into the bath, the overflow from the outlet tube being caught in a receiver. As soon as cool the contents of the crucible are emptied into a platinum dish containing cold water, and titrated till the first permanent color appears

¹J. P. Cooke, Am. Jour. Sci., 2d ser., Vol. XLIV, p. 347, 1867.

which usually will last for only a few seconds. Duplicate determinations are to be advised whenever possible, since even with the utmost care the results will occasionally differ more than is allowable.

Pratt's modification of the hydrofluoric acid method.—J. H. Pratt¹ has shown that very satisfactory ferrous iron determinations can be secured by simple boiling of the rock powder with hydrofluoric and sulphuric acids in a large crucible fitted with a cover and platinum tube for introduction of carbon dioxide. His test experiments on ferrous sulphate show that there need be practically no oxidation, even if the heating lasts several hours. The directions given in his paper (p. 150), with reference to the treatment of very refractory minerals which are not fully decomposed by this treatment, must be understood as referring only to homogeneous minerals and not to rocks, where the relations of ferrous and ferric iron in the undecomposed portion are certainly different from those in the part dissolved.

Influence of sulphides.—The presence of pyrite or marcasite is probably without serious effect on the ferrous-iron determination by any of the hydrofluoric acid methods. These sulphides are very resistant toward attack in the absence of oxygen, as is shown by the fact that if present in any quantity they can be readily recognized in the residue after titration.² In any case, it is impossible to allow for an error introduced by their possible decomposition, and the result of titration must count as ferrous iron. In the case of soluble sulphides two sources of error are introduced—that of reduction of ferric iron by hydrogen sulphide evolved, and that due to the ferrous iron which the sulphides themselves may contain, especially if pyrrhotite is present. The first of these is perhaps negligible, since most of the hydrogen sulphide would probably be expelled without reducing iron. The second is approximately measurable if it is known that pyrrhotite is the only soluble sulphide present and its amount has been ascertained by determining the hydrogen sulphide set free on boiling with hydrochloric acid in a current of carbon dioxide. In this case a correction is to be applied to the result of titration for total ferrous iron. (See also under Sulphur, p. 59.)

ALKALIES.

The Lawrence Smith method.—With the exception of a few determinations made in the early days of the Survey's existence, all alkali determinations have been made by the method of J. Lawrence Smith,³ which is far more convenient than, and fully as accurate as, the older one, in which decomposition is effected by hydrofluoric and sulphuric acids. One of its chief advantages is the entire elimination of magnesia at the start.

¹Am. Jour. Sci., 3d series, Vol. XLVIII, p. 149, 1894.

²See footnote, p. 62.

³Am. Jour. Sci., 2d series, Vol. L, p. 269, 1871; Am. Chemist, Vol. I, 1871; Annalen Chem. und Pharm., Vol. CLIX, p. 82, 1871.

The ammonium chloride used must be purified, preferably by sublimation, or by neutralizing pure ammonia by pure hydrochloric acid, and the calcium carbonate is best obtained from pure calcite by solution and reprecipitation. However obtained, this last is not entirely free from alkalies, which must be estimated once for all in order to apply a correction. Eight grams of the carbonate will contain usually from 0.0012 to 0.0016 grams of alkaline chlorides, almost entirely the sodium salt, but the amount has been brought down to half the above by very long washing. This correction may be admitted at once to be a defect of the method, but it is one easily applied with safety.

The ignition may be made in a covered crucible of ordinary shape and of about 20 to 30 cc. capacity, but the heat has to be kept so low in this case to avoid loss by volatilization that perfect decomposition is not always assured. Hence, to avoid waste of time in very fine grinding, the form of crucible with cap, originally advocated by Smith, is very much to be preferred, since it permits, when set at an angle through an opening in the side of a fire-clay cylinder, of the application of the full heat of two burners, and perfect decomposition invariably results without the need of extraordinary care in grinding. The crucible used in this laboratory for one-half gram of rock powder and 4 grams calcium carbonate is 8 cm. long, 1.8 cm. wide at the mouth, and 1.5 at the bottom. For double the amounts or more the dimensions are 8 cm., 2.5 cm., and 2.2 cm. The weights are 25 and 40 grams.

Perfectly satisfactory results are to be obtained with but a half gram of rock powder. This is weighed out, ground down somewhat finer in a large agate mortar, mixed with its own weight of sublimed ammonium chloride, and the two thoroughly ground together. Then nearly all of 4 grams of calcium carbonate is added and the grinding continued till a thorough mixing has resulted. The contents of the mortar are transferred to the long crucible, the rest of the carbonate being used for rinsing off mortar and pestle. The crucible is then capped and placed in a clay cylinder and heated for about ten minutes by a low, flat flame placed at considerable distance beneath. As soon as the odor of ammonia is no longer perceptible the nearly full flame of two Bunsen burners is applied, and continued for forty to fifty minutes. The sintered cake detaches readily from the crucible as a rule; if not, it is softened up in a few minutes by hot water and digested in a dish until thoroughly disintegrated. It is first washed by decantation, and any lumps are broken up by a pestle, then thrown on the filter and well washed with hot water. The residue should dissolve completely in hydrochloric acid without showing the least trace of unattacked mineral.

The calcium is separated at once by ammonia and ammonium carbonate, and again after evaporation of the filtrate and expulsion of ammonium chloride. The weighed alkaline chlorides should be dissolved in water and filtered before addition of platonic chloride, in order to correct for the few hundredths of a milligram of fixed residue which is invariably left on the filter.

If the rock contains sulphur this will in part be found with the alkaline chlorides as sulphate. Therefore, if the sulphur is at all considerable in amount it must be removed by barium chloride before the second precipitation by ammonium carbonate; otherwise there is danger of the potassium platinic chloride carrying sodium sulphate. A faint reaction for sulphate can usually be obtained, anyway, if the evaporations have been made on a water bath fed by gas.

Lithium.—After separation of the potassium platinic chloride, the alcoholic filtrate is evaporated and tested spectroscopically for lithium. This element is almost invariably present, but almost never in amount to warrant quantitative estimation. Should it be so, however, the very excellent Gooch method¹ of separation by amyl alcohol is to be followed, after removal of the platinum by hydrogen gas.² In rock analysis there need be no fear of enough lithium remaining with the potassium to cause any concern.

For the most accurate work it is still necessary to look for, and if possible estimate, the few hundredths of a milligram of calcium chloride that may be with the sodium chloride.

CARBON DIOXIDE.

For this estimation an apparatus permanently set up is used, of which several forms have been described by different writers. The rock powder is boiled with dilute hydrochloric acid in a small Erlenmeyer flask, attached to an upward-inclined condenser, whence, after passing through a compact arrangement of drying tubes—first, one of calcium chloride, then one of anhydrous copper sulphate to retain hydrogen sulphide from decomposable sulphides and any hydrochloric acid that may pass over, and finally a second calcium chloride tube—the carbon dioxide is retained by absorption tubes filled with soda lime followed by calcium chloride. Of course arrangement is made for a current of CO₂-free air with which to sweep out the apparatus before and after the experiment, and for a slow current during its continuance. The results are very accurate and the determination can be quickly carried out.

In the preliminary qualitative test for carbon dioxide, it must be remembered that while calcite gives off its carbon dioxide on treatment with cold acid, dolomite and siderite do not, and hence warming should not be omitted; otherwise, a few tenths per cent of carbon dioxide can very well be overlooked. Moreover, the powder should first be stirred up with a little hot water, to remove all entangled air which might otherwise appear to be carbon dioxide.

¹Proc. Am. Acad. Arts Sci., p. 177, 1886; Bull. U. S. Geol. Survey No. 42, p. 73, 1887; Chemical News, Vol. LV, pp. 18, 29, 40, 56, 78, 1887.

²When haste is not an object, this way of removing platinum from the chlorides of the alkalies is by far the neatest and most satisfactory. The small flask containing the solution is placed in a water bath and attached to a hydrogen generator. After expelling all air the flask is closed, without breaking connection with the generator, and left to itself, except for occasional light shaking up, till reduction is accomplished.

CHLORINE.

To make sure of getting all the chlorine, it is best to fuse with chlorine-free sodium-potassium carbonate, or even sodium carbonate alone, first over the full burner, then for a moment or two over the blast, leach with water, acidify with nitric acid, and precipitate by silver nitrate. If 1 gram of material has been used no precipitation of silica need be feared on acidifying or on standing.

In many cases it is quite sufficient to attack the powder by hydrofluoric acid and a little nitric acid, with occasional stirring, and after filtering through a large platinum cone, to throw down the chlorine by silver nitrate. The presence of nitric acid is necessary, since otherwise ferrous fluoride reduces silver nitrate with deposition of crystallized silver. When coagulated by heating and stirring, the precipitate is collected on the platinum cone, washed, dissolved by a little ammonia, and reprecipitated by nitric acid, when it can be collected in a Gooch crucible and weighed, or, if very small in quantity, on a small paper filter, which is then dried, wound up in a tared platinum wire, and carefully ignited. The increased weight of the wire is due to the metallic silver of the chloride which has alloyed with it.

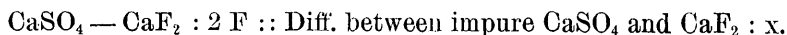
FLUORINE.

Fluorine can only be estimated by the method of Rose, care being taken to use sodium-potassium carbonate as a flux, and to avoid use of the blast if possible. The use of ammonium nitrate or chloride instead of carbonate for throwing out the silica and alumina is not to be recommended, because of loss of fluorine on evaporation (Rose). If the rocks are very basic it may happen that the amount of silica in the alkaline solution is so small that ammonium carbonate may be dispensed with and the ammonical zinc oxide solution added at once.

By whatever modification of the method the silica may have been separated, the alkaline carbonate must be converted into nitrate and not chloride if phosphorus or chromium, or both, are present. To remove the chromium and the last of the phosphorus, silver nitrate in excess is added to the solution containing still enough alkaline carbonate to cause a copious precipitate of silver carbonate, in order to take up the acid set free, and thus insure a neutral solution and consequent complete precipitation of phosphorus and chromium. After heating and filtering, the excess of silver is to be removed by sodium or potassium chloride, and sodium carbonate is to be added, when the fluorine is ready to be thrown out by calcium chloride in excess. At this stage there must be no ammonical salts in solution, otherwise calcium fluoride may be held in solution.

The well-washed and gently ignited calcium fluoride finally obtained in the course of this method should be converted to sulphate as a check upon its purity, and at the same time as a qualitative test to ascertain

if it really is calcium fluoride by the characteristic odor of its gas. Should fluorine be found, and the weight of sulphate not correspond to that of the fluoride, the former should be dissolved in hot nitric acid and tested for phosphorus by ammonium molybdate solution. If phosphate is absent the impurity may have been silica or calcium silicate—which of these it would be difficult to decide. In the former case the fluorine might be safely deduced from that of the sulphate, but not in the latter. If the rock were rich in sulphur it might happen that calcium sulphate would be thrown down with the fluoride, but this should be removed by thorough washing. If not, and it were certainly the only impurity present, the fluorine could be calculated, after conversion of the fluoride into sulphate, by the formula:



It is an exceptional case when there is exact agreement between the weight of fluoride and sulphate, and with the small amounts usually met in rocks the error may be an appreciable one in percentage of fluorine, though of no great significance otherwise.

There is no qualitative test which will reveal with certainty the presence of fluorine in rocks. Heating the powder before the blowpipe with sodium metaphosphate on a piece of curved platinum foil inserted into one end of a glass tube, or in a bulb tube, is not to be relied on in all cases. While as little as one-tenth of 1 per cent of fluorine can sometimes be thus detected with ease, much larger amounts in another class of rocks may fail to show.

SULPHUR.

If present in the form of soluble sulphates, simple boiling with hydrochloric acid suffices, which should be done in an atmosphere of carbonic acid if pyrite or other oxidizable sulphides are present.

The sulphur of sulphides, chiefly pyritic, may sometimes be determined by extraction with aqua regia or potassium chlorate and hydrochloric acid, but not always; so that it is better by far to fuse with sulphur-free sodium carbonate and a little niter over the Bunsen burner and for a few moments over the blast, fitting the crucible into a hole in asbestos board to prevent access of sulphur from the flame. The aqueous solution, after filtration, is just acidified by hydrochloric acid, and the sulphur at once thrown down at boiling heat by barium chloride, without fear of separation of silica in a bulk of about 250 cc. when 1 gram is operated on. It is well that this is so, for evaporation on the water bath heated by gas to remove silica would in many cases involve an error fully equal to the sulphur present by contamination from the sulphur of the gas burned.

Owing to the small amount of sulphur in rocks, special purification of the barium sulphate obtained is hardly ever needful, especially as it has been precipitated in absence of iron. Should there be fear of a

trace of silica being present, it can be removed by a drop of hydrofluoric and sulphuric acids before weighing the barium sulphate.

This, of course, gives the total sulphur in the rock. If soluble sulphates and sulphides as well as insoluble sulphates and sulphides are present together, the sulphur of the first is found in solution after extraction by hydrochloric acid in a carbon dioxide atmosphere, and that of the decomposable sulphides by collecting the hydrogen sulphide evolved. In the residue the sulphur of the insoluble sulphides can be estimated, or from the total sulphur found in another portion its amount can be calculated. The error involved in the above estimation of the sulphur of soluble sulphides, due to the possible reducing effect of hydrogen sulphide on ferric salts, is probably negligible. Most of the hydrogen sulphide would be expelled before any such action could take place and probably before the ferric salts were largely attacked, but of course the small proportion of sulphur set free as such from pyrrhotite would escape estimation and introduce further uncertainty. In general, it would be safe enough to assume the composition Fe_7S_8 for pyrrhotite. However carefully all these separate determinations may be carried out, the final figures for ferrous and ferric oxides can hardly be regarded as more than approximations when much sulphide is present.

BORON.

To the best of the writer's belief it has never been necessary in this laboratory to estimate boron in a silicate rock. Should it become necessary to do so, since most silico-borates are insoluble minerals, it would probably be necessary to fuse with sodium carbonate, extract with water, and apply the method of Dr. Gooch,¹ depending on expelling the boron as methyl borate by repeated distillations with methyl alcohol in nitric or acetic acid solutions, and binding the boric acid by a known weight of lime, the gain in weight being B_2O_3 . Fluorine would have to be first removed² by calcium nitrate or acetate before freeing the boron.²

NITROGEN.

Nitrogen has been found in igneous rocks or the minerals occurring in them by several observers. Thus, H. Rose³ says that pitchstone gives off ammoniacal water on heating; Silvestri⁴ mentions a nitride of iron in lavas from Etna; Sandberger finds ammonium carbonate to be given off from certain rocks of Příbram; the writer has shown nitro-

¹Proc. Am. Acad. Arts Sci., p. 167, 1886; Bull. U. S. Geol. Survey No. 42, p. 64, 1887; Chemical News, Vol. LV, p. 7, 1887.

²For a useful improvement in the way of collecting the boric ether in ammonia before bringing in contact with the lime, etc., see Penfield and Sperry, Am. Jour. Sci., 3d series, Vol. XXXIV, p. 222, 1887; also Moissan, Comptes rendus, Vol. CXVI, p. 1087, 1893, and Bull. Soc. chimique, Vol. XII, p. 955, 1894, who modifies the Gooch distilling apparatus and insures complete condensation of the boron in the distillate.

³Quantitative Analyse, p. 673. Finkener edition.

⁴Gazz. chim. ital., Vol. V, p. 303, 1875.

gen to exist in uraninite; Ramsay and others have noted it in traces with or without helium, etc., in numerous minerals; and lately Erdmann¹ has found it to be given off as ammonia on treating various minerals of "ancient igneous rocks" with a caustic alkali. Leudeking also found ammonium sulphate in a barite from Missouri, the presence of which the writer was able to confirm.

During the last two years it has been noted in this laboratory on three separate occasions, when analyzing as many different series of ores, roofing slates, and eruptive rocks, that ammonia, either in the form of chloride or sulphate or even as free ammonia, was given off on heating. Its appearance was not limited to one or a few specimens of a series, but seemed to be characteristic of all, and to be afforded by the unbroken rock as well as by the powdered sample. Not knowing the precise conditions under which the specimens were collected, it is impossible to affirm positively that the ammonia may not have been due to recent organic contamination of some sort, especially in the case of the slates, but it is believed that a more critical collection of material will not alter the general result. Its amount was sometimes readily determinable by Nesslerization, being as high as 0.04 per cent in some slates. Carbonaceous organic matter was absent from most of these, but doubtless existed in them in their early history. In their case the ammonia was, in part at least, evolved as such, imparting a strong alkaline reaction to the water in the upper part of the tube. The presence of sulphides, fluorides, or chlorides in the rock might cause the ammonia to appear as a sublimate of sulphate, fluoride, or chloride. Speculation on this matter would be altogether premature, but attention is now called to it in the hope that other observers may be led to look for and investigate similar appearances. It should be borne in mind that the nitrogen present would not necessarily appear as ammonia or ammonium salts, since it might be given off in the elemental condition, as with the gases obtained from uraninite.

SPECIAL OPERATIONS.

The problem often presents itself of ascertaining the composition of that portion of a rock powder which is soluble in special reagents or in a reagent of a particular concentration. No precise directions can be formulated to meet such cases. The procedure must vary with the character of the constituents of the rock and with the object which it is sought to attain, and only in exceptional cases can a separation of this kind be sharp. Much depends on the degree of fineness of the powder and on the length of time it is exposed to the action of the reagent.

Detection of nepheline in presence of olivine.—For confirmation of the microscopic diagnosis, Prof. L. V. Pirsson² has indicated a means of detecting nepheline in presence of olivine, as in nepheline basalts, based

¹Ber. Deutsch. chem. Gesell., Vol. XXIX, p. 1710, 1896.

²Am. Jour. Sci., 4th series, Vol. II, p. 142, 1896.

on the very ready solubility of nepheline, as compared with olivine, when boiled for but one minute with a sufficiency of very dilute nitric acid (1:40). Gelatinization of the filtrate on evaporation is taken as evidence of the presence of nepheline. If olivine is present in quantity, however, this test must not be accepted at once as final, for some, if not all, olivines are much more soluble in nitric acid of the above strength than Professor Pirsson was led to believe from his original tests. If, therefore, on evaporation of the filtrate, much iron is indicated, the gelatinization may well be due to olivine alone or in part, and then the quantitative relation of silica to iron plus magnesium should be ascertained. It must also be borne in mind that any other very soluble silicates present will be more or less affected, and that apatite is largely or wholly dissolved. It is possible that still more dilute nitric, or perhaps some other, acid may exert a slighter solvent action on olivine without being appreciably less effective in dissolving nepheline, etc. In combination with a quantitative analysis of the extract the method is, perhaps, susceptible of a wider application than the particular case for which it was first used. It is well worth further study.

Estimation of soluble silica.—Very often in treatment by acids silica is separated in gelatinous or granular form mixed with the unattacked minerals, and it becomes necessary to remove or estimate this silica, or else to discriminate between soluble and insoluble silica already existing together. Usually a boiling solution of sodium carbonate has been employed for this purpose. Its action is frequently slow and incomplete and the extraction must often be repeated many times as to silica, and its solvent action on other minerals is often marked. The filtering of hot saturated solutions of the carbonate is also unpleasant. Hence the substitution of a caustic hydroxide, as KOH or NaOH, has been advocated, especially by Michaelis,¹ who maintains with force that quartz is absolutely unattacked by boiling 10 per cent solutions (10 per cent Na₂O), or even by 25 per cent solutions when digested on the water bath, and that different results are probably due to the mechanical carrying off in the filtrate of portions of the fine powder, which is notoriously difficult to filter. In the case of separated silica the hydroxides certainly give very good results. Solution is almost immediate and complete in a quite dilute liquid, and the difficulty met with in filtering may often be overcome by faintly acidifying. If the dilution is sufficient, no separation of silica results from so doing, and less difficulty is experienced in filtering and washing, especially if very dilute acid is used for the latter.

ESTIMATION OF MINUTE TRACES OF CERTAIN CONSTITUENTS.

If, as sometimes may happen, the problem is presented of examining rocks for traces of gold, silver, and other elements which are not ordi-

¹ Chem. Zeitung, Vol. XIX, p. 1422, 1895.

narily looked for, as in Sandberger's investigations bearing on the origin of the metalliferous contents of veins, large weights of material must be taken, up to 50 grams or more. This involves the use, also, of large quantities of reagents, the purity of which must then be looked to with the utmost care. Special directions to meet such cases can not now be given, nor even a complete reference list of the scanty and scattered literature on this subject. Sandberger's own writings deal but little with its analytical side, and from its inaccessibility in the Washington libraries the writer is as yet unacquainted with the report by Von Foullon "*Ueber den Gang und die Ausführung der chemischen Untersuchung,*"¹ following Sandberger's own paper, in the general report "*Untersuchungen der Nebengesteine der Pribramer Gänge.*"² The present writer has published a few data as to gold, silver, lead, zinc, etc.,³ in Mr. S. F. Emmons's report on "*The Geology and Mining Industry of Leadville;*" and Mr. J. S. Curtis,⁴ in his report on "*The Silver-Lead Deposits of Eureka, Nevada,*" has given his method of assaying rocks for traces of gold and silver.

PRELIMINARY QUALITATIVE ANALYSIS.

A complete qualitative analysis of a rock, preceding the quantitative examination, is in most cases a sheer waste of time. A few constituents may now and then be specially looked for, but in general time is saved by assuming the presence of most of them and proceeding on that assumption in the quantitative analysis.

SUMMATION OF ANALYTICAL RESULTS.

As is well known, a complete silicate rock analysis which foots up less than 100 per cent is generally less satisfactory than one which shows a summation somewhat in excess of 100. This is due to several causes. Nearly all reagents, however carefully purified, still contain, or extract from the vessels used, traces of impurities, which are eventually weighed in part with the constituents of the rock. The dust entering an analysis from first to last is very considerable, washings of precipitates may be incomplete, and if large filters are used for small precipitates the former may easily be insufficiently washed.

Given the purest obtainable reagents, an ample supply of platinum, facilities for working, and a reasonably clean laboratory, there is no excuse for failure on the part of a competent chemist to reach a sum-

¹Jahrbuch der Bergakademie, Leoben u. Pribram, 1887, p. 363.

²From Sandberger's report it appears that the rocks were treated successively with water, acetic acid, boiling dilute hydrochloric acid for two days, and finally hydrofluoric acid, the several extracts and final residue of fluorides (and pyrite) being separately examined for heavy metals. The products of distillation were also examined. A striking fact observed in all cases was the complete insolubility of the pyrite, even after the severe treatment mentioned. This speaks strongly in favor of the correctness of ferrous iron estimations in silicates by the hydrofluoric and sulphuric acid method when pyrite is present unaccompanied by other sulphides. (See p. 54.)

³Mon. U. S. Geol. Survey, Vol. XII, Appendix B, pp. 592-596, 1886.

⁴Mon. U. S. Geol. Survey, Vol. VII, pp. 120-138, 1884.

mation within the limits 99.75 and 100.50. Failure to attain 100 per cent in several of a series of analyses of similar nature should be the strongest evidence that something has been overlooked. Excess above 100.5 per cent should be good ground for repeating portions of the analysis in order to ascertain where the error lies, for it is not proper to assume that the excess is distributed over all determined constituents. It is quite as likely, in fact more than likely, to affect a single determination and one which may be of importance in a critical study of the rock from the petrographic side.

QUALITY OF REAGENTS.

It is due to say that all analyses performed in the Survey laboratories have been made with the purest reagents obtainable, either by purchase in the open market or by special preparation on the part of manufacturers or in the laboratory. The best acids made in this country are of a high grade and need no redistillation except for special experiments. Ammonia has always been redistilled at short intervals; and no sodium carbonate which exceeds $2\frac{1}{2}$ milligrams of total impurity (see p. 36) in 20 grams (0.012 per cent) is used for the main portions, in which silica, alumina, etc., are to be estimated. For other portions, as phosphoric acid, fluorine, sulphur, a poorer grade is entirely allowable, provided it is free from the element to be determined, and from any other which might interfere with its estimation.

Hydrofluoric acid was always freshly distilled with potassium permanganate until the introduction of ceresine bottles afforded an article sufficiently pure for all but the most exacting work. Care must be exercised even yet, however, that no particles of paraffin or ceresine are floating on the acid, and that the latter is free from traces of chlorine whenever hydrofluoric acid is to be used for bringing the chlorine into solution (p. 57).

Potassium bisulphate has usually been prepared in the laboratory from sulphuric acid and potassium sulphate, since it is not always to be bought of satisfactory quality. Even then the normal sulphate had first to be examined, for it has been found to contain, on different occasions, notable amounts of lead, calcium, and silica.

The phosphorus salt used for precipitating magnesium has been found to contain iron, and calcium is sometimes a constituent of ammonium oxalate. The latter has therefore to be purified or specially prepared, as also oxalic acid, ammonium chloride (in which latter manganese has been observed), and occasionally other reagents. Some hydrogen peroxide contains fluorine, which renders it unfit for use as a chemical reagent.

A "C. P." label is no guaranty whatever of the purity of a reagent; hence no chemicals should be taken on trust because of bearing such a label. Every new purchase should be examined, if it is one in which purity is a desideratum. In general all so-called "C. P." chemicals

should at least stand the tests laid down by Krauch.¹ Of late the firm of E. Merck in Darmstadt has begun to advertise preparations of a certain guaranteed purity, thus inaugurating a long-needed reform in this direction. Even with them, however, the guaranty should be checked, at least until long experience shall have shown the precaution to be superfluous.

To his colleague, Dr. H. N. Stokes, who kindly examined the original draft of this paper, the writer is indebted for several suggestions which have been made free use of in the foregoing.

¹ Die Prüfung der chemischen Reagentien, 3d ed., Berlin, Julius Springer, 1896.

ANALYSES OF ROCKS.

ARRANGED AND TABULATED BY F. W. CLARKE, CHIEF CHEMIST.

IGNEOUS AND CRYSTALLINE ROCKS.

MAINE.

A. Elæolite-syenite from Litchfield. Described by Bayley in Bull. Geol. Soc. Amer., vol. 3, p. 231. Contains elæolite, two feldspars, and lepidomelane, with sodalite, cancrinite, and zircon as accessories. Analysis by L. G. Eakins, record No. 1298.

B. Albite from A. Sp. gr. 2.622.

C. Potash-feldspar from A. Sp. gr. 2.56. Analyses B and C by W. H. Melville, record No. 1275.

	A.	B.	C.
SiO ₂	60.39	68.28	65.14
Al ₂ O ₃	22.57	19.62	18.19
Fe ₂ O ₃ .....	.42		
FeO	2.26	.23	.25
MnO .....	.08		
CaO .....	.32	.31	.33
MgO .....	.13	.09	.16
K ₂ O	4.77	.39	14.14
Na ₂ O	8.44	10.81	1.68
H ₂ O .....	.57	.09	.17
	99.95	99.82	100.06

The minerals found in this rock were quite fully described by Clarke in Bull. 42, pp. 28-38. Analyses by F. W. Clarke.

D. Elæolite, dark gray.

E. Hydronephelite.

F. Lepidomelane. Contains no fluorine.

	D.	E.	F.
SiO ₂	43.74	38.99	32.09
Al ₂ O ₃	34.48	33.62	18.52
Fe ₂ O ₃			19.49
FeO.....			14.10
MnO.....			1.42
CaO.....	Trace.	.07	
MgO.....	Trace.		1.01
K ₂ O.....	4.55	1.12	8.12
Na ₂ O.....	16.62	13.07	1.55
H ₂ O.....	.86	12.98	4.62
	100.25	99.85	100.92

G. Sodalite, deep blue.

H. Cancrinite, bright orange yellow.

I. Cancrinite, pale yellow, cleavable.

J. Cancrinite, pale yellow, granular.

	G.	H.	I.	J.
SiO ₂	37.33	36.29	35.83	37.22
Al ₂ O ₃	31.87	30.12	29.45	28.32
Fe ₂ O ₃		Trace.	Trace.	Trace.
MnO.....		Trace.	Trace.	Trace.
CaO.....		4.27	5.12	4.40
MgO.....				.07
K ₂ O.....	.10	.18	.09	.18
Na ₂ O.....	24.56	19.56	19.33	19.43
H ₂ O.....	1.07	2.98	3.79	3.86
CO ₂		6.96	6.50	6.22
Cl.....	6.83			
	101.76 *	100.36	100.11	99.70
O = Cl.....	1.54			
	100.22			

NEW HAMPSHIRE.

A. Elæolite-syenite from Red Hill, Moultonboro. Described by Bayley in Bull. Geol. Soc. Amer., vol. 3, p. 231. Contains elæolite, augite, hornblende, biotite, sodalite, albite, and orthoclase, with accessory apatite, sphene, magnetite, and an occasional zircon. Fibrous decomposition products are also present.

B. Mixed albite and orthoclase from A.

C. Nepheline (elæolite) from A. Analyses by W. F. Hillebrand, record No. 1321. The mixed nepheline and feldspar were treated with dilute hydrochloric acid, and the residue was extracted with sodium carbonate solution. C represents the soluble part, and B the insoluble.

D. Camptonite from Campton Falls. Analysis by L. G. Eakins, record No. 1298. Described by J. P. Iddings for the Educational Series. Contains hornblende, plagioclase, orthoclase, augite, iron ore, biotite, apatite, pyrite, and a mineral which appears to be analcite. Also variable calcite, serpentine, and chlorite.

E. Quartz-porphyr, Pemigewasset. Analysis by Eakins, No. 1298.

	A.	B.	C.	D.	E.
SiO ₂	59.01	66.85	45.31	38.45	65.02
TiO ₂ .....	.81	.....	.....	.....	.....
Al ₂ O ₃	18.18	19.50	32.67	19.68	17.93
Fe ₂ O ₃	1.63	} .13	.....	4.01	4.69
FeO	3.65		.....	11.15	.17
MnO .....	.03	.....	.....	Trace.	.11
CaO	2.40	.11	2.00	9.37	1.34
SrO	Trace.	.....	.....	.....	.....
BaO .....	.08	.07	.....	.....	.....
MgO	1.05	Trace.	.16	6.65	1.24
K ₂ O	5.34	5.80	5.70	1.72	5.98
Na ₂ O	7.03	7.44	12.60	2.77	3.04
Li ₂ O	Trace.	None.	.....	.....	.....
H ₂ O at 100° .....	.15	.....	.....	} 1.49	} .86
H ₂ O above 100° .....	.50	.31	1.56		
P ₂ O ₅	Trace.	.....	.....	.....	.....
CO ₂ .....	.12	.....	.....	4.82	.....
	99.98	100.21	100.00	100.11	100.38

VERMONT.

1. ROCKS OF MOUNT ASCUTNEY.

Analyses by W. F. Hillebrand, record Nos. 1621, 1657. Samples received from T. A. Jaggar, jr. Petrographic data furnished by R. A. Daly.

A. Typical granite. Contains quartz, orthoclase, plagioclase (microperthite), biotite, magnetite, sphene, apatite, and zircon.

B. Basic segregation in granite. Contains biotite, hornblende, quartz, plagioclase, microperthite, much sphene and apatite, some magnetite and zircon.

C. Another sample of B.

D. Syenite. Contains hornblende, augite, orthoclase, microperthite, plagioclase, biotite, quartz, magnetite, sphene, apatite, and zircon.

E. Basic segregation in syenite. Contains hornblende, augite, microperthite, orthoclase, plagioclase, quartz, magnetite, zircon, and apatite.

F. Syenite-porphry. Contains orthoclase, quartz, hornblende, magnetite, apatite, and zircon.

	A.	B.	C.	D.	E.	F.
SiO ₃	71.90	56.01	59.27	65.43	56.51	73.03
TiO ₂.....	.35	1.13	1.12	.50	1.20	.30
ZrO ₂.....	.04	} 15.19	.04	.11	.04	.06
Al ₂ O ₃	14.12		15.76	16.11	16.59	13.43
Fe ₂ O ₃	1.20	2.34	2.07	1.15	1.35	.40
FeO.....	.86	4.89	3.57	2.85	6.59	1.49
MnO.....	.05	.40	.37	.23	.24	.15
(NiCo)O.....	None.	.03	Trace.	?	Trace?	?
CaO.....	1.13	4.85	3.69	1.49	4.96	.79
BaO.....	.04	Trace?	Trace?	.03	.03	Trace.
MgO.....	.33	4.67	3.04	.40	2.52	.14
K ₂ O.....	4.81	2.16	3.33	5.97	3.05	4.54
Na ₂ O.....	4.52	5.66	5.63	5.00	5.15	4.91
H ₂ O at 110° ..	.18	.36	.23	.19	.21	.18
H ₂ O above 110°	.42	.90	.74	.39	.71	.35
P ₂ O ₅.....	.11	.53	.42	.13	.41	.06
CO ₂.....	.21	Undet.	.30	Trace?	.33	Trace?
F.....	.06	Undet.	.42	.08	.24	.08
Cl.....	.02	Undet.	.03	.05	.07	.03
FeS ₂	Trace.	.09	.07	.07	.06	.09
Less O.....	100.35	99.21	100.10	100.18	100.26	100.03
	.03		.19	.04	.11	.04
	100.32		99.91	100.14	100.15	99.99

G. Syenite-porphry. Contains orthoclase, plagioclase, microperthite, hornblende, quartz, augite, magnetite, biotite, apatite, and zircon.

H. Granite-porphry. Composition like D, but with more quartz.

I. Basic segregation in H. Contains hornblende, green and brown augite, biotite, quartz, microperthite, magnetite, little apatite, and zircon.

J. Diorite. Contains hornblende, augite, biotite, plagioclase, titaniferous magnetite, sphene, zircon, and quartz.

K. Diorite. Composition like J.

L. Another sample of K.

	G.	H.	I.	J.	K.	L.
SiO ₂	64.88	73.69	56.53	52.12	57.97	64.62
TiO ₂.....	.69	.28	1.40	2.10	1.54	.81
ZrO ₂.....	.13	.14	.03	.02		.03
Al ₂ O ₃	16.24	12.46	16.47	16.35	17.28	16.46
Fe ₂ O ₃	1.37	1.21	1.58	3.68	2.23	1.82
FeO.....	2.70	1.75	5.40	6.02	3.75	2.14
MnO.....	.14	.15	.20	.17	.15	.12
(NiCo)O.....	None.	None.	Trace.	Trace.	Trace.	None.
CaO.....	1.92	.36	4.90	7.25	4.33	2.39
BaO.....	.06	None.	Trace.	.04	.07?	.03
MgO.....	.89	.17	2.67	4.14	2.20	1.10
K ₂ O.....	5.61	4.92	3.80	2.34	4.12	5.21
Na ₂ O.....	5.00	4.47	5.59	3.65	4.31	4.57
H ₂ O at 110°...	.19	.14	.23	.25	.18	.13
H ₂ O above 110°.	.46	.24	.60	.88	.57	.39
P ₂ O ₅.....	.13	.04	.27	.89	.64	.21
CO ₂	None.	Trace.	.05	.07	.05	.11
F.....	.08	.05	.19	.03	.04	Undet.
Cl.....	.04	.02	.07	.09	Undet.	.05
FeS ₂	None.	None.	Trace.	.24	.32	.19
	100.53	100.09	99.98	100.33	99.75	100.38
Less O.....	.04	.02	.09	.03	.02	.01
	100.49	100.07	99.89	100.30	99.73	100.37

M. Basic segregation in diorité. Contains hornblende, augite, biotite, plagioclase, magnetite, apatite, zircon, and a little quartz.

N. Diabase. Contains plagioclase, augite, and magnetite.

O. Camptonite. Contains brown hornblende, plagioclase, a little augite, olivine, magnetite, and apatite.

P. Phyllite. Contains quartz, sericite, graphite?, magnetite, pyrite, rare orthoclase, plagioclase, sphene, and rutile.

Q. Microperthite-hornfels. Contains biotite, quartz, red garnet, corundum, magnetite, iolite, microperthite, and rarely pleonaste.

R. Cordierite-hornfels. Contains quartz, biotite, pleonaste, corundum, iolite, magnetite, plagioclase, red garnet, and epidote?

	M.	N.	O.	P.	Q.	R.
SiO ₂	55.28	49.63	48.22	90.91	58.35	45.30
TiO ₂	1.64	1.68	2.79	.28	.87	1.48
ZrO ₂	Trace.	Trace?	.03	.02	None.	None.
Al ₂ O ₃	17.23	14.40	14.27	4.18	21.30	30.51
Fe ₂ O ₃	1.54	2.85	2.46	.22	.03	.24
FeO	6.23	8.06	9.00	1.27	6.41	8.80
MnO .....	.24	.17	.20	Trace.	.13	.20
(NiCo)O	?	.04	.03	None.	.03	.02
CaO	5.60	9.28	8.45	.22	.85	.90
BaO .....	.06	Trace?	.04	Trace.	.05	.03
MgO	2.69	7.25	6.24	.37	2.10	3.11
K ₂ O	2.12	.70	1.93	.58	5.63	4.84
Na ₂ O	5.42	2.47	2.90	.77	1.60	1.65
H ₂ O at 110° ..	.20	.27	.28	.06	.31	.26
H ₂ O above 110°	.71	1.47	1.66	.74	.86	1.05
P ₂ O ₅ .....	.73	.25	.64	.05	.18	.12
CO ₂ .....	.04	1.36	.15	.18	-----	-----
C	-----	-----	-----	.10	.40	.17
SO ₃	None.	None.	None.	None.	None.	.04
Cl .....	.07	.07	.10	-----	.03	.04
F .....	.28	Trace.	.05	Trace.	?	.04
FeS ₂ .....	.07	.22	.36	.11	.58	1.07
Less O	100.15	100.17	99.80	100.06	99.71	99.87
	.13	.02	.04			
	100.02	100.15	99.76			

In these rocks the sulphur is all reckoned as pyrite, although pyrrhotite also is probably present. The carbonic acid represents either dolomite or siderite; *not* calcite. Traces of lithia and strontia occur in nearly all. Samples H, L, O, Q contain traces of copper.

2. MISCELLANEOUS ROCKS.

A. Amphibolite, Guilford. Described by Emerson in Mon. XXIX. Contains hornblende needles, with albite and rutile. Analysis by L. G. Eakins, record No. 1326.

B. Granitoid gneiss, north of Lincoln's.

C. The same, west slope of Little Peco.

D. Chloritic granite, East Clarendon section.

E. Hornblende-granite, East Clarendon section.

Rocks B, C, D, E collected by C. L. Whittle, but not described. Analyses by H. N. Stokes, record No. 1396.

	A.	B.	C.	D.	E.
SiO ₂	49.16	71.02	69.97	67. 3	52.60
TiO ₂	1.03	.35	.44	.80	1.11
Al ₂ O ₃	16.43	15.00	14.90	16.20	18.45
Cr ₂ O ₃	Trace.				
Fe ₂ O ₃	3.92	1.12	2.16	1.40	2.47
FeO	7.19	1.81	.96	2.73	2.1
MnO .....	.23	Trace.	Trace.	Trace.	.23
CaO	9.21	.31	.45	2.81	7.55
BaO .....	.02	Trace.	.09	.05	
MgO	8.19	.69	.37	1.31	4.22
K ₂ O .....	.41	5.79	6.54	2.14	1.12
Na ₂ O	3.70	2.48	2.85	3.15	3.24
H ₂ O .....	.45	1.14	.66	1.84	2.53
P ₂ O ₅ .....	.16	.13	.12	.16	.20
	100.10	99.84	99.51	99.92	99.83

MASSACHUSETTS.

1. ROCKS OF THE CONNECTICUT VALLEY.

Described by Emerson in Mon. XXIX.

A. Serpentine derived from sahlite, Osburn's soapstone quarry, Blandford.

B. Dark-green, oily serpentine, center of large Middlefield bed.

C. Enstatite, slightly altered, from Granville. For comparison with D.

D. Serpentine derived from enstatite, Granville.

Analyses A, B, C, by W. F. Hillebrand, record No. 1555. Analysis D by Geo. Steiger, No. 1536.

	A.	B.	C.	D.
SiO ₂	40.77	38.62	54.04	37.82
TiO ₂	None.	None.	None.	Trace.
Al ₂ O ₃	1.16	.35	.52	.61
Cr ₂ O ₃.....	.28	.39	.14	.19
Fe ₂ O ₃	3.56	3.44	1.51	7.92
FeO.....	1.47	3.99	3.90	1.15
MnO.....	.09	.10	.11	.....
NiO.....	.17	.21	.23	.45
CoO.....	.....	.....	.....	.05
CaO.....	None.	.40	None.	None.
MgO.....	39.37	40.61	34.40	37.94
K ₂ O.....	.10	.08	} .08	} Trace.
Na ₂ O.....	.14	.10		
Li ₂ O.....	Trace.	Trace.	.....	.....
H ₂ O at 110°.....	.49	.36	.70	.75
H ₂ O above 110°...	12.48	10.91	3.07	12.50
P ₂ O ₅	Trace.	Trace.	None.	Trace.
CO ₂	None.	.52	1.32	.....
	100.08	100.08	100.02	99.38

E. Rich, dark-green serpentine, from Rowe.

F. Black serpentine containing marmolite, Atwater's quarry, Russell.

G. Blackish-green serpentine containing much chromite. From "The Crater," North Blandford.

H. Gray, splintery serpentine, from Chester.

Analyses by Steiger, record No. 1536.

	E.	F.	G.	H.
SiO ₂	40.42	36.94	39.14	33.87
TiO ₂	None.	Trace.	None.	None.
Al ₂ O ₃	1.86	.50	1.18	.77
Cr ₂ O ₃ .....	.28	.33	.33	.28
Fe ₂ O ₃	2.75	6.04	4.46	2.81
FeO	4.27	1.94	3.14	4.25
MnO	Trace.	Trace.	None.	.04
NiO .....	.53	.40	.47	} .33
CoO	Trace.	None.	Trace.	
CaO .....	.66	None.	None.	None.
MgO	35.95	38.35	41.45	38.57
K ₂ O	} .16	} None.	} None.	} None.
Na ₂ O				
H ₂ O at 100° .....	.21	.71	.34	.38
H ₂ O above 100°	10.51	12.07	9.48	7.00
P ₂ O ₅	Trace.	Trace.	.02	Trace.
CO ₂	1.44	1.85	None.	10.82
SO ₃	Trace.	.20	None.	.20
FeS ₂ .....	.43	-----	-----	-----
	99.47	99.33	100.01	99.42

I. Peridotite, Belchertown. Contains hornblende, pyroxene, biotite, olivine, and magnetite. Analysis by L. G. Eakins, record No. 1326.

J. Massive, coarse, altered diabase, Leverett. Contains saussuritic feldspar with black hornblende. Analysis by Eakins, record No. 1325.

K. Tonalite, South Leverett. Dark green, chloritic. Contains reddish feldspar, dark hornblende, and a network of dark-green epidotic quartz veins. Analysis by Eakins, record No. 1326.

L. Biotite-granite, Moore's quarry, Florence. Very feldspathic. Quartz rare, with fluid inclusions. Feldspar mostly triclinic, orthoclase and microcline present in small quantities. Little muscovite, some rutile. Analysis by Eakins, record No. 1414.

	I.	J.	K.	L.
SiO ₂	48.63	51.56	55.51	73.27
TiO ₂ .....	.47	1.97	.91	.10
Al ₂ O ₃	5.32	14.82	16.51	15.51
Cr ₂ O ₃ .....	.36	.....	.....	.....
Fe ₂ O ₃	2.91	4.30	1.68	.33
FeO	3.90	7.21	4.57	1.14
MnO .....	.12	Trace.	.11	Trace.
CaO	13.04	7.09	6.73	2.74
BaO	Trace.	Trace.	.02	.....
MgO	21.79	7.36	6.73	.15
K ₂ O .....	.23	.17	2.46	1.66
Na ₂ O .....	.34	4.21	3.19	4.79
H ₂ O	2.81	1.47	1.53	.68
P ₂ O ₅ .....	.21	.09	.17	Trace.
CO ₂	Trace.	.....	.....	.....
	100.13	100.25	100.12	100.37

M. Amphibolite, Bernardston. A black, heavy, massive hornblende rock. Analysis by L. G. Eakins, record No. 1327.

N. Porphyritic amphibolite, Heath. Analysis by Eakins, record No. 1325.

O. Amphibolite, New Salem. Analysis by Eakins, record No. 1325.

P. Amphibolite, Whitman's Ferry, Sunderland. Thin, shaly, aphanitic. Analysis by Eakins, record No. 1325.

	M.	N.	O.	P.
SiO ₂	51.72	51.38	45.48	49.86
TiO ₂	1.39	1.07	.77	1.58
Al ₂ O ₃	16.51	18.01	19.43	15.50
Cr ₂ O ₃			Trace.	
Fe ₂ O ₃	1.72	3.30	.13	2.99
FeO.....	9.56	8.53	6.58	8.01
MnO.....	Trace.	.19	Trace.	.07
CaO.....	8.89	6.27	10.66	8.89
BaO.....	Trace.	Trace.	.01	Trace.
MgO.....	6.58	5.08	11.08	7.79
K ₂ O.....	.34	.18	.11	.72
Na ₂ O.....	2.74	5.34	2.28	3.26
H ₂ O.....	.51	.56	3.17	1.51
P ₂ O ₅.....	.23	.18	.14	.11
CO ₂.....			.20	
	100.19	100.09	100.04	100.29

Q. Amphibolite, South Leverett. Deep green, ligniform. Analysis by L. G. Eakins, record No. 1327.

R. Amphibolite, Goshen. Derived from Conway limestone. Analysis by Eakins, record No. 1414.

S. Black, fissile amphibolite, Worthington. Nearly pure, matted hornblende. Titanite and sometimes zircon present. Analysis by Eakins, record No. 1326.

T. Black, fissile, porphyritic amphibolite, Warwick. Analysis by Eakins, record No. 1414. Collected by Emerson, but not described in the Monograph.

	Q.	R.	S.	T.
SiO ₂	47.56	55.64	48.53	50.65
TiO ₂	1.24	.50	.51	.50
Al ₂ O ₃	16.13	16.27	16.35	13.03
Cr ₂ O ₃	Trace.	.....	.....	Trace.
Fe ₂ O ₃	1.80	1.22	2.03	.27
FeO.....	9.39	7.20	10.52	12.67
MnO.....	.08	.28	.17	.15
CaO.....	6.67	9.23	9.83	1.73
BaO.....	Trace.	.....	Trace.	.....
MgO.....	9.21	5.58	9.71	16.96
K ₂ O.....	1.58	.19	.32	.04
Na ₂ O.....	2.52	.91	1.36	1.37
H ₂ O.....	3.51	3.11	.79	2.96
P ₂ O ₅.....	.21	.23	.07	Trace.
	99.90	100.36	100.19	100.33

2. MISCELLANEOUS ROCKS.

Collected by B. K. Emerson and unpublished at the date of writing.

A. Wehrlite, New Braintree. Contains diallage, enstatite, augite, anorthite, biotite, apatite, chromite, magnetite, and pyrrhotite. Analysis by L. G. Eakins, record No. 1327.

B. Black, serpentinized boltonite, Stow. Analysis by W. F. Hillebrand, record No. 1555.

C. Highly metamorphosed feldspathic conglomerate, graduating into arkose-gneiss. Electric railroad cut, Marlboro. Analysis by George Steiger, record No. 1536.

D. Phonolite, Southboro. No description furnished. Analysis by H. N. Stokes, record No. 1653. Contains traces of chlorine and fluorine; 63.2 per cent of the rock is decomposable by hydrochloric acid.

	A.	B.	C.	D.
SiO ₂	50.64	36.92	75.35	54.22
TiO ₂ .....	.82	None.	.21	.38
Al ₂ O ₃	7.93	.10	13.03	20.20
Cr ₂ O ₃ .....	.05	None.	.....	None.
Fe ₂ O ₃	1.41	1.19	.62	2.35
FeO	14.82	.87	.94	1.02
MnO .....	.16	Trace.	None.	.19
CaO	3.41	.59	1.33	.70
BaO .....	.....	None.	.07	Trace.
MgO	18.58	43.99	.21	.29
K ₂ O .....	.21	.05	5.14	4.85
Na ₂ O .....	.96		2.44	9.44
H ₂ O at 100° .....	.87	.72	.15	.42
H ₂ O above 100°		14.70	.73	5.57
P ₂ O ₅ .....	.27	Trace.	.08	.11
CO ₂ .....	.....	.90	.03	Trace.
SO ₃ .....	.....	.....	.03	None.
	100.13	100.03	100.36	99.74

Keratophyr from Marblehead Neck. Described by Sears, in Bull. Museum Compar. Zoology, vol. 16, No. 9, p. 170. Contains crystals of feldspar, with a decomposed base, irregular patches of quartz, some scales of biotite and grains of magnetite, and also some limonite and earthy matter. The feldspar is anorthoclase. Analyses by T. M. Chatard, record No. 1176.

A. The rock.

B. The separated feldspar.

	A.	B.
SiO ₂	70.23	65.66
TiO ₂ ?.....	.03	Undet.
Al ₂ O ₃	15.00	20.05
Fe ₂ O ₃	1.99	Trace.
FeO.....	Undet.	Trace.
MnO.....	.24	.13
CaO.....	.33	.67
MgO.....	.38	.18
K ₂ O.....	4.99	6.98
Na ₂ O.....	4.98	6.56
P ₂ O ₅.....	.06	Undet.
H ₂ O at 110°.....	.91	.04
H ₂ O at redness.....	1.28	.37
	100.42	100.64

Feldspars from schists of Berkshire County. Described by Wolff, Mon. XXIII, pp. 60 and 187. All albite. Analyses by R. B. Riggs, record Nos. 507 and 567.

A. From feldspathic schist, central shaft of the Hoosac Tunnel.

B, C. From the porphyritic mica-schist of Greylock Mountain.

	A.	B.	C.
SiO ₂	69.69	68.08	67.83
Al ₂ O ₃ .Fe ₂ O ₃	18.60	20.11	19.92
MnO.....		Trace.	Trace.
CaO.....	Trace.	Trace.	Trace.
MgO.....	.20	?	?
K ₂ O.....	.40	.36	.25
Na ₂ O.....	10.28	11.00	11.65
Ignition.....	.42	.31	.12
	99.59	99.86	99.77

Fe₂O₃ less than 0.5 in either case.

CONNECTICUT.

Basic pitchstone (tachylyte) from the so-called "ash-bed" northeast of Meriden. Described by Emerson in Bull. Geol. Soc. Amer., vol. 8, p. 77. Analysis by H. N. Stokes, record No. 1641.

SiO ₂	46.86	K ₂ O	2.02
TiO ₂	1.13	Na ₂ O	1.85
Al ₂ O ₃	13.96	Li ₂ O	Trace.
Fe ₂ O ₃	5.23	H ₂ O at 110°	1.29
FeO	4.67	H ₂ O above 110°	3.43
MnO	Trace.	P ₂ O ₅ .....	.15
CaO	9.42	CO ₂	2.19
SrO	Trace.	F	Trace.
BaO .....	.03		
MgO	7.69		99.92

NEW YORK.

Peridotite from Dewitt, near Syracuse. Described by Darton and Kemp, Amer. Journ. Sci., 3d series, vol. 49, p. 456. Contains olivine, partly serpentinized, biotite, and augite, with magnetite, apatite, and perofskite. Possibly a little chromite also. Classed by Kemp as limburgite.

Analysis by H. N. Stokes, record No. 1491. The FeO represents the total iron, because the sulphides present, possibly as pyrrhotite, prevent the separate estimation of the two iron oxides.

SiO ₂	36.80	Na ₂ O .....	.17
TiO ₂	1.26	H ₂ O below 100° .....	.51
Al ₂ O ₃	4.16	H ₂ O above 100°	6.93
Cr ₂ O ₃ .....	.20	P ₂ O ₅ .....	.47
FeO	8.33	CO ₂	2.95
NiO .....	.09	SO ₃ .....	.06
MnO .....	.13	S .....	.95
BaO .....	.12		100.22
SrO	Trace.	O=S .....	.47
CaO	8.63		99.75
MgO	25.98		
K ₂ O	2.48		

NEW JERSEY.

Rocks described for the Educational Series, by J. P. Iddings. Analyses by L. G. Eakins, record No. 1299.

A. Basalt, Watchung Mountain, Orange. Contains pyroxene, mostly malacolite, plagioclase, magnetite, and glass, with variable amounts of serpentine or chlorite. The feldspar is partly altered into a mineral which is probably prehnite.

B. Elæolite-syenite, Beemersville. Contains nephelite, orthoclase, ægirite, and biotite, with melanite, sphene, apatite, zircon, and magnetite in smaller amounts. Sodalite is probably present also.

C. Minette, Franklin Furnace. Contains alkali-feldspar, biotite, monoclinic pyroxene, magnetite, epidote, calcite, chlorite, apatite, sphene, pyrite, and a little secondary quartz.

	A.	B.	C.
SiO ₂	51.36	53.56	40.71
Al ₂ O ₃	16.25	24.43	19.46
Fe ₂ O ₃	2.14	2.19	7.46
FeO.....	8.24	1.22	6.83
MnO.....	.09	.10	.18
NiO.....	.03		
CaO.....	10.27	1.24	11.83
MgO.....	7.97	.31	6.21
K ₂ O.....	1.06	9.50	3.26
Na ₂ O.....	1.54	6.48	1.80
H ₂ O.....	1.33	.93	1.53
CO ₂.....			.74
	100.28	99.96	100.01

PENNSYLVANIA.

A. Aporhyolite, Monterey, Franklin County. Described by Florence Bascom for the Educational Series of Rocks. Contains alkali-feldspars, quartz, sericite, epidote, titaniferous magnetite, leucoxene, and rarely sphene. Analysis by H. N. Stokes, record No. 1479.

B. Quartz-porphyry, same locality. Analyzed for G. H. Williams, but never described. Analysis by L. G. Eakins, record No. 1350.

	A.	B.
SiO ₂	76.34	73.85
TiO ₂.....	.26	.....
Al ₂ O ₃	11.60	13.15
Fe ₂ O ₃	2.41	3.27
FeO.....	.30	.36
MnO.....	Trace.	.09
CaO.....	.55	.82
BaO.....	.09	.....
MgO.....	.06	.32
K ₂ O.....	2.75	5.42
Na ₂ O.....	5.50	2.29
H ₂ O at 100°.....	.10	} .71
H ₂ O above 100°.....	.39	
P ₂ O ₅	Trace.	.06
CO ₂	Trace.	.....
	100.35	100.34

DELAWARE.

Feldspars from gabbros. Separated by Diller, described by Chester in Bull. 59. Analyses by R. B. Riggs, record Nos. 459, 460, 461.

A. Sp. gr. 2.592 to 2.877, from a typical gabbro. Brandywine Creek, Wilmington.

B. Sp. gr. 2.592 to 2.780, from a typical hypersthene-gabbro, found at Fifth and Van Buren streets, Wilmington.

C. Sp. gr. 2.592 to 2.749, from "Iron Hill hyperite changing to diorite," near Whitaker's ore pit.

Samples dried at 105°. FeO not determined separately.

	A.	B.	C.
SiO ₂	70.37	51.44	44.09
Al ₂ O ₃	18.36	30.05	35.41
Fe ₂ O ₃ .....	.58	.96	.51
MnO	Trace.	.....	Trace.
CaO	5.08	13.19	18.47
MgO .....	.04	Trace.	None.
K ₂ O .....	.63	.21	.19
Na ₂ O	4.32	4.07	.99
Ign .....	.45	.35	.35
	99.83	100.27	100.01

MARYLAND, INCLUDING THE DISTRICT OF COLUMBIA.

1. PERIDOTITE AND PYROXENITE.

Described by Williams, Amer. Geologist, vol. 6, p. 35.

A. Porphyritic lherzolite, Johnny Cake Road, Baltimore County. Contains olivine, bronzite, and diallage, the olivine partly serpentinized. Analysis by T. M. Chatard, record No. 1094.

B. Pyroxenite, Johnny Cake Road. Consists entirely of hypersthene and diallage.

C, D. Alterations of B. B, C, and D dried at 104°.

E. Smaragdite rock, altered pyroxenite, Dogwood Road, Baltimore County.

Analyses B, C, D, E, by J. E. Whitfield, record Nos. 975, 976. C, D, and E are from the laboratory record, and do not appear in the published paper.

	A.	B.	C.	D.	E.
SiO ₂	43.87	50.80	50.10	51.94	53.22
TiO ₂ .....	.12	None.	None.	None.	None.
Al ₂ O ₃	1.64	3.40	2.00	2.53	3.14
Cr ₂ O ₃ .....	.44	.32	.36	.60	.23
Fe ₂ O ₃	8.94	1.39	2.38	2.88	-----
FeO	2.60	8.11	8.68	9.38	7.95
NiO	Trace.	-----	-----	-----	-----
MnO .....	.19	.17	.29	Trace.	.11
CaO	6.29	12.31	5.06	3.60	14.44
MgO	27.32	22.77	26.85	25.97	20.09
K ₂ O .....	.50	Trace.	None.	None.	Trace.
Na ₂ O					
H ₂ O at 110°	1.08	.52	4.16	2.82	.98
H ₂ O at red heat.	7.64				
P ₂ O ₅	Trace.	Trace.	None.	None.	-----
SO ₃	-----	Trace.	Trace.	.19	Trace.
Cl	-----	.24	.26	.16	.26
	100.63	100.03	100.14	100.07	100.42

F, G. Two samples of websterite, from Hebbville, 6 miles west of Baltimore.

H. Bronzite from G.

I. Diopside from G.

The rock consists entirely of bronzite and diopside. Analyses by T. M. Chatard, record Nos. 1094, 1123.

J. Cortlandtite from Ilchester, Howard County. Analysis by W. F. Hillebrand, record No. 1422. Published by Williams in 15th Ann., p. 674. The rock consists of olivine, pyroxene, and large hornblende crystals, the latter considerably altered to talc.

	F.	G.	H.	I.	J.
SiO ₂	53.98	52.55	54.53	51.80	39.20
TiO ₂ .....	.15	.14	Undet.	.13	.52
Al ₂ O ₃	1.32	2.71	1.93	2.21	4.60
Cr ₂ O ₃ .....	.53	.44	.30	.51	.41
Fe ₂ O ₃	1.41	1.27	1.70	1.29	3.45
FeO	3.90	4.90	8.92	3.50	6.15
NiO	Trace.				.30
MnO .....	.21	.24	.28	Trace.	.20
CaO	15.47	16.52	2.25	20.99	3.23
MgO	22.59	20.39	29.51	17.76	31.65
K ₂ O	Undet.	} .27		Undet.	.14
Na ₂ O	Undet.			Undet.	.42
Li ₂ O					Trace.
H ₂ O at 100° .....	.09	} 1.09	} 1.14	} .65	.50
H ₂ O above 100° .....	.83				9.38
P ₂ O ₅	Trace.	Trace.	Trace.	Trace.	Trace.
	100.48	100.52	100.56	98.84	100.15

2. GABBRO AND DIORITE.

Described by Williams, but not in detail, in 15th Ann., pp. 673, 674. Some of the rocks, with other analyses, are discussed by him in Bull. 28. Analyses by W. F. Hillebrand, record No. 1422. .

A. Olivine-gabbro from Orange Grove, Baltimore County. Contains plagioclase, diallage, hypersthene, fresh olivine, magnetite and apatite, and sometimes hornblende.

B. Hypersthene-gabbro, Wetheredville, Baltimore County. Rich in hypersthene and diallage, with plagioclase, magnetite, and apatite.

C. Gabbro-diorite, Ilchester, Howard County. A coarse anorthite-hornblende rock, probably an altered gabbro.

D. Biotite-diorite, Triadelphia, Montgomery County.

E. Biotite-diorite, Georgetown, D. C.

To these may be added an apparently unpublished analysis made for Williams by L. G. Eakins, record No. 1350, as follows:

F. Hornblende-diorite, Rock Creek Tunnel Shaft, Washington, D. C. Relations to E not stated.

	A.	B.	C.	D.	E.	F.
SiO ₂	48.91	44.76	43.42	55.97	56.41	56.18
TiO ₂.....	.37	.13	1.25	1.11	.69	.....
SnO ₂ , ZrO ₂?	.....	.....	.....	.....	.14	.....
Al ₂ O ₃	8.81	18.82	22.37	15.60	15.19	14.76
Cr ₂ O ₃.....	.15	.08	Trace.	.04	.05	.....
Fe ₂ O ₃	1.04	2.19	.81	1.21	1.60	2.12
FeO.....	9.52	4.73	9.25	6.28	6.24	6.98
MnO.....	.16	.15	.06	.08	.11	.17
CaO.....	14.69	14.58	13.34	7.31	6.77	7.97
MgO.....	15.19	11.32	5.75	6.83	7.18	8.11
K ₂ O.....	.10	.11	1.13	1.25	1.34	.80
Na ₂ O.....	.64	.89	1.24	2.23	2.21	1.62
Li ₂ O.....	Trace.	Trace.	Trace.	Trace.	Trace.	.....
H ₂ O at 100° ..	.07	.17	.09	.18	.08	} 1.37
H ₂ O above 100°	.52	2.36	1.54	1.85	2.00	
P ₂ O ₅	Trace.	None.	.10	.16	.05	.08
	100.17	100.29	100.35	100.10	100.06	100.16

3. GRANITE AND GNEISS.

For descriptions see Williams, 15th Ann., p. 657, and Keyes, *ibid.*, p. 685. The Rowlandville granite is described by Grimsley in Journ. Cincinnati Soc. Nat. Hist., vol. 17, p. 78.

A. White granite from Brookville, Montgomery County. (Williams.)

B. Binary granite from Guilford, Howard County. Contains quartz, orthoclase, a little plagioclase, muscovite, and biotite, with occasional zircon and apatite. (Keyes.)

C. Biotite-granite from Woodstock. Light colored, fine grained. Quartz, feldspar, and biotite, with accessory allanite and epidote. (Keyes.)

D. Biotite-granite from Rowlandville, Cecil County. Dark colored. Contains plagioclase, orthoclase, quartz, epidote, biotite, sphene, magnetite, and apatite, with a little secondary muscovite. The percentages of the several minerals are computed by Grimsley from the analysis.

Analyses by W. F. Hillebrand, record Nos. 1220, 1422, 1455. In B and C manganese was present, barium and strontium were not tested for, and the alumina contains possible titanium and phosphoric acid.

	A.	B.	C.	D.
SiO ₂	74.87	72.57	71.79	66.68
TiO ₂ .....	.05	Undet.	Undet.	.50
Al ₂ O ₃	14.27	13.11	15.00	14.93
Fe ₂ O ₃	Trace.	.59	.77	1.58
FeO .....	.51	1.02	1.12	3.32
MnO	Trace.	Undet.	Undet.	.10
CaO .....	.48	1.65	2.50	4.89
SrO		Undet.	Undet.	Trace.
BaO		Undet.	Undet.	.08
MgO .....	.16	.30	.51	2.19
K ₂ O	5.36	4.33	4.75	2.05
Na ₂ O	3.06	3.92	3.09	2.65
Li ₂ O	Trace.	Trace.	Trace.	Trace.
H ₂ O at 100° .....	.26	.47	.64	.16
H ₂ O above 100° .....	.66			1.09
P ₂ O ₅ .....	.21	Undet.	Undet.	.10
	99.89	99.96	100.17	100.32

E. Biotite-granite from Dorsey's Run, Howard County. Typical, dark colored. Quartz, feldspar, and biotite, with accessory allanite and epidote. (Keyes.)

F. Same locality, light-colored dikes.

G. Inclusions in E. Derived from gneiss.

H. The typical gneiss of the Dorsey's Run area. Perhaps of sedimentary origin.

Descriptions by Keyes. Analyses by Hillebrand. The remarks appertaining to B and C apply here also. Record No. 1220.

	E.	F.	G.	H.
SiO ₂	62.91	70.45	57.33	48.92
Al ₂ O ₃	19.13	15.98	15.31	16.57
Fe ₂ O ₃.....	.98	.75	3.39	4.21
FeO.....	3.20	1.84	8.19	9.18
CaO.....	4.28	2.60	3.95	9.69
MgO.....	1.69	.77	4.36	5.98
K ₂ O.....	3.38	3.59	4.57	1.56
Na ₂ O.....	3.94	3.83	1.22	2.47
Li ₂ O.....	Trace.	Trace.	Trace.	Trace.
H ₂ O.....	.63	.45	1.80	1.68
	100.14	100.26	100.12	100.26

I. Biotite-granite from Sykesville. Contains quartz, feldspar, and biotite, with accessory magnetite, zircon, and apatite.

J. Inclusion in I, derived from limestone. Yellowish central portion. Consists of epidote and quartz, with a little chlorite.

K. Same inclusion, fine-grained dark outer zone. Quartz, garnet, and epidote, with a little magnetite. Feldspar and muscovite in some portions. Descriptions by Keyes. Analyses by Hillebrand, record No. 1220, with the same limitations as in the Guilford, Woodstock, and Dorsey's Run granites.

	I.	J.	K.
SiO ₂	71.45	67.02	47.35
Al ₂ O ₃	14.36	13.77	29.76
Fe ₂ O ₃	2.07	4.64	2.94
FeO.....	2.78	1.02	3.15
CaO.....	1.58	11.09	2.20
MgO.....	1.17	.65	1.60
K ₂ O.....	3.28	.09	6.83
Na ₂ O.....	1.95	.66	2.84
Li ₂ O.....	Trace.	Trace.	Trace.
H ₂ O.....	1.30	1.16	3.15
	99.94	100.10	99.82

L. Typical gneiss of Washington, D. C. Quarry of Potomac Stone Company, 1 mile below Chain Bridge. A basic granite.

M. Fine-grained, fissile, chloritic gneiss, from northwest of Cabin John Bridge. Also a basic granite.

N. Fine-grained, hard gneiss from the second lock at the Great Falls of the Potomac. Probably of sedimentary origin.

Described by Williams. Analyses by Hillebrand, record No. 1459.

	L.	M.	N.
SiO ₂	67.22	63.43	78.28
TiO ₂ .....	.84	.91	.70
Al ₂ O ₃	15.34	16.69	9.96
Fe ₂ O ₃	2.78	3.36	1.85
FeO	3.41	3.87	1.78
MnO .....	.13	.09	.08
CaO	1.36	.80	1.68
SrO	Trace.	Trace.	Trace.
BaO .....	.04	.03	.02
MgO	1.65	2.33	.95
K ₂ O	3.26	3.22	1.35
Na ₂ O	2.00	2.38	2.73
Li ₂ O	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.29	.23	.12
H ₂ O above 110°	1.68	2.67	.83
P ₂ O ₅ .....	.14	.11	.11
	100.14	100.12	100.44

To these may be added three analyses of feldspars from the pegmatite of Jones Falls, Baltimore. Described by S. L. Powell in Johns Hopkins Univ. Circular, vol. 12, p. 49. Analyses by W. F. Hillebrand, record No. 1421.

O. Flesh-colored microcline.

P. Green microcline.

Q. Albite-oligoclase, near Ab_4An .

	O.	P.	Q.
SiO ₂	65.06	68.48	63.72
Al ₂ O ₃	18.41	16.11	22.26
Fe ₂ O ₃	Trace.	.20	Trace.
FeO.....		.17	
CaO.....	.26	.23	3.58
SrO.....	Trace.	Trace.	Trace.
BaO.....	.13	.05	.....
MgO.....	.04	.03	.06
K ₂ O.....	14.30	12.99	.76
Na ₂ O.....	1.60	1.27	8.98
H ₂ O at 100°.....	.04	.06	.09
H ₂ O above 100°.....	.26	.26	.43
	100.10	99.85	99.88

P contained a little unseparated quartz. All three contained traces of lithia. In O and Q the traces of iron were weighed with the alumina.

4. MISCELLANEOUS ROCKS.

A. Typical diabase, Rocky Ridge. Analyzed for J. S. Diller, but not described. Analysis by E. A. Schneider, record No. 1370.

B. Ottrelite-phyllite rock from Liberty, Frederick County. Analyzed for S. H. Williams, but not described.

C. Ottrelite separated from B. Analyses B and C by L. G. Eakins, record No. 1349.

D. Quartz-schist, Shoemaker quarry, near Stevenson Station, Green Spring Valley. Described by Bayley for the Educational Series of Rocks. Contains quartz, muscovite, occasional tourmalines, microcline, zircon, and iron stains. Analysis by Schneider, No. 1370.

E. Mica separated from D. Analysis by Schneider, No. 1377.

F. Sericite-schist from Ladiesburg. Described by Bayley for the Educational Series. Contains quartz, sericite, chlorite, a mineral thought to be kaolin, zircon, iron oxide, and rutile. Analysis by George Steiger, record No. 1600.

G. Another sample of F. Analysis by Schneider, No. 1370.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	51.68	34.92	23.40	91.65	44.93	57.24	58.11
TiO ₂ .....	.72	3.37	1.19	.13	1.05	.08	.81
Al ₂ O ₃	15.87	32.31	39.31	1.59	29.81	23.48	21.84
Fe ₂ O ₃	1.46	10.21	5.14	3.57	6.10	3.19	2.62
FeO	8.43	8.46	21.94	.21		4.87	5.63
MnO .....	.15	Trace.	Trace.	Trace.	Trace.	None.	.19
CaO	11.08	.36	Trace.	None.	.....	.09	None.
MgO	7.84	1.13	2.18	.17	1.16	.93	1.85
K ₂ O .....	.34	1.87	.20	1.93	10.28	3.55	3.66
Na ₂ O	1.86	2.12	.20	.07	.50	1.18	.97
Li ₂ O .....	.....	.....	.....	.....	Trace.	.....	.....
H ₂ O at 100° ..	.16	5.29	6.81	.....	1.38	.33	.35
H ₂ O above 100°	.15			.60	4.88	4.65	4.05
P ₂ O ₅ .....	.12	.23	Trace.	None.	.....	.09	.21
F .....	.....	.....	.....	.....	.22	.....	.....
	99.86	100.27	100.37	99.92	100.31	99.68	100.29

VIRGINIA.

Andesite from $3\frac{1}{2}$ miles east of Front Royal. Described by Keith in 14th Ann., p. 305. Intermediate between diabase and quartz-porphry. Contains plagioclase, quartz, magnetite, ilmenite, and a little epidote. Analysis by George Steiger, record No. 1450.

SiO ₂	51.08	K ₂ O	1.50
TiO ₂	2.67	Na ₂ O	5.54
Al ₂ O ₃	11.37	H ₂ O at 100° .....	.19
Fe ₂ O ₃	11.17	H ₂ O above 100°	1.31
FeO	5.64	P ₂ O ₅ .....	.39
MnO .....	.22		
CaO	5.20		100.24
MgO	3.96		

NORTH CAROLINA.

1. ROCKS FROM CORUNDUM HILL.

Collected, analyzed, and described by T. M. Chatard, Bull. 42, p. 45.

A. Altered gneiss. Made up of micaceous scales, with grains of quartz and some earthy matter.. Record No. 238.

B. Dunite. Olivine rock containing a little chromite. Record No. 256.

C, D. Yellow, clay-like alterations of dunite. Record Nos. 254, 255.

Other analyses of altered rocks are given in the paper, and also analyses of associated minerals.

	A.	B.	C.	D.
SiO ₂	64.27	40.11	40.18	40.04
TiO ₂	1.32	.....	None.	None.
Al ₂ O ₃	16.75	.88	1.35	3.17
Cr ₂ O ₃ .....	.....	.18	1.41	.....
Fe ₂ O ₃	6.08	1.20	10.97	12.15
FeO .....	.89	6.09	.....	.....
MnO .....	.07	.....	.....	.....
CaO .....	.25	.....	.....	.....
MgO	1.74	48.58	43.84	42.97
K ₂ O	3.09	.....	.....	.....
Na ₂ O .....	.89	.....	.....	.....
H ₂ O (Ign.)	4.97	2.74	2.01	2.14
P ₂ O ₅ .....	.05	.....	.....	.....
Chromite .....	.....	.56	.....	.17
	100.37	100.34	99.76	100.64

2. PYROXENITE FROM WEBSTER.

"Websterite." Described by Williams, Amer. Geologist, v. 6, p. 35. Consists of diopside and bronzite. Analysis by E. A. Schneider, record No. 1096. Material dried at 105°.

SiO ₂	55.14	MgO	26.66
TiO ₂	Trace.	CaO	8.39
Al ₂ O ₃ .....	.66	Na ₂ O .....	.30
Cr ₂ O ₃ .....	.25	H ₂ O .....	.38
Fe ₂ O ₃	3.48	P ₂ O ₅ .....	.23
FeO	4.73		
MnO .....	.03		100.36
NiO .....	.11		

KENTUCKY.

1. THE ELLIOTT COUNTY DIKE.

Described by Diller in Bull. 38. Also in Amer. Journ. Sci., 3d series, v. 32, p. 125.

A peridotite, consisting largely of olivine, sometimes altered to serpentine. Pyrope, ilmenite, a few scales of biotite, a little enstatite, and a trace of apatite are present as primary minerals. Secondary minerals are serpentine, dolomite, magnetite, and octahedrite.

A granitic rock occurs with the peridotite. It consists chiefly of feldspar, orthoclase, and plagioclase, with a considerable amount of quartz and ilmenite, and traces of hornblende, sphene, and apatite.

Analyses by T. M. Chatard, record Nos. 272, 273, 282, 305, 351, 352, 353, 354, and 358.

A. Granite.

B. Peridotite.

C. Olivine from peridotite.

D. Garnet from peridotite.

E. Ilmenite from peridotite.

The following analyses are of sedimentary rocks adjoining the dike:

F. Calcareous sandstone.

G. Fine-grained fissile sandstone.

H. Indurated shale.

I. Fragment of shale included in the peridotite.

	A.	B.	C.	D.	E.
SiO ₂	60.56	29.81	40.05	41.32	.76
TiO ₂	1.19	2.20	.07	.16	49.32
Al ₂ O ₃	16.19	2.01	.39	21.21	2.84
Cr ₂ O ₃ .....	.....	.43	.24	.91	.74
Fe ₂ O ₃	5.19	5.16	2.36	4.21	9.13
FeO	2.41	4.35	7.14	7.93	27.81
MnO .....	.36	.23	.20	.34	.20
NiO .....	.....	.05	.....	.....	.....
CoO .....	.....	.....	Trace.	.....	.....
CaO	2.09	7.69	1.16	4.94	.23
MgO	1.30	32.41	46.68	19.32	8.68
K ₂ O	4.82	.20	.21	.....	.19
Na ₂ O	4.78	.11	.08	.07	
P ₂ O ₅ .....	.30	.35	.04	None.	Trace.
CO ₂ .....	.....	6.66	?	.....	.....
SO ₃ .....	.....	.28	.....	.....	.....
H ₂ O, 110° .....	.....	} 8.92	.14	} .17	} .20
H ₂ O, ign .....	.51		.66		
	99.70	100.86	99.42	100.58	100.10

	F.	G.	H.	I.
SiO ₂	60.78	60.25	41.32	35.53
TiO ₂ .....	.03	.23	.48	.95
Al ₂ O ₃	10.54	20.18	20.71	18.23
Cr ₂ O ₃ .....	.....	.....	Trace.	.....
Fe ₂ O ₃	3.27	1.53	2.59	2.46
FeO .....	.....	3.42	5.46	4.81
MnO .....	.10	.10	.17	.13
CaO	10.15	.51	9.91	21.17
MgO	1.59	3.52	1.91	2.01
K ₂ O	2.36	3.17	.88	1.08
Na ₂ O	1.41	.39	7.19	2.53
P ₂ O ₅ .....	.09	.10	.08	.08
CO ₂	6.29	.....	.55	.88
H ₂ O, 110° .....	.85	1.94	.....	1.40
H ₂ O, ign	2.32	5.17	8.78	9.00
	99.78	100.51	100.03	100.26

"H" was dried five hours at 110°, previous to analysis.

2. THE CRITTENDEN COUNTY DIKE.

A mica-peridotite, described by Diller in Amer. Journ. Sci., 3d series, vol. 44, p. 286. Contains biotite, serpentine, and perovskite, with less apatite, muscovite, magnetite, calcite, chlorite, and some other secondary products.

A. The rock described by Diller. Analysis by W. F. Hillebrand, record No. 1241.

B. An unpublished analysis of probably the same rock, from a shaft 40 feet deep at Marion. Collected by J. R. Procter, analyzed by L. G. Eakins, record No. 965.

	A.	B.
SiO ₂	33.84	34.50
TiO ₂	3.78	.....
Al ₂ O ₃	5.88	14.37
Cr ₂ O ₃.....	.18	.....
Fe ₂ O ₃	7.04	2.85
FeO.....	5.16	4.46
MnO.....	.16	.....
NiO.....	.10	.....
CoO.....	Trace.	.....
CaO.....	9.46	11.43
BaO.....	.06	.....
MgO.....	22.96	21.81
K ₂ O.....	2.04	1.50
Na ₂ O.....	.33	.51
H ₂ O.....	7.50	7.14
P ₂ O ₅.....	.89	.77
Cl.....	.05	.....
CO ₂.....	.43	.21
SO ₃.....	.....	.60
	99.86	100.15

MISSOURI.

Granite and porphyry, from 6 miles east of Ironton. Described by Haworth in Mo. Geol. Survey, vol. 8, Annual Report, pp. 140, 180, and 213. Analyses by W. H. Melville, record No. 1206.

A, B. Granite.

C, D. Porphyry.

Rocks composed principally of orthoclase and quartz, with some microcline, plagioclase, and biotite, and minor accessory minerals.

	A.	B.	C.	D.
SiO ₂	69.94	72.35	71.33	71.88
TiO ₂.....	.25	.44	.55	.22
Al ₂ O ₃	15.19	13.78	12.55	12.88
Fe ₂ O ₃	1.88	1.87	3.75	3.05
FeO.....	.60	.36	.85	1.05
NiO.....	Trace.	.20	.15	.02
MnO.....	.03	.06	.04	Trace.
CaO.....	1.15	.87	.94	1.13
MgO.....	.92	.42	.58	.33
K ₂ O.....	4.29	4.49	4.20	4.46
Na ₂ O.....	3.95	4.44	4.52	4.21
H ₂ O at 100°.....	.14	.22	.12	.17
H ₂ O above 100°...	.85	.54	.30	.26
P ₂ O ₅.....	.13	.13	.16	.15
	99.32	99.87	100.04	99.81

ARKANSAS.

Ouachitite, from a dike near Maple Spring, 4 miles southwest of Hot Springs. Described by Kemp, in Ann. Rep. Geol. Survey Arkansas, 1890, vol. 2, p. 399. A dike rock of the monchiquite group. Contains abundant and conspicuous augite and biotite, magnetite, and minor accessory minerals in a groundmass considered by Kemp as glass. Calcite and other secondary products are also present. According to Pirsson, Journ. Geol., vol. 4, p. 679, the so-called "glass" in the monchiquites is really analcite. Analysis by L. G. Eakins, record No. 1023.

SiO ₂	36.40	K ₂ O	3.01
TiO ₂ .....	.42	Na ₂ O .....	.97
Al ₂ O ₃	12.94	H ₂ O	2.36
Fe ₂ O ₃	8.27	P ₂ O ₅	1.04
FeO	4.59	CO ₂	3.94
CaO	14.46		
MgO	11.44		99.84

TEXAS.

Quartz-pantellarite from the Vieja Mountains, San Carlos, Presidio County. Description furnished by E. C. E. Lord. Contains anorthoclase, augite, and grains of quartz in a groundmass of ægirine-augite, a brown hornblende, which is probably barkevikite, orthoclase, and quartz. Magnetite and apatite are present as accessory minerals. Analysis by George Steiger, record No. 1581.

SiO ₂	68.71	K ₂ O	5.51
TiO ₂ .....	.21	Na ₂ O	4.63
Al ₂ O ₃	13.45	Li ₂ O	None.
Fe ₂ O ₃	5.31	H ₂ O at 100° .....	.13
FeO .....	.75	H ₂ O above 100° .....	.36
MnO .....	.14	P ₂ O ₅ .....	.04
CaO .....	.96	SO ₃ .....	.05
BaO	None.	CO ₂	None.
SrO	None.		
MgO .....	.19		100.44

THE LAKE SUPERIOR REGION.

1. THE MARQUETTE AND MICHIGAMME REGION, MICHIGAN.

Rocks mostly described by Van Hise and Bayley. When not otherwise specified the descriptions have been published in Mon. XXVIII, and partly in 15th Ann., p. 485. A to E are Huronian volcanics from the Michigamme iron district, analyzed by H. N. Stokes, record No. 1617. The hitherto unpublished descriptions of these were furnished by Professor Van Hise.

A. Mica-andesite. Contains plagioclase, biotite with secondary chlorite, iron ore, calcite, epidote, and sphene.

B. Labradorite-porphyrity. Contains plagioclase, epidote, chlorite, uraltite, titanomagnetite, sphene, and calcite.

C. Microphytic amygdaloidal basalt. Contains plagioclase, labradorite, uraltite, epidote, chlorite, sphene, and calcite.

D. Spilosite, a contact product of dolerite intrusion. Contains quartz, feldspar, chlorite, epidote, and a little biotite.

E. Spilosite. Contains quartz, feldspar, actinolite, and epidote.

	A.	B.	C.	D.	E.
SiO ₂	47.20	52.59	46.47	52.51	57.77
TiO ₂	3.30	1.36	1.28	1.70	.92
Al ₂ O ₃	15.36	15.93	16.28	19.00	19.35
Cr ₂ O ₃	None.	Trace.	.01	None.	None.
Fe ₂ O ₃	3.06	6.12	3.15	3.31	1.29
FeO	8.87	3.96	8.96	7.19	3.37
MnO .....	.20	.25	.09	Trace.	Trace.
CuO	Trace.	Trace.	Trace.		
CaO	5.05	5.55	7.90	1.55	1.71
SrO	Trace.	None.	None.	Trace.	Trace.
BaO	Trace.	Trace.	None.	Trace.	None.
MgO	4.20	5.04	6.56	3.29	4.35
K ₂ O	1.40	.67	.21	.70	.22
Na ₂ O	4.72	5.79	3.64	6.72	8.22
Li ₂ O	Trace.	None.	Trace.	Trace.	None.
H ₂ O at 110° .....	.16	.16	.28	.34	.18
H ₂ O above 110°	3.04	2.16	3.89	3.26	2.34
P ₂ O ₅ .....	.36	.15	.13	.15	.04
CO ₂	3.34	None.	1.26	None.	None.
S and SO ₃	Trace.	None.	None.	None.	None.
F	Trace.	Trace.	Trace.	Trace.	None.
	100.26	99.73	100.11	99.72	99.76

F. Peridotite. Near Opin Lake, E. $\frac{1}{4}$ sec. 27, T. 48 N., R. 27 W. Contains diallage, olivine, magnetite, and plagioclase. The diallage is partly chloritized, and the olivine is partly serpentinized. Analysis by W. F. Hillebrand, record No. 1452.

G. Altered greenstone, Marquette district. Analysis by George Steiger, record No. 1586, hitherto unpublished.

H. Grünerite-magnetite-schist, Sec. 11, T. 47 N., R. 27 W. Mainly impure grünerite, with magnetite and quartz. Analysis by W. H. Melville, record No. 1403.

I. Like H, from sec. 18, T. 47 N., R. 28 W. Analysis by Melville, record No. 1403.

J. Like H and I, from sec. 20, T. 46 N., R. 30 W. Analysis by H. N. Stokes, record No. 1546. H, I, and J are similar schists, and alike in mineralogical composition.

	F.	G.	H.	I.	J.
SiO ₂	39.37	48.85	46.94	49.70	46.25
TiO ₂ .....	.66	1.28	None.	.....	None.
Al ₂ O ₃	4.47	15.83	.66	1.35	.92
Cr ₂ O ₃ .....	.68	.....	.....	.....	.....
Fe ₂ O ₃	4.96	2.50	4.51	3.10	30.62
FeO	9.13	10.79	33.72	37.19	16.92
MnO .....	.12	.11	.31	.93	1.01
NiO .....	.21	.....	.....	.....	None.
CuO .....	.....	.....	.....	.....	Trace.
CaO	3.70	6.20	3.22	.68	1.69
SrO	Trace.	.09	.....	.....	None.
BaO	Trace.	None.	.....	.....	None.
MgO	26.53	5.82	6.64	5.72	2.13
K ₂ O .....	.26	1.31	.....	.....	None.
Na ₂ O .....	.50	2.79	.16	Trace.	None.
H ₂ O at 110° .....	.87	.27	.67	1.40	.42
H ₂ O above 110°	7.08	3.77			
P ₂ O ₅ .....	.17	.22	.07	.12	.07
CO ₂	1.23	None.	2.79	.....	None.
SO ₃ .....	.....	.06	.....	.....	.....
	99.94	99.89	99.69	100.19	100.03

K. Green schist, from sec. 34, T. 48 N., R. 27 W. Near center of section. Contains plagioclase, chlorite, and quartz. Analysis by George Steiger, record No. 1447.

L. Sericite-schist associated with the preceding. Mainly sericite and quartz. Analysis by Steiger, No. 1447.

M. Dark-gray, foliated schist. SE. corner of sec. 30, T. 47 N., R. 30 W. Contains quartz, plagioclase, orthoclase, and biotite. Analysis by Steiger, No. 1525.

N. Schistose gneiss. NW. $\frac{1}{4}$ of sec. 35, T. 47 N., R. 26 W. Contains quartz, kaolin, sericite, plagioclase, chlorite, magnetite, and apatite. Analysis by Steiger, No. 1525.

O. Novaculite from Marquette. Described by Williams in Bull. 62. Contains quartz and sericite. Analysis by W. F. Hillebrand, record No. 759.

	K.	L.	M.	N.	O.
SiO ₂	61.35	70.76	63.50	82.38	76.99
TiO ₂ .....	.26	.33	.62	.14	.....
Al ₂ O ₃	16.45	14.83	17.89	11.32	13.92
Fe ₂ O ₃ .....	.94	1.46	1.12	.97	.45
FeO.....	4.20	3.09	5.38	.26	.77
MnO.....	.....	.....	Trace.	None.	Trace.
CaO.....	3.46	.36	2.34	.22	.32
MgO.....	3.12	1.99	1.22	.17	1.12
K ₂ O.....	1.05	3.50	2.43	1.04	3.65
Na ₂ O.....	5.24	.47	2.55	.59	.56
Li ₂ O.....	.....	.....	.....	.....	Trace.
H ₂ O at 100° .....	.10	.09	.22	.18	} 2.35
H ₂ O above 100°	2.51	2.70	2.04	2.33	
P ₂ O ₅.....	.18	.26	.19	.09	Trace.
CO ₂	1.98	.....	.....	.....	.....
	100.84	99.84	99.50	99.69	100.13

2. THE MENOMINEE RIVER.

1ST. THE STURGEON FALLS GABBRO.

From Sturgeon Falls, Menominee River, sec. 27, T. 39 N., R. 29 W., Michigan. Described by Williams, Bull. 62, p. 67.

A. Saussurite-gabbro. Contains plagioclase, almost wholly altered to saussurite, diallage, hornblende, and ilmenite, with quartz, calcite, and chlorite as alteration products.

B. The same, altered and somewhat schistose. Feldspar much altered into calcite, with secondary quartz and sericite; pyroxene and hornblende changed to chlorite. Leucoxene common.

C. Light-gray, silvery schist, derived from gabbro. Contains chlorite, calcite, and a little quartz, with remnants of feldspar and some leucoxene. Analyses by R. B. Riggs, record Nos. 389, 390, 391. Material dried at 105°. TiO_2 undetermined.

	A.	B.	C.
SiO_2	51.46	38.05	45.70
Al_2O_3	14.35	24.73	16.53
Fe_2O_3	3.90	5.65	4.63
FeO	5.28	6.08	3.89
CaO	9.08	1.25	4.28
MgO	9.54	11.58	9.57
K_2O} .....	.24	1.94	3.82
Na_2O	2.92	2.54	.55
CO_2 .....	.20	.93	5.95
H_2O	3.30	7.53	4.70
	100.27	100.28	99.62

2D. LOWER QUINNESEC FALLS, MENOMINEE RIVER.

Described by Williams, Bull. 62, pp. 89, 91.

A. Gabbro-diorite, shore below falls, Wisconsin side. Contains saussurite, hornblende, and ilmenite. Some calcite in the saussurite. Hornblende partly altered to chlorite and ilmenite to leucoxene.

B. The same, schistose form. Contains less saussurite. Hornblende and ilmenite completely altered into chlorite and leucoxene. Calcite present, and also porphyritic feldspar.

C. Silvery schist, adjoining B, and derived from gabbro. Resembles B in general, without the feldspar crystals. Calcite and sericite are present, and rutile in place of leucoxene.

D. Dark, massive greenstone. Contains hornblende, chlorite, epidote, quartz, leucoxene, with some ilmenite and traces of original feldspar.

E. Dark, schistose greenstone, forming a band in D. Chlorite entirely replaces hornblende, and rutile replaces leucoxene. Some feldspar, quartz, and calcite.

Analyses by R. B. Riggs, record Nos. 384, 385, 386, 387, 388. Material dried at 105°.

	A.	B.	C.	D.	E.
SiO ₂	47.96	49.19	46.21	43.80	44.49
Al ₂ O ₃	16.85	18.71	18.38	16.08	16.37
Fe ₂ O ₃	4.33	5.03	3.30	9.47	5.07
FeO.....	4.17	4.04	3.90	10.50	5.50
CaO.....	13.25	5.92	6.28	7.81	7.94
MgO.....	9.15	7.98	7.03	6.54	7.50
K ₂ O.....	.30	.77	.35	.34	.56
Na ₂ O.....	1.25	1.44	2.14	1.96	2.59
CO ₂.....	.08	1.82	8.32	.08	5.38
H ₂ O.....	2.89	5.05	3.82	3.99	4.99
	100.23	99.95	99.73	100.57	100.39

3D. UPPER QUINNESEC FALLS, MENOMINEE RIVER.

Described by Williams, Bull. 62, pp. 104, 113, 114, 121.

A. Light greenstone. Contains hornblende, feldspar much altered to saussurite, ilmenite with leucoxene border, and some secondary quartz.

B. Mica-diorite-porphyry. Mainly andesitic feldspar and biotite, with apatite, zircon, sphene, and some calcite.

C. Biotite-gneiss from Michigan side. Contains biotite, soda-orthoclase, and quartz. Sphene common, zircon and apatite present.

D. Schistose quartz-porphyry. Contains quartz, feldspar, sericite, some chlorite, anatase, and tourmaline, with zircon and apatite sparingly.

A, B, and D are from the Wisconsin side of the river.

Analyses by R. B. Riggs, record Nos. 392, 393, 394, 395. Material dried at 105°.

	A.	B.	C.	D.
SiO ₂	48.35	54.83	67.77	66.69
Al ₂ O ₃	15.40	25.49	16.61	16.69
Fe ₂ O ₃	4.04	1.61	2.06	2.06
FeO	4.63	1.65	1.96	.93
CaO	10.38	6.08	1.87	1.40
MgO	11.61	1.96	1.26	1.15
K ₂ O .....	.35	1.87	2.35	5.23
Na ₂ O	1.87	5.69	4.35	2.46
CO ₂ .....	.08	.18	.19	1.42
H ₂ O	3.60	1.18	1.69	1.70
	100.31	100.54	100.11	99.73

3. THE PENOKEE-GOGEBIC REGION.

Rocks mostly described by Van Hise in Mon. XIX. Analyses A to G by T. M. Chatard, record Nos. 991, 992, 993, 994, 995.

A. Diabase from near SE. corner of sec. 13, T. 47 N., R. 46 W., Michigan. Contains plagioclase, augite, magnetite, apatite, and olivine, with some ilmenite and leucoxene.

B. Same dike as A, partly altered. The pyroxene is altered to amphibole, and the latter partly to biotite. Biotite has also been derived from feldspar.

C. Feldspar separated from A.

D. Altered diabase from the Aurora mine, NE. $\frac{1}{4}$ of SW. $\frac{1}{4}$ of T. 47 N., R. 47 W., Michigan.

	A.	B.	C.	D.
SiO ₂	47.90	46.85	51.18	41.60
TiO ₂ .....	.82	1.12	.....	3.79
Al ₂ O ₃	15.60	22.62	27.00	37.20
Cr ₂ O ₃	Trace.	.....	.....	.....
Fe ₂ O ₃	3.69	5.12	3.19	3.21
FeO	8.41	1.58	Undet.	.30
MnO .....	.17	2.54	.17	.08
NiO .....	.10	.08	.....	.....
CaO	9.99	1.25	11.70	.23
BaO .....	.05	.10	.....	Trace.
MgO	8.11	2.01	1.92	.02
K ₂ O .....	.23	2.66	.41	.....
Na ₂ O	2.05	.80	3.48	.07
H ₂ O at 105° .....	.15	3.12	} 1.19	.29
H ₂ O above 105°	2.34	8.25		13.54
P ₂ O ₅ .....	.13	.16	.....	.14
CO ₂ .....	.38	1.89	.....	.38
	100.12	100.15	100.24	100.85

E. Feldspar separated from gabbro; southern half of sec. 14, T. 44 N., R. 4 W., Wisconsin.

F, G. Feldspars separated from olivine-diabase; NE. $\frac{1}{4}$ of sec. 13, T. 45 N., R. 1 W., Wisconsin.

	E.	F.	G.
SiO ₂	51.99	61.65	56.15
Al ₂ O ₃	29.32	19.91	26.05
Fe ₂ O ₃	1.23	2.28	1.98
FeO.....	Trace.	Undet.	Undet.
MnO.....		Trace.	.13
CaO.....		4.12	8.70
MgO.....	.63	.61	.54
K ₂ O.....	.28	5.72	1.56
Na ₂ O.....	2.91	4.74	4.79
H ₂ O at 105°.....	.03	.95	.13
H ₂ O above 105°.....	.54		.64
	99.53	99.98	100.67

The following analyses, by W. F. Hillebrand, of separations from the gabbro of Ashland County, Wisconsin, were made for the late R. D. Irving, but were never published by him:

H. Magnetite, record No. 687. Partial analysis.

I. Feldspar, record No. 688.

J. Diallage, record No. 686.

For convenience I also include here, although it is decidedly out of classification—

K. Graywacke, Hurley, Wisconsin. Collected for the Educational Series of Rocks. Analysis by H. N. Stokes, record No. 1314. Examined by W. S. Bayley. Contains quartz, feldspars, iron oxides, and probably kaolin. In the cement are chlorite, quartz, magnetite, pyrite, rutile, occasionally biotite, and either muscovite or kaolin.

	H.	I.	J.	K.
SiO ₂ .....	.....	53.30	49.80	76.84
TiO ₂	8.77	Trace.	1.29	.....
Al ₂ O ₃ .....	.....	29.03	2.86	11.76
Fe ₂ O ₃	50.29	.55	2.48	.55
FeO	30.70	.23	10.82	2.88
MnO .....	.....	None.	.37	Trace.
CaO .....	.....	11.40	16.50	.70
SrO .....	.....	Trace.	None.	.....
BaO .....	.....	Trace.	None.	.....
MgO .....	.....	.13	15.33	1.39
K ₂ O .....	.....	.40	.12	1.62
Na ₂ O .....	.....	4.87	.51	2.57
Li ₂ O .....	.....	None.	Trace?	.....
H ₂ O .....	.....	.23	.33	1.87
P ₂ O ₅ .....	.....	Trace.	Trace.	.....
	89.46	100.14	100.41	100.18

4. ROCKS OF PIGEON POINT, MINNESOTA.

Described by Bayley in Bull. 109. Also partially in Amer. Journ. Sci., 3d series, v. 37, p. 54.

A. Olivine-gabbro. Contains labradorite, olivine, pyroxene, apatite, and magnetite. Analysis by W. F. Hillebrand, record No. 496.

B. Diallage separated from gabbro. Partial analysis by R. B. Riggs, record No. 607.

C. Rock lying between the gabbro and the adjacent red porphyry. Contains red feldspar, quartz, hornblende, chlorite, magnetite, apatite, and rutile. Analysis by W. F. Hillebrand, record No. 500.

	A.	B.	C.
SiO ₂	49.88	48.34	57.98
TiO ₂	1.19	1.98	1.75
ZrO ₂	None.		
Al ₂ O ₃	18.55	2.90	13.58
Fe ₂ O ₃	2.06	4.68	3.11
FeO	8.37	14.15	8.68
MnO .....	.09		.13
CaO	9.72	15.10	2.01
SrO	Trace.		Trace.
BaO .....	.02		.04
MgO	5.77	11.34	2.87
K ₂ O .....	.68		3.44
Na ₂ O	2.59		3.56
Li ₂ O	None.		Trace.
H ₂ O	1.04		2.47
P ₂ O ₅ .....	.16		.29
Cl.	Trace.		Trace.
	100.12	98.49	99.91

D. Red soda-granite. Contains feldspar, quartz, chlorite, some muscovite, rutile, leucoxene, hematite and apatite, with sometimes secondary calcite. Granular variety. Analysis by W. F. Hillebrand, record No. 495. Dried at 110°.

E. Same as D, porphyritic variety. Called by Bayley a quartz-keratophyre. Analysis by Hillebrand, record No. 497.

F. Similar red porphyry from Little Brick Island, Lake Superior, near Pigeon Point. Consists chiefly of feldspar and quartz, with augite occasionally present. Analysis by L. G. Eakins, record No. 1059.

G. Red feldspar, anorthoclase, separated from D. Contains hematite inclusions. Analysis by J. E. Whitfield, record No. 521. Dried at 104°.

	D.	E.	F.	G.
SiO ₂	72.42	74.00	73.70	65.00
TiO ₂.....	.40	.34	.12	.....
Al ₂ O ₃	13.04	12.04	12.87	18.22
Fe ₂ O ₃.....	.68	.78	3.76	2.64
FeO.....	2.49	2.61	.31	.....
MnO.....	.09	.05	.07	.....
CaO.....	.66	.85	.14	1.06
SrO.....	Trace?	Trace.	.....	.....
BaO.....	.15	.12	.....	.....
MgO.....	.58	.42	.11	.06
K ₂ O.....	4.97	4.33	4.56	4.18
Na ₂ O.....	3.44	3.47	3.63	8.40
Li ₂ O.....	Trace?	Trace?	.....	.....
H ₂ O.....	1.21	.86	.57	.46
P ₂ O ₅.....	.20	.06	Trace.	.....
Cl.....	Trace.	Trace.	.....	.....
	100.33	99.93	99.84	100.02

H. Dark vitreous quartzite. Contains quartz, a little red feldspar, some chlorite, some green mica, a few scales of biotite, and grains of magnetite.

I. Lighter interbedded quartzite. Feldspar in it much altered.

J. Epidotic quartzite.

K. Unaltered quartzite.

Analyses by R. B. Riggs, record Nos. 569, 571, 572, 575. Material dried at 105°. Ba and Sr not looked for.

	H.	I.	J.	K.
SiO ₂	74.22	73.65	73.14	73.64
TiO ₂ .....	.16	Trace?	.04	Trace.
Al ₂ O ₃	10.61	11.08	12.60	11.25
Fe ₂ O ₃	7.45	7.24	7.57	6.24
FeO .....	.85	.77	1.31	1.04
MnO	None.	Trace.	Trace.	None.
CaO .....	.56	.40	.43	.36
MgO	1.48	1.52	1.67	1.57
K ₂ O	1.08	1.65	1.00	1.42
Na ₂ O	2.12	1.67	1.78	3.04
Ign	1.79	1.88	.83	1.98
	100.32	99.86	100.37	100.54

L. Altered quartzite. Contains more fibrous chlorite, some sericite, a little kaolin and biotite, grains of magnetite, earthy matter, and sometimes a little calcite. Analysis by R. B. Riggs, record No. 570.

M. Mottled quartzite. Analysis by Riggs, record No. 573.

N. Purplish slate, containing many small crystals of red feldspar and scales of mica. Analysis by J. E. Whitfield, record No. 520.

O. Very slightly altered slate. Analysis by Riggs, record No. 576.

Material for analysis dried at 104°-105°.

Ba and Sr not looked for.

	L.	M.	N.	O.
SiO ₂	71.00	72.25	63.82	59.71
TiO ₂.....	.44	Trace.	2.66	Trace.
Al ₂ O ₃	12.88	10.73	14.65	18.32
Fe ₂ O ₃	6.69	8.01	3.16	8.11
FeO.....	.65	.38	5.12	.85
MnO.....	Trace.	Trace.	None.	None.
CaO.....	.21	.42	.70	1.05
MgO.....	1.68	1.85	2.08	3.54
K ₂ O.....	2.95	2.56	2.81	3.43
Na ₂ O.....	1.43	2.03	1.95	1.93
Li ₂ O.....			None.	
H ₂ O.....	2.03	2.05	2.62	3.24
P ₂ O ₅.....			.19	
SO ₃.....			.33	
	99.96	100.28	100.09	100.18

P. Red granitic rock resembling D, but with more dark spots, found in contact with the purplish slate, N. Consists mainly of red feldspar, quartz, and chlorite. Analysis by J. E. Whitfield, record No. 519. Dried at 104°.

Q. Groundmass of red mottled quartzite. Analysis by W. F. Hillebrand, record No. 499.

R. Green mottlings from Q. Mostly quartz and sericite. Analysis by Hillebrand, record No. 498.

S. Another sample of the green mottlings, selected with especial care. Analysis by L. G. Eakins, record No. 1058.

T. Brilliantly red vitreous quartzite. Analysis by R. B. Riggs, record No. 574. Dried at 105°.

	P.	Q.	R.	S.	T.
SiO ₂	68.36	76.57	77.70	83.27	83.69
TiO ₂	1.57	.42	.30	Trace.	Trace ?
ZrO ₂		None.			
Al ₂ O ₃	13.76	9.21	7.67	7.81	7.50
Fe ₂ O ₃	2.65	1.67	3.55	1.99	1.81
FeO	2.75	3.94	3.29	1.81	.38
MnO	Trace.	.05	.04		Trace.
CaO .....	.70	.73	.26	.20	.39
SrO	Undet.	Trace ?	?		Undet.
BaO	Undet.	None.	None.		Undet.
MgO .....	.68	1.51	1.83	1.59	.35
K ₂ O	4.48	1.02	1.04	1.11	2.61
Na ₂ O	3.56	3.07	1.96	.19	2.46
Li ₂ O	None.	Trace.	Trace.		
H ₂ O .....	.98	1.89	2.36*	2.32	.72
P ₂ O ₅ .....	.33	Trace.	None.	Trace.	
SO ₃ .....	.66				
	100.48	100.08	100.00	100.29	99.91

* Determined by difference.

5. MISCELLANEOUS ROCKS FROM MINNESOTA.

A. Granulitic hypersthene-gabbro. From SE. $\frac{1}{4}$ sec. 20, T. 65 N., R. 4 W. Described by Bayley, Journal of Geology, vol. 3, p. 1. Contains hypersthene, biotite, diallage, magnetite, and plagioclase. Poor in feldspar. Analysis by H. N. Stokes, record No. 1267.

B. Hypersthene from A. Analysis by E. A. Schneider, record No. 1358.

C. Granulitic diallage-gabbro. SE. $\frac{1}{4}$ of NW. $\frac{1}{4}$ of sec. 26, T. 64 N., R. 8 W. Described by Bayley, Journ. Geol., vol. 3, p. 1. Contains diallage, hypersthene, magnetite, and plagioclase. Analysis by W. H. Melville, record No. 1403.

D. Olivine-gabbro. West side of Birch Lake, SE. $\frac{1}{4}$ of sec. 19, T. 63 N., R. 4 W. Described by Bayley, Journ. Geol., vol. 1, p. 688. Contains a large proportion of diallage and olivine. Analysis by Stokes, No. 1267.

E. Olivine from D. Analysis by W. F. Hillebrand, record No. 1308.

	A.	B.	C.	D.	E.
SiO ₂	46.96	48.44	49.56	45.66	35.58
TiO ₂ .....	.62	Undet.	.48	.92	1.22
Al ₂ O ₃	14.13	7.91	17.81	16.44	.92
Cr ₂ O ₃	Trace.	.....	.....	Trace.	Trace.
Fe ₂ O ₃ .....	.76	.33	2.76	.66	} 33.91
FeO.....	14.95	20.88	9.48	13.90	
MnO .....	.93	.92	.06	Trace.	.35
CoO.....	.....	.....	.....	.....	} .20
NiO .....	.06	.....	.....	.16	
CaO.....	2.32	1.44	9.70	7.23	.90
MgO	15.97	19.35	5.93	11.57	26.86
K ₂ O	1.68	.....	.....	.41	.....
Na ₂ O .....	.35	.....	2.87	2.13	.....
H ₂ O at 105°.....	.07	.08	} .50	.07	.11
H ₂ O above 105°.	1.26	None.		.83	.20
P ₂ O ₅.....	.03	.....	.67	.05	.....
CO ₂ .....	.....	.....	Trace.	.....	.....
	100.09	99.35	99.82	100.03	100.25

F. Average gabbro. South quarter post, sec. 35, T. 61 N., R. 12 W. Described by Bayley in Journ. Geol., vol. 1, p. 688. Contains plagioclase, olivine, pyroxene, and magnetite. Analysis by H. N. Stokes, record No. 1267.

G. Feldspar from preceding gabbro. Analysis by W. F. Hillebrand, record No. 1308.

H. Feldspar from gabbro, east side of North Fowl Lake. Analysis by Hillebrand, No. 1308.

I. Feldspar from gabbro. NW. $\frac{1}{4}$ of SE. $\frac{1}{4}$ of Sec. 23, T. 62 N., R. 10.

J. Feldspar from gabbro. Center of Sec. 25, T. 64 N., R. 8.

K. Feldspar from gabbro; Duluth and Iron Range R. R.

Analyses I, J, K, by Hillebrand, record No. 1115.

H, I, J, K analyzed for W. S. Bayley, but analyses hitherto unpublished.

	F.	G.	H.	I.	J.	K.
SiO ₂	46.45	51.89	62.71	52.50	52.61	53.45
TiO ₂	1.19	.....	Trace.	Trace.	Trace.	Trace.
Al ₂ O ₃	21.30	29.68	19.20	30.15	29.80	29.77
Fe ₂ O ₃ .....	.81	.32	1.08	.47	.57	.33
FeO	9.57	.37	.93	.15	.23	.15
NiO .....	.04	.....	.....	.....	.....	.....
MnO	Trace.	.....	Trace.	.....	Trace.	.....
CaO	9.83	12.62	.44	12.82	12.25	11.33
SrO .....	.....	.....	Trace.	.....	.....	.....
MgO	7.90	.38	.81	.10	.20	.11
K ₂ O .....	.34	.50	10.41	.53	.53	.68
Na ₂ O	2.14	3.87	2.96	3.72	3.80	4.33
H ₂ O at 100° .....	.14	.07	.23	} .25 }	} .29 }	} .23 }
H ₂ O above 100°	1.02	.39	.92			
P ₂ O ₅ .....	.02	.....	.....	.....	.....	.....
	100.75	100.09	99.69	100.69	100.28	100.38

L. Garnetiferous gabbro, Granite Falls. Collected for the Educational Series, and described by W. S. Bayley. Contains plagioclase, augite, garnet, magnetite, a little hornblende, some quartz grains, and apatite. Analysis by H. N. Stokes, record No. 1296. Sp. gr. 3.105.

M. Gabbro-diorite, Minnesota Falls. Collected for the Educational Series, and described by Bayley. Essentially plagioclase and hornblende, with some kaolin, augite, and biotite. Analysis by Stokes, No. 1296. Sp. gr. 2.935.

N. Pyroxene-schist, Odessa. Collected for the Educational Series, and described by Bayley. Contains quartz, plagioclase, pyroxene, biotite, garnet, magnetite, and sulphide of iron. Analysis by Stokes, No. 1296. Sp. gr. 2.770.

O. Mica-schist, bed of Cross River, near Gunflint Lake. Description furnished by C. E. Van Hise. Contains biotite, quartz, feldspar (?), and pyrites. Analysis by T. M. Chatard, record No. 896.

P. Actinolite-magnetite-schist. SE. $\frac{1}{4}$ of SE. $\frac{1}{4}$ of sec. 34, T. 61 N., R. 12 W. Described by Bayley in Amer. Journ. Sci., 3d series, vol. 46, p. 178. Mainly actinolite and magnetite. Analysis by W. H. Melville, record No. 1403.

Q. Magnetite rock near the preceding, also described with P by Bayley. Analysis by Melville, No. 1403.

	L.	M.	N.	O.	P.	Q.
SiO ₂	52.31	48.29	61.04	64.77	12.35	1.16
TiO ₂ .....				.60	.12	None.
Al ₂ O ₃	18.35	20.87	16.97	14.45	.10	1.81
Fe ₂ O ₃	5.90	1.13		1.84	58.68	69.08
FeO.....	11.06	4.93	5.58	4.54	21.34	27.10
MnO .....				.11	1.22	.33
CaO.....	7.33	14.32	5.99	2.33	1.91	.53
MgO	1.00	7.54	3.62	2.34	4.08	.25
K ₂ O .....	.49	.38	.55	5.03		
Na ₂ O.....	2.90	1.77	1.96	1.37	Trace.	
H ₂ O at 105°.....	.35	.89	.43	.07	.19	
H ₂ O above 105°.....				1.92		
P ₂ O ₅.....				.20	.25	.06
SO ₃ .....				.60		
CO ₂ .....				.41		
FeS			3.73			
	99.69	100.12	99.87	100.58	100.24	100.32

SOUTH DAKOTA.

A. Phonolite, Black Hills. Description furnished by Whitman Cross. Contains sanidine, nephelite, ægirite, nosean, and sodalite, with accessory sphene, apatite, and zircon, and possibly some rare zirconates or titanates. Also, sparingly, secondary zeolites and calcite. No magnetite, but minute ferritic flakes are disseminated through the rock. Analysis by W. F. Hillebrand, record No. 1618.

B. An earlier analysis of A, by H. N. Stokes, record No. 1314. This was made along the ordinary lines as regards "completeness," as requested by the collector, and without regard to minor accessory constituents. It serves well to illustrate the difference between the two modes of treatment, in comparison with the fuller analysis.

C. Tourmaline-biotite-schist, north of Harney Peak, Black Hills. Described by Bayley for the Educational Series of Rocks. Contains quartz, biotite, tourmaline, a little garnet and rarely muscovite, iron ore, and apatite. Analysis by Stokes, record No. 1296.

	A.	B.	C.
SiO ₂	57.86	58.60	66.77
TiO ₂.....	.22	.....	.....
ZrO ₂.....	.15	.....	.....
Al ₂ O ₃	20.26	20.98	17.65
Fe ₂ O ₃	2.35	2.22	1.55
FeO.....	.39	.44	3.29
MnO.....	.21	.20	.....
CaO.....	.89	1.13	.56
SrO.....	.04	.....	.....
BaO.....	.09	.....	.....
MgO.....	.04	.33	2.13
K ₂ O.....	5.19	5.49	4.49
Na ₂ O.....	9.47	8.38	.99
Li ₂ O.....	Trace.	.....	.....
H ₂ O at 110°.....	.21	} 1.92	} 1.89
H ₂ O above 110°.....	2.40		
P ₂ O ₅.....	.03	.....	.....
SO ₃.....	.06	.....	.....
S.....	.03	.....	.....
Cl.....	.08	.....	.....
F.....	(?)	.....	.....
CO ₂	None.	.....	.....
	99.97.	99.69	99.32

WYOMING.

Rocks studied by Whitman Cross, who has furnished the petrographic data. Analyses hitherto unpublished. Analysis I is by L. G. Eakins, record No. 1078. The others are by W. F. Hillebrand; one made in the Denver laboratory, and record Nos. 343, 355, 362, 368, 403, 463, and 1668.

A. Wyomingite, or leucite-trachyte, North Table Butte, Leucite Hills, contains sanidine, less leucite, phlogopite, amphibole, diopside, apatite, and rutile (?). Sp. gr. 2.699, 19°.

B. Wyomingite, Fifteen-mile Spring, Leucite Hills. Composition like A. Sp. gr. 2.686, 23°.

C. Mica (phlogopite) from B.

D. Groundmass of B. Sp. gr. 2.615, 16°.

Zirconia only looked for in A. The other analyses of Leucite Hills rocks are to this extent defective.

	A.	B.	C.	D.
SiO ₂	54.17	54.08	42.56	58.13
TiO ₂	2.67	2.08	2.09	1.48
ZrO ₂ .....	.22	Undet.	.....	Undet.
Al ₂ O ₃	10.16	9.49	12.18	11.72
Cr ₂ O ₃ .....	.05	.07	.73	.....
Fe ₂ O ₃	3.34	3.19	2.73	3.01
FeO .....	.65	1.03	.90	1.01
NiO	Trace.	.....	.....	.....
MnO .....	.06	.05	.....	Trace.
CaO	4.19	3.55	.20	2.24
SrO .....	.18	.20	Trace?	.10
BaO .....	.59	.67	1.00	.29
MgO	6.62	6.74	22.40	5.79
K ₂ O	11.91	11.76	10.70	12.58
Na ₂ O	1.21	1.39	.44	1.36
Li ₂ O	Trace.	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.52	.79	.....	.99
H ₂ O above 110°	1.01	2.71	2.35	1.16
P ₂ O ₅	1.59	1.36	.06	.32
SO ₃ .....	.16	.29	.....	.13
CO ₂ .....	.49	.....	.....	.....
Cl .....	.06	.04	.....	Trace.
F .....	.36	.49	2.46	Trace.
	100.21	99.98	100.80	100.31
Less O .....	.17	.21	1.03	
	100.04	99.77	99.77	

E. Mica-leucitite, Fifteen-mile Spring, Leucite Hills. Contains leucite, phlogopite, diopside, very little sanidine, and apatite. Sp. gr. 2.627, 30°.

F. Mica-leucitite, Boar's Tusk, Leucite Hills. Composition like E. Sp. gr. 2.779, 13.5°.

G. Rock from Pilot Butte, Leucite Hills, not yet named. Contains pale-green diopside, predominating; also phlogopite, perovskite, and magnetite, with a yellowish amorphous base having the composition of leucite plus nosite. Sp. gr. 2.857, 22°.

H. Pyroxene (mixed) from F. and G. Sp. gr. 3.290, 20°. Analyzed in the Denver laboratory. P_2O_5 included with the TiO_2 .

I. Dacite? Garfield Peak. Phenocrysts of plagioclase and hornblende, with microscopic sphene and apatite in a groundmass containing plagioclase, orthoclase, quartz, and magnetite. Sp. gr. 2.576, 26°.

	E.	F.	G.	H.	I.
SiO ₂	53.70	50.23	42.65	50.86	67.78
TiO ₂	1.92	2.27	1.64	†3.03	.....
Al ₂ O ₃	11.16	11.22	9.14	.....	16.67
Cr ₂ O ₃ .....	.04	.10	.07	.....	.....
Di ₂ O ₃ , etc *	None.	.03	.11	.....	.....
Fe ₂ O ₃	3.10	3.34	5.13	1.19	1.99
FeO	1.21	1.84	1.07	1.82	.751
MnO .....	.04	.05	.12	.03	Trace.
CaO	3.46	5.99	12.36	23.32	2.67
SrO .....	.19	.24	.33	.....	.....
BaO .....	.62	1.23	.89	.....	.....
MgO	6.44	7.09	10.89	17.42	.71
K ₂ O	11.16	9.81	7.99	.42	3.43
Na ₂ O	1.67	1.37	.90	.76	4.91
Li ₂ O	Trace.	Trace.	Trace.	.....	.....
H ₂ O at 110° .....	.80	.93	2.04	.....	} 1.44
H ₂ O above 110°	2.61	1.72	2.18	.31	
P ₂ O ₅	1.75	1.89	1.52	.....	.19
SO ₃ .....	.06	.74	.58	.....	.....
Cl .....	.03	.03	.03	.....	.....
F .....	.44	.50	.47	.....	.....
Less O	100.40	100.62	100.11	99.16	100.30
	.19	.22	.20		
	100.21	100.40	99.91		

* Includes other rare earths, probably. † Includes P_2O_5 .

THE YELLOWSTONE NATIONAL PARK AND ITS IMMEDIATE
VICINITY.

1. ELECTRIC PEAK.

Rocks described by Iddings in 12th Ann., p. 577. Also in Bull. Phil. Soc. Washington, vol. 11, p. 206. For analyses O, P, see Mon. XXXII.

A. Pyroxene-mica-diorite. Contains augite, hypersthene, plagioclase, quartz, biotite, hornblende, magnetite, and apatite. Analysis by J. E. Whitfield, record No. 830.

B. Pyroxene-mica-diorite. Same minerals as under A. Analysis by Whitfield, No. 921.

C. Pyroxene-mica-diorite. Like A. and B. Analysis by W. H. Melville, record No. 1231.

D. Pyroxene-porphyrityte. Contains augite, hypersthene, biotite, magnetite, plagioclase, and quartz. Analysis by Whitfield, No. 830.

E. Quartz-pyroxene-mica-diorite. Contains biotite, hornblende, augite, hypersthene, magnetite, plagioclase, orthoclase, and quartz. Analysis by Melville, No. 1231.

	A.	B.	C.	D.	E.
SiO ₂	56.28	58.05	61.22	57.38	64.07
TiO ₂.....	.84	1.05	.61	Trace.	.45
Al ₂ O ₃	14.23	18.00	16.14	16.86	15.82
Fe ₂ O ₃	4.69	2.49	3.01	2.49	3.40
FeO.....	4.05	4.56	2.58	5.17	1.44
MnO.....	.16	None.	Trace.	Trace.	Trace.
NiO.....	-----	-----	.09	-----	.05
CaO.....	7.94	6.17	5.46	7.32	4.43
MgO.....	6.37	3.55	4.21	5.51	3.39
K ₂ O.....	1.23	2.18	1.87	1.45	2.27
Na ₂ O.....	2.98	3.64	4.48	3.33	4.06
Li ₂ O.....	.01	None.	-----	.39	-----
H ₂ O at 100°.....	.93	.86	.04	.42	.10
H ₂ O above 100°.....			.40		.42
P ₂ O ₅.....	.40	.17	.25	Trace.	.18
SO ₃	Trace.	.07	-----	.21	-----
Cl.....	.17	Trace.	-----	.17	-----
	100.28	100.79	100.36	100.70	100.08

F. Quartz-mica-diorite. Contains biotite, hornblende, augite, hypersthene, plagioclase, orthoclase, and quartz. Analysis by Whitfield, No. 921.

G. Quartz-mica-diorite. Contains biotite, hornblende, plagioclase pyroxene, quartz, and orthoclase. Analysis by Whitfield, No. 921.

H, I, J. Quartz-mica-diorites. Contain hornblende, biotite, plagioclase, orthoclase, and quartz. Analyses by Whitfield, Nos. 921 and 830.

	F.	G.	H.	I.	J.
SiO ₂	65.11	65.60	64.85	66.05	67.54
TiO ₂ .....	.71	.75	.91	.34	.80
Al ₂ O ₃	16.21	17.61	16.57	16.96	17.02
Fe ₂ O ₃	1.06	.95	2.10	2.59	2.97
FeO	3.19	2.76	2.15	1.38	.34
MnO	None.	None.	None.	None.	Trace.
CaO	3.97	3.72	4.01	3.37	3.36
MgO	2.57	1.49	2.14	2.08	.13
K ₂ O	2.51	2.36	3.10	2.53	2.28
Na ₂ O	4.00	4.36	3.71	4.20	4.62
Li ₂ O .....	.04	.03	None.	None.	.03
H ₂ O .....	.94	.59	.35	.69	.55
P ₂ O ₅ .....	.02	.16	.14	Trace.	Trace.
SO ₃	Trace.	Trace.	Trace.	.03	.26
Cl	None.	None.	None.	Trace.	.15
	100.33	100.38	100.03	100.22	100.05

K. Quartz-mica-diorite-porphyrity. Contains biotite, hornblende, plagioclase, orthoclase, and quartz. Analysis by Whitfield, No. 830.

L. Quartz-mica-diorite-porphyrity. Contains quartz, biotite, plagioclase, alkali-feldspar, and hornblende. Analysis by Whitfield, No. 830.

M. Hornblende-porphyrity; intrusive sheet. Contains hornblende, plagioclase, magnetite, and quartz. Analysis by Whitfield, No. 429.

N. Hornblende-mica-porphyrity; intrusive sheet. Contains hornblende, plagioclase, biotite, magnetite, and quartz. Analysis by Whitfield, No. 420. The Indian Creek laccolite.

O. Augite-andesite-porphyrity; intrusive sheet, upper portion. Contains malacolite, plagioclase, probably orthoclase, magnetite, and little biotite, with secondary chlorite or serpentine and actinolite. Analysis by Whitfield, No. 830.

P. Same sheet as O, lower portion. Analysis by W. F. Hillebrand, record No. 1571.

	K.	L.	M.	N.	O.	P.
SiO ₂	65.97	69.24	58.49	61.50	52.10	50.59
TiO ₂.....	.42	.65	1.71	None.	.79	.80
Al ₂ O ₃	16.53	15.30	16.70	17.42	16.34	11.53
Fe ₂ O ₃	2.59	1.72	3.85	4.66	3.84	1.83
FeO.....	1.72	.69	2.37	1.09	6.82	7.64
MnO.....	None.	Trace.	.24	Trace.	Trace.	.17
NiO.....						.06
CaO.....	3.37	2.98	5.90	5.33	4.73	8.79
SrO.....						.03
BaO.....						.10
MgO.....	2.11	.95	3.12	1.26	4.33	11.27
K ₂ O.....	2.67	2.52	1.59	1.29	4.20	2.33
Na ₂ O.....	3.41	4.46	3.47	3.99	4.02	2.27
Li ₂ O.....	.09	None.	.01	.03	.13	Trace.
H ₂ O at 110°.....	1.23	1.30	2.44	2.44	1.74	.21
H ₂ O above 110°.....						1.76
P ₂ O ₅	Trace.	Trace.	Trace.	.60	.68	.48
SO ₃.....	.13	.27	.63	.35	.22	None.
Cl.....	.09	Trace.			.24	Trace.
	100.33	100.08	100.52	99.96	100.18	99.86
O=Cl.....	.02				.05	
	100.31				100.13	

2. SEPULCHRE MOUNTAIN.

Rocks described by Iddings, 12th Ann., p. 633. Also in Bull. Phil. Soc. Washington, vol. 11, p. 210.

A. Pyroxene-andesite. Essentially composed of augite, hypersthene, and plagioclase. Analysis by J. E. Whitfield, record No. 923.

B. Pyroxene-andesite. Composition like A. Analysis by Whitfield, No. 923.

C. Hornblende-andesite. Essentially plagioclase and hornblende. Analysis by Whitfield, No. 922.

D. Hornblende-pyroxene-andesite. Contains augite, hypersthene, plagioclase, and hornblende. Analysis by T. M. Chatard, record No. 712.

E. Hornblende-pyroxene-andesite. Minerals as in D, with magnetite also. Analysis by Chatard, No. 712.

	A.	B.	C.	D.	E.
SiO ₂	55.83	57.17	55.92	56.61	60.30
TiO ₂	1.05	1.03	.94	.79	.76
Al ₂ O ₃	17.11	17.25	17.70	13.62	16.31
Cr ₂ O ₃ .....				.05	Trace?
Fe ₂ O ₃	4.07	2.48	3.16	5.89	4.35
FeO	3.75	4.31	4.48	2.60	1.41
MnO	None.	None.	Trace.	.35	.13
CaO	7.40	6.61	5.90	6.61	5.62
BaO .....				.14	.15
SrO				Trace.	Trace.
MgO	5.05	4.83	4.34	5.48	2.39
K ₂ O	1.71	2.03	2.24	2.71	2.36
Na ₂ O	2.94	3.44	4.08	3.13	3.99
Li ₂ O	None.	Trace.	.09		
H ₂ O at 105°	1.28	1.20	1.42	1.20	.64
H ₂ O above 105°				1.07	1.86
P ₂ O ₅ .....	.21	.05	.18	.06	.20
SO ₃	Trace.	Trace.	Trace.	?	.10
Cl	None.	Trace.	None.		
	100.40	100.40	100.45	100.31	100.57

F. Hornblende-mica-andesite. Contains plagioclase, hornblende, biotite and magnetite. Analysis by Whitfield, No. 924.

G. Hornblende-mica-andesite. Contains plagioclase, hornblende, and biotite. Analysis by Chatard, No. 712.

H. Dacite. Contains plagioclase, hornblende, biotite, and quartz. Analysis by Whitfield, No. 830.

I. Dacite. Minerals as in H. Analysis by L. G. Eakins, record No. 1135.

J. Andesite-breccia. Not in paper cited. See Mon. XXXII. Analysis by Chatard, No. 712. Reported by Iddings as hornblende-mica-andesite, containing hornblende, plagioclase, quartz, biotite, and a little magnetite.

	F.	G.	H.	I.	J.
SiO ₂	64.27	65.50	65.66	67.49	67.95
TiO ₂ .....	.32	.45	1.37	.13	.45
Al ₂ O ₃	17.84	14.94	15.61	16.18	14.98
Fe ₂ O ₃	3.36	1.72	2.10	1.30	2.33
FeO	1.29	2.27	2.07	1.22	.95
MnO	None.	.20	None.	.08	.09
CaO	3.42	2.33	3.64	2.68	3.98
BaO .....		.13			.23
SrO		Trace?			Trace?
MgO	2.00	2.97	2.46	1.34	1.42
K ₂ O	2.48	2.76	2.03	2.40	2.86
Na ₂ O	3.84	5.46	3.65	4.37	4.39
Li ₂ O .....	.03		.36		
H ₂ O at 105°	1.32	.24	1.07	2.69	.37
H ₂ O above 105°		1.13			.61
P ₂ O ₅ .....	.16	.09	Trace.	.13	.07
SO ₃	Trace.	.06	.13		.11
Cl	None.		.12		
	100.33	100.25	100.27	100.01	100.79

3. THE CRANDALL BASIN.

Rocks from a dissected volcano. Described by Iddings in Mon. XXXII. The analyses also appeared in Bull. Phil. Soc. Washington, vol. 12, p. 204.

A. Gabbro-porphry, Hurricane Ridge. Contains augite, plagioclase, hypersthene, biotite, magnetite, and a little olivine. Analysis by L. G. Eakins, record No. 1089.

B. Basalt flow, north side of Timber Creek. Rich in olivine, augite, and magnetite. Analysis by Eakins, No. 1087.

C. Basalt dike, ridge south of Hurricane Ridge. Like B. Contains also labradorite and a little orthoclase. Analysis by Eakins, No. 1087.

D. Mica-gabbro-porphry, Hurricane Ridge. Contains plagioclase, augite, hypersthene, biotite, and magnetite. Analysis by Eakins, No. 1089.

E. Mica-gabbro, Hurricane Ridge. Like D, with some orthoclase and a little quartz and olivine. Analysis by Eakins, No. 1089.

F. Basalt-glass-breccia, ridge south of Indian Peak. A glass showing crystals of olivine, augite, plagioclase, and magnetite. Analysis by Eakins, No. 1087.

	A.	B.	C.	D.	E.	F.
SiO ₂	51.81	52.09	52.11	53.56	53.71	53.89
TiO ₂ .....	.77	.39	.53	.68	.74	.49
Al ₂ O ₃	15.24	17.84	16.58	16.07	18.00	18.81
Fe ₂ O ₃	3.66	4.27	3.66	3.21	3.99	4.92
FeO	4.86	4.56	4.99	5.29	4.05	2.81
MnO .....	.08	.14	.23	.11	.24	.17
CaO	9.06	8.03	6.43	8.77	6.88	5.42
MgO	8.89	5.33	6.87	7.23	5.19	3.29
K ₂ O	2.08	1.98	3.20	1.94	3.10	2.98
Na ₂ O	2.83	3.39	3.25	3.06	3.50	3.65
H ₂ O .....	.67	1.77	1.99	.19	.55	2.99
P ₂ O ₅ .....	.18	.27	.63	.18	.38	.52
	100.13	100.06	100.47	100.29	100.33	99.94

G. Orthoclase-gabbro-diorite, rich in mica. Hurricane Ridge. Contains orthoclase, plagioclase, quartz, biotite, augite, hypersthene, magnetite, and hornblende. Analysis by Eakins, No. 1089.

H. Another sample, like G. Same analyst and record number.

I. Dioritic facies of gabbro, Hurricane Ridge. Very feldspathic. Same analyst and number.

J. Monzonite, Hurricane Ridge. Contains orthoclase, biotite, augite, hypersthene, and magnetite. Analysis by W. H. Melville, record No. 1233.

K. Augite-andesite-porphry. Intrusive sheet, Hurricane Ridge. Analysis by Eakins, No. 1088. Contains plagioclase, augite, hypersthene, magnetite, biotite, quartz, and microscopic orthoclase.

	G.	H.	I.	J.	K.
SiO ₂	55.93	56.21	57.26	57.32	57.64
TiO ₂ .....	.81	.88	.76	.62	.77
Al ₂ O ₃	18.32	18.24	19.40	17.29	18.43
Fe ₂ O ₃	2.39	3.26	2.49	3.89	3.63
FeO	4.91	3.69	3.29	3.03	2.84
MnO .....	.14	.17	.16	.06	.10
NiO .....				.10	
CaO.....	6.17	5.91	5.68	5.81	5.49
MgO	3.97	3.38	2.57	3.56	3.32
K ₂ O	2.62	3.02	2.95	3.04	3.33
Na ₂ O.....	4.29	4.15	4.21	3.89	4.03
H ₂ O at 100° ....	.22	.78	.86	.33	.51
H ₂ O above 100° ..				.30	
P ₂ O ₅ .....	.56	.64	.51	.50	.34
Cl					Trace.
	100.33	100.33	100.14	99.74	100.43

L. Hornblende-mica-andesite-porphry dike, ridge south of Hurricane Ridge. Contains plagioclase, hornblende, biotite, augite, hypersthene, and magnetite, with a little chlorite or serpentine. Analysis by Eakins, No. 1087.

M. Quartz-diorite-porphry, Hurricane Ridge. Contains plagioclase, orthoclase, quartz, augite, hypersthene, magnetite, and a little biotite. Analysis by Melville, No. 1234.

N. Quartz-mica-diorite, Hurricane Ridge. Contains andesine, orthoclase, quartz, biotite, hornblende, magnetite, and a little pyroxene. Analysis by Melville, No. 1234.

O. Quartz-mica-diorite-porphry, Hurricane Ridge. Contains andesine, orthoclase, quartz, and biotite. Analysis by Melville, No. 1234.

P. Aplite dike, Hurricane Ridge. Contains quartz, orthoclase, oligoclase, biotite, magnetite, some chlorite, and a little hornblende. Analysis by Eakins, No. 1088.

	L.	M.	N.	O.	P.
SiO ₂	61.16	63.42	63.97	64.40	71.62
TiO ₂.....	.23	.35	.48	.40	.08
Al ₂ O ₃	16.17	17.16	15.78	15.77	14.99
Fe ₂ O ₃	2.89	3.09	2.35	2.47	1.27
FeO.....	2.18	1.50	1.87	1.15	1.01
MnO.....	Trace.	.04	.05	.04	.17
NiO.....		.19	Trace.	.17	
CaO.....	4.26	4.65	3.71	3.54	1.33
MgO.....	3.89	1.64	2.84	2.12	.74
K ₂ O.....	3.20	3.04	4.01	3.81	4.81
Na ₂ O.....	3.87	4.51	4.36	4.10	3.62
H ₂ O at 100°.....	2.09	.16	.09	.31	.41
H ₂ O above 100°.....		.28	.49	1.93	
P ₂ O ₅.....		.26	.40	.16	Trace.
Cl.....					Trace.
	100.07	100.29	100.40	100.37	100.05

4. ABSAROKITE-SHOSHONITE-BANAKITE SERIES.

Rocks from the Yellowstone Park and its immediate vicinity, described by Iddings in Journ. of Geology, vol. 3, pp. 938, 943, 947. The rock A, from Ishawooa Canyon, is also described by Hague in Amer. Journ. Sci., 3d series, vol. 38, p. 46.

A. Leucite-absarokite, Ishawooa Canyon, Wyoming. Boulder. Contains olivine and augite in a groundmass of orthoclase and leucite. Accessory minerals, magnetite, apatite, and a few flakes of brown mica. Analysis by J. E. Whitfield, record No. 1057. Material dried at 104°.

B. Absarokite dike, head of Lamar River. Contains olivine and augite in a groundmass of orthoclase and plagioclase, with accessory magnetite, biotite, and ilmenite.

C. Absarokite dike, south of Clark's Fork. Contains augite, quartz, biotite, magnetite, orthoclase, plagioclase, and sometimes analcite.

D. Absarokite lava flow, head of Raven Creek. Contains olivine, augite, orthoclase, labradorite, magnetite, apatite, and a little serpentine.

E. Absarokite dike, divide east of Cache Creek. Contains orthoclase, plagioclase, augite, biotite, magnetite, serpentine, and occasional quartz.

Analyses B, C, D, E by L. G. Eakins; record Nos. 1086, 1365.

	A.	B.	C.	D.	E.
SiO ₂	47.28	48.95	48.36	51.76	49.71
TiO ₂.....	.88	.49	1.18	.47	1.57
Al ₂ O ₃	11.56	12.98	12.42	12.36	13.30
Cr ₂ O ₃			Trace.		Trace.
Fe ₂ O ₃	3.52	3.63	5.25	4.88	4.41
FeO.....	5.71	4.68	2.48	4.60	3.37
MnO.....	.13	.13	.13	.11	.17
CaO.....	9.20	7.66	8.65	7.14	8.03
BaO.....			.29		.46
MgO.....	13.17	11.73	9.36	9.57	7.96
K ₂ O.....	2.17	3.96	3.97	3.83	4.81
Na ₂ O.....	2.73	2.31	1.46	1.99	1.49
H ₂ O.....	2.96	3.16	5.54	3.05	4.07
P ₂ O ₅.....	.59	.67	.84	.56	.66
Cl.....	.18				
	100.08	100.35	99.93	100.32	100.01
O=Cl.....	.04				
	100.04				

F. Shoshonite lava sheet, Lamar River, south of Bison Peak. Contains plagioclase, orthoclase, augite, olivine, magnetite, and serpentine, with amygdulæ of zeolite and calcite. Analysis by Eakins, No. 1086.

G. Shoshonite lava sheet, southeast fork of Beaverdam Creek. Contains plagioclase, orthoclase, augite, and serpentinized olivine.

H. Leucite (?) shoshonite lava sheet, mountain east of Pyramid Peak. Contains feldspars, olivine, serpentine, augite, magnetite, brown mica, and impure leucite (?).

I. Olivine-free shoshonite dike, northeast of Indian Peak. Contains augite, plagioclase, biotite, and magnetite.

J. Shoshonite lava sheet, Two Ocean Pass. Contains orthoclase, serpentinized olivine, magnetite, augite, chlorite, biotite, apatite, labradorite. Dried at 104°.

Analyses G, H, I by Eakins, Nos. 1371, 1375, 1379. Analysis J by Whitfield, No. 906.

	F.	G.	H.	I.	J.
SiO ₂	50.06	53.49	52.49	54.86	56.05
TiO ₂.....	.51	.71	.81	.69	.98
Al ₂ O ₃	17.00	17.19	17.89	17.28	19.70
Fe ₂ O ₃	2.96	4.73	5.76	4.08	3.74
FeO.....	5.42	3.25	2.08	2.28	2.32
MnO.....	.14	.14	.09	.19	Trace.
CaO.....	8.14	6.34	7.01	5.42	4.34
BaO.....		.06	.30	.37	
MgO.....	3.61	4.42	3.49	4.19	2.51
K ₂ O.....	3.40	3.86	3.73	3.96	4.44
Na ₂ O.....	3.53	3.23	3.18	3.94	3.29
Li ₂ O.....					.06
H ₂ O.....	4.85	2.17	2.63	2.16	1.86
P ₂ O ₅.....	.66	.43	.55	.48	.66
SO ₃.....					.19
	100.28	100.02	100.01	99.90	100.14

K. Banakite dike, head of Lamar River. Contains augite, serpentinized olivine, orthoclase, plagioclase, biotite, magnetite, ilmenite, apatite, and analcite. Adjoins rock B. Analyses by Eakins, No. 1375.

L. Banakite dike, Hoodoo Mountain. Like K, but with amygdaloidal zeolites. Analysis by Eakins, No. 1371.

M. Banakite dike, Ishawooa Canyon, Wyoming. Like K and L, but more feldspathic. Contains a little serpentine, probably from olivine; also possibly analcite or sodalite. Analysis by Eakins, No. 1086.

N. Banakite dike, near head of Stinkingwater River. Like M, but with more serpentine. Analysis by W. H. Melville, record No. 1232.

	K.	L.	M.	N.
SiO ₂	51.82	52.63	51.46	52.33
TiO ₂ .....	.71	.81	.83	.71
Al ₂ O ₃	16.75	16.87	18.32	18.70
Fe ₂ O ₃	4.56	4.52	4.61	4.95
FeO.....	3.36	3.11	2.71	1.83
MnO .....	.23	.10	.17	.03
NiO .....				.14
CaO.....	4.94	4.77	6.03	4.71
BaO.....	.26	.29		
MgO	4.03	3.69	2.91	2.69
K ₂ O	5.02	5.17	4.48	5.45
Na ₂ O.....	3.91	3.86	4.11	4.51
H ₂ O at 100°.....	3.97	3.65	3.89	.74
H ₂ O above 100°....				2.71
P ₂ O ₅ .....	.52	.63	.86	.81
	100.08	100.10	100.38	100.31

O. Leucite-banakite lava sheet, southeast fork of Beaverdam Creek. Overlies rock G. Contains olivine, augite, leucite, feldspars, magnetite, apatite, and a little brown mica. Analysis by Eakins, No. 1378.

P. Earlier unpublished analysis of O, another sample, by J. E. Whitfield, record No. 907.

Q. Quartz-banakite dike, near head of Stinkingwater River. Contains plagioclase, orthoclase, quartz, biotite, magnetite, augite, and a little calcite. Analysis by Melville, No. 1232.

R. Quartz-banakite dike, near Q. Contains plagioclase, orthoclase, quartz, biotite, magnetite, augite, chlorite, and serpentine. Analysis by Melville, No. 1232.

	O.	P.	Q.	R.
SiO ₂	52.93	51.56	57.29	60.89
TiO ₂ .....	.72	.65	.72	.49
Al ₂ O ₃	19.67	21.00	18.45	17.14
Fe ₂ O ₃	3.07	5.17	4.38	3.32
FeO	3.50	2.76	1.20	.95
MnO .....	.15	Trace.	Trace.	.09
NiO .....			.12	.19
CaO	4.69	4.83	3.57	3.58
BaO .....	.21			
MgO	2.88	2.52	2.08	1.16
K ₂ O	4.75	4.13	5.43	5.71
Na ₂ O	4.20	4.37	4.43	4.54
Li ₂ O .....		.13		
H ₂ O at 100°	2.73	2.27	.17	.39
H ₂ O above 100°			2.01	1.22
P ₂ O ₅ .....			.46	.27
SO ₃ .....		.21		
Cl		Trace.		
	100.09	100.29	100.31	99.94

The following analyses in this series are hitherto unpublished. Petrographic data communicated by J. P. Iddings.

S. Absarokite, Two Ocean Pass. Contains augite, olivine, orthoclase, magnetite, serpentine, little biotite, apatite, and an isotropic substance, probably glass. Analysis by J. E. Whitfield, record No. 906.

T. Shoshonite, Beaverdam Creek. Analysis by Whitfield, No. 907. Probably the rock already represented by analysis G.

U. Shoshonite, northeast spur of Sepulchre Mountain. Contains augite and serpentinized olivine, in a groundmass of plagioclase, orthoclase, augite, magnetite, and apatite. Analysis by Whitfield, No. 908.

V. Shoshonite, Baldy Mountain, Bear Gulch, Montana. Contains hypersthene, augite, olivine, plagioclase, orthoclase, and magnetite. Analysis by Whitfield, No. 909.

	S.	T.	U.	V.
SiO ₂	51.68	52.86	51.75	54.97
TiO ₂	1.08	1.04	.86	.97
Al ₂ O ₃	14.07	17.51	17.48	18.38
Fe ₂ O ₃	4.71	5.18	6.42	3.06
FeO.....	4.57	3.31	1.46	4.22
MnO	Trace.	Trace.	Trace.	Trace.
CaO.....	6.65	6.51	8.20	5.43
MgO	7.72	4.18	4.05	2.38
K ₂ O	4.16	3.41	3.72	3.37
Na ₂ O	2.45	3.22	3.33	3.45
Li ₂ O	Trace.	.04	Trace.	.03
H ₂ O.....	2.09	1.76	2.26	.82
P ₂ O ₅ .....	.72	.53	.67	.42
SO ₃ .....	.13	.22	.17	.03
Cl.....		.16	Trace.	Trace.
CO ₂				2.92
	100.03	99.93	100.37	100.45

5. MISCELLANEOUS ROCKS. FIRST GROUP.

Collected and investigated by Arnold Hague and J. P. Iddings.

A. Black obsidian, Obsidian Cliff. Described by Iddings, 7th Ann. Contains microlites of augite and magnetite, with traces of quartz and feldspar. Analysis by J. E. Whitfield, record No. 224.

B. Red obsidian, Obsidian Cliff. Described by Iddings, 7th Ann. Like A, with ferric oxide replacing magnetite. Analysis by Whitfield, No. 223.

C. Obsidian, east of Willow Park. Black and opaque. Described by Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 204. Analysis by Whitfield, No. 222.

D. Lithoidal rhyolite, Obsidian Cliff. Described by Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 204. Contains quartz and sanidine, with a little magnetite and augite. Analysis by Whitfield, No. 425.

E. Rhyolite, Upper Geyser Basin. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 204. Analysis by F. A. Gooch, record No. 114.

F. Rhyolite, Tower Creek. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 204. Analysis by Gooch, No. 115.

	A.	B.	C.	D.	E.	F.
SiO ₂	74.70	75.52	72.59	75.50	70.92	71.85
TiO ₂	None.	None.	.52	None.	.16	.43
Al ₂ O ₃	13.72	14.11	13.47	13.25	13.24	13.17
Fe ₂ O ₃	1.01	1.74	1.58	1.02	3.54	2.17
FeO .....	.62	.08	1.32	.91	.66	1.34
MnO	Trace.	None.	None.	None.	.14	.12
CaO .....	.78	.78	2.12	.90	1.42	2.25
MgO .....	.14	.10	1.05	.07	.23	.63
K ₂ O	4.02	3.63	2.52	2.85	4.25	3.89
Na ₂ O	3.90	3.92	4.63	4.76	4.28	4.06
Li ₂ O .....				.06	None.	
H ₂ O .....	.62	.39	.18	.41	.57	.43
P ₂ O ₅	None.			None.	.18	.14
SO ₃ .....				.32		
FeS ₂ .....	.40	.11	.26			
	99.91	100.38	100.24	100.05	100.59	100.48

G. Rhyolite, Great Paint Pots. Analysis by Gooch, No. 113, hitherto unpublished.

H. Rhyolite, Elephant's Back. Porphyritic obsidian. Analysis by Whitfield, No. 423, hitherto unpublished. Reported by Iddings as containing quartz, sanidine, and a little augite and magnetite, in a glassy, microlitic groundmass.

I. Rhyolite, Mount Sheridan. Composition reported by Iddings as quartz and sanidine, with a little magnetite and augite. Analysis by Whitfield, No. 426, hitherto unpublished.

J. Rhyolite, Madison Plateau. Like I. Analysis by Whitfield, No. 427, not yet published.

K. Trachytic rhyolite, Elk Creek. Analysis by Whitfield, No. 428, hitherto unpublished. Reported by Iddings as containing sanidine, labradorite, and little biotite, in a groundmass of quartz and alkali-feldspar.

	G.	H.	I.	J.	K.
SiO ₂	75.71	75.34	75.89	75.19	64.65
TiO ₂	1.25	None.	.50	None.	Trace.
Al ₂ O ₃	11.11	12.51	12.27	13.77	17.80
Fe ₂ O ₃	1.56	.42	1.12	.61	2.33
FeO .....	.37	1.55	1.37	1.37	2.10
MnO .....	.07	.07	None.	Trace.	Trace.
CaO .....	.88	1.07	.86	.68	1.73
MgO .....	.08	.32	.29	.09	.81
K ₂ O	4.18	4.17	3.42	3.33	2.83
Na ₂ O	4.64	3.31	3.23	3.83	4.18
Li ₂ O		Trace.	.01	.02	.17
H ₂ O .....	.35	.86	.82	.65	3.06
P ₂ O ₅		None.	None.	None.	Trace.
SO ₃ .....		.42	.28	.29	.43
	100.20	100.04	100.06	99.83	100.09

L. Trachytic rhyolite-tuff, Two Ocean Pass. Analysis by Whitfield, No. 906, hitherto unpublished. Reported by Iddings as containing sanidine, labradorite, biotite, magnetite, and augite, in a somewhat altered, glassy groundmass. Also contains fragments of andesite.

M. Glassy trachyte, approaching rhyolite, Sunset Peak, Bear Gulch. Contains phenocrysts of sanidine, plagioclase, and biotite. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 205; also Mon. XXXII. Analysis by L. G. Eakins, record No. 1378.

N. Altered rhyolite, "Iron Pot," Lower Basin. Collected by W. H. Weed. Analysis by Whitfield, No. 546, hitherto unpublished.

O. Dacite-porphry, Echo Peak. P. The same, Mount Holmes. Analyses by Whitfield, Nos. 421, 422, hitherto unpublished. Reported by Iddings as containing plagioclase, probably oligoclase, quartz, little biotite, and magnetite.

	L.	M.	N.	O.	P.
SiO ₂	61.15	69.45	89.20	74.51	69.54
TiO ₂.....	.69	.19	None.	None.	None.
Al ₂ O ₃	15.70	14.92	2.39	14.83	17.95
Fe ₂ O ₃	4.31	3.16	1.21	1.09	2.50
FeO.....	1.12	.23	None.	Trace.	.22
MnO.....	Trace.	.07	.....	None.	None.
CaO.....	2.84	1.19	Trace.	.81	1.80
BaO.....	.....	.03	.....	.....	.....
MgO.....	3.04	.05	Trace.	.47	.50
K ₂ O.....	2.22	5.95	.79	2.72	1.21
Na ₂ O.....	1.54	3.19	1.11	4.38	4.30
Li ₂ O.....	None.	.....	.....	.02	Trace.
H ₂ O.....	7.05	1.69	5.09	.92	1.96
P ₂ O ₅.....	.75	.06	None.	Trace.	None.
SO ₃.....	.18	.....	.44	.24	.37
	100.59	100.18	100.23	99.99	100.35

Q. Mica-dacite-porphyry, Bunsen Peak. Analysis by Whitfield, No. 419, hitherto unpublished. Reported by Iddings as containing oligoclase-andesine, quartz, biotite, little magnetite, apatite, and zircon.

R. Mica-dacite-porphyry, Birch Hills. Like Q in composition. Analysis by Whitfield, No. 718, hitherto unpublished.

S. Hornblende-mica-andesite-porphyry. Fan Creek. Analysis by Whitfield, No. 713, hitherto unpublished. Reported by Iddings as containing andesine-oligoclase, hornblende, and biotite, in a groundmass of feldspar (probably oligoclase and orthoclase), with a little magnetite, biotite, and hornblende.

T. Hornblende-mica-andesite-porphyry, Gray Peak. Analysis by Whitfield, No. 715, hitherto unpublished. Composition similar to that of S.

	Q.	R.	S.	T.
SiO ₂	70.52	70.24	65.63	65.64
TiO ₂	Trace.	Trace.	Trace.	None.
Al ₂ O ₃	15.85	17.36	17.00	17.29
Fe ₂ O ₃	2.28	1.38	2.55	3.07
FeO .....	.36	.79	1.19	1.29
MnO .....	.09	None.	None.	Trace.
CaO	2.59	2.74	3.48	1.98
MgO .....	.09	.53	2.03	1.78
K ₂ O	3.43	2.65	1.64	2.44
Na ₂ O	3.93	3.69	4.42	5.77
Li ₂ O	Trace.	None.	.04	.04
H ₂ O .....	.35	.71	2.00	1.03
P ₂ O ₅ .....	.17	Trace.	.07	.23
SO ₃ .....	.29	Trace.	Trace.	Trace.
Cl .....	.....	None.	Trace.	Trace.
CO ₂ .....	.....	None.	.27	.17
	99.95	100.09	100.32	100.73

U. Hornblende-mica-andesite, Crescent Hill. Analysis by Whitfield, No. 432, hitherto unpublished. Reported by Iddings as containing oligoclase-andesine, biotite, and subordinate decomposed hornblende, in a groundmass of feldspar and quartz, with a little magnetite and biotite.

V. Hornblende-andesite, Tower Creek. Analysis by Gooch, No. 117, hitherto unpublished. Reported by Iddings as containing plagioclase, hornblende, and a little augite.

W. Pyroxene-andesite, Agate Creek. Analysis by Whitfield, No. 432, hitherto unpublished. Reported by Iddings as containing augite, hypersthene, labradorite, and magnetite, in a glassy, microlitic groundmass.

X. Rhyolitic pearlite, collected for the Educational Series of Rocks. Analysis by H. N. Stokes, No. 1314, hitherto unpublished. From a bluff opposite the Midway Geyser Basin. Reported by Iddings as containing quartz, sanidine, plagioclase, and rarely augite and magnetite, with microscopic zircon and apatite, in a glassy groundmass.

	U.	V.	W.	X.
SiO ₂	64.61	61.56	61.45	73.84
TiO ₂	None.	.87	2.80	.....
Al ₂ O ₃	18.62	14.73	15.07	12.47
Fe ₂ O ₃	2.78	4.47	4.46	.32
FeO .....	.95	1.23	1.18	.90
MnO	Trace.	.34	None.	Trace.
CaO	4.20	4.87	5.37	1.08
MgO .....	.85	3.57	3.02	.25
K ₂ O	2.36	2.24	1.22	5.38
Na ₂ O	4.37	5.10	4.00	2.88
Li ₂ O .....	.01	.....	.05	.....
H ₂ O .....	.93	1.42	1.23	2.76
P ₂ O ₅ .....	.30	.04	Trace.	.....
SO ₃	Trace.	.....	.29	.....
Cl	Trace.	.....	.....	.....
CO ₂ .....	.25	.....	.....	.....
	100.23	100.44	100.14	99.88

MISCELLANEOUS ROCKS. SECOND GROUP.

Collected and investigated by Arnold Hague and J. P. Iddings.

A. Pyroxene-andesite, west of Dunraven Peak. Analysis by F. A. Gooch, record No. 116, hitherto unpublished. Reported by Iddings as containing labradorite, augite, hypersthene, and magnetite, in a micro-litic groundmass.

B. Basalt, southwest of Dunraven Peak. Analysis by Gooch, No. 118, hitherto unpublished. Reported by Iddings as containing augite, olivine, labradorite-bytownite, and magnetite, in a globulitic glassy groundmass.

C. Basalt, north spur of Prospect Peak. Analysis by J. E. Whitfield, record No. 431, hitherto unpublished. Reported by Iddings as containing labradorite, augite, olivine, and magnetite. Little glass in groundmass.

D. Basalt, Yellowstone Canyon. Analysis by Whitfield, No. 430, hitherto unpublished. Reported by Iddings as containing labradorite-bytownite, augite, olivine, magnetite, and a little brown glass.

E. Basalt, Stinkingwater Canyon. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 205. Analysis by W. H. Melville, record No. 1232.

	A.	B.	C.	D.	E.
SiO ₂	56.47	51.70	47.17	51.70	52.37
TiO ₂ .....	.99	1.24	2.13	3.17	.73
Al ₂ O ₃	15.33	15.18	17.85	17.90	16.57
Fe ₂ O ₃	2.54	2.09	7.42	7.24	6.34
FeO	4.53	8.54	1.18	1.00	2.35
Fe, metal			3.26	1.81	
MnO .....	.18	Trace.	None.	Trace.	.07
NiO .....					.12
CaO	6.93	8.73	10.12	6.94	8.54
MgO	5.08	8.18	6.54	2.77	5.27
K ₂ O	1.66	1.81	.56	1.62	2.45
Na ₂ O	3.81	2.31	2.94	4.17	2.99
Li ₂ O .....			.02	.03	
H ₂ O at 100°	1.65	.16	.65	1.15	1.18
H ₂ O above 100°					1.04
P ₂ O ₅ .....	.54	.21	.20	.41	.31
SO ₃ .....			.51	.32	
S .....		.09			
Cl		Trace.			
	99.71	100.24	100.55	100.23	100.33

F. Camptonite (?) dike, Stinkingwater Canyon. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 205. Analysis by Melville, No. 1232.

G. Kersantite, Bighorn Pass. Described by Iddings in Mon. XXXII. Contains hornblende, plagioclase, orthoclase, quartz, augite, biotite, magnetite, chlorite, calcite, and apatite. Augite and hornblende partly decomposed. Analysis by Whitfield, No. 714.

H. Basalt dike, north spur of Mount Washburn. Analysis by Whitfield, No. 717, hitherto unpublished. Reported by Iddings as approaching pyroxene-andesite in composition. Contains labradorite, augite, serpentinized olivine, and magnetite, in a groundmass of globulitic and microlitic brown glass.

	F.	G.	H.
SiO ₂	50.99	48.73	53.75
TiO ₂.....	.67	1.34	None.
Al ₂ O ₃	15.62	11.92	20.75
Fe ₂ O ₃	8.47	4.79	4.50
FeO.....	1.43	4.56	3.53
MnO.....	Trace.	.36	Trace.
NiO.....	.07		
CaO.....	6.53	9.24	7.18
BaO.....		Trace.	
MgO.....	5.23	5.93	3.76
K ₂ O.....	3.05	2.47	1.37
Na ₂ O.....	3.39	2.62	4.16
Li ₂ O.....		Trace.	Trace.
H ₂ O at 100°.....	1.39	1.52	1.55
H ₂ O above 100°.....	2.48		
P ₂ O ₅.....	.53	.32	.15
SO ₃.....		.34	Trace.
Cl.....		.11	None.
CO ₂		5.80	None.
	99.85	100.05	100.70

MONTANA.

1. THE MADISON AND GALLATIN VALLEYS.

Rocks collected by A. C. Peale and G. P. Merrill. Described by Merrill in Proc. U. S. National Museum, vol. 17, p. 637. See also Bull. 110, p. 47.

A. Basalt? From east side of Bozeman Creek, $2\frac{1}{2}$ miles southeast of Bozeman. Contains olivine and augite, chloritized and serpentinized. The colorless groundmass contains apparently two feldspars and a pyroxene, with grains of iron oxide. Analysis by T. M. Chatard, record No. 517. Sp. gr. 2.86.

B. Pyroxene from A. Analysis by L. G. Eakins, record No. 1046.

C. Portion of A soluble in hydrochloric acid. Contains olivine, iron oxides, and decomposition products. Analysis by Eakins, record No. 817.

	A.	B.	C.
SiO ₂	46.90	52.50	20.88
TiO ₂.....	.41	.....	.....
Al ₂ O ₃	10.17	2.26	3.89
Cr ₂ O ₃.....	.33	1.07	.....
Fe ₂ O ₃	1.22	2.05	2.21
FeO.....	5.17	2.47	4.28
MnO.....	.10	Trace.	Trace.
CaO.....	6.20	21.70	1.01
MgO.....	20.98	17.11	16.44
K ₂ O.....	2.04	.07	Trace.
Na ₂ O.....	1.16	.35	Trace.
H ₂ O at 120°.....	1.04	} .64	.....
H ₂ O above 120°.....	4.38		.....
P ₂ O ₅.....	.44		.....
	100.54	100.32	48.71

D. Highly altered porphyrite? Hills 1 mile north of East Gallatin River, near Camp 6. Rock contains hornblende paramorphs after augite in a devitrified base, with amygdules of calcite, chloritic and ferruginous matter derived from porphyritic augite and olivine. The base is also filled with needles, which may be mica. Analysis by Eakins, record No. 820.

E. Lamprophyre. From Cottonwood Creek. Contains porphyritic augite and olivine in an indeterminate groundmass carrying augite, iron oxides, and mica. Analysis by Chatard, record No. 516.

F. Augite-porphyrity, Cottonwood Creek. Contains feldspars, augite, and brown mica, with iron oxides, apatite, glass, and secondary calcite and chlorite. Carries porphyritic plagioclase and augite. No unaltered olivine visible. Sp. gr. 2.785. Analysis by Eakins, record No. 819.

	D.	E.	F.
SiO ₂	49.47	51.65	52.33
TiO ₂ .....	.21	.55	.14
Al ₂ O ₃	12.15	13.89	15.09
Cr ₂ O ₃	Trace.	.08	.....
Fe ₂ O ₃	1.93	2.70	4.31
FeO	4.07	4.80	4.03
MnO .....	.10	.15	.09
CaO	9.30	4.07	7.06
BaO .....	.03	.19	.07
MgO	10.86	11.56	6.73
K ₂ O	2.42	4.15	3.76
Na ₂ O	2.08	2.99	3.14
H ₂ O at 120°	4.14	1.30	2.68
H ₂ O above 120°		1.89	
P ₂ O ₅ .....	.37	.21	1.02
SO ₃ .....	.....	.19	.....
CO ₂	3.31	.....	.....
	100.44	100.37	100.45

G. Basalt? From Bear Creek. Resembles A, but with a more crystalline groundmass. Contains plagioclase, possibly sanidine, augite, olivine, and iron oxides. Analysis by Chatard, record No. 1154.

H. Lamprophyre. Between South Boulder and Antelope creeks. Contains porphyritic augite and olivine in a feldspathic groundmass, with apatite, augite, grains of iron oxide, and shreds of brown mica. Sp. gr. 2.96. Analysis by Eakins, record No. 1266.

I. Lamprophyre. Hills east of South Boulder Creek. Nodules from a decomposed mass. Shows sanidine, plagioclase, brown mica, and altered olivine.

	G.	H.	I.
SiO ₂	49.13	50.82	50.03
TiO ₂.....	.42	.59	.61
Al ₂ O ₃	9.05	11.44	14.08
Cr ₂ O ₃.....	.39	.03	Trace.
Fe ₂ O ₃	3.57	.25	2.92
FeO.....	5.05	8.94	6.11
NiO.....	Trace.	Trace.	Trace.
MnO.....	.15	.19	.08
CaO.....	5.68	8.14	7.46
BaO.....	.05	.06	.04
MgO.....	17.21	14.01	10.73
K ₂ O.....	2.24	3.45	2.64
Na ₂ O.....	2.01	1.79	1.46
H ₂ O at 110°.....	.84	.58	3.70
H ₂ O above 110°...	3.50		
P ₂ O ₅.....	.38	.20	.42
	99.67	100.49	100.28

J. Hornblende-picrite, North Meadow Creek. Contains hornblende, abundant fresh olivine, grains of pleonaste and iron oxides, and occasionally hypersthene. Sp. gr. 3.35.

K. Pyroxenite. Divide between Meadow and Granite creeks. Contains hornblende and hypersthene, with grains of iron oxide.

L. Hypersthene-andesite, northwest of Red Bluff. Contains plagioclase and pyroxene, with an amorphous glassy base, and sometimes olivine altered to chloritic matter.

M. Peridotite, var. wehrlite. Hills 3 miles northwest of Red Bluff. Contains olivine, diallage, brown mica, rarely plagioclase, and secondary iron oxides. Sp. gr. 3.37. Analyses J, K, L, M by Eakins, record No. 1266.

	J.	K.	L.	M.
SiO ₂	46.13	51.83	59.48	48.95
TiO ₂.....	.73	.29	.93	.81
Al ₂ O ₃	4.69	7.98	16.37	5.69
Cr ₂ O ₃.....	.04	.31	.03	.05
Fe ₂ O ₃.....	.73	1.48	3.21	1.20
FeO.....	16.87	8.28	3.17	12.11
MnO.....	Trace.	Trace.	.19	.08
NiO.....	.09	.11	Trace.	.16
CaO.....	4.41	5.26	4.88	5.33
BaO.....	Trace.	.....	.13	Trace.
MgO.....	25.17	24.10	3.29	23.49
K ₂ O.....	Trace.	.06	2.81	.79
Na ₂ O.....	.08	.35	3.30	1.58
H ₂ O.....	1.38	.29	2.01	.18
P ₂ O ₅.....	.07	.09	.41	.12
S.....	.24	.....	.....	.....
	100.63	100.43	100.21	100.54
Less O.....	.12			
	100.51			

The following rocks, at first supposed to be Pliocene sandstones, were also described by Merrill. Amer. Journ. Sci., 3d series, vol. 32, p. 119. All consist of pumiceous volcanic glass. C, from Idaho, is included here for convenience. Analyses by J. E. Whitfield, record No. 382.

A. Little Sage Creek.

B. Devils Pathway.

C. Marsh Creek Valley, Idaho.

Iron and alumina weighed together. The iron is mostly in the ferrous form.

	A.	B.	C.
SiO ₂	65.56	65.76	68.92
Al ₂ O ₃ , Fe ₂ O ₃	18.24	17.18	16.22
CaO	2.58	2.30	1.62
MgO .....	.72	Trace.	Trace.
K ₂ O	3.94	3.14	4.00
Na ₂ O	2.08	2.22	1.56
H ₂ O at 105°	1.12	3.46	1.60
H ₂ O at red heat	6.50	5.60	6.00
	100.74	99.66	99.92

The following examples of volcanic dust or sand, from the Gallatin Valley, were collected by A. C. Peale. That marked E belongs to the Educational Series of Rocks. Analyses A, B, C, D by F. W. Clarke, record No. 379. Analysis E by H. N. Stokes, record No. 1314.

A. Dry Creek Valley, above the mouth of Pass Creek.

B, C. Near Bozeman.

D. Near Fort Ellis.

E. Gallatin Valley.

	A.	B.	C.	D.	E.
SiO ₂	46.09	61.82	71.01	60.98	68.68
Al ₂ O ₃	14.35	19.86	15.17	21.69	12.69
Fe ₂ O ₃					1.14
FeO					1.17
MnO					Trace.
CaO	1.61	1.78	1.19	1.83	1.11
MgO	1.29	.51	.34	1.33	1.14
K ₂ O	1.47	1.31	2.97	1.23	5.58
Na ₂ O		2.38	2.77	.80	1.23
Ignition	6.45	11.47	6.34	11.96	7.99
CaCO ₃	28.72				
	99.98	99.13	99.79	99.82	100.73

2. THE CRAZY MOUNTAINS.

The greater number of the rocks in this group were received from J. E. Wolff, who has supplied the petrographic data. The few exceptions are properly indicated. The three tinguaïtes and the clæolite-syenite were described by Wolff and Tarr in Bull. Mus. Compar. Zoölogy, vol. 16, No. 12, 1893, in a paper upon "Acmite-Trachyte from the Crazy Mountains." The renaming of these rocks is due to Wolff. The analyses, except when otherwise stated, are by W. F. Hillebrand, record No. 1438.

A. Granitite, Big Timber Creek. Small dikes in main diorite stock. Contains quartz, orthoclase, plagioclase (oligoclase), and biotite.

B. Hornblende-granitite, main stock, Big Timber Creek. Contains biotite, hornblende, quartz, orthoclase, and plagioclase (oligoclase).

C. Granite-porphry, intrusive sheet, north part of the mountains. Contains orthoclase, albite, quartz, biotite, and green hornblende, in a groundmass of quartz and untwinned feldspar.

D. Porphyrite, intrusive sheet, Sweet Grass Creek. Contains hornblende and andesine in a groundmass of plagioclase, orthoclase, and quartz, with accessory magnetite.

E. Porphyrite, dike in contact zone, Sweet Grass Creek. Contains brown hornblende, biotite, and labradorite, in a groundmass of plagioclase, biotite, and hornblende, with a little quartz and orthoclase.

F. Porphyrite, intrusive sheet, middle peak of Three Peaks. Andesine, hornblende, augite, and biotite in a groundmass of plagioclase, orthoclase, and quartz.

	A.	B.	C.	D.	E.	F.
SiO ₂	74.37	64.47	69.93	66.28	64.49	61.08
TiO ₂ .....	.29	.75	.33	.50	.51	.73
Al ₂ O ₃	13.12	15.45	14.95	16.21	17.25	16.62
Fe ₂ O ₃ .....	.73	2.25	1.78	.80	.86	2.87
FeO .....	.87	2.25	.55	2.06	2.42	2.56
MnO	Trace.	.06	Trace.	Trace.	Trace.	Trace.
CaO	1.26	3.63	1.46	3.53	3.79	3.66
SrO	Trace.	.04	.06	.05	.08	.08
BaO .....	.10	.23	.29	.34	.30	.32
MgO .....	.35	2.68	.60	1.57	1.24	1.65
K ₂ O	6.09	3.19	3.99	3.20	4.15	3.90
Na ₂ O	2.57	4.54	5.30	4.36	4.19	4.75
Li ₂ O	Trace.	Trace?	Trace.	Trace?	Trace.	Trace.
H ₂ O at 110° ....	.05	.05	.12	.12	.06	.44
H ₂ O above 110° ..	.25	.63	.32	.78	.54	.97
P ₂ O ₅ .....	.06	.22	.33	.20	.23	.63
	100.11	100.44	100.01	100.00	100.11	100.26

G. Porphyrite, intrusive sheet, north of Shield's River Basin. Contains plagioclase, hornblende, and biotite, in a groundmass of plagioclase, a little orthoclase, augite, hornblende, and magnetite.

H. Porphyrite, intrusive sheet, northern part of the mountains. Contains brown hornblende, green augite, and plagioclase, in a groundmass of plagioclase, augite, and magnetite, with accessory apatite.

I. Syenite, ridge north of Shield's River Basin. Contains hornblende, green augite, and anorthoclase, with accessory sphene, apatite, and magnetite.

J. Diabase-porphyrite (?), dike south of Shield's River Basin. Contains labradorite and decomposed augite in a groundmass of plagioclase, epidote, and chlorite.

K. Diorite-porphyrite, Big Timber Creek. Contains labradorite, augite, hornblende, biotite, orthoclase, quartz, magnetite, and apatite.

L. Quartz diorite, main stock on Sweet Grass Creek. Contains hornblende, biotite, augite, labradorite, orthoclase, and quartz, with accessory apatite, magnetite, olivine, and hypersthene.

	G.	H.	I.	J.	K.	L.
SiO ₂	56.75	54.69	58.28	58.28	54.56	53.48
TiO ₂.....	.86	.91	.64	.96	1.34	1.07
Al ₂ O ₃	16.40	16.53	17.89	19.37	17.58	19.35
Fe ₂ O ₃	4.78	4.54	3.20	1.35	4.30	2.37
FeO.....	3.10	2.83	1.73	2.98	4.98	4.90
MnO.....	.17	.07	.06	.07	.06	.06
CaO.....	5.34	5.34	3.69	4.78	6.00	7.55
SrO.....	.10	.06	.05	.09	.08	.11
BaO.....	.33	.37	.36	.25	.27	.19
MgO.....	3.22	2.99	1.51	1.30	2.86	3.67
K ₂ O.....	3.36	3.93	5.34	3.75	2.70	1.41
Na ₂ O.....	4.19	5.19	5.89	4.40	4.43	4.07
Li ₂ O.....	Trace?	Trace?	Trace.	Trace?	Trace.	Trace?
H ₂ O at 110°.....	.40	.32	.17	.44	.02	.16
H ₂ O above 110°.....	.82	1.05	.98	1.78	.38	.80
P ₂ O ₅.....	.52	.73	.26	.35	.60	.62
Cl.....		Trace.				
CO ₂.....		.83		.33		.08
	100.34	100.38	100.05	100.48	100.16	99.89

M. Diorite, head of Rock Creek. Contains biotite, labradorite, and augite, in a groundmass of plagioclase, orthoclase, and quartz, with accessory magnetite, apatite, and hornblende.

N. Diorite, main stock, Big Timber Creek. Contains biotite, augite, labradorite, quartz, orthoclase, apatite, and magnetite.

O. Olivine-gabbro, Big Timber Creek. Contains labradorite (?), brown hornblende, augite, olivine, and magnetite.

P. Rock from Musselshell River, north of Crazy Mountains. Received from J. S. Diller, but undescribed. Regarded by W. H. Weed as monchiquite. Analysis by L. G. Eakins, record No. 1021.

Q. Hornstone, metamorphosed shale, contact zone, Sweet Grass Creek. An aggregate of augite, quartz, triclinic feldspar, and biotite.

	M.	N.	O.	P.	Q.
SiO ₂	57.97	50.73	40.42	44.66	57.31
TiO ₂.....	.60	1.59	2.51	1.02	.52
Al ₂ O ₃	15.65	19.99	9.98	12.12	14.24
Fe ₂ O ₃.....	.73	3.20	9.83	5.81	1.00
FeO.....	2.80	4.66	10.67	3.20	3.24
(CoNi) O.....			.02		
MnO.....	Trace.	.05	.25	.21	.08
CaO.....	10.93	8.55	10.78	8.14	11.31
SrO.....	.02	.11	.02		Trace?
BaO.....	.09	.27	.05		.19
MgO.....	4.96	3.48	11.56	8.77	4.60
K ₂ O.....	3.16	1.89	.60	2.75	4.55
Na ₂ O.....	3.03	4.03	1.26	4.47	2.64
Li ₂ O.....	Trace.	Trace.	Trace.		Trace?
H ₂ O at 110°.....	.22	.11	.45	} 4.33	.25
H ₂ O above 110°.....	.38	.66	1.17		.24
P ₂ O ₅.....	.15	.81	.63	2.02	.18
CO ₂				2.19	.17
Cl.....	Trace.				
F.....	Trace.				
	100.69	100.13	100.20	99.69	100.52

R. Elæolite-syenite, Peaked Butte, northeast side of the mountains. Described by Wolff and Tarr, *l. c.* Contains anorthoclase, augite, occasionally sodalite, ægirine, apatite, magnetite, and some interstitial nephelite. Analysis by W. H. Melville, record No. 1291.

Ra. Anorthoclase from R. Analysis by W. F. Hillebrand, record No. 1297.

S. Tinguaitite, var. sölvbergite; intrusive sheet north of Shields River.

T. Tinguaitite, var. sölvbergite, dike north part of mountains.

U. Tinguaitite, var. sölvbergite, dike at head of Sixteen-mile Creek.

S, T, and U are the rocks described by Wolff and Tarr in their paper upon "Acmite-Trachyte." Mineral composition the same as under R. Analyses by W. H. Melville, record No. 1291.

	R.	Ra.	S.	T.	U.
SiO ₂	59.66	62.31	58.70	62.17	64.33
TiO ₂	Trace.	.....	Trace.	Trace.	Trace.
Al ₂ O ₃	16.97	22.63	19.26	18.58	17.52
Fe ₂ O ₃	3.18	.....	3.37	2.15	3.06
FeO.....	1.15	.....	.58	1.05	.94
MnO.....	.19	.....	.10	Trace.	.35
CaO.....	2.32	.63	1.41	1.57	.56
SrO.....	.....	.57	.....	.....	.....
BaO.....	.....	.77	.....	.....	.....
MgO.....	.80	.....	.76	.73	.34
K ₂ O.....	4.17	4.79	4.53	3.88	4.28
Na ₂ O.....	8.38	7.68	8.55	7.56	7.30
H ₂ O at 105° ....	.07	.16	.07	.07	.04
H ₂ O above 105°.	2.53	.72	2.57	1.63	.95
P ₂ O ₅.....	.14	.....	.10	.11	Trace.
	99.56	100.26	100.00	99.50	99.67

V. Theralite, Gordon's Butte. Contains green augite, ægirine, biotite, olivine, nephelite, sodalite, and a feldspar partly sanidine, containing K, Na, Ba, Sr, and Ca; also accessory apatite, magnetite, and sphene.

W. Theralite, Gordon's Butte; another sample. Analysis by E. A. Schneider, record No. 1281.

X. Theralite, north of Alabaugh Creek. Described by Wolff for the Educational Series. Contains augite, ægirine, biotite, olivine, magnetite, apatite, nephelite partly zeolitized, a mineral of the sodalite group, sanidine, and analcite. Analysis by Schneider, No. 1281.

Y. Altered theralite, head of Shields River, west of Loco Mountain.

Received from W. H. Weed. Analysis by H. N. Stokes, record No. 1547.

Z. Hornblende-picrite, Conical Peak. Data supplied by J. P. Iddings. Contains hornblende, plagioclase, hypersthene, augite, olivine, very little primary quartz, and probably some magnetite and apatite. Analysis by L. G. Eakins, record No. 1379.

	V.	W.	X.	Y.	Z.
SiO ₂	44.65	44.31	47.67	48.90	45.71
TiO ₂ .....	.95	Undet.	Undet.	.95	1.83
Al ₂ O ₃	13.87	17.20	18.22	14.70	10.80
Cr ₂ O ₃ .....					.10
Fe ₂ O ₃	6.06	4.64	3.65	4.14	4.43
FeO	2.94	3.73	3.85	3.68	9.35
MnO .....	.17	.10	.28	.03	.17
CaO	9.57	10.40	8.03	8.26	10.48
SrO .....	.37			.13	
BaO .....	.76			.31	Trace.
MgO	5.15	6.57	6.35	3.95	13.75
K ₂ O	4.49	3.64	3.82	.56	.85
Na ₂ O	5.67	4.45	4.93	5.22	1.58
Li ₂ O	Trace.			Trace.	
H ₂ O at 110° .....	.96	.77	.38	.52	.97
H ₂ O above 110°	2.10	3.30	2.97	2.44	
P ₂ O ₅	1.50			.79	.11
CO ₂ .....	.11			5.42	
SO ₃ .....	.61			.04	
Cl	Trace.				
	99.92	99.11	100.15	100.04	100.13

3. THE LITTLE BELT MOUNTAINS.

Rocks collected by W. H. Weed and L. V. Pirsson, who furnish the petrographic data. To be described in a forthcoming Bulletin of the Survey on the Neilhart and Barker mining districts. Analyses by W. F. Hillebrand, record No. 1476, and H. N. Stokes, record No. 1547.

A. Quartz-porphyry, Yogo Peak, sheet at head of Belt and Running Wolf creeks. Phenocrysts of orthoclase and quartz in a groundmass of quartz and alkali-feldspar, with a little white mica and some kaolin. Chlorite, limonite, and calcite are also present, pseudomorphous after biotite and perhaps hornblende. Total amount of secondary minerals very small. Analysis by Hillebrand.

B. Granite-porphyry, Wolf Butte. Phenocrysts of quartz, orthoclase, plagioclase, and biotite in a groundmass of quartz and alkali-feldspar. A little apatite and iron ore, with secondary calcite, limonite, chlorite, and white mica. Analysis by Stokes.

C. Granite-porphyry, top of Barker Mountain. Phenocrysts of orthoclase, oligoclase, biotite, green hornblende, sphene, and iron ore, in a groundmass of quartz and alkali-feldspar. Also a little apatite and some secondary chlorite and limonite. Analysis by Stokes.

D. Syenite, Wright and Edwards's mine, Hughsville, near Barker. Very fresh rock. Contains magnetite, ilmenite, hornblende, anorthoclase, albite, subordinate quartz, a little chlorite, calcite, and limonite, and white mica in traces. Analysis by Stokes.

E. Syenite, Yogo Peak. Described in Amer. Journ. Sci., 3d series, vol. 50, p. 471. Contains apatite, sphene, iron ore, pyroxene, hornblende, biotite, orthoclase, oligoclase, and quartz, with traces of chlorite and limonite and a little kaolin. Analysis by Hillebrand.

F. Syenite-porphyry, dike at head of Sheep Creek. Phenocrysts of orthoclase, some plagioclase, and green hornblende, in a groundmass of alkali-feldspar, with some quartz. Also contains a little apatite and iron ore, with some secondary calcite and kaolin. Analysis by Hillebrand.

	A.	B.	C.	D.	E.	F.
SiO ₂	73.12	69.68	68.60	64.64	61.65	66.29
TiO ₂.....	.08	.28	.32	.51	.56	.27
Al ₂ O ₃	14.27	14.97	16.13	16.27	15.07	15.09
Cr ₂ O ₃	None.	.....	.....	.....	Trace.	None.
Fe ₂ O ₃.....	.51	.79	2.22	2.42	2.03	1.37
FeO.....	.26	.34	.44	1.58	2.25	1.17
MnO.....	.06	Trace.	Trace.	Trace.	.09	.06
CaO.....	1.10	2.10	1.36	2.65	4.61	2.38
SrO.....	Trace.	.06	.09	.08	.10	.07
BaO.....	Trace.	.14	.27	.18	.27	.30
MgO.....	.24	.66	.72	1.27	3.67	2.39
K ₂ O.....	4.90	4.40	4.89	4.98	4.50	4.91
Na ₂ O.....	3.43	3.38	4.37	4.39	4.35	3.96
Li ₂ O.....	Trace.	Trace.	Trace.	.....	Trace.	Trace.
H ₂ O at 110°.....	.68	1.09	.20	.09	.26	.39
H ₂ O above 110°.....	.73	.92	.58	.27	.41	.60
P ₂ O ₅.....	.03	.17	.18	.37	.33	.15
CO ₂.....	.77	.88	.....	.37	.....	.45
SO ₃.....	.....	Trace.	Trace.	Trace.	.....	.....
Cl.....	.....	Trace.	Trace.	.05	.....	.....
	100.18	99.86	100.37	100.12	100.15	99.85

G. Syenite-porphyry, intrusive sheet, between Yogo Peak and Big Baldy Mountain. Abundant phenocrysts of hornblende and orthoclase, with less biotite and plagioclase, in a groundmass of alkali-feldspar with accessory quartz. Also contains iron ore and apatite, with secondary calcite, chlorite, sericite, and kaolin. Analysis by Hillebrand.

H. Granite-syenite-porphyry, north end of Thunder Mountain. Phenocrysts of orthoclase, oligoclase, hornblende, and biotite, in a groundmass of alkali-feldspar and very abundant quartz. Also contains a little sphene, iron ore, and apatite, very little secondary chlorite and limonite, and a trace of kaolin. Analysis by Stokes.

I. Quartz-syenite-porphyry, top of Big Baldy Mountain. Phenocrysts of orthoclase, plagioclase, biotite, iron ore, brown hornblende, and sphene, in a groundmass of quartz and alkali-feldspar. Also contains a little apatite, with traces of chlorite, limonite, and kaolin. Analysis by Hillebrand.

J. Syenite-diorite-porphyry, talus slope on west slope of Bear Park. Phenocrysts of biotite, hornblende, plagioclase, and orthoclase, in a groundmass of quartz and alkali-feldspar. Also contains a little magnetite, chlorite, white mica, and apatite. Analysis by Stokes.

K. Diorite-porphyry, Steamboat Mountain. Phenocrysts of orthoclase, plagioclase, hornblende, and biotite, with a little iron ore and apatite, in a groundmass of orthoclase, plagioclase, and quartz. Analysis by Stokes.

L. Diorite, Carpenter Creek, near Neihart. Contains green hornblende, biotite, and plagioclase, with some apatite, iron ore, calcite, kaolin, and muscovite, and a very little quartz and orthoclase. Analysis by Hillebrand.

	G.	H.	I.	J.	K.	L.
SiO ₂	62.58	67.44	67.04	64.95	62.18	55.13
TiO ₂ .....	.40	.32	.20	.39	.55	.74
Al ₂ O ₃	16.42	15.78	15.25	15.44	15.77	20.27
Fe ₂ O ₃	2.46	1.58	1.69	2.02	1.83	1.52
FeO	1.96	.85	1.13	1.60	2.44	4.29
MnO .....	.08	Trace.	.05	Trace.	Trace.	.13
CaO	2.47	2.38	2.17	3.07	4.13	7.05
SrO .....	.10	.09	.03	.10	.16	.06
BaO .....	.41	.24	.33	.35	.43	.11
MgO	1.84	1.43	1.75	2.65	3.55	1.80
K ₂ O	3.91	4.87	5.10	3.87	3.91	2.84
Na ₂ O	4.57	4.11	4.09	4.25	3.92	4.31
Li ₂ O	Trace.	Trace.	Trace?	.....	Trace.	Trace.
H ₂ O at 110° .....	.38	.32	.56	.26	.30	.14
H ₂ O above 110°	1.40	.70	.51	.85	.70	.95
P ₂ O ₅ .....	.33	.21	.21	.25	.32	.40
CO ₂ .....	.77	.....	.....	.....	.....	.26
SO ₃ .....	.....	Trace.	.....	.02	Trace.	.....
Cl .....	.....	Trace.	.....	.04	.04	.....
	100.08	100.32	100.11	100.11	100.23	100.00

M. Minette, intrusive sheet, head of Sheep Creek. Chiefly biotite, augite, and orthoclase, with accessory apatite, plagioclase, quartz, and iron ore, and some secondary calcite, chlorite, and kaolin. Analysis by Hillebrand.

N. Monzonite, Yogo Peak. Described in Amer. Journ. Sci., 3d series, vol. 50, p. 473, and 4th series, vol. 1, p. 356. Contains apatite, sphene, iron ore, pyroxene, hornblende, biotite, orthoclase, and oligoclase, and a little secondary kaolin. Analysis by Hillebrand.

O. Monchiquite, dike on Big Baldy Mountain. Contains much pyroxene, a few serpentinized olivines, iron ore, and apatite in a colorless base of analcite. Analysis by Hillebrand.

P. Monchiquite, dike on Bandbox Mountain. Contains olivine, augite, biotite, analcite, and apatite, with traces of serpentine and chlorite. Analysis by Stokes.

Q. Shonkinite, Yogo Peak. Described in Amer. Journ. Sci., 3d series, vol. 50, p. 474. Chiefly augite and orthoclase, with a considerable amount of accessory biotite, iron ore, and andesine, less apatite and olivine, and a trace of kaolin. Analysis by Hillebrand.

	M.	N.	O.	P.	Q.
SiO ₂	52.26	54.42	48.35	48.39	48.98
TiO ₂ .....	.58	.80	.52	.73	1.44
Al ₂ O ₃	13.96	14.28	13.27	11.64	12.29
Cr ₂ O ₃	Trace.	Trace.	Trace.	.07	Trace.
Fe ₂ O ₃	2.76	3.32	4.38	4.09	2.88
FeO	4.45	4.13	3.23	3.57	5.77
NiO .....			.04		
MnO .....	.14	.10	.19	Trace.	.08
CaO	7.06	7.72	9.94	7.64	9.65
SrO .....	.05	.13	.09	.15	.08
BaO .....	.23	.32	.54	.32	.43
MgO	8.21	6.12	8.36	12.55	9.19
K ₂ O	3.87	4.22	3.01	3.24	4.96
Na ₂ O	2.80	3.44	3.35	4.14	2.22
Li ₂ O	Trace.	Trace.	Trace.	Trace.	Trace.
H ₂ C at 110°	1.53	.22	.90	.28	.26
H ₂ O above 110° ..	1.34	.38	2.89	2.56	.56
P ₂ O ₅ .....	.52	.59	.40	.45	.98
SO ₃ .....				.08	
Cl				Trace.	
CO ₂ .....	.49		.30		
F .....			.25		.22
	100.25	100.19	100.01	99.90	99.99

4. THE CASTLE MOUNTAIN DISTRICT.

Rocks described by Weed and Pirsson in Bull. 139. Analyses made by Pirsson in the laboratory of the Sheffield Scientific School.

A. Rhyolite, between Four-mile and Five-mile creeks, near Smith River. Contains quartz, soda-orthoclase, tourmaline, and a little iron ore and zircon.

B. Quartz-tourmaline-porphyry, upper Four-mile Creek. Contains quartz, orthoclase, plagioclase, tourmaline, fluorite, and a little white mica, apatite, and zircon.

C. Granite, Elk Peak. Contains quartz, orthoclase, oligoclase, biotite, hornblende, iron ore, apatite, sphene, and zircon. The last three minerals are rare.

D. Quartz-porphyry, sheet on ridge between Four-mile and Checkerboard creeks. Contains quartz, plagioclase, an untwinned feldspar and biotite, with occasional grains of iron ore and crystals of apatite and zircon.

E. Rhyolite-pitchstone, forks of Checkerboard Creek. Essentially glass, inclosing grains of iron ore.

F. Aplitic granite, dike between Blackhawk and Robinson. Contains quartz and unstriated feldspar, some plagioclase, and occasional biotite.

G. Quartz-porphyry, Musselshell Canyon. Contains quartz, biotite, plagioclase, apatite, iron ore, and zircon.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	74.90	74.82	72.48	72.38	72.56	72.88	71.67
TiO ₂.....	.15	.25	.32	.10	.20	.45	.10
Al ₂ O ₃	13.64	13.80	13.14	14.71	12.33	12.90	15.82
Fe ₂ O ₃.....	.66	.37	1.66	1.09	.80	.74	1.18
FeO.....	.50	.30	1.02	.82	.82	1.05	.35
MnO.....	Trace.	Trace.	Trace.	Trace.	Trace.	.05	Trace.
CaO.....	.61	.17	1.04	.67	Trace.	.81	.25
MgO.....	Trace.	.10	.15	.70	Trace.	.75	.13
K ₂ O.....	4.64	4.81	4.88	4.15	3.08	5.03	4.45
Na ₂ O.....	4.22	4.33	4.22	4.28	5.36	3.72	4.46
Li ₂ O.....	Trace.	Trace.	Trace.	Trace.	.....	.....	.....
H ₂ O.....	.33	.83	.42	.92	4.59	1.22	1.21
	99.65	99.78	99.33	99.82	99.74	99.60	99.62
Sp. gr.....	2.61	2.59	2.62	2.61	2.37	2.64	2.60

H. Feldspar-porphry dike, below Castle. Contains orthoclase, less plagioclase, hornblende, biotite partly altered to chlorite, sometimes allanite, and occasional iron ore, apatite, and zircon.

I. Rhyolitic tuff, near forks of Checkerboard Creek. Contains fragments of shale, quartz, plagioclase; sanidine, and hornblende, in a brownish material carrying pumiceous glass. Much decomposed, with formation of kaolin.

J. Syenitic mass included in granite, head of Cottonwood Creek. Contains orthoclase, plagioclase, quartz, hornblende, biotite, apatite, and iron ore. A hornblende-mica-syenite.

K. Diorite, between Blackhawk and Robinson. Contains plagioclase, orthoclase, quartz, biotite, diallage, hypersthene, iron ore, apatite, and zircon.

L. Basalt, Volcano Butte. Contains labradorite, augite, olivine, a little serpentine, occasional quartz grains, small patches of glass, iron ore, chiefly ilmenite, apatite, a trace of calcite, and a mineral which may be nephelite or analcite.

M. Augite-vogesite, dike on west side of upper Four-mile Creek. Contains augite, hornblende, iron ore, a little plagioclase, orthoclase, calcite, and some decomposition products.

N. Monchiquite-like dike rock, west side of upper Willow Creek. Contains augite, olivine, biotite, ilmenite, and a colorless base which appears to be partially zeolitized glass. Also a little serpentine, chlorite, and calcite.

In analysis L the symbol X refers to unseparated rare earths or metallic acids, such as columbic, tantallic, etc.

	H.	I.	J.	K.	L.	M.	N.
SiO ₂	65.87	61.21	61.87	56.80	46.52	45.15	42.46
TiO ₂ .....	.37	.56	.87	.46	2.98	2.80	2.47
X .....					.73		
Al ₂ O ₃	16.82	15.67	17.26	18.30	10.48	15.39	12.04
Fe ₂ O ₃	1.58	4.06	2.35	1.64	4.40	2.76	3.19
FeO	1.23	.62	2.43	5.58	7.79	5.64	5.34
MnO	Trace.	.10	.03	Trace.	.11	.14	.16
CaO	2.65	2.18	3.23	5.31	9.49	8.83	12.14
MgO	1.54	1.58	1.82	3.63	10.58	6.38	12.40
K ₂ O	3.15	2.75	3.83	3.28	1.55	2.77	2.68
Na ₂ O	4.72	1.57	5.18	4.35	3.12	2.67	1.21
Li ₂ O		Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
H ₂ O	1.43	10.20	1.07	.53	1.79	2.85	4.03
P ₂ O ₅	Trace.		Trace.	Trace.	.83	.56	.84
CO ₂					Trace.	4.27	.55
	99.36	100.50	99.94	99.88	100.37	100.21	99.51
Sp. gr	2.62		2.67	2.83	2.99	2.70	2.94

5. THE HIGHWOOD MOUNTAINS.

Rocks collected by W. H. Weed and L. V. Pirsson, who furnish the petrographic data. Analyses made in the laboratory of the Sheffield Scientific School, under the direction of Professor Pirsson.

A. Trachy-andesitic breccia, head of north fork of Willow Creek. Contains hornblende, biotite, iron ore, apatite, plagioclase, and orthoclase, with a little kaolin and limonite. E. B. Hurlbut and B. Barnes, analysts.

B. Trachyte, dike, 1 mile north of divide in Highwood Gap. Contains abundant phenocrysts of orthoclase and augite in a groundmass of the same minerals. Also a little biotite, apatite, and iron ore, and some secondary kaolin. E. B. Hurlbut, analyst.

C. Trachyte, dike, north end of South Mountain. Contains phenocrysts of alkali-feldspar, ægirine-augite and melanite, in a groundmass of alkali-feldspar. Apatite, iron ore, a trace of calcite, and some kaolin are also present. H. W. Foote, analyst.

D. Trachyte, dike, Aspen Creek. Contains alkali-hornblende and alkali-feldspar phenocrysts, in a groundmass of alkali-feldspars. Also some apatite and iron ore. Rock stained by limonite. H. W. Foote, analyst.

E. Trachyte, dike, head of Shonkin Creek. Contains augite, biotite, iron ore, and orthoclase, in a groundmass of alkali-feldspar. Also apatite and some kaolin. W. M. Bradley, analyst.

	A.	B.	C.	D.	E.
SiO ₂	59.24	58.04	57.18	55.23	51.94
TiO ₂.....	.22	.30	.30	.42	.39
Al ₂ O ₃	13.84	17.24	18.54	18.31	15.78
Fe ₂ O ₃	5.46	2.49	3.65	4.90	4.07
FeO.....	1.36	1.24	1.15	2.06	3.17
MnO.....	Trace.	Trace.	Trace.	Trace.	Trace.
CaO.....	5.60	3.50	2.31	3.62	6.04
SrO.....	None.	Undet.	Trace.	Trace.	.28
BaO.....	Trace.	Undet.	.49	.46	.42
MgO.....	4.79	1.79	.69	1.85	3.48
K ₂ O.....	4.22	10.06	8.58	6.43	7.69
Na ₂ O.....	3.13	3.37	4.48	4.02	3.44
H ₂ O.....	2.02	1.95	2.10	1.84	2.17
P ₂ O ₅.....	.34	.22	.05	.58	.59
SO ₃.....	.08	Trace.	.06	.23	.29
CO ₂	None.	.....	.....	None.	.....
Cl.....	.04	.38	.77	.32	.08
	100.34	100.58	100.35	100.27	99.83
Less O.....	.01	.09	.17	.08	.02
	100.33	100.49	100.18	100.19	99.81

F. Syenite, top of Palisade Butte. Contains augite, iron ore, apatite, alkali-feldspar, a little biotite, some limonite in cracks, much natrolite, and possibly other zeolites. H. W. Foote, analyst.

G. Leucite-syenite, head of Davis Creek. Contains augite, iron ore, olivine, biotite, apatite, alkali-feldspar, leucite, and some zeolites, with traces of limonite and serpentine. E. B. Hurlbut, analyst.

H. Monchiquite, dike east side of Highwood Gap. Contains augite, olivine, biotite, iron ore, apatite, and analcite, with some serpentine and a little kaolin. H. W. Foote, analyst.

I. Leucite-basalt, saddle between Highwood and Pinewood peaks. Contains augite, iron ore, leucite, apatite, altered olivine, chlorite, calcite, and zeolites. H. W. Foote, analyst.

J. Leucite-basalt or leucite-monchiquite, dike on Arrow Peak. Phenocrysts of augite, olivine, and biotite, with some leucite, in a groundmass of the same minerals. Also analcite, iron ore, and apatite. H. W. Foote, analyst.

	F.	G.	H.	I.	J.
SiO ₂	50.11	49.59	47.82	47.98	46.04
TiO ₂ .....	.82	.36	.67	.58	.64
Al ₂ O ₃	17.13	14.51	13.56	13.34	12.23
Fe ₂ O ₃	3.73	3.51	4.73	4.09	3.86
FeO	3.28	5.53	4.54	4.24	4.60
MnO	Trace.	Trace.	Trace.	Trace.	Trace.
CaO	5.09	9.04	8.91	9.32	8.97
SrO .....	.35	.21	.21	.14	.25
BaO .....	.63	.49	.16	.50	.48
MgO	2.47	6.17	7.49	7.01	10.38
K ₂ O	7.47	5.60	3.23	5.00	5.77
Na ₂ O	3.72	3.52	4.37	3.51	2.42
H ₂ O	4.47	1.95	3.37	2.10	2.87
P ₂ O ₅ .....	.67	.15	1.10	1.03	1.14
SO ₃ .....	.08	.02	Trace.	Trace.	Trace.
CO ₂				1.24	
Cl .....	.07	.13	.04	.21	.11
	100.09	100.78	100.20	100.29	99.76
Less O .....	.02	.03	.01	.07	.03
	100.07	100.75	100.19	100.22	99.73

K. Missourite, head of Shonkin Creek. Described in Amer. Journ. Sci., 4th series, vol. 2, p. 315. Contains apatite, iron ore, olivine, biotite, augite, and leucite, the two latter being the chief minerals. Some zeolites and analcite are also present. E. B. Hurlbut, analyst.

L. Pseudo-leucite-syenite, head of Shonkin Creek. Contains augite, olivine, biotite, iron ore, apatite, orthoclase, nephelite, zeolites, and traces of serpentine, limonite, and kaolin. Contains pseudomorphs after leucite. E. B. Hurlbut, analyst.

M. Monzonite, Highwood Peak. Contains augite, biotite, iron ore, apatite, plagioclase, and alkali-feldspar. E. B. Hurlbut, analyst.

N. Monzonite, Middle Peak. Contains augite, olivine, biotite, iron ore, apatite, plagioclase, and orthoclase. The two latter, with augite, are the chief minerals. E. B. Hurlbut, analyst.

	K.	L.	M.	N.
SiO ₂	46.06	51.75	51.00	52.05
TiO ₂.....	.73	.23	.13	.47
Al ₂ O ₃	10.01	14.52	17.21	15.02
Fe ₂ O ₃	3.17	5.08	2.41	2.65
FeO.....	5.61	3.58	4.23	5.52
MnO.....	Trace.	Trace.	Trace.	Trace.
CaO.....	10.55	7.04	9.15	8.14
SrO.....	.20	.07	.14	.28
BaO.....	.32	.30	.34	.42
MgO.....	14.74	4.55	6.19	5.39
K ₂ O.....	5.14	7.61	4.93	6.10
Na ₂ O.....	1.31	2.93	2.88	3.17
H ₂ O.....	1.44	2.25	.63	.35
P ₂ O ₅.....	.21	.18	.33	.21
SO ₃.....	.05	Trace.	.03	.02
Cl.....	.03	.05	Trace.	.24
	99.57	100.14	99.60	100.03
Less O.....	.01	.01	.....	.06
	99.56	100.13	.....	99.97

The following rock and separations, from Square Butte, at the east end of the Highwood Mountains, are described by Lindgren in Amer. Journ. Sci., 3d series, vol. 45, p. 286. Analyses by W. H. Melville, record No. 1268.

A. Post-Cretaceous sodalite-syenite. Contains orthoclase, some albite, hornblende, sodalite, analcite, and apatite. Orthoclase predominates. The sodalite amounts to 8 per cent.

B. Hornblende separated from A. Near barkevikite.

C. Sodalite from A. Sp. gr. 2.265.

D. Analcite from A. Sp. gr. 2.255.

In addition, the orthoclase gave 3.88 per cent Na_2O and 11.03 K_2O . A separation of mixed feldspars, sp. gr. 2.56, gave 6.08 Na_2O and 8.91 K_2O .

	A.	B.	C.	D.
SiO_2	56.45	38.41	41.56	49.54
TiO_2 .....	.29			
Al_2O_3	20.08	17.65	29.48	25.07
Fe_2O_3	1.31	3.75		
FeO	4.39	21.75	.49	.40
NiO	Trace.	Trace.		
MnO} .....	.09	.15		
CaO	2.14	10.52	.49	.22
MgO} .....	.63	2.54	.15	.20
K_2O	7.13	1.95	.91	.89
Na_2O	5.61	2.95	19.21	15.32
H_2O at 100°26		.45	Undet.
H_2O above 100°	1.51	.24	3.73	Undet.
P_2O_5 .....	.13			
Cl} .....	.43		4.79	1.67
	100.45	99.91	101.26	93.31
Less O .....	.10		1.08	.38
	100.35		100.18	92.93

6. THE LITTLE ROCKY MOUNTAINS.

Granite-syenite-porphry. Described by Weed and Pirsson, Journ. of Geology, vol. 4, p. 399. Contains orthoclase, quartz, oligoclase, iron oxides, and a little muscovite. Analysis by H. N. Stokes, record No. 1558.

SiO_2	68.65	Na_2O	4.86
TiO_2 .....	.20	Li_2O	Trace.
Al_2O_3	18.31	H_2O at 110°27
Fe_2O_3 .....	.56	H_2O above 110°83
FeO} .....	.08	P_2O_5	Trace.
MnO	Trace.	SO_3	Trace.
CaO	1.00	Cl} .....	.03
SrO} .....	.10	F	Trace.
BaO} .....	.13		
MgO} .....	.12		99.88
K_2O	4.74		

7. THE BEARPAW MOUNTAINS.

Described by Weed and Pirsson, Amer. Journ. Sci., series 4, vol. 1, pp. 283 and 351, and vol. 2, pp. 136 and 188. Analyses by H. N. Stokes, record Nos. 1558 and 1572.

A. Quartz-syenite-porphyry, from Gray Butte. Contains anorthoclase, microlites of plagioclase, ægirite, augite, quartz, and apatite, with an occasional zircon and very few biotite leaves.

B. Quartz-syenite, Beaver Creek stock. Contains orthoclase, albite, quartz, augite, and iron oxides, with very little biotite, hornblende, and sphene.

C. Basic syenite or monzonite (yogoite), from Beaver Creek. Contains orthoclase, plagioclase, diopside, biotite, iron oxides, and apatite.

	A.	B.	C.
SiO ₂	66.22	68.34	52.81
TiO ₂.....	.22	.21	.71
Al ₂ O ₃	16.22	15.32	15.66
Fe ₂ O ₃	1.98	1.90	3.06
FeO.....	.16	.84	4.76
MnO.....	Trace.	.07	Trace.
CaO.....	1.32	.92	7.57
SrO.....	.06	.04	.09
BaO.....	.29	.08	.24
MgO.....	.77	.54	4.99
K ₂ O.....	5.76	5.62	4.84
Na ₂ O.....	6.49	5.45	3.60
Li ₂ O.....	Trace.	None.	Trace.
H ₂ O at 110°.....	.08	.15	.16
H ₂ O above 110°.....	.24	.30	.93
P ₂ O ₅.....	.10	.13	.75
SO ₃.....	.02	Trace.	Trace.
Cl.....	.04	.04	.07
F.....	Trace.	None?	Trace.
	99.97	99.95	100.24

D. Shonkinite, Beaver Creek. Contains anorthoclase, diopside, biotite, iron oxides, and apatite, with very little olivine and probably a trace of nephelite.

E. Leucitite, Bearpaw Mountain. An olivine-free leucite-basalt. Contains leucite, augite, iron oxides, rarely biotite, and very little glassy base.

F. Tinguaita dike, Bear Creek. Contains orthoclase, nephelite, cancrinite, augite, ægirite, apatite, a little sodalite, and a doubtful fibrous hornblende.

G. Pseudo-leucite-sodalite-tinguaita, Beaver Creek. Contains orthoclase, nephelite, sodalite, nosean, ægirite, diopside, and fluorite.

	D.	E.	F.	G.
SiO ₂	50.00	46.51	57.46	51.93
TiO ₂ .....	.73	.83	.60	.20
Al ₂ O ₃	9.87	11.86	15.40	20.29
Cr ₂ O ₃ .....	.11	None.	.....	.....
Fe ₂ O ₃	3.46	7.59	4.87	3.59
FeO	5.01	4.39	.87	1.20
NiO .....	.07	.04	.....	.....
CoO .....	.....	Trace.	.....	.....
MnO	Trace.	.22	Trace.	Trace.
CuO .....	.....	Trace.	.....	.....
CaO	8.31	7.41	2.59	1.65
SrO .....	.07	.16	.16	.07
BaO .....	.32	.50	.60	.09
MgO	11.92	4.73	1.37	.22
K ₂ O	5.02	8.71	9.44	9.81
Na ₂ O	2.41	2.39	5.48	8.49
Li ₂ O	Trace.	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.17	1.10	.09	.10
H ₂ O above 110°	1.16	2.45	.82	.99
P ₂ O ₅ .....	.81	.80	.21	.06
SO ₃ .....	.02	.05	.13	.67
CO ₂ .....	.31	None.	.13	.25
Cl .....	.08	.04	.20	.70
F .....	.16	Trace.	Trace.	.27
Less O	100.01	99.78	100.42	100.58
	.08	.02	.05	.27
	99.93	99.76	100.37	100.31

COLORADO.

1. THE DENVER BASIN.

Rocks described by Cross, in Mon. XXVII. Analyses A, B, D, E by L. G. Eakins, C by W. F. Hillebrand. All but A were made in the Denver laboratory.

A. Dolerite, from a dike near Valmont. Contains augite, plagioclase, olivine, orthoclase, and biotite, with accessory magnetite and apatite. Record No. 1145.

B. Augite separated from A.

C. Basalt, Table Mountain, lower capping sheet. Contains plagioclase, orthoclase, augite, magnetite, and apatite, with olivine much serpentinized. Sp. gr. 2.83, 22.5°.

D. Basalt, earlier flow, south slope of North Table Mountain. Contains augite, olivine, plagioclase, probably orthoclase, magnetite, apatite, and a little biotite.

E. Augite-mica-syenite, from North Fork of Turkey Creek, Jefferson County. Contains orthoclase, augite, biotite, rhombic pyroxene, hornblende, plagioclase, quartz, apatite, and magnetite. Sp. gr. 2.857, 29.5°.

	A.	B.	C.	D.	E.
SiO ₂	48.25	49.10	52.59	49.69	56.90
TiO ₂ .....	.89	.....	.84	.85	.19
Al ₂ O ₃	16.73	7.95	17.91	18.06	18.50
Fe ₂ O ₃	3.99	.....	3.81	2.64	.17
FeO	6.28	8.30	5.18	6.19	4.61
MnO	Trace.	.....	Trace.	.13	Trace.
CaO	8.32	22.54	7.24	8.24	6.17
BaO .....	.01	.....	.....	.....	.....
MgO	5.77	12.37	4.11	5.73	5.10
K ₂ O	4.08	Trace.	3.83	3.90	4.14
Na ₂ O	3.24	Trace.	2.94	2.99	2.99
H ₂ O	1.72	.....	1.24	.91	.51
P ₂ O ₅ .....	.68	.....	.14	.81	.79
Cl .....	.08	.....	.05	.13	Trace.
SO ₃ .....	.12	.....	.....	.....	.....
	100.16	100.26	99.88	100.27	100.07

The following rocks from the Denver Basin were analyzed by L. G. Eakins in the Denver laboratory, but the analyses do not appear in the monograph. The subjoined data have been supplied by Whitman Cross.

A. Enstatite-diabase-porphry, Mount Morrison. Contains labradorite and enstatite in a groundmass of considerable amount, which is colorless and cryptocrystalline, probably feldspathic, and carries magnetite and other indistinct ferritic matter.

B. Augite-andesite, Table Mountain. Contains plagioclase (andesine), with rare augite and biotite, in a groundmass of plagioclase, augite, magnetite, and minor accessories. This rock contained ptilolite in its vesicular equivalent. Described in Proc. Colorado Sci. Soc., 1886, p. 72.

C. Augite-andesite, a pebble from the Denver beds, Table Mountain. A few augite and andesite phenocrysts in a groundmass of oligoclase, orthoclase, and quartz (?) grains, with some augite and magnetite.

	A.	B.	C.
SiO ₂	56.74	59.26	59.29
Al ₂ O ₃	18.80	23.63	21.27
Fe ₂ O ₃ .....	.15	.30	3.33
FeO	6.91	.57	1.04
MnO .....	.07	-----	.21
CaO	7.34	5.93	5.25
MgO	5.57	.31	1.12
K ₂ O .....	.77	4.78	3.00
Na ₂ O	2.32	4.94	3.39
H ₂ O	1.09	.74	1.63
P ₂ O ₅ .....	.20	-----	.23
	99.96	100.46	99.76
Sp. gr.....	2.876, 27°	2.625, 31°	2.596, 14° .5

2. THE PIKES PEAK DISTRICT.

First, granite, described by E. B. Matthews for a forthcoming publication of the Survey. Analyses by W. F. Hillebrand, record No. 1470.

A. Granite, Sentinel Point, western part of Pikes Peak massif. Contains microcline, microcline-perthite, quartz, biotite, a little oligoclase, and accessory fluorite, apatite, zircon, sphene, magnetite, and allanite.

B. Granite, near road between Florissant and the Platte River. Consists chiefly of microcline in perthitic intergrowth with albite, quartz, and biotite.

C. Porphyritic granite, south side of Pikes Peak, ridge between Middle and North Beaver creeks. Contains microcline, perthite, orthoclase, oligoclase, quartz, biotite, and accessory apatite, fluorite, zircon, and magnetite.

D. Sheared granite, Currant Creek Canyon, north of Twelve-mile Park. Contains perthitic microcline, quartz, muscovite, and sericitic aggregates replacing plagioclase and a part of the microcline.

E. Granite, Currant Creek Canyon, north of Twelve-mile Park. Consists chiefly of perthitic microcline, quartz, greenish biotite, muscovite, and plagioclase altered to a sericitic mass. Also flakes of limonite. Accessory minerals rare.

F. Granite, Middle Beaver Creek, south side of Pikes Peak. Contains microcline, orthoclase, perthitic albite, oligoclase, abundant quartz, biotite, and a little accessory magnetite, fluorite, and zircon.

G. Granite-gneiss, north of Twin Creek. Contains microcline, orthoclase, quartz, biotite, abundant fluorite, and a little sphene and apatite.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	77.03	75.92	75.17	74.40	73.90	73.51	66.90
TiO ₂ .....	.13	.05	.10	.12	.07	.18	.43
Al ₂ O ₃	12.00	12.96	12.66	14.43	13.65	13.28	14.86
Fe ₂ O ₃ .....	.76	.33	.23	.89	.28	.94	.93
FeO .....	.86	1.40	1.40	.22	.42	.97	3.41
MnO	Trace.	.04	Trace.	Trace.	Trace.	Trace.	.15
CaO .....	.80	.15	.82	.58	.23	1.11	1.23
SrO	None.	None.	Trace?	None.	None.	None.	None.
BaO	Trace.	Trace.	.03	Trace.	Trace.	Trace.	.14
MgO .....	.04	Trace.	.05	.07	.14	.05	.31
K ₂ O	4.92	4.15	5.75	6.56	7.99	5.22	5.02
Na ₂ O	3.21	4.60	2.88	1.76	2.53	3.79	5.56
Li ₂ O	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	.06
H ₂ O at 110° .....	.14	.16	.16	.15	.16	.16	.16
H ₂ O above 110° .....	.30	.32	.66	.92	.33	.62	.31
P ₂ O ₅	Trace.	Trace.	.03	.22	.05	Trace.	.12
F .....	.36	.12	.31	.04	None.	.55	1.00
CO ₂ .....		.03					
	100.55	100.23	100.26	100.36	99.75	100.38	100.59
Less O .....	.15	.05	.13	.02		.22	.42
	100.40	100.18	100.13	100.34		100.16	100.17

Second, rocks of the Cripple Creek district, described by Cross. Descriptions published, except when otherwise stated, in 16th Ann., Part II, pp. 38-50. Analyses, with two exceptions, which are properly noted, by W. F. Hillebrand, record Nos. 1448, 1453, and 1524.

A. Phonolite, dike in granite northeast of Big Bull Mountain. Contains anorthoclase, nepheline, sodalite, ægirine-augite, some ægirine, biotite, magnetite, and limonite. Nosite not distinguishable.

B. Phonolite, Mitre Peak. Contains sanidine, nepheline, sodalite, ægirine, nosite, and colorless particles which may be lāvenite.

C. Phonolite, from a hill one mile south of Straub Mountain. Contains anorthoclase, sanidine, nepheline, sodalite, nosite, analcite, and ægirine, with sometimes ægirine-augite.

D. Phonolite, Rhyolite Mountain. Contains nepheline, nosite, analcite, ægirine, and some ægirine-augite, in a feldspathic groundmass. Sp. gr. 2.52, 23°.

E. Phonolite from between Florissant and Manitou. Analysis by L. G. Eakins, made in the Denver laboratory, inserted here for comparison with the Cripple Creek samples. Described by Cross in Proc. Colorado Sci. Soc., vol. 2, p. 167. Contains sanidine, nepheline, hornblende with accessory pyroxene (?), magnetite, apatite, and sphene. Sp. gr. 2.576, 13°.

F. The portion of E. soluble in hydrochloric acid. This portion amounted to 25.39 per cent, and is reduced here to 100. Analysis also by Eakins.

	A.	B.	C.	D.	E.	F.
SiO ₂	59.00	58.98	58.78	58.64	60.02	44.66
TiO ₂ .....	.29	.24	.29	.20	.....	.....
ZrO ₂ .....	.20	.20	.17	.09	.....	.....
Al ₂ O ₃	20.07	20.54	20.03	19.62	20.98	31.59
Fe ₂ O ₃	1.58	1.65	1.87	2.17	2.21	.95
FeO.....	.65	.48	.49	.42	.51	.....
MnO .....	.12	.26	.15	.20	Trace.	.....
CaO.....	1.05	.67	.83	1.24	1.18	2.25
SrO.....	None.	None.	None.	Trace.	.....	.....
BaO.....	Trace.	None.	None.	Trace.	.....	.....
MgO .....	.10	.11	.16	.37	Trace.	.....
K ₂ O.....	5.63	5.31	5.50	5.26	5.72	2.13
Na ₂ O.....	8.34	9.95	9.36	8.39	8.83	18.42
Li ₂ O	Trace.	Trace.	Trace.	Trace.	.....	.....
H ₂ O at 100° .....	.24	.19	.31	.34	.70	.....
H ₂ O above 100°	2.03	.97	1.57	2.40		.....
P ₂ O ₅ .....	.05	.04	.03	.03	Trace.	.....
SO ₃ .....	.07	.20	.12	Trace?	.....	.....
Cl .....	.24	.28	.58	.14	Trace.	.....
CO ₂ .....	.26	.....	.....	.23	.....	.....
	99.92	100.07	100.24	99.74	100.15	100.00

G. Trachytic phonolite, dike on west slope of Bull Cliff. Contains alkali-feldspars, nepheline, nosite, sodalite, augite, scanty ægirine, brown hornblende, magnetite, sphene, apatite, and sometimes lävenite.

H. Altered phonolite, Washington shaft, Victor. Contains potash-feldspars, with some alteration to muscovite. Crystals of pyrite and fluorite are visible, but nepheline and ægirine have disappeared. Analysis hitherto unpublished.

I. Nepheline-syenite, near the Longfellow mine. Contains alkali-feldspars, nepheline, sodalite, augite, some ægirine, hornblende, biotite, sphene, apatite, and magnetite. Sp. gr. 2.68, 23°.

J. Nepheline-basalt, Appie Ellen shaft. Much altered. Rich in olivine, augite, and magnetite. Also contains nepheline, feldspars in small amount, and biotite. Sp. gr. 2.99, 23°.

K. Altered nepheline-basalt, Anna Lee mine. Analysis hitherto unpublished and not discussed.

L. Local facies of a phonolitic mass, Bull Cliff. Contains abundant augite, plagioclase, alkali-feldspar, magnetite, and a little red-brown biotite, with a colorless isotropic base in the darker spots. Analysis hitherto unpublished.

	G.	H.	I.	J.	K.	L.
SiO ₂	59.38	56.74	54.34	35.03	48.61	49.84
TiO ₂ .....	.58	.58	1.09	2.20	3.57	1.43
ZrO ₂ .....	.10	.07	.07	None.	.....	.03
Al ₂ O ₃	19.47	20.30	19.23	9.80	20.74	17.78
Cr ₂ O ₃ .....	.....	.....	.....	.....	Trace.	.....
Fe ₂ O ₃	1.60	1.06	3.19	5.55	4.29	5.86
FeO	1.19	.....	2.11	4.98	.22	2.62
MnO .....	.15	None.	.08	.06	None.	.21
CaO	1.96	.57	4.53	15.09	.25	7.35
SrO .....	.03	Trace.	.16	.17	None.	.18
BaO .....	.13	.19	.24	.14	None.	.22
MgO .....	.36	.23	1.28	9.78	2.11	3.02
K ₂ O	5.83	13.36	5.14	2.16	.77	3.04
Na ₂ O	7.80	.62	6.38	2.04	.16	5.20
Li ₂ O	Trace.	Trace.	Trace.	Trace.		Trace.
H ₂ O at 110° .....	.11	.33	.14	.41	12.10	.34
H ₂ O above 110° .....	.69	1.15	1.17	2.05	7.07	2.02
P ₂ O ₅ .....	.08	.25	.27	1.99	.29	.76
SO ₃ .....	.37	.....	.07	None.	.....	None.
Cl .....	.22	.....	.28	Trace.	.....	Trace.
F .....	.....	Undet.	Undet.	Undet.	.63	Undet.
CO ₂ .....	.....	.....	None.	7.83	.....	.52
FeS ₂ .....	.....	4.65	.....	.38	.....	.....
	100.05	100.10	99.77	99.66	100.81	100.42

Third, miscellaneous rocks in the Pikes Peak district. Analyses, hitherto unpublished, by W. F. Hillebrand, record Nos. 1448, 1453, and 1669. Petrographic data supplied by Whitman Cross. Names marked with a query are provisional designations only.

A. Trachyte? Near Robbins' ranch. Has scattered phenocrysts of alkali-feldspar, oligoclase, and biotite in a predominant trachytic groundmass of alkali-feldspar, tridymite, particles of residual glass, and ferritic flakes and grains.

B. Trachyte? Wicher Mountain. Shows biotite and a few glassy feldspars in a groundmass resembling that of A.

C. Andesite? Bare Hills. Composed mainly of plagioclase and alkali-feldspar, with small augites and much ferritic matter. Minute prisms of a yellowish-brown amphibole (?) and scales of tridymite are also visible.

D. Pyroxene-andesite? Wicher Mountain. Contains phenocrysts of plagioclase, a few of augite, minute specks of iddingsite, and flakes of limonite. In the groundmass are plagioclase, orthoclase (?), augite, iddingsite, and hypersthene. In the pores tridymite appears.

E. Plagioclase-basalt? Mesa east of Mac Gulch. Contains plagioclase, augite, olivine, iddingsite, magnetite, biotite, and apatite.

F. Plagioclase-basalt, Saddle Mountain. Phenocrysts of augite and olivine in a groundmass of plagioclase, orthoclase, augite, magnetite, biotite, and apatite. Very fresh.

	A.	B.	C.	D.	E.	F.
SiO ₂	69.52	66.12	62.64	57.48	52.97	48.76
TiO ₂.....	.23	.29	.59	1.00	1.04	1.65
ZrO ₂.....	.05	.06	.08	.04	.05	None.
Al ₂ O ₃	15.44	17.21	17.82	18.04	18.31	15.89
Fe ₂ O ₃	1.90	2.43	3.91	5.73	1.86	6.04
FeO.....	.09	Trace.	.31	.73	6.73	4.56
MnO.....	.08	.08	.04	Trace.	.09	.13
CaO.....	1.70	2.11	3.22	5.03	6.51	8.15
SrO.....	.04	.05	.07	.12	.14	.06
BaO.....	.19	.25	.28	.20	.18	.17
MgO.....	.17	.35	.47	1.17	3.04	5.98
K ₂ O.....	5.04	5.57	4.99	4.15	3.35	2.93
Na ₂ O.....	4.54	4.70	4.47	4.28	3.74	3.43
H ₂ O at 100°....	.33	.14	.58	.62	.44	.40
H ₂ O above 100°.	.27	.71	.65	.55	.31	1.48
P ₂ O ₅.....	.14	.11	.25	.66	.81	.60
SO ₃.....	.....	.....	.....	.16	.....	.....
CO ₂.....	.17	.....	.....	.....	.....	.....
	99.90	100.18	100.37	99.96	99.57	100.23

G. Analcite-basalt from the Basin. Contains phenocrysts of augite, olivine, and analcite. Also magnetite, with subordinate amounts of alkali-feldspars, biotite, and apatite.

H. Portion of the analcite-basalt soluble in hydrochloric acid.

I. Augite separated from G.

J. Analcite separated from G. After deduction of 4.22 per cent of substance insoluble in boiling, dilute hydrochloric acid, and later removal of liberated silica with weak potash solution. Sixty-two one hundredths per cent of the water goes off over sulphuric acid. A trace of lithia was found.

	G.	H.	I.	J.
SiO ₂	45.59	44.44	49.26	51.24
TiO ₂	1.32	}	1.53	.....
ZrO ₂ .....	.03		.....	.....
Al ₂ O ₃	12.98		6.01	24.00
Fe ₂ O ₃	4.97	}	3.31	} 1.20
FeO	4.70		4.23	
MnO .....	.14	Trace.	Undet.	.....
CaO	11.09	3.94	21.79	1.62
SrO .....	.12	.16	.06	.06
BaO .....	.13	?	?	.....
MgO	8.36	5.81	12.40	.33
K ₂ O	1.04	1.13	.41	1.25
Na ₂ O	4.53	8.17	.79	11.61
H ₂ O at 100° .....	.51	}	Undet.	} 9.09
H ₂ O above 100°	3.40		Undet.	
P ₂ O ₅ .....	.91	.....	.....	.....
Cl .....	.05	.10	.....	Trace.
	99.87	99.27	99.79	100.40

* Includes P₂O₅.

3. SILVER CLIFF AND ROSITA.

Rocks described by Cross, mostly in 17th Ann., Part II, p. 263. Also, partly, in Proc. Colorado Scientific Soc., vol. 2, p. 228. Analyses by L. G. Eakins. Those with record numbers attached were made in the Washington laboratory; all others in the laboratory at Denver.

A. Peridotite, Cottonwood Gulch. Contains hornblende, biotite, hypersthene, olivine, a little plagioclase, apatite, pyrrhotite, and sillimanite (?).

B. Augite-diorite, Mount Fairview, Rosita Hills. Contains augite, biotite, labradorite, and accessory orthoclase, olivine, magnetite, and apatite. Sp. gr. 2.870, 32°. Olivine a subordinate constituent.

C. The same as B, but with orthoclase in much larger amount. Sp. gr. 2.768, 34°. Record No. 1091.

D. Trachyte, Game Ridge. Contains sanidine, plagioclase, a little biotite, magnetite, apatite, and zircon, in a groundmass of orthoclase with a little quartz. Sp. gr. 2.592, 29°.

E. Trachyte from a dark-colored dike. Contains more magnetite than D, but otherwise the two are practically identical. Sp. gr. 2.621, 24°.

	A.	B.	C.	D.	E.
SiO ₂	46.03	50.47	53.80	66.03	65.41
TiO ₂ .....		.51	.43		
Al ₂ O ₃	9.27	18.73	20.13	18.49	18.78
Fe ₂ O ₃	2.72	4.19	3.57	2.18	.94
FeO	9.94	4.92	2.63	.22	.72
MnO .....	.40	.11	.29	Trace.	Trace.
CaO	3.53	8.82	5.60	.96	1.58
MgO	25.04	3.48	2.26	.39	.16
K ₂ O .....	.87	3.56	4.49	5.86	5.41
Na ₂ O	1.48	4.62	5.20	5.22	5.91
H ₂ O .....	.64	.58	.90	.85	1.38
P ₂ O ₅ .....	.17	.10	.56	.04	Trace.
CO ₂		Trace.		Trace.	
Cl		Trace.			
	100.09	100.09	99.86	100.24	100.29

F. Andesite, Pringle Hill. Contains plagioclase, orthoclase, quartz, biotite, augite, magnetite, and apatite, with sometimes a little hornblende. Sp. gr. 2.651, 17°. Record No. 1124.

G. Pringle andesite dike. Like F, but often contains sphene. Sp. gr. 2.690, 28°.

H. The Bunker andesite. Contains plagioclase, orthoclase, augite, biotite, hornblende, quartz, magnetite, and apatite. Sp. gr. 2.699, 34°. Record No. 1091. From Lookout Mountain.

I. Altered Bunker andesite from Robinson Plateau. Biotite gone, magnetite altered to limonite, feldspars not much attacked. Record No. 1124. Sp. gr. 2.580, 19°.

J. Much decomposed Bunker andesite from ridge near Knickerbocker Hill. Augite, hornblende, and biotite all replaced by decomposition products, plagioclase much muscovitized. Record No. 1124.

	F.	G.	H.	I.	J.
SiO ₂	58.94	63.49	57.01	63.88	67.13
TiO ₂.....	.27	Trace.	.27	.....	.30
Al ₂ O ₃	17.19	18.40	18.41	19.96	18.41
Fe ₂ O ₃	2.63	2.44	3.69	2.21	.45
FeO.....	1.98	1.09	2.36	.57	.07
MnO.....	.10	.16	.21	Trace.	Trace.
CaO.....	4.45	2.30	4.29	2.03	.55
MgO.....	1.52	.66	2.34	.58	.44
K ₂ O.....	3.90	4.62	3.72	3.88	5.28
Na ₂ O.....	4.20	5.70	4.95	4.19	4.17
H ₂ O.....	4.53	1.04	2.29	2.63	2.98
P ₂ O ₅.....	.23	Trace.	.42	.....	Trace.
CO ₂.....	.....	Trace.	.....	.....	.....
	99.94	99.90	99.96	99.93	99.78

K. Dacite, Bald Mountain, near Rosita. Contains plagioclase, biotite, hornblende, sometimes augite, magnetite, and quartz. Sp. gr. 2.574, 24°. Record No. 1068.

L. Mica-dacite. Contains plagioclase, sanidine, biotite, and quartz. Sp. gr. 2.563, 24°. Record No. 1068.

M. Rhyolite, Pennsylvania Hill. Sp. gr. 2.470, 26°. Record No. 1079.

N. Rhyolite, Round Mountain. Contains sanidine, quartz, some glass, and accessory garnet.

O. Rhyolite, Silver Cliff. Sp. gr. 2.560, 15°. Record No. 1125.

	K.	L.	M.	N.	O.
SiO ₂	66.46	67.49	70.87	75.20	75.39
TiO ₂			Trace.		Trace.
Al ₂ O ₃	17.91	17.76	15.18	12.96	13.65
Fe ₂ O ₃	2.42	2.54	2.18	.37	.38
FeO.....	.35	.08	.12	.27	.18
MnO.....	Trace.	Trace.	Trace.	.03	.14
CaO.....	2.89	1.67	1.58	.29	.51
MgO.....	.49	.35	.60	.12	.15
K ₂ O.....	3.74	4.40	5.04	8.38	6.81
Na ₂ O.....	4.79	5.03	3.47	2.02	1.84
H ₂ O.....	1.01	.52	1.08	.58	1.13
P ₂ O ₅		Trace.	Trace.	Trace.	Trace.
	100.06	99.84	100.12	100.22	100.18

P. Rhyolitic tuff. A lake-bed deposit, east of the Blue Mountains. Mainly composed of glassy rhyolite dust.

Q. Devitrified pitchstone, the gangue of ptilolite. Shows feldspar, quartz, and barite. Described by Cross and Eakins in Amer. Journ. Sci., 3d series, vol. 44, p. 96. From 3 miles southeast of Silver Cliff. Record No. 1342.

R. Pitchstone, Rosita. Record No. 1033.

S. Pitchstone, Fleetwood Tunnel, Silver Cliff.

T. Alteration product of S. Consists mainly of silica and kaolin. Record No. of S and T, 1034.

	P.	Q.	R.	S.	T.
SiO ₂	71.02	65.67	73.11	71.56	71.71
Al ₂ O ₃	14.27	13.48	13.16	13.10	12.36
Fe ₂ O ₃	1.22	1.51	.62	.66	1.10
FeO .....			.23	.28	
MnO		Trace.	.14	.16	.17
CaO	1.38	2.41	.54	.74	1.11
BaO .....		.32			
MgO	Trace.	.31	.19	.14	1.21
K ₂ O	3.97	2.42	5.10	4.06	.36
Na ₂ O	2.28	1.52	2.85	3.77	.17
H ₂ O	6.12	12.27	4.05	5.52	11.97
P ₂ O ₅		Trace.			
SO ₃ .....		.28			
	100.26	100.19	99.99	99.99	100.16

U. Syenite, Silver Cliff. Contains orthoclase and plagioclase in nearly equal amounts, colored by ferric hydroxide, with amphibole, a little biotite, and secondary epidote, calcite, and chlorite. Sp. gr. 2.689, 20°.

V. Quartz-alunite rock, Democrat Hill. About two-thirds quartz and one-third alunite. Record No. 1126.

W. The same, Mount Robinson. About one-fourth alunite. Record No. 1248.

X. Quartz-diaspore rock, Mount Robinson. About 18 per cent diaspore, the rest quartz. Record No. 1167.

Rocks V, W, and X are also described in Amer. Journ. Sci., 3d series, vol. 41, p. 471. These three rocks are decomposition products of rhyolite.

	U.	V.	W.	X.
SiO ₂	59.78	65.94	69.67	76.22
TiO ₂.....				.11
Al ₂ O ₃	16.86	12.95	13.72	19.45
Fe ₂ O ₃	3.08	.33		Trace.
FeO.....	3.72	.07		
MnO.....	.14	Trace.		
CaO.....	2.96	.10	.07	Trace.
BaO.....		Trace.		
MgO.....	.69	.05	Trace.	
K ₂ O.....	5.01	2.32	2.44	Trace.
Na ₂ O.....	5.39	1.19	.34	Trace.
H ₂ O.....	1.58	4.47	4.73	3.82
P ₂ O ₅.....				.13
SO ₃		12.47	9.27	.29
CO ₂.....	.75			
	99.96	99.89	100.24	100.02

The following analyses, all by L. G. Eakins, do not appear in the published memoir just cited. A and B were made in the Denver laboratory. The petrographic details have been supplied by Whitman Cross.

A. Spherulite in rhyolite, ridge west of Mount Tyndall. Mainly composed of quartz and feldspar needles, with some ferritic coloring due to decomposition of trichites.

B. Rhyolitic residual glass, same locality as A.

C. Interspherulitic mass, Rosita. Record No. 1285.

D. Spherulite, Rosita. Record No. 1286.

E, F, G. Spherulites, Silver Cliff. Record Nos. 1285, 1286.

These spherulites, C, D, E, F, G, are made up of orthoclase needles, with free silica in fibers or grains, or rarely as tridymite.

The "soluble silica" is that which is dissolved by sodium carbonate solution.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	71.27	85.50	74.47	80.61	83.91	79.21	78.77
Al ₂ O ₃	16.02	7.42	13.87	10.94	9.54	12.24	12.46
Fe ₂ O ₃	1.41	1.23	.....	.....	.....	.....	.....
FeO .....	.17	.34	.....	.....	.....	.....	.....
MnO	Trace.	.08	.....	.....	.....	.....	.....
CaO .....	.35	.37	.51	.26	.19	.43	.34
MgO	Trace.	.82	Trace.	.09	Trace.	.11	.09
K ₂ O	4.08	2.64	7.46	3.02	5.06	5.26	5.84
Na ₂ O	5.76	.74	2.10	2.90	.62	2.58	2.12
H ₂ O	1.14	1.22	1.88	2.20	.69	.66	.70
P ₂ O ₅	Trace.	None.	.....	.....	.....	.....	.....
	100.20	100.36	100.29	100.02	100.01	100.49	100.32
Soluble SiO ₂ .....	.....	.....	12.72	11.12	1.06	1.27	1.25

4. THE BUFFALO PEAKS.

Hypersthene-andesite, described by Cross in Bull. 1. Contains hypersthene, augite, plagioclase, magnetite, and apatite. Sp. gr. 2.742, 16°. Analyses made by W. F. Hillebrand in the Denver laboratory.

A. Hypersthene-andesite.

B, C, D. Hypersthene separated from the rock. Sp. gr. of D, 3.307, 23°. In B and C alkalis were not tested for. In C and D all the iron is given as FeO.

	A.	B.	C.	D.
SiO ₂	56.19	51.70	51.16	50.04
Al ₂ O ₃	16.12	1.72	2.15	2.91
Fe ₂ O ₃	4.92	.30	.....	.....
FeO.....	4.43	18.00	18.36	17.81
MnO.....	Trace.	.36	.36	.12
CaO.....	7.00	2.87	3.81	6.70
SrO.....	Trace.	.....	.....	.....
BaO.....	Trace.	.....	.....	.....
MgO.....	4.60	25.09	24.25	21.74
K ₂ O.....	2.37	.....	.....	.....
Na ₂ O.....	2.96	.....	.....	.27
H ₂ O.....	1.03	.....	.....	.....
P ₂ O ₅.....	.27	.....	.....	.....
Cl.....	.02	.....	.....	.....
	99.91	100.04	100.10	99.59

5. THE LEADVILLE REGION.

Rocks described by Cross in Mon. XII, Appendix A. Analyses made in the Denver laboratory.

A. Porphyry, Mount Zion. Contains orthoclase, plagioclase, quartz, biotite, apatite, magnetite, and zircon. Analysis by L. G. Eakins.

B. White, or Leadville porphyry. Contains orthoclase, plagioclase, quartz, muscovite, magnetite, apatite, and zircon, with crystals which appear to be rutile and anatase. Sp. gr. 2.680, 16°. Analysis by W. F. Hillebrand.

C. Porphyry, summit of Mount Lincoln. Contains quartz, orthoclase, plagioclase, biotite, apatite, sphene, magnetite, zircon, and allanite. The sample analyzed showed some muscovite, chlorite, and calcite. Sp. gr. 2.670, 16°. Analysis by W. F. Hillebrand.

	A.	B.	C.
SiO ₂	73.50	70.74	66.45
TiO ₂.....			.10
Al ₂ O ₃	14.87	14.68	15.84
Fe ₂ O ₃.....	.95	.69	2.59
FeO.....	.42	.58	1.43
MnO.....	.03	.06	.09
CaO.....	2.14	4.12	2.90
SrO.....	Trace.	Trace.	.07
BaO.....		.03	
MgO.....	.29	.28	1.21
K ₂ O.....	3.56	2.59	2.89
Na ₂ O.....	3.46	2.29	3.92
Li ₂ O.....			Trace.
H ₂ O.....	.90	2.09	.84
P ₂ O ₅	None.		.36
CO ₂		2.14	1.35
Cl.....		Trace.	.05
	100.12	100.29	100.09

D. Gray porphyry, Johnson Gulch, near Leadville. Slightly altered. Contains orthoclase, plagioclase, biotite, and quartz, with decomposition products probably derived from original hornblende. Sp. gr. 2.736, 16°. Analysis by Hillebrand.

E. Pink orthoclase crystals from D. Analysis by Hillebrand.

F. Hornblendic porphyrite, lower Buckskin Gulch. Contains plagioclase, orthoclase, quartz, hornblende, biotite, magnetite, apatite, and zircon, with a little secondary calcite and chlorite. Sp. gr. 2.768, 16°. Analysis by Hillebrand.

G. Biotite-porphyrity, from a dike in gneiss in the North Mosquito amphitheater. Composition like F, but with no hornblende, much biotite, and some pyrite. Sp. gr. 2.740, 16°. Analysis by Hillebrand.

	D.	E.	F.	G.
SiO ₂	68.10	62.22	56.62	64.81
TiO ₂.....	.07	.....	.....	.08
Al ₂ O ₃	14.97	20.33	16.74	15.73
Fe ₂ O ₃	2.78	.....	4.94	1.68
FeO.....	1.10	.....	3.27	2.91
MnO.....	.09	.....	.15	.08
CaO.....	3.04	2.95	7.39	4.22
SrO.....	.08	.....	Trace.	Trace.
MgO.....	1.10	.....	4.08	2.82
K ₂ O.....	2.93	8.31	1.97	1.43
Na ₂ O.....	3.46	3.45	3.50	3.98
H ₂ O.....	1.28	1.90	.92	.62
P ₂ O ₅.....	.16	.....	Trace.	.23
CO ₂.....	.92	.....	1.15	1.08
Cl.....	.03	.....	.....	.04
FeS ₂.....	.....	.....	.....	.90
	100.11	99.16	100.73	100.61

H. Rhyolite (nevadite), from Chalk Mountain. Mainly quartz and feldspar, the latter being sanidine and plagioclase. A little biotite, magnetite, apatite, and zircon are present. Analysis by Hillebrand.

I. Sanidine from H. Analysis by Hillebrand.

	H.	I.
SiO ₂	74.45	65.04
Al ₂ O ₃	14.72	20.40
Fe ₂ O ₃	None.	.....
FeO.....	.56	.....
MnO.....	.28	.....
CaO.....	.83	.79
MgO.....	.37	.....
K ₂ O.....	4.53	9.74
Na ₂ O.....	3.97	} 4.11
Li ₂ O.....	Trace.	
H ₂ O.....	.66	.29
P ₂ O ₅.....	.01	.....
	100.38	100.37

6. THE TEN MILE DISTRICT.

Rocks described by Cross in 14th Ann., p. 165. Analyses made in the Denver laboratory, A and C by W. F. Hillebrand, B by L. G. Eakins.

A. Quartz-hornblende-mica-porphyrity, Gold Hill. Contains plagioclase, hornblende, biotite, and quartz, in a groundmass of quartz, orthoclase, and a little plagioclase.

B. Quartz-porphyrity, Sugar Loaf. Contains plagioclase, biotite, and quartz, in a groundmass of quartz and orthoclase.

C. Quartz-porphyrity, Chicago Mountain. Contains plagioclase, orthoclase, biotite, and quartz.

	A.	B.	C.
SiO ₂	63.66	67.29	68.30
TiO ₂	Undet.	None.	Undet.
Al ₂ O ₃	17.05	15.78	16.24
Fe ₂ O ₃	1.97	1.86	1.60
FeO.....	2.62	1.97	1.63
MnO.....	.14	.21	.12
CaO.....	3.89	2.36	2.79
SrO.....	.08	None.	.04
BaO.....			Trace.
MgO.....	1.99	.72	1.05
K ₂ O.....	3.09	3.55	3.52
Na ₂ O.....	4.13	3.77	3.90
Li ₂ O.....	None.	Trace.	Trace.
H ₂ O at 110°.....	1.19	2.10	.71
H ₂ O above 110°.....			
P ₂ O ₅.....	.27	.28	.13
CO ₂.....		.27	
	100.08	100.16	100.03

The following rocks were also analyzed in the Denver laboratory, but the analyses are hitherto unpublished. Petrographic data furnished by Whitman Cross.

A. Granite-porphyry, McNulty Gulch. Contains phenocrysts of orthoclase, oligoclase, andesine, quartz, biotite, and altered hornblende, in a groundmass of quartz, orthoclase, and magnetite. Accessory sphene, allanite, apatite, and zircon, and a little secondary chlorite are also present. Analysis by W. F. Hillebrand.

B. Granite-porphyry, Jefferson Tunnel. Contains orthoclase, oligoclase, quartz, and biotite, in a groundmass of mainly quartz and orthoclase; also accessory magnetite, apatite, zircon, and allanite. Chlorite appears as a decomposition product of biotite, and calcite and magnetite are present in small amounts. Analysis by Hillebrand.

C. Same as B. Analysis by L. G. Eakins.

D. Diorite-porphyry, Copper Mountain. Contains oligoclase, hornblende, and biotite, in a groundmass of quartz, orthoclase, plagioclase, and magnetite; also accessory zircon, sphene, and apatite, and a little secondary chlorite and epidote. Analysis by Eakins.

E. Diorite-porphyry, McNulty type. Contains oligoclase, andesine, hornblende, biotite, and magnetite, in a groundmass of orthoclase, plagioclase, quartz, magnetite, apatite, allanite, and sphene; also secondary chlorite, epidote, and calcite. Analysis by Eakins.

	A.	B.	C.	D.	E.
SiO ₂	68.60	65.94	65.51	67.01	63.02
Al ₂ O ₃	16.21	16.00	17.01	18.03	17.61
Fe ₂ O ₃	1.67	.60	None.	.66	1.78
FeO.....	1.57	1.74	2.79	.72	2.76
MnO.....	.09	.14	.....	.09	Trace.
CaO.....	2.61	2.87	3.16	3.99	3.30
SrO.....	Trace.	Trace.	.....	.....	.....
BaO.....	.....	.....	.....	.10	.08
MgO.....	1.05	1.02	.90	.84	1.63
K ₂ O.....	3.88	4.56	4.67	3.53	3.23
Na ₂ O.....	3.29	3.85	3.82	4.42	4.72
H ₂ O.....	.92	1.13	1.78	.91	2.03
P ₂ O ₅.....	.21	.23	.13	.10	.16
CO ₂.....	.19	1.55	.....	.....	.....
Cl.....	.03	.03	Trace.	.....	.....
S.....	.....	.....	.38	.....	.....
FeS ₂.....	.....	.60	.....	.....	.....
	100.32	100.26	100.15	100.40	100.32
Sp. gr.....	2.640, 27°	2.672, 21°	2.666, 26°	.....	2.689, 16°5

7. THE ELK MOUNTAINS.

Analyses made by L. G. Eakins in the Denver laboratory, and hitherto unpublished. Petrographic data supplied by Whitman Cross.

A. Rhyolite, East Mountain, Crested Butte district. Phenocrysts of orthoclase, oligoclase, quartz, and biotite, in a microspherulitic and crypto-crystalline groundmass.

B. Rhyolite, Round Mountain, Crested Butte district. Small phenocrysts of quartz, sanidine, biotite, and oligoclase, in a groundmass of quartz and orthoclase.

C. Diorite, Brush Creek, Gunnison County. Contains several varieties of plagioclase, with orthoclase, quartz, hornblende, biotite, augite, sphene, apatite, and magnetite.

	A.	B.	C.
SiO ₂	74.84	71.56	62.71
Al ₂ O ₃	14.05	14.91	17.06
Fe ₂ O ₃.....	.17	1.47	3.79
FeO.....	.31	1.04	2.74
MnO.....			Trace.
CaO.....	1.57	1.98	5.51
MgO.....	Trace.	.08	1.78
K ₂ O.....	3.14	4.94	2.96
Na ₂ O.....	3.66	3.78	3.54
H ₂ O.....	2.33	.44	.24
P ₂ O ₅		Trace.	None.
	100.07	100.20	100.33
Sp. gr.....	2.38, 17°	2.59, 18°	2.791, 30°

8. THE WEST ELK MOUNTAINS.

Rocks described by Cross in 14th Ann., p. 165.

A. Hornblende-mica-porphyrity, Cliff Creek. Contains plagioclase, hornblende, and biotite, in a groundmass of quartz, feldspar, and mica. Analysis by W. F. Hillebrand, record No. 1429.

B. Porphyrite, Storm Ridge. Contains plagioclase, biotite, hypersthene, hornblende, and augite, in a groundmass of quartz and orthoclase. Analysis by L. G. Eakins, record No. 1238.

C. Porphyrite-diorite, Mount Marcellina. Contains plagioclase, hornblende, and a little biotite, in a groundmass of quartz and orthoclase. Analysis by T. M. Chatard, record No. 1238.

D. Quartz-porphyrity, Mount Carbon. Contains plagioclase, orthoclase, biotite, hornblende, augite, and quartz. Analysis by Chatard, record No. 1238.

E. Quartz-porphyrity, Crested Butte. Contains plagioclase, orthoclase, hornblende, biotite, quartz, and a little augite. Analysis made by Eakins in the Denver laboratory.

	A.	B.	C.	D.	E.
SiO ₂	63.05	61.42	62.85	65.36	65.71
TiO ₂.....	.60	.37	.41	.52	Undet.
Al ₂ O ₃	15.58	17.69	16.21	15.48	18.30
Fe ₂ O ₃	2.92	4.24	3.08	3.09	1.19
FeO.....	2.11	1.74	1.46	1.21	1.53
MnO.....	.12	.19	.15	.19	.02
CaO.....	4.15	5.29	4.72	4.14	2.17
SrO.....	.07				
BaO.....	.13	.09	.11	.08	
MgO.....	1.70	1.81	1.47	1.53	.98
K ₂ O.....	3.66	3.19	3.10	3.41	3.95
Na ₂ O.....	3.77	3.14	3.49	3.58	5.00
Li ₂ O.....	Trace.				
H ₂ O at 100°.....	.55	.97	.29	.82	1.39
H ₂ O above 100°.....	1.38		2.03	.70	
P ₂ O ₅.....	.27	.14	.48	.25	
CO ₂					
	100.06	100.28	99.85	100.36	100.24

9. MISCELLANEOUS ROCKS.

A. Rhyolite, east bank of Arkansas River, Nathrop. Described by Cross in Proc. Colorado Sci. Soc., vol. 2, p. 69. Contains quartz and sanidine in a groundmass mainly of quartz and alkali-feldspar. This rock carries topaz and spessartite in its lithophysae. Analysis made by L. G. Eakins in the Denver laboratory.

B. Rhyolitic vitrophyre, near Del Norte, Rio Grande County. Reported by Cross as containing phenocrysts of oligoclase, quartz, biotite, and augite in a dark, fresh, glassy groundmass, the latter being predominant. Analysis made by Eakins in the Denver laboratory.

C. Rhyolite, Summit district, Rio Grande County. Description furnished by Cross. Large phenocrysts of sanidine, with smaller ones of oligoclase and biotite, in a groundmass of orthoclase, quartz, oligoclase, biotite, and magnetite. Analysis by Eakins, made in the Denver laboratory.

D. Granite, Platte Canyon. Described by E. B. Matthews for the Educational Series. Contains microcline, quartz, biotite, oligoclase, and fluorite. Apatite, zircon, magnetite, hematite, limonite, epidote, and rutile (?) are sometimes present. Analysis by H. N. Stokes, record No. 1314.

	A.	B.	C.	D.
SiO ₂	69.89	68.61	68.85	77.02
Al ₂ O ₃	17.94	16.43	17.01	11.63
Fe ₂ O ₃ .....	.39	.73	1.78	.32
FeO.....	.52	1.52	.65	1.09
MnO.....	.23	.....	Trace.	Trace.
CaO.....	Trace.	1.79	1.62	1.24
MgO.....	.14	.05	Trace.	.14
K ₂ O.....	4.38	4.65	5.11	5.21
Na ₂ O.....	4.21	2.82	3.44	2.85
Li ₂ O.....	Trace.	.....	.....	.....
H ₂ O.....	2.07	3.35	1.79	.35
P ₂ O ₅	Trace.	.....	.....	.....
	99.77	99.95	100.25	99.85
Sp. gr.....	2.602, 29°	2.423, 14°	2.489, 14°	.....

E. Hornblende-porphyrite, Hermano Peak, Sierra El Late. Described by Cross in 14th Ann., p. 165. Contains plagioclase, hornblende, rare quartz, and a little biotite. Analysis by W. F. Hillebrand, record No. 1429.

F. Hornblende-porphyrite, Ute Peak, Sierra El Late. Described by Cross in 14th Ann., p. 165. Contains plagioclase, hornblende, and very little augite, in a groundmass of quartz, orthoclase, and plagioclase. Analysis by Hillebrand, No. 1429.

G. Porphyritic augite-diorite, Lone Cone, San Miguel Mountains. Described by Cross in 14th Ann., p. 165. Contains plagioclase, augite, hornblende, and biotite, in a groundmass of quartz, orthoclase, and plagioclase. Inclusions of magnetite and apatite in the augite. Analysis by Hillebrand, No. 1429.

H. Augite-diorite, Sultan Mountain, San Juan County. Description furnished by Whitman Cross. Contains plagioclase, orthoclase, quartz, augite, biotite, magnetite, and apatite. Some chlorite and epidote as alteration products. Analysis by L. G. Eakins in the Denver laboratory. Sp. gr. 2.751, 14°.

I. Augite-diorite, Stony Mountain, Ouray County. Analysis by Eakins in the Denver laboratory. Sp. gr. 2.891, 13° 5.

	E.	F.	G.	H.	I.
SiO ₂	62.65	59.42	59.19	63.91	52.05
TiO ₂.....	.42	.68	.58	.....	.....
Al ₂ O ₃	16.68	16.79	18.00	17.07	17.96
Fe ₂ O ₃	2.35	3.23	3.07	4.39	4.09
FeO.....	2.63	3.29	2.32	1.51	6.33
MnO.....	.16	.13	.19	.....	.43
CaO.....	4.96	5.57	6.55	4.47	8.64
SrO.....	.11	.07	.13	.....	.....
BaO.....	.13	.14	.18	.....	.....
MgO.....	1.43	2.24	1.41	.81	5.03
K ₂ O.....	2.75	2.82	2.74	3.74	1.61
Na ₂ O.....	4.45	4.15	4.01	3.48	2.99
Li ₂ O.....	Trace.	Trace.	Trace.	.....	.....
H ₂ O at 100°.....	.27	.27	.46	.....	.....
H ₂ O above 100°.....	.66	.79	1.06	.33	.97
P ₂ O ₅.....	.28	.35	.29	.21	.31
CO ₂.....	.....	.44	.....	.....	.....
	99.93	100.38	100.18	99.92	100.41

J. Diorite, La Plata Mountains. Data supplied by Whitman Cross. Contains augite, hornblende, plagioclase, and orthoclase in large amount, with biotite, quartz, sphene, apatite, and magnetite as subordinate constituents. Also secondary chlorite, muscovite, and calcite. Analysis by W. F. Hillebrand, record No. 1640. Sp. gr. 2.79, 21°.

K. Diorite-porphry, La Plata Mountains. Data supplied by Cross. Contains phenocrysts of hornblende, plagioclase, occasional quartz, sphene, apatite, and magnetite, in a groundmass of orthoclase, plagioclase, and quartz. Also secondary epidote, chlorite, and calcite. Analysis by Hillebrand, record No. 1636. Sp. gr. 2.677, 24°. A trace of sulphur is present.

	J.	K.
SiO ₂	55.53	60.44
TiO ₂.....	.95	.60
Al ₂ O ₃	16.80	16.67
Fe ₂ O ₃	4.06	2.31
FeO.....	3.35	3.09
(NiCo)O.....	Trace.	None.
MnO.....	.16	.13
CaO.....	6.96	4.22
SrO.....	.11	.11
BaO.....	.13	.12
MgO.....	3.00	2.18
K ₂ O.....	3.57	2.71
Na ₂ O.....	4.31	5.18
Li ₂ O.....	Trace.	Trace.
H ₂ O at 110°.....	.09	.36
H ₂ O above 110°.....	.55	1.07
P ₂ O ₅.....	.47	.29
CO ₂.....	.09	.48
FeS ₂.....	.04	.....
	100.17	99.96

L. Tinguaité? From Two Buttes. Collected by G. K. Gilbert; petrographic data supplied by Whitman Cross. Consists chiefly of pale-green augite, hornblende, apatite, magnetite, and occasional crystals of alkali-feldspar, in an obscure, largely isotropic groundmass. Sp. gr., 2.79, 25°.

M. Pyroxene from L. Sp. gr., 3.43, 28°.

N. Portion of L soluble in $\frac{1}{10}$ nitric acid.

O. Syenitic lamprophyre? Two Buttes. Collected by Gilbert; description by Cross. Chief constituents, diopside, alkali-feldspar, considerable biotite, magnetite, and olivine. The ferromagnesian minerals predominate. Sp. gr., 2.88, 29°.

P. Pyroxene from O. Sp. gr., 3.45, 25°.

Q. Portion of O soluble in $\frac{1}{10}$ nitric acid.

Analyses L to Q by W. F. Hillebrand, record No. 1604.

	L.	M.	N.	O.	P.	Q.
SiO ₂	47.61	47.54	13.27	50.41	51.27	1.58
TiO ₂	1.38	3.00	.....	1.47	.70	.....
ZrO ₂.....	.18	None.	.....	None.	None.	.....
Al ₂ O ₃	14.26	4.14	9.40	12.30	3.05	1.00
Cr ₂ O ₃	Trace?	Trace?	.....	Trace.	None.	.....
Fe ₂ O ₃	4.90	5.64	.....	5.71	3.08	None.
FeO.....	4.07	6.42	Trace.	3.06	4.34	.87
NiO.....	Trace.	Trace.	.....	.04	.03	.....
MnO.....	.30	.36	Trace.	.15	.28	Trace.
CaO.....	8.71	21.57	1.70	7.08	22.58	.68
SrO.....	.36	None.	.11	.06	None.	?
BaO.....	.41	None.	None.	.23	None.	None.
MgO.....	2.62	10.05	Trace.	8.69	14.21	1.22
K ₂ O.....	4.08	.12	.66	7.53	.06	Undet.
Na ₂ O.....	6.70	1.38	5.41	.97	.67	Undet.
Li ₂ O.....	Trace.	Trace.	?	Trace.	.....	.....
H ₂ O at 110°.....	.26	None.	Undet.	.46	None.	None.
H ₂ O above 110°.....	1.89	Undet.	Undet.	1.80	Undet.	Undet.
P ₂ O ₅	1.38	.....	1.34	.46	.....	.46
SO ₂	1.17	.....	.77	None.	.....	.....
S.....	.03	.....	.03	None.	.....	.....
Cl.....	.37	.....	.37	Trace.	.....	Trace.
F.....	Trace.	.....	Trace.	Trace?	.....	.....
	100.68	100.21	33.06	100.42	100.27	5.81

UTAH.

Rocks from the Henry Mountains.

A. Porphyry. Not hitherto published. Reported by J. S. Diller as containing prominent plagioclase with some augite and hornblende in a crystalline groundmass of quartz and orthoclase. Analysis by R. B. Riggs, record No. 728.

B. Augite-porphyrite dike, north spur of Mount Pennell. Contains hornblende, augite, and plagioclase in a feldspathic groundmass.

C. Hornblende-porphyrite, Mount Hillers. Contains plagioclase, hornblende, quartz, and magnetite.

Analyses B and C by W. F. Hillebrand, record No. 1428. Rocks described by Cross in 14th Ann., p. 165.

	A.	B.	C.
SiO ₂	63.16	60.98	62.88
TiO ₂ .....	.21	.36	.51
Al ₂ O ₃	17.21	19.09	17.13
Fe ₂ O ₃	2.43	1.76	1.86
FeO.....	2.30	1.15	2.58
MnO	Trace.	.15	.16
CaO.....	6.27	3.67	5.39
SrO	Trace?	.28	.12
BaO .....	.09	.43	.16
MgO	1.27	.65	1.48
K ₂ O	1.84	3.53	2.25
Na ₂ O.....	4.70	6.70	4.50
Li ₂ O	Trace.	Trace.	Trace.
H ₂ O at 100° .....	.....	.48	.16
H ₂ O above 100°.....	.69	.44	.42
P ₂ O ₅.....	.12	.10	.26
CO ₂ .....	.....	.52	.....
SO ₃	Trace.	.....	.....
	100.29	100.29	99.86

Rhyolite from the Thomas Range. Analysis made by L. G. Eakins in the Denver laboratory. Published by Cross in Proc. Colorado Sci. Soc., vol. 2, p. 69. Contains phenocrysts of quartz and sanidine in a groundmass mainly made up of quartz and alkali-feldspar.

SiO ₂	74.49	K ₂ O	4.64
Al ₂ O ₃	14.51	Na ₂ O	3.79
Fe ₂ O ₃ .....	.57	Li ₂ O	Trace.
FeO .....	.32	H ₂ O .....	.64
MnO	Trace.		99.99
CaO	1.03		
MgO	Trace.		

NEW MEXICO.

1. BASALTS FROM RIO GRANDE CANYON.

Described by Iddings, Bull. 66; also in Amer. Journ. Sci., 3d series, vol. 36, p. 220. Contain plagioclase, augite, olivine, and magnetite. A, B, and C contain quartz also; D is quartzless. Analyses by L. G. Eakins, record Nos. 847, 850.

A. Light gray, dense.

B. Greenish black, dense.

C. Dark red, vesicular.

D. Gray, dense.

	A.	B.	C.	D.
SiO ₂	52.27	52.37	51.57	52.38
TiO ₂	1.49	1.60	1.43	1.22
Al ₂ O ₃	17.68	17.01	17.72	18.79
Fe ₂ O ₃	2.51	1.44	6.24	2.88
FeO	5.00	5.89	1.78	4.90
MnO .....	.23	.32	.45	.18
CaO	8.39	7.59	8.82	7.70
BaO .....	.06	.06	.16	.11
MgO	6.05	6.86	4.91	4.91
K ₂ O	1.58	1.59	1.99	1.76
Na ₂ O	4.19	3.51	3.59	3.99
H ₂ O .....	.82	1.29	.64	.53
Co ₂	Trace.	.37	.58	.....
Cl	Trace.	Trace.	.....	.....
P ₂ O ₅ .....	.....	.....	.....	.56
	100.27	99.90	99.88	99.91

2. THE MOUNT TAYLOR REGION.

Rocks received from J. S. Diller: Analyses by T. M. Chatard, record Nos. 219, 227, 228, 235, 271, 268, and 269. Not hitherto published. Petrographic details furnished by Diller.

A. Lava, from canyon on east side of San Mateo Mountain.

B. Phonolitic andesite, from canyon on east side of San Mateo Mountain. Contains feldspar and corroded augite, with sometimes olivine, in a groundmass of feldspar and a green ferromagnesian silicate.

C. Mica-andesite, from canyon on east side of San Mateo Mountain. Shows prominent plagioclase, with augite and biotite.

D. Mica-andesite, from 6 miles northeast of Grant's. Principally plagioclase and biotite, with less epidote, quartz, sphene, and carbonates.

E. Basalt, from 6 miles northeast of Grant's. Contains chiefly plagioclase, augite, and olivine, with much magnetite.

F. Augite from E.

G. Feldspar, from E. Analysis on three-fourths gram of material.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	68.40	65.51	65.78	49.80	47.54	47.06	52.54
TiO ₂.....		.92	.27	2.67	2.76	1.82	Undet.
Al ₂ O ₃	17.99	16.89	17.32	15.33	16.73	7.77	31.26
Cr ₂ O ₃						Trace.	
Fe ₂ O ₃	2.66	1.41	3.68		6.69	1.30	
FeO.....	1.63	2.52	.46	7.44	6.67	8.15	
MnO.....	.21	.31	.32	.30	.19	.20	
(CoNi)O.....						Traces.	
CaO.....	.67	1.19	1.66	7.19	8.74	19.33	12.34
BaO.....					.03		Trace ?
MgO.....	.49	.39	.47	6.61	6.38	13.52	.28
K ₂ O.....	3.54	5.02	4.64	4.36	1.10	.11	.42
Na ₂ O.....	4.54	6.42	5.23	2.71	2.81	.33	3.55
H ₂ O.....	.52	.16	.14	1.38	.36	.20	.26
P ₂ O ₅.....		.07	.13	.73	.51	.06	
CO ₂				2.56	(?)		
	100.65	100.81	100.10	101.08	100.51	99.85	100.65

3. MISCELLANEOUS.

A. Obsidian, from Obsidian Hill camp, Tewan Mountains. Described by Iddings, Ann. 7, p. 292. A rhyolitic obsidian, containing grains of iron oxide and a few microscopic feldspars. Resembles that from Obsidian Cliff in the Yellowstone National Park. Analysis by L. G. Eakins, record No. 851. Sp. gr., 2.352, 23°C.5.

B. Trachyte (?), from Los Cerillos. Described by Diller, Bull. 42, p. 39. Analysis by F. W. Clarke, record No. 346. Rock composed chiefly of orthoclase, with a considerable amount of biotite, epidote, pyrite, and limonite, and some amorphous substance. It is the matrix or gangue rock of the Los Cerillos turquois.

	A.	B.
SiO ₂	76.20	56.68
TiO ₂	Trace.	.22
Al ₂ O ₃	13.17	16.62
Fe ₂ O ₃.....	.34	6.28
FeO.....	.73	
FeS ₂		2.21
MnO.....	.10	1.02
CaO.....	.42	.59
MgO.....	.19	.79
K ₂ O.....	4.46	11.18
Na ₂ O.....	4.31	1.03
H ₂ O.....	.33	3.28
P ₂ O ₅.....		.73
CuO.....		Trace.
	100.25	100.63

ARIZONA.

A, B, C, D. Mica-basalt, Santa Maria Basin. See Iddings, Bull. Phil. Soc. Washington, vol. 12, p. 212. Not fully described. Analyses by W. F. Hillebrand, record No. 1261.

E. Hornblende-porphyrity, Sierra Carrizo. Described by Cross, 14th Ann., p. 165. Contains plagioclase and hornblende, in a groundmass of quartz and orthoclase. Analysis by Hillebrand, No. 1429.

	A.	B.	C.	D.	E.
SiO ₂	49.36	55.35	57.04	57.48	63.18
TiO ₂.....	.98	.87	.94	.94	.60
Al ₂ O ₃	16.35	12.91	13.66	14.09	16.47
Fe ₂ O ₃	2.93	4.67	4.96	5.21	2.36
FeO.....	8.55	2.06	1.77	1.35	2.28
MnO.....	.19	.08	.17	.09	.15
NiO, CoO.....	.05	.05	.07	.08	.....
CaO.....	10.08	5.77	6.23	6.05	4.77
SrO.....	None.	Trace.	Trace.	Trace.	.09
BaO.....	.04	.19	.22	.23	.15
MgO.....	7.06	6.29	4.43	3.49	1.33
K ₂ O.....	.83	4.86	4.95	4.69	2.93
Na ₂ O.....	2.67	2.65	3.08	3.00	4.40
Li ₂ O.....	None.	Trace.	Trace?	None.	Trace.
H ₂ O at 100°.....	.22	2.67	1.11	1.20	.27
H ₂ O above 100°.....	.65	1.18	1.10	1.37	.60
P ₂ O ₅.....	.30	.58	.63	.65	.28
	100.25	99.98	100.36	99.92	99.86

F. Typical hypersthene-andesite, San Francisco Mountains. Not described. Analysis by T. M. Chatard, record No. 270.

G. Recent lava, 2 miles south of Mount Trumbull. Not described. Analysis by L. G. Eakins, record No. 1024.

	F.	G.
SiO ₂	64.82	45.30
TiO ₂ .....	.56	2.66
Al ₂ O ₃	18.27	14.95
Fe ₂ O ₃	3.48	1.98
FeO .....	.56	9.32
MnO .....	.20	Trace.
CaO	2.89	8.87
MgO .....	.85	8.29
K ₂ O	2.67	1.27
Na ₂ O	5.05	4.27
H ₂ O .....	.20	.85
P ₂ O ₅ .....	.23	2.23
	99.78	99.99

NEVADA.

1. ROCKS FROM WASHOE.

Described by Hague and Iddings, in Bull. 17. Analyses by F. A. Gooch, record Nos. 119, 129. FeO not separately determined.

A. Rhyolite. South-southeast of McClellan Peak. Contains feldspars, orthoclase predominating over plagioclase, quartz, mica, and hornblende.

B. Dacite. Spur northeast of McClellan Peak. More plagioclase than orthoclase, much mica, less hornblende, little quartz.

	A.	B.
SiO ₂	73.07	69.96
Al ₂ O ₃	11.78	15.79
Fe ₂ O ₃	2.30	2.50
CaO	2.02	1.73
MgO .....	.39	.64
K ₂ O	6.84	4.12
Na ₂ O	1.19	3.80
Ignition	2.24	1.53
	99.83	100.07

2. ROCKS FROM EUREKA.

Described by Hague and Iddings, in Mon. XX.

A. Basalt, summit of Richmond Mountain. Red, porous. Contains augite, less hypersthene, feldspars, and magnetite, in a glassy base, with accessory olivine and quartz. Analysis by J. E. Whitfield, record No. 424.

B. Andesitic pearlite, south of Carbon Ridge. Contains plagioclase, hornblende, biotite, quartz, hypersthene, augite, magnetite, apatite, and zircon, with a glassy base. Analysis by W. H. Melville, record No. 1240.

	A.	B.
SiO ₂	50.38	65.13
TiO ₂	None.	.58
Al ₂ O ₃	19.83	15.73
Fe ₂ O ₃	6.05	2.24
FeO	2.00	1.86
NiO .....		.07
MnO .....	.38	Trace.
CaO	10.03	3.62
MgO	5.36	1.49
K ₂ O	1.76	3.96
Na ₂ O	2.15	2.93
Li ₂ O	Trace.	
H ₂ O at 105°	1.37	.52
H ₂ O above 105°		1.91
P ₂ O ₅	None.	.23
SO ₃ .....	.83	
	100.14	100.27

CALIFORNIA.

1. MOUNT SHASTA.

Description of rocks furnished by J. S. Diller.

A. Hornblende-andesite, Black Butte, west base of Shasta. Contains plagioclase and hornblende in a microlitic groundmass. The latter carries hypersthene, magnetite, and amorphous matter. Analysis by W. H. Melville, record No. 1346.

B. Hypersthene-andesite, older flow, west base of Shasta. Contains plagioclase, hypersthene, magnetite, and glass. Analysis by Melville, No. 1346.

C. Hypersthene-andesite, like B, same locality, later flow. Analysis by Melville, No. 1346.

D. Hornblende-andesite, late flow, eastern side of Shasta. Contains small crystals of plagioclase and hornblende in a dark groundmass. Thin section not examined. Analysis by H. N. Stokes, record No. 1532.

E. Ophitic basalt from near the McCloud River, south of Mount Shasta. A gray cellular rock. Thin section not examined. Analysis by Stokes, No. 1532.

F. Andesite basalt, Delta, Shasta County. Much plagioclase and a few hypersthene crystals in a groundmass chiefly of feldspar, pyroxene, magnetite, and a trace of olivine. Analysis by Melville, No. 1346.

	A.	B.	C.	D.	E.	F.
SiO ₂	64.48	64.52	63.03	61.58	47.94	55.08
TiO ₂	Undet.	Undet.	Undet.	.49	.57	Trace.
Al ₂ O ₃	19.28	18.31	17.72	16.96	18.90	18.93
Fe ₂ O ₃	1.40	.90	2.27	1.75	2.21	2.02
FeO	1.78	2.51	1.92	2.85	8.59	5.56
MnO				Trace.	Trace.	
CaO	5.06	5.11	5.97	6.28	9.86	8.40
SrO				Trace.	None.	
BaO .....				.03	None.	
MgO	1.64	2.35	3.63	3.67	8.21	5.17
K ₂ O	1.12	1.25	1.06	1.28	.29	.74
Na ₂ O	4.41	4.64	3.92	3.94	2.81	4.23
Li ₂ O				Trace.	Trace.	
H ₂ O at 110° .....	.06	.20	.44	.24	.39	.29
H ₂ O above 110°				1.06	.74	
P ₂ O ₅ .....				.22	.15	
	99.23	99.79	99.96	100.35	100.66	100.42

The following rocks are from Shasta County, but not within either the Mount Shasta or the Lassen Peak areas. Collected by J. S. Diller, who furnishes the petrographic data.

A. Dacite-porphyry, east fork of Clear Creek, 9 miles above French Gulch. Contains conspicuous phenocrysts of plagioclase, a few of quartz, and smaller ones of biotite and pyroxene, in a groundmass of quartz and feldspar. Analysis by J. E. Whitfield, record No. 970.

B. Dacite-porphyry, Smiths Gulch, 6 miles up Clear Creek from French Gulch. Contains phenocrysts of plagioclase, quartz, biotite, and hornblende, in a groundmass chiefly of quartz and feldspar. Analysis by Whitfield, No. 971.

C. Diorite, from Ono. Not described. Analysis by T. M. Chatard, record No. 1107.

	A.	B.	C.
SiO ₂	66.30	64.24	68.10
TiO ₂	Trace.	.76	.35
Al ₂ O ₃	17.55	18.67	15.18
Fe ₂ O ₃	2.19	1.40	1.34
FeO.....	.55	1.96	1.70
MnO.....	Trace.	Trace.	.20
CaO.....	3.12	4.11	4.66
BaO.....			.06
MgO.....	.97	1.48	2.06
K ₂ O.....	2.45	1.71	1.48
Na ₂ O.....	5.15	4.14	3.71
H ₂ O.....	1.25	1.18	.55
P ₂ O ₅.....	.15	.08	.18
SO ₃.....	.28	.22	
Cl.....		.25	
	99.96	100.20	99.57
Less O.....		.05	
		100.15	

2. THE LASSEN PEAK REGION.

Rocks collected by J. S. Diller, who has furnished the petrographic data. Nearly all are from the area covered by the Lassen Peak map sheet of the U. S. Geological Survey. The quartz basalts have been described by Diller in Bull. 79, and partly in Amer. Journ. Sci., 3d series, vol. 33, p. 49. The analyses are so numerous that it seems best to divide them into subordinate groups.

1st. RHYOLITES.

A. Rhyolite, a short distance northwest of Willow Lake, near the Geyser, Plumas County. A light-gray rock with occasional phenocrysts of quartz and feldspar in a granular groundmass of the same materials. Analysis by W. F. Hillebrand, record No. 414.

B. Rhyolite, 2 miles northwest of Deer Creek Meadows, Tehama County. Shows many small crystals of quartz, feldspar, and biotite in a spherulitic groundmass. Analysis by Hillebrand, No. 415.

C. Rhyolite, Slate Creek, west of Deer Creek Meadows. Composed wholly of spherulites, some of which include crystals of feldspar or biotite. Analysis by Hillebrand, No. 416.

D. Rhyolite, summit of Mt. Stover, Plumas County. Composed almost wholly of spherulites, with a few crystals of feldspar and hornblende. Analysis by Hillebrand, No. 417.

E. Rhyolite, from near Slate Creek, west of Deer Creek Meadows. A pearlite, composed chiefly of little glass balls, with a few spherulites, and crystals of feldspar and biotite. Analysis by Hillebrand, No. 418.

F. Rhyolite, $1\frac{1}{2}$ miles northeast of Clipper Mills, on tramway to Rock Creek, Shasta County. A spherulitic rock containing a few microscopic particles of feldspar and hornblende. Analysis by Hillebrand, No. 678.

G. Rhyolite-tuff, from the divide between the west fork of Willard's Creek and the stage road, in Lassen County. Elevation, 5,800 feet. Composed almost wholly of fine angular particles of clear glass. Analysis by George Steiger, record No. 1427.

Materials for A to F dried at 110° previous to analysis.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂	74.24	74.65	73.62	72.40	73.64	74.60	70.01
TiO ₃ .....	.20	.21	.21	.18	.11	.16	.....
Al ₂ O ₃	14.50	14.11	14.24	14.81	13.44	13.41	12.61
Fe ₂ O ₃	1.27	1.08	.93	.81	.60	1.28	1.47
FeO .....	.67	.29	.67	.88	.74	.30	.50
MnO .....	.06	.11	.08	.07	.06	.06	Trace.
CaO .....	.11	.80	1.07	1.94	1.26	1.08	1.06
SrO	Trace.	Trace.	Trace.	.04	.02	None.	.....
BaO .....	.18	.08	.10	.10	.11	.11	.....
MgO .....	.25	.20	.33	.47	.26	.26	.72
K ₂ O	3.66	4.59	4.28	3.90	4.50	4.50	5.12
Na ₂ O	3.00	2.81	3.25	3.91	3.51	3.38	1.94
Li ₂ O	None.	None.	None.	Trace.	Trace.	Trace.	.....
H ₂ O at 100°	2.37
H ₂ O above 100° ..	2.04	1.40	1.29	.59	1.99	.85	4.68
P ₂ O ₅ .....	.07	Trace.	.02	.03	.06	.03	.04
SO ₃ .....	.03	.....	.....	.....	.....	.....	.....
	100.28	100.33	100.09	100.13	100.30	100.02	100.52

2ND. DACITES AND ANDESITES.

A. Gray dacite, Lassen Peak. Contains hornblende, biotite, plagioclase, quartz, scarce pyroxene, magnetite, apatite, and a glassy base. Analysis by T. M. Chatard, record No. 111.

B. Secretion in dacite, Lassen Peak. Composed chiefly of plagioclase and hornblende. Analysis by Chatard, No. 110.

C. Reddish dacite, Lassen Peak. Essentially like A. Analysis by Chatard, No. 110.

D. Dacite from near the timber line, west base of Lassen Peak. Small phenocrysts of plagioclase and hornblende, with a few of quartz, in a reddish-gray groundmass containing much amorphous matter. Analysis by W. F. Hillebrand, record No. 668.

E. Secretion in D. Composed essentially of plagioclase and hornblende. Analysis by Hillebrand, No. 669.

	A.	B.	C.	D.	E.
SiO ₂	69.51	58.97	68.20	68.32	55.14
TiO ₂ .....				.31	.52
Al ₂ O ₃	15.75	18.60	16.98	15.26	19.10
Fe ₂ O ₃	3.34	5.94	3.75	1.66	6.16
FeO				1.26	.54
MnO .....				.04	.11
CaO	1.71	2.84	4.33	3.26	8.36
SrO				Trace.	.07
BaO .....				.07	Trace.
MgO	2.09	6.89	2.07	1.32	4.23
K ₂ O	3.34	2.24	1.52	2.81	1.04
Na ₂ O	3.89	3.05	2.98	4.27	3.71
Li ₂ O				Trace.	Trace.
H ₂ O .....	.56	1.35	.44	1.37	.91
P ₂ O ₅	Trace.	Undet.		.12	.18
	100.19	99.88	100.27	100.07	100.07

F. Dacite, east end of Chaos, northwest base of Lassen Peak. The youngest dacite of the region. Contains quartz, feldspar, biotite, and hornblende, embedded in a clear pumiceous glass. Analysis by W. F. Hillebrand, record No. 670.

G. Secretion in F. Consists chiefly of plagioclase and hornblende, with some olivine and clear glass. Analysis by Hillebrand, No. 671.

H. Dacite (?), west side of old crater rim near the Thumb, at the head of Mill Creek, Shasta County. Shows phenocrysts of hornblende, plagioclase, and pyroxene, and apparently of quartz, in a gray, micro-litic groundmass. Analysis by Hillebrand, No. 674.

I. Streaked dacite, Falls of South Fork of Bear Creek, Shasta County. Contains plagioclase with a little sanidine, hornblende, quartz, magnetite, some pyroxene inclusions, and glass base. Analysis by R. B. Riggs, record No. 524.

J. Dacite-tuff, Rice's Quarry, 6 miles southeast of Paskenta, Tehama County. Clear glass, with fragments of quartz, feldspar, and hornblende. Analysis by George Steiger, record No. 1427.

	F.	G.	H.	I.	J.
SiO ₂	68.72	53.35	63.81	68.10	65.78
TiO ₂.....	.31	.56	.38	.15	
Al ₂ O ₃	15.15	19.22	17.07	15.50	14.87
Fe ₂ O ₃	1.16	3.28	2.11	3.20	1.27
FeO.....	1.76	4.48	2.15	None.	1.00
MnO.....	.11	.15	.09	Trace.	Trace.
CaO.....	3.30	9.76	4.97	3.02	2.41
SrO.....	.03	.03	.03	Trace.	
BaO.....	.07	Trace ?	.04	.06	
MgO.....	1.28	4.86	2.28	.10	1.89
K ₂ O.....	2.78	.99	1.96	3.13	2.71
Na ₂ O.....	4.26	2.89	4.08	4.20	2.58
Li ₂ O.....	Trace.	Trace.	Trace.	None.	
H ₂ O at 100°.....					2.87
H ₂ O above 100°.....	.74	.77	1.03	2.72	4.32
P ₂ O ₅.....	.09	.10	.10	.03	.08
	99.76	100.44	100.10	100.21	99.78

K. Pyroxene-andesite, west end of Butte Mountain, Plumas County. Prominent phenocrysts of pyroxene and minute ones of plagioclase, in a dark groundmass containing much globulitic matter. Analysis by W. F. Hillebrand, record No. 411.

L. Pyroxene-andesite, south base of Burney Butte, Shasta County. Numerous small phenocrysts of plagioclase and a few of pyroxene, in a gray groundmass containing much amorphous matter. Analysis by R. B. Riggs, record No. 684.

M. Hornblende-andesite, Tuscan Buttes, 7 miles east of Red Bluff. A few small phenocrysts or fragments of hornblende, in a groundmass consisting mainly of plagioclase and gray microlitic matter. Analysis by Hillebrand, No. 412.

N. Hornblende-andesite, near Buntingville, Lassen County. A few phenocrysts of hornblende, in a groundmass consisting mainly of small feldspars. Analysis by T. M. Chatard, record No. 413.

O. Hornblende-andesite, northwest summit, head of Burney Creek, Shasta County. Inconspicuous plagioclase and rarely olivine, in a groundmass of plagioclase and pyroxene. Numerous dark spots are due to altered hornblende. Analysis by Riggs, No. 683.

Rocks in this group dried at 105° before analysis.

	K.	L.	M.	N.	O.
SiO ₂	55.53	62.44	60.93	67.89	60.04
TiO ₂ .....	.56	.31	.61	.21	.49
Al ₂ O ₃	17.63	16.39	18.56	17.29	17.43
Fe ₂ O ₃	2.81	4.66	2.68	2.39	5.39
FeO	3.59	1.00	2.19	.21	.53
MnO .....	.08	Trace.	.10	.12	.08
CaO	8.74	6.22	6.63	3.01	6.65
SrO .....	.06	Trace.	.12	.04	?
BaO .....	.02	.03	.02	.03	.04
MgO	5.85	2.65	2.37	.66	3.51
K ₂ O .....	.92	2.25	1.33	1.69	1.24
Na ₂ O	3.09	3.16	3.79	5.11	4.15
Li ₂ O	None.	Trace.	None.	.....	Trace.
H ₂ O	1.24	1.02	.90	1.34	.90
P ₂ O ₅ .....	.21	.05	.18	.12	.04
SO ₃ .....	.....	Trace.	.....	.....	Trace.
	100.33	100.18	100.41	100.11	100.49

P. Hypersthene-andesite, 1 mile west of summit on Bidwell's Road, Butte County. Rich in small phenocrysts of plagioclase and pyroxene, mostly hypersthene, in a groundmass of the same minerals, with magnetite, and probably some amorphous matter. Analysis by W. F. Hillebrand, record No. 410.

Q. Hypersthene-andesite, old crater at head of Mill Creek. Contains small phenocrysts of plagioclase and hypersthene, in a groundmass of plagioclase, pyroxene, magnetite, etc. Some greenish pseudomorphs suggest former olivine. Analysis by T. M. Chatard, record No. 409.

R. Hypersthene-andesite, 2 miles south of Suppan's Mountain, Tehama County. Abundant plagioclase and hypersthene, with traces of hornblende, in a microlitic groundmass. Analysis by Hillebrand, No. 672.

S. Secretion in R. Composed chiefly of plagioclase and hypersthene, with some quartz and amorphous matter. Analysis by Hillebrand, No. 673.

T. Hypersthene-andesite, west base of Suppan's Mountain, near Lassen Peak, Tehama County. Contains numerous microscopic crystals of plagioclase and hypersthene, in a microlitic groundmass. Analysis by Hillebrand, No. 676.

Rocks dried at 100° to 110° before analysis.

	P.	Q.	R.	S.	T.
SiO ₂	55.20	57.11	63.47	57.04	58.08
TiO ₂ .....	.92	.95	.37	.47	.44
Al ₂ O ₃	18.68	17.78	16.75	19.11	18.37
Fe ₂ O ₃	3.14	3.54	2.15	4.37	2.92
FeO	4.42	2.74	2.75	2.48	3.38
MnO .....	.14	.33	.09	.12	.13
CaO	8.02	7.21	5.72	7.34	7.05
SrO .....	.02	Trace?	.04	.02	.02
BaO .....	.03	.03	.04	Trace?	.03
MgO	4.59	3.41	3.04	3.94	3.35
K ₂ O	1.01	1.86	1.62	1.16	1.33
Na ₂ O	3.66	3.81	3.94	3.48	3.66
Li ₂ O	None.	.....	Trace.	Trace.	Trace.
H ₂ O .....	.51	.98	.55	1.09	1.09
P ₂ O ₅ .....	.24	.26	.13	.08	.16
	100.58	100.01	100.66	100.70	100.01

U. Hypersthene-andesite, 1 mile southwest of Thumb, head of Bailey Creek, near Lassen Peak. Abundant but inconspicuous plagioclase and hypersthene, in a microlitic groundmass containing many small crystals of plagioclase. Analysis by W. F. Hillebrand, record No. 675.

V. Hypersthene-andesite, west summit of Crater Peak, Shasta County. Microphenocrysts of feldspar and hypersthene in a groundmass consisting largely of the same minerals, with some amorphous matter. Analysis by Hillebrand, No. 679.

W. Hypersthene-andesite, north slope of Crater Peak. Phenocrysts of plagioclase and hypersthene in a groundmass containing much dark amorphous matter. Analysis by Hillebrand, No. 680.

X. Secretion in W. Composed chiefly of plagioclase, hypersthene, and a globulitic base. Analysis by Hillebrand, No. 681.

Y. Andesitic tuff, Stillwater Creek, 8 miles northeast of Redding. Contains plagioclase, hornblende, rare hypersthene, magnetite, and glass. Fragments of andesite are inclosed. Analysis by W. H. Melville, record No. 1346.

Rocks dried at 100° to 110° before analysis.

	U.	V.	W.	X.	Y.
SiO ₂	59.84	68.12	61.17	53.85	69.51
TiO ₂ .....	.57	.25	.45	.50	Trace.
Al ₂ O ₃	16.81	16.24	17.74	18.53	15.61
Cr ₂ O ₃	Trace?	None.	None.	Trace.	.....
Fe ₂ O ₃	1.88	1.26	1.78	1.96	.56
FeO	3.60	2.08	3.51	5.30	1.27
MnO .....	.14	.10	.12	.12	.....
CaO	6.30	3.80	5.90	9.66	2.80
SrO .....	.02	.02	.04	.04	.....
BaO .....	.07	.09	.06	.03	.....
MgO	3.85	1.35	2.76	5.88	.61
K ₂ O	2.13	2.54	1.71	.74	2.81
Na ₂ O	3.63	3.89	3.79	2.98	3.43
Li ₂ O	Trace.	Trace.	Trace.	Trace.	.....
H ₂ O	1.04	.40	.83	.45	3.63
P ₂ O ₅ .....	.19	.14	.14	.05	.....
	100.07	100.28	100.00	100.09	100.23

3RD. BASALTS.

The quartz-basalts are described by Diller in Bull. 79. That from Mitylene was analyzed for comparison with the Cinder Cone series.

A. Quartz-basalt, from Cinder Cone, 10 miles northeast of Lassen Peak. Contains plagioclase, pyroxene (mostly hypersthene), olivine, quartz, and much unindividualized base; the latter about 25 per cent. Magnetite is also present; augite occurs sparingly. Analysis by W. F. Hillebrand, record No. 407.

B. Volcanic bomb from quartz-basalt of Cinder Cone. Analysis by Hillebrand, No. 665.

C. Lapilli from quartz-basalt of Cinder Cone. Analysis by Hillebrand, No. 667.

D. Volcanic sand, one-half mile northeast of Cinder Cone. Analysis by Hillebrand, No. 663.

E. White pumiceous inclosure from quartz-basalt of Cinder Cone. Analysis by Hillebrand, No. 664. Mainly glass.

Rocks dried at 100° to 110° before analysis.

	A.	B.	C.	D.	E.
SiO ₂	57.25	56.70	56.53	55.93	79.49
TiO ₂.....	.60	.65	.54	Undet.	Undet.
Al ₂ O ₃	16.45	15.75	17.50	17.34	11.60
Cr ₂ O ₃		Trace.	Trace.		
Fe ₂ O ₃	1.67	1.29	1.35	1.50	.33
FeO.....	4.72	5.32	5.03	5.20	.49
MnO.....	.10	.19	.12	Undet.	None.
CaO.....	7.65	7.67	8.07	8.04	1.64
SrO.....	Trace.	Trace.	Trace?	?	?
BaO.....	.03	.03	Trace.	?	?
MgO.....	6.74	7.16	5.94	7.29	.09
K ₂ O.....	1.57	1.56	1.55	1.35	1.52
Na ₂ O.....	3.00	3.36	3.51	3.32	4.04
Li ₂ O.....	None.	Trace.	Trace.	?	?
H ₂ O.....	.40	.30	.27	.26	.68
P ₂ O ₅.....	.20	.20	.15	Undet.	Undet.
	100.38	100.18	100.56	100.23	99.88

F. Quartz-basalt, one-half mile south of Cinder Cone, on border of lava field. Analysis by Hillebrand, No. 666.

G. Quartz-basalt, west end of Lake Bidwell, on border of Cinder Cone lava field. Contains a few grains of quartz, much olivine and plagioclase, less pyroxene, and a globulitic base. Analysis by Hillebrand, No. 661.

H. Quartz-basalt, Silver Lake, near Lassen Peak. Contains occasional grains of quartz, much feldspar and olivine, less pyroxene, and a brownish base. Analysis by Hillebrand, No. 662.

I. Quartz-basalt, resting on dacite, near west base of Lassen Peak. Analysis by Hillebrand, No. 677.

J. Quartz-basalt from the island of Mitylene, coast of Asia Minor. Analysis for comparison with the Cinder Cone series, by T. M. Chatard, record No. 845.

Rocks F to I dried at 100° to 110° before analysis.

	F.	G.	H.	I.	J.
SiO ₂	54.56	56.18	57.59	56.51	56.58
TiO ₂ .....	.53	Undet.	Undet.	.48	.77
Al ₂ O ₃	16.04	16.59	16.49	18.10	14.88
Cr ₂ O ₃	Trace.	.....	.....	Trace.	Trace?
Fe ₂ O ₃ .....	.95	1.51	1.22	4.26	2.31
FeO	6.07	5.51	4.89	2.68	3.04
MnO .....	.17	Undet.	Undet.	.11	.16
CaO	8.89	7.64	7.40	8.15	8.69
SrO	Trace.	?	?	.04	.....
BaO .....	.03	?	?	.04	.07
MgO	8.71	7.26	7.72	4.52	3.76
K ₂ O	1.18	1.47	.99	1.15	2.18
Na ₂ O	3.05	3.58	3.62	3.23	3.36
Li ₂ O	Trace.	?	?	Trace.	.....
H ₂ O at 105° .....	.....	.....	.....	.....	.69
H ₂ O above 105° .....	.28	.42	.86	.69	1.43
P ₂ O ₅ .....	.18	Undet.	Undet.	.14	.15
CO ₂ .....	.....	.....	.....	.....	2.32
	100.64	100.16	100.78	100.10	100.39

K. Recent basalt, Pit River. Rich in feldspar and augite; poor in olivine. Partial analysis by F. W. Clarke, record No. 109.

L. Basalt, 1 mile southeast of Paine's Creek, on the road from Red Bluff to Lassen Peak. A normal basalt, rather rich in olivine. Analysis by T. M. Chatard, record No. 405.

M. Basalt, summit of Inskip Crater, 25 miles east of Red Bluff. Mainly feldspar and augite, with a few phenocrysts of olivine. Analysis by Hillebrand and Chatard, record No. 406.

N. Basalt from the cone at south base of Burney Butte, Shasta County. Composed of plagioclase and augite, with some olivine and a globulitic base. Analysis by R. B. Riggs, record No. 685.

O. Basalt, near eastern end of rim of Crater Peak, Shasta County. Contains plagioclase and pyroxene, some of the latter being hypersthene with a trace of olivine. Analysis by R. B. Riggs, record No. 682.

P. Hornblende-basalt, Kosk Creek, near its mouth, by the great bend of Pit River, Shasta County. Contains abundant phenocrysts of hornblende, with a few of plagioclase, pyroxene and olivine, in a ground-mass of plagioclase, augite, and magnetite. The hornblendes are deeply corroded, and some have disappeared, leaving groups of magnetite grains to mark their former presence. Analysis by L. G. Eakins, record No. 1022. Described by Diller in Amer. Geologist, vol. 19, p. 253.

Rocks dried at 105° to 110° before analysis, except in the case of the rock marked L.

	K.	L.	M.	N.	O.	P.
SiO ₃	51.92	47.93	50.89	52.63	52.95	44.77
TiO ₂ .....		.73	.79	.07	.66	.53
Al ₂ O ₃	19.76	18.51	16.76	17.62	18.25	17.82
Fe ₂ O ₃	11.21	2.07	3.86	6.49	4.36	5.05
FeO		7.25	4.69	3.10	4.19	6.95
MnO .....		.20	.13	Trace.	.12	Trace.
CaO	9.30	11.14	11.72	8.62	8.73	10.36
SrO				Trace.	Trace.	
BaO			Trace.	.04	.01	
MgO	3.38	9.03	8.49	5.64	4.93	8.22
K ₂ O .....	.60	.24	.32	1.73	.77	.92
Na ₂ O	2.16	2.28	2.61	3.38	3.57	2.13
Li ₂ O				Trace.	?	
H ₂ O	1.54	.76	.41	.79	1.47	2.64
P ₂ O ₅ .....		.11	.09	.47	Trace.	.72
CO ₂		None.				
SO ₃				Trace.	Trace.	
	99.87	100.25	100.76	100.58	100.01	100.11

3. PLUMAS COUNTY.

Other rocks from this county are described under the heading of the Lassen Peak area. The following rocks, with two exceptions, were collected by H. W. Turner, who supplies the descriptions:

A. Granite, dike in serpentine, south slope of Grizzly Hill. Described by Turner in Amer. Geologist, vol. 17, p. 375. Contains quartz, albite, and muscovite. Analysis by H. N. Stokes, record No. 1562.

B. Quartz-porphyry, near Tower Rock, Grizzly Mountains. Described by Turner in 14th Ann., p. 441. Contains porphyritic quartz, feldspar, and pyrite, in a fine groundmass. Analysis by W. F. Hillebrand, record No. 1273.

C. Quartz-porphyry, near Greenville. Collected by Diller, who finds phenocrysts of quartz in a groundmass chiefly of quartz and feldspar. Analysis by Hillebrand, record No. 1458.

D. Granodiorite, southwest base of Mount Ingalls. Description supplied by Turner. Contains plagioclase, quartz, orthoclase, brown mica, green hornblende, iron oxide, and a little apatite, sphene, and epidote. Analysis by Hillebrand, record No. 1456.

E. Granodiorite, Spanish Peak. Description supplied by Turner. Contains plagioclase, quartz, orthoclase, biotite, hornblende, iron ore, and apatite; also abundant secondary epidote and chlorite. Analysis by Stokes, record No. 1562.

	A.	B.	C.	D.	E.
SiO ₂	76.00	73.25	72.77	67.33	59.68
TiO ₂ .....	.04	Trace.	.22	.36	.65
Al ₂ O ₃	14.88	13.25	13.00	15.93	17.09
Fe ₂ O ₃ .....	.65	.....	1.28	1.90	2.85
FeO .....	.10	1.74	2.65	1.59	2.75
MnO	Trace.	Trace.	.08	.09	Trace.
CaO .....	.19	2.23	2.47	4.09	6.62
SrO .....	.....	Trace?	Trace.	Trace.	Trace.
BaO	Trace.	Trace.	Trace.	.08	.04
MgO .....	.06	.28	.67	1.63	3.54
K ₂ O	2.77	3.79	.34	2.46	1.31
Na ₂ O	3.52	2.69	4.95	3.76	3.87
Li ₂ O .....	.....	Trace.	Trace.	Trace.	Trace.
H ₂ O at 100° .....	.20	.07	.07	.19	.15
H ₂ O above 100°	1.42	1.03	1.16	.66	1.00
P ₂ O ₅ .....	.11	Trace.	.04	.11	.25
CO ₂ .....	.....	1.05	.47	.....	.20
SO ₃	Trace.	.....	.....	.....	Trace.
Cl	Trace.	.....	.....	.....	.03
F	Trace.	.....	.....	.....	.....
FeS ₂ .....	.....	.58	.....	.....	.....
	99.94	99.96	100.17	100.18	100.03

F. Rhyolite, $3\frac{1}{2}$ miles southwest of Grizzly Peak. Description furnished by Turner. Contains sanidine, with less quartz and biotite, in a glassy groundmass. Analysis by Hillebrand, record No. 1461.

G. Hornblende-andesite, 4 miles from Pilot Peak. Described by Turner in 14th Ann., p. 441. Contains plagioclase and hornblende in a groundmass carrying grains of magnetite. Analysis by Hillebrand, record No. 1432.

H. Hornblende-pyroxene-andesite, southwest base of Mount Ingalls. Description supplied by Turner. Contains plagioclase, rhombic pyroxene, augite, brown hornblende, and magnetite, with much glass in the groundmass. Analysis by Hillebrand, No. 1456.

I. Hypersthene-andesite, Franklin Hill. Description supplied by Turner. Contains plagioclase, rhombic pyroxene, augite, and magnetite. Probably no glass. Analysis by Hillebrand, No. 1548.

	F.	G.	H.	I.
SiO ₂	71.39	60.20	58.47	56.88
TiO ₂.....	.17	.57	.51	.45
Al ₂ O ₃	14.13	17.21	18.80	18.25
Fe ₂ O ₃.....	.63	3.12	3.34	2.35
FeO.....	.37	2.69	2.64	4.45
MnO.....	Trace.	.12	.13	.18
CaO.....	1.01	6.04	6.60	7.53
SrO.....	Trace.	Trace.	.05	.04
BaO.....	.09	.11	.09	.11
MgO.....	.08	3.18	2.69	4.07
K ₂ O.....	5.69	1.44	2.01	1.42
Na ₂ O.....	2.89	3.35	3.58	3.29
Li ₂ O.....	Trace.	Trace.	Trace.	Trace.
H ₂ O at 100°.....	.42	1.12	.14	.24
H ₂ O above 100°....	3.32	1.18	.92	.50
P ₂ O ₅.....	.03	.17	.22	.30
	100.22	100.50	100.19	100.06

J. Dolerite, Mount Ingalls. Described by Turner in 14th Ann., p. 441. Contains plagioclase, augite, hypersthene, magnetite, and a few olivines. Analysis by W. F. Hillebrand, record No. 1273.

K. Dolerite, Mount Ingalls. Also in 14th Ann., p. 441. Like J, but with scarcely any olivine. Analysis by Hillebrand, record No. 1432.

L. Basalt, 4 miles southeast of Mount Ingalls. Also in 14th Ann., p. 441. Contains plagioclase, olivine, augite, and magnetite. Analysis by Hillebrand, record No. 1273.

M. Olivine-basalt, $1\frac{1}{2}$ miles from Franklin Hill. Contains plagioclase, augite, partly altered olivine, magnetite, and probably some glass. Description supplied by Turner. Analysis by George Steiger, record No. 1596.

N. Serpentine, Greenville. Collected by J. S. Diller, who supplies the description. Besides serpentine, the rock contains some magnetite and less chromite, with remnants of the pyroxene from which the serpentine was in great part derived. Analysis by W. H. Melville, record No. 1346.

	J.	K.	L.	M.	N.
SiO ₂	53.91	52.81	50.56	51.21	39.14
TiO ₂.....	.52	.84	1.71	.31	.....
Al ₂ O ₃	17.95	16.60	14.71	17.59	2.08
Fe ₂ O ₃	2.21	2.66	3.54	4.71	4.27
FeO.....	4.80	6.13	8.90	4.42	2.04
MnO.....	.10	Undet.	.13	Trace.	.....
CaO.....	10.40	10.14	7.58	10.36	Trace.
SrO.....	Trace.	Trace.	Trace?	.....	.....
BaO.....	.05	.03	.25	None.	.....
MgO.....	5.52	6.12	4.07	7.12	39.84
K ₂ O.....	1.34	1.05	2.10	.91	.....
Na ₂ O.....	2.90	2.79	2.94	2.49	.....
Li ₂ O.....	Trace.	Trace.	Trace?	None.	.....
H ₂ O at 100°.....	.20	.38	1.06	.58	} 12.70
H ₂ O above 100°.....	.20	.54	1.12	1.07	
P ₂ O ₅.....	.21	.23	1.14	.09	.....
Chromite.....	.....	.....	.....	.....	.11
	100.31	100.32	99.81	100.86	100.18

4. BUTTE COUNTY.

Rocks from this county are also to be found under the heading of the Lassen Peak area. The following rocks were collected by H. W. Turner, to whom the petrographic data are due. Analyses, with one exception, by W. F. Hillebrand, record Nos. 1432, 1456, 1461, and 1548. Analysis F is by H. N. Stokes, record No. 1562.

A. Granodiorite, north side of south fork of Feather River, opposite Enterprise. Described in 14th Ann., p. 441. Contains plagioclase, potash-feldspar, quartz, hornblende, brown mica, and accessory minerals. The ferromagnesian minerals are largely altered to chlorite.

B. Granodiorite, 2 miles east of Bangor. Composition like A. The mica is largely altered to chlorite. See 14th Ann., p. 441.

C. Diorite, South Husent Creek. Description supplied by Turner. Contains feldspar, probably all plagioclase, brown hornblende, and a little chlorite.

D. Quartz-diorite, dike in Bidwell Bar quadrangle. Described in 17th Ann., Part I, p. 521. Contains hornblende, feldspar, quartz, and a little secondary chlorite.

	A.	B.	C.	D.
SiO ₂	70.36	63.43	57.87	54.64
TiO ₂.....	.20	.73	.53	.61
Al ₂ O ₃	15.47	14.20	16.30	12.09
Fe ₂ O ₃.....	.98	1.54	1.71	1.81
FeO.....	1.17	4.56	3.86	5.03
NiO.....				.05
MnO.....	Trace.	.03	.08	.13
CaO.....	3.18	5.51	5.53	7.74
SrO.....	Trace.	Trace.	Trace.	Trace.
BaO.....	.06	.06	.05	.05
MgO.....	.87	2.35	5.50	11.86
K ₂ O.....	1.71	2.19	.75	1.01
Na ₂ O.....	4.91	3.49	5.01	2.35
Li ₂ O.....	Trace.	None.	Trace.	Trace.
H ₂ O at 100°.....	.06	.15	.26	.12
H ₂ O above 100°...	1.00	1.50	2.40	2.44
P ₂ O ₅.....	.11	.11	.27	.08
	100.08	99.85	100.12	100.01

E. Diabase-tuff. Described in 14th Ann., p. 441. Contains plagioclase, augite, epidote, chlorite, and secondary hornblende.

F. Uralite-diorite, 1 mile southeast of Forbestown. Described in 17th Ann., Part I, p. 521. Contains plagioclase, hornblende, and magnetite.

G. Basalt, Oroville Table Mountain. Described in 14th Ann., p. 441. Contains plagioclase, olivine, augite, and magnetite.

H. Altered peridotite, 5 miles northeast of Strawberry Valley. Largely serpentine, with olivine, hornblende, magnetite, and calcite or dolomite.

	E.	F.	G.	H.
SiO ₂	54.66	51.07	50.66	44.81
TiO ₂.....	.67	1.65	2.39	} 1.88
Al ₂ O ₃	15.85	14.93	13.97	
Cr ₂ O ₃.....				.29
Fe ₂ O ₃	1.82	6.44	2.55	1.98
FeO.....	5.12	5.98	10.20	4.52
MnO.....	.18	.22	.29	.13
NiO.....	Trace?		Trace.	.09
CaO.....	8.75	7.89	8.08	6.58
SrO.....	Trace.		Trace.	None.
BaO.....	.04		.22	None.
MgO.....	5.64	4.84	4.45	30.91
K ₂ O.....	.47	.16	1.95	} .15
Na ₂ O.....	3.46	5.04	3.32	
Li ₂ O.....	None.		None.	
H ₂ O at 100°.....	.25	.24	.27	.15
H ₂ O above 100°...	2.48	1.73	.43	6.88
P ₂ O ₅.....	.15	.19	1.01	.02
CO ₂.....	.39			1.79
Cl.....		Trace.	.02	
F.....		Trace.		
SO ₃		Trace.		
FeS ₂.....	.09			
	100.02	100.38	99.81	100.18

5. SIERRA COUNTY.

Rocks collected and described by H. W. Turner. See paper in 17th Ann., Part I, p. 521. Additional details, supplied by Turner, are given here. Analyses A to H by W. F. Hillebrand, record Nos. 1456 and 1548. Analysis I by H. N. Stokes, record No. 1514.

A. Granulite (aplite), Yuba Gap, road east of Sierra Buttes. Contains orthoclase, microcline, quartz, plagioclase, some shreds of greenish mica, and a little iron ore, chlorite, and apatite.

B. Granulite (aplite), dike east of Milton. Contains orthoclase, quartz, plagioclase, a little microcline, brown mica, and iron ore.

C. Biotite-granite, Indian Valley. Contains plagioclase, orthoclase, quartz, brown mica, apatite, and iron ore.

D. Quartz-diorite-porphry, dike in Indian Valley granite. Contains plagioclase, hornblende, biotite, and quartz.

E. Quartz-mica-diorite, large area east of Milton. Contains plagioclase, a turbid feldspar which is apparently not orthoclase, quartz, green hornblende, brown mica, iron ore, and apatite.

	A.	B.	C.	D.	E.
SiO ₂	76.03	75.97	68.65	66.65	57.26
TiO ₂ .....	.07	.09	.28	.33	.53
Al ₂ O ₃	13.39	13.07	16.34	17.61	16.51
Fe ₂ O ₃ .....	.48	.61	.93	.93	3.27
FeO .....	.31	.39	1.48	1.67	5.19
MnO	Trace.	Trace.	.08	.07	.18
CaO	1.28	1.49	3.07	4.44	6.69
SrO	Trace.	.03	.07		.06
BaO .....	.04	.14	.09	.12	.10
MgO .....	.05	.14	1.29	1.26	3.41
K ₂ O	5.18	5.62	1.85	1.70	2.93
Na ₂ O	2.98	2.51	4.85	4.59	2.65
Li ₂ O	None.	Trace.	Trace.	Trace.	Trace.
H ₂ O at 100° .....	.15	.14	.24	.03	.20
H ₂ O above 100° .....	.34	.24	.62	.41	.95
P ₂ O ₅ .....	.03	Trace.	.15	.18	.30
	100.33	100.44	99.99	99.99	100.23

F. Diabase-porphry, dike east of Milton. Contains labradorite and other plagioclase, augite, and hornblende, the last mineral being perhaps secondary.

G. Hypersthene-andesite, point northeast of Goodyears Bar. Contains plagioclase and rhombic pyroxene, a little augite, and scales which seem to represent former biotite, now replaced by magnetite.

H. Hornblende-pyroxene-andesite, dike southeast of Poker Flat. Contains plagioclase, augite, hornblende, magnetite, some glass, and occasional quartz.

I. Quartz-bearing andesite, northwest of Downieville. Contains plagioclase, augite, enstatite, magnetite, occasional quartz, and probably glass.

	F.	G.	H.	I.
SiO ₂	51.27	66.94	59.34	60.02
TiO ₂ .....	.60	.30	.32	.42
Al ₂ O ₃	12.14	16.49	17.61	16.07
Cr ₂ O ₃				Trace.
Fe ₂ O ₃	2.51	1.41	3.63	2.17
FeO	6.71	1.87	2.28	3.46
NiO .....	.04			
MnO .....	.21	.13	.12	.10
CaO	10.32	4.77	6.45	7.01
SrO	Trace?	.05	.04	Trace.
BaO .....	.07	.07	.11	.08
MgO	10.88	1.98	3.50	4.57
K ₂ O	1.63	1.65	1.94	1.59
Na ₂ O	2.00	3.88	3.40	3.55
Li ₂ O	Trace.	Trace.	Trace.	None.
H ₂ O at 100° .....	.17	.35	.64	.24
H ₂ O above 100°	1.16	.22	.74	.45
P ₂ O ₅ .....	.21	.12	.25	.17
SO ₃ .....				.06
	99.92	100.23	100.37	99.96

6. NEVADA CITY AND GRASS VALLEY.

Rocks of a mining district in Nevada County, described by Lindgren in 17th Ann., Part II, p. 1.

A. Granodiorite, 1 mile southeast of Nevada City. Contains hornblende, biotite, quartz, plagioclase, orthoclase, magnetite, apatite, sphene, and pyrite. Analysis by W. F. Hillebrand, record No. 1478.

B. Granodiorite, Kate Hayes Hill, Grass Valley. Contains plagioclase, orthoclase, quartz, hornblende, pyrite, magnetite, apatite, sphene, and zircon. Analysis by Hillebrand, No. 1478.

C. Hornblende-porphyrity, Nevada City. Contains feldspar, hornblende, quartz, epidote, sericite, and biotite. Analysis by H. N. Stokes, record No. 1531.

D. Quartz-porphyrity, New Ophir claim, Grass Valley. Contains plagioclase, quartz, uraltite, epidote, and augite, and hornblende altered into chlorite. Analysis by Stokes, No. 1531.

E. Diabase, near Maryland mine, Grass Valley. Contains feldspar, augite, hornblende, ilmenite, pyrrhotite, pyrite, and some chlorite. Analysis by Stokes, No. 1522.

F. Diabase, Grass Valley. Contains feldspar, pyroxene, hornblende, ilmenite, pyrrhotite, pyrite, and chlorite, and probably a little quartz. Analysis by Stokes, No. 1522.

	A.	B.	C.	D.	E.	F.
SiO ₂	66.65	63.85	62.09	63.39	51.01	53.19
TiO ₂ .....	.38	.58	.32	.44	.98	1.34
Al ₂ O ₃	16.15	15.84	16.69	16.58	11.89	17.12
Cr ₂ O ₃ .....					.04	None.
Fe ₂ O ₃	1.52	1.91	1.45	1.41	1.57	4.35
FeO	2.36	2.75	3.76	3.08	6.08	5.16
MnO .....	.10	.07	Trace.	Trace.	Trace.	Trace.
CaO	4.53	4.76	6.08	4.76	10.36	9.39
SrO	Trace.	Trace.				
BaO .....	.07	.06	.10	.11	None.	Trace.
MgO	1.74	2.07	1.93	2.15	8.87	3.98
K ₂ O	2.65	3.08	1.84	2.79	.15	.28
Na ₂ O	3.40	3.29	3.36	3.47	4.17	2.79
Li ₂ O	Trace.	Trace.				
H ₂ O at 110° .....	.18	.28	.19	.22	.24	.17
H ₂ O above 110° .....	.72	1.65	1.47	1.87	2.09	1.21
P ₂ O ₅ .....	.10	.13	.39	.14	.17	.13
SO ₃ .....			.10			
FeS ₂ .....	.02	.04			1.73	.94
CuS (?)					Trace.	
	100.57	100.36	99.77	100.41	99.35	100.05

G. Wall rock, Federal Loan mine. A siliceous argillite, of sedimentary origin. Contains quartz, feldspar, biotite, pyrrhotite, and a little calcite. Analysis by Hillebrand, No. 1478.

H. Altered wall rock, Providence mine. Derived from granodiorite. Analysis by Hillebrand, No. 1478.

I. Altered wall rock, Providence mine, back vein. Derived from granodiorite and schist. Analysis by Hillebrand, No. 1478.

J. Altered wall rock, North Star mine. Derived from uralite-dia-base. Contains quartz, sericite, calcite, pyrite, and sphene. Analysis by Hillebrand, No. 1478.

K. Altered country rock, Idaho mine. Derived from serpentine. Analysis by Hillebrand, No. 1478.

	G.	H.	I.	J.	K.
SiO ₂	73.63	60.26	59.76	45.74	36.19
TiO ₂ .....	.52	.42	.46	.36	.16
Al ₂ O ₃	10.54	15.73	14.45	5.29	4.93
Fe ₂ O ₃	1.87	1.25	1.04	.13	.21
FeO		2.68	3.52	2.06	5.36
MnO	Trace?	.04	.09	.26	.12
NiO .....					.10
CaO	2.47	5.44	6.09	23.85	4.60
SrO	Trace.	Trace.	Trace?	None.	Trace.
BaO .....	.12	.07	.05	Trace.	Trace.
MgO	1.84	1.82	2.26	.94	22.94
K ₂ O	1.89	3.71	3.73	1.29	.06
Na ₂ O	1.81	1.92	1.12	.11	.16
Li ₂ O	Trace.	Trace.	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.11	.33	.26	.22	.18
H ₂ O above 110°	1.07	2.54	2.58	1.07	2.87
P ₂ O ₅ .....	.13	.12	.16	.07	.05
CO ₂ .....	.62	3.99	4.47	18.91	21.82
FeS ₂ .....		.08	.24	.49	.22
Fe ₇ S ₈	3.16				
Organic C .....	.59				
	100.37	100.40	100.28	100.79	99.97

L. Bleached country rock, next to vein, Osborne Hill mine. Derived from sandstone. Analysis by George Steiger, record No. 1541.

M. Altered wall rock, Empire mine. Derived from granodiorite. Analysis by Steiger, No. 1541.

N. Altered wall rock, Ebaugh tunnel. Derived from granodiorite. Mainly quartz and sericite, with pyrite, apatite, sphene, and carbonates. Analysis by Steiger, No. 1541.

O. Altered wall rock, Federal Loan mine. Derived from siliceous argillite. Analysis by Steiger, No. 1541.

	L.	M.	N.	O.
SiO ₂	71.97	58.43	56.25	34.91
TiO ₂ .....	.88	None.	.25	1.65
Al ₂ O ₃	15.75	17.40	17.65	15.55
Fe ₂ O ₃ .....	.77	.77	.76	.17
FeO .....	.45	2.19	2.64	4.96
MnO	None.	None.	None.	None.
CaO .....	.80	5.25	4.46	11.10
BaO	Trace.	None.	.03	None.
MgO .....	.80	1.50	1.69	4.58
K ₂ O	4.88	4.03	6.01	4.28
Na ₂ O .....	.33	1.76	.30	.19
H ₂ O at 100° .....	.30	.30	.30	.30
H ₂ O above 100°	2.16	2.61	2.36	1.86
P ₂ O ₅ .....	.15	.13	.21	.82
SO ₃	Trace.	None.	None.	None.
CO ₂ .....	.38	4.04	4.82	15.57
FeS ₂ .....	.56	1.59	2.87	4.20
	100.18	100.00	100.60	100.14

7. PLACER COUNTY.

First, a series of rocks from the Ophir mining district, described by Lindgren in 14th Ann., p. 249. Analyses by W. F. Hillebrand, record Nos. 1419, 1433, 1434.

A. Granodiorite, from quarries at Lincoln, 8 miles west of Ophir. Contains feldspars, quartz, biotite, and hornblende.

B. Pyritiferous amphibolite, Conrad tunnel. Partly altered. Contains pyrite, hornblende, magnetite, feldspars, quartz, epidote, chlorite, a few scales of mica, rutile, and carbonates.

C. Dike rock, near camptonite, Casey's tunnel, Flat Ledge, Duncan Hill. Contains hornblende, feldspars, pyrite, and apatite, with secondary epidote and quartz.

D. Altered wall rock, Mina Rica vein.

E. Altered wall rock, Plantz vein. These rocks, D and E, contain quartz, muscovite, a little chlorite, pyrite, and sphene, with carbonates of calcium, magnesium, and iron.

	A.	B.	C.	D.	E.
SiO ₂	65.54	45.56	60.09	37.01	46.13
TiO ₂ .....	.39	1.11	.63	.85	.67
Al ₂ O ₃	16.52	14.15	16.43	12.99	15.82
Fe ₂ O ₃	1.40	1.20	2.28	.43	.89
FeO	2.49	9.83	3.01	3.57	2.27
MnO .....	.06	.25	.12	.24	.09
Ni, Zn	Traces.	Traces.	Traces.	Traces.	Traces.
CaO	4.88	2.30	5.76	9.78	10.68
SrO	Trace.	Trace.	Trace.	Trace.	Trace.
BaO	Trace.	Trace.	Trace.	Trace.	Trace.
MgO	2.52	6.76	4.37	5.49	2.13
K ₂ O	1.95	1.18	.70	4.02	5.30
Na ₂ O	4.09	1.57	4.52	.13	.17
Li ₂ O	Trace.	Trace.	None.	Trace.	Trace.
H ₂ O at 100° ....	.12	.23	.20	.13	.12
H ₂ O above 100° ..	.59	4.84	1.16	1.92	2.42
P ₂ O ₅ .....	.18	.14	.12	.06	.10
SO ₃ .....	.....	.03	Trace.	.04	.04
CO ₂ .....	.....	3.04	.07	15.04	11.24
FeS ₂ .....	.....	7.86	.34	7.99	1.61
Cu ₂ S (?) .....	.....	.10	.....	.....	.....
	100.73	100.15	99.80	99.69	99.68

Second, rocks from other localities in Placer County. Studied also by Lindgren, who furnishes the petrographic data. Analysis A by W. H. Melville, record No. 1346; B, C, D, E, by W. F. Hillebrand, record No. 1419.

A. Granite from Rocklin. Collected for the Educational Series. A normal granite, containing quartz, orthoclase, plagioclase, biotite, muscovite, magnetite, apatite, and zircon, with some secondary chlorite and epidote derived from the biotite.

B. Granodiorite, Donner Pass. Contains plagioclase, orthoclase, quartz, hornblende, biotite, and sphene.

C. Gabbro, 2 miles south of Emigrant Gap, on road to Onion Valley, Contains biotite, hypersthene, diallage, plagioclase, and orthoclase.

D. Gabbro, same locality as the last. Contains hypersthene, diallage, plagioclase, and orthoclase.

E. Augite-granite, southeast spur of English Mountain. Contains "basic" plagioclase, augite, and quartz.

	A.	B.	C.	D.	E.
SiO ₂	73.00	59.48	55.40	55.87	64.67
TiO ₂ .....		.93	.60	.56	.51
Al ₂ O ₃	16.38	17.25	15.32	13.52	16.62
Fe ₂ O ₃	None.	2.15	2.70	2.70	.51
FeO.....	.99	4.06	5.49	5.89	.76
MnO .....		.11	.11	.10	Trace.
CaO	2.42	6.50	9.90	8.87	9.50
SrO		Trace.	None.	None.	Trace.
BaO .....		.09	.07	.02	.02
MgO .....	.48	2.67	5.75	6.51	2.26
K ₂ O	1.87	2.27	1.52	1.72	.34
Na ₂ O	4.53	3.53	2.89	2.42	4.10
Li ₂ O		Trace.	Trace.	Trace.	Trace.
H ₂ O at 100° .....	.52	.09	.03	.09	.08
H ₂ O above 100° .....		.71	.38	1.56	.37
P ₂ O ₅ .....		.33	.22	.25	.12
	100.19	100.17	100.38	100.08	99.86

8. ELDORADO COUNTY.

A. Granitite, Placerville Canal, one-third mile north of Ditch Camp No. 7. Collected by W. Lindgren, who reports it as containing biotite, orthoclase, plagioclase, and quartz. Analysis by George Steiger, record No. 1591.

B. Granodiorite, 2 miles south of Silver Lake Hotel. Collected by Lindgren, who reports it as containing hornblende, biotite, plagioclase, and quartz. Analysis by Steiger, No. 1591. Analyses A and B are published by Lindgren in Amer. Journ. Sci., 4th ser., vol. 3, p. 306.

C. Porphyrite, 1 mile southwest of Latrobe. Published by Turner in 17th Ann., Part I, p. 521. Contains abundant plagioclase, less augite, calcite or dolomite, iron disulphide, a little chlorite, and secondary greenish mica. Analysis by W. F. Hillebrand, record No. 1432.

	A.	B.	C.
SiO ₂	77.68	67.45	68.58
TiO ₂.....	.14	.58	.57
Al ₂ O ₃	11.81	15.51	13.04
Fe ₂ O ₃.....	.72	1.76	.26
FeO.....	.51	2.21	3.40
MnO.....	Trace.	.....	.15
CaO.....	.72	3.60	3.22
SrO.....	.....	.....	Trace.
BaO.....	.....	.....	.10
MgO.....	.18	1.10	1.01
K ₂ O.....	5.00	3.66	1.90
Na ₂ O.....	2.96	3.47	4.94
H ₂ O at 100°.....	.04	.14	.16
H ₂ O above 100°.....	.27	.63	1.00
P ₂ O ₅.....	.10	.12	.20
CO ₂.....	.....	.....	1.31
FeS ₂.....	.....	.....	.15
	100.13	100.23	99.99

9. AMADOR COUNTY.

Rocks collected by H. W. Turner, and analyses published in 14th Ann., p. 441, and 17th Ann., Part I, p. 521. Additional data supplied by Turner. Analyses by W. F. Hillebrand, record Nos. 1432, 1456, and 1597.

A. Rhyolite, south point of Buena Vista Peak. Contains sanidine, quartz, and biotite in a glassy groundmass.

B. Biotite-granite, north fork of Tuolumne River. Contains plagioclase, microcline, quartz, abundant biotite, iron ore, sphene, apatite, and perhaps rutile.

C. Biotite-granite, north fork of the Tuolumne River. Like B.

D. Quartz-porphyrite-schist, $2\frac{1}{2}$ miles southeast of Buena Vista Peak. Contains porphyritic quartz and hornblende; also calcite and other carbonates. See 14th Ann.

E. Quartz-diorite-gneiss, north fork of Tuolumne River. Contains plagioclase, hornblende, quartz, brown mica, accessory biotite, and iron oxide.

F. Diorite-porphry, north fork of Tuolumne River. Contains plagioclase, brown hornblende, epidote, and a little sulphide of iron and chlorite.

	A.	B.	C.	D.	E.	F.
SiO ₂	73.23	70.75	70.43	70.29	57.41	55.18
TiO ₂ .....	.09	.42	.24	.29	1.04	.83
Al ₂ O ₃	12.73	15.13	15.51	11.83	17.71	17.35
Fe ₂ O ₃ .....	.99	.98	.96	1.30	2.16	2.77
FeO .....	.16	1.43	1.28	2.08	5.01	3.90
NiO .....	.....	None.	?	.....	.02	.03
MnO	Trace.	Trace.	Trace.	.12	.15	.15
CaO .....	.61	3.09	2.76	2.30	6.73	7.98
SrO	None.	.04	.05	Trace?	.04	.06
BaO .....	.02	.12	.20	.07	.09	.04
MgO .....	.22	.73	.37	1.24	3.38	4.80
K ₂ O	5.17	3.62	5.14	3.05	1.82	1.42
Na ₂ O	1.91	3.05	2.75	2.68	3.12	3.42
Li ₂ O	Trace.	Trace.	Trace.	None.	Trace.	Trace.
H ₂ O at 100° .....	.53	.10	.08	.10	.20	.16
H ₂ O above 100°	4.51	.51	.40	1.35	1.14	1.52
P ₂ O ₅ .....	.02	.10	.11	.07	.24	.20
CO ₂ .....	.....	None.	None.	3.25	None.	None.
FeS ₂ .....	.....	.06	Trace.	.....	None.	.28
	100.19	100.13	100.28	100.02	100.26	100.09

G. Diorite, north fork of Tuolumne River. Contains quartz, feldspar, biotite, sphene, epidote, and secondary chlorite.

H. Diorite, north fork of Tuolumne River. Contains plagioclase, quartz, hornblende, biotite, apatite, iron ore, epidote, and chlorite.

I. Plagioclase-gneiss, north fork of Tuolumne River. Contains plagioclase, hornblende, biotite, and apatite.

J. Plagioclase-gneiss, north fork of Tuolumne River. Contains plagioclase, hornblende, brown mica, apatite, epidote, and grains of iron ore.

K. Wollastonite-gneiss, north fork of Tuolumne River. Mainly wollastonite, but garnet, quartz, and sphene are also present.

L. Melaphyr-tuff, altered basalt, west of Jackson. Contains augite and plagioclase, with secondary quartz, chlorite, and chrysotile. Originally glassy in part, but devitrified. See 14th Ann.

	G.	H.	I.	J.	K.	L.
SiO ₂	69.66	55.86	52.21	46.63	50.67	49.24
TiO ₂ .....	.21	1.20	1.16	1.82	.20	.96
Al ₂ O ₃	17.57	19.30	18.79	19.49	6.37	14.79
Fe ₂ O ₃ .....	.21	.91	2.71	3.26	.31	1.36
FeO	1.04	4.78	5.30	6.63	.50	8.00
NiO	None.	Trace.	Trace.	.02	None.	.....
MnO	Trace.	.16	.06	.21	Trace.	.18
CaO	4.54	7.31	8.01	9.15	40.34	10.74
SrO .....	.05	.04	}	.06	None.	Trace.
BaO .....	.03	.13		.14	None.	.04
MgO .....	.58	2.94	5.11	5.37	.58	6.89
K ₂ O .....	.71	1.52	1.60	1.55	.22	.88
Na ₂ O	4.91	3.52	3.31	3.19	.14	2.76
Li ₂ O	None.	Trace.	Trace.	Trace.	None.	Trace.
H ₂ O at 110° .....	.05	.19	.12	.10	.08	.20
H ₂ O above 110° .....	.50	1.23	1.35	1.61	.31	2.97
P ₂ O ₅ .....	.03	.38	.36	.66	None.	.17
CO ₂	None.	None.	None.	None.	.52	.90
FeS ₂	Trace?	.39	.06	.19	None.	.....
	100.09	99.86	100.23	100.08	100.24	100.08

10. CALAVERAS COUNTY.

Rocks collected by H. W. Turner, and described in 14th Ann., p. 441. Additional data supplied by Turner relative to analysis B. Analyses by W. F. Hillebrand, record No. 1432.

A. Granitoid quartz-porphyrity, $1\frac{3}{4}$ miles southeast of Milton. Contains quartz, feldspar, and hornblende.

B. Quartz-porphyrity, $1\frac{1}{2}$ miles northeast of Milton. Contains feldspar, quartz, epidote, chlorite, and iron ore, in a groundmass made up probably of feldspar and quartz.

C. Porphyryite, $1\frac{1}{2}$ miles northward from Jenny Lind. Contains quartz, plagioclase, epidote, and chlorite derived from augite.

	A.	B.	C.
SiO ₂	72.24	71.19	61.37
TiO ₂.....	.41	.35	.60
Al ₂ O ₃	13.84	13.81	15.41
Fe ₂ O ₃	1.45	1.45	3.15
FeO.....	1.86	1.68	3.89
MnO.....	.12	.07	.47
CaO.....	3.40	2.87	4.42
SrO.....	Trace.	Trace.	Trace.
BaO.....	.08	.16	.08
MgO.....	1.10	.74	3.48
K ₂ O.....	.39	1.82	.34
Na ₂ O.....	4.43	4.24	3.76
H ₂ O at 100°.....	.17	.15	.29
H ₂ O above 100°.....	.69	.92	2.70
P ₂ O ₅.....	.10	.08	.08
CO ₂.....	.....	.82	.....
	100.28	100.35	100.04

11. TUOLUMNE COUNTY.

Rocks collected by H. W. Turner, and partly described in his papers in the 14th and 17th Annuals. Additional data supplied by Turner.

A. Soda-syenite-porphry, dike east of Moccasin Creek. Consists mainly of albite, with a greenish mineral which is probably aegirite. Analysis by H. N. Stokes, record No. 1563.

B. Augite-syenite dike, Turnback Creek, about 1 mile north of Carter Post-office. Hitherto unpublished. Contains orthoclase and augite, with less plagioclase and quartz. Analysis by Stokes, No. 1642.

C. Trachyte-andesite-tuff, $1\frac{3}{4}$ miles southwest of Clover Meadow. Described in 17th Ann., Part I, p. 521. Contains glass, plagioclase, probably some sanidine, and biotite. Analysis by W. F. Hillebrand, record No. 1597.

D. Trachyte-andesite, from about 14 miles northeast of the Big Trees Hotel, near Clover Meadow. Hitherto unpublished. Examined petrographically by F. L. Ransome. Contains plagioclase, in part labradorite, augite, iron ore, some olivine, apatite, and brown glass. The potassium is probably in the glass, as no potash mineral was observed. Analysis by H. N. Stokes, record No. 1645.

	A.	B.	C.	D.
SiO ₂	67.53	61.28	62.33	59.43
TiO ₂.....	.07	.41	1.05	1.38
ZrO ₂.....			.04	.08
Al ₂ O ₃	18.57	14.71	17.31	16.68
Fe ₂ O ₃	1.13	1.21	3.00	2.54
FeO.....	.08	2.85	1.63	3.48
MnO.....	Trace.	Trace.	.08	Trace.
CaO.....	.55	5.61	3.23	4.09
SrO.....	Trace.	.04	.05	Trace.
BaO.....		.72	.24	.14
MgO.....	.24	1.69	1.05	1.84
K ₂ O.....	.10	7.70	4.46	5.04
Na ₂ O.....	11.50	2.99	4.21	3.72
Li ₂ O.....			Trace.	None.
H ₂ O at 110°.....	.15	.28	.44	.27
H ₂ O above 110°....	.31	.43	.75	.72
P ₂ O ₅.....	.11	.16	.29	.58
SO ₃	Trace.	.08		None.
F.....	Trace.			Trace.
Cl.....				.05
C.....			.11	
FeS ₂.....			.06	
	100.34	100.16	100.33	100.04

E. Diorite, dike $1\frac{1}{2}$ miles southeasterly from Sonora. Contains feldspar largely altered to hornblende. A few black grains are probably iron ore. Analysis by W. F. Hillebrand, record No. 1548.

F. Quartz-pyroxene-diorite, large area east of Sonora. Contains plagioclase, quartz, biotite, augite, rhombic pyroxene, and a trace of iron ore. Analysis by Hillebrand, No. 1548.

G. Diorite, dike about $1\frac{1}{2}$ miles southeasterly from Sonora. Contains altered plagioclase and hornblende, with epidote, chlorite, and iron disulphide as secondary products. Analysis by Hillebrand, No. 1548.

H. Basalt, Table Mountain. See 14th Ann. Contains plagioclase, olivine, augite, and magnetite. Analysis by Hillebrand, record No. 1273.

	E.	F.	G.	H.
SiO ₂	58.05	57.80	53.46	56.19
TiO ₂ .....	.72	.70	.70	.69
Al ₂ O ₃	15.46	16.43	14.81	16.76
Fe ₂ O ₃	1.69	1.62	2.60	3.05
FeO	5.09	6.51	5.15	4.18
MnO .....	.14	.18	.18	.10
NiO	None.	.03	.05	-----
CaO	6.94	7.21	8.44	6.53
SrO	Trace.	Trace?	Trace.	Trace.
BaO .....	.07	.09	.05	.19
MgO	4.84	4.14	7.27	3.79
K ₂ O	2.14	2.29	1.30	4.46
Na ₂ O	2.86	2.35	2.64	2.53
Li ₂ O	Trace.	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.10	.11	.12	.34
H ₂ O above 110°	2.02	.38	2.13	.66
P ₂ O ₅ .....	.16	.19	.16	.55
CO ₂	None.	None.	.44	-----
FeS ₂	None.	None.	.26	-----
	100.28	100.03	99.76	100.02

12. MARIPOSA COUNTY.

Rocks collected by H. W. Turner, and partly described in his papers in the 14th and 17th Annuals. Additional data supplied by Turner.

A. Soda-granulite or aplite, about 4 miles west of Mariposa. See 17th Ann., Part I, p. 721. Contains plagioclase (albite?) and micropegmatite, with less epidote, quartz, sphene, and apatite. Analyses by W. F. Hillebrand, record No. 1461.

B. Micropegmatite, Agua Fria Creek. See 17th Ann., Part I, p. 691. Contains quartz, plagioclase, brown mica, epidote, and a little iron ore. Analysis by Hillebrand, No. 1461.

C. Soda-granite-porphyry, Merced River, below the mouth of the north fork. Published in 17th Ann. Contains feldspar, largely albite, hornblende, muscovite, abundant epidote, apatite, and a little iron ore. Analysis by George Steiger, record No. 1573.

D. Granite-porphyry, about one-fourth of a mile north of Lake Tenaya, Yosemite National Park. See 14th and 17th Anns. Contains orthoclase, quartz, plagioclase, and biotite, with a little iron ore and sphene. Analysis by Hillebrand, record No. 1432.

E. Granite, west of Lake Tenaya, Yosemite National Park. See 14th and 17th Anns. Contains quartz, orthoclase, plagioclase, and biotite, with some hornblende, iron ore, sphene, and apatite. Analysis by Hillebrand, No. 1432.

	A.	B.	C.	D.	E.
SiO ₂	74.21	73.18	71.88	72.48	66.28
TiO ₂ .....	.30	.25	.17	.28	.54
Al ₂ O ₃	14.47	13.66	15.57	14.06	16.03
Fe ₂ O ₃ .....	.35	.21	1.07	.89	1.80
FeO .....	.50	2.24	.30	1.05	1.88
MnO	None.	.07	None.	Trace.	.05
CaO	1.71	2.10	2.03	2.17	3.75
SrO	Trace.	Trace.	.08	Trace.	Trace.
BaO	None.	.10	.02	.08	.08
MgO .....	.28	.93	.68	.62	1.12
K ₂ O .....	.10	2.72	1.80	4.75	3.49
Na ₂ O	7.62	3.70	5.81	3.30	4.10
Li ₂ O	Trace.	Trace.	None.	Trace.	Trace.
H ₂ O at 110° ....	.15	.10	.11	.16	.10
H ₂ O above 110° ..	.23	.57	.68	.35	.39
P ₂ O ₅ .....	.07	.09	.08	.09	.30
CO ₂ .....		.17	None.		
	99.99	100.09	100.28	100.28	99.91

F. Quartz-mica-diorite, Chowchilla River. See 17th Ann., Part I, p. 691. Contains plagioclase, quartz, a little orthoclase (?), brown mica, hornblende, rather abundant apatite, a little iron ore, and one zircon-like crystal was noted. Analysis by W. F. Hillebrand, record No. 1461.

G. Quartz-mica-diorite, Yaqui Creek. For the Educational Series of Rocks. Contains plagioclase, quartz, biotite, hornblende, a little pyroxene, iron ore, and apatite. Analysis by George Steiger, record No. 1643.

H. Diabase, dike $1\frac{1}{2}$ miles northeast of Hornitos. See 17th Ann., Part I, p. 694. Contains plagioclase, partly labradorite, augite, brown hornblende, and iron ore. Analysis by Hillebrand, No. 1461.

I. Igneous rock, near Cathay Hill. See 17th Ann., Part I, p. 694. Contains two minerals unidentified. Neither is olivine. Analysis by Hillebrand, No. 1461.

	F.	G.	H.	I.
SiO ₂	62.62	58.09	51.32	47.75
TiO ₂ .....	.55	.95	1.23	.37
Al ₂ O ₃	17.51	17.46	15.28	10.56
Cr ₂ O ₃ .....				.24
Fe ₂ O ₃ .....	.49	1.12	.47	.74
FeO	4.06	5.08	8.59	8.34
NiO .....				.07
MnO .....	.05	None.	.16	.10
CaO	5.49	6.24	11.58	9.62
SrO	Trace.	.04	Trace.	Trace.
BaO	Trace.	.07	None.	None.
MgO	2.84	4.06	7.25	19.09
K ₂ O	1.76	2.02	.22	.12
Na ₂ O	3.49	2.94	2.92	1.32
Li ₂ O	Trace.	None.	Trace.	Trace.
H ₂ O at 110° .....	.22	.29	.06	.05
H ₂ O above 110° .....	.92	1.45	.95	2.06
P ₂ O ₅ .....	.12	.17	.25	.03
CO ₂ .....		.21		
SO ₃ .....		.05		
Cl .....		.02		
F		Trace.		
C .....		.11		
	100.12	100.37	100.28	100.46

J. Feldspathic mica-schist, Chowchilla River. See 17th Ann., Part I, p. 691. Contains quartz, feldspar, biotite, muscovite, apatite, and specular iron. Analysis by W. F. Hillebrand, record No. 1461.

K. Andalusite-hornfels, Yaqui Gulch. For the Educational Series of Rocks. Principally quartz, andalusite, brown and white mica, black graphite-like grains, a little iron ore, and probably feldspar. Analysis by George Steiger, record No. 1643.

L. Andalusite-schist, Chowchilla River. See 17th Ann., Part I, p. 691. Contains quartz, biotite, andalusite, sericite, a little muscovite, probably graphite, iron ore, a few garnets and apparently chlorite. Analysis by Hillebrand, No. 1461.

M. Chiastolite-schist, Yaqui Gulch. Contains chiastolite, sillimanite, brown mica, sericite(?), probably graphite, and clear grains which appear to be quartz and feldspar. Analysis by Steiger, No. 1643.

N. Hornfels, Agua Fria Creek. See 17th Ann., Part I, p. 691. Contains quartz, brown mica, iron ore and plagioclase. Analysis by Hillebrand, No. 1461.

	J.	K.	L.	M.	N.
SiO ₂	70.40	65.10	64.28	62.15	68.27
TiO ₂ .....	.51	.72	.65	.80	.57
Al ₂ O ₃	14.70	17.77	17.28	19.34	14.03
Fe ₂ O ₃ .....	.65	1.95	1.10	4.23	.46
FeO	2.57	3.29	5.34	2.25	4.68
MnO .....	.08	None.	.09	Trace.	.04
CaO	1.63	1.38	1.19	1.50	3.89
SrO	Trace.	None.	Trace.	None.	Trace.
BaO .....	.09	None.	.10	.04	.08
MgO	1.47	1.43	2.57	1.88	2.23
K ₂ O	3.46	2.45	2.93	3.07	3.35
Na ₂ O	3.17	2.25	.91	1.60	2.29
Li ₂ O	Trace.	None.	Trace.	None.	Trace.
H ₂ O at 110° .....	.19	.47	.20	.19	.08
H ₂ O above 110° .....	.91	2.49	2.72	1.79	.98
P ₂ O ₅ .....	.05	.14	.27	.15	.21
SO ₃ .....		.03		.13	
Cl		Trace.		None.	
F .....		.12		.22	
C .....	.15	1.21	.43	1.12	
	100.03	100.80	100.06	100.55	100.16
Less O .....		.06		.10	
		100.74		100.45	

13. THE QUICKSILVER REGION.

Rocks described by Becker in Mon. 13. Analyses made by W. H. Melville in the San Francisco laboratory. With one exception, the serpentine from New Idria, all the rocks are from the districts north of San Francisco.

A. Pseudo-dabase from near Mount St. Helena. Contains augite, hornblende, oligoclase, albite, zoisite, ilmenite, leucoxene, and a little chlorite.

B. Pseudo-dabase from Sulphur Bank. Contains oligoclase, a little quartz, pyroxene, hornblende, ilmenite, sphene, serpentine, and chlorite.

C. Pseudo-diorite from Knoxville. Mainly actinolite, with a little white mica, chlorite, serpentine, sphene, rutile, and zircon.

D. Glaucophane-schist, Sulphur Bank. Mainly glaucophane and zoisite. Quartz, albite, muscovite, and sphene are also present.

	A.	B.	C.	D.
SiO ₂	49.08	51.28	50.44	49.68
TiO ₂	1.72	1.33	.....	1.31
Al ₂ O ₃	14.68	15.05	8.18	13.60
Cr ₂ O ₃ .....	.....	.....	.48	.....
Fe ₂ O ₃	1.95	2.42	1.06	1.86
FeO	9.63	8.01	6.29	8.61
MnO .....	.15	.25	.21	.04
NiO .....	.....	.10	.....	.....
CaO	10.09	7.08	11.55	10.97
MgO	6.69	6.07	17.63	6.26
K ₂ O .....	.20	.12	.50	.12
Na ₂ O	4.60	4.43	2.98	3.09
H ₂ O at 100° .....	.27	.39	.07	.....
H ₂ O above 100°	1.18	2.96	.92	3.84
P ₂ O ₅ .....	.23	.13	.....	.21
	100.47	99.62	100.31	99.59

E. Andesitic obsidian, Clear Lake. Shows grains of plagioclase, augite, and hypersthene. Sp. gr. 2.391.

F. Andesite (asperite), Clear Lake. Contains pyroxene, plagioclase, magnetite, and sometimes biotite. Pyroxene mostly rhombic. Sp. gr. 2.664.

G. Obsidian, from south of Borax Lake. Sp. gr. 2.390.

H. Basalt, south of Burns Valley. Rich in olivine, with a microlitic groundmass of plagioclase and augite. Sp. gr. 2.380.

I. Ordinary basalt from Knoxville.

	E.	F.	G.	H.	I.
SiO ₂	74.01	65.43	75.40	57.37	51.66
TiO ₂ .....	.24	.83	.....	.60	Trace.
Al ₂ O ₃	12.95	17.10	7.72	15.66	11.22
Cr ₂ O ₃ .....	.....	.....	.....	.....	.25
Fe ₂ O ₃ .....	.....	2.39	1.41	2.06	} 7.62
FeO	1.42	1.19	.....	4.46	
MnO	Trace.	.70	.12	.27	.12
NiO .....	.....	.2	.....	.41	.....
CaO .....	.99	3.88	1.55	4.94	7.72
MgO .....	.48	1.48	1.26	8.84	13.61
K ₂ O	4.65	2.83	4.52	1.51	.89
Na ₂ O	5.34	3.66	8.09	3.05	5.98
H ₂ O at 100° .....	.....	.20	} .43	.61	} 1.06
H ₂ O above 100° .....	.29	.36		.12	
P ₂ O ₅ .....	.01	Trace.	.....	.02	.....
Cl .....	.07	.....	.12	.....	.....
	100.45	100.25	100.62	99.92	100.13

J. Light-green, marmolitic serpentine, New Idria.

K. Black serpentine, Sulphur Bank.

L. Light-green serpentine, Sulphur Bank.

	J.	K.	L.
SiO ₂	41.54	39.64	41.86
Al ₂ O ₃	2.48	1.30	.69
Cr ₂ O ₃ .....	.....	.29	.24
FeO	1.37	7.76	4.15
MnO .....	.....	.12	.20
NiO .....	.04	.33	Trace.
MgO	40.42	37.13	38.63
H ₂ O	14.18	13.81	14.16
	100.03	100.38	99.93

14. ROCKS OF MOUNT DIABLO.

Described by Turner and Melville in Bull. Geol. Soc. Amer., vol. 2, pp. 383-414. Analyses by W. H. Melville. Those with record numbers were made in the Washington laboratory; the others were made in the laboratory at San Francisco.

A. Diabase, Mitchell Canyon. Composed of augite, plagioclase, and ilmenite, with uralite and chlorite secondary.

B. The same rock, partly altered and partly uraltic. Called "diabase-diorite" by Turner.

C. Pyroxenite. Composed of bronzite and diallage. Equivalent to the websterite of North Carolina. From near Bagley Creek.

D. Glaucoaphane-schist, containing numerous cinnamon garnets. From Pine Canyon.

A, B, C have the record No. 1247.

	A.	B.	C.	D.
SiO ₂	52.06	51.58	53.25	47.84
TiO ₂ .....	.47	1.05	.....	.....
Al ₂ O ₃	14.34	14.99	2.80	16.88
Cr ₂ O ₃ .....	.....	.....	.54	.....
Fe ₂ O ₃	2.11	2.04	.69	4.99
FeO	7.74	8.36	5.93	5.56
NiO .....	.....	.....	.07	.....
MnO	Trace.	Trace.	.09	.56
CaO	8.05	8.59	16.22	11.15
MgO	9.26	6.51	19.91	7.89
K ₂ O .....	.73	.31	Trace.	.46
Na ₂ O	1.74	3.08	.19	3.20
H ₂ O at 105° .....	.59	.34	.05	.17
H ₂ O above 105°	2.90	2.67	.24	1.81
P ₂ O ₅ .....	.13	.24	.....	.14
	100.12	99.76	99.98	100.65

E. Crystalline gabbro from Bagley Creek. Contains plagioclase and diallage. No. 1166.

F. Shaly gabbro. Friable, containing carbonates and sulphates. Somewhat resembles serpentine.

G. Shaly gabbro, like F, much resembling a true serpentine.

According to Turner, F and G are merely weathered layers of the gabbro.

	E.	F.	G.
SiO ₂	47.49	45.43	45.69
Al ₂ O ₃	15.81	12.55	13.30
Fe ₂ O ₃	1.07	.....	1.85
FeO	4.50	6.50	4.72
NiO .....	.06	.....	.....
MnO .....	.41	.21	.24
CaO	15.53	12.39	13.50
MgO	10.39	13.41	13.06
K ₂ O	Trace.	.11	Trace.
Na ₂ O	1.16	1.71	1.36
H ₂ O at 105°	1.20	2.41	2.29
H ₂ O above 105°	1.83	2.74	2.47
P ₂ O ₅	Trace.	.04	.06
CO ₂ .....	.....	2.35	1.89
SO ₃ .....	.....	.24	.43
Organic matter .....	.....	Trace.	.....
	99.45	100.09	100.86

The following analyses are of serpentines, derived from a peridotite-pyroxenite dike:

H. Almost black. Possibly derived from adjacent shale.

I. Almost black. Derived from pyroxenite.

J. Bastite. Derived from pyroxenite. No. 1166.

K. Friable serpentine.

L. Serpentine.

M. Talc-like, yellowish-green serpentine.

N. Weathered serpentine.

O. Olive colored, probably serpentine.

Samples H, I, J are from near Bagley Creek. K, L, M, N from near Arroyo del Cerro. O from Ferguson ravine. M and O carry considerable chromite.

	H.	I.	J.	K.
SiO ₂	38.53	40.50	36.57	36.96
Al ₂ O ₃	14.55	.78	.95	.39
Cr ₂ O ₃	Trace.	.41	.33	.78
Fe ₂ O ₃	2.65	4.01	7.29	5.00
FeO.....	4.01	2.04	.37	2.34
NiO.....	Trace.	.11	.31	Trace.
MnO.....	.32	.13	.10	.09
CaO.....	3.13	.39	.14	3.81
MgO.....	21.79	37.43	40.27	33.84
K ₂ O.....	.88	.16	Trace.	.14
Na ₂ O.....	.07	.28	.31	.34
H ₂ O at 100°.....	4.51	2.81	.94	2.16
H ₂ O above 100° ..	9.56	10.94	12.43	14.02
P ₂ O ₅	Trace.	Trace.	.....	.02
	100.00	99.99	100.01	99.89

Accidental organic matter was deducted from Analyses H and I, with subsequent recalculation of the data to 100 per cent.

	L.	M.	N.	O.
SiO ₂	34.84	32.27	41.52	30.98
Al ₂ O ₃.....	.42	11.45	1.57	1.04
Cr ₂ O ₃.....	.68	5.19	.....	.34
Fe ₂ O ₃	6.08	Trace.	3.50	4.88
FeO.....	1.85	5.05	1.07	2.01
NiO.....	Trace.	.19	.....	.....
MnO.....	.01	Trace.	.29	.42
CaO.....	7.02	.41	.44	.22
MgO.....	30.74	33.30	36.84	38.44
K ₂ O.....	.07	Trace.	.....	.16
Na ₂ O.....	.42	Trace.	.....	.40
H ₂ O at 100°.....	1.67	.44	3.32	.39
H ₂ O above 100°...	15.72	12.40	12.51	20.43
P ₂ O ₅.....	.04	Trace.	.....	Trace.
SO ₃.....	.....	.....	.....	.44
	99.56	100.70	101.06	100.15

15. MISCELLANEOUS ROCKS.

A. Rhyolitic obsidian, Medicine Lake, Modoc County. Collected by J. S. Diller, who reports it to be a banded obsidian, containing a few minute feldspar crystals. The banding is due to a multitude of trichites. Analysis by L. G. Eakins, record No. 1072.

B. Tuff from Hyampom, south fork of Trinity River, Trinity County. Almost wholly made up of particles of clear glass. Collected and described by Diller. Analysis by George Steiger, record No. 1427.

C. Diabase-porphyrity, one-half mile west of Browns Valley, Yuba County. Collected and described by W. Lindgren. Contains augite, plagioclase, magnetite, chlorite, and epidote. Analysis by W. F. Hillebrand, record No. 1419.

D. Amphibolitic schist, 1 mile northeast of Browns Valley, Yuba County. Collected and described by W. Lindgren. From metamorphism of C. Contains chiefly green hornblende and feldspar. Analysis by Hillebrand, No. 1419.

	A.	B.	C.	D.
SiO ₂	73.51	70.40	48.26	54.13
TiO ₂.....			.51	.46
Al ₂ O ₃	14.42	13.50	14.83	14.53
Fe ₂ O ₃.....	.46	1.31	3.27	1.50
FeO.....	1.49	1.61	5.97	5.25
MnO.....	Trace.	Trace.	.15	.15
CaO.....	1.26	.56	11.38	4.91
SrO.....			Trace.	Trace.
BaO.....			.05	.02
MgO.....	.33	.37	8.77	10.93
K ₂ O.....	4.29	2.39	1.13	.32
Na ₂ O.....	4.03	2.11	1.57	3.53
Li ₂ O.....			Trace.	None.
H ₂ O at 100°.....	.40	1.05	.10	.20
H ₂ O above 100°.....		7.41	3.37	4.01
P ₂ O ₅.....	.04	.08	.25	.09
CO ₂			1.24	
	100.23	100.79	100.85	100.03

E. Scoriaceous rhyolite, Mono Craters, south of Mono Lake. Described by Russell in 8th Ann., Part I, p. 380. Analysis by T. M. Chatard, record No. 36.

F. Obsidian, Mono Lake. Collected for the Educational Series of Rocks. Analysis by W. H. Melville, record No. 1346.

G. Pumice, Mono Lake. Educational Series. Analysis by Melville, No. 1346.

H. Volcanic ash, east shore of Owens Lake. Collected and analyzed by Chatard, record No. 783.

	E.	F.	G.	H.
SiO ₂	74.05	75.78	67.39	55.81
TiO ₂ .....				.80
Al ₂ O ₃	13.85	12.39	15.99	10.07
Fe ₂ O ₃	Trace.	.22	.56	3.43
FeO		1.25	1.99	.67
MnO .....				.23
CaO .....	.90	.81	1.63	1.05
MgO .....	.07	.31	.77	2.22
K ₂ O	4.31	4.64	4.80	2.98
Na ₂ O	4.60	4.00	4.74	.75
H ₂ O at 110°	2.20	.41	2.06	.65
H ₂ O above 110° ..				2.50
P ₂ O ₅ .....				.27
CaCO ₃				14.44
NaCl, soluble				1.45
Na ₂ SO ₄ , soluble...				.80
Na ₂ CO ₃ , soluble ..				2.09
	99.98	99.81	99.93	100.21

OREGON.

1. BASALT, MOUNT THIELSON.

Partly described by Diller in Am. Journ. Sci., 3d series, vol. 28, p. 257. A hypersthene-basalt containing hypersthene, olivine, feldspar, and magnetite. In the printed paper only the analyses of the groundmass and the fulgurite formed in it are given.

A. Hypersthene-basalt.

B. Pyroxene.

C, D. Feldspars.

E. Groundmass.

F. A fulgurite, or lightning tube.

Analyses A, F, by F. W. Clarke, record Nos. 108, 105. B, C, D, E, by T. M. Chatard, record Nos. 135, 133, 134, 128. These analyses were made early in the history of the laboratory and are by no means complete.

	A.	B.	C.	D.	E.	F.
SiO ₂	55.68	53.31	55.48	51.95	55.85	55.04
TiO ₂ .....			.39	Trace.		
Al ₂ O ₃	18.93	5.99	26.91	28.84	22.95	
Fe ₂ O ₃	8.73	13.43	2.32	2.24	4.59	28.99
FeO						
CaO	7.99	3.69	8.11	11.42	8.41	7.86
MgO	4.86	21.69	2.27	1.34	3.08	5.85
K ₂ O .....	.48		.72	.59	2.67	
Na ₂ O	2.12		3.14	3.22	2.16	
H ₂ O .....	.60		.66	.40	.52	1.11
P ₂ O ₅					Trace.	
	99.39	98.11	100.00	100.00	100.23	98.85

Iron oxides not separated. Analyses B, C, D, F made on very small quantities of material. C and D were analyzed by the hydrofluoric-acid method, and the silica was determined by difference.

2. PERIDOTITE FROM DOUGLAS COUNTY.

The matrix of the nickel silicate at Riddle. Described by Diller and Clarke in Bull. 60, p. 21.

The rock, which may be classed as saxonite, consists essentially of olivine and enstatite, with a little chromite and magnetite. Olivine predominates, and the enstatite forms less than one third of the mass. Quartz, serpentine, and genthite are present as alteration products. Analyses by F. W. Clarke, record Nos. 811, 814, 792.

A. The fresh rock.

B. Separated olivine.

C. The genthite found in the altered rock. Probably derived from olivine.

	A.	B.	C.
SiO ₂	41.43	42.81	44.73
Cr ₂ O ₃.....	.76	.79	.....
Al ₂ O ₃.....	.04	.....	} 1.18
Fe ₂ O ₃	2.52	2.61	
FeO.....	6.25	7.20	.....
MnO.....	None.	None.	.....
NiO.....	.10	.26	27.57
CaO.....	.55	None.	.....
MgO.....	43.74	45.12	10.56
H ₂ O at 110°.....	.....	.....	8.87
H ₂ O ign.....	4.41	.57	6.99
	99.80	99.36	99.90

3. BASALT, NEAR CRATER LAKE.

Collected by J. S. Diller, 1 mile east of the summit of the Cascade Range, on the road from Fort Klamath to Crater Lake. A typical basalt, containing a considerable amount of hypersthene. Analysis by W. F. Hillebrand, record No. 408.

SiO ₂	57.47	BaO.....	.03
TiO ₂.....	.75	MgO.....	4.27
Al ₂ O ₃	18.86	K ₂ O.....	.73
Fe ₂ O ₃	2.21	Na ₂ O.....	3.85
FeO.....	4.08	H ₂ O.....	.22
MnO.....	.10	P ₂ O ₅.....	.24
CaO.....	7.42		
SrO.....	.11		100.34

ALASKA.

Rocks A to H inclusive, collected by G. F. Becker, who furnishes the petrographic data. Analyses by W. F. Hillebrand, record No. 1585.

A. Augite-bronzite-andesite, Delarof Harbor, Unga Island. Greenish black. Contains plagioclase, near labradorite, with much smaller proportion of augite and bronzite, in a groundmass of plagioclase, with a little glass and much light-green indeterminate material.

B. Augite-bronzite-andesite, St. Augustine Volcano, Cooks Inlet. Purplish gray. Contains labradorite, augite, and bronzite, in a groundmass of plagioclase and magnetite.

C. Quartz-porphyry, bed of Bear Creek, 4 miles from its mouth, Turnagain arm of Cooks Inlet. Resembles D, with more feldspar and less quartz.

D. Quartz-porphyry, east of mouth of Indian River, Sitka, Baranof Island. Contains plagioclase, quartz, a little pyroxene, and some carbonaceous matter, with secondary quartz, calcite, and muscovite.

E. Diorite, head of Captains Bay, Unalaska Island. Contains plagioclase, biotite, hornblende, chlorite, magnetite, and sometimes tourmaline.

	A.	B.	C.	D.	E.
SiO ₂	56.63	60.40	62.92	65.94	58.63
TiO ₂ .....	.67	.61	.84	.80	.74
Al ₂ O ₃	16.85	16.89	14.29	13.74	16.23
Fe ₂ O ₃	3.62	1.88	.84	.49	1.91
FeO	3.44	3.72	4.66	5.21	4.20
NiO	Trace?	.02	Trace.	Trace?	.02
MnO .....	.23	.12	.15	.11	.11
CaO	7.53	7.25	2.72	2.87	6.59
SrO	Trace.	Trace.	Trace.	Trace?	Trace.
BaO .....	.09	.06	.10	.12	.06
MgO	4.23	3.82	3.14	2.33	4.28
K ₂ O	2.24	.77	1.39	1.63	2.09
Na ₂ O	3.08	3.80	4.30	2.80	3.51
Li ₂ O	Trace.	Trace.	Trace.	Trace.	Trace.
H ₂ O at 110° .....	.80	.09	.22	.21	.15
H ₂ O above 110° .....	.51	.20	2.84	2.59	1.17
P ₂ O ₅ .....	.16	.16	.13	.21	.20
CO ₂	None.	None.	1.24	.59	None.
C .....				.20	
FeS ₂ .....	.06	.08	.32	.41	.04
	100.14	99.87	100.10	100.25	99.93

F. Diorite, Karluk Cliffs, Kadiak Island. Contains labradorite and hornblende, with subordinate quartz, biotite, and magnetite.

G. Diorite, Lane and Hayward mine, Silver Bow Basin. Contains plagioclase, biotite, hornblende, and scattering grains of quartz, with secondary chlorite, epidote, and muscovite.

H. Diorite, Treadwell mine, Douglas Island. Contains plagioclase, mostly albite, with secondary quartz, calcite, and pyrite; the latter apparently replacing ferromagnesian silicates.

I. Hornblende-andesite, Boguslof Island. Described by Merrill in Proc. U. S. National Museum, vol. 8, p. 31. Contains hornblende, augite, plagioclase, tridymite, grains of iron ore, a little apatite, and probably sanidine.

J. Like I, but darker colored. Contains more hornblende, no glass, and little or no tridymite. Same locality, also described by Merrill. Analyses I and J, by T. M. Chatard, record Nos. 209, 210.

	F.	G.	H.	I.	J.
SiO ₃	61.58	54.20	63.01	56.07	51.54
TiO ₂.....	.63	1.35	.13	1.24	.32
Al ₂ O ₃	15.89	15.86	18.48	19.06	20.31
Fe ₂ O ₃	2.19	3.32	.06	5.39	4.64
FeO.....	5.50	4.14	.32	.92	3.56
NiO.....	Trace?	.02	None.	.....	.....
MnO.....	.20	.19	.06	.23	.32
CaO.....	6.49	5.32	2.66	7.70	9.55
SrO.....	Trace?	.04	Trace.	.....	.....
BaO.....	.06	.41	.02	.....	.....
MgO.....	2.69	3.51	.06	2.12	3.16
K ₂ O.....	.51	3.30	.39	1.24	2.47
Na ₂ O.....	3.04	3.28	10.01	4.52	4.29
Li ₂ O.....	Trace.	Trace.	None.	.....	.....
H ₂ O at 110°.....	.16	.55	.05	.99	.34
H ₂ O above 110°.....	1.26	2.40	.27		
P ₂ O ₅.....	.12	.68	.06	.16	.57
CO ₂	None.	1.45	2.01	.....	.....
FeS ₂.....	.06	.26	2.10	.....	.....
	100.38	100.28	99.69	99.64	101.07

STONY METEORITES.

1. ROCKWOOD, TENNESSEE.

From the Crab Orchard Mountains, Cumberland County, Tenn., about $8\frac{1}{2}$ miles west of Rockwood. Analyzed by J. E. Whitfield, record No. 735, and described by him in Bull. 60, p. 103.

A. Analysis of the material as a whole.

B. Nickel iron separated. Forms not over 16 per cent of the mass.

C. Nodule from meteorite.

D. Portion of nodule, 94 per cent, insoluble in hydrochloric acid. May be enstatite.

The stony part of the meteorite appears to be mainly pyroxene and anorthite. Fe_2O_3 was not determined, and FeO represents the total iron oxide.

	A.	B.	C.	D.
SiO_3	41.92	.....	49.96	51.85
Al_2O_3	9.27	.....	4.75	4.52
FeO	22.94	.....	15.97	13.26
CaO	9.09	.....	1.15	1.09
MgO	8.76	.....	28.15	29.28
Fe	3.75	87.59	.....	.....
Ni	1.74	12.09	.....	.....
Co	Trace.	Trace.	.....	.....
Cu	Trace.	Trace.	.....	.....
P} .....	.65	.....	.....	.....
S	1.58	.....	.....	.....
Cl} .....	.18	.....	.....	.....
	99.88	99.68	99.98	100.00

2. HAMBLLEN COUNTY, TENNESSEE.

Mass of about half and half stone and iron found about 6 miles WSW. of Morristown. Analyzed by L. G. Eakins, and described in Bull. 113, p. 61.

A. The nickel iron.

B. The part of the stony portion soluble in hydrochloric acid; 37.63 per cent, recalculated to 100, with sulphur deducted.

C. Insoluble part of the stony portion; 62.10 per cent, recalculated to 100.

A petrographic description of this meteorite is given by Merrill in Amer. Journ. Sci., 4th series, vol. 2, p. 149, together with an analysis of the feldspar. He finds it to contain, in addition to the nickel iron, enstatite, diallage, anorthite, olivine or monticellite, oldhamite or secondary gypsum derived from oldhamite, lawrenceite, troilite, and schreibersite.

	A.		B.	C.
Fe	90.92	SiO ₂	45.61	50.67
Ni	7.71	Al ₂ O ₃	22.62	14.89
Co .....	.80	Cr ₂ O ₃		1.32
Cu	Trace.	FeO	11.73	10.55
P .....	.19	NiO	1.06	
S .....	.04	MnO .....		.76
	99.66	CaO	14.09	3.61
		MgO	3.64	17.98
		K ₂ O .....		.03
		Na ₂ O .....		.19
		P ₂ O ₅	1.25	
		S		
			100.00	100.00

3. WINNEBAGO COUNTY, IOWA.

Fell May 2, 1890. Sp. gr. 3.804, 28° 5. Analyzed by L. G. Eakins, record No. 1190, and described in Bull. 78, p. 95.

Composition of the mass.

Nickel iron	19.40
Troilite	6.19
Soluble silicates	36.04
Insoluble silicates	38.37
	100.00

Separate analyses:

A. The nickel-iron.

B. Silicate soluble in hydrochloric acid, calculated to 100 per cent.

C. Insoluble silicate, recalculated to 100 per cent. The Cr_2O_3 probably represents chromite.

	A.		B.	C.
Fe	92.65	SiO_2	39.74	55.51
Ni	6.11	Al_2O_3 .....	.....	5.43
Co .....	.65	Cr_2O_3 .....	.....	.25
P	Trace.	FeO	18.42	9.45
S	Trace.	NiO} .....	.38	.....
	99.41	MnO	Trace.	.....
		CaO} .....	.69	3.00
		MgO	40.77	24.09
		K_2O	Trace.	.15
		Na_2O	Trace.	2.12
		P_2O_5	Trace.	.....
			100.00	100.00

4. TANEY COUNTY, MISSOURI.

Analysis by J. E. Whitfield, record No. 736. See Bull. 60, p. 106. Sp. gr. 4.484.

A. The separated nickel-iron.

B. The stony portion as a whole.

C. Silicates soluble in hydrochloric acid, recalculated to 100 per cent.

D. Insoluble silicates, recalculated to 100 per cent.

	A.		B.	C.	D.
Fe	89.41	SiO_2	45.88	28.95	52.39
Ni	10.41	Al_2O_3	7.89	17.69	7.11
Co .....	.29	FeO	19.73	35.98	14.68
P .....	.16	CaO	6.02	15.98	4.49
	100.27	MgO	17.96	3.40	21.33
		NiS	1.67	.....	.....
		FeS} .....	.54	.....	.....
			99.69	100.00	100.00

5. WASHINGTON COUNTY, KANSAS.

Fell July 25, 1890. Analyzed by L. G. Eakins, record No. 1227, and described in Bull. 90, p. 45. Sp. gr. 3.49, $21^{\circ}.6$.

Composition of the mass.

Nickel-iron	7.7
Troilite	5.0
Soluble silicates	46.0
Insoluble silicates	41.5
	<hr/> 100.2

Separate analyses.

A. The nickel-iron.

B. Silicates soluble in hydrochloric acid, calculated to 100 per cent.

C. Insoluble silicates, calculated to 100 per cent.

	A.		B.	C.
Fe	86.76	SiO ₂	38.50	53.80
Ni	12.18	Al ₂ O ₃		4.32
Co .....	.83	Cr ₂ O ₃		1.41
	99.77	FeO	23.54	11.98
		NiO .....	.69	
		CoO	Trace.	
		MnO .....	.34	Trace.
		CaO .....	.12	4.08
		MgO	36.81	22.37
		K ₂ O .....		.27
		Na ₂ O		1.77
			100.00	100.00

6. KIOWA COUNTY, KANSAS.

A pallasite found in Brenham Township. Analyzed by L. G. Eakins, record No. 1188, and described in Bull. 78, p. 94.

A. The nickel-iron. Sp. gr. 7.93, $23^{\circ}.4$.

B. The pure olivine. Sp. gr. 3.376, $23^{\circ}.2$.

C. Dark outer zone of olivine, containing troilite.

	A.		B.	C.
Fe	88.49	SiO ₂	40.70	34.14
Ni	10.35	Al ₂ O ₃	Trace?	.....
Co .....	.57	Fe ₂ O ₃ .....	.18	.....
Cu .....	.03	FeO	10.79	23.20
P .....	.14	NiO .....	.02	Trace.
S .....	.08	CoO .....	.....	.03
Si	Trace?	MnO .....	.14	.09
C	Trace.	MgO	48.02	40.19
	99.66	S .....	.....	5.42
			99.85	103.07
		Less O=S .....	.....	2.71
				100.36

7. TRAVIS COUNTY, TEXAS.

Analyzed by L. G. Eakins, record No. 1097, and described in Bull. 78, p. 91. Sp. gr. 3.543, 20°. According to Cross, the stony portion contains olivine and enstatite, with a small amount of a colorless mineral, which is probably feldspar. Chromite is also present.

Approximate composition of the mass.

Nickel-iron	2.23
Troilite.....	5.03
Soluble silicates	39.84
Insoluble silicates	52.42
	<hr/> 99.52

A. Total analysis.

B. Nickel-iron.

C. Silicates soluble in hydrochloric acid, calculated to 100 per cent.

D. Insoluble silicates, calculated to 100 per cent.

	A.	B.	C.	D.
SiO ₂	44.75	.....	38.13	56.14
Al ₂ O ₃	2.72	.....	2.58	3.73
Cr ₂ O ₃.....	.52	.....	.....	1.00
CuO	Trace.	.....	.....	.....
FeO.....	16.04	.....	19.76	9.15
Fe	1.83	88.74	.....	.....
NiO .....	.52	.....	1.19	.....
Ni .....	.22	10.68	.....	.....
Co .....	.01	.58	.....	.....
MnO	Trace.	.....	.....	.....
CaO.....	2.23	.....	1.02	3.59
MgO	27.93	.....	37.32	24.44
K ₂ O .....	.13	.....	Undet.	.19
Na ₂ O.....	1.13	.....	Undet.	1.76
P ₂ O ₅ .....	.41	.....	.....	.....
S	1.83	.....	.....	.....
H ₂ O.....	.84	.....	.....	.....
	101.11	100.00	100.00	100.00
Less O = S .....	.92			
	100.19			

8. BLUFF, FAYETTE COUNTY, TEXAS.

Analyzed by J. E. Whitfield, record No. 824, and described in Bull. 60, p. 107. Sp. gr. 3.510. Examined microscopically by G. P. Merrill, who reports, in addition to nickel-iron and pyrrhotite, olivine, enstatite, and what appears to be augite or an allied pyroxene. See Amer. Journ. Sci., 3d series, vol. 36, August, 1888.

A. Total analysis.

B. Nickel-iron (5.67 per cent of total).

C. Part soluble in hydrochloric acid, calculated to 100 per cent (60.62 per cent of total).

D. Insoluble part, calculated to 100 per cent (33.3 per cent of total).

	A.	B.	C.	D.
SiO ₂	37.70	.....	33.59	49.64
Al ₂ O ₃	2.17	.....	1.34	4.12
FeO.....	23.82	.....	31.12	15.56
Fe.....	4.41	82.42	.....	.....
NiO.....	1.59	.....	2.66	Trace.
Ni.....	.88	15.44	.....	.....
CoO.....	.16	.....	.27	Trace.
Co.....	.37	2.14	.....	.....
MnO.....	.45	.....	.43	.54
CaO.....	2.20	.....	1.00	4.93
MgO.....	25.94	.....	28.08	25.21
P ₂ O ₅.....	.25	.....	.42	.....
S.....	1.30	.....	2.18	.....
	101.24	100.00	101.09	100.00
Less O=S.....	.65	.....	1.09	
	100.59	.....	100.00	

This meteorite also contained a dark vein of sp. gr. 3.585, which carried 2.30 per cent of metallic iron. Analyses, made on less than 0.4 gram of material, gave as follows, recalculated to 100 per cent:

- E. Soluble in hydrochloric acid, metal deducted.
- F. Insoluble.

	E.	F.
SiO ₂	27.63	56.52
Al ₂ O ₃	2.41	1.51
FeO	34.31	12.35
NiO + CoO	3.27	4.09
CaO	Trace.	Trace.
MgO	32.12	25.53
S .....	.52	.....
	100.26	100.00
Less O=S .....	.26	
	100.00	

E represents 51 and F 44 per cent of the vein.

9. SAN BERNARDINO COUNTY, CALIFORNIA.

Found in the San Emigdio Mountains. Analyzed by J. E. Whitfield, record Nos. 804 and 936, and described in Bull. 60, p. 114. In fragments, badly altered.

Approximate composition.

Nickel-iron	6.21
Soluble silicates, etc	51.26
Insoluble silicates	42.23
	<hr/> 99.70

The soluble part was probably olivine and pyrrhotite, with secondary iron oxide. The insoluble part was enstatite, essentially.

- A. The nickel-iron.
- B. The enstatite.

	A.		B.
Fe	88.25	SiO ₂	54.42
Ni	11.27	FeO	14.03
Co .....	.48	CaQ	2.46
	100.00	MgO	29.11
			100.02

10. BEAVER CREEK, BRITISH COLUMBIA.

Fell May 26, 1893, near Beaver Creek, West Kootenai district. Described by Howell, Hillebrand, and Merrill in Amer. Journ. Sci., 3d series, vol. 47, p. 430.

Composition of the mass.

Nickel-iron	17.13
Magnetite .....	.16
Troilite	5.05
Soluble silicates and phosphate	37.23
Insoluble silicates and chromite	40.43
	<hr/> 100.00

According to Merrill, the silicates visible are olivine, enstatite, probably a little plagioclase, and some glassy base.

Analyses by W. F. Hillebrand, record No. 1444.

A. Nickel-iron.

B. Nonmagnetic, stony portion.

C. Portion of B soluble in hydrochloric acid, calculated to 100 per cent.

D. Insoluble portion, calculated to 100 per cent. From C and D troilite and chromite are excluded. The chromite forms about 0.75 per cent of the stony matter.

	A.		B.	C.	D.
Fe	90.68	SiO ₂	45.87	38.26	57.75
Ni	8.80	TiO ₂ .....	.09	.....	.18
Co .....	.49	Al ₂ O ₃	2.30	.56	4.89
Cu .....	.03	Cr ₂ O ₃ .....	.51	.....	.....
	100.00	FeO	12.68	19.52	8.02
		Fe	3.87	.....	.....
		NiO .....	.07	.09	Trace.
		MnO .....	.26	.27	.35
		CaO	1.96	1.03	3.44
		MgO	28.24	38.74	23.19
		K ₂ O .....	.15	.02	.25
		Na ₂ O .....	.98	.13	1.87
		H ₂ O .....	.34	.70	.06
		P ₂ O ₅ .....	.30	.68	.....
		S	2.21	.....	.....
		Cl	Trace.	Trace.	.....
			99.83	100.00	100.00
		Troilite	6.08		
		Chromite .....	.75		

11. LLANO DEL INCA, CHILI.

Analyzed by L. G. Eakins, record No. 1201, and described in Bull. 78, p. 97.

Approximate composition.

Nickel-iron	25.8
Troilite	10.6
Soluble silicates	30.9
Insoluble silicates	32.6
	<hr/> 99.9

Separate analyses.

A. The nickel-iron.

B. Silicates soluble in hydrochloric acid, calculated to 100 per cent.

C. Insoluble silicates, calculated to 100 per cent.

Is the P_2O_5 in B derived from schreibersite?

	A.		B.	C.
Fe	89.77	SiO ₂	28.08	53.11
Ni	9.17	Al ₂ O ₃	12.74	2.32
Co .....	.61	Cr ₂ O ₃ .....		.90
	99.55	FeO	42.52	18.82
		NiO	2.90	.....
		MnO .....	.20	.....
		CaO	9.33	1.75
		MgO	1.98	23.10
		P ₂ O ₅	2.25	.....
			100.00	100.00

METEORIC IRON.

A. The Mount. Joy meteorite. From near Two Taverns post-office, near Gettysburg, Pa. Analysis by L. G. Eakins, record No. 1318.

B. From Pulaski County, Va. Sp. gr. 7.95, 23°. Analysis by Eakins, No. 1228. Described by Eakins in Bull. 90, p. 45.

C. From Ellenboro, Rutherford County, N. C. Described and analyzed by Eakins, Bull. 78, p. 93. Record No. 1160.

D. From Linnville Mountain, North Carolina. Analyzed by J. E. Whitfield, record No. 822, and described in Bull. 60, p. 107. Sp. gr. 7.778.

E. From Cherokee County, Ga. Analysis by H. N. Stokes, record No. 1527.

	A.	B.	C.	D.	E.
Fe	93.80	93.59	88.05	84.56	91.96
Ni	4.81	5.56	10.37	14.95	6.70
Co .....	.51	.53	.68	.33	.50
Cu .....	.005	Trace.	.04	.....	.03
P .....	.19	.27	.21	Trace.	.11
S .....	.01	.01	.08	.12	.01
Si .....	.....	Trace.	.02	None.	Trace.
C .....	.....	.....	.....	Trace.	Trace?
	90.325	99.96	99.45	99.96	99.31

F. From near Holland's Store, Chattooga County, Ga. Analysis by J. E. Whitfield, record No. 765. See Bull. 60, p. 106. Sp. gr. 7.801.

G. From Hamilton County, Tex. Sp. gr. 7.95, 27°. Analysis by L. G. Eakins, record No. 1189. See Bull. 78, p. 95.

H. From near Scottsville, Allen County, Ky. Analysis by Whitfield, record No. 509. See Bull. 55, p. 64.

I. Fell 6 miles east of Cabin Creek, Johnson County, Ark., March 27, 1886. Analysis by Whitfield, record No. 505. See Bull. 55, p. 63.

J. From near Grand Rapids, Mich. Sp. gr. 7.87. Analysis by R. B. Riggs, record No. 296. See Bull. 42, p. 94.

	F.	G.	H.	I.	J.
Fe	94.60	86.54	94.32	91.87	88.71
Ni	4.97	12.77	5.01	6.60	10.69
Co .....	.21	.63	Trace.	Trace.	.....
Cu .....	.....	.02	.....	.....	.07
Mg .....	.....	.....	.....	.....	.02
Mn .....	.....	.....	.....	Trace.	.....
P .....	.21	.16	.16	.41	.26
S	Trace.	.03	.34	.05	.03
Si .....	.....	.....	None.	.....	.....
C	Trace.	.11	.12	.15	.13
Insoluble .....	.....	.....	.....	.34	.....
	99.99	100.26	99.95	99.42	99.91

K. The El Capitan iron, from near Bonito, N. Mex. Analysis by H. N. Stokes, record No. 1527.

L. From La Bella Roca, Sierra de San Francisco, Mexico, State of Durango. Analysis by J. E. Whitfield, record No. 1037. Bull. 64, p. 28.

M. Troilite nodule from L, outer part, somewhat altered.

N. Troilite nodule M, inner part. Analyses L and M also by Whitfield, record No. 1037.

O. From Puquios, Chile. Sp. gr. 7.93, 25°2. Analysis by L. G. Eakins, record No. 1181. See Bull. 78, p. 95.

P. The Abert iron, of unknown origin. Analysis by R. B. Riggs, record No. 356. Sp. gr. 7.89. See Bull. 42, p. 94.

	K.	L.	M.	N.	O.	P.
Fe	90.51	91.48	.....	9.37	88.67	92.07
Ni	8.40	7.92	.....	.....	9.83	7.01
Co .....	.60	.22	.....	.....	.71	.66
Cu .....	.05	.....	.....	.....	.04	.....
P .....	.24	.21	.....	.....	.17	.08
S	Trace.	.21	.....	.....	.09	.01
Si .....	.....	.....	.....	.....	Trace?	.....
C .....	.....	.06	.....	.....	.04	.05
NiS .....	.....	.....	2.07	2.13	.....	.....
FeS .....	.....	.....	37.51	85.27	.....	.....
Fe ₃ O ₃ .....	.....	.....	37.80	.....	.....	.....
Moisture .....	.....	.....	19.85	.....	.....	.....
	99.80	100.10	97.23	96.77	99.55	99.88

The two following meteoric irons were analyzed by L. G. Eakins in the Denver laboratory.

A. Found near Albuquerque, N. Mex. Described by Eakins in Proc. Colorado Sci. Soc., vol. 2, p. 14.

B. From Wyoming. Partial analysis.

	A.	B.
Fe	88.76	89.26
Ni	9.86	5.94
Co .....	.51	.78
Cu .....	.034	.....
Zn .....	.03	.....
Mn	Trace.	.....
P .....	.182	.24
S .....	.012	.....
Si .....	.044	.....
C	Undet.	.....
	99.432	96.22

SANDSTONES AND CHERTS.

SANDSTONES FROM OHIO.

A. Blue sandstone from near Cleveland. Analysis by T. M. Chatard, record No. 214.

B. Sandstone from Berea. Analysis by L. G. Eakins, record No. 914.

C, D, E. Three samples of the "Pebbles-Henley sandstone," from Portsmouth. Analyses by H. N. Stokes, record No. 1239. Alkalies, etc., undetermined.

	A.	B.	C.	D.	E.
SiO ₂	91.67	92.91	90.40	89.32	87.12
Al ₂ O ₃	6.92	3.78	5.15	5.52	5.96
Fe ₂ O ₃	Trace.	Trace.	.65	.87	.85
FeO.....	.....	.91	.27	.35	.85
CaO.....	.28	.31	.....	.....	.....
MgO.....	.34	Trace.	.28	.51	.73
K ₂ O.....	.....	.61	.....	.....	.....
Na ₂ O.....	.....	.34	.....	.....	.....
H ₂ O.....	1.17	1.19	.99	1.49	2.00
	100.38	100.05	97.74	98.06	97.51
Insol. in HCl ...	97.50	.....	98.00	96.90	95.52

SANDSTONES FROM CALIFORNIA.

1. SANDSTONES FROM MOUNT DIABLO.

Described by Turner and Melville in Bull. Geol. Soc. Amer., vol. 2, pp. 383-414. Analyses made by W. H. Melville in the San Francisco laboratory.

A. Upper Cretaceous, Chico sandstone. Light brown, finely granular, carrying grains of mica and feldspar.

B. Lower Cretaceous, Neocomian sandstone. Hard, granular, greenish. From headwaters of Bagley Creek.

C. Miocene sandstone. Granular, particles light brown and black, friable. From near Wall Point.

D. Chico sandstone. Greenish gray, compact, crystalline.

	A.	B.	C.	D.
SiO ₂	73.71	56.84	44.54	36.93
Al ₂ O ₃	10.40	11.37	12.63	7.22
Fe ₂ O ₃	3.89	1.46	2.50	1.59
FeO	1.88	4.95	3.08	2.95
MnO .....	.17	.22	.44	.57
CaO .....	.96	7.62	14.65	29.34
MgO	1.62	3.10	5.55	2.34
K ₂ O .....	.99	.86	1.37	.64
Na ₂ O	3.48	3.26	3.35	2.94
H ₂ O at 100°	1.06	1.45	1.43	.57
H ₂ O above 100° ...	2.60	3.34	2.25	3.45
P ₂ O ₅	None.	.10	.29	.16
CO ₂	None.	5.10	7.76	* 11.30
	100.76	99.67	99.84	100.00

* CO₂ determined by difference.

Traces of organic matter are found in all four sandstones, but were not determined.

2. SANDSTONE DIKES IN SHASTA COUNTY.

Described by J. S. Diller, in Bull. Geol. Soc. Amer., vol. 1, p. 411. The rock is made up of quartz, feldspar, and biotite, with a calcite cement. Serpentine, sphene, magnetite, and zircon also occur in it, but are less common.

A. From Salt Creek, one-half mile above McNett's.

B. One and one-fourth miles below Ono Bridge, North Fork of Cottonwood.

C, D. Three-fourths of a mile below John Allen's, Dry Creek.

E. From John Allen's, Dry Creek.

Analyses A, B, by T. M. Chatard, record No. 1106. C, D, E, by J. E. Whitfield, record Nos. 972, 973.

	A.	B.	C.	D.	E.
SiO ₂	48.13	48.10	59.10	61.60	54.55
TiO ₂ .....	.24	.47	.70	Trace.	Trace.
Al ₂ O ₃	11.19	12.16	14.02	12.15	10.64
Fe ₂ O ₃	1.25	1.02	3.16	2.09	1.59
FeO	1.47	2.14	1.42	3.30	1.16
MnO .....	.29	.26	Trace.	Trace.	1.53
CaO	16.39	15.88	9.35	6.92	14.30
BaO .....	.04	Undet.			
MgO	2.22	1.65	1.72	2.33	1.29
K ₂ O	1.17	1.56	1.49	1.41	1.68
Na ₂ O	2.29	2.46	2.21	2.16	2.60
H ₂ O at 110° .....	.78	.46			
H ₂ O at red heat.	1.78	3.27	2.63	3.10	1.60
CO ₂	12.73	10.36	4.65	5.05	9.05
P ₂ O ₅ .....	.14	.13	Trace.	.08	.10
SO ₃			Trace.	.27	.10
Cl			Trace.	Trace.	.72
	100.11	99.92	100.45	100.46	100.31

The following bedded sandstones of the same region are also described:

F. From Middle Fork of Cottonwood, 1 mile above Miller's.

G. Top of cascade, $1\frac{1}{2}$ miles up Byron Creek from North Fork of Cottonwood.

H. Two and one-half miles above John Allen's, Dry Creek.

Analyses F and G, by Chatard, record No. 1106. H, by Whitfield, record No. 974.

	F.	G.	H.
SiO ₂	55.85	67.62	60.74
TiO ₂.....	.76	.48	.86
Al ₂ O ₃	13.20	13.63	10.25
Fe ₂ O ₃	2.56	1.25	4.31
FeO.....	4.77	3.27	6.21
MnO.....	.24	.15	Trace.
CaO.....	6.93	2.80	4.97
BaO.....	Undet.	.03	.....
MgO.....	1.90	2.34	3.69
K ₂ O.....	1.89	1.11	.52
Na ₂ O.....	2.60	2.78	1.83
H ₂ O at 110°.....	1.13	.64	.....
H ₂ O at redness.....	2.99	2.83	4.36
CO ₂	4.97	.72	2.29
P ₂ O ₅.....	.18	.08	Trace.
SO ₃.....	.....	.....	.40
Cl.....	.....	.....	Trace.
	99.97	99.73	100.43

3. SANDSTONE FROM SULPHUR BANK.

Described by Becker in Mon. XIII, p. 92. Analysis made by Melville in the San Francisco laboratory. An altered sandstone, showing grains of quartz, plagioclase, and orthoclase.

SiO ₂	68.50	K ₂ O.....	1.26
TiO ₂.....	.60	Na ₂ O.....	6.03
Al ₂ O ₃	12.82	H ₂ O at 100°.....	.28
Fe ₂ O ₃	1.29	H ₂ O above 100°.....	2.11
FeO.....	3.37	P ₂ O ₅.....	.16
MnO.....	.02		100.47
CaO.....	1.82		
MgO.....	2.21		

MISCELLANEOUS SANDSTONES.

A. Triassic sandstone from the Jaittelle quarry, near Hancock, Md. Hard, compact, brown. Analysis by F. W. Clarke, record No. 613.

B. Brown sandstone, Hummelstown, Pa. Analysis by E. A. Schneider, record No. 1280.

C. Yellow sandstone from Stony Point, Mich. Analysis by F. W. Clarke, record No. 213.

D. Carboniferous sandstone adjoining the peridotite dike of Elliott County, Ky. See Diller, Amer. Journ. Sci., 3d series, vol. 32, p. 125. Analysis by T. M. Chatard, record No. 354.

E. Yellow sandstone, Armejo quarry, Colorado. Analysis, partial, by T. M. Chatard, record No. 289.

	A.	B.	C.	D.	E.
SiO ₂	76.43	88.13	84.57	60.78	81.27
TiO ₂.....				.03	
Al ₂ O ₃	17.78	5.81	5.90	10.54	9.81
Fe ₂ O ₃		1.77	6.48	3.27	1.44
FeO.....		.31			
MnO.....	Trace.			.10	
CaO.....	.84	.20		10.15	.44
MgO.....	.92	.53	.68	1.59	.42
K ₂ O.....	Undet.	2.63	Undet.	2.36	Undet.
Na ₂ O.....	Undet.	.06	Undet.	1.41	Undet.
H ₂ O at 100°.....	2.79	.23	1.92	.85	1.19
H ₂ O above 100°.....		.26		2.32	
P ₂ O ₅.....				.09	
CO ₂				6.29	
	98.76	99.93	99.55	99.78	94.57
Insol. in HCl...	88.68		91.87		95.54

F. Potsdam sandstone, Sauk County, Wis. Analysis by E. A. Schneider, record No. 1280.

G. Banded sandstone, Peoa, Utah. Analysis by Schneider, record No. 1280.

H. Brown sandstone, Flagstaff, Ariz. Analysis by T. M. Chatard, record No. 1144.

I. Sandstone, Robinson mine, Summit County, Colo. Analysis by L. G. Eakins, made in the Denver laboratory, partial.

	F.	G.	H.	I.
SiO ₂	99.42	96.60	*79.19	56.33
Al ₂ O ₃.....	.31	2.02	1.30	.77
Fe ₂ O ₃			2.45	.97
CaO.....			7.76	14.01
MgO.....		.08	.23	7.30
K ₂ O.....				Undet.
Na ₂ O.....				Undet.
H ₂ O at 100°.....	.18	.11	.32	Undet.
H ₂ O above 100°.....		.20	2.94°	Undet.
CO ₂			5.77	† 19.04
	99.91	99.14	99.96	98.42

* Silica and insoluble matter.

† Calculated for bases.

CHERT.

From the lead-zinc region of southwestern Missouri and its extension into Kansas.

Collected by W. P. Jenney.

A. Unaltered chert, East Hollow, Belleville, Jasper County, Mo.

B. Partly altered, same locality.

C. Altered to "cotton rock," same locality.

D. From the Surprise mine, Joplin, Mo.

Analyses by E. A. Schneider, record No. 1205.

	A.	B.	C.	D.
SiO ₂	98.17	98.92	98.71	99.46
Al ₂ O ₃ . Fe ₂ O ₃.....	.83	.48	.43	.29
CaO.....	.05	.03	.03	.04
MgO.....	.01	.02	.02	Trace.
Ignition.....	.78	.42	.50	.34
	99.84	99.87	99.69	100.13

E. Blue chert, unaltered, Bonanza shaft, Galena, Kans.

F. Same locality.

G. Altered, same locality.

H. "Jasperite," Joplin, Mo.

I. "Jasperite," Galena, Kans.

Analyses E, F, G, by E. A. Schneider, record No. 1205. H and I, by L. G. Eakins, record No. 1208.

	E.	F.	G.	H.	I.
SiO ₂	99.23	98.60	99.13	95.77	97.33
Al ₂ O ₃ . Fe ₂ O ₃.....	.22	.52	.16	1.84	1.89
CaO .....	.02	.10	Trace.	.54	.11
MgO	Trace.	Trace.	.01	.24	.09
Ignition.....	.50	.40	.20	1.17	.77
	99.97	99.62	99.50	99.56	100.19

THE CARBONATE ROCKS: LIMESTONE, DOLOMITE, SIDERITE, ETC.

VERMONT AND MASSACHUSETTS.

A. White marble, Rutland, Vt. Analysis by L. G. Eakins, record No. 1213.

B. The portion of A insoluble in dilute hydrochloric acid. Same analyst and number.

C. White marble, Lee, Mass. Analysis by E. A. Schneider, record No. 1279.

D. Limestone, Lee, Mass. Collected by B. K. Emerson. From cut on west side of railroad. Analysis by George Steiger, record No. 1654.

E. Dolomite, Charlemont, Mass. Collected by Emerson. Analysis by Eakins, record No. 1343.

F. Dolomite, Webster, Mass. Collected by Emerson. Analysis by H. N. Stokes, record No. 1634.

	A.	B.	C.	D.	E.	F.
Insoluble.....	8.00	-----	.19	-----	-----	-----
SiO ₂	-----	56.69	-----	.95	.67	1.01
Al ₂ O ₃.....	.39	31.16	} .24	.09	Trace.	.17
Fe ₂ O ₃	-----	-----		None.	.08	None.
FeO.....	.14	2.13	-----	.10	7.60	.37
MnO.....	-----	-----	-----	-----	1.61	.08
NiO.....	-----	-----	-----	-----	.03	-----
CaO.....	50.79	2.68	30.88	54.75	28.63	30.82
MgO.....	Trace.	3.27	21.42	.56	16.17	21.35
K ₂ O.....	-----	Undet.	-----	.15	-----	.10
Na ₂ O.....	-----	Undet.	-----	.02	-----	.01
H ₂ O.....	1.01	-----	-----	.08	-----	.09
P ₂ O ₅	-----	-----	-----	.03	-----	.06
CO ₂	39.80	-----	46.72	43.38	45.35	45.84
SO ₃	-----	-----	-----	.05	-----	-----
	100.13	95.93	99.45	100.16	100.14	99.90

NEW YORK, PENNSYLVANIA, MARYLAND.

A. Dolomite-marble, New York Quarry Company, Tuckahoe, Westchester County, N. Y. Analysis by W. F. Hillebrand, record No. 746.

B. Hydraulic cement-rock, Akron, N. Y. Analysis by George Steiger, record No. 1655.

C. Compact gray limestone, Greason, Pa. Analysis by E. A. Schneider, record No. 1279.

D. Dolomite-marble, Cockeysville, Md. Analysis by Schneider, No. 1279.

E. An earlier sample of D. Analysis by J. E. Whitfield, record No. 827.

	A.	B.	C.	D.	E.
Insoluble.....	1.33	-----	11.07	5.57	-----
SiO ₂	-----	9.03	-----	-----	.44
TiO ₂	-----	.16	-----	-----	-----
Al ₂ O ₃	-----	2.25	-----	.40	1.22
Fe ₂ O ₃.....	.21	.85	-----		-----
FeO.....	-----	.52	-----	-----	Trace.
CaO.....	30.68	26.84	39.26	29.08	30.73
MgO.....	20.71	18.37	9.00	20.30	20.87
K ₂ O.....	-----	.85	-----	-----	-----
Na ₂ O.....	-----	None.	-----	-----	-----
H ₂ O.....	.16	.98	.18	-----	1.22
P ₂ O ₅	-----	.03	-----	-----	-----
CO ₂	46.66	40.33	38.82	44.26	45.85
Organic matter.....	-----	-----	.75	-----	-----
	99.75	100.21	99.08	99.61	100.33

VIRGINIA AND WEST VIRGINIA.

A. Limestone, upper ledge, Moundsville Narrows, W. Va.

B. Same as A, lower ledge. Analyses A and B by T. M. Chatard, record No. 127.

C. Trenton limestone, Lexington, Va. Analysis by R. B. Riggs, record No. 365.

D. Limestone, Staunton, Va. Analysis by George Steiger, record No. 1630.

E. Part of D, insoluble in one-tenth hydrochloric acid.

F. Soluble part of D. Analyses E and F also by Steiger, same number. These three analyses are accompanied by analyses of the residual clay, formed by the weathering of the limestone. See section on clays.

	A.	B.	C.	D.	E.	F.
Insoluble.....	10.33	1.53	.....	.....	.....	.....
SiO ₂.....	.....	.....	.44	7.37	6.98	.39
TiO ₂.....	.....	.....	.....	.09	.09	None.
Al ₂ O ₃.....	.....	.....	.....	1.92	1.39	.53
Fe ₂ O ₃.....	.90	.96	.42	.29	.25	.04
FeO.....	.....	.....	.....	.63	None.	.63
MnO.....	Trace.	Trace.	.....	None.	None.	None.
CaO.....	48.02	53.26	54.77	28.39	.04	28.35
MgO.....	1.08	.93	Trace.	18.30	.15	18.15
K ₂ O.....	.....	.....	.....	1.09	.91	.18
Na ₂ O.....	.....	.....	.....	.09	.04	.05
H ₂ O at 100°.....	.05	.10	1.08	.09	Undet.	Undet.
H ₂ O above 100°.....				.49	.15	.34
P ₂ O ₅	Trace.	Trace.	.....	.03	None.	.03
CO ₂	39.18	43.16	42.72	41.85	None.	41.85
	99.56	99.94	99.43	100.63	10.00	90.54

GEORGIA.

- A. Marble, Happy Valley.
B. "Creole" marble, Happy Valley.
C. Portion of B insoluble in dilute hydrochloric acid.
D. "Cherokee" marble, Happy Valley.
E. Portion of D insoluble in dilute hydrochloric acid.
Analyses by L. G. Eakins, record Nos. 464, 485.

	A.	B.	C.	D.	E.
Insoluble.....		1.84		2.01	
SiO ₃	2.23		58.21		55.48
Al ₂ O ₃.....	.91	.17	7.37	.15	15.58
Fe ₂ O ₃.....	.22				
FeO.....		.05	.31	.06	Trace.
CaO.....	52.16	53.91	12.53	53.69	14.52
MgO.....	2.09	.83	20.42	.83	12.88
H ₂ O.....	.45	.13		.17	
CO ₂	42.22	43.16		43.13	
	100.28	99.69	98.84	100.04	98.46

TENNESSEE, ALABAMA, LOUISIANA.

A. Limestone, Knoxville, Tenn. Analysis by L. G. Eakins, record No. 1159.

B. Knox dolomite, Morrisville, Ala. Described by Russell in Bull. 52, together with a residual clay derived from it. See section on clays. Analysis by W. F. Hillebrand, record No. 797.

C. Limestone from Rayborn's salt-lick, Bienville Parish, La. Analysis by R. B. Riggs, record No. 323.

D. White marble, streaked with black. From 5 miles west of Winnfield, La. Analysis by W. F. Hillebrand, record No. 760. In addition to the constituents named in the table, this marble contains traces of barium, strontium, chlorine, and organic matter.

	A.	B.	C.	D.
Insoluble.....				.65
SiO ₂.....	.17	3.24	.55	
Al ₂ O ₃.....	.04	.17	1.61	Trace.
Fe ₂ O ₃.....	.23	.17		
FeO.....		.06		Trace.
MnO.....			Trace.	.10
CaO.....	55.47	29.58	54.09	55.01
MgO.....	.30	20.84	.06	.60
H ₂ O.....	.21	.30		.13
P ₂ O ₅.....			.05	
CO ₂	43.63	45.54	44.12	43.43
SO ₃.....			.05	.27
	100.05	99.90	100.53	100.19

FLORIDA.

Coral and shell rocks, collected by N. S. Shaler. Partial analyses only. Chlorides and sulphates present; alkalies and phosphates not looked for.

A, B, C, D. Coquina gravel, Tortugas.

E. The same, Key West.

Analyses by F. W. Clarke, record No. 878.

	A.	B.	C.	D.	E.
SiO ₂.....	.19	.22	.32	.21	.25
Al ₂ O ₃ , Fe ₂ O ₃ ....	.19	.47	.56	.76	.56
CaO.....	52.24	51.24	49.38	51.95	51.52
MgO.....	1.53	2.09	1.93	1.44	2.08
CO ₂	41.46	41.07	40.39	41.53	41.58
H ₂ O.....	3.27	3.57	5.12	3.07	3.19
	98.88	98.66	97.70	98.96	99.18

F. Near Fort Worth.

G. East side of St. Johns River, near Seville.

H. Corroded surface, Miami Reef.

I. Near Oak Hill.

J. Near Melbourne.

Analyses by F. W. Clarke, record No. 885.

	F.	G.	H.	I.	J.
SiO ₂	2.94	8.50	2.99	5.87	17.83
Al ₂ O ₃ , Fe ₂ O ₃ ....	.23	.73	.65	.95	1.18
CaO.....	51.51	47.29	51.22	50.34	43.85
MgO.....	.71	1.51	.06	.37	.26
CO ₂	41.59	39.00	41.22	39.62	34.31
H ₂ O.....	2.64	3.37	2.23	3.21	2.53
	99.62	100.40	98.37	100.36	99.96

K. Coarse shell mass, Senote.

L. Coral rock, Salt Key Bank.

M. Loggerhead Key.

Analyses by L. G. Eakins, record No. 882. The following analyses, also by Eakins, No. 883, are included for comparison:

N. Coralline bottom, Barbados.

O. Recent coral (*Siderostria*), Bermuda.

	K.	L.	M.	N.	O.
SiO ₂.....	.22	.11	.20	1.17	.23
Al ₂ O ₃.....	.18	.04	.22	.31	Trace.
Fe ₂ O ₃					
CaO.....	54.87	53.54	53.54	46.45	55.16
MgO.....	.64	.71	.78	5.15	.20
CO ₂	43.89	43.87	43.71	43.40	43.74
H ₂ O.....	.11	1.13	.81	2.73	.54
	99.91	99.40	99.26	99.21	99.87

OHIO.

A, B, C, D. Trenton limestone from New Vienna.

Partial analyses by F. W. Clarke and R. B. Riggs, record Nos. 729, 730, 732. Iron and alumina are present in soluble form.

	A.	B.	C.	D.
Insoluble	8.47	9.93	2.12	28.43
CaO	47.16	49.04	51.18	23.00
MgO	1.5	.58	3.08	12.90
CO ₂	36.20	37.64	42.04	30.82
	92.35	97.19	98.42	95.15

E. Trenton limestone, Arcadia, Hancock County.

F. Air-line Junction, Toledo. This sample contains a good deal of ferrous carbonate.

G. Gas-rock, St. Henry's well, Mercer County.

H. Oil-rock, Lima.

All Trenton. Analyses, partial, by Clarke and Riggs, record Nos. 729, 730.

	E.	F.	G.	H.
Insoluble.....	8.56	3.52	2.27	1.64
CaO.....	47.17	30.64	50.34	32.24
MgO.....	2.59	18.05	2.86	17.36
CO ₂	38.54	42.82	40.96	43.92
	96.86	95.03	96.43	95.16

The following partial analyses by F. W. Clarke, record No. 738, all relate to Trenton limestones:

A. Well No. 3, Bryan. Gas-rock.

B. McElree well, Kenton. Depth, 1,315 feet.

C. Huntsville. Depth, 1,405 feet.

D. Prospect. Depth, 1,650 feet.

E. Findlay street well, Dayton. Depth, 975 feet.

F. Xenia. Depth, 1,075 feet.

G. New Madison. Depth, 1,150 feet.

	A.	B.	C.	D.
Insoluble.....	9.22	5.26	4.41	26.12
Fe ₂ O ₃ , Al ₂ O ₃	1.51	1.10	3.15	2.57
CaCO ₃	49.00	84.32	57.23	66.02
MgCO ₃	38.59	8.43	33.16	3.77
	98.32	99.11	98.95	98.58

	E.	F.	G.
Insoluble.....	12.34	9.23	11.11
Fe ₂ O ₃ , Al ₂ O ₃.....	.58	.18	3.60
CaCO ₃	82.36	86.54	64.91
MgCO ₃	1.67	2.99	17.98
	96.95	98.94	97.60

In C and G there is ferrous carbonate.

Partial analyses by Charles Catlett, record Nos. 754, 755, 756, 757; all of Trenton limestones from the natural-gas belt.

A. London. Depth, 1,594 feet.

B. Air-line Junction, Toledo. Depth, 1,415 feet.

C. Celina. Depth, 1,112 feet.

D. City well No. 2, Upper Sandusky.

E. Sandusky. Depth, 2,260 feet.

F. Gas-rock. Pauck well, St. Marys Township, Auglaize County.

G. Gas-rock. Bennett well, St. Marys Township. Depth, 1,121 feet.

H. First city well, Carey. Depth, about 1,350 feet.

I. Well No. 2, Fort Recovery. Depth, 1,065 feet.

J. Waggoner well, 6 miles west of Fremont. Gas-rock.

K. Loomis and Nyman well, Tiffin. Depth, 1,470 to 1,481 feet.

L. Loomis and Nyman well, Tiffin. Depth, 1,488 to 1,494 feet.

M. Port Clinton. Depth, 1,660 to 1,700 feet.

N. Wauseon. Depth, 2,135 feet.

O. Napoleon. Depth, 1,830 feet.

P. Kossuth, Allen County. Oil-rock.

Q. Doenze's well, Franklin Township, Mercer County. Depth, 1,107 feet.

	A.	B.	C.	D.	E.	F.
Insoluble.....	15.90	2.88	2.95	8.18	3.65	3.18
Al ₂ O ₃ , Fe ₂ O ₃	1.84	8.68	2.95	4.31	4.58	3.12
CaCO ₃	77.69	54.68	68.41	64.25	54.62	52.18
MgCO ₃	1.89	25.73	24.18	15.93	33.67	38.42
	97.32	91.97	98.49	92.67	96.52	96.90
	G.	H.	I.	J.	K.	L.
Insoluble.....	1.66	5.72	1.89	5.22	5.66	9.88
Al ₂ O ₃ , Fe ₂ O ₃	2.48	3.08	1.57	6.32	4.86	1.46
CaCO ₃	56.94	80.11	87.88	52.93	52.89	79.39
MgCO ₃	35.55	8.09	7.43	32.75	33.46	6.20
	96.63	97.00	98.77	97.22	96.87	96.93
	M.	N.	O.	P.	Q.	
Insoluble.....	7.46	18.24	2.66	1.08	3.68	
Al ₂ O ₃ , Fe ₂ O ₃	4.16	7.28	2.14	.66	8.38	
CaCO ₃	71.96	42.82	53.85	90.72	69.53	
MgCO ₃	14.34	28.11	37.33	6.69	10.98	
	97.92	96.45	95.98	99.15	92.27	

INDIANA.

A. Buff limestone, Hoosier Stone Company, Bedford.

B. Blue limestone, same locality.

Analyses by F. W. Clarke, record Nos. 306, 307.

	A.	B.
SiO ₂.....	.63	1.69
Fe ₂ O ₃.....	.39	.49
CaO.....	54.19	54.18
MgO.....	.39	.37
P ₂ O ₅	Trace.	Trace.
CO ₂	44.01	43.08
SO ₃	None.	None.
	99.61	99.81

The following Trenton limestones are all from the natural-gas belt:

C. Union City. Depth, 1,160 feet.

D. Bluffton. Depth, 1,062 to 1,067 feet.

E. Muncie. Depth, 920 feet.

F. Greensburg. Depth, 867 feet.

G. Vernon. Depth, 905 feet.

H. Wabash. Depth, about 900 feet.

Analysis C by F. W. Clarke, record No. 738. The remainder by Charles Catlett, Nos. 753, 758.

	C.	D.	E.	F.	G.	H.
Insoluble	2.14	2.37	3.30	.87	8.00	3.52
Al ₂ O ₃ .Fe ₂ O ₃	1.23	4.48	3.72	.55	.60	7.58
CaCO ₃	83.21	53.43	51.96	94.60	85.56	53.18
MgCO ₃	12.48	37.47	38.11	.36	Trace.	30.53
	99.06	97.75	97.09	96.38	94.16	94.81

MISSOURI.

Limestones and dolomites collected by W. P. Jenney. Analyses by L. G. Eakins, record Nos. 1184, 1207. CO₂ calculated.

A, B. Cherokee limestone, quarry near Seneca, Newton County.

C, D. The same, from near Grand Falls, Newton County.

E, F. Dolomite, Oswego land, Joplin.

	A.	B.	C.	D.	E.	F.
Insoluble .....	.66	1.21	1.01	1.01	29.77	11.66
Al ₂ O ₃.....	.11	.13	.08	.13	1.32	1.03
FeO.....	.05	.07	.05	Trace.		
MnO.....	Trace.	Trace.	.03	Trace.	-----	
CaO.....	55.29	54.92	54.98	55.11	21.46	28.72
MgO.....	.23	.20	.31	.32	14.79	17.26
CO ₂	43.69	43.31	43.54	43.65	33.13	41.55
	100.03	99.84	100.00	100.22	100.47	100.22

KANSAS.

A. Limestone from Silverdale. Analysis by Charles Catlett, record No. 967.

B. Cherokee limestone, Short Creek, near Spring River, Cherokee County. Analysis by L. G. Eakins, record No. 1184.

	A.	B.
Insoluble .....		.32
SiO ₂	5.27	-----
Al ₂ O ₃	1.07	.17
Fe ₂ O ₃ .....	.71	-----
FeO .....	.32	.20
MnO .....		.02
CaO	50.36	55.25
MgO .....	.56	.35
K ₂ O .....	.10	-----
Na ₂ O .....	.20	-----
H ₂ O .....	.78	-----
P ₂ O ₅ .....	.06	-----
CO ₂	40.34	43.79
SO ₃ .....	.07	-----
	99.84	100.10

MICHIGAN, WISCONSIN, MINNESOTA, CANADA.

Most of the rocks considered under this heading were described by Irving and Van Hise in Mon. XIX, pages 131 and 191. A few other analyses, also representing Van Hise's collections, are taken from the laboratory records. The Canadian rocks are from near the boundary line, and relate directly to others gathered upon the Minnesota side.

A. Dolomite. Near Sunday Lake, Gogebic district, Michigan. Analysis by W. F. Hillebrand, record No. 767.

B. Dolomite. Penokee region, Wisconsin, NW. $\frac{1}{4}$ sec. 22, T. 44 N., R. 5 W. Analysis by Hillebrand, No. 768.

C. Limestone. Bed of Slate Creek, Huron Bay slate quarries, Michigan. Analysis by T. M. Chatard, record No. 894. From laboratory records; not in the monograph cited.

D. Limestone, east end of Ogiskemannis Lake, Minnesota. Analysis by Chatard, record No. 899. Not in monograph.

	A.	B.	C.	D.
SiO ₂	3.07	.63	7.05	41.99
Al ₂ O ₃.....			.48	1.24
Fe ₂ O ₃.....	.09	.03	1.33	.42
FeO.....	.86	.75	Undet.	4.77
MnO.....	.15	.08	.19	.26
CaO.....	29.72	30.94	50.08	16.85
MgO.....	19.95	20.68	.57	8.41
H ₂ O at 105°.....	.30	.27		.05
H ₂ O ign.....			.25	1.02
P ₂ O ₅.....			.27	.05
CO ₂	45.31	46.27	39.68	24.70
SO ₃.....			.21	.32
Cl.....	Trace.	Trace.		
	99.45	99.65	100.11	100.08

E. Iron carbonate, from SE. $\frac{1}{4}$ sec. 20, T. 47 N., R. 43 W., Michigan.

F. Iron carbonate, south side of Sunday Lake, Michigan.

G. Iron carbonate, Palms mine, Gogebic district, Michigan.

Analyses E, F, G, by W. F. Hillebrand, record Nos. 769, 770, 771.

H. Iron carbonate, Miner and Wells Option, sec. 13, T. 47 N., R. 46 W., Michigan. Analysis by T. M. Chatard, record No. 893.

I. Iron carbonate, NW. $\frac{1}{4}$ sec. 18, T. 47 N., R. 45 W., Michigan. Analysis by Chatard, No. 895.

	E.	F.	G.	H.	I.
SiO ₂	3.16	28.86	46.47	46.01	36.73
TiO ₂.....		.20	.10	.12	.19
Al ₂ O ₃.....	.08	1.29	.70	.83	.38
Fe ₂ O ₃.....	.93	1.01	.86	1.35	.98
FeO.....	15.18	37.37	28.57	26.07	34.81
MnO.....	1.15	.97	.40	2.09	.52
CaO.....	26.65	.74	.49	.63	.48
MgO.....	11.01	3.64	2.30	2.86	2.74
H ₂ O at 105° ....	.54	.68	.60	1.71	.12
H ₂ O ign.....					1.40
P ₂ O ₅.....	.06	Trace.	Trace.	.07	.01
CO ₂	41.10	25.21	19.24	17.72	22.44
SO ₃.....				.15	.16
Cl.....	Trace.		?		
FeS ₂.....	.34				
	100.20	99.97	99.73	99.61	100.96

J. Iron carbonate, Penokee iron range, N. E. $\frac{1}{4}$ sec. 6, T. 45, R. 2 E., Wisconsin.

K, L. Black, slaty, carbonaceous iron carbonates, Animikie formation, Kakabikka Falls, Kaministiquia River, Canada.

M. Iron carbonate, west end of Gunflint Lake, Minnesota.

N. Iron carbonate, north side of Gunflint Lake, Minnesota.

O. Iron carbonate, north side of Gunflint Lake, Canada.

Analyses J, K, L, by R. B. Riggs, record Nos. 376, 377, 378. M, N, O, by T. M. Chatard, record Nos. 897, 898, 900.

	J.	K.	L.	M.	N.	O.
SiO ₂	15.62	37.73	54.26	58.23	46.46	23.90
TiO ₂				Trace?	Trace?	None.
Al ₂ O ₃	4.27	3.41	2.57	.06	.24	.07
Fe ₂ O ₃	8.14	6.42	3.62	5.01	.64	.44
FeO	32.85	22.92	19.63	18.48	26.34	10.72
MnO	5.06	.40	.19	.25	.21	.28
CaO .....	.81	1.26	1.07	.38	1.87	22.25
MgO	2.66	3.98	2.93	9.59	3.10	8.52
H ₂ O at 110° .....	.68	2.74	1.20	.07	.07	None.
H ₂ O at redness ..				2.01	1.15	.99
P ₂ O ₅ .....				.03	.13	Trace.
CO ₂	30.32	18.01	14.93	5.22	19.96	32.42
SO ₃ .....				.19	.14	.17
C		3.54	.45			
	100.41	100.41	100.85	99.52	100.31	99.76

P. Ferrodolomite, Marquette district, Michigan. Analysis by George Steiger, record No. 1473.

Q. Ferrodolomite, Marquette district, Michigan.

R. Portion of Q insoluble in hydrochloric acid.

S. Soluble portion of Q.

Analyses Q, R, S, by George Steiger, record No. 1442. These rocks are not in the monograph cited.

	P.	Q.	R.	S.
SiO ₂	42.37	26.97	26.67	.30
Al ₂ O ₃		1.30	.12	1.18
Fe ₂ O ₃	1.09	2.31	.16	2.15
FeO	31.41	39.77		39.77
MnO .....		.29		.29
CaO .....	.50	.66		.66
MgO	2.48	1.94	.10	1.84
Alkalies .....		.09		.09
H ₂ O at 100° .....		.10		
H ₂ O above 100° .....		.51		
P ₂ O ₅ .....		.03		.03
CO ₂	21.80	26.20		26.20
	99.65	100.17	27.05	72.51

MONTANA.

Rocks collected by A. C. Peale. Analyses by Charles Catlett, record Nos. 890, 905.

A. North of East Gallatin River.

B. West of North Boulder River.

C, D. North of East Gallatin River.

E. Base of Carboniferous, west side of Bridger Range.

F. Middle Carboniferous, north of Gallatin River.

G, H. Upper Carboniferous, north of Gallatin River.

Analyses all partial. A, B, C, D, H were published by Peale in Bull. 110, pp. 16, 28, and 40.

	A.	B.	C.	D.
Insoluble.....	.34	1.78	23.50	35.26
Fe ₂ O ₃ , Al ₂ O ₃ .....	.22	.40	2.50	1.92
CaCO ₃	54.54	54.54	67.85	59.11
MgCO ₃	43.63	42.62	6.18	1.96
	99.73	99.34	100.03	98.25
	E.	F.	G.	H.
Insoluble.....	9.98	5.99	50.74	25.24
Fe ₂ O ₃ , Al ₂ O ₃ .....	.38	.58	.30	5.30
CaCO ₃	88.50	91.96	32.28	40.21
MgCO ₃ .....	.95	1.35	13.91	25.25
	99.81	99.88	97.23	96.00

COLORADO.

1. THE DENVER BASIN.

Rocks described by Emmons in Mon. XXVII. Analyses made by L. G. Eakins, in the Denver laboratory.

A. Upper Wyoming limestone, from Morrison.

B. Niobrara dolomite.

	A.	B.
Insoluble.....	5.32	12.01
Al ₂ O ₃.....	.53	.54
Fe ₂ O ₃.....	.38	.11
MnO.....	.49	.20
CaO.....	48.73	27.49
MgO.....	2.95	18.03
H ₂ O.....	.11	.61
P ₂ O ₅.....	.03	.03
CO ₂	41.71	41.40
	100.25	100.42

2. THE LEADVILLE DISTRICT.

Rocks described by Emmons in Monograph XII. Analyses A, E, by W. F. Hillebrand; B, C, D, by A. Guyard; all made in the Denver laboratory.

- A. Silver Wave mine. Upper blue limestone.
 B. Dugan quarry. Upper blue limestone.
 C. Glass-Pendery mine. Upper blue limestone.
 D. Montgomery quarry. Near base of blue limestone.
 E. Carbonate Hill quarry. White limestone, upper part.

	A.	B.	C.	D.	E.
SiO ₂.....	.21	.70	.27	7.76	11.84
Al ₂ O ₃.....	.27	.17	.04	.11	1.66
Fe ₂ O ₃.....	.21	.11	.22	.10	1.51
FeO.....	.24	.38	.13	.57	.83
MnO.....	Trace.	.05	.20	.06	.....
CaO.....	30.79	30.43	29.97	27.26	26.60
MgO.....	21.14	20.78	21.52	20.05	17.41
K ₂ O.....	.03	.05	.01	.02	.02
Na ₂ O.....	.06	.09	.02	.04	.03
H ₂ O.....	.22	.04	.07	.05	.48
P ₂ O ₅	Trace.	.12	.03	.07	Trace.
CO ₂	46.84	46.93	47.39	43.79	40.01
SO ₃	Trace.	.....	.....	Trace.	.....
Cl.....	.10	.14	.04	.06	.05
FeS ₂	Trace.	Trace.	.....	Trace.	.....
Organic matter.	.03	.03	.02	.07	.....
	100.14	100.02	99.93	100.01	100.44

3. FAIRPLAY, PARK COUNTY.

Analyses made by W. F. Hillebrand, in the Denver laboratory.

A. Serpentinous limestone, Buckskin Gulch.

B. Limestone, Fairplay.

C. Limestone, Mount Silverheels.

D. Dolomite-limestone, Mount Silverheels.

Analyses B, C, D, partial, with CO₂ calculated to satisfy bases.

	A.	B.	C.	D.
Insoluble.....	-----	2.37	.51	1.98
SiO ₂	17.64	-----	-----	-----
Al ₂ O ₃.....	.99	-----	-----	-----
Fe ₂ O ₃.....	.62	-----	-----	-----
FeO.....	.18	} .19	} .10	} .46
MnO.....	Trace.			
CaO	32.23	53.64	55.50	30.19
MgO	19.01	.73	.17	20.47
Alkalies.....	.07	-----	-----	-----
H ₂ O.....	3.72	.51	-----	-----
P ₂ O ₅ .....	.05	-----	-----	-----
CO ₂	25.33	42.93	43.82	46.52
Cl .....	.08	-----	-----	-----
	99.92	100.37	100.10	99.62

4. PITKIN COUNTY.

Limestones and dolomites collected under the direction of S. F. Emmons. Analyses by George Steiger, record No. 1559. CO₂ calculated to satisfy bases. Analyses partial only.

	A.	B.	C.	D.	E.	F.	G.
Insoluble.....	.16	.80	1.02	13.63	1.42	31.12	7.78
Fe ₂ O ₃.....	.22	1.63	2.10	1.88	3.34	.36	.88
FeO.....	.09	.23	.06	.64	.42	.19	.22
CaO.....	30.66	31.19	33.74	35.98	31.61	37.28	38.85
MgO	20.94	19.69	16.76	8.25	18.06	.54	9.97
CO ₂	47.13	46.16	44.94	37.35	44.70	29.88	41.47
	99.20	99.70	98.62	97.73	99.55	99.37	99.17

The following samples from Aspen were analyzed by L. G. Eakins in the Denver laboratory. Partial analyses, CO₂ calculated as before.

H. Blue limestone.

I. Limestone.

J. Dolomite.

	H.	I.	J.
Insoluble .....	.52	.33	.84
Fe ₂ O ₃ .....	.88	Trace.	1.31
CaO	31.16	55.81	30.46
MgO	20.64	.16	20.90
CO ₂	47.19	44.03	46.92
	100.39	100.33	100.43

5. GLENWOOD SPRINGS, GARFIELD COUNTY.

Limestones and dolomites, collected under the direction of S. F. Emmons. Analyses, partial only, by George Steiger, record No. 1559. CO₂ calculated to satisfy bases.

	A.	B.	C.	D.	E.	F.	G.
Insoluble.	21.45	47.74	6.47	3.71	9.44	17.82	1.96
Fe ₂ O ₃ .....	.97	.18	.42	None.	.26	.74	.03
FeO .....	.23	.71	.35	.55	.32	.57	.35
CaO	40.64	15.87	46.65	47.40	39.56	26.50	32.14
MgO .....	.73	10.60	2.64	4.49	8.56	14.86	18.72
CO ₂	32.73	24.13	39.55	42.15	40.52	37.18	45.85
	96.75	99.23	96.08	98.30	98.66	97.67	99.05

	H.	I.	J.	K.	L.	M.
Insoluble.	2.27	.22	.23	.06	.22	.11
Fe ₂ O ₃ .....	.14	Trace.	.09	None.	.10	.03
FeO				None.	.10	.07
CaO	53.79	55.17	55.49	55.81	55.45	55.68
MgO .....	.46	.21	.24	Trace.	.24	Trace.
CO ₂	42.76	43.58	43.87	43.85	43.84	43.75
	99.42	99.18	99.92	99.72	99.95	99.64

6. TEN MILE DISTRICT, SUMMIT COUNTY.

Partial analysis, made in the Denver laboratory, by W.F. Hillebrand. CO₂ calculated to satisfy bases. Manganese and iron present as carbonates, but Fe₂O₃ and Al₂O₃ were not separated from them.

- A. A. V. Fletcher shaft, Copper Mountain.
- B. Pittston tunnel.
- C. Pearl Hill, Middle Carboniferous.
- D. Summit quarry.
- E. Sheep Mountain. Dolomite.
- F. Northwest corner of map. Oolitic limestone.
- G. Pittston tunnel.

	A.	B.	C.	D.	E.	F.	G.
Insoluble.....	2.69	.62	10.09	1.75	.78	1.37	7.91
FeO, MnO....	.21	.25	1.19	.32	1.50	.20	.32
CaO	54.23	55.24	28.01	53.60	30.55	55.17	50.83
MgO .....	.21	.24	18.33	1.23	20.15	.28	.70
CO ₂	42.97	43.81	42.63	43.65	47.04	43.76	40.90
	100.31	100.16	100.25	100.55	100.02	100.78	100.66

- H. Blackbird tunnel, Tucker Mountain. Dolomite.
- I. Summit King shaft, Summit City.
- J. Ptarmigan Hill. Middle Carboniferous dolomite.
- K. Hill north of Sugar Loaf.
- L. Quarry on southeast side of Searl's Gulch.
- M. Open cut below Sabbath Rest tunnel, Elk Mountain.
- N. Jacque Mountain. Triassic.

	H.	I.	J.	K.	L.	M.	N.
Insoluble	2.68	6.75	.65	4.42	.36	.82	2.04
FeO, MnO....	1.52	3.08	1.67	.10	.17	.07	.15
CaO	31.60	28.05	30.90	52.97	55.58	55.47	54.62
MgO	18.27	18.15	19.75	.40	.37	.22	.25
CO ₂	45.75	43.88	47.02	42.12	44.17	43.86	43.28
	99.82	99.91	99.99	100.01	100.65	100.44	100.34

UTAH.

Marble from the Ontario mine, east end of the 1,000-foot level.

Analysis made by L. G. Eakins in the Denver laboratory.

Insoluble	9.61
Al ₂ O ₃	Trace.
CaO	50.63
MgO .....	.09
CO ₂ (calculated)	39.89
	<hr/> 100.22

NEVADA AND CALIFORNIA.

A. Crystalline limestone, Eureka, Nevada. Analysis by E. A. Schneider, record No. 1279.

B. From base of the Hamburg limestone, Eureka district, Nevada.

C. From summit of Hamburg limestone, Eureka.

D. Pogonip limestone, Eureka district, Silurian. Analyses B, C, D made by W. F. Hillebrand in the Denver laboratory. Described by Hague in Mon. XX, pp. 40, 49. In D the CO₂ was taken by difference.

E. Cretaceous limestone from Mount Diablo, California. Analysis made by W. H. Melville in the San Francisco laboratory, and published in Bull. Geol. Soc. Amer., vol. 2, p. 409. FeO and alkalis undetermined.

	A.	B.	C.	D.	E.
Insoluble.....	.53				
SiO ₂		24.00	3.94	9.34	21.19
Al ₂ O ₃.....		.12	.64	.31	.39
Fe ₂ O ₃.....		.12	.43	.29	1.52
FeO.....			.20		
MnO.....			.61		3.61
CaO.....	30.60	41.97	51.96	50.01	35.61
MgO.....	21.69	.80	.52	.54	1.39
Alkalies.....		Traces.	Traces.	Traces.	
H ₂ O at 100°		} .16	} .37	} .13	.76
H ₂ O above 100.....					2.33
P ₂ O ₅.....		.07	.50	.24	2.55
CO ₂	47.13	32.62	40.71	39.11	26.84
Organic matter.....		Traces.	.03	Traces.	
Cl.....		.01	.01	.03	
	99.95	99.87	99.92	100.00	96.19

HAWAIIAN ISLANDS.

Coral and shell rocks, analyzed for N. S. Shaler by L. G. Eakins, record Nos. 886, 887, 889. Analyses only partial.

A. Laie.

B. C. Kohuku Bluff.

D. Kohuku coral-flat.

E. Point near coral-flat.

F. "Modern chalk," Oahu.

G. Diamond Head.

H. Under lava, Honolulu.

I. Old reef, Waialua.

J. Campbell's ranch, Waianea, Oahu.

K. Wailuku Bay.

L. Reef No. 3, Honolulu.

M. Prison Knoll, Honolulu.

	A.	B.	C.	D.	E.	F.	G.
SiO ₂.....	.35	.19	.67	.25	.26	33.25	2.97
Al ₂ O ₃.....	.19	.52	.73	.49	.21	19.53	2.88
Fe ₂ O ₃						10.71	
CaO.....	49.38	49.34	51.09	53.34	52.17	11.37	44.82
MgO.....	1.74	4.60	2.50	.67	1.51	3.06	5.32
CO ₂	41.89	44.33	43.64	43.89	43.95	11.09	40.81
H ₂ O.....	4.74	.40	.79	.93	.70	9.84	1.86
	98.29	99.38	99.42	99.57	98.80	98.85	98.66

	H.	I.	J.	K.	L.	M.
SiO ₂	5.34	1.05	.53	.45	3.53	.81
Al ₂ O ₃	5.11	1.26	.62	1.82	2.26	1.19
Fe ₂ O ₃						
CaO.....	42.24	51.07	50.69	50.54	46.52	52.67
MgO.....	5.95	.11	2.98	1.83	2.45	.42
CO ₂	38.71	42.68	43.96	42.80	40.59	42.81
H ₂ O.....	1.61	1.33	.46	1.93	2.75	1.24
	98.96	97.50	99.24	99.37	98.10	99.14

SLATES AND SHALES.

VERMONT.

Samples A to I, inclusive, were collected by T. Nelson Dale, and analyzed by W. F. Hillebrand, record Nos. 1567, 1656. Roofing slates of Cambrian age.

A. McCarty quarry, South Poultney.

B. Unfading green, Eureka quarry, Poultney.

C. Sea green, Griffith and Nathaniel quarry, South Poultney.

D. Sea green, Rising and Nelson's quarry, Pawlet.

E. Sea green, Brownell quarry, Pawlet.

F. Black, American Black Slate Company, Benson.

All six contain traces of lithia, of sulphates, and of nickel or cobalt.

	A.	B.	C.	D.	E.	F.
SiO ₂	61.63	59.27	62.37	67.76	59.84	59.70
TiO ₂.....	.68	.99	.74	.71	.74	.79
Al ₂ O ₃	16.33	18.81	15.43	14.12	15.02	16.98
Fe ₂ O ₃	4.10	1.12	1.34	.81	1.23	.52
FeO.....	2.71	6.58	5.34	4.71	4.73	4.88
MnO.....	.09	.13	.22	.10	.34	.16
CaO.....	.50	.42	.77	.63	2.20	1.27
BaO.....	.06	.05	.07	.04	.09	.08
MgO.....	2.92	2.21	3.14	2.38	3.41	3.23
K ₂ O.....	5.54	3.75	4.20	3.52	4.48	3.77
Na ₂ O.....	1.26	1.88	1.14	1.39	1.12	1.35
H ₂ O at 100°.....	.31	.32	.34	.23	.41	.30
H ₂ O above 100°.....	3.24	3.98	3.71	2.98	3.44	3.82
P ₂ O ₅.....	.16	.11	.06	.07	.09	.16
CO ₂.....	.41	.21	.87	.40	2.98	1.40
FeS ₂.....	.04	.15	.06	.22	.05	1.18
C.....	None.	None.	Trace.	None.	Trace?	.46
	99.98	99.98	99.80	100.07	100.17	100.05

G. Unfading green, Valley Slate Company's quarry, Poultney.

H. Mottled, purple and green, Eureka quarry, Poultney.

I. Purple 1 mile south of Hydeville, in Castleton.

All three contain traces of lithia, nickel, and chlorine, and possibly of zirconia. In G and H, traces of strontia, but none in I.

	G.	H.	I.
SiO ₂	59.48	60.24	60.96
TiO ₂	1.02	.92	.86
Al ₂ O ₃	18.22	18.46	16.15
Fe ₂ O ₃	1.24	2.56	5.16
FeO.....	6.81	5.18	2.54
MnO.....	.07	.07	.07
CaO.....	.56	.33	.71
BaO.....	.05	.03	.04
MgO.....	2.50	2.33	3.06
K ₂ O.....	3.81	4.09	5.01
Na ₂ O.....	1.55	1.57	1.50
H ₂ O at 110°.....	.17	.18	.17
H ₂ O above 110°.....	4.05	3.81	3.08
P ₂ O ₅.....	.10	.11	.23
CO ₂.....	.39	.08	.68
FeS ₂.....	.13	.16	None.
F.....	.08	Undet.	Undet.
N, as NH ₃.....	.03	.03	.01
	100.26	100.15	100.23

J. Slate from Guilford, collected for the Educational Series of Rocks.
Analysis by L. G. Eakins, record No. 1316.

K. Slate from the Lakeshore quarry, Hydeville. Analysis by
Eakins, record No. 1159.

	J.	K.
SiO ₂	60.72	58.15
TiO ₂ .....		.93
Al ₂ O ₃	22.59	18.93
Fe ₂ O ₃		2.91
FeO	6.03	5.64
MnO	Trace.	.07
CaO .....	.41	.60
MgO	2.05	2.70
K ₂ O	3.69	3.92
Na ₂ O .....	.86	1.17
H ₂ O.....	3.01	4.56
P ₂ O ₅ .....	.13	.12
SO ₃ .....		.16
C .....	.57	.....
	100.06	99.86

NEW YORK.

Roofing slates from Washington County, collected by T. Nelson Dale.
Of Cambrian age.

A. Red, three-fourths mile south of Hampton Village.

B. Empire Red Slate Company, near Granville.

C. National Red Slate Company, Granville.

D. Green, three-fourths mile northwest of Janesville.

Analyses by W. F. Hillebrand, record No. 1567. All contain traces of lithia, of sulphates, and of nickel or cobalt. No carbonaceous matter is present.

	A.	B.	C.	D.
SiO ₂	67.61	67.55	56.49	67.89
TiO ₂ .....	.56	.58	.48	.49
Al ₂ O ₃	13.20	12.59	11.59	11.03
Fe ₂ O ₃	5.36	5.61	3.48	1.47
FeO	1.20	1.24	1.42	3.81
MnO .....	.10	.19	.30	.16
CaO .....	.11	.26	5.11	1.43
BaO .....	.04	.31	.06	.04
MgO	3.20	3.27	6.43	4.57
K ₂ O	4.45	4.13	3.77	2.82
Na ₂ O .....	.67	.61	.52	.77
H ₂ O at 110° .....	.45	.40	.37	.36
H ₂ O above 110° ...	2.97	3.03	2.82	3.21
P ₂ O ₅ .....	.05	.10	.09	.10
CO ₂	None.	.11	7.42	1.89
FeS ₂ .....	.03	.04	.03	.04
	100.00	100.02	100.38	100.08

E. Red slate, from quarry 3 miles north of Raceville.

F. Green spot in E.

G. Purple rim of green spot F.

Analyses by W. F. Hillebrand, record No. 1656. Contain traces of lithia and nickel. Fluorine not determined.

	E.	F.	G.
SiO ₂	63.88	65.44	64.59
TiO ₂.....	.47	.52	.51
Al ₂ O ₃	9.77	9.38	10.23
Fe ₂ O ₃	3.86	1.09	1.79
FeO.....	1.44	1.06	1.19
MnO.....	.21	.32	.26
CaO.....	3.53	4.53	4.07
BaO.....	.05	.06	.05
MgO.....	5.37	4.92	5.12
K ₂ O.....	3.45	3.57	3.70
Na ₂ O.....	.20	.22	.23
H ₂ O at 110°.....	.27	.25	.28
H ₂ O above 110°.....	2.48	2.10	2.29
P ₂ O ₅.....	.08	.08	.08
CO ₂	5.08	6.55	5.84
FeS ₂	Trace.	.04	Trace.
	100.14	100.13	100.23

KENTUCKY, GEORGIA, ALABAMA.

A. Indurated Carboniferous shale, in contact with the peridotite dike of Elliott County, Ky. Described by Diller in Bull. 38. Analysis by T. M. Chatard, record No. 351.

B. Fragment of shale included in the Elliott County dike. Analysis by Chatard, record No. 353.

C. Bituminous shale, Dry Gap, Georgia. Analysis by L. G. Eakins, record No. 1316.

D. Middle Cambrian shale, Coosa Valley, near Blaine, Cherokee County, Ala. Analysis by H. N. Stokes, record No. 1549.

	A.	B.	C.	D.
SiO ₂	41.32	35.53	51.03	55.02
TiO ₂ .....	.48	.95	.....	.65
Al ₂ O ₃	20.71	18.23	13.47	21.02
Fe ₂ O ₃	2.59	2.46	8.06	5.00
FeO	5.46	4.81	.....	1.54
MnO .....	.17	.13	.....	Trace.
CaO	9.91	21.17	.78	1.60
BaO .....	.....	.....	.....	.04
SrO .....	.....	.....	.....	Trace.
MgO	1.91	2.01	1.15	2.32
K ₂ O .....	.88	1.08	3.16	3.19
Na ₂ O	7.19	2.53	.41	.81
Li ₂ O .....	.....	.....	.....	.03
H ₂ O at 110° .....	.....	1.40	} .81	2.44
H ₂ O above 110°	8.78	9.00		5.65
P ₂ O ₅ .....	.08	.08	.31	.06
SO ₃ .....	.....	.....	.....	.02
S .....	.....	.....	7.29	.....
Cl .....	.....	.....	.....	Trace.
CO ₂ .....	.55	.88	.....	.83
Carbonaceous matter .....	.....	.....	.....	.32
Fixed carbon .....	.....	.....	13.11	.....
Volatile hydrocarbons .....	.....	.....	3.32	.....
Less O=S	100.03	100.26	102.90	100.54
			2.74	
			100.16	

OHIO.

Three samples of Utica shale, from New Vienna. Collected by Edward Orton. Partial analyses by F. W. Clarke and R. B. Riggs, record No. 731.

	A.	B.	C.
Insoluble.....	60.17	29.51	25.80
CaO.....	17.11	33.43	35.27
MgO.....	1.25	2.16	1.32
CO ₂	15.24	27.16	27.40
	93.77	92.26	89.79

Iron and alumina are present in the soluble portion of these shales, the solvent being dilute hydrochloric acid.

WISCONSIN.

Slates of the Penokee-Gogebic series, collected by C. R. Van Hise. A and C are described in Mon. XIX, p. 306, as magnetitic clay-slates. Analyses by L. G. Eakins, record No. 392.

A. From sec. 6, T. 45 N., R. 2 E.

B. From sec. 1, T. 45 N., R. 1 E.

C. From sec. 4, T. 44 N., R. 2 W.

	A.	B.	C.
SiO ₂	53.44	59.73	52.58
Al ₂ O ₃	19.62	22.78	20.76
Fe ₂ O ₃	11.38	.11	12.17
FeO.....	5.35	5.98	4.08
MnO.....	Trace.	.09	.21
CaO.....	.42	.53	.30
MgO.....	1.58	2.94	1.33
K ₂ O.....	1.73	3.48	4.87
Na ₂ O.....	2.61	1.41	.37
Li ₂ O.....	Trace.	.....	Trace.
H ₂ O.....	4.07	3.28	3.43
P ₂ O ₅	Trace.	.....	.....
	100.20	100.33	100.10

COLORADO.

Shales from the Pueblo quadrangle, collected by G. K. Gilbert.

A, B. Near Nushbaum Spring.

C. Salt Creek.

D. Head of Rock Creek.

E. Near Rush Creek.

Analyses by George Steiger, record No. 1466.

	A.	B.	C.	D.	E.
SiO ₂	60.80	51.69	60.60	63.60	45.89
TiO ₂ .....	.47	.66	.35	.66	.52
Al ₂ O ₃	15.63	16.50	16.42	16.74	13.24
Fe ₂ O ₃	4.62	7.90	4.95	4.63	3.88
CaO	1.63	4.41	1.61	.68	12.09
MgO	2.73	2.10	1.43	1.19	2.12
K ₂ O	2.55	2.68	2.98	2.92	2.31
Na ₂ O	1.45	2.07	.92	.29	.47
H ₂ O at 100°	3.19	3.02	3.91	2.88	1.38
H ₂ O above 100°	4.16	6.00	5.72	5.99	4.16
P ₂ O ₅ .....	.10	.22	.31	.16	.17
CO ₂		3.19			10.38
Organic matter	2.87	.53	.84	.46	3.47
	100.20	100.97	100.04	100.20	100.08

Calcareous shales from Fairplay, Park County. Partial analyses, by W. F. Hillebrand, made in the Denver laboratory.

	F.	G.
Insoluble	68.72	35.14
Fe ₂ O ₃ , Al ₂ O ₃ , etc	2.10	
FeO, MnO		2.10
CaO	9.06	19.34
MgO	5.72	12.55
H ₂ O	1.01	.73
CO ₂ , calculated	13.41	30.28
	100.02	100.14

CALIFORNIA.

Cretaceous shales from Mount Diablo. Described by Turner and Melville, Bull. Geol. Soc. Amer., vol. 3, pp. 383-414. Analyses by W. H. Melville, made in the laboratory at San Francisco, except F (record No. 1166), which was done in the Washington laboratory.

A. Brownish-black, resinous. From Bagley Canyon.

B. Slate-colored, soft, friable, little altered. From near Bagley Creek.

C. Same locality as B, less friable, but considerably altered.

D. Slate-colored, friable. From Arroyo del Cerro.

E. Very friable, same locality as D.

	A.	B.	C.	D.	E.
SiO ₂	56.66	53.65	49.14	25.05	40.17
Al ₂ O ₃	17.64	17.64	16.91	8.28	12.76
Fe ₂ O ₃.....	.49	4.06	4.39	.27	2.10
FeO.....	5.22	3.72	3.82	2.41	3.56
NiO.....	Trace.	Trace.	Trace.	Trace.	Trace.
MnO.....	.19	.01	.22	4.11	.16
CaO.....	1.67	2.27	3.28	27.87	4.24
MgO.....	3.50	5.15	5.43	2.61	15.42
K ₂ O.....	2.27	2.22	1.53	Undet.	1.36
Na ₂ O.....	2.17	2.53	4.67	Undet.	.57
H ₂ O at 100°....	3.01	3.95	3.39	1.44	9.19
H ₂ O above 100°.	5.92	4.57	6.97	2.86	6.73
P ₂ O ₅.....	.15	.23	.24	.08	.08
CO ₂.....	.....	.....	.....	24.20	3.48
SO ₃.....	.93	.....	.....	.....	.....
	99.82	100.00	99.99	99.18	99.82

F. Neocomian shale, altered, light brown, friable. From near Arroyo del Cerro.

G. Calcareous shale near Arroyo del Cerro. Hard, compact, dark colored. Very much altered.

H. Red shale from the metamorphic area, head of Bagley Creek.

I. Silicified shale or phthanite. Same locality as H.

J. Clay-slate from near the head of Yaqui Gulch, in Mariposa County. Collected by H. W. Turner for the Educational Series of Rocks. Contains grains of quartz and feldspar, abundant carbonaceous particles, a chloritic substance (?), and a fibrous alteration of sillimanite (?). Analysis by George Steiger, record No. 1643.

	F.	G.	H.	I.	J.
SiO ₂	45.64	44.56	69.98	93.54	60.35
TiO ₂ .....					.75
Al ₂ O ₃	15.42	3.12	11.69	2.26	17.62
Cr ₂ O ₃ .....	.12				
Fe ₂ O ₃	3.40	1.27	6.23	.48	5.64
FeO	3.73	5.21	1.08	.79	2.20
MnO .....	.33	Trace.	.49	.23	None.
CaO	8.11	12.70	.38	.09	.45
BaO .....					.12
MgO	4.62	3.39	1.29	.66	1.04
K ₂ O	1.86	.88	3.72	.51	3.16
Na ₂ O	3.13	3.09	.73	.37	1.00
H ₂ O at 100°	8.74	1.41	1.03	.21	1.02
H ₂ O above 100°		6.24	2.92	.72	4.36
P ₂ O ₅ .....	.27	.16	.05		.17
CO ₂	4.59	17.62			None.
SO ₃ .....					.05
Cl .....					.01
F					Trace.
C					1.72
	99.96	99.65	99.59	99.86	99.76

CLAYS, SOILS, ETC.

MASSACHUSETTS.

Clays and soils from Marthas Vineyard, collected by N. S. Shaler. See 7th Ann., p. 303. Analyses by F. W. Clarke, record Nos. 439, 440, 441, 442, 443, 444, 445, 446, 454, and 455. Partial analyses only.

A. Average sample of white clay, east end of Chilmark Cliffs.

B. Average sample of clays, Weyquosque series, Chilmark Cliffs.

C. Average sample of fine clay and soil, east end of Weyquosque Cliffs.

D. Sandy white clay, south end of Gay Head Cliffs.

E. Average sample of fine white clay, south end of Gay Head Cliffs.

	A.	B.	C.	D.	E.
SiO ₂	82.95	61.76	70.81	56.19	73.46
Al ₂ O ₃ , Fe ₂ O ₃	13.45	25.35	20.67	30.65	19.06
CaO.....	None.	.51	Trace.	None.	None.
MgO.....	Trace.	1.95	1.99	Trace.	Trace.
K ₂ O.....	.....	3.01	1.67	.....	.73
Na ₂ O.....	.....	1.83	1.23	.....	.70
Ignition.....	3.47	5.76	3.39	10.79	6.36
P ₂ O ₅	None.	Trace.	None.	None.	None.
SO ₃.....	.....	.....	.....	2.45	None.
	99.87	100.17	99.76	100.08	100.31

F. Average sample of clay, north end of Gay Head Cliffs.

G. Average sample of southernmost red clays, Gay Head.

H. Brown clay, south of light-house, Gay Head Cliffs.

I. Average sample of red clay from the greensand, north end of Gay Head.

J. Pyritiferous clay, central part of Gay Head section.

	F.	G.	H.	I.	J.
SiO ₂	49.19	57.50	56.62	55.93	72.74
Al ₂ O ₃ , Fe ₂ O ₃	39.77	31.21	31.24	33.51	21.46
CaO.....	None.	.19	Trace.	None.	None.
MgO.....	Trace.	.20	1.97	.19	Trace.
K ₂ O.....	.....	.40	2.76	Undet.	.....
Na ₂ O.....	.....	.....	.40	Undet.	.....
Ignition.....	11.47	9.83	7.57	9.98	5.69
P ₂ O ₅	None.	None.	None.	None.	None.
	100.43	99.33	100.56	99.61	99.89

NEW YORK, PENNSYLVANIA; DELAWARE.

A. Clay from near Richfield Springs, N. Y. Partial analysis by Charles Catlett, record No. 946.

B, C. Two clays from Northumberland County, Pa. Analyses by Charles Catlett, record No. 952.

D. Kaolin, Hockessin, Del.

E. Portion of D insoluble in sulphuric acid.

F. Portion of D soluble in sulphuric acid.

Analyses D, E, F by George Steiger, record No. 1626.

	A.	B.	C.	D.	E.	F.
SiO ₂	49.65	65.97	59.16	48.73	29.55	19.18
TiO ₂.....	.....	.....	.....	.17	.11	.06
Al ₂ O ₃	} 23.82	20.37	18.68	37.02	18.44	18.58
Fe ₂ O ₃		2.75	10.32	.79	.27	.52
CaO.....	6.48	.64	.52	.16	.02	.14
MgO.....	Trace.	.52	.67	.11	Trace.	.11
K ₂ O.....	Undet.	3.32	3.35	.41	.41	None.
Na ₂ O.....	Undet.	.05	.11	.04	.02	.02
H ₂ O at 100°.....	} 16.18	} 6.28	} 6.87	.52	.....	.....
H ₂ O above 100°.....				12.83	6.84	5.99
P ₂ O ₅.....	.....	.....	.....	.03	Undet.	Undet.
	96.13	99.90	99.68	100.81	55.66	44.60

VIRGINIA, NORTH CAROLINA.

A. Residual clay from decay of Trenton limestone, Lexington, Va. Described by Russell in Bull. 52. Analysis by R. B. Riggs, record No. 373. See also analysis of the limestone.

B. Residual clay from limestone, Staunton, Va.

C. Portion of B soluble in weak hydrochloric acid.

D. Insoluble portion of B. Analyses B, C, D, by George Steiger, record No. 1630. See also analysis of limestone.

E. Decomposed dolerite, from near Wadesboro, N. C. Described by Russell in Bull. 52. Analysis by T. M. Chatard, record No. 327.

F. Residual clay from decay of chloritic schist. From Cary, 8 miles west of Raleigh, N. C. Analysis by R. B. Riggs, record No. 364. Described by Russell in Bull. 52.

	A.	B.	C.	D.	E.	F.
SiO ₂	43.07	55.90	3.09	52.81	39.55	54.54
TiO ₂ .....		.20	.04	.16	.64	
Al ₂ O ₃	25.07	19.92	3.96	15.96	28.76	26.43
Cr ₂ O ₃					Trace.	
Fe ₂ O ₃	15.16	7.30	6.25	1.05	16.80	9.04
FeO .....		.39	.30	.09		
MnO		None.			Trace.	
CaO .....	.63	.50	.30	.20	.37	
MgO .....	.03	1.18	.43	.75	.59	
K ₂ O	2.50	4.79	.28	4.51	Undet.	
Na ₂ O	1.20	.23	.20	.03	Undet.	
H ₂ O at 110°	12.98	2.54			13.26	9.87
H ₂ O above 110°		6.52	2.10	4.42		
P ₂ O ₅ .....		.10	.04	.06	.10	
CO ₂ .....		.38	.38	None.		
	100.64	99.95	17.37	80.04	100.07	99.88

SOUTH CAROLINA, GEORGIA.

A, B, C. Clays from near Augusta, Ga. Partial analyses by George Steiger, record No. 1395.

D. Kaolin from Aiken, S. C. Analysis by Steiger, No. 1472.

	A.	B.	C.	D.
SiO ₂	60.24	61.36	60.70	44.94
TiO ₂.....				.65
Al ₂ O ₃	26.72	29.04	29.24	39.18
Fe ₂ O ₃.....				.52
CaO.....	.88	.76	.68	
MgO.....	Present.	Present.	Present.	
Alkalies.....	Undet.	Undet.	Undet.	
H ₂ O at 100°.....				.47
H ₂ O at 200°.....	6.28	7.46	6.74	.20
H ₂ O at 300°.....				.27
H ₂ O, ignition.....				13.38
P ₂ O ₅.....				.12
	94.12	98.62	97.36	99.73

FLORIDA.

A. Hammock clay, Melborne Creek. Collected by N. S. Shaler. Partial analysis by L. G. Eakins, record No. 881.

B. Clay from Tampa.

C. Clay from Lakeland.

B, C, collected by W. H. Dall. Analyses by L. G. Eakins, record No. 1255, partial.

	A.	B.	C.
SiO ₂	38.04	70.78	80.39
Al ₂ O ₃ , Fe ₂ O ₃	27.19	11.33	15.03
CaO.....	10.73	2.18	1.22
MgO.....	.46		
H ₂ O.....	23.61	14.55	4.34
CO ₂			
	100.03	98.84	100.98

Clays collected by G. H. Eldridge.

D, E. From the Sandlin place, 2 miles southeast of Marion, Hamilton County.

F. From Richmond's, 6 miles south of Leesburg, Lake County.

G, H. From Bartow Junction.

Analyses D, E, F by H. N. Stokes, record No. 1493; G, H, by George Steiger, No. 1545.

	D.	E.	F.	G.	H.
SiO ₂	15.68	78.23	84.41	79.99	79.48
Al ₂ O ₃.....	.61	7.30	11.02	10.82	12.14
Fe ₂ O ₃.....	.45	1.85	Trace.	3.25	2.64
FeO.....				.25	.09
CaO.....	26.11	1.60	.20	.23	.31
MgO.....	17.28	2.11	Trace.	.07	.07
H ₂ O at 100°.....	1.97	*8.48	*4.25	.90	.86
H ₂ O above 100°.....				4.09	4.73
P ₂ O ₅	Trace.	Trace.	Trace.		
CO ₂	37.90			* None.	None.
	100.00	99.57	99.88	99.87	100.32

* Includes a little CO₂.

ALABAMA, MISSISSIPPI.

A. Kaolin, Greenville, Ala. Contains about 40 per cent of kaolin, with fragments of quartz, feldspar, and mica. Analysis by T. M. Chatard, record No. 1148.

B. Residual clay from decay of Knox dolomite, Morrisville, Ala. Described by Russell in Bull. 52. Analysis by W. F. Hillebrand, record No. 797. See also analysis of the dolomite.

C. Loess from Vicksburg, Miss. Described by Chamberlin and Salisbury, 6th Ann., p. 282. Analysis by R. B. Riggs, record No. 294.

	A.	B.	C.
SiO ₂	69.84	55.42	60.69
TiO ₂.....			.52
Al ₂ O ₃	19.91	22.17	7.95
Fe ₂ O ₃.....	.90	8.30	2.61
FeO.....		Trace.	.67
MnO.....	Trace.		.12
CaO.....	.07	.15	8.96
MgO.....	.28	1.45	4.56
K ₂ O.....	2.14	2.32	1.08
Na ₂ O.....	.21	.17	1.17
H ₂ O at 110°.....	.06	2.10	
H ₂ O, ign.....	6.72	7.76	1.14
P ₂ O ₅.....			.13
CO ₂			9.63
C, organic.....			.19
SO ₃.....			.12
Cl.....			.08
	100.13	99.84	99.62

ILLINOIS, IOWA, MINNESOTA.

A. B. Clays from Henry County, Ill. Analyses by T. M. Chatard, record No. 144.

C. Loess; a stratum overlying residuary clay, 350 feet above the Mississippi River, near Galena, Ill. Described by Chamberlin and Salisbury, 6th Ann., p. 282. Analysis by R. B. Riggs, record No. 293. Dried at 100°.

D. Loess, 300 feet above the Mississippi, 3½ miles northwest of Dubuque, Iowa. Described by Chamberlin and Salisbury (*l. c.*), and analyzed by Riggs, No. 292. Dried at 100°.

E. Tallow clay, from a lead mine at Lansing, Iowa. Collected by W. P. Jenney. Analysis by H. N. Stokes, record No. 1337. Dried at 100°. Partial analysis.

F. Greenish-gray clay, New Ulm, Minn. Analysis by T. M. Chatard, record No. 825.

	A.	B.	C.	D.	E.	F.
SiO ₂	46.12	42.58	64.61	72.68	52.08	61.32
TiO ₂.....	.79	.64	.40	.72	.....	.66
Al ₂ O ₃	15.24	12.16	10.64	12.03	23.11	12.27
Fe ₂ O ₃	4.41	3.90	2.61	3.53	9.34	3.62
FeO.....	.....	.....	.51	.96	.....	4.18
MnO.....	.28	.09	.05	.06	.....	.27
ZnO.....	.....	.....	.....	.....	Trace.	.....
PbO.....	.....	.....	.....	.....	Trace.	.....
CaO.....	8.63	11.33	5.41	1.59	1.04	.99
BaO.....	.....	.....	.....	.....	.....	.05
MgO.....	3.63	4.32	3.69	1.11	2.12	1.76
K ₂ O.....	3.79	3.88	2.06	2.13	Undet.	3.59
Na ₂ O.....	1.54	1.96	1.35	1.68	Undet.	.42
H ₂ O.....	15.57	18.64	2.05	2.50	9.80	10.73
P ₂ O ₅.....	.08	.10	.06	.23	.....	.27
CO ₂.....	.....	.....	6.31	.39	.....	.....
C, organic.....	.....	.....	.13	.09	.....	.....
SO ₃.....	.....	.....	.11	.51	.....	.19
Cl.....	.....	.....	.07	.01	.....	.....
	100.08	99.60	100.06	100.22	97.49	100.32

WISCONSIN.

Clays, etc., described by Chamberlin and Salisbury in 6th Ann., pp. 250 and 282. Analyses by R. B. Riggs, record Nos. 259, 260, 261, 262, 290, 295. Dried at 100°.

A. Residuary clay from Dodgeville, $4\frac{1}{2}$ feet below surface.

B. The same, $8\frac{1}{2}$ feet below surface.

C. Residuary clay from near Cobb, $4\frac{1}{2}$ feet below surface.

D. Same as C, $3\frac{1}{2}$ feet below surface.

E. Red, putty-like clay, containing pebbles, Milwaukee.

F. Red pebble clay, Milwaukee.

	A.	B.	C.	D.	E.	F.
SiO ₂	71.13	49.59	49.13	53.09	40.22	48.81
TiO ₂ .....	.45	.28	.13	.16	.35	.45
Al ₂ O ₃	12.50	18.64	20.08	21.43	8.47	7.54
Fe ₂ O ₃	5.52	17.19	11.04	8.53	2.83	2.53
FeO .....	.45	.27	.93	.86	.48	.65
MnO .....	.04	.01	.06	.03	Trace.	.03
CaO .....	.85	.93	1.22	.95	15.65	11.83
MgO .....	.38	.73	1.92	1.43	7.80	7.05
K ₂ O	1.61	.93	1.60	.83	2.36	2.60
Na ₂ O	2.19	.80	1.33	1.45	.84	.92
H ₂ O	4.63	10.46	11.72	10.79	1.95	2.02
P ₂ O ₅ .....	.02	.03	.04	.03	.05	.13
CO ₂ .....	.43	.30	.39	.29	18.76	15.47
C, organic .....	.19	.34	1.09	.22	.32	.38
SO ₃ .....					.13	.05
Cl .....					.06	.04
	100.39	100.50	100.68	100.09	100.27	100.50

MISSOURI, ARKANSAS.

A. Typical loess, Kansas City, Mo. Dried at 100°. Described by Chamberlin and Salisbury, 6th Ann., p. 282. Analysis by R. B. Riggs, record No. 291.

B, C, D, E. Tallow clays, Joplin, Mo. Collected by W. P. Jenney. Analyses by T. M. Chatard, record No. 1210.

F. Tallow clay, Aurora, Mo. Collected by Jenney. Analysis by Chatard, No. 1210. In analyses B, C, D, E, F the percentages of bases relate to the portion soluble in hydrochloric acid. Analyses only partial.

	A.	B.	C.	D.	E.	F.
Insoluble.....		40.64	43.07	39.34	39.62	34.04
SiO ₂	74.46					
TiO ₂ .....	.14					
Al ₂ O ₃	12.26	5.72	7.60	6.17	6.45	10.01
Fe ₂ O ₃	3.25	1.30	1.12	1.16	1.53	3.62
FeO.....	.12					
MnO .....	.02					
ZnO.....		32.46	29.43	34.28	33.55	33.49
CaO.....	1.69	1.80	1.70	2.13	1.77	2.09
MgO	1.12	.27	.32	.27	.30	.25
K ₂ O	1.83					
Na ₂ O	1.43					
H ₂ O	2.70	17.19	16.74	17.63	16.95	16.96
P ₂ O ₅ .....	.09					
CO ₂ .....	.49					
C, organic.....	.12					
SO ₃ .....	.06					
Cl .....	.05					
	99.83	99.38	99.98	100.98	100.17	100.46

The following partial analyses by H. N. Stokes, record No. 1260, all relate to tallow clays collected by W. P. Jenney. The same remarks apply as to B, C, D, E, F.

G. Cave Springs mine, Jasper County, Mo.

H. Great Western mine, Granby, Mo.

I, J, K. Woodcock mine, Granby.

L. Coon Hollow, Boone County, Ark.

Material dried at 103°.

	G.	H.	I.	J.	K.	L.
Insoluble.....	34.89	11.25	2.41	16.17	3.85	18.18
Soluble SiO ₂	16.75	32.89	36.71	28.62	37.08	29.02
Al ₂ O ₃	7.38	10.78	8.21	8.93	6.46	6.34
Fe ₂ O ₃	10.34	3.89	2.75	5.98	3.49	4.40
ZnO.....	14.35	29.54	38.59	26.23	38.90	30.50
CaO.....	1.55	2.65	2.77	2.01	2.56	1.91
MgO.....	.35	.90	.78	.46	.42	.75
Ignition.....	10.37	8.22	7.99	9.19	7.52	8.36
	95.98	100.12	100.21	97.59	100.28	99.46

COLORADO.

A. Loess from Denver.

B. Loess from Highland.

C. Concretion in loess from Wray.

A, B, C collected by S. F. Emmons, analyses by L. G. Eakins, record No. 1066.

D. Clay from Davis ranch, Pueblo quadrangle.

E. From head of Rock Creek, Pueblo quadrangle.

D and E collected by G. K. Gilbert, analyses by George Steiger, record No. 1457.

	A.	B.	C.	D.	E.
SiO ₂	69.27	60.97	70.63	63.52	76.56
TiO ₂.....				.68	.60
Al ₂ O ₃	13.51	15.67	10.43	24.72	8.30
Fe ₂ O ₃	3.74	5.22	2.58	.43	.38
FeO.....	1.02	.35	.48		
MnO.....	Trace.	Trace.			
CaO.....	2.29	2.77	4.64	.30	.12
MgO.....	1.09	1.60	1.13	.13	.24
K ₂ O.....	3.14	2.28	2.50	Trace.	Trace.
Na ₂ O.....	1.70	.97	1.29	Trace.	Trace.
H ₂ O at 100°.....	4.19	9.83	3.77	1.58	1.26
H ₂ O above 100°.....				8.41	4.40
P ₂ O ₅.....	.45	.19	.20	Trace.	.06
CO ₂	Trace.	.31	2.59		
Organic matter.....				.40	8.31
	100.40	100.16	100.24	100.17	100.23

F. From Red Creek Canyon, south part Colorado Springs quadrangle.

G. From 2 miles southeast of F.

H. From near Canyon.

I. Overlying H.

Collected as probable fire clays by G. K. Gilbert, analyses by George Steiger, record No. 1578. Fe_2O_3 represents total iron. Al_2O_3 includes TiO_2 . In I, the ignition includes some CO_2 , which is absent from the others.

	F.	G.	H.	I.
SiO_2	85.09	86.79	57.98	69.04
Al_2O_3	6.98	8.29	27.51	14.51
Fe_2O_3	1.10	.75	1.68	3.78
CaO}.....	.21	.34	.42	1.24
MgO}.....	.27	.13	.32	.73
K_2O}.....	.13	.25	.56	.48
Na_2O	None.	None.	.03	.08
P_2O_5.....	.06	.05	.06	.07
Ignition.....	6.37	3.78	11.80	10.50
	100.21	100.38	100.36	100.43

J to K. Supposed fire-clays collected in the area of the Apishapa sheet, by G. K. Gilbert. Analyses, partial, by H. N. Stokes, record No. 1503. Titanium present, alkalis undetermined. Analyses made on ignited material, reckoned as 100. The loss on ignition is separately stated below each analysis.

	J.	K.	L.	M.	N.
SiO_2	86.58	78.07	76.96	61.98	93.11
Al_2O_3	12.72	20.22	20.77	37.51	5.56
Fe_2O_3.....	.45	.89	1.11	.45	1.15
CaO}.....	.11	.....	.71	.19	.32
MgO}.....	.11	.26	.32	.09	.10
	98.97	99.44	99.87	100.22	100.24
Ignition.....	4.75	7.51	7.98	12.51	4.45

	O.	P.	Q.	R.
SiO_2	85.98	85.25	54.93	58.56
Al_2O_3	13.67	11.45	43.65	39.17
Fe_2O_3.....	.41	2.24	.69	.55
CaO}.....	.21	.26	.64	1.08
MgO}.....	.....	.21	.05	.45
	100.27	99.41	99.96	99.81
Ignition.....	5.07	4.81	16.80	19.58

S. Loess-like alluvium, Golden, Jefferson County.

T. Fire-clay, Golden, Jefferson County.

Analyses S and T made by W. F. Hillebrand in the Denver laboratory.

	S.	T.
SiO ₂	72.31	50.35
Al ₂ O ₃	12.66	34.44
Fe ₂ O ₃	4.67	.75
CaO.....	1.15	.....
MgO.....	.94	Trace.
K ₂ O.....	3.75	.48
Na ₂ O.....	2.47	.10
H ₂ O + organic matter.....	1.80	13.88
P ₂ O ₅.....	.23	.....
	99.98	100.00

WYOMING, UTAH, NEW MEXICO.

A. Loess from Cheyenne, Wyo. Analysis by L. G. Eakins, record No. 1066.

B. Adobe soil, Salt Lake City, Utah.

C. Adobe soil, Santa Fe, N. Mex.

D. Adobe soil, Fort Wingate, N. Mex.

Analyses B, C, D by Eakins, Nos. 981, 996.

	A.	B.	C.	D.
SiO ₂	67.10	19.24	66.69	26.67
Al ₂ O ₃	10.26	3.26	14.16	.91
Fe ₂ O ₃	2.52	1.09	4.38	.64
FeO.....	.31	.....	.....	.....
MnO.....	.....	Trace.	.09	Trace.
CaO.....	5.88	38.94	2.49	36.40
MgO.....	1.24	2.75	1.28	.51
K ₂ O.....	2.68	Trace.	1.21	Trace.
Na ₂ O.....	1.42	Trace.	.67	Trace.
H ₂ O.....	5.09	1.67	4.94	2.26
P ₂ O ₅.....	.11	.23	.29	.75
CO ₂	3.67	29.57	.77	25.84
SO ₃.....	.....	.53	.41	.82
Cl.....	.....	.11	.34	.07
Organic matter...	.....	2.96	2.00	5.10
	100.28	100.35	99.72	99.97

NEVADA.

A. Grayish clay from Upper Lahontan lake beds, Humboldt River bridge, Mill City.

B. Grayish clay, same locality, Lower Lahontan beds. Analyses by T. M. Chatard, record Nos. 32, 33.

C. Adobe soil, Humboldt. Analysis by L. G. Eakins, record No. 981.

D. Halloysite, pale greenish, Lucia mining district, Elko County. Analysis by George Steiger, record No. 1472.

	A.	B.	C.	D.
SiO ₂	56.30	50.70	44.64	42.11
Al ₂ O ₃	16.52	19.01	13.19	33.83
Fe ₂ O ₃	5.08		5.12	.04
FeO.....				.28
MnO.....			.13	
CuO.....				2.83
CaO.....	5.45	10.26	13.91	.33
MgO.....	2.64	3.19	2.96	.30
K ₂ O.....	2.17	2.16	1.71	
Na ₂ O.....	2.60	1.91	.59	
H ₂ O at 100°.....	9.78	13.03	3.89	6.54
H ₂ O at 200°.....				1.07
H ₂ O at 300°.....				1.26
H ₂ O, ignition.....				12.04
P ₂ O ₅.....			.94	Trace.
CO ₂			8.55	
SO ₃.....			.64	
Cl.....			.14	
Organic matter...			3.43	
	100.54	100.26	99.84	100.63

CALIFORNIA, WASHINGTON, HAWAIIAN ISLANDS.

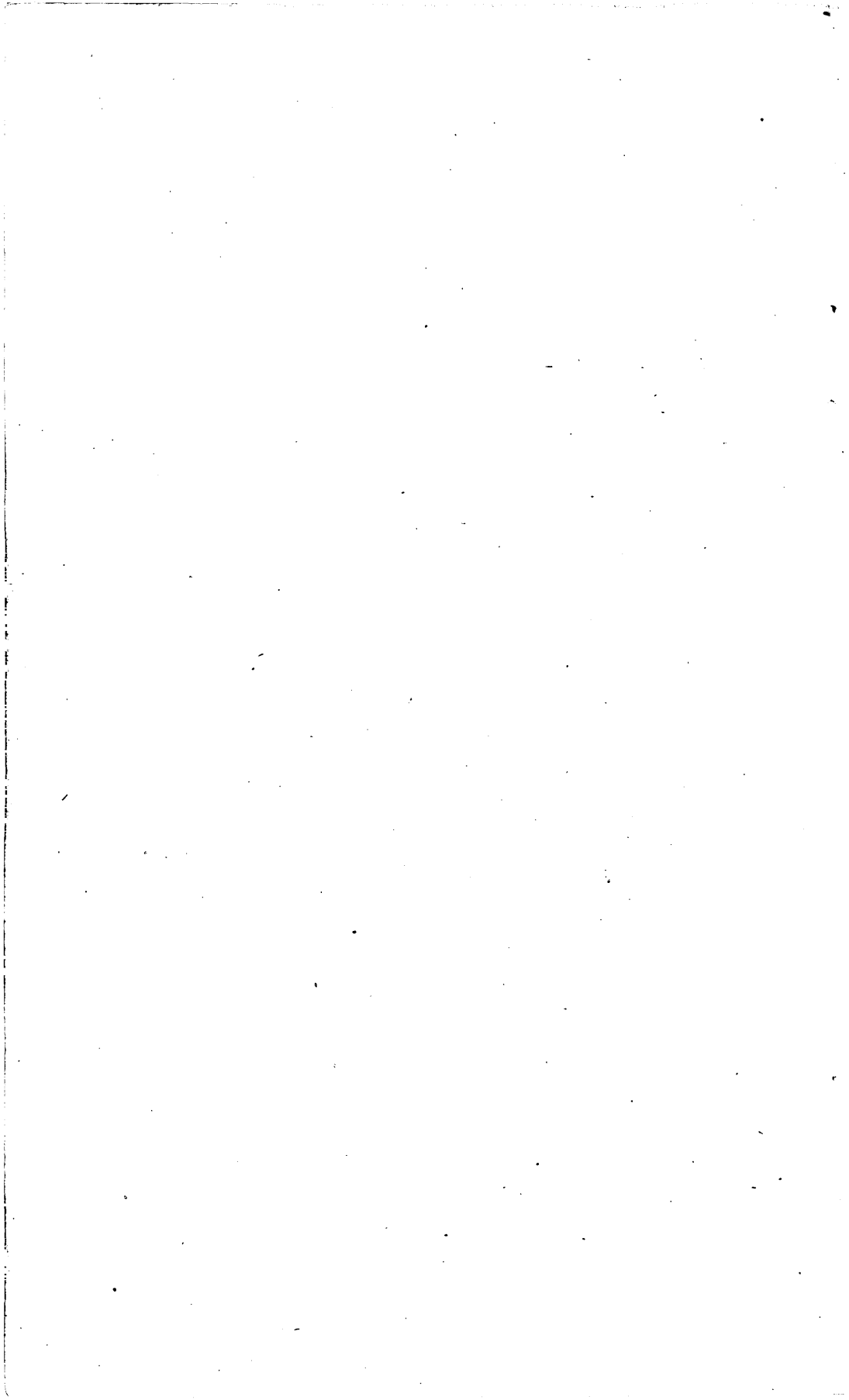
A. Sandy clay, Owens Lake, California.

B. Blue clay, Owens Lake, California. Analyses by T. M. Chatard, record No. 551.

C. Clay from foot of Rickey Hill, Kittle Falls, Stevens County, Wash. Analysis by W. F. Hillebrand, record No. 1428.

D. Lava soil, Diamond Head, Hawaiian Islands. Analysis by L. G. Eakins, record No. 888.

	A.	B.	C.	D.
SiO ₂	53.24	54.92	62.74	32.88
TiO ₂.....	.25	.30	.....	.....
Al ₂ O ₃	10.84	11.25	16.45	12.02
Fe ₂ O ₃	2.59	2.77	2.62	11.52
FeO.....	.77	.94	1.91	.....
MnO.....	.10	.08	Trace.	Trace.
CaO.....	9.18	8.76	3.68	12.20
SrO.....	.....	.....	Trace.	.....
MgO.....	5.82	4.91	2.41	11.70
K ₂ O.....	2.64	2.77	3.53	Undet.
Na ₂ O.....	2.06	2.10	3.05	Undet.
H ₂ O at 110°.....	1.41	2.05	} 2.69	} 5.30
H ₂ O at redness.....	2.73	2.40		
P ₂ O ₅.....	.....	.....	.....	.24
CO ₂	8.75	7.24	.65	11.41
SO ₃.....	.08	Trace.	.....	.....
Cl.....	.05	Trace.	.....	.91
	100.51	100.49	99.73	98.18



INDEX TO ROCKS

A.	Page.
Absarokite	125, 129
Acmite-trachyte.....	145
Actinolite-magnetite-schist	113
Adobe soil	299, 300
Albite	65, 67, 78
Amphibolite	71, 75, 76, 211, 228
Analcite	155, 164
Analcite-basalt	164
Andalusite-schist	221
Andesite	91, 97, 119, 120, 121, 133, 134, 135, 140, 152, 159, 163, 165, 171, 188, 189, 190, 195, 196, 197, 202, 207, 217, 223, 232, 233
Andesite-basalt	190
Anorthoclase.....	78, 107, 145
Aplite	124, 150, 206, 219
Aporhyolite.....	81
Argillite	209, 210
Arkose-gneiss	77
Asperite	223
Augite.....	158, 164, 185
Augite-andesite	119, 123, 159
Augite-andesite-porphry	119, 123
Augite-bronzite-andesite	232
Augite-diorite.....	165, 180
Augite-granite	212
Augite-mica-syenite	158
Augite-porphryite.....	138, 183
Augite-syenite	217
Augite-vogesite	151
B.	
Banakite	127, 128
Basalt.....	80, 97, 122, 135, 136, 137, 139, 151, 153, 158, 162, 163, 164, 184, 185, 189, 190, 198, 199, 200, 203, 205, 215, 218, 223, 230, 231
Biotite-diorite.....	85
Biotite-gneiss	102
Biotite-granite	74, 86, 87, 206, 214
Biotite-porphryite.....	173
Boltonite	77
Bronzite	84

C.	Page.
Camptonite	67, 70, 136, 211
Cancrinite	66
Chert	252, 253
Chiasolite-schist.....	221
Clay	287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301
Coquina	259
Coral	260
Coral rock	259, 260, 276
Cordierite-hornfels	70
Cortlandtite	84
D.	
Dacite	116, 121, 132, 167, 188, 191, 193, 194
Dacite-porphry	191
Diabase	70, 90, 103, 104, 143, 159, 205, 208, 220, 224
Diabase-diorite.....	224
Diabase-porphryite.....	143, 228
Diabase-porphry	207
Diallage	104, 106
Diallage gabbro.....	111
Diopside	84
Diorite.....	69, 70, 85, 117, 118, 119, 124, 143, 144, 148, 151, 165, 176, 177, 178, 180, 181, 191, 204, 205, 206, 214, 215, 218, 220, 232, 233
Diorite-porphryite.....	143
Diorite-porphry	148, 176, 181, 214
Dolerite	158, 203, 289
Dolomite	254, 255, 258, 264, 265, 270, 272, 273, 274
Dunite.....	91
E.	
Elæolite	66, 67
Elæolite-syenite.....	65, 67, 80, 145, 162
Enstatite	72, 241
Enstatite-diabase-porphry.....	159
F.	
Feldspar	65, 67, 78, 82, 89, 103, 104, 105, 107, 112, 145, 173, 174, 185, 230

	Page.		J.	Page.
Feldspar-porphyr	151	Jasperite		253
Ferrodolomite	268		K.	
Fulgurite	230	Kaolin		288, 290, 291
		Keratophyr		78
G.		Kersantite		136
Gabbro	82, 85, 100, 104, 106, 111, 112, 113, 122, 123, 144, 212, 225		L.	
Gabbro-diorite	85, 101, 113, 123	Labradorite-porphyr		97
Gabbro-porphyr	122	Lamprophyre		138, 139, 182
Garnet	92	Lava soil		301
Genthite	231	Lepidomelane		66
Glaucophane-schist	222, 224	Leucite-absarokite		125
Gneiss	77, 87, 88, 91, 99, 102, 160, 214, 215	Leucite-banakite		128
Granite	68, 71, 74, 86, 87, 92, 95, 107, 110, 142, 150, 159, 160, 179, 201, 206, 212, 213, 214, 219	Leucite-basalt		153
Granite-porphyr	69, 142, 146, 147, 176, 219	Leucite-monchiquite		153
Granite-syenite-porphyr	148, 155	Leucite-shoshonite		126
Granitite	68, 142, 159, 160, 213	Leucite-syenite		153, 154
Granodiorite	201, 204, 208, 209, 210, 211, 212, 213	Leucite-trachyte		115
Granulite	206, 219	Leucitite		116, 157
Graywacke	105	Lherzolite		83
Greenstone	98, 101, 102	Limburgite		79
Grünerite-magnetite-schist	98	Limestone		254-275
		Loess		292, 293, 295, 297, 299
H.			M.	
Halloysite	300	Magnetite		105, 113
Hornblende	154	Marble		254, 255, 257, 258, 275
Hornblende-andesite	120, 134, 190, 195, 202, 233	Melaphyr		215
Hornblende-basalt	200	Meteorites		234-246
Hornblende-diorite	85	Mica-andesite		97, 185
Hornblende-granite	71, 142	Mica-basalt		187
Hornblende-mica-andesite	121, 134	Mica-dacite		167
Hornblende-mica-andesite-por- phyry	124, 133	Mica-dacite-porphyr		133
Hornblende-mica-porphyr	119, 178	Mica-diorite		85
Hornblende-picrite	140, 146	Mica-diorite-porphyr		102
Hornblende-porphyr	119, 173, 180, 183, 187, 208	Mica-gabbro		122
Hornblende-pyroxene-andesite	120, 202, 207	Mica-gabbro-porphyr		122
Hornfels	70, 221	Mica-leucitite		116
Hornstone	144	Mica-peridotite		94
Hydronephelite	66	Mica-schist		113, 221
Hypersthene	111, 171	Microcline		89
Hypersthene-andesite	140, 171, 188, 190, 196, 197, 202, 207	Micropegmatite		219
Hypersthene-basalt	230	Microperthite-hornfels		70
Hypersthene-gabbro	85, 111	Minette		80, 149
		Missourite		154
I.		Monchiquite		144, 149, 151, 153
Ilmenite	92	Monzonite		123, 149, 154, 156
Iron carbonate	266, 267, 268	Muscovite		90
			N.	
		Nepheline		66, 67
		Nepheline-basalt		162
		Nepheline-syenite		65, 67, 80, 145, 162
		Nevadite		174
		Novaculite		99

O.	Page.
Obsidian.....	130, 186, 223, 228, 229
Olivine.....	92, 111, 231, 238
Olivine-basalt.....	203
Olivine-diabase.....	104
Olivine-gabbro.....	85, 106, 111, 144
Orthoclase.....	67, 173, 174
Orthoclase-gabbro-diorite.....	123
Ottrelite.....	90
Ottrelite-phyllite.....	90
Onuchitite.....	96

P.	Page.
Pantellarite.....	96
Pearlite.....	134, 189
Peridotite.....	74, 79, 91, 92, 94, 98, 140, 165, 205, 231
Phlogopite.....	115
Phonolite.....	77, 114, 161, 162
Phthanite.....	286
Phyllite.....	70, 90
Picrite.....	140, 146
Pitchstone.....	79, 168
Plagioclase-andesite.....	163
Plagioclase-basalt.....	163
Plagioclase-gneiss.....	215
Porphyrite.....	97, 117, 119, 138, 142, 143, 173, 175, 178, 180, 183, 187, 208, 213, 214, 216
Porphyrite-diorite.....	178
Porphyry.....	68, 69, 95, 102, 107, 119, 122, 123, 124, 132, 133, 142, 146, 150, 151, 155, 156, 172, 173, 176, 181, 183, 191, 201, 206, 207, 217, 232
Pseudo-diabase.....	222
Pseudo-diorite.....	222
Pseudoleucite-sodalite-tinguaite..	157
Pseudoleucite-syenite.....	154
Pumice.....	141, 198, 229
Pyroxene.....	84, 105, 116, 137, 158, 171, 182, 185, 230
Pyroxene-andesite.....	120, 134, 135, 195
Pyroxene-mica-diorite.....	117
Pyroxene-porphyrite.....	117
Pyroxene-schist.....	113
Pyroxenite.....	83, 140, 224

Q.	Page.
Quartz-alunite rock.....	169
Quartz-andesite.....	207
Quartz-banakite.....	128
Quartz-basalt.....	198, 199
Quartz-diaspore rock.....	169
Quartz-diorite.....	143, 204, 214
Quartz-diorite-gneiss.....	214

Page.	Page.
Quartz-diorite-porphyry.....	124, 206
Quartz-hornblende-mica-porphy- rite.....	175
Quartzite.....	108, 109, 110
Quartz-mica-diorite.....	118, 124, 206, 220
Quartz-mica-diorite-porphyry..	119, 124
Quartz-pantellarite.....	96
Quartz-porphyrite.....	175, 178, 208, 214, 216
Quartz-porphyrite-schist.....	214
Quartz-porphyry.....	67, 81, 102, 146, 150, 201, 232
Quartz-pyroxene-diorite.....	218
Quartz-schist.....	90
Quartz-syenite.....	156
Quartz-syenite-porphyry.....	148, 156
Quartz-tourmaline-porphyry.....	150

R.	Page.
Rhyolite.....	81, 130 131, 132, 134, 150, 151, 167, 168, 170, 174, 177, 179, 184, 188, 192, 202, 214, 228, 229
Rhyolite-pitchstone.....	150

S.	Page.
Sandstone.....	92, 210 247, 248, 249, 250, 251, 252
Saussurite-gabbro.....	100
Saxonite.....	231
Schist.....	78, 90, 98, 99, 100, 101, 113 114, 214, 221, 222, 224, 228
Sericite-schist.....	90, 99
Serpentine.....	72, 73, 203, 205, 209, 223, 226, 227
Shale.....	92, 282, 283, 284, 285, 286
Shell rock.....	259, 260, 276
Shonkinite.....	149, 157
Shoshonite.....	126, 129
Siderite.....	266, 267, 268
Slate.....	109, 277, 278, 279, 280, 281, 283
Smaragdite.....	83
Sodalite.....	66, 154
Sodalite-syenite.....	154
Sölvbergite.....	145
Spherulites.....	170
Spilosite.....	97
Syenite.....	68, 143, 147, 151, 153, 156, 158, 169, 217
Syenite-diorite-porphyry.....	148
Syenite-porphyry.....	68, 69, 147, 217

T.	Page.
Tachylite.....	79
Tallow clay.....	293, 295, 296
Theralite.....	145
Tinguaite.....	145, 157, 182

	Page.		Page.
Tonalite	74	Volcanic ash	229
Tourmaline-biotite-schist	114	Volcanic dust	141
Trachyte .. 115, 132, 145, 152, 163, 165, 186		Volcanic sand	141
Trachyte-andesite	217		
Trachytic rhyolite	131, 132	W.	
Troilite	246	Websterite	84, 92, 224
U.		Wehrlite	77, 140
Uralite-diabase	209	Wollastonite-gneiss	215
Uralite-diorite	205	Wyomingite	115
V.			
Vitrophyre	179	Y.	
Vogesite	152	Yogoite	156