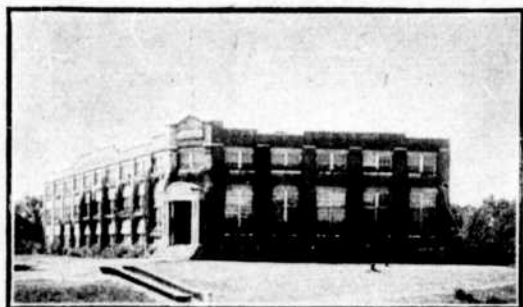




The Institute of Industrial and Domestic Arts

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STUDY PAPER

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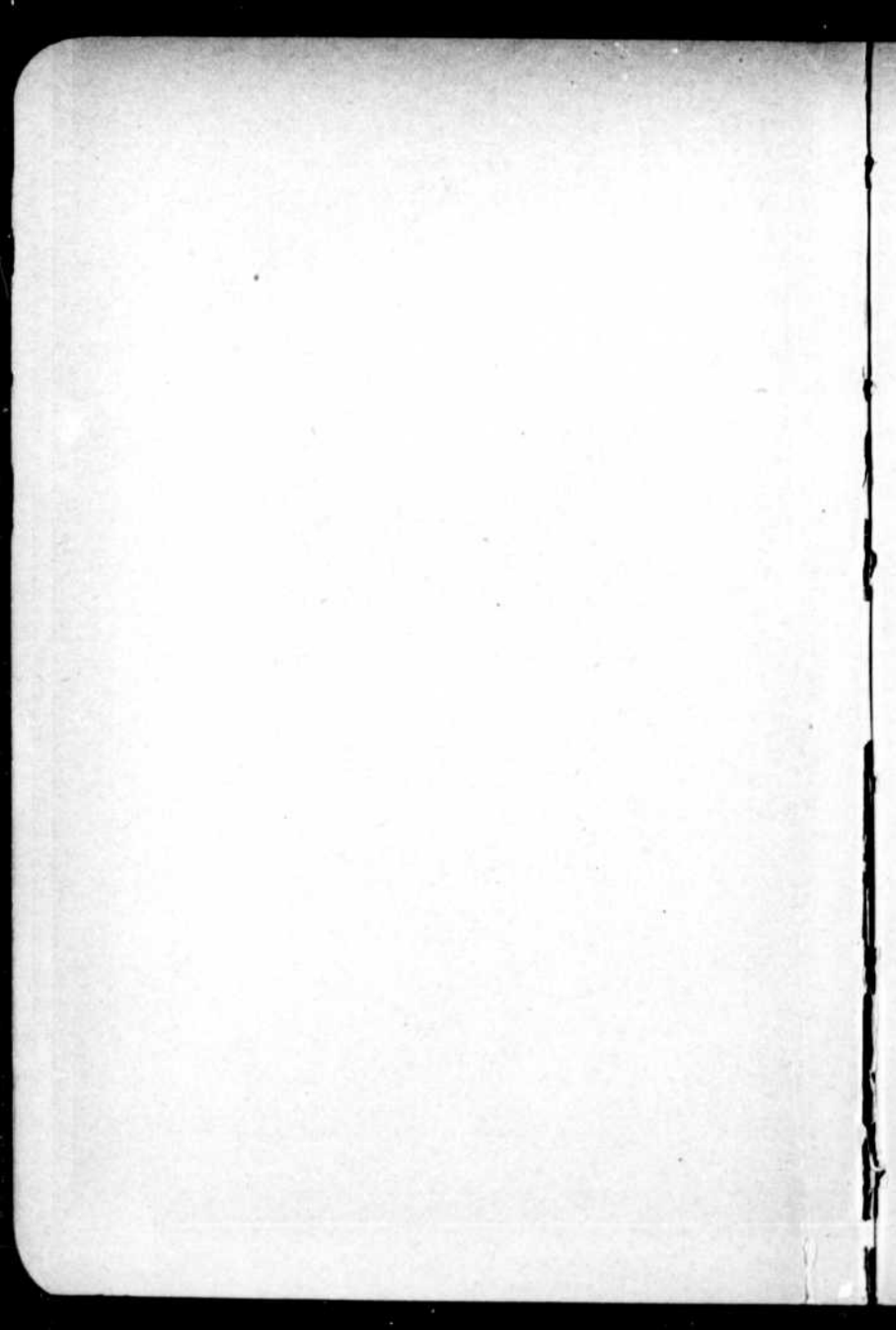
PROSPECTING

PART 1

BY W. L. GOODWIN, D. Sc., LL.D.

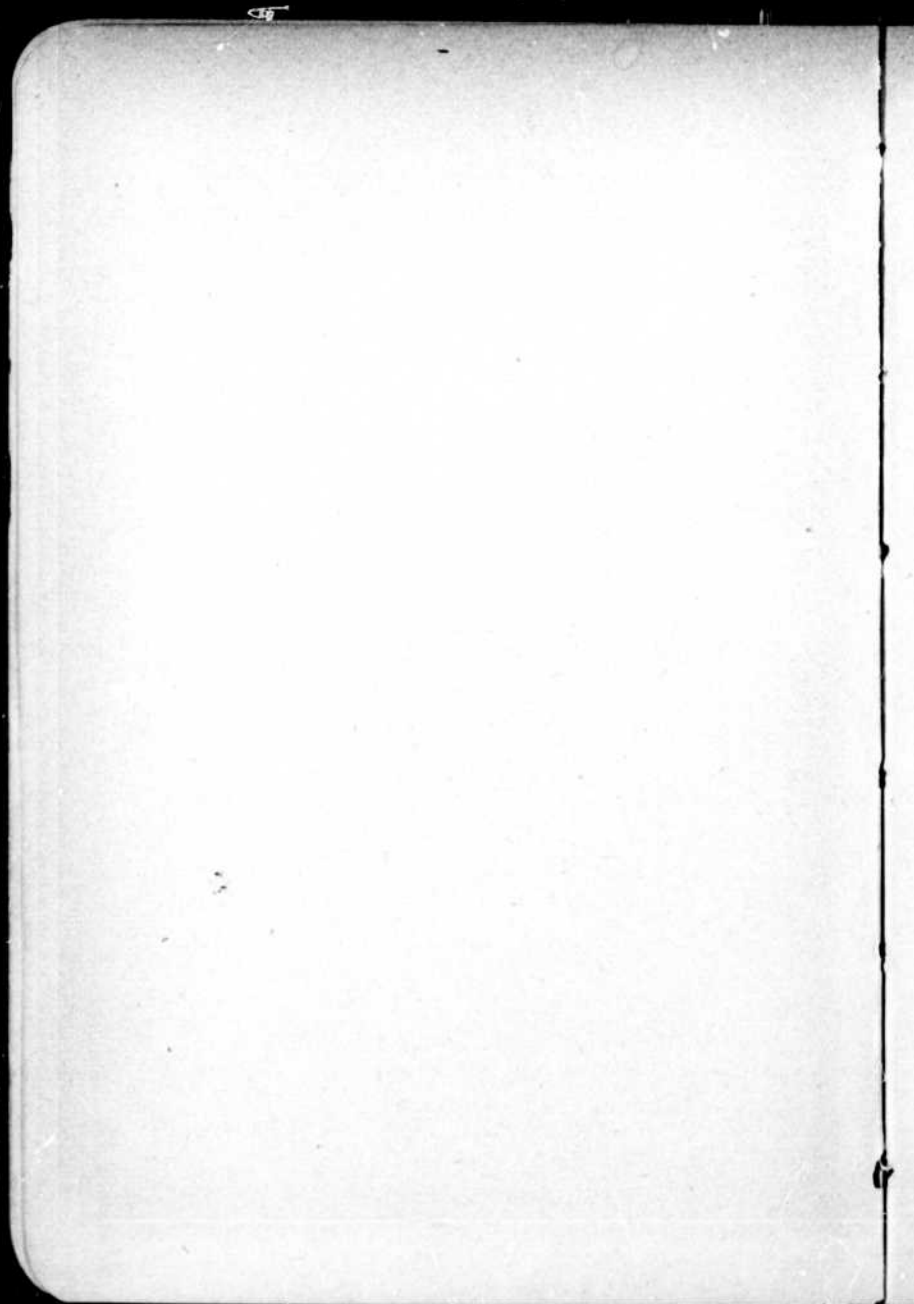
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PROSPECTING

A HANDBOOK FOR
CANADIAN PROSPECTORS



A HANDBOOK OF

PROSPECTING

PREPARED FOR THE INSTRUCTION AND GUIDANCE OF ALL
PROSPECTORS, WITH SPECIAL REFERENCE TO THE
NEEDS OF THOSE PROSPECTING IN CANADA

BY

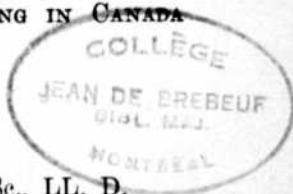
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FIRST EDITION

GARDENVALE, QUEBEC
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PREFACE

This book has been written for prospectors working in Canada, and most of the mineral deposits herein described are therefore Canadian. But it is hoped that the volume may be found generally useful to all who are interested in the discovery and development of mineral deposits and in the advancement of mineral industries. It will be found that a larger amount of space has been accorded to the description of minerals, the principles of geology, and the subject of mineral deposits than is usual in books written for prospectors. Although a final section of the work is devoted to the subject of prospecting, a great part of the special information required by the prospector will be found scattered through the preceding sections.

In the preparation of this textbook, free use has been made of standard works of mineralogy, geology, and ore deposits, and this general acknowledgement will suffice for what has been borrowed from so many sources. The author particularly wishes to thank Dr. W. H. Collins, Director of the Geological Survey of Canada, and Mr. A. G. Burrows, Ontario Department of Mines, for their criticisms of the section on geology; Prof. A. L. Parsons, of the University of Toronto, who read the manuscript

of the section on mineral deposits; Dr. J. L. Tanton and other members of the Geological Survey of Canada, whose contributions, based on their field experience, have been used in the final section on prospecting; Mr. W. M. Goodwin, Editor *Canadian Mining Journal*, for helpful criticisms and suggestions, and for original contribution to the section on Practical Prospecting; and Mr. J. J. Clark, Vice Principal of the Institute of Industrial and Domestic Arts, for his careful editing of the entire work.

The illustrations of crystals and crystal forms have been mostly redrawn from Dana's *Text Book of Mineralogy*; the sources of the other illustrations are mentioned in their places, a few having been made from lantern slides, the sources of which are not known to the author.

Canadian Pacific Steamship, Montrose.

July 12th, 1923.

CONTENTS

PART 1

	Page
Preface	vii

Introduction

Valuable Minerals and Divisions of the Subject	1
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Minerals

Properties of Minerals	3
Scale of Hardness	7
Crystals	10
The Crystal Systems	11
Composition of Minerals	16

Description of Minerals

Division into Groups	19
Group I—Native Elements	23
Metals	23
Non-Metals	26
Group II—Sulphides and Arsenides	31
Group III—Oxides	42
Group IV—Chlorides, Fluorides, etc.	56
Group V—Carbonates	58
Group VI—Silicates	63
Group VII—Phosphates, etc.	81
Group VIII—Sulphates, etc.	83
Mineral Tables (Description of)	86
Tables of Atomic Weights, etc.	90
Mineral Tables	91
Examination Questions	99

PART 2

Rocks and Rock Structures

	Page
Introduction	103
Rocks and Eras	107
Erosion	110
Changes Caused by Waves	118
Changes Caused by Ice	122
Weathering	130

Rock Building

Sedimentation	139
Sedimentary Rocks	141
Movements of Earth's Crust	146
Volcanoes, Lava, etc.	153
Igneous Rocks	163
Plutonic Rocks	165
Volcanic Rocks	168
Porphyritic Rocks	172
Metamorphism	174
Metamorphic Rocks	175
Examination of Rock Specimens	181
Table of Rocks	184
Examination Questions	187

PART 3

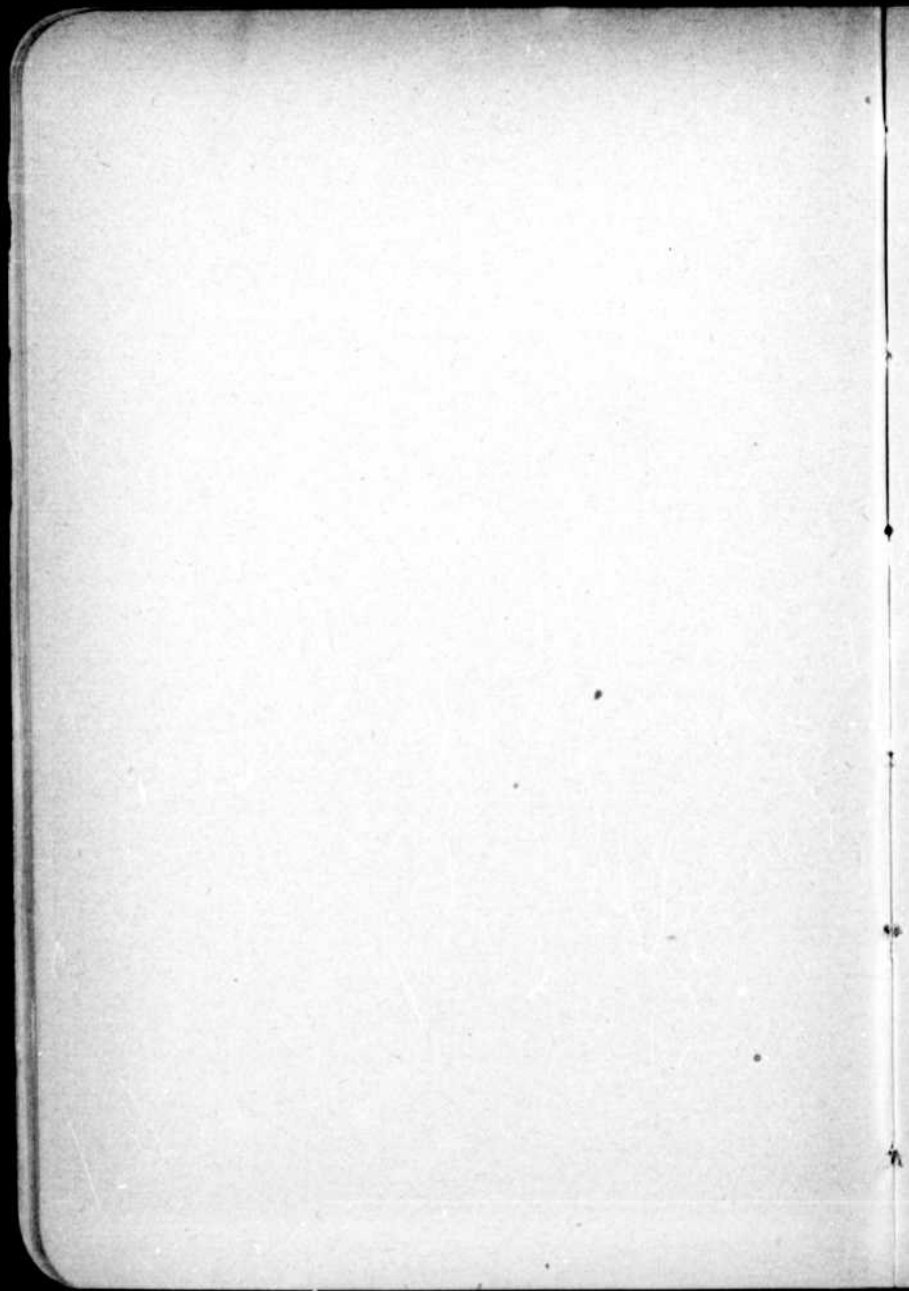
Mineral Deposits

Definitions and Classification	191
Veins and Similar Deposits	193
Mineral Deposition in Veins, etc.	197
Veins, etc. Independent of Igneous Intrusions	203

	Page
Sedimentary Mineral Deposits	204
Surface Enrichment	205
Ore-Forming Epochs	207
Faulting of Ore Bodies	210
Metallic Mineral Deposits	212
Gold and Platinum	212
Silver, Lead, and Zinc	221
Mercury, Antimony, and Arsenic	229
Copper, Nickel, and Cobalt	230
Iron	233
Metals Used in Steel Alloys	238
Other Metallic Ores	244
The Common Non-Metallic Minerals	248
Precious and Semi-Precious Stones	263

Practical Prospecting

Introduction	272
Prospecting Details	274
Surface Indications	296
Handling Discoveries	306
Examinations Questions	311



PROSPECTING

(PART I)

INTRODUCTION

1. **Valuable Minerals and their Occurrence.**—The aim of the prospector is to discover in the earth's crust deposits of certain valuable substances, such as gold, silver, copper, asbestos, talc, fluorspar, etc. These substances are called **minerals**; but it is better to call them **valuable minerals**, because any distinct substance found in the earth's crust is called a mineral, whether it is valuable or not.

In the same district, mineral deposits of several different kinds often occur; and if the prospector be acquainted with only one kind, he will miss chances of making good discoveries. Therefore the wider his knowledge concerning valuable minerals the greater his chances of discovering them.

Valuable minerals are found in veins and other masses, surrounded by barren rock. These ore deposits may be found in some kinds of rocks peculiar to a district and not in others; consequently, it is necessary to study the rocks, in order to avoid wasting time

in searching for valuable minerals in rocks that do not contain them. All rocks are made of minerals; thus, common granite, for example, is composed of feldspar, quartz, and mica. Therefore, to recognize rocks, it is first necessary to be acquainted with the minerals of which they are composed.

2. Divisions of the Subject.—The topography of a country, by which is meant its hills, valleys, precipices, gullies, plains, water courses, lakes, soil, boulders, etc., is the result of the action of forces that have been at work during past ages, and which are still in action. It is important for the prospector to know the origin and meaning of the topography of a country, since it has a distinct relation to the kinds of rocks and to the occurrence of ore deposits. Therefore, the student should practice careful observation of the topography of his own district, where he will find examples of many of the natural phenomena described in these pages.

After mastering these general principles of geology, the student is prepared to study in detail the different kinds of rocks, and to connect their characteristics with the various ways in which they have been found. He will find that there is a close connection between the origin and composition of rocks and the kind of mineral deposits found in them.

The study of minerals and rocks prepares the way for the subject of mineral deposits, which are important masses of valuable minerals in their places in the rocks. While experience in the field is the great requisite, study of mineral deposits as set forth in the

following pages will furnish the student with certain principles and knowledge that he cannot get by merely looking at mineral deposits. But he should lose no opportunity of examining mineral deposits for himself.

Finally, there are a number of practical details pertaining to choice of area, prospecting, staking claims, recording, developing, sampling, use of geological survey maps and reports, note keeping, etc., a knowledge of which is essential to success in the business.

MINERALS

PROPERTIES OF MINERALS

3. General Remark.—Every prospector must have a thorough knowledge of minerals and their properties, the uses to which minerals are put, and the manner in which they occur; and he must be able to recognize them when he finds them. Although the number of minerals is very great, the prospector is concerned with only a small proportion of them; but, even so, the number is considerable, and the student must have some convenient way of getting information regarding them. For this reason, minerals have been divided into classes and groups, the minerals in each class having many properties in common.

The first step in identifying a mineral is to find to what class it belongs; this immediately separates that mineral from the minerals that belong to all

other classes, and it greatly restricts the field of investigation. Then, by making certain simple tests, as described in the text, the various properties are revealed and the mineral is definitely identified.

It will be evident that the student must have a thorough knowledge of how to make these tests, and this can be acquired only by actual practice. By carefully studying the text and applying the instructions contained therein to the specimens he receives for this purpose, he will soon become proficient. In the beginning, it is advisable to work with specimens whose names he already knows, following the directions carefully, and comparing the results he obtains with the properties the specimen is known to possess. When he has become sufficiently familiar with the routine of the process, and has verified the statements in the text in connection with quite a number of different specimens, of all classes, he can then take a specimen whose name is not given, and can apply the same methods to its identification. By proceeding thoroughly and systematically in this manner, he will soon be able to identify minerals in the field.

While the student is not expected to memorize all that is here given relating to each separate mineral, it is advisable that he memorize everything possible regarding those of most importance or those in which he may be particularly interested.

4. Characteristics of Minerals.—A mineral is a distinct substance that is found naturally in the earth's crust; miners often use the word in the sense of ore, or, sometimes, to apply to minerals, like pyrite, that accompany more valuable material, such as gold.

Minerals are usually more or less mixed, which is the reason for one difficulty in spotting (recognizing) them. Thus, quartz, when pure, is free from color, and it is like glass in appearance; but it is often found colored brown, red, pink, etc., due to small quantities of other substances mixed with it. The relative amount of the second substance that imparts the false color to the quartz may be very small.

Minerals can be spotted (recognized, identified) by such properties as color, weight, brittleness or its opposite, malleability, crystal form, cleavage, etc. The student should read very carefully the following description of properties, and should then practice observing and testing these properties, using the named specimens that are supplied to him¹, and comparing his results with the descriptions of the minerals in the text.

5. Color and Streak.—In addition to the difference caused by impurities, the color of a mineral varies more or less with the size of the grain, and this often gives a valuable method for determining the mineral. For example: coarse-grained hematite, which is of a shiny gray or black color, turns red when finely powdered; a golden-yellow piece of iron pyrites gives a

¹ These instructions are intended primarily for those users of this book who are taking the course of instruction offered in this subject by the Institute of Industrial and Domestic Arts, Gardenvale, P. Q., Canada. A set of minerals and rock specimens is supplied to such students. Those who are not taking this course are advised to use these directions and the mineral table to practice the identification of mineral specimens that they may procure from other sources.

black powder; black zinc blende turns brown when rubbed to a fine powder. In making this test, any means of getting a clean, fine powder of the mineral may be used; when the mineral is soft enough, this may be done with the point of a knife blade. Hold the knife short and shove it like a gouge, until a little powder gathers on the point. Rub this off on the palm of the hand or on a piece of white paper, and note the color. Hard minerals may be carefully rubbed on a surface of clean white quartz. Pieces of hard, unglazed porcelain are often used for this purpose, the piece of mineral being so rubbed on them as to make a *mark* or *streak*. The *streak* of a mineral is simply the fine powder made in this way. A *very* hard mineral can be powdered by rubbing or grinding one piece on another.

6. Luster.—**Luster** is the appearance of the surface in regard to the way in which it reflects light. Metals have a peculiar luster, called **metallic luster**, and some minerals that are not metals have **metallic luster**. In the case of some other minerals, the luster is glassy, resinous, etc.

7. Hardness.—The hardness of a mineral is tested by trying to scratch it with some common thing, such as the finger nail or a knife, or by rubbing one mineral against another. Use the knife as directed in Art. 5.¹ As standards of hardness, ten minerals have been selected, forming a scale, numbered from 1 to 10 as follows:

¹This book is divided into numbered divisions, which are called **articles**. The abbreviation for the word article is **Art.**, and for articles, **Arts.**; hence, **Art. 5** means the division numbered 5, and **Arts. 3-5** means articles 3 to 5, inclusive.

SCALE OF HARDNESS

1. Talc—easily scratched by finger nail.
2. Gypsum—not so easily scratched by finger nail.
3. Calcite—scratched by copper coin, but also scratches copper coin, showing the hardness of both to be about equal.
4. Fluorspar—not scratched by copper coin; does not scratch glass.
5. Apatite—rather easily scratched by knife; scratches glass, but not easily.
6. Feldspar—hard to scratch with knife; scratches glass easily.
7. Quartz—not scratched by knife; easily scratches glass.
8. Topaz—scratches quartz (best done with smooth quartz crystal).
9. Corundum—scratches topaz and quartz..
10. Diamond—scratches corundum.

The exact degree of hardness can be found only when pure specimens of these ten minerals are at hand. In practice, one depends on the finger nail and the knife to get a rough approximation.

8. Testing for Hardness.—When testing for hardness, care must be taken to note which object — the specimen or the standard — gives the line of powder when one is rubbed on the other. Thus, when a knife makes a scratch on apatite, the scratch can still be seen when the loose powder is rubbed off; but when a piece of feldspar is drawn over the quartz surface, the line it leaves can be rubbed off, and no scratch remains on

the quartz, which indicates that the powder came from the feldspar and not from the quartz.

Judgment must also be used when testing specimens composed of small grains that are loosely held together. Each grain may be hard, and yet the specimen may give the false impression of being soft, due to the fact that the grains are easily separated from one another. For example, sandstone, which is made up mostly of grains of quartz, may sometimes be scratched by a knife, though each grain, if tested by itself, would be found to be harder than steel.

Hereafter, in stating the hardness of a mineral, the scale of hardness given in Art. 7 will be used, and the hardness will be denoted by **H** and a number. Thus, if the hardness be specified as $H = 6$, for example, this means that the mineral is of the same hardness as feldspar; and if specified as $H = 6.5$, the hardness is between that of feldspar and that of quartz.

9. Weight.—When trying the weight of a piece of mineral in the hand, it is natural to think of its size; but its shape should also be noted; because what is really being done is to estimate the weight as compared with the bulk. A thin, flat specimen is apt to give the idea of largeness, while a thick or rounded piece of the same bulk looks smaller. That this simple rough test may give a reasonably correct idea of the weight as compared with the bulk, always choose a specimen that is as near as possible to a cube or a ball in shape. The specimens with which the student is supplied are, as far as is practicable, all of the same size and shape. With practice and judgment, testing

by trying in the hand will give a fair idea of the relative weight of minerals; it is quite easy, for example, to distinguish calcite, which is about $2\frac{3}{4}$ times as heavy as water, and barite, which is about $4\frac{1}{2}$ times as heavy as water. For exact work, the weight of a mineral is always compared with the weight of the same bulk of water, and the result is called the **specific gravity** of the substance, which will hereafter be denoted by **G**. Thus, the specific gravity of calcite is specified as $G = 2.7$, which means that a piece of calcite weighs 2.7 times as much as the same bulk of water. The weight of a cubic foot of water is 62.4 pounds, and the weight of a cubic inch is $62.4 \div 1728 = .0361$ pound; hence, the weight of a cubic foot of calcite is $62.4 \times 2.7 = 168.5$ pounds, and the weight of a cubic inch is $.0361 \times 2.7 = .0975$ pound.

10. Magnetism.—If a mineral is attracted by a magnet, it is said to be **magnetic**. The relative strength of this property (attraction) can be judged by noting the size (weight) of the pieces the magnet will pick up, because the specimen attracts the magnet just as much as the magnet attracts the specimen. If the strength of attraction be tested by powdering the mineral with the point of a knife, a wrong impression may be obtained on account of bits of steel being rubbed off the knife. It is therefore better to test grains of the mineral that are large enough to identify and separate.

CRYSTALS

11. How Crystals are Formed.—Minerals. have taken their place in the earth's crust by becoming solid from an originally liquid condition, either melted rock matter (magma) or dissolved in water. When the change from a liquid to a solid has been slow enough and undisturbed, the minerals have grown as crystals, which are beautiful, smooth forms. Each mineral has its own distinct form; and it is therefore possible to distinguish minerals one from another by the shape of their crystals, provided the crystals have had a chance to form. That they may grow to perfection, crystals must not be crowded, and they must grow slowly. Where a number of minerals are mixed in the same liquid, each substance goes to its own place, where very small crystals of that particular mineral have started to grow; in this way, there is more or less separation of minerals one from another. Where there has been a very slow growth, very large crystals have been formed, as in the case of the best feldspar deposits, where the separation of quartz from feldspar has been so perfect that great bodies of clean feldspar can be mined.

The various kinds of crystals are distinguished by the angles which their faces make with one another. Though there are thousands of different forms, it has been found that they can all be grouped into six (6) systems. A thorough study of these is too much of a task for a beginner's course, but the simple introduction that follows will be found useful.

THE CRYSTAL SYSTEMS

12. Description of the Systems.—As stated in the last paragraph, the crystal systems are six in number. Any crystal, no matter what its shape, may be assigned to one and only one of these six systems. These systems are differentiated as follows:

I. Cubic or Regular.—The forms are shaped on the plan of a cube, so that the crystal has the same properties, for example, cleavage, in three directions at right angles to one another.

A crystal may grow faster or slower in one direction than in others. In this way, a cube may become elongated or flattened, so as to appear to belong to the tetragonal or to the orthorhombic system. But its place in the cubic system is shown by the equal brilliancy of its surfaces, equally good cleavage in three directions at right angles to one another, or some other property. Irregular growth may so distort a crystal as to make it look very unlike the perfect form, but the angles between the corresponding surfaces are unchanged.

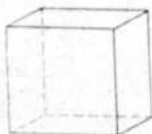


FIG. 1
Cube

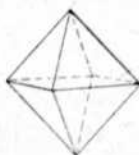


FIG. 2
Octahedron

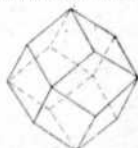


FIG. 3
Rhombic
dodecahedron

Cubic System

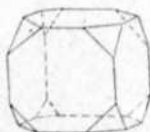


FIG. 4
Cube and Octahedron
The small faces if extended
would form Fig. 2

Cubic System

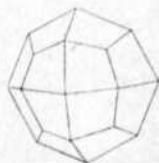


FIG. 5
Trapezohedron

PROSPECTING



FIG. 6

Rhombic
dodecahedron

FIG. 7

Rhombic dodeca-
hedron distorted by
more rapid growth
in one direction

Cubic System

II. Tetragonal.—Crystals resemble those of the cubic system in being shaped on the square plan; but they have the same properties in only two of the three directions, those for the third being different.



FIG. 8

Prism

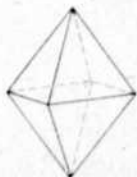


FIG. 9

Pyramid



FIG. 10

Prism and
pyramid

FIG. 11

Prisms
and pyramid

Tetragonal System

III. Hexagonal.—Crystals in which angles of 60° and 120° are characteristic; example, the six-side prism.

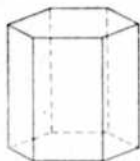


FIG. 12
Prism

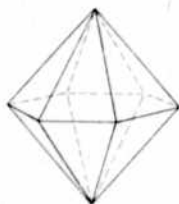


FIG. 13
Pyramid

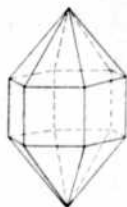


FIG. 14
Prism and
pyramid

Hexagonal System



FIG. 15
Rhombohedral



FIG. 16
Scalenohedron
and rhombohedron

Hexagonal System

IV. Orthorhombic.—Like I and II, ruled by right angles, but the properties of the crystals differ in all three directions.

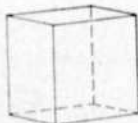


FIG. 17
Prism

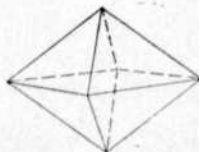


FIG. 18
Pyramid

Orthorhombic System

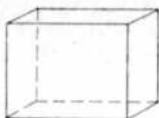


FIG. 19
Pinacoids



FIG. 20
Pyramids
Orthorhombic System

V. Monoclinic.—The plan of the crystals is such that it is off the square in one direction.

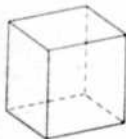


FIG. 21
Prism



FIG. 22



FIG. 23



FIG. 24

Pyroxene crystals
Monoclinic System

VI. Triclinic.—The crystals in this system have departed altogether from the square plan.

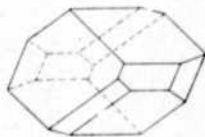


FIG. 25
Axinite crystal
Triclinic System

13. Cleavage and Fracture.—**Cleavage** is a property of crystals; it may be compared with the splitting of wood. Crystals of some minerals break in *certain* and *definite* directions, with smooth, flat surfaces, while others break irregularly in every direction

the former are said to have **good cleavage** and the latter, **no cleavage**. The irregular break, or fracture, is described as **uneven**, **hackly**, or **granular** when it is rough, and as **conchoidal** when it is smooth and rounded, like a shell. The break may be flat and even and very much like that of true cleavage; but close examination will reveal small hollows and elevations that are not seen on a true cleavage surface.

It should be noted that cleavage is a property of the single crystal, and that a mineral with good cleavage splits nicely only in certain and definite directions. If a specimen is made up of a great many small crystals having good cleavage, these crystals will be set at all sorts of angles relatively to the directions of good cleavage; so when the specimen is broken across, the cleavage will appear as smooth, flat patches, of a size depending on the size of the crystals, and set at various angles. On examining such specimens in a strong light, good cleavage surfaces will reflect like mirrors, as the specimen is turned very slowly.

14. Parting.—Crystals of some minerals break with smooth, flat surfaces at some places; but this differs from true cleavage in the fact that between these places, the break is rough and irregular. Corundum crystals have this property, which is called **parting**.

15. Twinning.—Two or more crystals may grow together in certain definite ways, thus producing a crystal body that is called a **twin**. (See Fig. 49.) Grooves, or striations, and other irregularities on the surface are sometimes due to twinning. (See Fig. 52.)

COMPOSITION OF MINERALS

16. Pure Minerals always Have same Composition.

A pure mineral, one that is not mixed with any other mineral, is always of the same composition (certain exceptions). For example, iron pyrites is composed of iron and sulphur, in the proportion of 46.67% of iron and 53.33% of sulphur; and any specimen of the pure mineral will, when analyzed, always contain iron and sulphur in these proportions. But it is usual to find iron pyrites more or less mixed with other minerals, and the analysis of an ordinary specimen will be somewhat different from that given above.

17. Atomic Weights and Composition Formulas.

Chemists have worked out a very handy way of stating the composition of substances by what are called **composition formulas**. All substances are made up of about 80 *simple* substances, called **elements**. Some substances are composed of a single element. For example, native gold, silver, copper, and sulphur are examples of minerals each of which is composed of a single element of like name. Substances made up of two or more unlike elements are called **compounds**, and the elements in compounds are combined in twos, threes, etc. For example, calcite, the mineral of limestone, is composed of three elements, calcium, carbon, and oxygen; hematite is composed of iron and oxygen; galena, of lead and sulphur; etc. It has also been found that the composition of minerals, as well as of all other substances, is on such a simple, natural plan that it can be stated in terms of certain numbers, called

atomic weights, one number being assigned to each of the 80 or so elements. For example, the numbers (atomic weights) for lead, iron, oxygen, and sulphur are 207, 56, 16, and 32, respectively (omitting small fractions). The composition of galena is such that the weight of the lead is to the weight of the sulphur as 207 is to 32. The composition of iron pyrites can be stated as 56 of iron to 2×32 of sulphur; and of hematite as 2×56 of iron to 3×16 of oxygen.

A very convenient shorthand has been built up in connection with this. A letter (or two letters) is chosen as a symbol to represent the name and the weight-number (atomic weight) of each element; thus, Pb represents 207 parts of lead (by weight), Fe = 56 parts of iron, O = 16 parts of oxygen, and S = 32 parts of sulphur. By placing these symbols together, what are called **composition formulas** are constructed for substances composed of two or more elements. Thus, galena has the formula PbS, which means that it is composed of lead and sulphur in the proportion of 207 to 32. The composition formula for iron pyrites is FeS₂, the subscript 2 being a multiplier of the value of the symbol S. A subscript always belongs to the symbol that **precedes** it. Consequently, from this formula, it is known that iron pyrites is composed of iron and sulphur in the proportion of 56 parts of iron to $2 \times 32 = 64$ parts of sulphur. Hematite has the formula Fe₂O₃, which means that it is composed of $2 \times 56 = 112$ parts of iron and $3 \times 16 = 48$ parts of oxygen.

These formulas, when rightly understood, convey a great deal of information. Since only about 30 ele-

ments are represented in the composition of the common minerals, the symbols and atomic weights of these may be memorized with little effort; then, if the formula for any particular mineral be known, the percentage of each element in it can be readily calculated. Thus, to find the per cent of iron in pure hematite, which has the formula Fe_2O_3 .

Number of parts of iron	=	2	×	56	=	112
“ “ “ “ oxygen	=	3	×	16	=	48
						160
					Total	= 160

Then, iron = $\frac{112}{160} = .70 = 70\%$. By proceeding in

this manner, the per cent of any element in any mineral whose formula is known can be readily found.

At the end of this Part, a table is given that includes all the known elements, their symbols, and their atomic weights according to the latest determinations. In this table, the atomic weight of iron is given as 55.84, of sulphur as 32.07, of silicon as 28.3, etc. But for calculating the per cents of an element in a mineral, it is sufficiently exact to take iron as 56, sulphur as 32, and silicon as either 28 or 28.3. In any case, not more than one decimal place should be used.

18. Chemical Changes in Minerals.—The prospector should have a clear idea of the nature of certain changes that minerals often undergo, which may be so radical that minerals are transformed into other minerals; these transformations are called **chemical changes**. For example, when iron pyrites is acted upon by air and water, it becomes changed into a rusty sub-

stance, limonite, well known to prospectors as **gossan**. The pyrites, air, and water all take part in this change, and a second new substance, sulphuric acid, which is not noticed, is formed at the same time.

DESCRIPTION OF MINERALS

19. Remark.—In the following pages, Arts. 25-123, the common minerals are described, and the descriptions are of direct interest to the practical man. The student should read these descriptions very carefully, but without attempting to memorize them; the memorizing is done more easily and surely while handling specimens. Those who are taking the course of instruction founded on this book are provided with a set of specimens, some of which are named and some are unnamed. These specimens should be handled in the manner described in Arts. 21 and 22. The set includes the minerals that are valuable as ores of metals and for other purposes; it also includes a number of minerals of no value in themselves, but which are of importance as rock-forming minerals. In addition to the descriptions of the commoner minerals, there are included descriptions of rarer but still important minerals; these descriptions are printed in smaller type.

20. Division into Groups.—The great majority of minerals are compounds of two or more elements, though a few are **native elements**, i. e., elementary substances, as gold, silver, platinum, copper, carbon, and

sulphur, which are found naturally. Minerals may be conveniently divided into the following eight groups, and the descriptions will be in accordance with this plan:

- I. Native elements.
- II. Sulphides and arsenides.
- III. Oxides.
- IV. Chlorides, fluorides etc.
- V. Carbonates.
- VI. Silicates.
- VII. Phosphates, etc.
- VIII. Sulphates.

In the following descriptions of minerals, **H** is used for hardness (see Art. 8), and **G** for specific gravity (see Art. 9). After the name of an element is its symbol; and the names of mineral compounds are usually followed by their composition formulas.

21. How to Study the Descriptions.—Study these descriptions with the specimens before you, and wherever possible, test the properties as described in the text in accordance with the following plan:

Take, for example, specimen No. 20, galena. Turn to the description of galena, Art. 45. Note the appearance of the specimen, bright like a metal, thus corresponding to *metallic luster*, as given in the text. The specimen looks like lead; compare this with what the text states about its color. Using the point of a knife (see Art. 5), dig a little powder from the specimen, and note the color of the powder when rubbed off on the palm of the hand or on a piece of white paper.

The powder is gray; but if you happen to get it very fine, it will be darker gray than the specimen. See what the text states. While doing this, you have got the impression that the mineral is fairly soft. The text gives the hardness as $H = 2.5$ to 2.75 ; look at the Scale of Hardness, Art. 7, and see where these numbers fit into it. Heft (weigh) the specimen in the hand, and compare the impression it gives you with the specific gravity as given in the text. Remembering that the piece you are examining was broken from a larger piece, note how it has broken, with very smooth, flat, brilliant surfaces, indicating very perfect cleavage, which agrees with the text. The specimen may have been broken from a single crystal, in which case, the corners and edges of the whole piece are square, with occasional steps that are also built on the square. If the specimen is made up of a great many small crystals, each will also show the square corners, edges, and steps on the broken surface. Break out a very small bit, examine it carefully, and note that it is bounded by six faces (barring steps), all showing equally perfect cleavage. This shows that galena crystallizes in the cubic system, and that its cleavage is cubic. Read the entire description of galena as given in the text.

22. Specimen No. 50, Quartz.—Compare it with galena, and note that quartz does not have a metallic luster; its luster is like that of glass. Compare with the description of quartz, Art. 75. The specimen is white. Note what the text states about the color of quartz. Try to powder the quartz with the point of a

knife; if this does not work, grind the corner of a small piece into the large piece, and note the color of the powder. Read what is stated about the powder in the text. When trying to get some powder by digging with the knife, you get the impression that quartz is very hard. Try again, pressing very hard and pushing slowly; the black mark on the quartz is steel from the knife. See if you can scratch the knife blade with the quartz. The results show that quartz is harder than steel. Note what number is given in the text for the hardness of quartz, and then look up its place in the Scale of Hardness. Heft the specimen in the hand, and compare its weight with that of the galena specimen. The specific gravity of quartz, as given in the text, is 2.6 to 2.66; galena is nearly three times as heavy. Verify this by comparing the numbers (specific gravities). The specimen you are examining was broken off a larger piece; examine the surface and note that it is rough and irregular. Compare this with what the text states regarding the cleavage of quartz. Read the whole description of quartz as given in the text, but do not attempt to memorize all the information about the varieties.

23. Advice to the Student.—It is important that the student have a great deal of practice in observing and testing the properties of known specimens, so as to train the eye, the hand, and the general powers of observation. This will be a fine preparation for the much harder task of identifying specimens whose names are not given. Work through the named specimens supplied in the set, systematically observing and

comparing the results obtained with the statements in the text.

After finishing with these, the unnamed specimens supplied in the set are to be identified by the use of the mineral table, instructions regarding the use of which are given in Arts, 124 and 125. It is not always possible to identify a mineral by its appearance or even by applying all the simple tests given in the table. Often the most accomplished mineralogist must use the appliances of a laboratory in testing a mineral, before he can identify it. But by using the table to identify a considerable number of "unknowns", the student is getting experience that familiarizes him with the commoner minerals; and he gradually learns to recognize them at sight, or after testing the weight and hardness.

GROUP I — NATIVE ELEMENTS

METALS

25. Subdivisions of Group I.—Group I is subdivided into two classes, metals and non-metals, to accord with similar divisions in chemistries.

26. Gold.—Symbol, Au.; color, yellow, but paler when mixed with silver, which is usually present in native gold; **H** = 2.5 to 3; **G** = 19.33 for pure gold, but is less in proportion to the amount of silver present, and it may be as low as 15. Malleable, and thus spreads or draws out without powdering when pressed with point of a knife. **Electrum** is a natural alloy of

gold and silver; it is white or quite pale yellow. Pyrite and copper pyrites, which resemble gold in color, powder and turn black, while yellow scales of mica powder and turn white. Another distinction between these substances and gold is that a speck of gold shows the same brightness at every angle, but a bit of pyrite or yellow mica changes in brightness as it is turned. When the specimen is wet, the color of the gold comes out better. Since gold is the standard of values (23.22 grains being exactly equivalent to a dollar), an ounce Troy is always worth $480 \div 23.22 = \$20.6718 +$, say \$20.67.

Gold is usually found in quartz veins in certain schists (schists are rocks having a sheeted or laminated structure), as chlorite, talc, and slaty schists; also in mica schist, hornblende schist, gneiss, diorite, porphyry, rhyolite, and occasionally in granite; and in South Africa, in an altered conglomerate. It likewise often extends into the wall rocks of such veins. Gold is commonly associated with pyrite, the gold values being partly in this mineral. Other minerals found in gold veins are copper pyrites, galena, zinc blende, mispickel, tellurides, native bismuth, bismuthinite, native arsenic, stibnite, magnetite, hematite; also, sometimes, scheelite, siderite, fluorite, and apatite. In gold regions, gold is also found in the sand and gravel that is formed by the washing down of the weathered rocks and gold veins; this is known as placer or alluvial gold, and it is accompanied by such hard, heavy minerals as magnetite, garnet, zircon, topaz, corundum, etc., and sometimes by platinum.

27. Silver.—Symbol, Ag; color, white on fresh surfaces, but tarnishes to brown or black; **H** = 2.5 to 3; **G** = 10.5, but may be as high as 11.1 on account of gold (up to 10%) alloyed with it. When pressed with the point of a knife, it spreads or flattens, but does not powder. Silvery specks of galena or mispickel, which resemble silver, are powdered and turn black; while silvery scales of mica, sericite, or talc are powdered and turn white. The value of silver varies from 60 cents an ounce Troy up to \$1.00 or more (exceptionally). Found in veins in gneiss, schist, porphyry, etc.; in Ontario, in calcite veins in conglomerate, slate, and diabase.

28. Copper.—Symbol, Cu; color, red, but may be covered with a black, brick-red, green, or blue tarnish; **H** = 2.5 to 3; **G** = 8.8 to 8.9. Its malleability distinguishes it from other coppery-red minerals, such as niccolite and breithauptite, which are powdered black when rubbed with the point of a knife. The value of copper when ready for the market is about 15 cents a pound, but varies according to market conditions.

Native copper accompanies other ores, especially cuprite, malachite, and azurite. In the Lake Superior district, it is found in amygdaloid trap and sandstone, near the contact.

29. Platinum.—Symbol, Pt; color, light steel-gray; **H** = 4 to 4.5; **G** = 14 to 19; for the purified metal. **G** = 21 to 22. Native platinum is more or less alloyed with iron (up to 18%), copper, palladium, rhodium, iridium, and osmium. It is often magnetic, particularly when it contains much iron. Value varies; but at pre-

sent, 1923, it is \$116.00 per ounce. On account of its freedom from rusting, its resistance to chemicals, and its high melting point, platinum is very useful in chemical manufactures and analysis, for certain parts of electrical appliances, for jewelry, etc.

Platinum is found mostly in alluvial (placer) deposits; also, in peridotite and other olivine rocks, and in serpentine, accompanied by chromite.

Iridosmine, or **osmiridium**, is a silvery-white, hard, heavy alloy of the valuable metal iridium with platinum, osmium, and other metals; it is found with native platinum and gold.

30. Arsenic.—Symbol, As; color, tin-white, but usually tarnished to dark gray; luster, dull metallic; $H = 3.5$; $G = 5.63$ to 5.73 . Arsenic is brittle; it powders to metallic gray-white. Native arsenic is not a common material, and is not found by itself in commercial quantities, although it occurs in ores of silver, nickel, and cobalt. From such ores, the arsenic is extracted in the form of the oxide, **white arsenic**, commonly called arsenic, which sells at 3 cents to 7 cents a pound.

31. Bismuth.—Symbol, Bi; color, silvery-white, with slightly reddish tint; powder, the same; tarnishes to brass-yellow; $H = 2$ to 2.5 ; $G = 9.70$ to 9.83 ; cuts easily; cleavage, perfect.

All the minerals so far described are metals (or near-metals), and all have the peculiar shining appearance called **metallic luster**.

NON-METALS

32. Sulphur.—Symbol, S; color, commonly yellow, but sometimes brownish, greenish, reddish, or gray; luster, resinous; $H = 1.5$ to 2.5 ; $G = 2.05$ to 2.09 ;

rather brittle; powder, white; melts easily; burns with a blue flame and choking gas. Sometimes found in crystals of the orthorhombic system. (See Fig. 20).

Native sulphur is found in volcanic districts, in deposits from hot springs, in gypsum beds, and very extensively in limestone in Texas and Louisiana. It is used in the manufacture of sulphuric acid and many other chemicals, and in the manufacture of wood pulp by the sulphite process. The selling price is from \$16.00 to \$20.00 per ton.

33. Diamond.—Symbol, C; color is ordinarily white, but various other colors occur; **H** = 10; **G** = 3.516 to 3.525; luster, adamantine, i. e., very brilliant, but the natural surfaces are often rough and dull. The diamond is a kind of carbon, and is found in crystals belonging to the cubic system, often rounded; cleavage (octahedral) is very perfect. **Carbonado** is black diamond, amorphous or confused in its crystallization; it is used for diamond drilling, etc. **Bort** is diamond too dull or defective for use as a precious stone; it is used for glass-cutting, diamond-drilling, etc. Diamonds burn when heated strongly in air or oxygen. Very small diamond crystals have been made from charcoal. The value of clear crystals is large, and it increases very rapidly with the size.

Diamonds are found in placer diggings, but most abundantly in South Africa in volcanic "necks" or "pipes", which are filled with decomposed rock derived from peridotite.

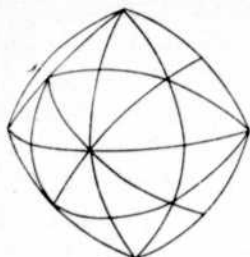


FIG. 26

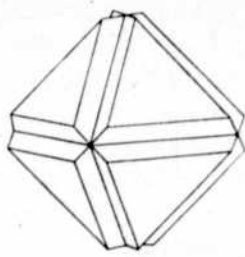


FIG. 27

Diamond Crystals

34. Graphite.—Symbol, C; color, iron-black or dark steel-gray; **H** = 1 to 2; **G** = 2.09 to 2.23. Graphite is also a kind of carbon, but crystallizing in the hexagonal system; other names for graphite are **plumbago** and **black lead**. Cleavage, perfect, but not apparent in very fine-grained varieties; luster, **metallic**, very bright when crystals are large, but dull in fine-grained varieties; but the luster appears when the specimen is rubbed with a knife. Graphite makes a gray mark on paper, and it has a greasy feel. Considerable quantities of artificial graphite are made from coke by using the electric current to heat it to a very high temperature. Graphite is used for lead pencils, crucibles, lubricants (Acheson's **oildag** and **aquadag** are made from artificial graphite), foundry facings, etc. In the market, two classes of graphite are distinguished: flake or crystalline, which sells for from \$65.00 to \$160.00 per ton, and amorphous, which sells for from \$15.00 to \$65.00 per ton.

Although not elements, coal, petroleum, and amber may be conveniently described here.

35. Coal.—Coal is composed more or less of the element carbon, but (especially in the softer varieties) mixed with compounds of carbon. First-class anthracite coal is mostly carbon (up to 95%); it is amorphous, i. e., not crystalline. All varieties of coal contain non-combustible substances that are left behind as ash when the coal is burned. Coal has been formed by the slow change, under water at first, of accumulations of plant remains. The first stage is *peat*, which is still being formed. The peat of past ages has slowly changed into *lignite* then into *bituminous coal* (soft coal), and finally into *anthracite*, these varieties shading into one another. Ordinary peat shows the plants of which it is composed, matted together. In lignite, the forms of the plants have mostly been destroyed, still more so in ordinary bituminous coal, while in anthracite, the bodies of plants are rarely seen. True coal has not been found in rocks older than those of the Devonian period, and only very little has been found in Devonian rocks.

Anthracite is black, of bright luster; powder is black; breaks with rounded surfaces (conchoidal fracture); composition, from 80% to 95% carbon, the remainder being mostly ash and carbon compounds; **H** = 2.5 to 3.5; **G** = 1.4 to 1.7.

Bituminous coal (*soft coal*) is black; powder is black. It differs from lignite in containing less oxygen and less water, and it differs from anthracite in giving, when heated, more oily and tarry substances, which cause it to burn with a smoky flame. It breaks more

easily than anthracite, and often shows a layered structure. **H** = 2 to 3; **G** = 1.2 to 1.4.

Lignite (*brown coal*) is from brown to black in color; powder is brown or black; contains from 15% to 36% of water, and shades into ordinary bituminous coal; **H** = 1 to 2; **G** = 1.2 to 1.4 **Jet** is a black variety, capable of taking a high polish, which is used for ornaments.

Peat is mostly made up of decaying bodies of mosses; when dried, it is a good domestic fuel. When pulped and air-dried, it forms a solid mass, which might be used in place of coal to a large extent; but it is not practicable to transport it long distances.

36. Petroleum.—**Petroleum** is an oil. — thin, though sometimes thick (viscous), — usually of a greenish-brown color, but sometimes colorless, yellow, brown, or nearly black; it finally grades into **asphalt**. Since its specific gravity is from 0.6 to 0.9, it floats on water. Petroleum is a mixture of a great many compounds of carbon and hydrogen. **Natural gas**, which is found in petroleum fields, is a mixture of similar compounds of carbon and hydrogen; it contains in addition hydrogen and other elementary gases and sometimes helium.

37. Amber.—**Amber** is a fossil resin, usually of a yellow color, but sometimes reddish, brownish, or whitish; **H** = 2 to 2.5; **G** = 1.096; when heated, it softens and melts. Amber is composed of carbon, hydrogen, and oxygen; it has been found extensively near and on the shore of *Cedar Lake*, in Northern Manitoba.

GROUP II — SULPHIDES AND ARSENIDES

REMARK.—The sulphide and arsenide minerals are compounds of the metals with sulphur and arsenic. Nearly all these minerals have a metallic luster, i. e., the peculiar shining appearance of metals, such as gold, silver, copper, lead, tin, iron, etc. They are all heavy minerals, and nearly all are of economic importance. The student should read the descriptions with specimens in hand, make the usual tests, look up the atomic weights corresponding to the symbols, and calculate the per cents of valuable constituents, as shown in Arts. 17, 38, and 40.

38. Iron Pyrites or Pyrite; FeS_2 .—Color, pale brass-yellow; fine powder (streak), greenish-black or brownish-black; luster, metallic; $H = 6$ to 6.5 . i. e., a little harder than ordinary steel; it strikes fire with steel, and the name "pyrite" refers to this, being derived from the Greek word for fire; $G = 4.95$ to 5.10 , i. e., it is about 5 times as heavy as water. Since a cubic foot of water weighs about 62.4 pounds, a cubic foot of pyrite weighs about $62.4 \times 5 = 312$ pounds, and 7 cubic feet of pure pyrite will weigh rather more than a ton (2,000 pounds). As actually found in the earth's crust, a workable deposit of pyrite is mixed more or less with lighter minerals; hence, in making an estimate, the weight of 7 cubic feet may be taken as a ton. The crystals are in the cubic system; cleavage, almost absent.

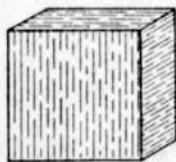


FIG. 28

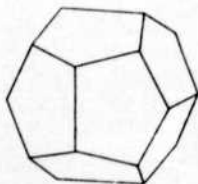


FIG. 29

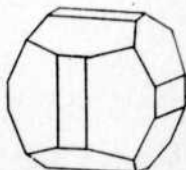


FIG. 30

Pyrite Crystals

To calculate the percentage of sulphur, which is the valuable constituent in this case, the atomic weights of iron and sulphur may be taken as 56 and 32, respectively. This mineral, then, is composed of 56 parts of iron and $2 \times 32 = 64$ parts of sulphur; the total number of parts considered is $56 + 64 = 120$, and the

proportion of sulphur is $\frac{64}{120} = .533 = 53.3\%$. The

per cent of iron is $100 - 53.3 = 46.7\%$. In making rough estimates, the composition may be considered as 50-50, i. e., as half sulphur and half iron.

Pyrite is found in rocks of all ages; it burns freely when fed into special furnaces. The gas that is formed by the combustion is sulphur dioxide, SO_2 ; it is used in the manufacture of sulphuric acid, and in the sulphite-pulp process. The furnace residue, called **blue billy**, is of the same composition as hematite, and it is sometimes used as an iron ore. The selling price is 11 cents to 14 cents per unit, by which is meant 11 cents to 14 cents per ton for each 1% of sulphur in the ore. For a 50% ore, this would work out as $\$0.11 \times 50 = \5.50 to $\$0.14 \times 50 = \7.00 per ton. As a source of sulphur, native sulphur that is guaranteed 99.5% pure, at \$16.00 to \$20.00 per ton, may compete favorably with pyrite, due to lower cost of transportation and of handling in the furnaces, the iron in the pyrite being so much dead weight.

39. Marcasite; FeS_2 .—Marcasite has same composition as pyrite, but is paler in color; whence, it is called **white iron pyrites**. It weathers more easily than

pyrite, and is therefore more apt to have a sour, inky taste; **H** = 6 to 6.5; **G** = 4.85 to 4.90. It crystallizes in a different system, the orthorhombic, (see Fig. 30A.) The crystals are wedge-shaped and are often in masses notched like the comb of a cock, whence the name **cock's comb pyrites**.

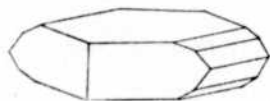


FIG. 30A
Marcasite Crystal

40. Copper Pyrites, or Chalcopyrite; CuFeS_2 . Color, brass-yellow, rather deeper than pyrite, often tarnished with a variety of colors; powder, greenish-black; luster, metallic; **H** = 3.5 to 4; **G** = 4.1 to 4.3; it is much softer than pyrite, and is easily scratched with a knife; visible crystals (tetragonal system) are not common; cleavage, usually indistinct. Note that it is lighter than pyrite, a cubic foot weighing about $62.4 \times 4.2 = 262$ pounds, and there are nearly 8 cubic feet to the ton ($2,000 \div 262 = 7.63$). Taking the atomic weight of copper as 64, there are 64 parts of copper, 56 parts of iron, and $2 \times 32 = 64$ parts of sulphur, a total of 184 parts; hence, the proportion of copper is

$$\frac{64}{184} = .348 = 34.8\%, \text{ which is also the proportion of}$$

184 sulphur. The proportion of iron is $100 - (34.8 + 34.8) = 30.4\%$. Roughly, the ore may be considered as composed of one-third each of copper, sulphur, and iron. This is the commonest ore of copper; but its value

depends so much on circumstances other than the percentage of copper contained in it that it is not quoted on the market.

Copper pyrites is found in veins and lenses in a great variety of rocks, often mixed with iron pyrites, zinc blende, galena, pyrrhotite, bornite, and chalcocite.

41. Pyrrhotite, or Magnetic Pyrites.—Color, bronze-yellow, sometimes inclined to copper-red, occasionally nearly gray; powder, grayish black; luster, metallic; $H = 3.5$ to 4.5 ; $G = 4.58$ to 4.64 ; magnetic; composition, iron and sulphur in variable proportions — iron 59% to 62%, and sulphur 41% to 38%. By reason of the lower sulphur content, pyrrhotite does not burn by itself, but requires that it be mixed with wood or coal. It cannot be used in place of iron pyrites, although it has been mixed with that mineral as a source of sulphur. Sometimes, as in the Sudbury district, it carries nickel; but most of the nickel is in the form of distinct minerals, especially *pentlantide*, a sulphide of iron and nickel that contains 22% of nickel.

Pyrrhotite is found in many kinds of rocks; but in large masses, it is usually associated with basic rocks, such as gabbro and norite.

42. Bornite, or Peacock Copper Ore.—Color, copper-red or brownish, usually tarnished with a variety of colors, often very brilliant; powder, grayish-black; luster, metallic; $H = 3$; $G = 4.9$ to 5.4 ; composition, copper, iron, and sulphur in variable proportions, with copper from 44% to 71%; cleavage, almost absent. Bornite is found mostly with other copper ores

43. Chalcocite, or Copper Glance; Cu_2S .—Color, dull, blackish lead-gray, often tarnished blue or green; powder, dark gray; luster, metallic; somewhat sectile. i. e., cuts with a smooth surface; $\text{H} = 2.5$ to 3 ; $\text{G} = 5.5$ to 5.8 ; cleavage, indistinct; composition, nearly 80% copper, with sometimes a little iron, and occasionally silver. Found mostly with copper pyrites and other copper ores, but occasionally alone, as in the sandstone near Dorechester, New Brunswick.

44. Tetrahedrite, or Gray Copper Ore; $\text{Cu}_8\text{Sb}_2\text{S}_{10}$.—Color, grayish or grayish-black; powder, grayish or grayish-black, sometimes inclining to brown or reddish; luster, metallic; $\text{H} = 3$ to 4 ; $\text{G} = 4.4$ to 5.1 ; no cleavage; composition, about 52% copper, and, in addition to the antimony and sulphur, sometimes mercury or silver, also zinc and iron; weathers to a yellowish coating. **Tennantite** is a similar mineral, but contains arsenic instead of antimony. Tetrahedrite is associated with other copper ores, and with zinc blende, galena, etc. as vein matter.

45. Galena; PbS .—Color, pure lead-gray; very fine-grained galena (steel galena) is sometimes quite dark; powder, same as ore; may be weathered to white or gray; luster, metallic; $\text{H} = 2.5$ to 2.75 ; $\text{G} = 7.4$ to 7.6 . Contains 86.6% lead, more or less silver, up to 1% or more, sometimes as a part of the galena, but sometimes as another mineral (as argentite) mixed with the galena. The opinion that paying quantities of silver are found oftener in fine-grained than in coarse-grained galena is not well founded. When galena carries about 25 ounces of silver to the ton, it begins to count as a silver ore, and when rich in silver, it is called **silver lead**. Crystals are in the cubic system, mostly cubes, sometimes octahedrons; cleavage (cubic), very perfect. The square corners and edges, both of

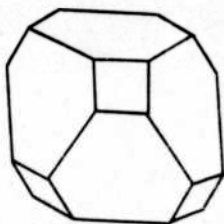


FIG. 31
Galena Crystal

the whole crystals and of the broken pieces, are very characteristic. This is the common ore of lead, and its value is \$70.00 per ton for ore carrying 80% lead. Zinc blende is often found mixed with galena; this reduces the value of the ore, because of the cost of separating.

Galena is found in sedimentary rocks, particularly limestone, in crystalline limestone, slate, gneiss, etc.

46. **Jamesonite; $Pb_3Sb_2S_7$.**—Color, steel-gray to dark lead-gray; powder, grayish-black; luster, metallic; $H = 2$ to 3; $G = 5.5$ to 6; crystals are unusually long. Contains about 50% lead, and sometimes silver.

47. **Bournonite; $PbCuSbS_3$.**—Composition varies; color, steel-gray, lead-gray, or iron-black; powder, the same; luster, metallic; $H = 2.5$ to 3; $G = 5.7$ to 5.9; cleavage, imperfect.

48. **Stibnite, Gray Antimony, or Antimony Glance; Sb_2S_3 .**—Color, lead-gray to steel-gray; powder, the same, may be tarnished black; luster, metallic; $H = 2$; $G = 4.52$ to 4.62; a thin splinter melts in the flame of a match. Contains about 71% antimony, and sometimes carries gold and silver. Crystals are often long and slender; cleavage, very perfect, often showing in streaks, with duller spots or bands between.

This is the common ore of antimony, a metal used in making Babbitt metal, type metal, and other alloys.

The value of the ore depends on conditions, and is not often quoted on the market. The metal, antimony, sells at $3\frac{1}{2}$ to $8\frac{3}{4}$ cents per pound. Stibnite is found in quartz veins and granite; also in veins in slate and quartzite. Sometimes carries gold, as at West Gore, Hants Co., N. S., as high as \$200.00 a ton.

49. Bismuthinite; Bi_2S_3 .—Color, lead-gray to tin-white, may have yellowish or varied tarnish; powder, gray; luster, metallic; **H** = 2; **G** = 6.4 to 6.5 cleavage, good; melts very easily. Bismuthinite is an ore of the metal bismuth, but is found mostly in complex mixtures of ores of silver, cobalt, gold, etc., and is extracted as a by-product, which sells at about \$2.00 per pound. It is used in making easily fusible alloys (safety plugs), and in a number of medical and chemical substances.

50. Molybdenite; MoS_2 .—Color, pure lead-gray; powder, bluish-gray or greenish-gray; marks paper; luster, metallic; **H** = 1 to 1.5; **G** = 4.7 to 4.8; crystals, hexagonal; cleavage, very perfect, splits in thin layers, flexible, but not elastic. Molybdenite resembles graphite, but is decidedly bluish-gray; it is also much heavier than graphite. When the marks on paper are rubbed until spread out thin, that of graphite is gray, but that of molybdenite is greenish-gray. It is an ore of the metal molybdenum, of which it contains 60%. It is used in making molybdenum steel and other alloys, and there are smaller uses in chemical analysis, etc. Value, 50 cents a pound of molybdenite in concentrates containing 85% of the mineral, equivalent to \$850 per ton of such concentrates. It is found mostly in granite

and gneiss, also in crystalline limestones; sometimes in gold veins.

51. Argentite; Ag_2S .—Color, blackish lead-gray; cuts like lead; when rubbed with knife, becomes shiny; luster, metallic; $\text{H} = 2$ to 2.5 ; $\text{G} = 7.20$ to 7.36 . Contains about 87% of silver. Found with other ores in veins, mostly of calcite, in slate, graywacke, conglomerate, schists, and diabase.

52. Pyrargyrite, or Dark-Red Silver Ore; Ag_3SbS_3 .—Color, black to grayish-black showing deep-red when seen in thin layer; powder, purplish-red; luster, metallic-adamantine; $\text{H} = 2.5$. $\text{G} = 5.77$ to 5.86 ; conchoidal fracture. Contains nearly 60% silver.

53. Proustite, or Light-Red Silver Ore; Ag_3AsS_3 .—Color scarlet, vermilion; powder, the same; luster, like diamond; $\text{H} = 2$ to 2.5 ; $\text{G} = 5.57$ to 5.64 ; conchoidal fracture. Contains 65.4% of silver.

53A. Cinnabar, HgS .—Color, cochineal-red, brownish-red, sometimes grayish; powder, scarlet; somewhat sectile; luster, adamantine, sometimes near-metallic; $\text{H} = 2$ to 2.5 ; $\text{G} = 8$. Cinnabar looks like red hematite and cuprite; is often found mixed with clay, hematite, etc. Found in veins in shale and slate, rarely in granite and porphyry.

54. Tellurides.—These are compounds of tellurium with metals, found sometimes in gold ores. Tellurides of gold and silver are an important part of such ores. Tellurides have a metallic luster.

Sylvanite; AuTe_2 , and AgTe_2 .—Sylvanite is a telluride of gold and silver in varying proportions; color, steel-gray to silver-white, inclining to yellow; $\text{H} = 1.5$ to 2 ; $\text{G} = 7.9$ to 8.3 ; good cleavage. **Calaverite** is similar in composition to sylvanite; color, pale bronze-yellow. **Petzite** is also a telluride of gold and silver; color, steel-gray to iron-black; $\text{H} = 2.5$ to 3 ; $\text{G} = 8.7$ to 9 . **Hessite, AgTe ,** is lead-gray to steel-gray in color; somewhat sectile; $\text{H} = 2.5$ to 3 ; $\text{G} = 8.31$ to 8.45 . **Altaite, PbTe ,** is tin-white in color, with yellowish tinge, may have bronze-yellow tarnish. **Coloradoite; HgTe ,** is iron-black in color. **Kalgoorlite** is a telluride of gold, silver, and mercury; color, black. **Tetradymite, Bi_2Te_3 ,** is a telluride of bismuth; color, pale steel-gray; $\text{H} = 1.5$ to 2 ; $\text{G} = 7.2$ to 7.6 ; marks paper; cleavage, perfect; flexible in thin sheets.

When roasted, the tellurides of gold often show globules of metallic gold.

55. Smaltite; CoAs_2 .—Color, tin-white to steel-gray; the white color is seen in the larger crystals, but since

smaltite is usually massive (i. e., in a mass not showing distinct crystals), the steel-gray color is most common; powder, grayish-black; luster, metallic; $H = 5.5$ to 6 ; $G = 6.4$ to 6.6 . Nickel is usually present, taking the place of a part of the cobalt.

Chloanthite, $NiAs_2$, is very much like smaltite, and, in composition, a specimen may be anywhere between the two. **Cobaltite**, $CoAsS$, **gersdorffite**, $NiAsS$, are very like smaltite. All crystallize in the cubic system, and in forms like those of pyrite, but differing in having good cleavage. When the cobalt minerals weather, they form **erythrite** or **cobalt bloom**, $Co_3As_2O_8$ (with water), a crimson or peach-red mineral, usually earthy, but sometimes in crystals of glassy or adamantine luster. The corresponding nickel mineral, **annabergite**, $Ni_3As_2O_8$ (with water), is green. It sometimes happens that the mineral has nickel and cobalt in such proportions that, when weathering takes place, one color kills the other, giving a gray or white product. Small quantities of smaltite and cobalt bloom are rather widely distributed, particularly, in connection with diabase and other basic rocks. Workable deposits are not numerous.

Cobalt, nickel, and arsenic are extracted from these ores. Cobalt sells at about \$3.00 per pound, and the black oxide of cobalt at \$2.00 per pound. The metal is used principally to make stellite alloys, which are very hard, stainless alloys of cobalt and chromium, with sometimes other metals. (See Chromite, Art. 65.) Cobalt oxide is used for making **smalt blue**, a color much in demand in the manufacture of porcelain ware

and stained glass. Nickel sells at 30 to 40 cents a pound; it is used to give hardness and toughness to steel, for nickel plating, etc. The arsenic comes into commerce as white arsenic, the oxide, which sells at 3 to 5 cents a pound.

56. Mispickel, or Arsenopyrite; FeAsS .—Color, silver-white to steel-gray, the former showing in the larger crystals. As mispickel quite commonly shows distinct crystallization, the silver-white color is oftener seen than in the case of smaltite. Powder, grayish-black; luster, metallic; $H = 5.5$ to 6 ; $G = 5.9$ to 6.2 ; strikes fire with steel, causing a garlic smell; crystals, in the orthorhombic system, often showing fine grooves; cleavage, fairly good. Mispickel is composed

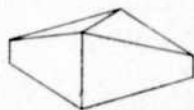


FIG. 32

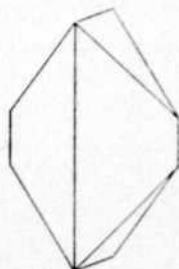


FIG. 33

Mispickel Crystals

of iron, sulphur, and arsenic; the latter is a gray, brittle element that is usually classed as a metal, the oxide of which, a white powder, is usually called arsenic, and is obtained by roasting mispickel and collecting the fumes. Arsenic (not the white powder) is used to harden lead in the manufacture of lead shot and bullets.

Mispickel is found in veins, mostly mixed with quartz, and is often gold-bearing, as in eastern Ontario in the Sudbury district, and near Temagami.

57. Dyscrasite; Ag,Sb. — Color, silver-white to tin-white, may be tarnished yellow or blackish; powder, the same; luster, metallic; cuts like lead (sectile); $H = 3.5$ to 4 ; $G = 9.44$ to 9.85 . Found with other silver ores of Cobalt.

58. Niccolite; NiAs.—Color, pale copper-red; powder, pale brownish-black; luster, metallic; $H = 5$ to 5.5 ; $G = 7.33$ to 7.67 . An ore of nickel and also of arsenic. **Breithauptite, NiSb**, is a similar mineral of rose-copper color; both are found with silver and cobalt ores in the Cobalt district, and also with copper ores.

59. Zinc Blende, or Sphalerite; ZnS.—Color, yellow, brown, black, sometimes nearly colorless; the black color is usually due to iron sulphide; rarer colors are red, white, and green; pure zinc sulphide is white; powder, brownish, yellow, or white; the darker varieties (**black jack**), which are the commonest, give a brownish powder; luster, resinous, particularly in the light-colored varieties; black zinc blende is somewhat metallic in luster; $H = 3.5$ to 4 ; $G = 3.9$ to 4.1 . Zinc blende crystallizes in the cubic system; cleavage, very perfect. This is the common ore of zinc, of which it contains 67% when pure; it may carry silver and gold. Value, \$27.00 to \$32.00 per ton, on the basis of \$31.00 for an ore carrying 60% zinc. Often found mixed with galena; this reduces the value of the ore, owing to the expense of separating. Found in sedimentary rocks such as limestone, crystalline limestone, limey shale, chert, and quartzite; also in veins in igneous rocks.

GROUP III — OXIDES

REMARK.—Oxide minerals are compounds of oxygen with metals; in one case, quartz, the oxygen is combined with a non metal.

60. Magnetite, or Magnetic Iron Ore; Fe_3O_4 .—Color, iron-black; powder, black; luster, metallic. but sometimes rather dull; brittle; **H** = 5.5 to 6.5; **G** = 5.168 to 5.180; composition (as calculated from the composition formula) iron, 72.4%, oxygen, 27.6%. Sometimes contains titanium, sometimes, manganese. Crystals in the cubic system, mostly octahedrons (see Fig. 2), but frequently dodecahedrons. Cleavage is usually

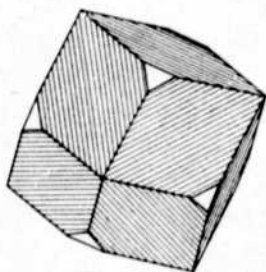


FIG. 84
Magnetite Crystal

indistinct; but coarse-grained magnetite often breaks with smooth, flat surfaces (parting planes); strongly magnetic. The word **magnetic** is used in two senses: (a) attracted by a magnet; (b) attracts certain substances (as iron), i. e., it is itself a magnet. Magnetite is always magnetic in the first sense; it is occasionally magnetic in the second sense, in which case, it is called **loadstone**. A piece of loadstone has a north pole and a south pole, like a compass, which property is called

polarity. The magnetic property of minerals can be conveniently tested with a magnetized knife blade; and a blade that has been rubbed with a strong magnet will keep its charge for many years. To test for magnetism, break off a number of small grains of the mineral, and bring the point of the magnetized knife blade to them slowly; if strongly magnetic, the grains will jump to the knife blade. Do not put the point of the blade on the little pieces, as they may stick together by reason of other causes besides magnetism. When testing for hardness by scratching the mineral with the point of the blade, a magnetic mineral will form a fringe around the point. But caution is necessary here; if the mineral is about the same hardness as the blade or harder, the fringe may be made up of bits of steel from the blade.

Magnetite is a common iron ore. In some localities, as in Sweden, it is valued on account of its purity, being free from phosphorus and sulphur; but, because it is usually harder and less porous than hematite, the latter is preferred, as it is easier to smelt. Value, \$5.25 a ton (1923); but an ore low in phosphorus and containing 65% of iron is quoted at \$7.50 a ton.

Taking the specific gravity of the ore as 5, the number of cubic feet per ton is calculated as follows: weight of a cubic foot of water is 62.4 pounds; weight of a cubic foot of hematite is $62.4 \times 5 = 312$ pounds; number of cubic feet to the ton is $2,000 \div 312 = 6.41$. Since a cubic yard contains 27 cubic feet, a cubic yard weighs $27 \div 6.41 = 4.21$ tons. Hence, roughly, $6\frac{1}{2}$ cubic feet weigh a ton, and a cubic yard weighs $4\frac{1}{4}$

tons. The ordinary ore, mixed more or less with rock, will run from $6\frac{1}{2}$ to $7\frac{1}{2}$ cubic feet to the ton.

Magnetic iron ore is found in igneous and metamorphic rocks in lenses or in vein-like deposits; also in beds of siliceous ore in pre-Cambrian rocks of sedimentary origin.

61. Ilmenite, or Titanic Iron Ore; FeTiO_3 .—Color, iron-black, very much like magnetite; powder, black to brownish-red; luster, near-metallic; **H** = 5 to 6; **G** = 4.5 to 5. Composition: iron, 36.8%; titanium 31.6%; oxygen 31.6%. Very slightly magnetic, and thus distinguished from magnetite. Titanium in iron ores is objectionable, causing difficulties in smelting; but since there are large deposits of magnetite high in titanium, though otherwise pure, these difficulties will, in time, be overcome, and these ores will then become valuable. Ilmenite is valued as an ore of titanium, selling at \$25.00 to \$40.00 a ton of ore on the basis of 52% titanic oxide, TiO_2 . Ilmenite is used for making ferro-titanium, employed in making steel, and for making titanium-white, a white paint of great covering power and durability. Titanic oxide, made from ilmenite, is used to give a yellow color to enamel. In Norway, a number of paints (red, orange, yellow) have been manufactured by roasting titanic iron ores.

Found in gabbro, diorite, syenite, etc., often mixed with more or less magnetite. Sometimes altered to a dull-white substance, **leucoxene**, of variable composition, but sometimes of the same composition as titanite (Art. 112) or rutile (Art. 74).

62. Franklinite.—An oxide of iron, zinc, and manganese; has no simple composition formula, as the proportions of the metals vary. Color, iron-black; looks much like magnetite, but is not so strongly magnetic; powder, reddish-brown or black; $H = 5.5$ to 6.5 ; $G = 5.07$ to 5.22 . An average analysis of franklinite shows it to contain iron, 45.53%, manganese, 10.29%, zinc, 18.70%, oxygen, 25.48%. It is used as an ore of zinc, and the residue as an iron ore; its value is not quoted on the market. Crystals, in the cubic system, octahedrons, like those of magnetite. Found with other zinc ores.

63. Hematite; Fe_2O_3 .—Color, dark steel-gray or iron black; powder, red or reddish-brown; luster, metallic, sometimes dull; $H = 5.5$ to 6.5 ; $G = 4.9$ to 5.3 . Since hematite deposits are often compacted powder or partly so, the ore in such case is red. **Red ocher** is fine-grained hematite loosely compacted; **reddle** and **red chalk** are the same, with more or less clay; **specular hematite** is in brilliant black crystals (from **speculum**, a mirror); when the crystals are small and thin, like scales of mica, the mineral is **micaceous hematite**; **clay ironstone** is a hard, brownish-black to reddish-brown mixture of hematite and clay or sand, etc.; **Kidney ore** is hematite in rounded masses, which break with a smooth fracture and more or less radiating structure.

All varieties of hematite give a red powder. Earthy and micaceous varieties seem much softer than they really are, because the test results in separating the grains already formed; it does not give a correct idea of the hardness of the individual grains. Sometimes the ore is slightly magnetic. The pure mineral contains iron, 70%, oxygen, 30%. As mined, iron ores are more or less mixed with rock (gangue), which lessens the percentage of iron; an ore is considered

rich if it carries 60% of iron, and the average per cent of iron in the ores as fed into the furnaces is not much above 50. Poorer ores are often improved (beneficiated) by washing, which removes the lighter material, or by magnetic concentration (in the case of low-grade magnetite).

Value of hematite is from \$5.55 to \$5.70 a ton for non-bessemer ore (that is, high in phosphorus), 51½% iron, and \$6.20 to \$6.45 for bessemer ore, 55% iron. Found in rocks of all ages, in vast quantities in sedimentary rocks, and in smaller masses in igneous rocks.

64. Limonite; $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$.—Color, brown or black, the compact, hard ore is dark brown, sometimes nearly black; when soft and earthy (**bog ore** and **yellow ochre**), it is brownish-yellow or yellow; powder, yellow or yellowish-brown; luster, non-metallic, near-metallic, or earthy, sometimes silky; **H** = 5 to 5.5, but the earthy varieties crumble easily when tested with the point of a knife, and thus may seem quite soft; **G** = 3.6 to 4; not crystalline. The composition is the same as that of hematite, with the addition of water (H_2O). The formula as written above shows that there are 2 ($56 \times 2 + 16 \times 3$) = $2 \times 160 = 320$ parts of hematite and 3 ($1 \times 2 + 16$) = 54 parts of water; and the pro-

$$\text{portion of iron in the ore is } \frac{2 \times 56 \times 2}{320 + 54} = \frac{224}{374} = .599$$

— 59.9%. Limonite is found in large deposits of hard ore, and also as a loose covering of the bottoms of shallow lakes and bogs.

Goethite, or göthite, $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, is like limonite, but is crystalline; it is a little heavier than limonite ($G = 4$ to 4.4), and is sometimes reddish in color; powder, brownish-yellow to yellow. **Turgite**, $2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, is like limonite in appearance, but gives a red powder, like hematite. In composition, it lies between the two, having some water, but less than göthite.

Limonite is peculiar among valuable minerals in the fact that in some places it is being deposited fast enough to renew the supply in a few years after it has been exhausted. At Radnor Forges, in Quebec, the bottoms of the shallow lakes were cropped every seven or eight years. As iron ores, limonite, göthite, and turgite have values similar to those of magnetite and hematite. Ore such as was mined at the Helen Mine, Michipicoten District, Ontario, ranks with the best hematite.

65. Chromite; FeCr_2O_4 .—Color, iron-black to brownish-black; powder, brown; luster, metallic or near-metallic; sometimes slightly magnetic; looks like magnetite, but is usually duller in luster; seldom strongly magnetic; $H = 5.5$; $G = 4.32$ to 4.57. Composition, oxide of iron and chromium; the latter metal gives the mineral its value for the manufacture of chromates and similar chemicals, paints (chrome yellow, chrome orange, chrome red, chrome green). The metal chromium is used in making chrome steel, in demand for the stamps and dies of gold mills, and also in making stellite alloys, mentioned under smaltite (see Art. 55). Value, \$20.00 per ton for ore containing

40% to 44% chromium oxide. Chromite is found in serpentine rocks.

Stellite Alloys.—Since Ontario produces most of the world's cobalt ores and Quebec is a considerable producer of chromite, Canada has the raw materials for making stellite alloys, manufactured at Deloro, in eastern Ontario, since 1915. While the original stellite contained only cobalt and chromium, a third metal, tungsten, has been added, the percentages being: cobalt 50% to 60%; chromium, 40% to 30%; tungsten, 20% to 8%. The alloy is used for the manufacture of machine tools, cutlery, surgical and dental instruments, evaporating dishes, annealing dishes, ornamental work, valves, plumbing fixtures, pens, and combs. The silvery-white color, stainlessness, and great hardness (some varieties are harder than quartz) fit it for these uses. By using stellite tools, the speeds of machine tools have been increased as much as 50%.

66. Tinstone, or Cassiterite; SnO_2 .—Color, brown or black, sometimes red, gray, yellow, or white; pure oxide of tin is white; powder, brownish, gray, or white; luster, adamantine (like diamond); $H = 6$ to 7 ; $G = 6.8$ to 7.1 ; crystals, tetragonal; when in crystals, the luster is sometimes very brilliant, but other samples are dull. **Wood tin** has a somewhat fibrous structure, and mixed brownish shades, like dry wood. **Toad's eye tin** is similar to wood tin. **Stream tin** is pebbles and grains of tinstone, as found in beds of streams and on shores.

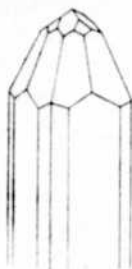


FIG. 35

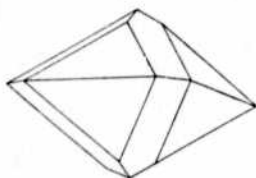


FIG. 36

Tinstone Crystals

Tinstone is the common ore of tin; its value is not quoted; but as tin is worth about 30 cents a pound, the value of the ore can be judged from the percentage of tin it contains. Tinstone is found in veins in granite, gneiss, mica schist, clay schist, quartzite, and porphyry. It is stated that in all productive tinstone areas, the ore is associated with a peculiar granite called **greisen**, which is composed mostly of quartz and white mica. The greater part of the world production of tin ore is stream tin.

67. Corundum; Al_2O_3 .—Color, commonly gray or brown, also blue, red, yellow, and nearly white; pure aluminum oxide is white; powder, white or gray; luster, like diamond or glassy; **H** = 9; **G** = 3.95 to 4.10; fine, clear blue crystals are valuable as gems, and are then called sapphires; rubies are crystals of red corundum. Crystals, in hexagonal system; parting, good, but no true cleavage.



FIG. 37

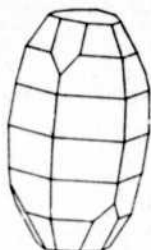


FIG. 38

Corundum Crystals

Emery is usually black, fine-grained corundum, with magnetite or hematite; is sometimes **hercynite**, FeAl_2O_4 .

Corundum being harder than quartz is valuable as an abrasive (material for grinding and polishing). Value, about \$120 per ton. Artificial corundum is now made by an electric furnace process from non-crystalline aluminum oxide, which can be made cheaply from bauxite, and being of the same composition as corundum, requires only to be crystallized. Corundum is found in nepheline-syenite and similar rocks; also in peridotite.

68. Bauxite; $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$.—Color, whitish, grayish, yellow, brown, red; powder, yellowish, brownish, or white; $G = 2.55$; earthy, often found with round masses like small eggs, and therefore called oölitic in structure. Composition is the same as corundum, with water in addition; but generally more or less limonite is mixed with the bauxite, causing the brown color. Value, \$5.00 to \$9.00 per ton. Its principal use is as an

ore of aluminum. It is first purified, then fed into a bath of fused cryolite (Art. 79), in which aluminum oxide is soluble; the aluminum is deposited by a current of electricity. **Alundum** is artificial corundum made from bauxite by heating in electric furnaces. Bauxite bricks are used for furnace linings.

Bauxite is found in limestone and around the margins of clay deposits, in pockets or as "blanket" deposits.

69. Pyrolusite; MnO_2 .—Color, iron-black, dark steel-gray, sometimes bluish; powder, black or bluish-black; luster, metallic; $H = 2$ to 2.5 ; soils the fingers when handled; $G = 4.73$ to 4.86 ; usually in long crystals, radiating or columnar, sometimes granular; composition, manganese oxide; it is often called **manganese ore**. Used in the manufacture of certain chemicals, particularly **permanganates**, but mostly in steel manufacture. **Manganese steel** or **Hadfield steel** usually contains 12% to 15% of manganese. It is very hard, and is used for jaws and other wearing parts of rock crushers and similar machinery; for railway frogs, crossings, and curves; for mine-car wheels, trolley wheels, linings of ball mills, burglar-proof safes, etc. It lasts much longer than ordinary steel, because it is not only very hard but it is also not brittle. Manganese is added in small quantities to ordinary steel up to 1%; more than this makes the steel brittle; but when the amount of manganese is increased to 7%, the properties of Hadfield steel begin to appear. **Ferromanganese** is an alloy of iron and manganese, containing from 40% to 80% manganese; it is used in

making manganese steel. **Spiegeleisen** is pig iron very high in manganese, 15% to 30%; it is used to give the required amount of manganese to ordinary steel.

Pyrolusite and other manganese ores are sold on the unit system, 26 to 27 cents per unit, the unit being 1% of manganese in a ton of ore. Consequently, for an ore containing 50% manganese, the value of a ton at 26 cents per unit is $\$0.26 \times 50 = \13.00 ; at 27 cents per unit, the value of a ton of ore is $\$0.27 \times 50 = \13.50 . With manganese below 40%, the ore is not usually merchantable. Pure pyrolusite contains about 65% of manganese. The best ore, used in chemical manufactures, sells for from \$45.00 to \$60.00 per ton. Pyrolusite and other ores of manganese are found in limestone, shale, sandstone, etc. in veins and bunches; sometimes in quartzite, chert, and jasper; occasionally in bunches in clay.

70. Psilomelane, or Hard Manganese Ore.—Color, black, bluish, or brownish-black; powder, brownish-black; luster, silky or dull; **H** = 5 to 6; **G** = 4.1 to 4.7; composition, oxides of manganese with potash or baryta, with sometimes water; generally impure. This is a common ore of manganese; often found with pyrolusite, but distinguished from it by its greater hardness. **Wad**, or **bog manganese**, is a brown, soft, earthy manganese ore, variable in composition; it looks like bog iron ore, but is often darker, and is often found with pyrolusite. **Asbolite**, or **earthy cobalt ore**, resembles wad, but contains cobalt, sometimes enough to make it a cobalt ore. **Lampadite** is a variety of wad containing 3% to 13% of copper.

71. **Braunite.**—Color, brownish-black to steel-gray, powder, the same; luster, near-metallic; $H = 6$ to 6.5 ; $G = 4.75$ to 4.82 ; crystals, tetragonal; cleavage, perfect; composition, oxides of maganese with some silica. This is an ore of manganese, often found with other manganese ores. **Hausmannite**, Mn_2O_3 , is a similar mineral of brownish-black color; powder, chestnut-brown; $H = 5$ to 5.5 ; $G = 4.856$.

72. **Zincite, or Red Zinc Ore;** ZnO .—Color, red to brownish-red; powder, orange-red; luster, like diamond; $H = 4$ to 4.5 ; $G = 5.43$ to 5.70 ; crystals, hexagonal like quartz, cleavage, perfect; composition, zinc (about 80%) and oxygen. Pure oxide of zinc is white; the color of the mineral is caused by a little hematite or oxide of manganese. Zincite is an ore of zinc, but is chiefly used in the manufacture of white zinc paint. For value, see Zinc Blende, Art 59.

73. **Cuprite, or Red Copper Ore;** Cu_2O .—Color, various shades of red sometimes almost black; powder, brownish-red, shining; luster, somewhat metallic or earthy; $H = 3.5$ to 4 ; $G = 5.85$ to 6.15 ; crystals, in cubic system, usually octahedrons; cleavage, fair. Often has green covering of malachite; often looks like hematite but is softer. Contains nearly 80% of copper. Found sometimes with the commoner ores of copper.

74. **Rutile;** TiO_2 .—Color, reddish-brown or red, sometimes yellowish, bluish, violet, black, or grass-green; powder, pale brown; luster, somewhat metallic; $H = 6$ to 6.5 ; $G = 4.18$ to 4.25 (for a black variety, **nigrine**, $G = 5$); crystals, in tetragonal system, like those of tinstone; cleavage, distinct; composition, titanium oxide, with a little iron, sometimes up to 10%. For uses, see Ilmenite, Art. 61. Value, 12 cents a pound for ore containing 95% titanium oxide (TiO_2). Found in granite, gneiss, mica slate, and syenite; sometimes in crystalline limestone and dolomite.

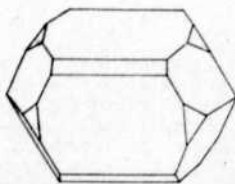


FIG. 39

Rutile Crystal

75. Quartz; SiO_2 .—Color, colorless when pure, yellow, red, green, brown, blue, purple, black; powder, usually white, but sometimes of a pale color corresponding to that of the impure varieties; luster, glassy (vitreous); $H = 7$; $G = 2.6$ to 2.66 ; crystals, in hexagonal system; no cleavage; composition, silicon oxide. The chemist's name for quartz is **silica**.

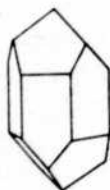


FIG. 40



FIG. 41

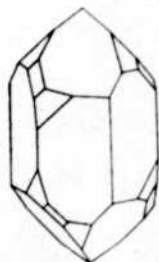


FIG. 42

Quartz Crystals. Figs. 41 and 42 show right and left handedness in the positions of the small surfaces.

VARIETIES OF QUARTZ.—I. Plainly crystallized (phenocrystalline), including ordinary white quartz as seen in granite, quartz veins etc., rock crystal (Cape diamonds, Brazilian pebbles, etc.), amethyst (purple or violet blue), rose quartz, false topaz (yellow), cat's eye, tiger-eye, aventurine (spangled with scales of mica, hematite, etc.), and many others.

II. Not plainly crystalline (cryptocrystalline or partly amorphous). **Chalcedony**, somewhat waxy luster, transparent or translucent; white, grayish, blue, brown, black. **Carnelian**, clear, red chalcedony. **Chrysoprase**, apple-green chalcedony, color due to nickel oxide. **Bloodstone**, green, with small spots of red jasper. **Agate**, chalcedony, banded, clouded, or mossy, in various colors. **Onyx**, like agate, but in even layers of white and black, white and red, and so on; used for cameos. **Sardonyx**, like onyx, but including layers of carnelian. **Siliceous sinter**, irregularly cellular quartz deposited from siliceous hot springs, etc. **Flint**, somewhat like chalcedony, but not so clear and of dull colors, usually gray, smoky brown, and brownish black. **Hornstone**, like flint, but more brittle.

and with a more splintery break. **Chert**, any impure flinty rock, including hornstone, jasper, etc. **Touchstone**, or **lydian stone**, a velvet-black siliceous stone or flinty jasper. **Jasper**, impure, opaque, colored quartz; commonly red, also, dark green and grayish-blue. **Quartzite**, **quartz sandstone**, **quartz conglomerate**, **flexible sandstone** (itacolumite), and **buhstone** are rocks composed mostly of grains or pebbles of quartz.

III. **Opal**, SiO_2 , with water in varying proportions. Color, white, yellow, red, brown, green, gray, blue, sometimes with a fine play of colors (precious opal): $H = 5.5$ to 6.5 ; $G = 1.9$ to 2.3 ; not crystalline. **Tripolite** or **Tripoli**, and **infusoria' earth**, deposits of microscopic shells, are similar to opal in composition; though soft and earthy in appearance, they are hard enough to scratch glass.

Ordinary vein quartz, white sandstone, and quartzite are used for lining smelting furnaces, and in the manufacture of glass and pottery; but for these latter purposes, pure quartz sand and flints are commonly used. For all these purposes the quartz is valued at from \$1.00 to \$2.00 per ton; very pure, white quartz brings \$3.00 per ton, to grind for wood filler, to make the wood take a high polish. Tripoli and infusorial earth are used as polishes, packing for boilers, etc., to absorb the nitroglycerine in the manufacture of dynamite (sawdust is more commonly used for this now), and in soap manufacture. The raw material sells for from \$3.00 to \$5.00 per ton. Some varieties of natural quartz, such as sand and sandstone, have well-known uses in building.

Quartz crystals, when large, colorless, and flawless, are sometimes ground into spheres for ornamental purposes, a sphere $5\frac{1}{2}$ inches in diameter being valued at \$3,000.00. Clear, finely colored crystals (amethysts) are classed as jewels. The finer specimens of agate, carnelian, bloodstone, onyx, etc. are also of considerable value. Large sound pieces of ordinary agate are

of value for making agate mortars, used in chemical laboratories.

GROUP IV — CHLORIDES, FLUORIDES, ETC.

REMARK.—To this class belong compounds of metals with the elements chlorine, fluorine, etc.

76. Common Salt, or Halite; NaCl.—Color, colorless when not stained with some impurity; luster, glassy; $H = 2.5$; $G = 2.14$; crystals, in cubic system; cleavage, perfect, cleavage pieces with square edges and corners; well-known taste; composition, sodium chloride, a combination of the metal, sodium, with the gas, chlorine. Domestic and preservative uses are well known; large quantities are used in the manufacture of sodium, chlorine, washing soda, baking soda, caustic soda, etc. Found in large quantities in sedimentary rocks of many ages, with gypsum, shale, sandstone, and limestone. It is mined as **rock salt**. Its presence in sea water, salt springs, and salt lakes is well known.

Sylvite, KCl, is sometimes found with rock salt, and is valuable as a source of potassium products, and as a fertilizer in agriculture.

77. Horn Silver, or Cerargyrite; AgCl.—Color, pearl-gray, grayish-green, colorless; turns violet-brown when exposed to light; luster, resinous or diamond-like; $H = 1$ to 1.5 ; $G = 5.55$; cuts easily, like horn, accompanies other silver ores.

78. Fluorspar, or Fluorite; CaF₂.—Color, white, yellow, green, red, blue, deep purple, sometimes brown; powder, white; luster, glassy; $H = 4$; $G = 3.01$ to 3.25 ; crystals, in cubic system, mostly cubes; cleavage, perfect, cleavage pieces tending to show equilateral triangles which are also often to be seen outlined by

cracks and edges; composition, calcium and fluorine, forming calcium fluoride.

Used principally as a flux in smelting, particularly in the manufacture of iron and steel; in the manufacture of enamels and opaque glass; in the manufacture of hydrofluoric acid, used in etching glass. Very perfect, colorless crystals are valuable for use in making certain optical instruments. Some colored varieties (Derbyshire **blue john**) are used for ornamental vases.

Value, lump, containing not less than 85% calcium fluoride and not over 6% silica, \$20.00 per ton; gravel, \$17.50 per ton; poorer qualities, \$2.50 to \$13.50 per ton. Best quality, for manufacture of hydrofluoric acid, \$40.00 to \$50 per ton. Fluorspar is found generally in veins, in gneiss, slate, limestone, crystalline limestone, and sandstone; often as **gangue** of metal ores, particularly of lead ores. It is sometimes mixed with barite and celestite; and as these minerals are partly sulphur in composition, they lower the value of fluorspar, as sulphur is injurious to iron and steel.

79. Cryolite; Na_3AlF_6 .—Color, snow-white or ice-like, sometimes reddish, brownish, or even black; luster, glassy and greasy; **H** = 2.5; **G** = 2.95 to 3; cleavage, perfect; looks rather like quartz, but distinguished by softness and good cleavage; composition, a fluoride of sodium and aluminum. Used as a solvent in the manufacture of aluminum. Aluminum oxide, Al_2O_3 , made from bauxite, is dissolved in melted cryolite, and the aluminum is then deposited by an electric current. Also used for making enamels and opaque

glass. Value, about \$15.00 per ton. Found in quantity, so far, only in one place, at Ivigtut, Greenland, in a granite dike in gneiss.

GROUP V — CARBONATES

REMARK—Carbonates are compounds of carbon dioxide (frequently called carbonic acid) with oxides of metals. In naming individual carbonates, the name of the metal is used; but if the name of the oxide of the metal is better known, as lime, for example, which is calcium oxide, the name of the oxide will be used instead of the name of the metal in the following descriptions. Carbonates can be "spotted" by testing with acids, which cause "fizzing", owing to the escape of carbon dioxide. All carbonates are non-metallic in luster.

80. Calcite, or Calcspar; CaCO_3 .—Color, white or colorless, also pale shades of gray, red, green, blue, violet, yellow, and sometimes brown and black, from impurities; powder, white or grayish; luster, glassy or earthy; **H** = 3; **G** = 2.714; crystals, in hexagonal system; cleavage, very perfect, cleavage pieces having

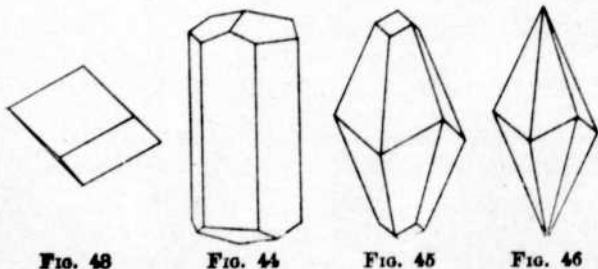


FIG. 43

FIG. 44

FIG. 45

FIG. 46

Calcite Crystals. Fig. 44 is "nail-head spar", and Fig. 46, "dog-tooth spar."

angles of about 75° and 105° over the edges. The word or syllable, **spar**, in the names of minerals refers to bright surfaces, particularly when due to notice-

ably good cleavage. Calcite is carbonate of lime, and contains 44% carbon dioxide and 56% of lime; it effervesces (fizzes) with acids, even when the acids, are mixed with water, i. e., diluted. Vinegar may be used for this test, and no heating is required.

VARIETIES OF CALCITE.—**Dog-tooth spar**, sharp-pointed crystals (Fig. 46) **Nail-head spar**, blunt-pointed crystals. (Fig. 44) **Ice-land spar**, very perfect, transparent, colorless crystals. **Satin spar**, fibrous and of a satiny luster; a variety of gypsum is also called satin spar. **Limestone, marble**, and **chalk** are granular or very fine-grained rocks composed of calcite. **Lithographic stone** is a very fine, even-grained limestone. **Hydraulic limestone** and **calcareous marl** are composed of calcite, with more or less clay, etc. **Stalactites**, hanging like icicles from the roofs of caves, and **stalagmites**, sticking up from the floors, are usually composed of calcite. **Oriental alabaster**, or **onyx marble**, and **Mexican onyx**, are calcite formed in layers on the bottoms of caves, or, are deposited from springs and rivers, particularly in volcanic regions.

The uses of calcite, in the form of limestone, for building stone and marble, for making lime and cement, for fluxing iron ore, etc. are well known. For these purposes, limestone is a cheap material, a dollar or two a ton. Pure calcite is ground to a fine powder, and is used instead of whiting. Ice-land spar (large, very perfect crystals of calcite) is used in microscopes (Nicol's prism); good pieces, clear, colorless, and free from flaws, are of considerable value, but are rarely found free from imperfections.

81. Dolomite; $\text{CaCO}_3 \cdot \text{MgCO}_3$.—Color, red, reddish, or greenish-white, sometimes, rose-red, green, brown gray, or black; powder, white; luster, glassy; **H** = 3.5 to 4; **G** = 2.8 to 2.9; crystals, hexagonal system, like calcite; cleavage, perfect, giving cleavage pieces like those of calcite; composition, carbonate of lime and

carbonate of magnesia, in about equal parts. True dolomite fizzes with acid only when heated; but dolomite is often mixed with calcite, which is active with cold acids. Most limestones contain more or less carbonate of magnesia, so that limestones are sometimes *dolomitic*, and shade into true dolomite. Dolomite is useful as a building stone, and crystalline dolomite forms a part of the marble of commerce. Dolomite is also used in smelting iron ore, the magnesia tending to carry the sulphur into the slag, and thus purifying the pig iron; it is sometimes used instead of common limestone in making the sulphite liquor in wood-pulp manufacture. Value, \$1.00 to \$2.00 per ton.

82. Magnesite; $MgCO_3$.—Color, white, yellowish, or grayish-white, brown; powder, white; luster, glassy; **H** = 3.5 to 4.5; **G** = 3 to 3.12; crystals, in hexagonal system, like calcite; cleavage, perfect; composition, carbonate of magnesia, often mixed with a little carbonate of iron; fizzes with hot acid. Used largely for making magnesia bricks, for lining electric, basic-steel, copper, and other furnaces, and for sulphite-pulp manufacture, fire-proof flooring, etc.; also for manufacturing magnesia medical preparations and various chemicals. Value, \$8.00 to \$12.00 per ton. Found in serpentine, talc schist, and other magnesian rocks, including dolomite.

Hydromagnesite is a carbonate of magnesia, with extra magnesia and water. It is found as tufts of small crystals, and also as chalky crusts.

83. Siderite, or Iron Spar; $FeCO_3$.—Color, yellowish-gray, greenish-gray, sometimes brown, or brown-

ish-red, or white; powder, white; luster, glassy or pearly; $H = 3.5$ to 4 ; $G = 3.83$ to 3.88 ; crystals, in hexagonal system, like calcite; cleavage, perfect; composition, carbonate of iron, containing 48.3% of iron; but it usually contains more or less carbonate of manganese, magnesia, and lime, which lowers the percentage of iron. **Clay ironstone** is siderite mixed with clay. (See also under Hematite, Art. 63.) Siderite is valuable as an ore of iron, but it usually requires calcination before it can be used.

Ankerite is carbonate of lime, magnesia, and iron. Minerals of various composition between calcite and ankerite are met with; they usually look much like calcite when fresh, but weather to a rusty color ("rusty weathering carbonate").

As an iron ore, siderite forms extensive deposits in sedimentary rocks. In Ontario, there are very large quantities in the Keewatin iron formation. In Nova Scotia, veins are found of siderite, ankerite, etc., cutting sedimentary rocks near bodies of acid igneous rocks.

84. Rhodochrosite, or Manganese Spar; $MnCO_3$.—Color, rose-red, sometimes yellowish-gray, fawn colored, dark red, brown; powder, white; luster, glassy or pearly; $H = 3.5$ to 4.5 ; $G = 3.5$ to 3.6 ; crystals, in hexagonal system, like calcite, but not common; composition, carbonate of manganese, usually with some iron, lime, and magnesia; fizzes with hot acids. May be used as an ore of manganese. Value, see pyrolusite, Art. 69. Found usually with other ores of manganese; also in veins with ores of gold, silver, lead, and copper.

85. Strontianite; $SrCO_3$.—Color, green, sometimes white-gray, yellowish, brown; powder, white; luster, glassy; $H = 3.5$ to 4 ; $G = 3.680$ to 3.714 ; cleavage, good; composition, strontium carbonate; fizzes with acids. This and celestite are commonly called strontium ores, used in making stron-

tium nitrate for red flares and fireworks; also, to make strontium hydrate for use in refining sugar, and for other smaller chemical uses. Value, \$25.00 to \$35.00 per ton. Found mostly in association with lead ores.

86. Witherite; BaCO_3 .—Color, white, yellowish, grayish; powder, white; luster, glassy; inclining to resinous on broken surfaces; $H = 3$ to 3.75; $G = 4.27$ to 4.35; cleavage, good; composition, barium carbonate; fizzes with acids. When found in quantity, can be used for the same purposes as barite (Art. 115). Used in the manufacture of pressed brick, to neutralize the sulphuric acid formed by oxidation of sulphides, its use prevents the unsightly, white efflorescence. Found mostly with lead ores.

87. Cerussite, or White Lead Ore; PbCO_3 .—Color, white, gray, grayish-black, sometimes tinged blue or green with carbonates of copper; powder, white; luster, like diamond; $H = 3$ to 3.5; $G = 6.46$ to 6.574; very brittle; cleavage, distinct; composition, carbonate of lead. Cerussite is formed by weathering of galena.

88. Smithstone; ZnCO_3 .—Also called calamine; miners call it dry bone; color, white, often grayish, greenish, brownish-white, sometimes green, blue, brown; powder white; luster, glassy to pearly; $H = 5$; $G = 4.30$ to 4.45; cleavage perfect; composition, carbonate of zinc. Usually found as a product of zinc blende weathering.

89. Malachite; $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$.—Color, bright green; powder, paler green; luster, dull and earthy or glassy; $H = 3.5$ to 4; $G = 4$; cleavage, perfect; composition, carbonate of copper, etc., containing 57.5% of copper. Formed by weathering of sulphides of copper; sometimes, as at the Copper Queen, Bisbee, Arizona, there is enough of it to be valuable as a copper ore.

Azurite, $2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$, is a blue carbonate of copper, carrying 55% of copper; powder, blue, luster, earthy or glassy; $H = 3.5$ to 4; $G = 3.77$ to 3.83. Azurite is also a weathering product from sulphides of copper.

GROUP VI — SILICATES

REMARK.—The chemist's name for the substance of quartz is silica; and any mineral that is composed in part of silica is a silicate. In the study of minerals and rocks, silica is called an acid; in silicates, the substances other than silica are called bases, for example, lime, potash, and soda. When giving the full name of a silicate, the names of these bases will generally be used, but the names of the metals of which they are the oxides will be substituted, if better known. The silicates are of importance, both as useful materials and because some of them make up in whole or in part a good many common rocks, such as diabase, granite, syenite, gneiss, etc.

All the silicates here described are non-metallic in luster.

90. The Feldspars.—These constitute a group of similar minerals, which may be described as silicates of aluminum and either potash or soda or lime. Color, white, or pale shades of yellow, red, or green, sometimes gray; powder, white; luster, glassy, usually opaque; $H = 6$ to 6.5 ; $G = 2.55$ to 2.75 ; crystals, in the monoclinic system (orthoclase) or in the triclinic system (microcline, albite, oligoclase, andesine, labradorite, anorthite); cleavage, perfect, differing a little in two directions, which are at right angles in orthoclase, and which make an angle of nearly 90° in the other feldspars; good cleavage pieces of feldspar will thus show four smooth surfaces and two rough ones, so arranged that the smooth surfaces form four sides of a square or nearly square prism, of which the two rough surfaces are the ends.

1. Orthoclase: $KAlSi_3O_8$.—Color, reddish, gray, white, pale yellow, rarely green; powder, white; $H = 6$; $G = 2.57$; composition, silicate of aluminum and potash, and therefore a potash feldspar; contains 64.7% silica, 18.4% alumina (aluminum oxide), 16.9% potash, usually soda in place of a part of the potash. *Adularia* is a transparent variety. *Sandine* is a glassy, transparent or nearly transparent variety

found in some volcanic rocks. Orthoclase is the common feldspar of granite and rhyolite.

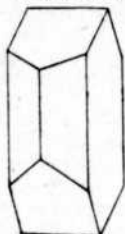


FIG. 47

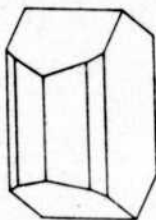


FIG. 48

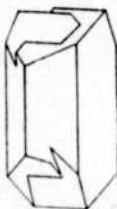


FIG. 49

Orthoclase Crystals. Fig. 49 is a twin crystal

2. **Microcline** has the same composition as orthoclase, but differs from it in having the edges made by its four cleavage surfaces a little off the square, about half a degree. **Amazonstone** is a green variety.

3. **Albite**, $\text{NaAlSi}_3\text{O}_8$, is usually white, as its name indicates (from *albus*, white); composition, soda feldspar; contains 68.7% silica, 19.5% alumina, 11.8% soda.

4. **Oligoclase**, a soda-lime feldspar; contains 62% silica, 24% alumina, 9% soda, 5% lime. **Sunstone** is a variety.

5. **Andesine** is also a soda-lime feldspar, but with more lime and less soda; it varies in composition.

6. **Labradorite** has still more lime and still less soda; it is gray, brown, or greenish, and often shows a beautiful play of colors; composition about as follows: 53% silica, 30% alumina, 4% soda, 13% lime.

7. **Anorthite**, $\text{CaAl}_2\text{Si}_2\text{O}_8$, is a lime feldspar; contains 43% silica, 37% alumina, 20% lime.

Albite, oligoclase, andesine, labradorite, and anorthite are often called **plagioclase feldspars**, which refers to the cleavage, making edges about 4° off the square. Their crystals are nearly always grooved, due to twinning.

Note that labradorite and anorthite are much lower in silica than the others; this leads to a separation of the feldspars into two classes: (a) **acidic feldspars**, orthoclase, microcline, albite, oligoclase, and andesine, with 62% to 65% silica (characteristics of acid rocks, such as granite); (b) **basic feldspars**, labradorite and anorthite, with 43% to 53% silica (characteristic of basic rocks, such as diabase, diorite, etc.).

In commercial quantity and condition, feldspar is found mostly in pegmatite dikes (coarsely crystalline

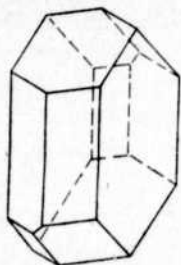


FIG. 50

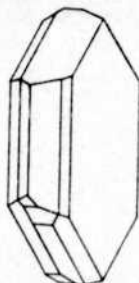


FIG. 51

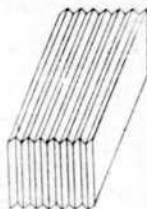


FIG. 52

Albite Crystals. Fig. 52 is grooved by repeated twinning

granite). It must be free from black mica, hornblende, tourmaline, and other dark minerals. The feldspar and the quartz are often crystallized in separate large masses, so that pure feldspar is easily quarried. Sometimes the two minerals are intergrown in a peculiar way, the quartz appearing like letters set in the feldspar, the so-called **graphic granite**. Feldspar containing a certain proportion of quartz is saleable; No. 1 contains less than 5% of quartz, No. 2 up to 15% or 20%, and No. 3, still higher. Microcline and orthoclase are the varieties of feldspar commonly mined. Users prefer a potash feldspar, but the soda feldspar, albite, is used to some extent. Ground feldspar is used largely in the manufacture of pottery, partly to mix with the clay and partly as glaze; also, for the manufacture of enamels, door-knobs, electrical insulators, opal glass, soaps, and polishes; it is likewise used as a bond in the manufacture of corundum, emery, and carborundum wheels, etc. The purest selected feldspar is used in the manufacture of artificial teeth (**dental spar**).

The lowest grades are used for roofings and artificial stone. Value, No. 1 pottery, \$6.50 to \$6.85 per long ton; No. 2 pottery, \$5.75; No 1 soap, \$7.25 to \$7.50; No. 1 Canadian (ground), \$22.00 to \$23.00, f. o. b. mill; the other quotations are f. o. b. cars, presumably at a shipping point near the mines.

Amazonstone is orthoclase or microcline of a beautiful green color; it is valuable for ornamental purposes.

91. Hornblende, or Amphibole.—A group of silicates of magnesia, lime, iron, etc., variable in composition, but having a general resemblance in properties.

1. Common hornblende is a silicate of magnesia, iron, and lime, with some soda and alumina. Color, between black and white, inclining to blackish-green; powder, gray or white; luster, glassy; **H** — 5 to 6; **G** — 2.9 to 3.4; crystals, in monoclinic system; cleavage, perfect, the cleavage surfaces making angles of about 56° and 124° .



FIG. 53

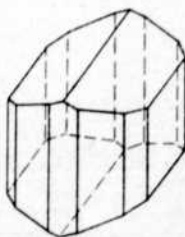


FIG. 54

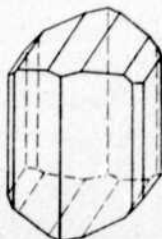


FIG. 55

Hornblende Crystals

Hornblende is a common constituent of the light-colored acidic rocks, like granite and gneiss. A fibrous variety has been used as asbestos.

2. Tremolite, $\text{CaMg}_2\text{Si}_4\text{O}_{12}$, is white to dark gray in color; luster, glassy; in distinct crystals, long-bladed or short and stout, sometimes long, thin needles or fibers in bunches, radiating. Common in crystalline limestones. Fibrous tremolite is a variety of asbestos.

3. Actinolite is similar in composition to tremolite, but contains some iron, which gives it a green color. It is sometimes fibrous, and is then a variety of asbestos. Has been used to manufacture roofing.

92 Pyroxene.—Pyroxene is a name applied to a group of silicates that are similar in composition to the hornblende group, but not so often containing soda and potash. Cleavage pieces show angles of 93° and 87° , thus making nearly square edges, a clear distinction between them and the sharp and obtuse edges of cleavage pieces of hornblende.

1. Augite, common pyroxene, is usually dull green, grayish, brown, black, sometimes white, rarely bright green or blue; powder, white, gray, or grayish-green; luster, glassy or dull; $H = 5$ to 6 ; $G = 3.2$ to 3.6 ;

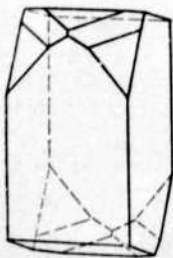


FIG. 56

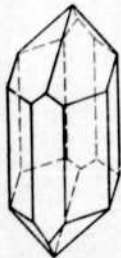


FIG. 57

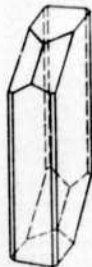


FIG. 58

Pyroxene Crystals

crystals, in monoclinic system; cleavage, sometimes rather perfect; composition, silicate of magnesia, lime, alumina, and iron. Augite is a characteristic mineral of basic igneous rocks.

2. Diopside contains little or no alumina; color, white, light green, or gray. Is found in crystalline limestone, especially in igneous contact zones. It is the common pyroxene of the mica deposits in Ontario and Quebec.

3. Diallage is a pyroxene of green or brown color and lamellar (thin platy) structure; the characteristic pyroxene of gabbro, etc.; perhaps only a variety of augite.

4. Hypersthene is a pyroxene of dark, brownish-green, grayish-black, or brown color; powder, grayish or brownish-gray; luster, somewhat pearly or slightly metallic on a cleavage surface; is high in iron, up to 10% to 12%. Is a common constituent of such dark basic rocks as norite, gabbro, etc.

5. Enstatite is a pyroxene of white, grayish-green, olive-green, or brown color; found characteristically in peridotites and serpentines derived from them; composition, MgSiO_3 , sometimes with iron.

6. Jadeite is a hard, very tough mineral of various shades of green; $H = 6.5$ to 7 . It is related to pyroxene in properties, but is somewhat different in composition, being a silicate of soda and alumina. This mineral and similar varieties of hornblende and the like, have long been used by man in the manufacture of jade ornaments and implements, the finer varieties being still in use for ornaments.

7. Spodumene, $\text{LiAlSi}_2\text{O}_6$, is gray, green, yellow, purple; powder, white; $H = 6.5$ to 7 ; $G = 3.13$ to 3.20 ; crystals, monoclinic; cleavage, good. The green variety, **hiddenite**, is used as a gem. Found in pegmatite granite and in gneiss.

93. Nepheline, or Nephelite.—Color, usually colorless or yellowish, sometimes dark green, gray, reddish; powder, white; luster, glassy to greasy; $H = 5.5$ to 6 ; $G = 2.55$ to 2.65 ; cleavage, distinct; composition, silicate of alumina and soda with more or less potash, and therefore like feldspar. It is low in silica (44%), corresponding to the most basic feldspars (see anorthite, Art. 90). It is found in the rocks, nepheline-syenite and phonolite.

94. Scapolite, or Wernerite.—A silicate of alumina and lime with more or less soda; color, white, gray, light blue, green, red; powder, white or gray; luster, glassy or pearly; $H = 5$ to 6 ; $G = 2.66$ to 2.73 ; crystals, tetragonal; cleavage, rather good, giving square edges (90°), the cleavage surfaces having a fibrous appearance. Found plentifully in crystalline limestone near contacts with granite and other igneous rocks, and thus associated with apatite and mica deposits.

95. Sodalite; $3NaAlSiO_3 + NaCl$.—Color, gray, green, yellowish, white; powder, white or gray; luster, glassy; crystals, in cubic system; cleavage, more or less distinct; composition, like that of a basic feldspar, but with sodium chloride ($NaCl$) in addition. Found in nepheline-syenite and similar rocks. A variety of a deep blue color is found near Bancroft, Ontario, and has been used as ornamental stone and for jewelry.

Lapis-lazuli, or lazurite, is a similar mineral of a rich blue or greenish-blue color; it contains sulphur. Found mostly in limestone, with iron pyrites. Valuable for jewelry and the manufacture of a fine blue color, ultramarine; but artificial ultramarine has almost completely displaced the natural product.

96. Zircon; $ZrSiO_4$.—Color, colorless, pale yellow, grayish, yellowish-green, brownish-yellow, reddish-brown; powder, white or nearly so; luster, like diamond or glassy; $H = 7.5$; $G = 4.68$ to 4.70 ; crystals, tetragonal; cleavage, imperfect; composition, silicate of zirconia (ZrO_2). Found in igneous rocks of the acidic kind, for example, syenite, and especially in pegmatite dikes; also, sometimes in crystalline limestone, schists, and gneiss. On account of its weight and hardness, it survives the destruction of these rocks by weathering, and so is found with placer gold, etc. The finer crystals are used as jewels under the names of *hyacinth* (red and yellow) and *jargon*. A preparation called *zirkite* is on the market as a refractory, selling at \$50.00 to \$100.00 per ton.

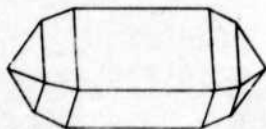


FIG. 59

Zircon Crystal

Thorite; $ThSiO_4$, with some water.—This is a mineral similar to zircon, but is usually opaque-black; powder, dark

brown; there is a yellow variety called **orangeite**; composition silicate of thorium (ThO_2). **Thorium** is used for making incandescent mantles for gas lighting.

Beryl; $\text{BeAl}_2\text{Si}_6\text{O}_{18}$.—Color, emerald-green, pale green, blue, yellow, white, sometimes rose-red; powder, white; $\text{H} = 7.5$ to 8; $\text{G} = 2.63$ to 2.8; crystals, hexagonal; cleavage, poor. The green crystals, when transparent and free from flaws, are

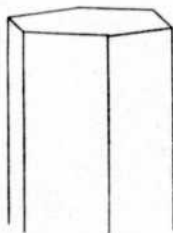


FIG. 60

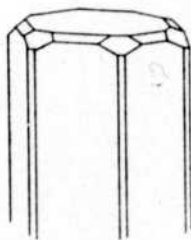


FIG. 61

Beryl Crystals

valuable as gems, then called **emerald**. Found in pegmatite granite dikes, or in gneiss or mica schist in contact with these dikes. The crystals are sometimes very large. **Beryllium** nitrate, made from beryl and other minerals containing beryllium, is used in the manufacture of gas mantles. Beryllium silicate is used in spark plugs.

97 Garnet.—A group of minerals, silicates of varying composition, including; (a) aluminum garnet, a silicate of alumina, and lime, magnesia, or iron; (b)

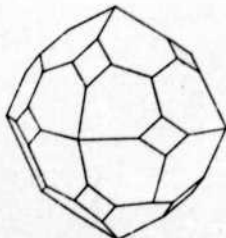


FIG. 62

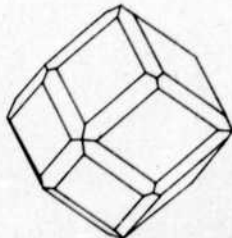


FIG. 63

Garnet Crystals

iron garnet, a silicate of iron and lime; (c) chromium garnet, a silicate of chromium and lime.

The commonest color is a deep red, also, brown, yellow, apple-green, black; powder, white; luster, glassy or resinous; $H = 6.5$ to 7.5 ; $G = 3.15$ to 4.3 ; crystals, in cubic system; has no true cleavage, but sometimes has a regular break, called *parting*.

Garnet is found in the contact zone between igneous rocks and crystalline limestone, or in calc schist, mica schist, granite, gneiss, quartzite. The common varieties are useful as abrasives, particularly in the form of garnet sandpaper. The lime-iron variety has been used as a flux in smelting iron ores. Finely colored, perfectly transparent crystals are valuable as gems. **Cinnamon stone** is pale red, yellow, and cinnamon-brown. **Pyrope**, of the characteristic deep red color, is found in peridotite, dunite, and serpentine rock. **Almandine**, the commoner precious garnet, is found in mica schist, etc. On account of its hardness, garnet survives the weathering and the wearing of the rocks in which it is found, and its weight causes it to collect with other hard, heavy minerals, such as magnetite, zircon, etc.

98. Olivine, Chrysolite, or Peridot.—A silicate of magnesia and iron, varying in composition; color, commonly olive-green, sometimes yellowish-green, occasionally reddish; powder, white, rarely yellowish; luster, glassy; $H = 6.5$ to 7 ; $G = 3.27$ to 3.37 ; usually in grains or crystal masses; cleavage, rather distinct. Has been used in jewelry, but not often found clear and solid enough.

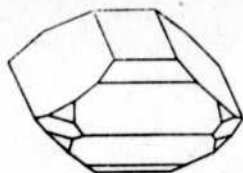


FIG. 64
Peridot Crystal

Olivine is the principal constituent of the rocks dunite and peridotite; it is also found more or less plentifully in diabase and gabbro. Associated with olivine in these rocks are a number of valuable minerals, including chromite, precious garnet, and platinum. Diamonds have also been found in such rocks. Olivine is also found as a contact mineral in dolomite and other magnesian rocks.

99. Epidote, or Pistacite.—A silicate of lime, alumina, and iron, and water; color, usually yellowish-green or brownish-green, sometimes black, yellow, red, gray, white; powder, white or gray; luster, glassy: **H** = 6 to 7; **G** = 3.25 to 3.5; cleavage, perfect.

Epidote is found mostly in metamorphic (changed) rocks, such as gneiss, mica schist, hornblende schist, and serpentine, usually as the result of changes caused by neighboring igneous rocks. In Lake Superior copper district, it is found plentifully, along with quartz and native copper. It has been used as a blast-furnace flux in smelting the Swedish magnetite with which it occurs.

100. Topaz.—A silicate of alumina, with fluorine, and sometimes water; usually colorless or pale yellow, sometimes pale blue, pink, etc.; luster, glassy: **H** = 8; **G** = 3.5; crystals, in

orthorhombic system; cleavage, perfect. Found in granite, gneiss, talc¹ schist, mica schist.

The finer transparent crystals are used as gems, the pink variety being the most valuable. Topaz accompanies tinstone, both in the ore in place and in placer deposits; it is also found with placer gold; its hardness and weight explain this.



FIG. 65

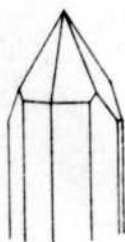


FIG. 66

Topaz Crystals

101. Tourmaline, or Schorl.—Color, commonly black, brownish-black, or bluish-black, sometimes, blue, green, red, pink, rarely white; powder, white or gray; luster, glassy; **H** = 7 to 7.5; **G** = 2.98 to 3.2; crystals, in hexagonal system, usually long prisms, sometimes needle-like; the faces are usually finely grooved lengthwise of the prism, and the crystals are more or less triangular in cross section; cleavage, almost absent. When a crystal of tourmaline is heated (or cooled), it becomes positively electrified at one end and negatively at the other end (pyro-electric). Composition, silicate of alumina and boron, with lime, magnesia, potash, etc. or iron. Iron tourmaline is

¹ So reported from Brazil; perhaps sericite schist, which is very like talc schist.

usually deep-black; it resembles black hornblende, but can be distinguished by the grooving and absence of cleavage.

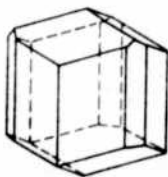


FIG. 67

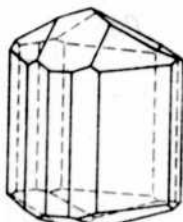


FIG. 68

Tourmaline Crystals

102. Tourmaline is usually found in pegmatite granite dikes and other granite masses, and is especially to be found near the contact of such rocks with schist, gneiss, and crystalline limestone. Large masses of tourmaline, commonly called **schorl**, have been mistaken for coal. Finely colored, transparent crystals are of value as jewels.

103. Calamine. or Hemimorphite; $H_2Zn_2SiO_4$.—This has been confused with carbonate of zinc and called Smithsonite; in Great Britain, it is also called electric calamine, as it is strongly pyro-electric (see Tourmaline, Art. 101). Color, white, sometimes bluish or grayish, rarely yellowish or brownish; powder, white; luster, glassy; $H = 4.5$ to 5 ; $G = 3.4$ to 3.5 ; Cleavage, perfect. Usually found with zinc blende and galena in limestone and dolomite.

104. Staurolite.—A silicate of aluminum, iron, and hydrogen; color, dark reddish-brown, brownish-black, yellowish-brown, sometimes gray by weathering; powder, white or gray, luster, between glassy and resinous; $H = 7$ to 7.5 ; $G = 3.65$ to 3.77 ; crystals, in orthorhombic system, often grown together in the form of a cross (twins); cleavage, good. Found in schists and other metamorphic rocks.

105. Andalusite.—A silicate of aluminum; color, white, reddish, violet, brownish, green; powder, white; $H = 7.5$; $G = 3.16$ to 3.20 ; crystals, orthorhombic; cleavage, good. Found in schists and other metamorphic rocks.

106. Rhodonite; $MnSiO_3$.—Color, light brownish-red; flesh-red, rose-pink, sometimes greenish or yellowish, weathers black; powder, white; luster, glassy; $H = 5.5$ to 6.5 ; $G = 3.4$ to 3.68 . Found with iron ores and with manganese ores.

107. Mica.—A group of silicates of alumina, with potash, iron, magnesia; characterized by easy cleavage into thin, flexible, elastic sheets. Mica gives off water when strongly heated.

1. Muscovite, or white mica, $(K,H)AlSiO_4^1$, is colorless, sometimes gray, brown, ruby, etc.; powder, white; luster, glassy or pearly; $H = 2$ to 2.5 ; $G = 2.76$ to 3 ; crystals, usually hexagonal in appearance when well formed. This is the commonest mica, always present in mica schist, and often in granite and gneiss. The large crystals, or "books", are useful for electric insulation, as a substitute for glass ("isinglass"), and for other purposes. Found in pegmatite granite dikes. It is stated to be inferior to **amber mica** (phlogopite) for electric motor and dynamo manufacture, as it is rather harder and is somewhat brittle. India is the largest producer, though Quebec, Ontario, and British Columbia, and other countries produce muscovite. Value, as quoted in market reports, 36 cents to \$9.00 per pound, according to size, quality, and color. Brazil produces the finest mica for ornamental purposes.

Sericite is muscovite in fine, silky scales.

¹ (K,H) means that potassium and hydrogen are in variable amounts, but such that when taken together they have the composition value of potassium, or 39.1 parts.

2. **Phlogopite**, or **amber mica**, differs in composition from muscovite in that it contains about 25% to 30% magnesia; it is usually free from iron. Color, yellowish-brown to brownish-red, etc.; powder, white; $H = 2.5$ to 3; $G = 2.78$ to 2.85. Found in dikes of pyroxenite (a rock composed of pyroxene with more or less feldspar), particularly at their contact with gneiss, mica schist, and crystalline limestone; often along with apatite. In the best deposits, pink calcite is plentiful.

Canada produces amber mica in large quantity; it is preferred for the manufacture of armatures of dynamos and motors, because it is softer and tougher than most commercial muscovite. For this purpose, it must be smooth, free from cracks, and from penetrating crystals of tourmaline, rutile, etc., also from stains of magnetite or hematite, which would lower the insulating power. The ordinary sizes, from 1 by 3 inches to 5 by 8 inches, bring prices of from 10 cents to \$1.50 per pound, or even higher; these are the prices for mica as it leaves the cutting tables; sizes 1×3 and below, down to 1×1 , are split thin and built up into **micanite**, or **mica plate**, by cementing with shellac; it can be cut and bent into any required size or shape. **Scrap mica** is sold for from \$5.00 to \$8.00 per ton, to grind for use as a lubricant, to protect the surface of roofing paper, for decorative purposes, to absorb nitroglycerine in the manufacture of dynamite, and for many other purposes.

Both white mica and amber mica are used in stove fronts, spectacles, gramophone diaphragms, fuse plugs, instead of glass in some workshops, and in lamp chimneys.

3. **Biotite**, or **black mica**, contains a high percentage of iron (up to about 25%), which causes its usual black color; it is also high in magnesia, and so is often called **magnesia-iron mica**. On account of its dark color and high percentage of iron, which lowers its insulating power, it is not often merchantable. The powder is white or gray.

108. Chlorite.—A group of minerals like mica in being cleavable into thin sheets or scales, but lacking the elasticity of mica; when bent, chlorite does not spring back. These minerals are silicates of aluminum, magnesium, and iron, with water; color, usually green; powder, white; luster, earthy or pearly; $H = 1$ to 3 ; $G = 2.65$ to 2.78 . Chlorites are mostly **secondary minerals**, being formed by the *alteration* of such minerals as biotite, pyroxene, hornblende, etc. There is another use of the word "secondary" as applied to minerals: sometimes a mineral is deposited in fissures, crevices, or hollows in rocks, after the rocks are formed; in such cases, the mineral is said to be **secondary**, the original minerals of the rock being **primary**. The quartz of granite is primary; it took its place as the granite was forming. But quartz filling a crack in the granite is secondary; it was brought there later.

109. Serpentine; $H_4Mg_3Si_2O_{10}$.—Color, green of various shades, brownish-red, brownish-yellow, yellowish-gray, sometimes nearly white; powder, white; luster, waxy or oily; smooth or slightly greasy feel; $H = 2.5$ to 4 , rarely harder; $G = 2.50$ to 2.65 ; fracture, shelly or splintery.

This is a secondary mineral, often forming large rock areas by the alteration of such igneous rocks as peridotite, dunite, etc., or of metamorphic rocks composed largely of pyroxene or hornblende. Magnesite, chromite, and platinum are sometimes found in serpentine rocks. **Serpentine marble** is a mottled serpentine rock. **Verde antique** is serpentine mixed with more or less calcite, magnesite, or dolomite, giving it a clouded appearance. **Noble serpentine** is of a rich green color, and is translucent. **Fibrous serpentine** is the asbestos mostly in use, although fibrous hornblende has also been used as asbestos. Serpentine asbestos is found in veins in ordinary serpentine. The fiber runs across the vein, but there is always a parting in the vein, which cuts across the fiber, the length of which rarely exceeds 2 or 3 inches. The value of the asbestos depends on the length and quality of the fiber. First-class fiber can be spun like silk or cotton. The better grades are spun, woven, and used for making firemen's suits, mitts for furnace workers, etc. The lower grades are used for the manufacture of asbestos sheeting, shingles, roofing paper, cement, etc. The quantity of the poorer grades so much exceeds that of the better qualities that the average price for the whole production of Quebec is only from \$60 to \$80 per ton. The rock as mined averages about \$4 worth of asbestos to the ton. The market quotations (1923) are as follows: crude No. 1, \$500 per ton; No. 2, \$250 to \$325; spinning fiber, \$135 to \$200; magnesia compressed sheet fibers, \$100 to \$150; shingle stock, \$65 to \$95; paper stock, \$35 to \$42; cement stock, \$20 to \$25; floats, \$9 to \$14.

Garnierite, a hydrated silicate of magnesia and nickel, of a bright apple-green color. It is soft, and may be smooth-feeling, like serpentine. $G = 2.5$. Has been mined as an ore of nickel.

110. Talc; $H_2Mg_3Si_4O_{12}$.—Color, white, apple-green greenish, dark green, or reddish; powder, white or slightly colored; luster, pearly; greasy feel; $H = 1$ to 1.5; $G = 2.7$ to 2.8; sometimes foliated, i. e., separable into thin sheets, and occasionally fibrous; mostly a secondary mineral.

Soapstone or **steatite**, is a granular talc, more or less impure, and sometimes as hard as 2.5. **Potstone** and **French chalk** are other varieties of impure talc.

Talc is found in association with serpentine, talc schist, chlorite schist, and especially with dolomite, as in Madoc, Ontario. It sometimes forms extensive rock areas which are quarried for sinks and table tops, where heat and acids are to be resisted, for ornaments, fireplaces, and ovens. Ground, shaped, strongly heated, it is made into gas-burner tips. Ground talc, made from the pure mineral, is used in the manufacture of paper, white cotton goods, talcum powder, lubricants, and paints. Value of ground talc (1923), from \$6.00 to \$14.75 per ton.

11. Kaolin, or China Clay; $H_4Al_2Si_2O_9$.—This is the composition of the pure mineral, **kaolinite**. The ordinary varieties of clay are more or less impure. The pure mineral is usually white; it has a greasy feel, powders easily, and when mixed with water it makes a sticky mass; when breathed upon it gives off a peculiar smell, **clayey**. Although crystallized kaolin-

ite has a hardness of 2 to 2.5, the powdery mass usually found is at least as soft as talc. $G = 2.6$.

Kaolin is a secondary mineral; it is formed by the alteration of feldspar and other aluminous minerals by the action of water and carbon dioxide, which extract the potash, soda, lime, etc. In this way, masses of granite and similar rocks have in some cases been converted into large clay deposits — sometimes left in place, more or less mixed with quartz, and sometimes washed into hollows, and deposited as clay beds. The best white clay is used in the manufacture of china ware and paper; impure varieties are used in the manufacture of brick, tile, etc. Value, crude kaolin, \$6 to \$20 per ton. **Marl** is a mixture of clay and carbonate of lime. It is used in the manufacture of Portland cement.

112. Titanite, or Sphene; CaTiSiO_5 .—Color, usually brown or black, sometimes gray, yellow, green, rose-red; powder, white; luster, diamond-like to resinous; $H = 5$ to 5.5; $G = 3.4$ to 3.56; crystals, in monoclinic system, mostly flat and wedge-shaped; cleavage, rather distinct. Found in hornblende granite, syenite, dio-

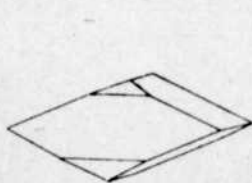


FIG. 69

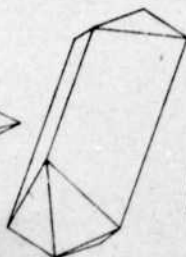


FIG. 70

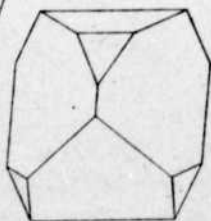


FIG. 71

Sphene Crystals

rite, in nepheline-syenite, and also in schists, gneiss, and crystalline limestones. Since it contains about 40% of titanium oxide, it is of value as an ore of titanium; but it is not often found in quantity.

GROUP VII — PHOSPHATES, ETC.

REMARK.—This group includes a number of rare minerals, and apatite.

113. Pitchblende, or Uraninite.—Color, pitchy-black, greenish, or brownish-black; powder, brownish-black, grayish, greenish; luster, dull and pitchy, sometimes slightly metallic. $H = 5.5$; $G = 9$ to 9.7 ; no cleavage; contains uranium, radium, etc. Found in pegmatite granite dikes, and also, in some cases, with ores of silver, lead, copper, and tin; it is apt to have yellow spots or crust of uranium ochre. Very valuable for manufacture of uranium and radium products. Pitchblende might be concentrated from the feldspar mined in the pegmatite dikes where pitchblende has been found. Being a black mineral, it lowers the value of the feldspar.

Euxenite and samarskite are uranium minerals, somewhat like pitchblende in appearance, but not so heavy as pure pitchblende.

Carnotite is a uranium mineral found extensively in Colorado and Utah, in sandstone; it has also been found with ilmenite. It is yellow in color, and in addition to uranium and radium, it contains the valuable metal, **vanadium**, used in making vanadium steel. Value, ore containing $1\frac{1}{2}\%$ of uranium oxide (U_2O_3) and 5% vanadium oxide (V_2O_5), \$105 per ton. All uranium minerals contain radium, and if found in sufficient quantity, can be used for the extraction of radium as well as uranium.

144. Monazite.—A phosphate of certain rare elements, as cerium, thorium, etc. Color, red, brown, yellowish; luster, somewhat resinous; $H = 5$ to 5.5 ; $G = 5$. Found in granite and gneiss, in scattered grains, and in sand resulting from the breaking down and weathering of such rocks. Used for making ferro-cerium (\$12 to \$15 per pound), for gas lighters and for the manufacture of materials for gas mantles, etc. The most valuable constituent is thorium oxide (ThO_2). Value of ore, 8 cents to 10 cents per pound.

115. Apatite.—Color, usually green, bluish-green, or brownish, sometimes blue, white, yellow, red, gray;

powder, white; luster, glassy or slightly resinous; $H = 5$; $G = 3.2$; crystals in hexagonal system; cleavage,

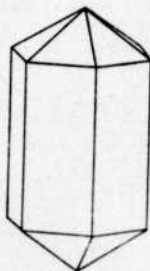


FIG. 72

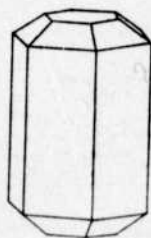


FIG. 73

Apatite Crystals

poor; composition, phosphate of lime ($Ca_3P_2O_8$), with calcium chloride ($CaCl_2$) or calcium fluoride (CaF_2). Present in most rocks as occasional very small crystals, and, as a consequence, in all soils, since they have been formed by the breaking down of rocks; it supplies growing plants with phosphorus. In merchantable quantities, apatite or, "phosphate," is found in pyroxenite and similar dikes in granite, gneiss, mica schist, crystalline limestone, etc.; it is also found as a sedimentary deposit in South Carolina and other southern states and likewise in Tunis and Algiers. Formerly, there was a prosperous phosphate industry in eastern Ontario and western Quebec; but, in 1890, the more easily mined sedimentary phosphate drove the Canadian mineral out of the market. At present, in Canada, it is produced only as a by-product in mica mining. Phosphate is used in the manufacture of phosphorus and artificial fertilizers. Value, \$4.40 to \$9.50 per ton.

Pyromorphite is of similar composition, but with lead instead of calcium. Color, green, sometimes white, yellow, brown; powder, white; $H = 3.5$ to 4 ; $G = 6.5$ to 7.1 .

GROUP VIII — SULPHATES, ETC.

REMARK.—The sulphates correspond to sulphuric acid, H_2SO_4 . In sulphates, there are metals in place of the hydrogen of the acid; they are to be distinguished from sulphides, which contain no oxygen, but are made up of sulphur and metals.

116. Barite or Barytes; $BaSO_4$.—Also called **heavy spar**. Color, usually white, sometimes gray, reddish, brown, etc.; powder, white; luster, glassy; $H = 2.5$ to 3.5 ; $G = 4.3$ to 4.6 ; crystals, in orthorhombic system, usually tabular, often in clusters with wedge-like edges projecting; cleavage, perfect, cleavage pieces with two sets of square edges and one set of 78° and 102° (Fig. 74).



FIG. 74



FIG. 75

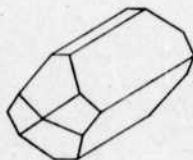


FIG. 76

Barite Crystals

Found in veins in rocks of many ages and kinds, often along with ores of lead, copper, silver, etc., and with fluorspar. When ground to a fine powder, used in paper, linoleum, rubber, etc; also, to make lithopone and other substitutes for white lead. Barite is

the raw material for the manufacture of a number of chemicals, including barium nitrate, for green fire; but witherite is more easily worked for this purpose. **Derbyshire spar** is a dark-brown variety found as stalactites, and used as an ornamental stone, for vases, etc. Value, \$7.80 to \$9.00 per ton. When ground, it sells for \$16 to \$23 per ton, according to purity.

117. Celestite; SrSO_4 .—Color, white, often bluish and sometimes reddish; powder, white; luster, glassy; **H** = 3 to 3.5; **G** = 3.95 to 3.97; crystals, similar to those of barite; cleavage, perfect, cleavage pieces with square edges (see Barite); composition, strontium sulphate. Celestite is often fibrous. Value, \$15 to \$18 per ton. Used chiefly to make strontium nitrate, for red fire, and strontium hydrate, for use in refining beet sugar. (See Strontianite, Art. 85.)

118. Anglesite; PbSO_4 .—Similar to barite and celestite, but rather softer and much heavier; **H** = 2.75 to 3; **G** = 6.3 to 6.4; composition, lead sulphate. Found with galena as a result of its weathering. (See also Cerussite, Art. 87.)

119. Gypsum; $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.—Color, white when pure, but variously colored with impurities; powder, white; luster, glistening, sometimes dull; **H** = 2; **G** = 2.3; crystals in monoclinic system; cleavage, very perfect, almost like mica in yielding thin, smooth leaves when crystals are large enough, but differs from mica in that the leaves will not return to original shape



FIG. 77
Gypsum Crystal

(inelastic); composition, calcium sulphate (sulphate of lime), with water.

Found in beds as a sedimentary deposit, often with rock salt, suggesting its origin by the evaporation of sea water; sometimes in crystals in clay and soil.

Selenite is gypsum in large, clear crystals, often very beautiful. **Satin spar** is fine-fibrous gypsum, with pearly opalescence. **Alabaster** is a fine-grained, compact variety, white or of delicate shades.

Gypsum is used chiefly for making plaster of Paris, most of the water being driven off by heating in kilns, and then grinding. When plaster of Paris is mixed with water, the crystals of gypsum are again formed, and the whole mass "sets", becoming solid. Gypsum is also used as a soil fertilizer. Clear crystals of selenite are used in optical instruments; satin spar is used for making beads and other ornaments; and alabaster is used for ornamental sculpture for monuments, vases, etc.

Anhydrite, CaSO_4 , is often found with gypsum; it is of little value.

120. **Epsomite, or Epsom Salt**; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.—Appearance and taste are well known; $\text{H} = 2$ to 2.5; $\text{G} = 1.751$. Found in mineral waters and in deposits from alkaline lakes in British Columbia. Used in tanning, dyeing, for weighting silk, paper, and leather, in enameling, in fireproofing compounds, in medicine, etc.

121. **Mirabilite, or Glauber's Salt**; $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.—A white easily soluble substance of a cool, slightly bitter taste, found as a deposit or incrustation around mineral springs, and in salt lakes. It may be of value to replace salt cake (Na_2SO_4) in the manufacture of pulp by the sulphate process.

122. **Wolframite, or Wolfram**.—An ore of tungsten; color, dark grayish or brownish-black; powder.

nearly black or brownish-red; luster, somewhat metallic; **H** = 5 to 5.5; **G** = 7.2 to 7.5; cleavage very perfect; sometimes weakly magnetic; composition, tungstate of iron and manganese, FeWO_4 and MnWO_4 , containing about 75% of tungsten oxide, WO_3 .

Found in granite and other acid rocks often with tinstone; also, in quartz veins, and sometimes with gold. Used mainly for making tungsten steel, and to make tungsten as an ingredient of stellite (see Chromite, Art 65). Value \$3.50 to \$3.75 per unit of WO_3 . If the ore or concentrates carry, say, 50% of WO_3 , or 1,000 pounds in a ton of ore, it will sell at \$175.00 to \$187.50 per ton. The unit is 1%, and $\$3.50 \times 50 = \175.00 .

123. Scheelite; CaWO_4 . — Color, white, yellowish, brownish, greenish, reddish; powder, white; luster, glassy; **H** = 4.5 to 5; **G** = 6; cleavage, distinct; composition, calcium tungstate, or tungstate of lime. Usually found in quartz veins, sometimes associated with gold (as in the Porcupine area, Ontario), tinstone, wolframite, etc. See Wolframite Art. 122.

MINERAL TABLES

124. Purpose of Mineral Tables. — In the foregoing pages, the various minerals have been described individually, so that any mineral specimen may be compared with a careful description of that mineral. The prospector's task is to discover valuable minerals; and to be proficient in this, he must be practiced in their identification. The best method of obtaining the requisite experience is to work in a systematic way with selected mineral specimens, the names of which

are unknown to the reader. For this purpose, mineral tables have been prepared, by means of which the identification of minerals may be conducted in an orderly manner. Such a table follows, and the proper method of using it will now be explained.

125. How to Use the Mineral Table. — First note the luster, and then place the specimen in one of the two great classes: I. Minerals of Metallic Luster; II. Minerals of Non-Metallic Luster. Minerals having a doubtful luster will be found in both classes. The search has now been restricted to one of these two classes. In the metallic-luster class, the search is further narrowed by determining the color of the specimen; and in the non-metallic luster class, the color of the powder makes two divisions. By continuing this principle of subdivision according to some property, either the name of the mineral is reached or a small subdivision is reached that contains a few minerals that cannot be distinguished without making laboratory tests.

Since a few minerals are attracted by a magnet, the blade of the knife should be kept magnetized, so this property may be tested. This may be done by rubbing the blade eight or ten times from heel to point against one pole of a magnet, or by drawing the blade a few times along the armature of a dynamo in motion, but taking care, in either case, always to move the blade in the same direction.

To practice the use of the table, take unnamed specimen No. 1. Note its luster, metallic; therefore it belongs to Class I. Its color is yellowish, which puts it

in Division A. Try to scratch it with the knife point; it is very hard, and the specimen is thus narrowed down to the small group containing pyrite and marcasite. These two minerals are of the same composition, and are hard to distinguish one from the other. Try the taste. Pyrite usually has no taste, but marcasite is likely to taste slightly sour and inky. This specimen is pyrite, and it should now be compared with the description given in Art. 38.

Take unnamed mineral No. 2. Its metallic luster puts it in Class I. Note its color, black; this puts it in Division E. Try its hardness with a knife; it is easily powdered, and so belongs to Group 2 of Division E. Try marking paper with the specimen; it makes a mark like that of a lead pencil, and it is either graphite or molybdenite. Try the weight; it feels light, and the specimen is therefore graphite. Confirm this by reading Art. 34, Graphite, and Art. 50, Molybdenite.

Next take unnamed mineral No. 3. Its non-metallic luster puts it in Class II. Try the color of its powder; it is distinctly colored, which puts it in Division A. The powder is yellow, which puts it in Group 3. The specimen is either limonite or carnotite. The specimen is rusty colored, which answers to the description of limonite. Confirm by reading Art. 64, Limonite.

Now practice with unnamed mineral No. 4. Since its luster is non-metallic, it belongs in Class II. Powder it a little with the point of the knife; the powder is white, which puts mineral in Division B; when making the powder you noticed that the mineral was

hard to scratch with the knife; it therefore belongs to Group 1 of Division B. The cleavage is distinct, which puts the mineral in Subdivision (b); and since the specimen feels light, it is to be placed in Subdivision 3. The description of feldspar answers best to the appearance of the specimen.

Take unnamed mineral No. 5. Luster, non-metallic; therefore look in Class II. Powder it with the point of the knife; since powder is white, go to Division B. When making the powder, you noticed that the mineral was easy to scratch; go to Group 2. Heft the specimen; it feels light; hence, go to subdivision (a). Compare the hardness with that of the named specimen, calcite; it is as hard as calcite. Break a piece into small fragments, and note the cleavage; remarkably perfect, as shown by the brilliance of the surfaces. Note also the shape of the pieces as regards the corners and edges; the cleavage is called rhombohedral. These points, and the white color, correspond to the mineral calcite; but it is rather hard to distinguish between calcite, dolomite, and magnesite without laboratory tests.

Take unnamed specimen No. 6. Its non-metallic luster puts it in Class II; its white powder in Division B; its softness, in Group 2; and its lightness, in Subdivision (a). Compare its softness with that of calcite; it is softer; hence, go to (2), and read the description carefully. That of gypsum corresponds best. In Group 2, the minerals are hard to distinguish by the simple tests used in this Table; the most experienced mineralogist may need to use laboratory tests to identify them.

LIST OF ELEMENTS, THEIR SYMBOLS AND ATOMIC WEIGHTS

Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
Aluminum....	Al	27.1	Molybdenum....	Mo	96.0
Antimony....	Sb	120.2	Neodymium....	Nd	144.3
Argon.....	A	39.88	Neon.....	Ne	20.2
Arsenic.....	As	74.96	Nickel.....	Ni	58.68
Barium.....	Ba	137.37	Niton.....	Nt	222.4
Bismuth.....	Bi	208.0	Nitrogen.....	N	14.01
Boron.....	B	11.0	Osmium.....	Os	190.9
Bromine.....	Br	79.92	Oxygen.....	O	16
Cadmium.....	Cd	112.40	Palladium.....	Pd	106.7
Cæsium.....	Cs	132.81	Phosphorus.....	P	31.04
Calcium.....	Ca	40.07	Platinum.....	Pt	195.2
Carbon.....	C	12.00	Potassium.....	K	39.10
Cerium.....	Ce	140.25	Praseodymium.....	Pr	140.6
Chlorine.....	Cl	35.46	Radium.....	Ra	226.4
Chromium.....	Cr	52.00	Rhodium.....	Rh	102.9
Cobalt.....	Co	58.97	Rubidium.....	Rb	85.45
Columbium.....	Cb	93.5	Ruthenium.....	Ru	101.7
Copper.....	Cu	63.57	Samarium.....	Sa	150.4
Dysprosium.....	Dy	162.5	Scandium.....	Sc	44.1
Erbium.....	Er	167.7	Selenium.....	Se	79.2
Europium.....	Eu	152.0	Silicon.....	Si	28.3
Fluorine.....	F	19.0	Silver.....	Ag	107.88
Gadolinium.....	Gd	157.3	Sodium.....	Na	23.00
Gallium.....	Ga	69.9	Strontium.....	Sr	87.63
Germanium.....	Ge	72.5	Sulphur.....	S	32.07
Glucium.....	Gl	9.1	Tantalum.....	Ta	181.5
Gold.....	Au	197.2	Tellurium.....	Te	127.5
Helium.....	He	3.99	Terbium.....	Tb	159.2
Holmium.....	Ho	163.5	Thallium.....	Tl	204.0
Hydrogen.....	H	1.008	Thorium.....	Th	232.4
Indium.....	In	114.8	Thulium.....	Tm	168.5
Iodine.....	I	126.92	Tin.....	Sn	119.0
Iridium.....	Ir	193.1	Titanium.....	Ti	48.1
Iron.....	Fe	55.84	Tungsten.....	W	184.0
Krypton.....	Kr	82.92	Uranium.....	U	238.5
Lanthanum.....	La	139.0	Vanadium.....	V	51.0
Lead.....	Pb	207.10	Xenon.....	Xe	130.2
Lithium.....	Li	6.94	Ytterbium.....	Yb	172.0
Lutecium.....	Lu	174.0	Yttrium.....	Yt	89.0
Magnesium.....	Mg	24.32	Zinc.....	Zn	65.37
Manganese.....	Mn	54.93	Zirconium.....	Zr	90.6
Mercury.....	Hg	200.6			

MINERAL TABLE

For Determination of Minerals by Field Tests

(The numbers in parenthesis are same as those of the articles describing the same minerals in the Text. The descriptions of the rarer minerals are in smaller type.)

I. MINERALS OF METALLIC LUSTER

A. Yellow or Yellowish Color

1. NOT SCRATCHED WITH KNIFE

Brass-yellow; powder, grayish-black; crystallizes in cubes, octahedrons, etc. **Pyrite (38)**

Light yellow or nearly white; powder, grayish black; inky, sour taste; forms wedge-shaped crystals. **Marcasite (39)**

2. CAN BE SCRATCHED WITH KNIFE

Brass-yellow, often with many colored tarnish; powder, greenish-black or dark green **Copper Pyrites (40)**

Bronze-yellow, bronze-brown, or yellowish-gray; powder, black; magnetic. **Pyrrhotite (41)**

Pale yellow; powder, gray; brittle. **Calaverite (54)**

Golden yellow; does not powder, but spreads out. **Gold (26)**

B. Red or Reddish Color.

1. HARD TO SCRATCH

Pale copper-red; powder, brownish-black; very heavy. **Niccolite (58)**

Copper-red, rosy shade; powder, reddish-brown; very heavy. **Breithauptite (58)**

Brownish or grayish-red; powder, red; heavy. **Hematite (63)**

2. EASY TO SCRATCH

Brown-red when fresh, tarnishes to purple, etc.; powder, grayish-black. **Bornite (42)**

Bright red or brownish-red; luster, near metallic; powder, vermillion red; very heavy **Cinnabar (53 A)**

Bright red or reddish-black; luster, near metallic; powder, brownish-red, shining; heavy **Cuprite (70)**

Reddish-black or black; luster, near-metallic; powder, purple red. **Pyrrargyrite (52)**

Vermillion-red; luster, near-metallic; powder, vermillion-red. **Proustite (53)**

Copper-red; does not powder, but spreads out.

Copper (28)

C. Gray Color

1. HARD TO SCRATCH

Steel-gray; powder, dull red; sometimes micaceous, then seems soft.

Hematite (63)

Tin-white to steel-gray; powder, grayish

black. { Yellow tinge; crystals grooved. Mispickel (56)
 { Blue tinge. Smaltite (55)

2. EASY TO SCRATCH

(a) Dark Gray to Nearly Black

Powder, gray-black; rather sectile¹; cleavage, poor

Chalcocite (43)

Powder, gray-black; brittle; no cleavage.

Tetrahedrite (44)

Powder, iron-black; slightly sectile; no cleavage.

Petzite (54)

Perfectly sectile; shiny where cut or rubbed.

Argentite. (51)

(b) Lead-Gray

Powder, lead-gray; brittle; cubic cleavage, very perfect.

Galena (43)

Powder, lead-gray; rather sectile; cleavage perfect, but often in streaks.

Stibnite (45)

Powder, lead-gray; somewhat sectile; often yellowish or many-colored tarnish; cleavage, perfect.

Bismuthinite (49)

Powder, light gray; black tarnish; brittle;

Arsenic (30)

Powder, iron-black; somewhat sectile; cleavage, poor.

Hessite (54)

Light gray with yellowish tint; cubic cleavage.

Altaite (54)

(c) Steel-Gray

Slightly sectile; soils paper; commonly in thin flexible crystals; cleavage, perfect.

Tetradymite (54)

Sometimes yellowish; brittle; powder, steel-gray; cleavage, perfect.

Sylvanite (54)

Powder, grayish-black; brittle; often needle-like crystals; cleavage, perfect.

Jamesonite (46)

Powder, grayish-black; brittle; cleavage, poor.

Bournonite (47)

¹Sectile means the opposite of brittle; cuts like lead or cheese, without cracking or crumbling.

D. White Color

1. HARD TO SCRATCH

Silver-white to pale gray; powder,
grayish-black; very heavy.

- | | |
|-----------------------------------|-----------------------|
| { Yellow tinge; crystals grooved. | Mispickel (56) |
| { Blue tinge. | Smaltite (55) |

2. EASY TO SCRATCH

Malleable; may have brown or black
tarnish.

Sectile; rather hard

Silver (27)

Sectile; softer; slightly reddish
tint; very perfect cleavage

Dyscrasite (57)

Brittle; sometimes yellowish; pow-
der, steel-gray; cleavage, perfect.

Bismuth (57)

Brittle; sometimes pale yellow;
powder, yellowish-gray or greenish-
gray; no cleavage.

Sylvanite (54)

Calaverite (54)

E. Black Color

1. HARD TO SCRATCH

(a) *Strongly Magnetic*

Powder, black.

Magnetite (60)

(b) *Slightly Magnetic or Non-Magnetic*

Powder, red.

Hematite (63)

Powder, brown-red, dark brown, or
black; no cleavage; slightly magnetic

Ilmenite (61)

Powder, brown; no cleavage; seldom
magnetic, and then very slightly.

Chromite (65)

Powder, brownish, grayish, or white;
imperfect cleavage; very heavy; very
hard.

Tinstone (66)

Powder, dark brown; no cleavage;
slightly magnetic; like magnetite.

Franklinite (62)

Powder, brownish-black, shiny; lus-
ter, near-metallic; no cleavage; non-
magnetic.

Psilomelane (70)

Powder, brownish-black, grayish or
olive-green, a little shiny; luster,
near-metallic; no cleavage; non-
magnetic; looks like black pitch;
very heavy.

Pitchblende (113)

Powder, nearly black; cleavage,
very perfect; sometimes slightly
magnetic; very heavy; color usually
brown-black; luster, near-metallic.

Wolframite (122)

2. EASY TO SCRATCH

(a) Makes Clean Mark on Paper

Gray mark; mineral is light.

Graphite (34)

Bluish-gray mark, slightly green when rubbed; mineral is heavy.

Molybdenite (50)

(b) Too Hard to Make Clean Mark on Paper

Powder, black; brittle; fibrous or granular.

Pyrolusite (69)

Powder, brown; brittle; luster, near-metallic; cleavage, very perfect.

Zinc Blende (59)

Powder, dark lead-gray; perfectly sectile.

Argentite (51)

Powder, black; very heavy.

Coloradoite (54)

II. MINERALS OF NON-METALLIC LUSTER

A. Powder Distinctly Colored

1. POWDER, BLACK OR BROWN-BLACK

Coal-black; soft; light; very brittle.

Coal (35)

Brown to dull black; earthy, like bog iron.

Bog Manganese (70)

Luster, near-metallic; very hard; cleavage, perfect.

Braunite (71)

Luster, near-metallic; hard.

Psilomelane (70)

Luster near-metallic; pitchy; no cleavage; very heavy.

Pitchblende (113)

Like pitchblende, but harder; not so heavy.

Euxenite (113)

2. POWDER BROWN

Not scratched by knife; very heavy; color, black or brown; cleavage, poor

Tinstone (66)

Hard to scratch; heavy; color, black; no cleavage.

Chromite (65)

Easier to scratch; color, black or brown; luster, resinous; cleavage, perfect.

Zinc Blende (59)

Harder to scratch; color, black or brown;; luster, near metallic; like zinc blende, but harder and heavier.

Wolframite (122)

Not scratched, or very hard to scratch; color, reddish-brown or red; luster, near-metallic; fairly heavy; cleavage, distinct.

Butile (74)

3. POWDER, YELLOW

Color, dull brown, brownish-yellow, or yellow; powder, brownish-yellow; no cleavage.

Limonite (64)

Color, deep red or orange-yellow; powder, orange-yellow;; cleavage, perfect.

Zincite (72)

Color, canary-yellow; powder, canary-yellow.

Carnotite (113)

4. POWDER, RED

Color, brick-red; powder, red or reddish-brown; earthy.

Hematite (63)

Color, cochineal-red; powder, vermilion-red; somewhat sectile.

Cinnabar (58)A

Color, cochineal-red; powder, brownish-red, shiny; crystals or earthy.

Cuprite (73)

5. POWDER, GREEN

Color, green; fairly hard; rather heavy.

Malachite (89)

Color, light apple-green; soft; light. Garnierite (109)

6. POWDER, BLUE

Color, azure-blue; fairly hard.

Azurite (89)

B. Powder, White or Faintly Colored

1. HARD TO SCRATCH, OR NOT SCRATCHED

(a) *Cleavage, None or Indistinct*

Color, white, amethystine, or smoky, etc.; luster, glassy; light; crystals, hexagonal.

Quartz (75)

Color, black, brown, or green; luster, glassy; light; crystals, triangular prisms, grooved.

Tourmaline (101)

Color, garnet-red, brown, or green; luster, glassy; fairly heavy; crystals, roundish.

Garnet. (97)

Color, black, brown, gray, or white; luster, adamantine; very heavy; crystals, tetragonal.

Tinstone (66)

Color, yellowish or brown; luster, adamantine; heavy; crystals, tetragonal; harder than quartz.

Zircon (96)

Color, green, blue, yellow, or white; luster, glassy; light; crystals, hexagonal; harder than quartz.

Beryl (96)

*(b) Cleavage Distinct**(1) Rather Heavy*

H = 10; **G** = 3.5; cleavage, very perfect; roundish crystals; faces curved.

Diamond (33)

H = 9; **G** = 4; cleavage, good (parting); crystals, hexagonal.

Corundum (67)

H = 8; **G** = 3.5; cleavage, very perfect; crystals, grooved; color, yellow.

Topaz (100)

H = 9; **G** = 3.5 cleavage, fair; crystals; flat or wedge-like; color, brown.

Spheue (112)

(2) Not so Heavy

H = 6.5; color, yellowish green or brownish green.

Epidote (99)

H = 6.5; color, olive-green.

Olivine (98)

H = 5.5; cleavage pieces with angles of 56° and 124°.

Hornblende (91)

H = 5.5; cleavage pieces with angles nearly 90°.

Pyroxene (92)

(3) Light

Cleavage, perfect, angles 90° or nearly 90°; luster, rather pearly.

Feldspar (90)

Cleavage, fair, angles 90°; luster, rather glassy; cleavage surface, fibrous looking.

Scapolite (94)

Cleavage, only fair; color, blue, etc.

Sodalite (95)

Cleavage, good; color, white

Nepheline (93)

2. EASIER TO SCRATCH*(a) Light (G = 2.7 to 3.5)**(1) Hard as Calcite or Harder*

H = 3; cleavage, remarkably perfect, pieces rhombohedral; color, white.

Calcite (80)

H = 3.5; cleavage, perfect, pieces rhombohedral; color, white.

Dolomite (81)

H = 3.5; cleavage, perfect, pieces rhombohedral; color, pink.

Rhodochrosite (84)

H = 4; cleavage, perfect, pieces rhombohedral; sometimes like porcelain; color, white.

Magnesite (82)

H = 4; cleavage, perfect, with some faces equilateral triangles; color, white green, or violet-blue.

Fluorspar (78)

H = 4.5 to 5; cleavage, perfect; color, white, sometimes with pale blue or green tint.

Calamine (88)

H = 5; crystals hexagonal; cleavage, imperfect; color, green or brown, etc.

Apatite (115)

H = 2.5 to 4; not crystalline; fracture, conchoidal or splintery.

Serpentine (109)

(2) *Softer than Calcite*

H = 2.5 to 4 (see above).

Serpentine (109)

H = 2.5; looks like ice, especially if wet.

Cryolite (79)

H = 2 to 3, but feels softer because of easy splitting; cleavage, very perfect, into thin, elastic leaves.

Mica (107)

H = 2; color, white; glistening; cleavage, very perfect; not elastic.

Gypsum (119)

H = 1 to 2; color, green; fine grained or in scales like mica; not elastic.

Chlorite (108)

H = 1; color, white, pale green, or gray; soapy feel.

Talc (110)

Soft, powdery; clayey smell when breathed on; plastic when wet.

China Clay (111)

H = 1 to 3; color, white, yellow, brown, or red; clayey smell when breathed upon; usually oolitic, that is, with round grains like fish eggs.

Bauxite (68)

(b) *Heavy (G = 3.7 to 6.5)*

(1) *Hard as Calcite or Harder*

H = 3; **G** = 6.3; cleavage, distinct; very brittle; color, white, slightly tinted.

Anglesite (118)

H = 3; **G** = 6.5; cleavage, distinct; very brittle; color, white; luster, brilliant, like diamond.

Cerussite (87)

H = 3 to 3.5; **G** = 4; cleavage, perfect; often fibrous; color, white, faintly blue.

Celestite (117)

H = 3.5; **G** = 3.7; cleavage, perfect; color, white.

Strontianite (85)

H = 3.5; **G** = 4.3; cleavage, distinct; color, white.

Witherite (86)

H = 3.5; **G** = 3.8; cleavage, perfect; color, white or gray, often rusty.

Siderite (83)

H = 4.5; **G** = 6; cleavage, distinct; color, white or light brown or yellow.

Scheelite (123)

PROSPECTING

H = 5; **G** = 5; in roundish grains;
color, red or brown. **Monazite (114)**

H = 5; **G** = 4.3; mostly in roundish
masses, crusts, etc., like calamine. **Smithsonite (88)**

(2) Softer than Calcite

H = 2.5; **G** = 4.5; cleavage perfect;
in flat crystals grouped so as to show
wedge-like edges; color, white.

Barite (116)

PROSPECTING

(PART 1)

EXAMINATION QUESTIONS

(1) (a) What is the meaning of *mineral*, as the word is generally used in this text? (b) with what other meaning is the word used by mining men?

(2) (a) Give examples of the way in which the color of a mineral varies with the size of the grain. (b) How is this property made use of in identifying minerals?

(3) (a) What practical means has the prospector for testing the hardness of a mineral? (b) Write the Scale of Hardness, giving the names of the minerals in it. (c) Mention some practical way of testing the hardness of each mineral.

(4) (a) The specific gravity of orthoclase feldspar is 2.55; what is the practical meaning of this statement? (b) Taking the weight of a cubic foot of water as 62.4 pounds, calculate the number of cubic feet to the ton of this feldspar.

Ans. (b) 12.57 cubic feet.

(5) (a) What are crystals? (b) When a number of minerals have been mixed in the same liquid (all being in a fluid condition), to what extent are they mixed

in the solid formed by the cooling of the liquid? (c) How does the rate of cooling affect the result?

(6) (a) What is cleavage, as applied to minerals? (b) How would you detect good cleavage in a mineral?

(7) (a) Referring to the Table of Atomic weights and using the values of the symbols as there given, calculate the per cent of copper in copper pyrites, CuFeS_2 . (b) Calculate the weight of copper in a ton of the pure mineral. (c) If an ore contain 20% of copper pyrites, how many pounds of copper would there be in a ton of it?

Ans. $\left\{ \begin{array}{l} (a) \quad 34.63\% \\ (b) \quad 693 \text{ pounds.} \\ (c) \quad 138\frac{1}{2} \text{ pounds.} \end{array} \right.$

(8) (a) How would you distinguish a speck of gold from any other mineral? (b) What minerals are most commonly mistaken for gold?

(9) (a) What are sulphides? (b) What are oxides? (c) Mention three examples of both classes.

(10) (a) What is a carbonate? (b) By what test can carbonates be recognized, and what happens when the test is made?

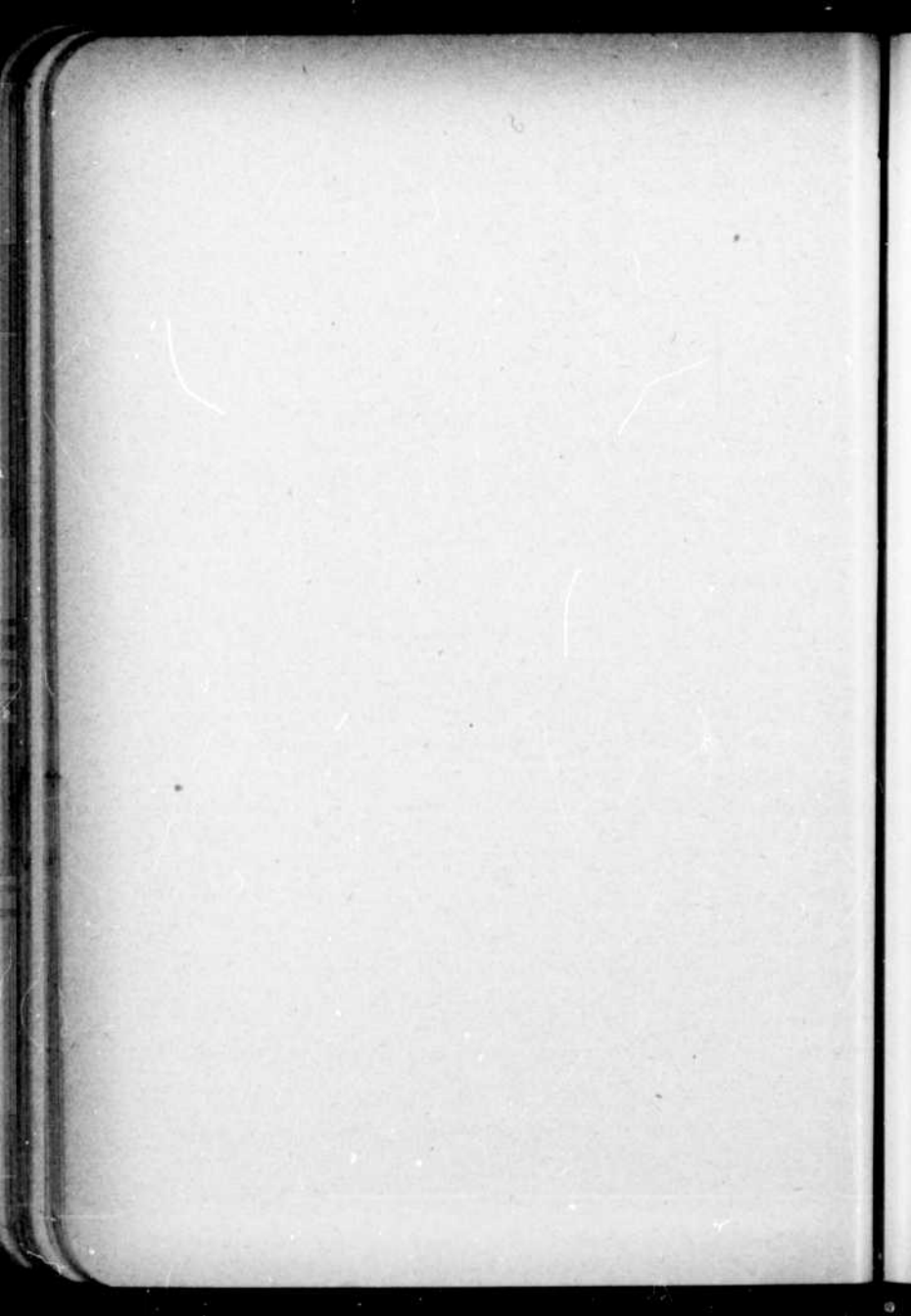
(11) (a) Write definitions of *silica* and *silicates*. (b) Write a statement of the composition of feldspar. (c) Describe a cleavage piece of orthoclase with regard to the arrangement of surfaces that show good cleavage and those that show no cleavage.

(12) Compare the three micas, muscovite, phlogopite, and biotite, as to composition.

(13) (a) Compare feldspar and kaolin as to their composition. (b) What is removed from feldspar when it is changed to kaolin by weathering?

(14) (a) What are sulphates? (b) how do they differ in composition from sulphides?

(15) In so far as you are able, use the mineral table to identify the mineral specimens supplied you. Make out a report giving your findings, and send us the report with your answers to the foregoing questions.



PROSPECTING

(PART 2)

ROCKS AND ROCK STRUCTURES

INTRODUCTION

126. The Earth.—As a preparation for the systematic study of rocks, it will be useful to look at the earth as a whole, inquiring into its origin, the changes that it has undergone and is still undergoing, and the nature and causes of the great variety of surface features.

127. Origin of the Earth.—From comparison with the sun and other heavenly bodies that are known to be fiery globes, it is inferred that the earth began in the same manner, reaching its present condition by cooling until a solid crust was formed. That the interior of the earth is hot, at least in places, is shown by hot springs, volcanoes, lava flows, and by the steady rise in temperature with increasing depths in mines, tunnels, and bore holes.

128. Structure of the Earth.—The earth's crust

is made up of rocks, more or less covered with loose material that has been formed by the decay and breaking up of rocks. This crust consists of soil, subsoil, boulders, sand clay, gravel, etc. Water is present everywhere, down to a considerable depth.

The solid crust is supposed to be ten or twelve miles thick. Beneath that, the temperature is calculated to be high enough to keep the rock-matter, or **rock-magma**, in the melted condition, and at a still greater depth, the temperature is high enough for the rock magma to be gaseous. But the enormous pressure due to gravitation keeps the whole globe as rigid as steel.

129. Weight of the Earth.—The earth weighs about twice as much as it would, if the specific gravity of the whole globe (5.57) were the same as that of the known rocks (averaging about 2.7). This may be explained by supposing that heavier materials, such as iron, occupy the central part of the earth. This idea agrees with the well-known fact that meteors, which may fairly be assumed to be samples representing the composition of heavenly bodies, are made up partly of rock materials and partly of iron, etc. But, on the other hand, the greater density may possibly be explained by the enormous pressures existing within the earth.

130. Surface of the Earth.—The appearance of the surface of different parts of Canada may be taken as representing that of the whole earth. Southern Ontario is flat, with rock outcrops, which are composed of flat-lying layers. Southeastern Quebec and the Maritime Provinces show a surface that is partly

flat, as in Prince Edward Island and in much of New Brunswick, and partly hilly, with bare rock exposed, as in much of Nova Scotia, Quebec, and northern New Brunswick. The northern parts of Quebec, Ontario, and Manitoba present a varied surface, low rounded hills, valleys, lakes, muskegs, swift rivers, numerous falls and rapids, and many rock exposures — some stratified, more showing no layers — the great pre-Cambrian "shield," enclosing Hudson Bay like a V, the point of which extends down to the St. Lawrence, below Kingston. The prairie provinces, Manitoba, Saskatchewan, and Alberta, are level country, the greater part of which shows no rock at the surface. In startling contrast is the "sea of mountains" of British Columbia, with jagged peaks of bare rock, steep valleys, torrential streams, and glaciers.

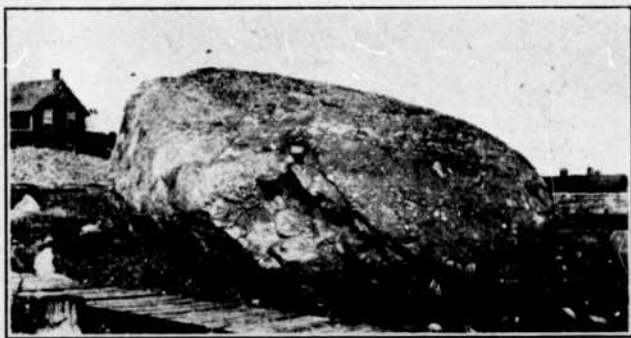


Photo by L. E. Hamilton.
FIG. 78.—Conglomerate boulder. Galena St., Cobalt, Ont.

There are a number of things to be noticed and explained concerning the loose material that covers the solid rock. In most parts of Canada, there are to be

seen pieces of rock on top of the soil, or partly buried; they are often rounded, but are sometimes angular. When resting upon solid rock, they are usually found to be of a different kind from the rock upon which they lie; and it is often known that there is no solid rock of the same kind as these boulders or erratics.

In some places, both large and small boulders are gathered in heaps or ridges, sometimes covering large extents of country; these are called moraines, eskers, etc. The loose material is often sand, which may be in distinct layers, i. e., stratified. If the grains of sand



FIG. 79.—Stratified clay on boulder clay.

are carefully examined, they will be seen to be mostly quartz, with here and there a grain of mica, magnetite, ilmenite, garnet, etc. The sand grains may be round or nearly so, like sand that is well washed and worn on a lake or sea beach; or the grains may be more an-

gular, **sharp sand**, the kind that is best for mortar. Beds of clay are sometimes clean and stratified. In other places clay is found mixed with boulders and not distinctly in layers, the so-called **boulder clay**. Such irregular mixtures of clay, sand, gravel, and boulders are called **drift**.

There are also to be noted heaps, scattered pieces, or large areas of broken rock of the same kind as the solid rock beneath them or quite near them. Often the broken rock forms a sloping pile, or **talus**, at the foot of a cliff or steep hillside.

ROCKS AND ERAS

131. Rocks.—In some places there is no loose covering, and the solid rock appears at the surface as an outcrop. It is important not to mistake for an outcrop a very large boulder showing above the soil.



FIG. 80.—Limestone. St. Mary R., Ont.

The rocks are of two kinds, **stratified rocks**, which are more or less distinctly layered, and **unstratified**

rocks. The stratified rocks may look like compacted and cemented mud, sand, or gravel, not distinctly crystalline; or they may be composed of crystalline masses of such minerals as calcite, quartz, feldspar, mica, etc.

132.. Three Classes of Rocks.—There are thus three great classes of rocks:

I. Stratified, but not crystalline; these are **sedimentary rocks**, such as sandstone, conglomerate, limestone.

II. Not stratified, but crystalline; the **igneous rocks**, such as granite, diorite, diabase. This class also includes **volcanic rocks**, not distinctly crystalline.

III. Stratified and crystalline; the **metamorphic rocks**, such as gneiss, quartzite, schist. Derived from I or II through geological change.

133. Arrangement of Sedimentary Rocks.—A careful study of sedimentary rocks, as seen outcropping or exposed in cliffs, shows an orderly arrangement of the layers, suggesting a rough process of building, interrupted in some places, and the results destroyed in others. By noting the succession of the different kinds of rocks over the whole earth, an *ideal section* of the earth's crust from top to bottom of the sedimentary rocks has been constructed.

The idea suggested in this is that, as soon as a solid crust was formed and weathering began, sedimentary rocks were built on a foundation of igneous rocks; and this process was continued age after age, not over the whole surface of the earth simultaneously but in

certain regions; also not continuing throughout in one place, but changing with the movements of the earth's crust.

134. Fossils.—Fossils are petrified remains of plants and animals, found in sedimentary rocks; they are not found in igneous rocks, and but rarely in metamorphic rocks. They form a fragmentary record of the living beings that have inhabited the earth. The first distinct fossils are of simple forms of life; but since they are not so simple as some that exist now, it is inferred that still simpler forms may have existed at an earlier period, their bodies being too fragile to leave any remains.

From that point upward, the rocks contain fossils of plants and animals more and more highly organized.

135. Life Eras.—Taking into account the foundation igneous rocks, formed at a time when life was impossible, five eras are distinguished, in order from above downwards:

Eras	Characteristic Animals
I. Recent Life, or Cenozoic	Mammals, man.
II. Middle Life, or Mesozoic	Reptiles.
III. Ancient Life, or Paleozoic	Amphibians, Fishes, Invertebrates.
IV. Dawning Life or Eozoic	Not certainly known
V. No Life or Azoic	

Since every fossil-bearing sedimentary rock formation has fossils peculiar to itself, the geologist is able to determine the relative age of such rocks by studying the fossils found in them.

EROSION

136. Forces Causing Erosion.—It is plain that ever since the crust of the earth became solid and cool enough to allow water to stand, waves to form, rain to fall, and weather to act, these forces have been working on the surface much as they are doing now.

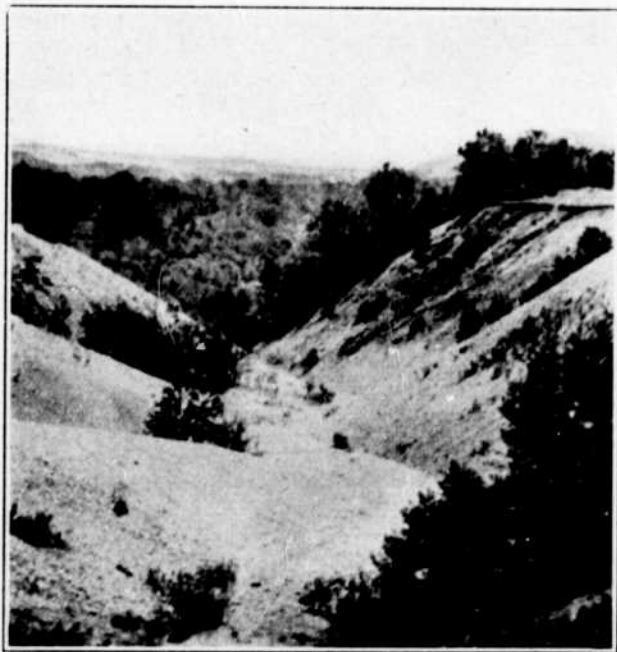


FIG. 81.—Gully and side gullies near Sault Ste. Marie, Ont.

It is quite possible that in earlier ages they worked more actively. As a result of their action the rocky heights of the Earth have been continually worn down.

This process is called **erosion**. To reach an explanation of the past, it will be useful for us to study carefully what is going on at the present.

137. Changes Caused by Running Water.—The effect of a single heavy shower gives the key. The

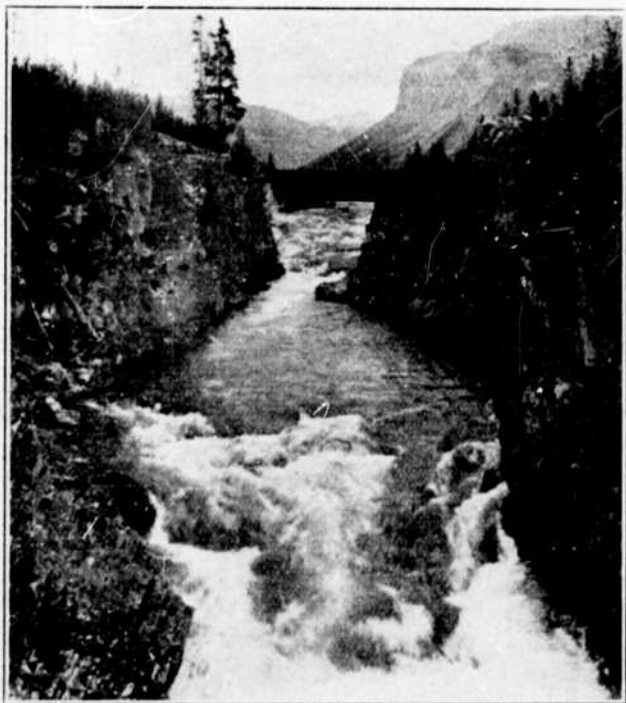


FIG. 82.—The Devil's Canyon, Rocky Mts., B. C.

running water carries the loose material down, spreads it out at a lower level, and sorts it more or less into coarse and fine, heavy and light. As the water moves

the grains and pebbles, they grind one another smooth and round; the softer minerals are ground faster, so that the tendency is for them to be destroyed sooner and to be moved farther. This action provides for a further separation into deposits of different minerals, with the result that the harder and heavier minerals are collected in one place, the softer ones being ground up and deposited as mud, lower down.

But running water, in the form of rivers, does more than move the loose stuff. Using the pebbles, etc. for scouring, it grinds its way down into the solid rock, and thus forms a valley with steep rocky banks, a **canyon**. These sides are later sloped off by other forces, to be discussed hereafter. (See Weathering, Arts. 153-160.

Clear water has probably very little grinding and cutting effect, but its power to do this is very considerable when aided by the sand and gravel that the water carries along. The ability of moving water to transport solid masses increases very fast with its velocity. A rapid river carrying along pieces of rock of considerable size, grinds them on its rocky bed, and so cuts down its channel. Where the rock is too large to be moved along or where it lodges in a hollow, it may be whirled around and around, grinding its way down into the rock; it is in this way, that **potholes** and **kettles** are formed, in rapids and falls. The potholes that are often seen where there is no running water now, must have been made at a time when the shape of the land was very different from its present condition. The rivers have changed their courses, owing to changes of level and to other causes.

138. Rapids and Waterfalls—Where a stream is flowing over the exposed edges of rock layers, if the upper layer is harder than the layers beneath, the latter wear away faster, and this tends to produce a



Geology Dept. McGill University

FIG. 83.—Kettle. Kettle Falls, Abitibi R., Ont.

rapid, which becomes steeper as the wearing goes on, until a **waterfall** is formed. A waterfall may also be caused by a break and a downward slip in a river valley, forming a precipice over which the water drops. In this case, a waterfall will gradually change into a rapid, if the surface rock is softer than that beneath. But if the harder layer is above, the waterfall wears its way back upstream without becoming a rapid, as in the case of Niagara Falls, which since the close of the last great glacial period has worn its way back the whole length of the gorge, about seven miles.

130. Natural Bridges.—When the rock in the bed of a stream above a fall is cracked or jointed, the



Photo J. G. Cross, Port Arthur, Ont.

FIG 84.—Smoky Falls, Mattagami R., Ont.

water has sometimes found its way down a crack and then along to the face of the cliff over which the stream falls. This underground channel has been gradually



FIG. 85.—Natural Bridge. Lower Falls of Bruar.
Perthshire, Scotland.

enlarged by the flow of water, until it was large enough to accommodate the whole stream, which then fell over the cliff at a lower level than formerly. The

result of the wearing action of the stream has been to leave the rock above the underground channel as a **natural bridge** across the stream.

140. River Terraces.—While the river is flowing down a steep valley, it carries its load of sand, gravel, and clay; but when it leaves the mountains and flows through flat country, it is unable to carry so much material; the excess is then deposited, and plains are built up. River **terraces** or **benches** are, in some cases, the remains of former flood plains, left by the river when it has cut its channel deeper. The finer material is carried on to deeper water, into a lake or the ocean, where it settles to the bottom.

141. Underground Rivers, Caves.—Streams occasionally disappear and form underground rivers, which then wear down underground channels; it is in this way that some caves are formed. Most caves, however are caused by the dissolving action of water as it sinks through the rocks; the water enlarges the crevices by carrying away in solution calcite, gypsum, and others of the more easily soluble rock materials.

142.. Leveling Effect.—Rivers and other running water are thus constantly moving material from the higher parts of the land to the lower levels, finally depositing a great part of it in the ocean. The quantity thus transported is very large. It has been calculated that the Mississippi River and its tributaries, are lowering the level of their whole drainage basin one foot in 9,000 years, and are building up islands and shoals in the Gulf of Mexico at a corresponding rate.

143. Underground Water.—A large part of the water that falls upon the surface of the earth sinks through the soil and subsoil, and finds its way downward through the crevices in the rocks. Some of it finds underground channels, through which it flows as distinct streams; but the greater part makes its way slowly through the pores and cracks. All rock contains more or less water moving in this way; but some rocks, like sandstone, are more porous than others. The greater part of the underground water finds its way to the surface as springs and seepage, which may also come out at the bottoms of lakes and rivers; and cases are known where streams of considerable size issue from the ground. Part of the water works its way downward until it meets with hot rock, and this later comes to the surface as geysers and hot springs, which are particularly numerous in the Yellowstone Park and in Iceland. But the dryness of some deep mines in their lower levels shows that the depth to which ground water penetrates is limited. The water of hot springs may come directly from the hot rock material.

The upper level of this **ground water** depends largely upon the rainfall. In countries with a heavy rainfall, the rocks and loose material are kept full of water to a relatively high level, marked in any district by the level to which water rises in wells, bore holes, and abandoned mine shafts; this level is called the **water table**. Locally, the water table may be influenced by the pressure created by underground water gathering in a porous rock that is overlain by a **tight rock**. If

these rocks are lying at a slope, the pressure of the water at the lower levels of the slope will be greater than it is higher up; this is the explanation of **flowing springs** and **artesian wells**.

CHANGES CAUSED BY WAVES

144. Erosion by Waves.—The wearing action of waves upon the shores of lakes and seas is a matter of common observation. The building of breakwaters and other protecting structures is our recognition of the destructive force of the waves.



Photo M. H. Willison, Port Arthur, Ont.
FIG. 86.—Waves, near Silver Islet, Lake Superior, Ont.

Storm waves hit the shore with a force of from a few hundred pounds to two or three tons on a square foot, varying with the violence of the storm. The force of the rushing water is great enough to move stones weighing as much as 100 tons. Waves striking a cliff

have been known to dash up 200 feet, and it is said that the windows of Dunnett Light, Scotland, were once broken by stones carried up by a wave to a height of 300 feet.

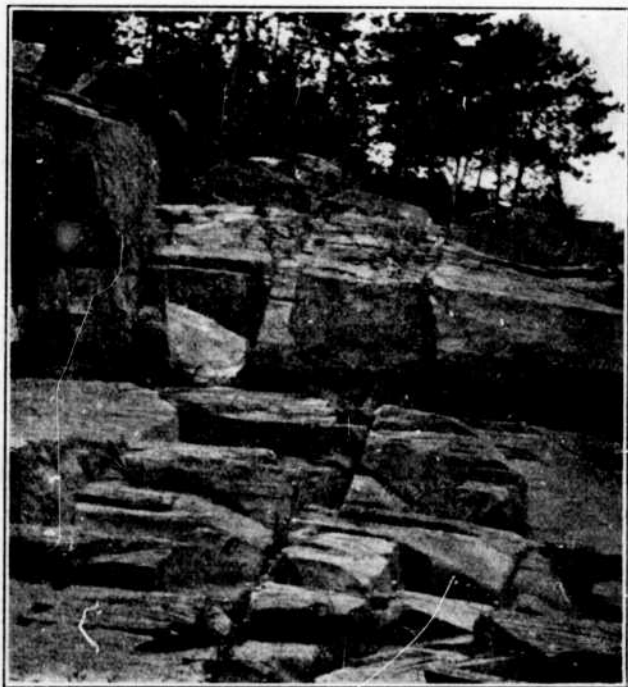


Photo by W. G. Dauncey

FIG 87.—Joints in rock. Shawinigan Falls, Quebec.

When the shore consists of loose material the waves have a comparatively easy task, washing out the smaller stuff, dislodging the larger pieces of rock, and in their retreat, moving the whole downwards.

145. Effects of Waves on Rocky Shores.—Rocky shores are not so easily eroded; but the firmest rocks are attacked in ways not at first sight obvious. All rocks are more or less cracked, and these **joints** block out a rocky cliff into pieces, which the heavy blows of waves may break out. Stratified rocks are especially open to this attack of the waves, because the layers make up other lines of weakness. Both the joints and the planes between the layers are widened and deepened until some unusually strong wave dislodges a whole block. This result is aided by the hydraulic pressure of the wave working in the depths of the crevices. In cold countries, the blocks may be loosened by the action



Photo M. H. Willison, Port Arthur, Ont.
FIG. 88.—Pierced rock, near Silver Islet, Lake Superior,
Ont.

of frost; the cold freezes the water, which then expands and exerts an enormous pressure against the surfaces between which it is confined.

It is doubtful if the blow of water alone would have much effect upon hard rock, fairly free from open joints. But as the wave advances, it carries with it sand, gravel, and pebbles; even large stones are moved forward and used as battering rams. Waves armed with these materials make a formidable attack upon even the hardest rocks. By these means the waves wear away the sea cliffs, sometimes carving it into columns, chimneys, islets, and pierced rocks; or they may hollow it into the sea caves, or undermine it until there is a fall of rock from above.

The material washed down from the shore or broken out of the sea cliff is kept in motion by the waves and the *undertow* (the flow downward of the water which has moved up the shore in wave-form). It is thus sorted into: (a) coarse material, which does not move down so far; (b) finer material, which is carried to greater depths; (c) the finest product (silt), which does not settle until it reaches depths ordinarily undisturbed. The presence of this fine silt is sometimes shown by heavy storms, which cause the water to become muddy a long distance from shore.

146. Resultant Effects of Wave Action.—The waves are continually increasing the quantity of fine material by grinding the boulders, cobbles, pebbles, and grains of sand against one another, the effect being to round these pieces of rock and to reduce their size. Large pieces, not movable by the waves, may in this way be worked down to a manageable size. The total effect of the wave action is the gradual disappearance of the land into the sea. Part of the coast

of Holland has been eaten into for about two miles within historic times. Whole villages have disappeared from the coast of England, and one of the most dangerous shoals on the east coast, the Goodwin Sands, is the ruin of what was once a great English estate.



FIG. 89.—The Goodwin Sands, England.

CHANGES CAUSED BY ICE

147. Origin of Glaciers.—In temperate and cold climates, and even in tropical countries, where there are very high mountains, the wastage of the snow by melting and evaporation may be less than the snowfall on the tops of the mountains; the snow, therefore, accumulates continually. In cold climates, like that of Greenland, snow accumulates even at ordinary levels, so that the whole of Greenland, except for a fringe of sea coast, is permanently covered. This ac-

accumulated snow slowly changes to ice by growth of the larger crystals at the expense of the smaller.

Ice that is formed in this way on the tops of mountains moves slowly *down* as **glaciers**. Where a more level country in a very cold climate is covered with an ice-cap, the ice moves *forward*. The condition of motion in both cases is that the upper surface of the ice shall have a slope downwards; this is provided for in the case of mountains, by the sloping sides. Ice-caps

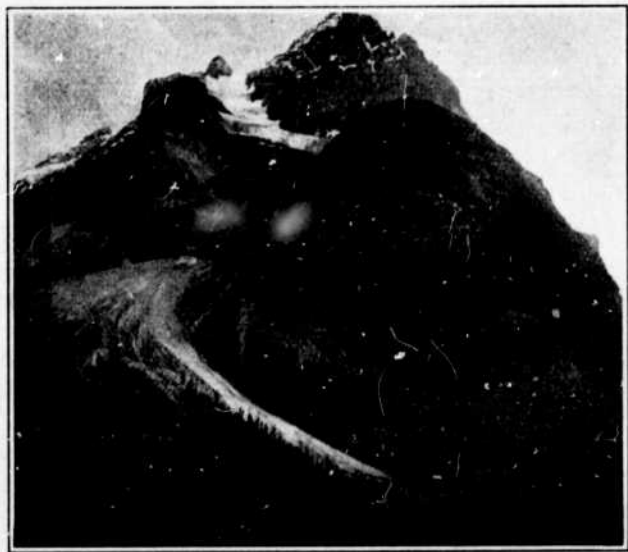


FIG. 90.—Glacier, Mt. Stephen, B. C.

that cover a relatively flat country become thicker at some central area, where the snow accumulates faster, and this gives an upper surface sloping from a

thick part outward; this slope makes it possible for an ice-cap to move forward over ground that is comparatively level. The Greenland ice-cap is probably between 5,000 and 10,000 feet thick at the centre. The thickness of mountain glaciers in countries like British Columbia is often several hundred feet.

148. Motion of Glaciers.—The ice of a mountain glacier moves slowly down the mountain side, often in a valley, which it follows very much as a viscous liquid would, narrowing and widening and changing its direction, with the changes in the valley. The ice



Geology Dept. McGill University

FIG. 91.—Glacial grooving, L. Winnipeg.

changes its shape to fit the changes in its bed, induced, probably, by the melting of the ice-crystals by pressure, and followed by freezing, when the pressure is

relieved by a slight movement of the water. It is a well-known fact that ice at or near the melting point can be melted by pressure. The rate of motion varies from 2 or 3 inches to as much as 100 feet a day.

The front end of a glacier is at a point where the ice melts as fast as it reaches that place; but the end may recede or advance according to temperature and other circumstances.

149. Work of Glaciers.—(1) **EROSION:** The ice encloses boulders, pebbles, and other loose material, and carries them along with it in its descent. Its rock-

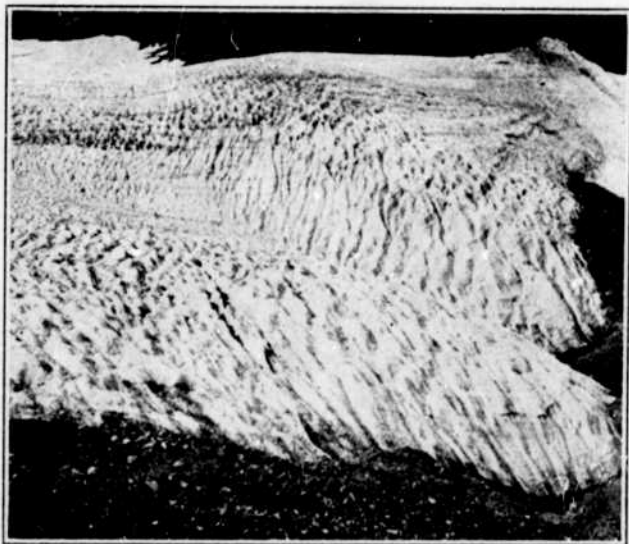


Geology Dept. McGill University
FIG. 92.—Glacial Valley, Stahlheim, Norway.

shod bottom grinds and grooves the rocks beneath; these grinding tools are further assisted by pieces of

rock broken off by the ice in its advance. Thus the valley is deepened and its **V** shape changed to a **U**.

Rough country is planed down smooth, sharp rocks are rounded, and the tendency, as in the case of rivers, is to carry loose material to lower levels, and to make more loose material. But when the ice moves over a flat area, it does not necessarily push the covering ahead of it; it may even ride over vegetation without destroying it.



Geology Dept. McGill University
FIG. 93.—Glacier and Moraine, Mt. Dana, California.

(2) **TRANSPORTATION**: Large amounts of material are moved by glaciers. In addition to the **boulders**, pebbles, and silt picked up from the bottom, the top

of the glacier carries a load of rocks that have fallen from cliffs, and of dust and sand blown upon it by winds.

(3) **DEPOSITION:** As the ice melts at the end of the glacier, its load is deposited; it is thus that the **terminal moraine** is built up. Along the sides of the glacier are ridges of bowlders, etc., carried down by the edges of the ice. These ridges are called **lateral moraines**. Moraines are sometimes 1,000 to 2,000 feet high. When a glacier melts back a long distance, it leaves its load as an irregular heap, a **ground moraine**. Some glaciers form streams, which flow considerable distances under the ice and build up long ridges of gravel; when the glacier melts, these ridges appear as **eskers**.

Deposits left by the ice differ from those made by rivers in that: (a) the glacial material is not sorted, bowlders, pebbles, and silt being left in a mixed mass; (b) the stones are not rounded like river or wave-worn stones, but part of them are worn into angular shapes, and the surfaces are scratched and grooved; (c) the deposits are not stratified, except when carried and deposited by glacial streams; and (d) the finer material is **rock-flour**, composed of small grains of fresh rock, thus differing from river silt, which is formed by the decay of rock.

150. Work of Glacial Streams.—Glacial streams carry the finer material, the rock-flour, and are often milky as they come from the glacier. This and coarser material are sometimes washed out and carried forward to form an **outwash plain**, which differs from

moraines in being stratified and sorted, and differs from ordinary alluvial deposits in being composed of comparatively fresh pieces of rock, often including soft or easily weathered rocks that are not found in the older deposits.

151. The Glacial Period.—When the surface of our country is examined, there is ample evidence that, at some time in the past, an ice-cap covered the northern part of the continent, just as, at present, Greenland is covered with a great glacier. Rock surfaces are scratched and grooved; moraines are frequent; boulders are to be seen almost everywhere, many of these showing the characteristic grooves or scratches; and, in short, a large part of the covering of the country is **glacial drift**. In addition, the smooth, rounded surfaces of rocky hills and islets, and the U-shaped valleys, all these compose a convincing mass of evidence. There is evidence also of earlier glacial periods.

There were three great ice-caps in North America: one with its center in Labrador; a second, covering the central part of Canada; and a third, covering British Columbia. The eastern ice-cap extended as far south as Ohio and Illinois. There are ways of calculating roughly the time that has passed since the ice-cap finally melted. For example, calculating the time it has taken for Niagara Falls to wear back the six or seven miles from Queenston, where it began its life (when the ice-sheet retreated), to its present position, it seems that something like 30,000 years must have elapsed since the great eastern ice-cap melted away.

The principal work done by the ice in the glacial period was the removal of the loose material, and the smoothing of the rocky surface. It is thought that the ice-action is not accountable for any great lowering of the level of the rocky surface.



After Salisbury

FIG. 94.—The last Glacial age in North America. The ice moved in a direction at right angles to the curves and away from the center of the ice sheet.

152. Practical Results.—The practical results so far as prospecting is concerned are:

- (a) The uncovering of a great deal of rocky surface.
- (b) The transportation of material in a general southerly direction. The glacial grooves are guides to the actual direction in any locality. Their direction varies even within short distances; but their general trend in any district is a fairly definite indication. Another result is the occurrence of bowlders of a kind of rock found in place only in a certain direction from the position of the bowlders. Prospectors sometimes find valuable minerals in the glacial débris. It is often possible to follow this "float" back to its origin, and the glacial grooves show the direction in which to prospect. If the float is not much worn, the distance it has travelled is not likely to be very great.
- (c) The deposition of bowlders, gravel, and boulder clay, composed of material different from the rock underneath.

WEATHERING

153. Weathering Forces.—Under this head are grouped a number of agencies that have their origin in the atmosphere, and which work not only on the surface but as far down as air and water, heat and cold, can penetrate. Because these forces work invisibly, they are apt to be more or less overlooked, although the results of their activity are to break up, decay, and at last pulverize the solid rock, thus preparing it for transportation by running water, wind, ice, and waves.

154. Mechanical Action.—The air is constantly moving dust and sand over the surface of the earth, and this, in the course of ages, accounts for a considerable distribution of material. The general tendency must be downwards through the air, although in some cases, as in the case of **sand dunes** and **coral islands**, the wind drives some of the material to higher levels.

In dry climates, sand driven by wind acts as a **sand-blast** when it strikes rock surfaces. The rock is slowly cut by this means, and in time the results are considerable.



FIG. 95.—Mountain top shattered by frost. Switzerland.

Heat and cold are the most destructive agencies of a **mechanical** kind. Rocks are broken by the changes of temperature at the surface, in the same way as **glass**

is, when cold water drops on hot glass, or hot water on cold glass; the unequal contraction or expansion cracks the material. The sun shining on a rocky surface may heat it to a high temperature, if the conditions are favorable, and since rock is a poor conductor of heat, the surface becomes hot while the rest of the rock stays cool; the expansion of the surface then causes it to shell off. This effect can be seen on boulders and also on cliffs and rocky peaks. Dark-colored rocks are more strongly heated than the light-



Geology Dept. McGill University
FIG. 96.—Talus, Wyoming, U. S.

colored ones. The effect is greatest in dry climates, and at such latitudes or elevations that there is a considerable fall of temperature at night, when the shrinking of the heated surface is equally destructive. In

the case of exposed rocky peaks the effect of this alternate heating and cooling is to extend the joints, and to develop new cracks, so that the rock is finally broken up into blocks. High mountain peaks are almost always covered with broken rock. Cliffs and steep, rocky, mountain sides have a sloping heap of broken rock, a *talus*, sometimes of great extent, particularly on the south side.

While crystalline rocks on account of their uneven, mixed texture, suffer more than such sedimentary rocks as limestone and sandstone, thin layers of the latter are sometimes buckled up and broken by a hot sun. In cold climates, or at high levels, the freezing of water in cracks and pores causes a great deal of rock destruction.



FIG. 97.—Granite boulder split by frost. Madoc, Ont.

155. Chemical Action.—The destructive effects of chemical weathering are more apt to be overlooked than those caused by mechanical action. The chemical

effects are due to the presence in the atmosphere of *carbonic acid* (carbon dioxide) and *oxygen*, which are continually being brought into contact with the rocks, by dissolving in rain water and other water. Water is favorable to the activity of these substances, and they are therefore more destructive in moist than in dry climates.

156. Action of Carbonic Acid.—Lime, potash, soda, and iron are present more or less in all rocks; they form a part of such common rock-forming minerals as feldspar, mica, hornblende, and pyroxene. The carbonic acid of the atmosphere combines with these substances to form carbonates, which dissolve in water



Ontario Dept. of Mines
FIG. 98.—Spheroidal weathering, Wabigoon, Ont.

and are carried into the rivers, lakes, and oceans. This leaves the rocks in a loose condition at the surface, which is thus continually wasting away, a part dis-

appearing into rivers, etc., and a part remaining as loose material on the surface.

157.^aAction of Oxygen.—Oxygen works on rocks that contain certain iron compounds, converting these into limonite; this loosens the structure and prepares the rock to be washed away by running water. Sulphides, such as pyrite and copper pyrite, are in this way converted into **gossan** or **iron capping**. But any rock high in iron may acquire a rusty capping by oxidation.

Chemical weathering is most active in the joints of rocks and on sharp points and edges, resulting in the

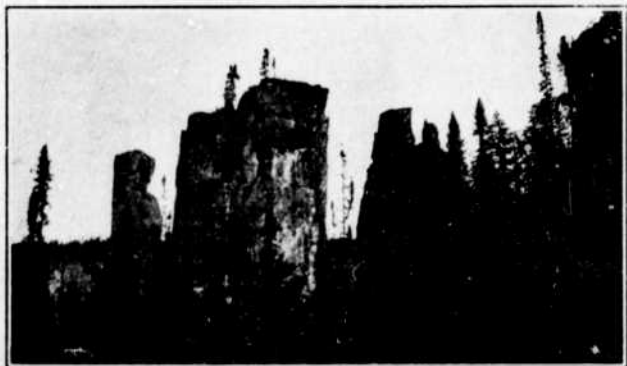


Photo by P. E. Hopkins
Ontario Dept. of Mines

FIG. 99.—Diabase columns, Castle L. near L.Nipigon, Ont.

widening of the joints and the rounding of edges. Loose, angular blocks are thus rounded, and rock with vertical joints is worn into pillars.

158. General Effects of Weathering.—The weathering forces, working on the rocky surface of the earth, slowly cover it with a mantle of rock *débris*, the pieces becoming gradually smaller through the continued work of heat and cold and the dissolving action of carbonic acid. In favorable situations, this mantle may lie thick enough to protect the underlying rock from heat and cold, but on slopes or cliffs, it is continually washed away. This accounts for the V shape of old river valleys, the walls of which would remain perpendicular, if it were not for weathering. Ter-

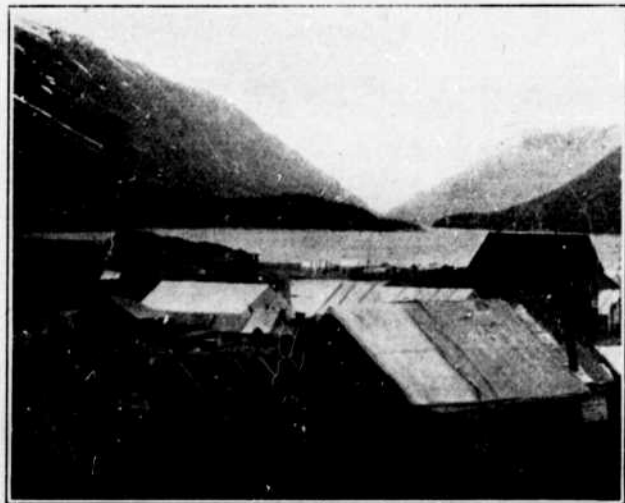


FIG. 100.—Old Valley, V shaped.

aces or benches are, in some cases, caused by the resistance of certain layers of rock to the weathering process. In Canada the results of weathering cannot

be seen as extensively as in countries which have not been glaciated. In unglaciated countries, the loose covering left in place is sometimes many hundreds of feet in depth.

159. Deep Weathering.—The active constituents of the air are carried down by rain into the rock joints, cracks, and pores, and may penetrate to great depths: thus the decay of rock is not confined to the surface. It is estimated that the cracks and pores in rock are sufficient to hold, on the average, a quantity of water amounting to from $2\frac{1}{2}\%$ to 5% of the bulk of the rock. The ground water dissolves out of the rocks such substances as salt and gypsum; and with the aid of carbonic acid, it dissolves limestone. In a limestone country, this action may go on so extensively as to form caves. When the roofs of limestone caves are weakened by continued loss in this way, they sometimes fall in, forming the **sink-holes** common in limestone districts.

The circulating ground-water may replace some substances by others; as when the substance of a piece of wood is slowly carried away and silica is deposited in its place forming petrified wood. The structure of this petrified wood is still visible, although its substance is completely changed. The water sometimes carries a valuable mineral that it puts in place of that which it removes, which accounts for the occurrence of some deposits of zinc and lead ores in limestone.

Veins are sometimes formed by the deposition of minerals in cracks, into which the ground-water flows.

Stalactites are icicle-like deposits, usually of calcite, hanging from the roofs of caves. The water, dripping

from the roof and evaporating, deposits part of the carbonate of lime that it carries in solution; this hardens and forms the stalactite. In a similar manner, water dropping on the floor of the cave builds up a **stalagmite**. The two actions may go on until the two meet and form a pillar.

160. General Results.—While the ground water does a certain amount of building up in the form of veins, etc., the net result of its work is to loosen the rock and to carry away a large amount of material in solution. As a great part of the water at length finds its way into rivers, and from thence into the oceans, it is plain that the general effect is to lower the land-level. It is estimated that the Mississippi River carries into the Gulf of Mexico annually nearly 113 million tons of dissolved matter, about half of which is carbonate of lime.

ROCK BUILDING

161. Rock-Making Processes.—There are three great rock-making processes: namely (a) sedimentation; (b) movements of the rock magma from within outwards; (c) metamorphism, or transformation of rocks by heat and pressure. These will now be discussed in order; and after the description of each process, there follows an account of the principal kinds of rocks formed by that process.

SEDIMENTATION

162. Disposition of the Sediment.—It is now proper to inquire into what becomes of the vast quantities of material being carried from the land into the ocean; this will throw some light on the effects of the same agencies that have been working on the earth for ages.

The bottom of the ocean is covered with sediment, coarser in the shoal water, and becoming finer with the increasing depths. The edge of these deposits can be seen, between high-water and low-water levels, as gravel and sand; while finer material is found in the deeper waters. At the mouths of many rivers, the building up of extensive shoals, stretching far into the ocean, accounts for the large amount of the material lost from the land; and in the low lands, in such countries as Holland, Belgium, and Guiana, more is accounted for.

163. Origin of Sedimentary Rocks.—If conglomerate rock be compared with a bed of gravel, it is plain that the rock was at one time loose gravel; it became rock by a natural process of cementing. A similar conclusion is arrived at by comparing sandstone with beds of sand lying in layers; shale and some kinds of limestone look rather like hardened mud. These resemblances are still more suggestive when the fossils (which are petrified bodies of plants and animals) in these rocks are found to be exact representations of the plants and animals buried in the sediments. There have been preserved even such details of the original sediments as ripple marks on sand, mud cracks caused

by the drying of mud left bare at low tide, rain-drop marks, etc.

The sedimentary rocks are made, in one way or another, from the broken-down rocks of past ages. With the exception of some limestones and quartz sediments precipitated chemically they are formed of *fragments* of older rocks, or of the shells, etc., of animals and plants. But a few sedimentary mineral deposits, particularly gypsum and rock salt, are exceptional. The layered structure (*stratification*) of sedimentary rocks is similar to that of the corresponding loose material. The layers represent periods of deposition, between which the conditions changed. For example, between two layers of limestone, there is often a thin seam of



Fig. 101.—Stratified rocks. Mt. Biddis, Rocky Mts., B. C.

shaly material, registering a time when clayey matter was worked off from the shore. A layer is called a **stratum**; but if very thin, it is called, a **lamina** (plural,

laminae or laminas). So the layers of sandstone and limestone are called strata, but the thin layers of shale are called laminas. The consolidation was due partly to cementing and partly to pressure.

SEDIMENTARY ROCKS

164. Classification.—The sedimentary rocks are classified as follows:

1. Conglomerate, breccia, arkose.
2. Sandstone, graywacke.



Photo by Ed. Marks

FIG. 102.—Gravel, Manicaugan R., Que.

3. Shale.
4. Limestone and other rocks formed from dissolved matter.

There are certain sedimentary rocks which are of more value than ordinary rocks; these are sought after and mined, and so have already been described in Part 1. These are: *coal, gypsum, salt, siderite, limonite, hematite, and phosphate.*

165. Conglomerate.—The prospector may expect to find rocks corresponding to any collection of rock waste that is now to be seen on the surface of the earth. The beds of gravel of the past ages are now **conglomerate**, consisting of worn rock fragments of all sizes, boulders, cobbles, pebbles, sand, and even silt. As there is often a grading of size, on the sea shore, from



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FIG. 103.—Conglomerate, Cobalt, Ont.

coarse, at the higher levels, to fine, at the lower levels, so at times conglomerate is found that gradually passes from large to small pebbles and, finally, into sandstone.

Occasionally a pebble or boulder in a conglomerate is a worn piece of an older conglomerate, showing that a part of the earth's crust had been twice broken up, worn, and re-cemented to solid rock.

The pebbles in conglomerate may be pieces, from the size of a pea up, of any mineral or rock (including volcanic fragments) hard enough to have survived the amount of wear undergone by the rock waste before it was cemented. The spaces between the pebbles are filled with sand, silt, etc. The cement, is commonly silica, calcite, or limonite.

Since the materials of conglomerate are pieces of various kinds of rocks, the specific gravity of conglomerate varies, but is not far from 2.75.

166. Volcanic agglomerate, volcanic tuff, and volcanic ash, are rocks made by the consolidation of fragments of volcanic rock.

167. Breccia.—Breccia is a rock composed of angular pieces of rocks cemented together. It is often not sedimentary, as the broken material has been consolidated without transportation and wearing by water.

168. Sandstone.—Sandstone is a stratified rock composed of grains of sand (mostly quartz), from the size of a pea down, more or less rounded, consolidated by pressure and a natural cement, which may be silica, calcite, oxide of iron, or clayey material. The grains are mostly quartz, sometimes large enough to be easily seen, forming a coarse sandstone; sometimes it is finer-grained. On one side, sandstone shades into conglomerate, and on the other side, into shale.

The color of sandstone depends largely upon the cementing material. Silica or calcite makes a gray or white sandstone; oxides of iron give a red, brown, or yellowish color. The value of sandstone as a building stone depends upon its color, its texture, whether fine or coarse, its strength and durability (depending on the cement), and its working qualities. Very complete cementing with silica gives a stone hard to work. On the other hand, some sandstones have



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Fig. 104.—Potsdam Sandstone. Pittsburg Tp., Frontenac Co.

been consolidated by pressure with very little cement; these are weak and not durable.

Sandstone very completely cemented with silica has a hardness near to that of quartz. Stones in which the grains are only slightly cemented, or in which there is a good deal of calcite or clay are softer. $G = 2.63$ to 2.66 .

169. Graywacke.—Graywacke is made up of grains, more or less angular, of quartz, feldspar, and various

other minerals and rocks. It is sometimes so fine-grained that the microscope is needed to see the structure. The cement is usually silica.

170. Arkose.—Arkose is a sandstone derived from granite or gneiss, the waste of which was not moved far or water-worn very long, so that plenty of the feldspar remains.

171. Shale.—Shale is mixed clay, mud, and silt consolidated by pressure and to a less extent by cementing. It forms in thin layers or laminae, which are easily separated, so that shale is usually a rock of little strength. It varies in composition, being sometimes mostly *clay*, in other cases, *calcareous*, (approaching limestone), *siliceous* or sandy (approaching sandstone), or *ferruginous* (with oxides of iron). **Bituminous shale** is charged with blackish material, often of the nature of petroleum; hence, it is called also **oil shale**, and is sometimes used for the production of oil, with ammonia as a by-product.

Fossils are abundant in shale, the soft material, and quiet depths having preserved the forms of plants and animals. Shale has preserved its clayey nature and composition. It can be ground and used in making bricks, tiles, etc. It is easy to scratch with a knife. **G** = about 2.7.

172. Limestone.—Limestone is rock formed of the shells of minute plants (*algæ*, etc.) and animals (*foraminifera*, etc.), with fragments of the shells of larger animals, all set in a consolidated mud that is made.

partly, of the ground up shells of animals and, partly, of carbonate of lime that has been precipitated by the escape from the water of the carbonic acid that held it in solution. Limestone is composed mostly of *carbonate of lime*, and that part of it which forms the shells of animals was extracted from the water in which the animals lived. Its original source was from the rocks weathered by the action of carbonic acid. (See Art 156). Deposition of carbonate of lime mud is going on now, and it is found to be composed of the same materials (shells of foraminifera, etc.) as are found in limestone rocks. **Chalk** is made up largely of these shells and their fragments. **Coral** reefs and islands are built up by animals of a low order, which extract carbonate of lime from the sea water for this purpose; the building is aided by seaweeds, which have the same power. Limestone is sometimes partly formed of coral, in fragments, or in reefs.

Fossils are plentiful in limestone, particularly those of shell-fish, the shells of which sometimes form the greater part of the stone. The hardness of limestone is close to that of calcite (for which $H = 3$) of which it mostly consists. Its specific gravity is from 2.7 to 2.9.

MOVEMENTS OF EARTH'S CRUST

173. **Earth's Crust in Constant Motion.**—A comparison of modern sediments with rocks has led to the conclusion that stratified rocks are sediments of past ages. It remains to explain how they have been uplifted to their present position.

There is abundant evidence that the crust of the earth is in constant motion. Some coast lines are slowly sinking and others rising. The Atlantic coast of the United States is sinking. In some places stumps of trees can be seen under the sea. The coast of Labrador has been rising, as shown by the old shore lines. On the coast of Scotland are sea-caves that are far above the present shore line.

These movements going on in past geological times account for: (a) the piling up of thousands of feet of sediments in shoal water, *without interruption*, which could only occur because the coast slowly sank as the sedimentation went on; (b) the rise of the consolidated sediments out of the ocean.

174. Rock Series.—Wave erosion on a coast line that was sinking would form a layer of gravel near the shore. If the shore were sinking a little faster than this coarser material accumulated, sand would be deposited on it, and this would be succeeded by still finer material, *mud*, as the water became deeper. These various materials, when consolidated, would form conglomerate, sandstone, shale (or limestone), in a series, and from below upwards. It is quite common to find conglomerate at the base of a **rock series**, with the finer-grained rocks above it.

But this arrangement of the layers is not the only one. The deposition of sediments has taken place under different circumstances, such as a rising or stationary coast line, shoal water or deep water, and so on. The rock series represents a period of deposition, the end of which came when the sea bottom

gradually rose above water, or some other great change interrupted the process. Examples are the *Cobalt series* and *Timiskaming series* of Northern Ontario, the *Grenville series* of Eastern Ontario and Quebec, the *Meguma* (gold bearing) *series* of Nova Scotia, and the *Kootanie series* (coal bearing) of British Columbia.

175. Unconformity.—The layers of a rock series were deposited one upon another without interruption, and this building up continued as long as that part of the earth was covered with water. When it rose from the water, *erosion* began and continued as long as the surface was exposed. It has often happened that after such a period of erosion, a change of level has brought the surface again under water, for further deposition of sediment, to be at length consolidated into rock and once more elevated. When such a place is examined, it is seen that the newer rocks do not *conform* to the

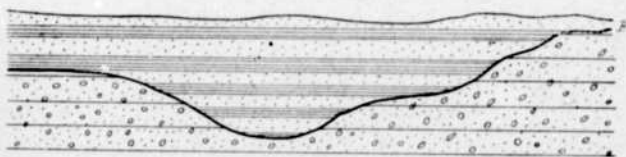


FIG. 105.—Unconformity. The lower series was eroded so as to leave a surface shown by the line B. The upper series was then laid down upon this surface.

older; there is always evidence of the interruption in the process of sedimentation and rock-building. The upper rocks lie **unconformably** on the lower, and the junction is called an **unconformity**.

176. Folding.—The movements of the earth's crust have resulted in the **folding** or **wrinkling** of the rocky surface, the larger folds being mountain ranges, and the smaller, hills, ridges, or small distortions of the rocks. Erosion has greatly changed the surface of the country (topography) from the form given to it by folding. The **topography** of a country is the combined result of the *folding* forces, which tend to elevate parts, and the *eroding* agencies, which are continually cutting down and leveling.

The possibility of changing the shape of rock by pressure without breaking it has been shown by experiments. In nature, the folding has taken place very slowly; great mountain chains have taken millions of years to rise. The folding has doubtless been due in part at least to the pressure of intrusive masses of rock. The shrinkage of the earth on cooling may account for it in part.

The great folding movements have taken place at long intervals in geological history, separated by long

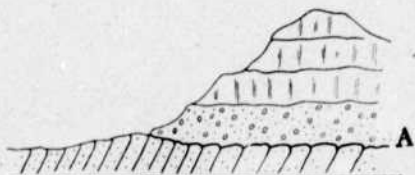


FIG. 106.—Unconformity. The lower series was folded and eroded so as to expose the edges of the strata, A. The upper series was laid down upon these tilted strata.

periods of erosion. For example, the mountain ranges of British Columbia and Alberta were formed by two great folding movements, the first of which ended in

the age of amphibians, and the second after the age of reptiles.

177. Anticlines and Synclines.—When the rocks are stratified, folding has caused the strata to take a wave-like form. An **anticline** is formed by the sides of a fold sloping up toward one another. A **syncline** is formed by the sides of neighboring folds sloping down towards one another; it is the hollow or valley between two folds. (Fig. 108).

By erosion, the crests of these waves, the anticlines, have been cut off, the edges of the strata appear, and the strata are seen to slope more or less. The angle

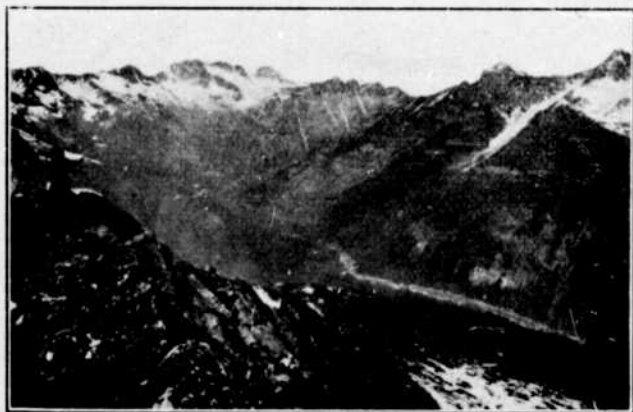


FIG. 107.—The Selkirks, B. C.

of slope is called the **dip**. (Fig. 109.) The dip may be very small, where the folding has been slight, or it may be as great as 90° or more, where the folding has gone far.

The horizontal direction of the fold is called the **strike**. (Fig. 109). The strike is noted by the compass for example, an anticline may have a strike that is N 21° E; this means that the ridge of rock runs in a direction 21 degrees east of north.

In crossing an eroded anticline, the rocks are passed in a certain order and are seen to dip at a certain angle, until the centre of the anticline is reached, after which the dip is in the opposite direction; the same rocks are passed over, but in the reverse order. The two **sides** of the anticline usually lean towards each other. (Fig. 110). In the case of an eroded syncline, the two sides lean away from each other. (Fig. 111).

The folding of rocks sometimes produces very complicated, wavy structures on a small scale, which can often be seen where erosion has laid bare the edges of such folded rocks.

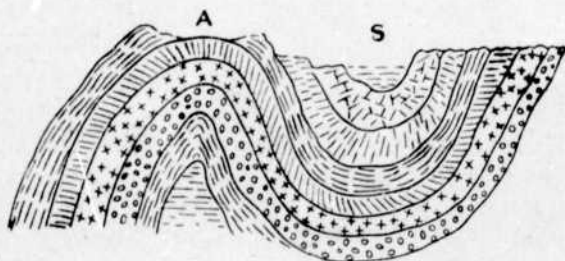


FIG. 108. A. Anticline. S. Syncline.

178. Breaks and Faults.—The rocks do not always bend without breaking. If a green branch be bent sharply, the strain will be seen as a pull on the outside of the curve, which will cause the bark to break; on the inside of the curve, the force is a crushing one, which

causes the bark to wrinkle. It is for this reason that the tops of anticlines are weak places in the rock, and that **breaks** are very apt to occur there, a fact that has its bearing on prospecting. Folding is not the only cause of breaks. The rocky exterior of the earth is continually adjusting itself; and in this process it may break at a weak place, for example, where two formations are lying against each other and are not very firmly held together. When a break takes place suddenly, the shock which spreads through the earth's crust like a wave is called an **earthquake**. There are other causes of earthquakes, for example, volcanic explosions.



FIG. 109.



FIG. 110.—Eroded anticline

When a break takes place, there is always movement of the two sides with regard to each other; this often takes the form of a grinding and crushing motion, which fills the crack with broken pieces of rock. Vein breccia has been formed in this way.

Generally one side moves down or up permanently, or it may move in any direction to a new position. A break with displacement of the rock in this way is called a **fault**. Commonly the hanging wall (the side opposite the slope of the break) slips down. . This is

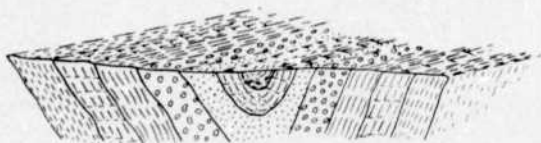


FIG. 111.—Eroded syncline

a **normal fault**. When that side is pushed up the slope (the foot wall) a **reverse** or **thrust fault** results. Faults sometimes displace parts of ore-bodies. (See Art 217).

VOLCANOES, LAVA, ETC.

179. **Volcanoes.**—A volcano is the most striking evidence of a hot interior. There are about 250 active volcanoes at present, and about as many more that have been active in historic times. The *cone shape* of a volcano is due to its gradual building up by the ejection of material from the central hole, the *volcanic vent*. The hot **lava** flows outward and downward; or if shot into the air, it falls in a shower of fragments, forming **volcanic ash, tuff, or breccia**. Thus a conical mountain peak is built up, with a cup-shaped hollow, the **crater**, at the top.

When a volcano becomes inactive, the lava in the crater and vent solidifies. Sometimes activity is re-

renewed, and the lava may burst out somewhere on the slope and build up a second cone.



FIG. 112.—Volcanic eruption. Vesuvius, 1921

Eruptions are sometimes quiet, like those of Kilauea, Hawaii Islands, or violently explosive. The eruption

of Krakotoa, in 1885, blew up a cubic mile of shattered rock, forming a column of volcanic dust 17 miles high. This moved with the upper air current completely around the earth. Vast quantities of volcanic ash and dust have in this way spread over the earth's surface.

Large quantities of water come out with the lava, as great volumes of steam. It is believed that deep down in the hot interior, where the pressure is very great, the rock and water mix like alcohol and water, to form a solution. When the lava comes to the surface, the lower pressure allows the water to escape as steam, the expansion of which may blow the lava full of cavities. When these are very small and abundant, the rock formed is lighter than water, and it is then called **pumice stone**.

180. Lava Flows.—Lava from volcanoes sometimes flows many miles, covering large extents of country. Great **lava flows** have taken place in past geological ages, the lava having poured out of cracks instead of volcanic vents. One in the Western United States covered about 200,000 square miles of country to an average depth of 2,000 feet. Another equally extensive flow in India is still deeper, about 4,000 feet in places. The greatest flow of all is that which at one time covered the Lake Superior District, remains of which can be seen in the flat capping of dark rock on many of the hills and islands. Lava flows through fissures have taken place in recent times in Iceland.

181. Volcanic Rocks.—The majority of lava flows are basic, that is they contain only about 40 to 50 per cent of silica; this may be contrasted with *acid* flows

which have 70 to 80 per cent of silica. *Silica* the substance of quartz, is the common *acid* of minerals and rocks. Substances like lime, magnesia, potash, and soda are called bases. A rock high in silica is said to be *acid*; one low in silica and high in bases is said to be *basic*. Basic rocks melt at lower temperatures than acid rocks; hence, as a consequence, the basic lavas are more fluid and flow longer distances.

The top of a lava flow is wrinkled, broken, and

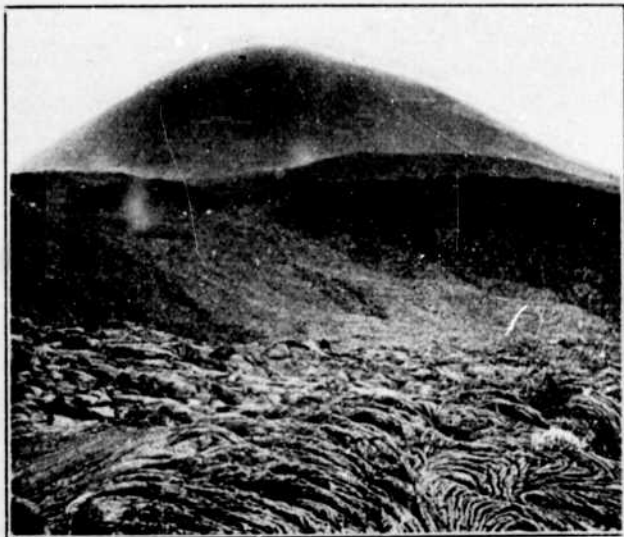


FIG. 113.—Lava flow, Vesuvius, 1858

covered more or less with fragments, giving it the appearance called **scoriaceous**, very much like that of slag. This distinguishes a surface lava flow from one

which has forced its way between strata and has afterwards been exposed by erosion.

Lava sometimes flows from vents under the ocean. The peculiar structure called **pillow lava** or **ellipsoidal basalt** is supposed to have originated in this way. **Basic** lavas form dark colored rocks called **basalt** or **trap**. The light colored acid lavas are called **rhyolite**.

182. Rock Magma.—The molten rock material in the interior of the earth is called **rock magma**. The water that is believed to be dissolved in this magma is called **magmatic water**; it has played a very important part in the making of veins, metamorphic rocks, and some other rock structures.



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FIG. 114.—Pillow lava. Wabigoon, Ont.

183. Geysers.—**Geysers** and **hot springs** are further evidence of heat in the interior of the earth. **Geysers** are hot springs that burst up into fountains periodically. The flow of hot water and the escape of steam.

continuing for a great many years, can be explained only by the presence of a deep-down mass of hot rock or rock magma. In the Valley of Ten Thousand Smokes, in Alaska, steam comes out at such high temperatures that a stick held in it bursts into flame when moved out into the air.

The water of geysers and hot springs deposits, sometimes, silica and, sometimes, carbonate of lime, as a white incrustation, often colored by low forms of plant life(*algæ*), which are able to withstand the high temperatures. Other minerals, such as pyrite and sulphur, are also deposited, and even gold has been found in the siliceous deposit of hot springs. This has a bearing on the origin of mineral veins.

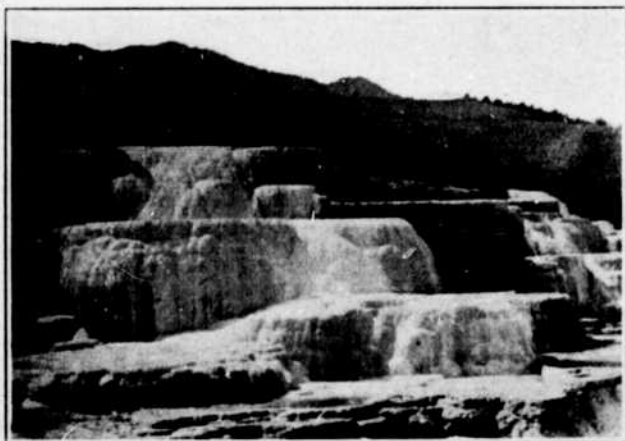


FIG. 115.—Deposit from hot springs, Yellowstone Park, Wyoming, U. S.

184. Rock Intrusions.—By flowing into breaks and between strata, the rock magma has formed masses of

rock by comparatively slow cooling, allowing time for growth of crystals. The deeper the position of the mass, the slower the cooling, and therefore the larger the crystals. The heat of the intruding rock causes changes in the rock with which it is in contact. Dikes, sills, laccoliths, volcanic necks, and stocks, are some of the forms taken by these *intruders* among the rocks.

185. Dikes.—Dikes are igneous rocks (igneous means produced by action of fire) formed by the cooling of the rock magma in fissures. They vary in width from a fraction of an inch to many feet, and vary in length from a few feet to miles. They are sometimes branched; some are straight, and others curved or crooked. Dikes may dip at any angle; but in stratified rocks, an *intrusive rock* is not called a dike unless

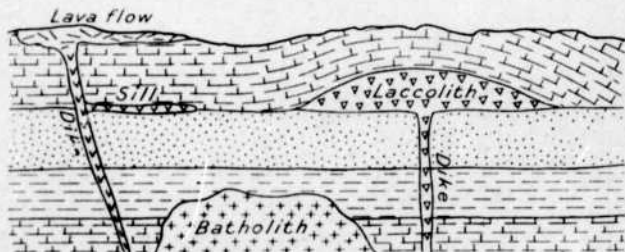


FIG. 116.—Relations of igneous intrusions to stratified rocks. The batholith is shown as if it had eaten its way upward. In some cases at least, such masses have made room for themselves by pushing up the overlying rocks.

it cuts across the strata. The walls of a dike are usually nearly parallel. Faster weathering of the other rock leaves the dike standing out as a ridge. When the dike has weathered faster, a ditch-like

hollow may result. The faster cooling of the part of the dike in contact with the wall allows less time for growth of crystals, and a finer grained structure is the result, almost always noticeable in the broader dikes.

Basic dikes, such as those of diabase, are very conspicuous in granite and other light-colored rocks. (Fig. 117). On the other hand, **granite** and other **acid dikes** often show up as light-colored bands in the darker rocks. (Fig. 118).

186. Sills.—**Sills** are comparatively thin sheets of rock, which have been formed by the intrusion of the magma between the layers of sedimentary or metamorphic rocks; they are usually composed of the basic rocks, and may be miles in extent. A basic magma



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FIG. 117.—Diabase dike cutting granite Kowkash, Ont.

flows more freely than acid magma. The silver ores of the Cobalt district are associated with a **diabase sill**. (Fig. 119).

187. Laccoliths.—When an intrusive sheet has been pushed in between the strata with force enough to arch up the overlying beds, a large, dome-shaped space has been filled, and a **laccolith** has been formed, which, by erosion, may have been brought to view at the surface; they are sometimes of the dimensions of mountains. The nickel ores of the Sudbury area are found around the edge of a great basic laccolith.

188. Volcanic Necks.—**Volcanic necks** are the rock-filling of the vents of ancient volcanoes. By erosion, the greater part of the cone may have disappeared; and if the neck or *plug* has resisted better, it is left standing out as a rounded rocky mass. Other volcanic necks may have weathered faster than surround-



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FIG. 118.—Porphyry dike, Kowkash, Ont.

ing rocks, leaving rounded depressions. The South African diamond fields are volcanic necks, filled with weathered olivine rock, etc.

189. Stocks.—A **stock**, or **boss**, is an irregular, somewhat round mass of igneous rock, which has probably formed at great depths by the rock magma pushing up the overlying rock, or by melting its way upward; the mass has then slowly crystallized. If composed of a resistant rock, like granite, the stock may be left standing up as a rounded hill, when erosion has carried away the surrounding rock.

190. Batholiths.—When such rock masses (stocks) are very large, extending hundreds of miles, they are called **batholiths**, meaning "deep rocks", referring to



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FIG. 119.—Diabase sill with overlying graywacke.
Gowganda, Ont.

the idea that they are the exposed tops of great masses of deep-lying rocks. Granite batholiths underlie large parts of Canada, particularly in British Columbia, Ontario, and Quebec.

IGNEOUS ROCKS

191. Characteristics of Igneous Rocks.—Rocks formed directly from the rock magma by cooling, either at the earth's surface, (**volcanic rocks**) or at some depth in the earth's crust (**plutonic or intrusive rocks**), are called **igneous rocks**. They are essentially mixtures of some of the following common minerals, quartz, feldspar, mica, hornblende, pyroxene, olivine, etc.; or, if not crystalline, they have a composition which would make one or more of these minerals. Quartz, feldspar, and light-colored mica give the lighter color to acid rocks. Hornblende, pyroxene, and dark mica that is high in iron and magnesia, are classed as *ferro-magnesian* minerals. They give the dark color to basic rocks.

In *color*, the igneous rocks vary from light (acid rocks) to dark or nearly black (basic rocks). Being composed of minerals that are hard (except mica), they are mostly hard. In *specific gravity*, they vary from 2.67 (for granite) to 3.3 (for olvine rocks). The *acid rocks* are light, and the *basic rocks* are heavy. In *structure*, they vary from coarsely crystalline to very fine grained or even glassy. When the crystals are large enough to be easily seen, the perfect cleavage of feldspar, the absence of cleavage and glassy appearance of quartz, the softness and thin leaves of mica, the good cleavage and dark color of hornblende and pyroxene, often enable the beginner to name the rock. But in many cases, and especially with fine-grained or badly-weathered rocks, the most experienced man may

have to use the petrographical microscope and other laboratory apparatus, before he can name the rock.

The composition varies with the minerals composing the rock; and as there is almost every mixture of the minerals named above, and, in addition, more or less of accessory minerals, such as tourmaline, epidote, magnetite, etc., no general statement of composition can be made.

192. Classes of Igneous Rocks.—According to *percentage of silica*, four classes of igneous rocks are distinguished; but it must not be forgotten that one class shades into another:

1. Acid Igneous Rocks — containing above 65% silica.

Examples: **granite, rhyolite.**

2. Intermediate Igneous Rocks — containing 50% to 65% silica.

Examples: **syenite, andesite.**

3. Basic Igneous Rocks — containing below 50% silica.

Examples: **gabbro, basalt.**

4. Ultrabasic (very basic) Igneous Rocks, — containing 35 to 43% silica.

Examples: **peridotite, dunite, serpentine.**

According to *structure and origin*, igneous rocks are divided into:

- (a) **Plutonic Rocks** — distinctly crystalline and therefore coarse-grained.

- (b) **Volcanic Rocks** — glassy or fine-grained.

An intermediate class may be made, (c) **porphyritic**

rocks, with larger crystals, in a fine-grained or glassy ground mass.

The crystals in plutonic rocks are crowded together so that they have not taken the regular shapes into which minerals grow when not crowded.

PLUTONIC ROCKS

193. Granite.—**Granite** is a coarse- or medium-grained rock, composed of quartz, an acid feldspar or two of them (orthoclase, microcline, albite), and generally mica (biotite, or muscovite, or both). Instead of the whole or a part of the mica, there may be hornblende or, rarely, pyroxene (augite). The commonest granite is that composed of quartz, feldspar, and black mica (biotite), and white mica (muscovite). Other varieties are biotite-granite, with black mica only; muscovite-granite, with white mica only; hornblende-granite, etc. These rocks contain 65 to 80% silica.

Pegmatite is a name given to very coarse-grained rocks, commonly of the composition of granite; but there are also **syenite-pegmatites** and **diorite-pegmatites**. Pegmatite often contains large masses of pure feldspar, quartz, and mica, which can be quarried out separately. Pegmatite may carry tinstone, wolframite, scheelite, zircon, topaz, uranium-radium ores, etc.

Aplite is granite of very even, fine-grained texture, occurring in narrow dikes cutting through larger granite masses or in the neighborhood of them. It is higher in silica than the main mass of granite, and it

is supposed to have come from the same body of magma, solidifying after the main body.

Pegmatite is supposed to have had a similar origin, but coming from a part of the magma containing a higher proportion of water.

Graphic granite is composed of feldspar and quartz coarsely crystallized, the quartz being set in the feldspar in masses shaped somewhat like letters of the alphabet.

Greisen is composed of quartz and white mica. It has been derived from granite by the conversion of feldspar into mica. It is important in being associated with tinstone.

194. Syenite.—**Syenite** may be defined as *quartzless granite*. The commonest variety is hornblende-syenite, which looks very much like hornblende-granite, but the absence of quartz distinguishes one from the other. Sometimes a little quartz is present. Some of the rock quarried as granite for building stone and paving blocks is really syenite. Syenite contains 50% to 65% of silica.

Nepheline-syenite contains the mineral nepheline instead of the feldspar of ordinary syenite. It may carry corundum and sodalite, as near Bancroft, Eastern Ontario.

195. Diorite.—**Diorite** is composed of hornblende and feldspar, the hornblende in equal amount or in greater quantity than the feldspar, so that the rock is dark. Often the feldspar shows as light-colored spots. The feldspar is mostly of the less acid varieties, oligoclase and labradorite. The structure is apt to

be finer-grained than that of **granite** and **syenite**. Diorite sometimes has quartz, and then may look like **granite**, particularly if the feldspar is about as plentiful as the hornblende.

Amphibolite, or **hornblendite** consists mostly of hornblende.

196. Gabbro.—**Gabbro** is coarse to medium-grained, dark-colored rock, composed of pyroxene and basic feldspar, mostly labradorite. The pyroxene usually predominates, and is partly of the variety, *diallage*, partly *augite*. The crystals of pyroxene and feldspar are broad in outline. Contains 40% to 50% of silica.

Norite has the variety of pyroxene called *hypersthene*, as well as *diallage*. **Olivine-gabbro** and **olivine-norite** are characterized by the presence of olivine.

Diabase is of the same composition as **gabbro**, but the crystals of feldspar are long (lath-shaped) and are set in the masses of pyroxene, giving the structure called **ophitic**. **Olivine-diabase** is common.

Pyroxenite is composed mostly of **pyroxene**, with a little feldspar. **Anorthosite** is a light-colored rock composed mostly of the feldspar, labradorite, with very little pyroxene. **Greenstone** is a useful field name for any fine-grained greenish rock of igneous origin. **Dolerite** is a field name for **gabbro**, **diabase**, and **diorite** when too fine-grained to be distinguished.

Gabbro, **norite** and **anorthosite** are associated with deposits of magnetite, copper pyrites, and pyrrhotite.

197. Peridotite.—**Peridotite** is a very basic, heavy ($G = 3$ to 3.3), green to black, coarse-grained rock, sometimes schistose, composed mostly of olivine (**peri-**

dot), the other minerals being pyroxene, hornblende, with sometimes magnetite, garnet, etc. Very little or no feldspar. It usually occurs in dikes and bosses. Contains 35% to 45% of silica. It is very high in magnesia (35% to 48%). Peridotite is interesting in connection with the occurrence of magnesite in serpentine rocks, which are generally the result of changes in peridotite. While it generally changes to serpentine, it occasionally changes to talc. By continued weathering it forms a rusty gossan or a rust-colored soil deficient in potash, and therefore a barren soil. Peridotite is an important rock, because of the occurrence in it of chromite, platinum, and diamonds.

Dunite, or **olivine-rock**, is composed of olivine, with very little of other minerals. Usually light green.

The following tabular statement shows how the principal plutonic rocks are related to one another in respect to the minerals that compose them.

CONSTITUENTS OF PRINCIPAL PLUTONIC ROCKS

		Kind of Feldspar	Other Essential Minerals
Granite ¹	}	Mostly orthoclase or microcline	Quartz
Syenite ¹			
Diorite	}	Mostly labradorite	Hornblende or mica
Gabbro and Diabase			or both Pyroxene

¹Also contains mica or hornblende or both as accessory minerals.

VOLCANIC ROCKS

Volcanic rocks that are formed at or near the surface by comparatively quick cooling of lava cannot be classified without the aid of the microscope and

chemical analysis, except roughly as *light-colored* and *dark lavas*, conveniently called *rhyolite* and *basalt* or *trap*.

198. Rhyolite.—**Rhyolite** is made up of light-colored acid lava flows, often called **felsite**; it sometimes occurs as dikes. Color, white or gray, sometimes red, yellow, brown, or green; $G = 2.4$ to 2.7 ; fine-grained, with "flow" structure. The fresh broken surface of rhyolite shows thin flakes, which are light-colored even when the rhyolite is comparatively dark. The same appearance is seen at thin edges of a broken piece. The break of rhyolite is apt to be smooth with curved surfaces like a shell (*conchoidal*). But in other cases, especially surface flows, the break may be hackly with a rough feel. Near ore deposits of the vein kind, rhyolite is often changed to a soft mass, which may be clay or sericite. The weathered surface is dull gray, brownish, or reddish. Contains 55% to 80% of silica.

As a field name, rhyolite includes *rhyolite* proper, having the composition of granite, *trachyte*, having the composition of syenite, and *phonolite*, with composition of nepheline-syenite.

Visible crystals (*phenocrysts*) of feldspar are sometimes present, and there are occasionally visible quartz, biotite, pyroxene, and hornblende crystals.

Obsidian is glassy in texture, from quick cooling. It has conchoidal fracture. Color, jet black to red. **Pitchstone** is a dark green or nearly black rock of dull, pitchy luster and conchoidal fracture.

Pumice is acid lava of a fine vesicular structure,

that is, full of very small cavities or *vesicles*, which have been formed by the steam in the lava.

199. Basalt, or Trap.—Basalt is formed from dark-colored, basic, lava flows, sometimes as dikes. Color, gray-black to black, usually not white in thin flakes as rhyolite is; heavy, $G = 2.9$ to 3.1 ; silica, 40% to 55%, Phenocrysts (visible crystals) of pyroxene, feldspar, and olivine sometimes show. Sometimes basalt is plainly crystalline; but parts that have cooled rapidly from contact with cold rocks are glassy, as in basalt dikes next to the walls.



Ontario Dept. of Mines
FIG. 120.—Lava with gas cavities. Madoc, Ont. Size of specimen, about 8 in.

Basalt is much jointed, often in a very regular way as in the Giant's Causeway, Ireland, and at a places along

the Grand Trunk Pacific Railway in British Columbia. The weathered surface is usually rusty, sometimes green. The vesicular structure (roundish holes) is common (Fig. 120), and the hollows are sometimes about the shape of almonds, from which the name, **amygdaloid basalt**, when these hollows are filled with calcite, quartz, etc., as secondary minerals. (Fig. 121). The surface of basalt may be weathered green by the formation of chlorite, or rusty brown or red from oxides of iron.



Ontario Dept. of Mines

FIG. 121.—Amygdaloid lava, Madoc, Ont. Size of specimen, about 7 in.

Serpentine, carbonates, red oxide of iron, and clay are apt to be formed near ore deposits in basalt. Basalt (trap) is one of the best materials for roads and con-

crete. Basalt, if well crystallized, would form **gabbro** or **diabase**.

200. Andesite is a dark, fine-grained, volcanic rock of the composition of diorite.

COMPARISON OF VOLCANIC AND PLUTONIC ROCKS

ACID, LIGHT-COLORED, $G = 2.4$ to 2.7

Volcanic

Rhyolite
Trachyte
Phonolite

Plutonic

Granite
Syenite
Nepheline-syenite

BASIC, DARK-COLORED, $G = 2.7$ to 3.1

Volcanic

Basalt
Andesite
Dacite

Plutonic

Gabbro, Diabase
Diorite
Quartz-diorite

PORPHYRITIC ROCKS

201. Porphyry. — This name refers to the structure, which is formed of larger crystals set in a fine-grained or glassy ground-mass. (Fig. 122). The porphyritic structure may be plainly visible, the larger crystals being easily seen (phenocrysts), or it may require the microscope to bring it out. Porphyritic structure may appear in any igneous rock, but the true porphyries are rocks in which there is a marked contrast between the large crystals and the ground mass. The explanation suggested for their origin is that the cooling went on slowly enough, at first, for the growth of large crystals; but, before the whole mass became solid, some change caused more rapid cooling, perhaps by the pushing up to the surface of a deep cooling mass of magma.

Quartz-porphyry has phenocrysts of feldspar and usually quartz, in a fine-grained ground mass. When the ground mass is composed of small crystals of feldspar and quartz, the rock is called **granite-porphyry**. Both are of the composition of granite, and both are found in the elvan dikes of the tin district in Cornwall.



Geology Dept. McGill University
FIG. 122.—Porphyry

Syenite-porphyry or **feldspar-porphyry** is characterized by crystals of feldspar in a fine-grained or glassy ground mass; it has the composition of syenite. Both are light-colored rocks, corresponding to granite and

syenite; they are characteristic rocks of the Northern Ontario goldfields.

Lamprophyre, is a dark-colored, fine-grained rock, with phenocrysts of black mica, hornblende, or pyroxene. It occurs in small dikes and sills, usually accompanied by aplite dikes. Mica-lamprophyre is called **minette**.

METAMORPHISM

202. Explanation of Term.—After consolidation, some sedimentary and igneous rocks have undergone more or less change due to heat, pressure, and the chemical action of water and hot gases; in this way the structure of the rocks has sometimes been altered very much. For example: (a) by growth of crystals in limestone; (b) a laminated structure developed, different from the original stratification, as when shale is changed into slate; (c) new mineral combinations formed, as when olivine is changed into serpentine. This process is called **metamorphism**, and the resulting rocks are called **Metamorphic rocks**, which means *changed* or *altered* rocks.

Igneous rocks have also been changed to some extent (for example, granite to *gneiss*) by pressure, which has caused the granite to squeeze out or flow, so as to develop a somewhat stratified appearance, conspicuous minerals like black mica having been pressed out into lines. This process carried further produced **schists**, rocks with a sheeted or laminated structure. Gneiss and schists have also been formed by metamorphosis of sedimentary rocks, where these have con-

tained the materials for the formation of the characteristic minerals, feldspar, mica, quartz, etc. In some places the metamorphic rock, say gneiss, can be seen shading into the corresponding sedimentary rock, (a conglomerate or an impure sandstone) or into the corresponding igneous rock (granite or syenite).

The heat, which is one cause of metamorphism, comes, partly, from the hot interior and, partly, from the pressure and internal movement which accompany folding. Fossils have been almost completely destroyed in sedimentary rocks that have been metamorphosed.

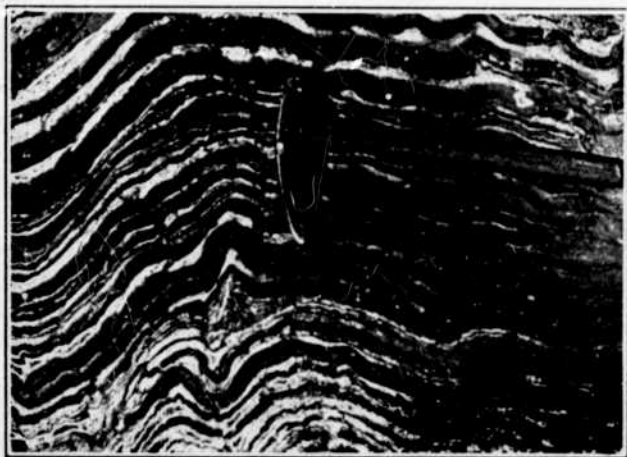
In their crystalline structure, most metamorphic rocks resemble igneous rocks. In an appearance like stratification, they resemble sedimentary rocks.

The changes here mentioned may have taken place throughout large extents of rock by the action of heat, pressure, or hot water or gases, working on a large scale (**regional metamorphism**), or they may have been confined to the local influence of hot masses such as those that formed dikes, etc. (**local or contact metamorphism**). The rocks at these contacts have become crystallized; and the change sometimes extends for a considerable distance from the contact, occasionally a mile or more.

METAMORPHIC ROCKS

Rocks that have been formed from other rocks, sedimentary and igneous, by internal changes caused by pressure, heat, and the chemical action of water and hot gases, are called metamorphic rocks.

203. Crystalline Limestone.—This is a rock that results from the crystallization of the calcite in sedimentary limestone. More or less of the calcite may have been replaced by carbonate of magnesia, forming **dolomitic limestone**; or, when the replacement has gone far enough, the rock becomes **dolomite**. The impurities in the limestone and other materials brought from without appear in the crystalline limestone as crystals of mica, tremolite, garnet, titanite, magnetite, graphite, etc. **Banding or schist-structure** is sometimes present, and crystalline limestone sometimes shades into **calc-schist**.



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FIG. 123.—Crystalline limestone, crumpled.

204. Slate.—True slates have been formed by the change, of shale, mud, or clay, by pressure and heat,

into a compact fine-grained rock, which can be split into smooth sheets or thin slabs. The direction of cleavage is not usually that of the original strata, but may cross it at any angle. The stratification has more or less completely disappeared, and the slaty cleavage has been developed by pressure. Heat or pressure has destroyed the clayey property of the shale, etc., and the microscope shows the growth of small crystals of quartz, mica and other minerals.

Slate is fairly soft, and it can be cut and punched; its value depends on this, and on its clean, easy splitting. The original stratification, or bedding, sometimes shows as lines called 'ribbons,' which may spoil the slate. The slaty structure is sometimes found in rocks not originally of a clayey nature; for example, volcanic ash rocks. These slates are not so likely to be merchantable.

Phyllite is a slaty rock in which crystallization is farther advanced than in true slate. It is distinctly micaceous, and is intermediate between slate and mica schist.

205. Quartzite.—This rock is formed from sandstone by the complete filling of the spaces between the grains with **secondary quartz**, that is, silica, crystallized upon the grains of quartz or around the grains of other minerals. It is a hard compact rock, which breaks with a conchoidal (shell-like) or splintery fracture, unlike the rough-grained break of sandstone. In quartzite, the break passes through the grains of quartz; in sandstone it passes between them. The grains are sometimes visible in quartzite, although not

so distinct as in sandstone. Crystals of mica, feldspar, epidote, magnetite, etc. may be scattered through the rock; but sometimes quartzite is a very clean, white rock, almost pure silica. The color is sometimes gray, yellowish, greenish, or reddish. The hardness is that of quartz, $H = 7$; and the specific gravity is also near that of quartz, $G = 2.6$.

The great hardness of quartzite makes it difficult to drill and dress; but, on account of its durability, it is sometimes used as a building stone. The crushed rock makes good railroad ballast and concrete. Pure white quartzite is ground and used in making glass. It is also used in the manufacture of ferro-silicon, and silica brick.

206. Gneiss.—This is a banded rock, composed of the same minerals as granite, syenite, diorite, gabbro, etc., the crystals of which are mostly large enough to be seen. It is sometimes a changed sedimentary rock, and sometimes it has been formed from an igneous rock; in both cases the banding has been developed by pressure. The banded structure may also have been caused by the flowing and drawing out of the stiffening magma. The materials of the original sedimentary rocks have been chemically changed and crystallized.

In some localities, gneiss can be seen grading into conglomerate, clayey sandstone, or granite, etc. The commonest gneiss is that which has the composition of granite. The banding may be very distinct or it may be quite irregular. Gneiss sometimes splits readily, and is then easily worked into blocks for foundations, etc.

207. Schists.—**Schists** are rocks in which the changes caused by pressure have gone farther than in slate, quartzite, and gneiss, so that a structure of thin layers or sheets has been developed — the **schistose or foliated structure**. Schists are distinctly crystalline. In composition there are many varieties, named after some conspicuous mineral; as, *mica schist*, *chlorite schist*, *talc schist*, *hornblende schist*, *quartz schist*, etc. **Calcareous schist** or **calc-schist**, has been formed by the metamorphism of impure limestone.



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FIG. 124.—Squeezed Conglomerate.

208. Serpentine.—This rock is composed largely or altogether of the mineral serpentine (see Art. 109), a hydrated silicate of magnesia. It has been formed

by the change of basic rocks composed mostly of olivine, hornblende, pyroxene, etc., for example, *peridotite*, *hornblende schist*, and *pyroxenite*. Water has taken part in the change, and the resulting principal mineral is *hydrated*. The origin of the serpentine rock can sometimes be seen in a little olivine, pyroxene, or hornblende, which remains unchanged. For uses and value see Art. 109.

209. Soapstone, or Steatite.—This rock is composed mostly of the mineral talc (see Art. 110) with mica, chlorite, tremolite, pyroxene, etc. Color, bluish or greenish-gray, sometimes dark gray. May be considerably harder than pure talc, but is soft enough to be easily quarried and cut. It is used mostly in the manufacture of table tops, sinks, and gutters in chemical laboratories, laundry tubs, switch boards, etc. The harder varieties are used for stair treads. Soapstone free from the harder minerals is ground and used as a lubricant. For value, see Talc, Art. 110.

The following list gives some well-known sedimentary and igneous rocks, on the left-hand side, and opposite each the metamorphic rock into which it is changed by the processes described above:

Sedimentary Rocks changed to Metamorphic Rocks

Conglomerate	to	Gneiss and schist
Sandstone	to	Quartzite and gneiss
Shale	to	Slate and schist
Limestone	to	Crystalline limestone and schist

Igneous Rocks changed to Metamorphic Rocks

Granite	to	Gneiss
Syenite	to	Gneiss
Diorite, etc.	to	Gneiss
Rhyolite, porphyry, etc.	to	Schist
Gabbro, basalt, etc.	to	Schist
Peridotite, etc.	to	Serpentine
Pyroxenite, etc.	to	Serpentine

EXAMINATION OF ROCK SPECIMENS

210. Table for Identification of Rocks.—Those who are using this textbook in connection with the course of instruction offered by the Institute of Industrial and Domestic Arts are supplied with a set of rock specimens, which are to be identified systematically, using the Table for the Identification of Rocks. It may here be mentioned that the identification of rocks presents peculiar difficulties. Rocks are not definite substances; in some cases, they are mixtures of minerals, while in other cases, they are mixtures of pieces of older rocks. The rock is often so fine grained that it is impossible to distinguish the minerals or the fragments without the aid of the microscope and other laboratory appliances. But, in many cases, the nature of the rock is plainly visible. The student need not feel discouraged if he is not able to "spot" every rock at sight; the most experienced geologist is unable to do this. The following illustrations will explain the method of using the Table.

Specimen No. 1.—Consult the Table and note that this specimen comes under Division C, Distinctly and Evenly Crystalline. Try its hardness with the knife; it comes under (6), Hard to Scratch. Note, further, that there are three minerals in this rock; the reddish one is identified as feldspar by its good cleavage and hardness; the grayish-white one as quartz, by its glassy look, hardness, and lack of cleavage; the black mineral as mica, by its shiny appearance, softness, and cleavage into thin, elastic sheets, or as hornblende, by its hardness and good cleavage. The rock is granite. Study the description of this rock, Art. 193.

Specimen No. 4.—Study its appearance, and note that it also comes under Division C. Identify the black, or dark, or green mineral as hornblende or pyroxene, by good cleavage and hardness. Note light-colored crystals, hard and with good cleavage, as feldspar. The specimen is diorite, gabbro, or diabase, hard to distinguish from one another. Actually, this specimen is gabbro. Read the descriptions of these three rocks in Arts. 195 and 196.

Specimen No. 10.—Note its fine-grained appearance; it comes under Division B. As it is not scratched with a knife, it is rhyolite, flint, chert, or basalt. Its color is light, and thin flakes are white; therefore, it is rhyolite. Read description, Art. 198, and compare the specimen with it.

Specimen No. 11.—Study the specimen carefully as a whole, and note that it comes under E in the Table. Identify the minerals in it as feldspar, quartz, and either mica or hornblende, the same as in granite, specimen No.

1; this specimen is gneiss. Read the description, Art. 206.

Specimen No. 20.—Note from the rounded pebbles and grains of quartz, etc., that the specimen comes under F in the Table. The pieces are mostly of the harder minerals and rocks (try with a knife), and feldspar is not noticeable; the pieces are mostly as large as peas or larger. The rock is conglomerate; see Art. 165.

By means of the Table, identify all the other rock specimens to the best of your ability; report them by their numbers to the Institute.

TABLE FOR IDENTIFICATION OF ROCKS

(The numbers in parenthesis are the same as those of the articles describing the same rocks in the Text.)

A. Glassy in Texture

- | | |
|-------------------------------------|-------------------------|
| 1. Glassy luster. | Obsidian (198) |
| 2. Resinous or dull, pitchy luster. | Pitchstone (198) |
| 3. Cellular; very light. | Pumice (198) |

B. Fine-Grained, Dull, or Stony

(a) SCRATCHED BY FINGER NAIL

- | | |
|---|-------------------------------------|
| 1. Strong, clayey odor when breathed upon; greasy feel after long rubbing; does not fizz with acid. | Clay (111) |
| 2. No clayey odor (marl may have clayey odor); no greasy feel; fizzes with acid. | { Chalk (172)
Marl (111) |
| 3. Same as (2), but does not fizz with acid. | Tripolite (75) |
| 4. Harder; does not fizz with acid; good cleavage. | Gypsum (119) |
| 5. Soft; greasy feel; often in scales, like mica, but not elastic. | Soapstone (209) |

(b) NOT SCRATCHED WITH FINGER NAIL, BUT EASILY WITH KNIFE

- | | |
|--|-------------------------|
| 1. Laminated; clayey odor; usually gray; no fizzing, or very little, with acid. | Shale (171) |
| 2. No clayey odor, or very feeble; usually gray; powder, white; fizzes with acid. | Limestone (172) |
| 3. Same as 2, but fizzes only when acid is hot. | Dolomite (203) |
| 4. Usually greenish; powder, white; slightly soapy feel; luster, often waxy; sometimes rather hard to scratch with knife; does not fizz with acid. | Serpentine (208) |

(c) NOT SCRATCHED WITH KNIFE; SCRATCHES GLASS

- | | |
|--|------------------------------------|
| 1. Color, light, white in thin flakes; sometimes clayey odor. | Rhyolite (198) |
| 2. Very hard, scratches steel and feldspar; conchoidal fracture. | { Flint (75)
Chert (75) |
| 3. Not so hard as 1* and 2; color, dark; heavy; sometimes with roundish holes or amygdulæ. | Basalt (199) |

6. Harder than talc; smooth; green; powder, white or gray; shines like mica. Chlorite Schist (207)

F. Composed of Fragments of Rocks or Minerals

1. Rounded pebbles, from the size of a pea to boulders. Conglomerate (165)
2. Angular pieces. Breccia (168)
3. Pieces of volcanic rock.

}	Volcanic Tuff (167)
}	Volcanic Breccia (179)
4. More or less rounded grains, mostly of quartz from the size of a pea down. Sandstone (169)
5. Same as 4, but with feldspar grains. Arkose (170)
6. Gray color; fine-grained; quartz, feldspar, and other minerals and rocks. Graywacke (166)

PROSPECTING

(PART 2)

EXAMINATION QUESTIONS

(1) What are the reasons for supposing that the interior of the earth is composed of iron and other metals?

(2) Write definitions of the following expressions: (a) outcrop; (b) talus; (c) stratified rocks; (d) canyon; (e) ground water; (f) erosion; (g) joints.

(3) (a) In what ways does running water work to change the face of the earth? (b) How are potholes and kettles made?

(4) Describe the way in which waves work to destroy the land.

(5) (a) What is a glacier? (b) At what rate do glaciers move? Define: (c) terminal moraine; (d) lateral moraine; (e) glacial grooves; (f) drift.

(6) (a) How do heat and cold work to destroy rock? (b) State what substances in the air destroy rock by chemical action, and explain as well as you can how they work.

(7) Write a list of sedimentary rocks, mentioning the loose material from which each kind of rock has been formed.

(8) What kind of fragments would you expect to find in conglomerate? In answering this question, consider the processes through which the pieces have passed and the effects of these processes on materials of different kinds.

(9) Insofar as you can, trace the history of lime in limestone, as regards its movements and changes before it became part of the limestone.

(10) Account for the deposition of sediments that are many thousands of feet in thickness, in shallow water without interruption.

(11) (a) Define rock series, and (b) unconformity.

(12) Define: (a) anticline; (b) syncline; make sketches to illustrate your meaning. Define: (c) dip, and (d) strike, and illustrate with sketch.

(13) Define: (a) lava; (b) amygdaloidal lava; (c) pillow lava; (d) rock magma; (e) magmatic water.

(14) (a) What are igneous-rock intrusions? (b) Describe the principal forms of these intrusions, illustrating with sketch.

(15) What is the chief difference in composition and appearance between a basic dike and an acid dike?

(16) Give the meanings of the following expressions: (a) igneous rocks; (b) volcanic rocks; (c) plutonic rocks. (d) Volcanic rocks are apt to be fine grained, and plutonic rocks coarse grained, why is this?

(17) (a) What are the principal minerals composing igneous rocks? (b) Why are igneous rocks mostly hard?

(18) Define: (a) aplite; (b) pegmatite; (c) graphic granite; (d) syenite; (e) pyroxenite.

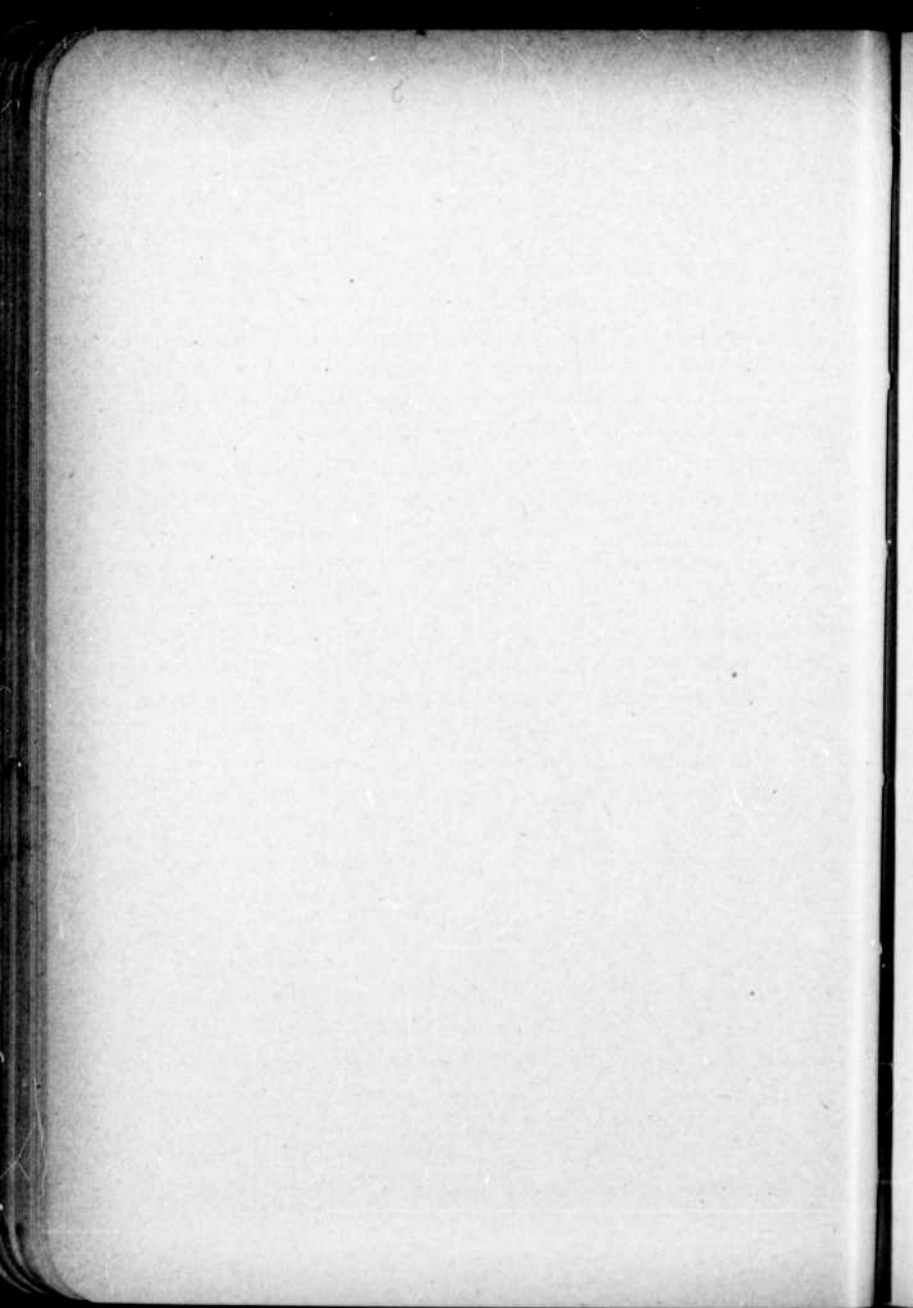
(19) (a) What difference in composition between diorite and gabbro? (b) What minerals give these rocks their usual dark color?

(20) Define: (a) porphyry; (b) quartz-porphyry; (c) granite-porphyry; (d) syenite-porphyry.

(21) (a) What are metamorphic rocks? (b) When sedimentary rocks have been metamorphosed, it is quite common for the layers to be tilted, so their edges show; account for this as fully as you can.

(22) Make a list of the principal sedimentary rocks and the rocks into which they are converted by metamorphism. As far as you can, mention the nature of the change.

(23) To the best of your ability, use the rock table to identify the rock specimens supplied you. Make a report stating your findings and send us your report with your answers to the foregoing questions.



PROSPECTING

(PART 3)

MINERAL DEPOSITS

DEFINITIONS AND CLASSIFICATION

211. Ores.—An ore is a mineral or rock from which some valuable constituent, usually a metal, can be profitably extracted. Thus hematite and magnetite are ores of iron; galena is an ore of lead; zinc blende is an ore of zinc. With the ore-mineral is more or less material of no value, called gangue; and whether the ore as a whole can be profitably mined or not depends partly on the proportion of ore to gangue.

In the discussion of mineral deposits it is usual to include certain minerals of commercial value, such as talc, barite, apatite, feldspar, and fluorspar, which are not used as sources of metals.

212. Mineral Deposits.—The valuable minerals sought by the prospector are always present in all rocks, but are generally so scattered and diffused as to be useless. Even in sea-water, gold can always be detected, and

appreciable quantities have been found in granite, syenite, basalt, diabase, marble, and mud, quite apart from any workable ore deposits.

Mineral deposits are exceptional concentrations. The natural concentration processes that have given us ore deposits have used water as the agent in various ways, mechanical and chemical; but some ores, and perhaps many, have been separated directly from the *rock magma* while an intrusive mass has been cooling and solidifying. **Magma** is the liquid rock material below the solid crust of the earth. It comes to the surface as lava. It also pushes its way into the rocks as *intrusive masses*.

According to their origin, mineral deposits may be conveniently put in three classes:—

- I. Magmatic segregations.
- II. Veins and other deposits in fissures, shear zones, joints, etc.
- III. Sedimentary deposits.

213. Magmatic Segregation.—Magmatic Segregation, or separation and concentration of the ore from the cooling, crystallizing rock magma, has taken place where the magma has pushed its way upward and formed large masses (laccoliths, etc.) at sufficient depths to allow slow cooling. As the ore was heavier than the rest of the magma, it went to the bottom as it crystallized, or it may have separated in the liquid condition. The separation effect of the growth of crystals should also be taken into account. With very slow cooling, the crystals that first started would attract their own substance from the liquid, and thus concentrate it in one place. The basic rocks, such as gabbro, norite, dia-

base, and peridotite are the commoner country rocks for magmatic segregations. Some ore bodies grade into the country rock, but others have well-defined walls. The ore bodies are apt to be irregular in shape, and not tabular, like veins. An exception to this is where the ore body is in the form of a dike of solid ore, and without any of the parent rock; some titaniferous magnetite ore bodies are of this kind.

214. Pegmatite dikes are magmatic segregations that are thought to represent a late stage of the solidification of the parent body, when the magmatic water and other substances tending to keep the rock matter in the liquid condition promoted a very slow crystallization and the consequent growth of large crystals. In this way, the acid pegmatites sometimes supply large masses of pure feldspar, quartz, and mica.

The conditions were also favorable for the concentration of certain valuable minerals, for example, tin-stone, molybdenite, monazite, scheelite, wolframite, topaz, rutile, uraninite, (commonly called pitchblende), tourmaline, emerald, ruby, and sapphire.

It has been suggested that a great many veins and other ore bodies have been formed directly from the magma by separation of the minerals along with water and other substances that tended to keep the mass in a liquid state until it was pushed into a position where the cooling caused it to become solid.

VEINS AND SIMILAR DEPOSITS

215. Remark.—This division includes a considerable variety of ore deposits formed under various conditions by the agency of water, which concentrates the ore in

fissures and in joints, crevices, and pores, or makes room for the ore by dissolving the rock and carrying it away.

216. Veins.—A **vein** is a mineral mass of a tabular form, deposited from water solutions in a rock fracture. By *tabular* is meant having two long dimensions and one short dimension, the length and depth of the vein being the long dimensions, and the width the short one. **Country rock**, or **country**, is the rock on each side of the vein.

The **dip** of a vein is the angle it makes with the horizontal, measured at right angles to the strike. The **strike** is the direction of the vein horizontally. See Fig. 109.

The **walls** are rock boundaries of the vein on each side. If the vein is sloping, the upper is called the **hanging wall**, and the lower the **foot wall**; but when the vein is vertical (dips at 90°) there can be no distinction.

Gouge or selvage is soft or shaly material on the walls of veins, due probably to grinding movements of the two surfaces on each other. This sometimes causes a polished surface, *slickensides*.

A **druse** or **vug** is an unfilled part of a vein; it is usually lined with crystals that project inward.

Vein matter is the mineral mass filling the vein; it may or may not be valuable. The whole may be of value, for example, fluorspar and barite veins. Or the value may be in minerals like gold, silver, copper, and other ores scattered through quartz, calcite, or other mineral forming the main part of the vein matter, the *gangue*.

To form ore deposits, the waters or the separated part of rock magma must have channels.

216. Joints.—All rocks are cracked by small breaks, which are usually in roughly parallel sets that cross, and thus form intersecting channels. These breaks, called **joints**, are due to a number of causes; for example, shrinkage of the rocks by cooling or drying. Joints are more numerous near the surface than they are at greater depths.

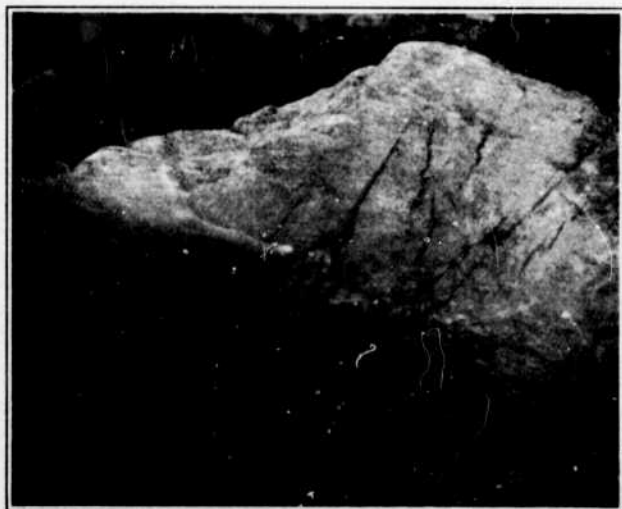
217. Faults.—A break of greater extent is called a **fault** if there has been displacement, as there usually is; but if there be no displacement, the word fault cannot be used. A fault is not usually one break, but quite commonly a main break, flanked on each side by a zone of smaller fractures; and it is common experience that these zones are the more favorable places for ore-deposits. In some regions, there are sets of parallel fissures, sometimes one set crossing another. It is important to study the directions of these fissures, as the fracturing may have taken place at different times; and some fractures may be accompanied by ore deposition and others not.

218. Shear Zones and Crush Zones.—These are bands of rock in which many fractures have been formed by a twisting or shearing movement, or in which the rock has been brecciated by such disturbances. Shear zones sometimes induce the deposition of valuable ore deposits.

219. Cause of Fractures.—Fractures are found mostly in disturbed folded regions; pressure and tension due to folding and warping explain the breaks. It is believed that the cause of the pressure, at least in a great many cases, has been the pushing of the intrusive magma

that formed the rocks with which so many ore deposits are associated. The fact that ore deposits are more common in rough country is explained by the connection between folding and breaks. As the folding and warping set up pressures and tensions slowly and in a definite, regular way, parallel systems of fractures are apt to be developed, as has been shown by applying similar forces to a strip of glass (Fig. 125).

220. Direction of Fractures.—The direction of a fracture is likely to be straight in solid uniform rock. In a stratified rock, the fracture is apt to run across



Ontario Dept. of Mines
FIG. 125.—Torsion cracks in Keewatin Greenstone,
Cobalt, Ont.

the strata, as, for example, in sandstone and limestone; but in loose rock, like shale or slate, it is more likely to

run with the layers or cleavage. A strong fracture in passing from a dense, hard rock into shale or schist may change its direction and die out.

MINERAL DEPOSITION IN VEINS, ETC.

221. Deposition of Ore.—The mineral deposits in this class may be conveniently studied in two divisions:

- A. Veins, etc, near intrusions of igneous rock.
- B. Veins, etc, independent of igneous intrusions.

VEINS, ETC. NEAR INTRUSIONS OF IGNEOUS ROCKS

222. Mineral Deposits connected with Intrusive Igneous rocks.—It is believed that the ore has been deposited by hot solutions derived from the intrusive rock. The hot water (magmatic water) finds its way upward through the channels, carrying with it various minerals, which it is able to dissolve in large quantity¹ because of the high temperature and pressure prevailing at those great depths. Then: (1) As it slowly moves upward, the water cools, and this may cause it to deposit part of its load. (2) It may find in the rock through which it is passing materials that cause the formation of new substances, which the water cannot keep in solution; for example, shale, sandstone, and limestone supply vegetable and animal matter containing sulphur for the formation of sulphides. (3) Two streams may meet at the intersection of two channels, and the mingling of the different solutions may cause substances to be pre-

¹ Perhaps so large that the material may be looked upon as mineral and rock matter with water dissolved in it, the whole being capable of forming a vein by solidifying.

cipitated. (4) When once an ore-mineral is deposited the tendency is for more of that mineral to gather in that place, as the circulating water brings it along.

The ore may have been deposited in open fissures by simply filling the spaces, but generally the water has enlarged these by dissolving the rock. In the same way joints, shear fractures, and other crevices have been enlarged, and sometimes the crushed rock has been completely removed and *replaced* by ore; it is plain that a well-fractured rock of porous texture is most favorable for this process. Another favorable condition is schistifying of the rock next to the vein. That minerals may be carried in this way is sufficiently proved by the presence of lead, zinc, arsenic, gold, and other constituents of ore-minerals in the water of hot springs, and in the limey and siliceous sinter¹ deposited by hot water. The ore may, however, have been concentrated from the magma by successive changes such that at length the ore was separated along with the water, forming a liquid that pressed its way into a fissure. The fissures may have been formed by the pressure of this part of the magma.

223. Minerals Characteristic of Deposits Connected with Igneous Intrusions.—The ore minerals are mostly sulphides. When these substances accompany more valuable minerals, for example, gold, and are not themselves present in sufficient quantity to be valuable, they are often called **mineralizers**². A vein in which sul-

¹ Sinter has somewhat the same meaning as cinder. The material is often of a porous nature, like cinder; but it is sometimes solid and in layers.

² This word is used in a different sense by some writers, to indicate substances like water, hydrochloric acid, and hydrofluoric acid, which promote the transportation, concentration, and crystallization of minerals from the magma.

phides and other mineralizers are plentiful is said to be *well-mineralized*. In many of these deposits, high temperature minerals, such as epidote, pyroxene, feldspar, garnet, graphite, specular hematite, ilmenite, magnetite, pyrrhotite, scheelite, and wolframite are found in the vein matter and in wall rock; also minerals like tourmaline, fluorspar, and apatite, which are suggestive of the work of intensively hot vapors. But high-temperature minerals are absent from some deposits.

224. Depths at which Ore Bodies may be Formed.

The ascending stream of ore material may have deposited ore at depths of at least two or three miles, and from that upward.



Ontario Dept. of Mines

FIG. 126.—Quartz vein (white) with tourmaline (black)
Goudreau, Ont.

225. Fissure Veins.—These are ore bodies bounded by rather regular, straight walls, of fairly constant width,

and with a definite direction of strike and dip: this gives a roughly tabular shape to the ore body. But the original fissure may have been irregular, with expansions and contractions due to displacements of irregular walls by faulting.

The ore body has sometimes been formed partly by filling the fissure and partly by replacing the wall-rock with ore, or by filling its pores with ore minerals to such an extent as to give it value. In this way, a large ore body, — a replacement vein, — may have been formed about a fissure originally very narrow. The outcrop of such an ore body may be very unattractive, showing only a thin streak of quartz or other gangue. But the altered condition of the rock on each side of the break, and its mineralization, are indications of ore deposition.

A **lode** is a number of parallel fissure veins, the rock between being sometimes mineralized, so as to form a continuous ore body. A **vein system** is a larger collection of fissure veins, often with cross veins connecting them. A **bedded vein** is one that follows the bedding of a stratified rock. Such ore bodies may be in the form of a succession of *lenses*, sometimes overlapping.

226. Saddle Reefs.—The tension in the rocks of an anticline (Art. 177) often causes fissures and also a separation of the layers of stratified rock. These openings form channels for the circulating waters, so that anticlines are favorable places for ore-deposition. The ore may not only fill the fissure that breaks through the strata (where the rock is a stratified one) but it may also be deposited between the strata as a saddle-shaped

ore-body, called a **saddle reef**. The space for the ore may have been greatly enlarged by the water dissolving the rock; and this is particularly apt to be the case with limestone. The outcrop of such an ore-body may be very inconspicuous.

Ore is sometimes deposited in the apex of an anticline, when there is a layer of tight rock above that stops the flow of water upward; the ore gathers under this layer. A very favorable situation is where a cross fold has caused a dome-shaped structure in the rock; and it is under such *domes* that oil and gas are most favorably prospected for.



After T. A. Ricard
FIG. 127.—Saddle-reef (black) in anticline.

As the country is usually folded into a number of parallel folds, when an ore-body is found in one anticline, others should be looked for in a similar situation

in *all* anticlines. This is well shown in the gold districts of Nova Scotia.

227. Shear Zones and Crush Zones.—**Shear zones** are caused by a movement of the rock which results in many small fractures, somewhat regularly placed, and which form a system very favorable for ore deposition, because the water moves slowly, allowing time for the necessary changes. When the rock has been extensively broken, it is called a **crush-zone**. There are sometimes fairly distinct walls between the sheared or broken rock and the more solid rock outside the zone. The rock within the zone may be more or less completely replaced by ore.

228. Chimneys and Stocks.—A **chimney** is an ore body of a roughly circular shape in cross section, and extending downward to a considerable depth. A **stock** is an irregular mass of rock with a network of veins and veinlets. The rock between the veins may be mineralized, so that the whole body may be mined as ore.

229. Fahlbands.—A **fahlband** is a belt of rock, usually schist, with pyrite, copper pyrites, and other mineralizers scattered through it, not usually rich enough to work; but workable veins may be found near or in the fahlbands. *Disseminated deposits* are somewhat like fahlbands, but may occur in igneous or sedimentary rocks; they are sometimes workable.

230. Contact Metamorphic Deposits.—These are irregular ore bodies in the metamorphic (altered) zone of sedimentary rocks at or near their contact with igneous intrusive rocks. Limestone or limey shales are the usual

sedimentary rocks, and the igneous rocks are commonly of the acidic or intermediate class, such as granite, diorite, and the corresponding porphyries. The ore has been deposited by hot solutions from the igneous rock, by a process of *replacement*, the rock having been dissolved and carried away and the ore deposited in place of it.

VEINS, ETC. INDEPENDENT OF IGNEOUS INTRUSIONS

231. Ore Deposition by Water from Surface.—In this class are ore-deposits that have been formed by the action of *meteoric* waters, that is, water derived from the air (rain, etc.). They are found mostly in sedimentary rocks, particularly limestone, shale, and sandstone. The ore may be in fissure veins or in deposits of an irregular kind.

Gash veins are fissures of no great extent, not much more than enlarged joints. **Runs** are narrow ore-bodies following the stratification. **Flats** are more extensive deposits between the layers. **Pitches** are similar to flats, but following inclined joints; they are characteristic of the lead and zinc ore deposits of Wisconsin. **Breccia veins** are formed by ore filling in the spaces between broken rock in a fissure. Some ore deposits of this class have been formed in old underground water courses and in caves.

232. Ores Found.—The principal metal ores found in these deposits are sulphides of zinc, lead, copper, and iron, and oxides of iron and manganese. The carnotite

deposits of Colorado, yielding uranium, radium, and vanadium, are found in sandstone.

Among non-metallic minerals, barite veins are sometimes of this class. It is possible that many of the ore bodies not obviously connected with igneous intrusive rocks have been formed in association with intrusions that are still hidden; for example, the fluorspar veins of the Madoc district, Eastern Ontario, may have been formed in this way.

SEDIMENTARY MINERAL DEPOSITS

233. Mechanical Deposition.—The ore mineral, on account of its resistance to weathering and its hardness, survived the destruction of many of the rock minerals; and, during sedimentation, on account of its weight, it was sorted out from the fragments of quartz and other resistant minerals. Thus the ore-mineral was deposited, without being chemically changed, in a layer by itself or approximately so. Black magnetic sand illustrates this process of concentration, and if consolidated, it would form a bed of iron ore. Placer deposits of gold, platinum, tin-stone, monazite, etc., are natural concentrations of heavy minerals, separated from the lighter substances by the sorting action of running water. Clay beds owe their concentration to the lightness and fineness of grain of the clay, allowing it to be carried farther by water than the heavier and coarser materials.

234. Chemical Deposition.—In the weathering of rocks, iron and manganese are dissolved as carbonates by water containing carbonic acid, and are carried down

to swamps, lakes and seas, where they have been deposited as beds of ore; under some circumstances, they have been deposited as *carbonates* (siderite and rhodochrosite), and under others, as *oxides* (limonite, hematite, pyrolusite, etc.). When the sedimentary rocks have undergone folding and metamorphism, the character of the ore may have been altered; for example, limonite changed to hematite or magnetite.

The vast hematite deposits at Bell's Island, Newfoundland, are sedimentary. The siliceous magnetite of Moose Mountain, Ontario, and the siderite of the Michipicoten District, Ontario, are of sedimentary origin. Gypsum and salt are examples of minerals deposited by the evaporation of sea water.

SURFACE ENRICHMENT

235. Concentration of Ore Bodies by Weathering. By weathering or by the action of magmatic water, an ore body may be concentrated in two ways; (a) by the removal of valueless material so as to leave a richer ore; (b) by solution of the valuable material and re-deposition at a lower level.

236. By Removal of Valueless Material.—Ore bodies formed in this manner are called **residual ore bodies**; some examples are the following:

(1) The siliceous iron ores of the Lake Superior region have been concentrated in places where the conditions have been favorable. The underground waters have removed the silica and left the iron mostly as hema-

tite. Nearly all the ores mined in the Lake Superior district are residual ore bodies of this kind.

(2) Some limestones have nodules of phosphate of lime scattered through them. The limestone has been dissolved, leaving the phosphate as a valuable residue, as in the Florida deposits.

(3) Gold veins may be richer at the surface, where the gold has been left behind in the process of weathering and washing away of the vein matter, particularly when the gangue has been pyrite.

237. By Solution of the Valuable Material.—At the surface, where air and water are acting together, sulphides are oxidized to sulphates, and carried down in solution. When they reach the ground water, which keeps out the air, sulphides are formed again and deposited. The result of this in the case of copper pyrite is to leave a leached zone of *gossan* at the surface, reaching down to the level of the ground water. At or below the ground-water surface, the zone of enrichment may begin and continue as far down as the enrichment solutions have reached. Below this again the original ore will be found. Since most sulphides contain iron or are mixed with pyrite, the oxidation and leaching leave a residue of limonite, called *gossan* or *iron capping*. Whenever *gossan* is found, it is always a valuable indication to the prospector.

238. Mineral Associations.—There are a number of mineral groups occurring so commonly that it is useful to the prospector to carry their association in his memory. Here are some of the important ones:

Gold with quartz, with pyrite, with copper pyrites, with pyrrhotite, with zinc blende, with galena, with tellurides, with stibnite.

Silver with galena, with zinc blende, with cobalt and nickel minerals.

Galena and zinc blende.

Copper pyrites and pyrite.

Galena and barite.

Fluorspar, barite, and celestite.

Native copper with a group of silicates called *zeolites*.

Tinstone, wolframite, tourmaline, topaz.

ORE-FORMING EPOCHS

239. Relative Ages of Rock.—Doubtless mineral deposits began to form as soon as there was a solid crust, and the process has gone on up to the present; but the records of the rocks show that the concentration of ores into ore-bodies has been faster at some periods than at others. Valuable mineral deposits are found in rocks of every age, but there have been special periods of disturbance, such as mountain-building, folding, volcanic activities, and special conditions of sedimentation, during which ore deposition has been more active than in the intervals between these periods.

The **relative ages** of stratified rocks are determined by the order of the strata, the younger being above the older. Even where folding and erosion have made the succession less plain than it is when the strata are horizontal, careful study in the field, aided by chemical and microscopical analysis and the evidence of fossils, solves the problem.

The relative age of intrusive rocks is determined by evidence of various kinds. For example, an igneous rock must be younger than the youngest rock which it intrudes.

240. Times of Forming of Mineral Deposits.—In somewhat the same way, the time can be judged at which a mineral deposit has been formed. If it is a sedimentary deposit, its age is the same as that of the sedimentary rocks with which it lies. The time of formation of veins and other such ore-deposits, and of magmatic segregations, must be after the consolidation of the youngest rocks in which the deposits are found. For example, many of the fluorspar veins of the Madoc area occur in the youngest rocks of that district, sandstone and limestone of the Ordovician period; they were therefore formed after those rocks. The gold veins of Nova Scotia are in rocks of Cambrian (or possibly pre-Cambrian) age, and are therefore younger than those rocks. The veins of the Kirkland Lake gold area in Northern Ontario are associated with igneous rocks that intrude conglomerate and other sedimentary rocks, pre-Cambrian in age; this fixes a limit for the age of the veins.

241. Great periods of Ore Deposition.—When such evidence is studied throughout the rock record, the following great periods of ore-deposition in North America are made out (beginning with the oldest):

Pre-Cambrian—Iron, gold, silver, copper, nickel, cobalt.

Devonian—Gold, copper.

Cretaceous—Gold, copper, silver, lead, zinc.

Tertiary—Gold, silver, copper.

In Canada are valuable ore deposits which have been formed in each of these periods.

The gold, copper, and some of the iron ores of Nova Scotia, New Brunswick, and Eastern Quebec were deposited in the *Devonian*, at a time of intense folding, in connection with granite intrusions of that period; the intrusion to which we owe the asbestos field of Southern Quebec may belong to the same time. The zinc-lead veins of the Gaspé Peninsula were deposited in Devonian shale and limestone, intruded by porphyry and syenite.

To the *pre-Cambrian* times must be referred the deposition of the silver, gold, copper, and iron ores of Western Quebec, Ontario, and Manitoba. The silver-cobalt-nickel ores of the Cobalt and Thunder Bay districts were deposited in connection with intrusions of diabase. The copper-nickel ore of the Sudbury area is found at the contact of a great norite laccolith with pre-Cambrian granite, gneiss, etc. The gold veins of Northern Ontario are found closely associated with intrusions of granite rock. The great sedimentary deposits of low-grade silicious iron ores found in the Lake Superior region and in other parts of Ontario were laid down in this age. In British Columbia, there was a long period of igneous activity in late Jurassic and early Cretaceous times, the result of which was the great granitic intrusion of the Coast Range, around the edges of which, mostly in the Cretaceous sedimentary rocks, have been found valuable deposits of gold, copper, and silver ores. The silver-lead-zinc ores of the southern border districts are referred to the same period of activity.

Activity of a very different kind, vigorous plant growth, is responsible for the extensive carboniferous

coal beds of Nova Scotia and New Brunswick, and the equally important British Columbia and Alberta coal beds formed mostly in Cretaceous times. The lignite beds of British Columbia and Saskatchewan are partly of Cretaceous and partly of Tertiary age.

FAULTING OF ORE-BODIES

242. Definitions.—The complete study of faulting belongs to mining rather than to prospecting. But there are surface results of importance to the prospector. As explained in the Art. 178, faulting is due to the breaking of the rock under strain; there has been displacement at the same time, so that the two sides of the break do not fit. If the break crosses an ore-body the two parts of the ore-body no longer join.

A **fault** is a break or fracture with displacement of the rock along the fracture. The **strike** is the direction of the break, measured horizontally. The **dip** is the slope of the break, measured at right angles to the strike. The **hanging wall** is the upper wall of the fault. The **footwall** is the lower wall of the fault. A **strike-fault** has a strike parallel to that of the ore-body. A **dip-fault** has a strike about at right angles to the strike of the ore-body. An **oblique** fault has a direction between that of a strike fault and that of a dip fault. The **slip** is the distance between the broken ends of the ore-body, measured along the fault. When measured at right angles to the strike of the ore body as seen in the outcrops, it is called the **offset**. A **normal fault** is one in which the hanging wall side seems to have moved downwards. A **reverse fault** is one in which the hanging wall side seems to have been pushed up.

243. Direction of Movement.—The direction of movement can often be traced by *drag ore*, which has been drawn along the break, but drag ore is sometimes found in both directions from the end of a faulted ore-body, owing probably to more than one movement. *Grooves* or *striae* on the fault face are another indication of direction.

Breaks may be sudden, as when they cause earthquakes, or may take a long time. The ore-body may be curved at the break, and the curve then points in the direction of movement. This curving is probably caused by a very slow movement.

In studying the effects of faults on ore-bodies, surface appearances only are included here.

244. Strike Fault.—Fig. 128 represents a block of country rock supposed to be cut so as to show the vein not only at the surface VV_1 , but underground, $V_1V_2V_3$. Suppose a break takes place along FF_1 , and the right-hand part slips down. The ore body then shows as indicated by the black band (Fig. 129). If the country

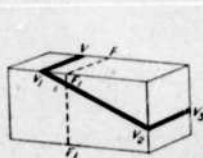


FIG. 128

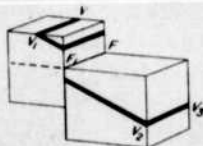


FIG. 129

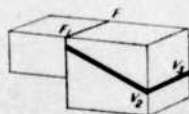


FIG. 130

Strike Fault

is then eroded to a level (Fig. 130), the ore body does not show on the surface, unless a little drag ore has been left along the break FF_1 .

245. Dip Fault.—Figs. 131, 132, and 133 show the result of a dip fault followed by erosion. The appearance of the vein at the surface is as if the country had moved horizontally, so as to separate the broken ends. This may sometimes have taken place, but the diagrams show how a downward movement of one side followed by erosion may cause the same appearance.

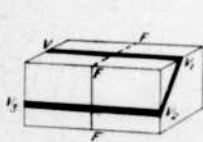


FIG. 131

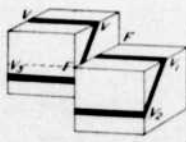
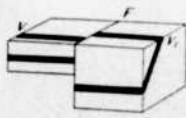
FIG. 132
Dip Fault

FIG. 133

METALLIC MINERAL DEPOSITS

GOLD AND PLATINUM

246. Placer Gold.—Placer deposits of gold are formed by the concentration of the gold from the debris of gold veins and other deposits of gold in rock. As the loose material is washed down hillsides into gullies and valleys, the gold, being six or seven times as heavy as quartz and other rock-minerals, quickly works its way to the bottom of the moving mass and stays there. The larger nuggets may lodge in crevices and behind ledges; but if the slope is steep, everything loose is moved forward until it reaches a gentler descent, which is apt to be the mouth of a gully where it joins the main valley. There the gold is deposited on bed rock or perhaps on

a hard clayey bottom. The pay streaks would be found along the gulch and at the junction with the larger valley.

Panning is the prospector's method in searching for placers; it is an art requiring practice. Though it cannot be learned from a book, a hint as to gold "colors" may be useful. Although the particles of gold are hammered so thin in their passage downwards that it may take one or two thousand of them to make the value of one cent, each of these small "colors" may be easily visible. So a good long "tail," making a brilliant show, might be worth only one twentieth or one fiftieth of a cent. But when the prospector attains skill in estimating the value of the "tail," panning becomes his best helper in hunting for gold in veins and placers.

247. Origin of Placers.—The important gold placers are the result of long periods of erosion. Changes of level may have drained away the original streams, or the streams may have worn down their beds, leaving the placers high up on *benches*. Changes of level sometimes lead to a further concentration of the gold by a stream that cuts down an old gravel deposit. This re-concentration, repeated again and again, accounts for some extraordinarily rich placers that have been found. It should be remembered that while this is going on, the rock material is being ground down, so that only the hardest survives in any quantity; this is commonly quartz and quartzite.

Sorting by wave-action has sometimes formed gold placers, such as the beach placers at Nome, Alaska, where the prospector had a good guide in another heavy

mineral, red garnet, concentrated along with the gold, and showing very conspicuously.

Placer gold may often be followed back to its source in the rocks, and this sometimes leads to valuable discoveries. Small placers sometimes occur near gold veins, having been formed by recent weathering in a glaciated country like Ontario. They should be looked upon as surface enrichments, which here moved a short distance from their source, and as not likely to be of much extent or value. But there may be places where it would pay to work these recent placers in a small way.

248. Minerals Associated with Gold.—Heavy hard minerals that concentrate with the gold are often a guide. The commonest are magnetite and ilmenite (or "black sand"), garnet (or "ruby sand"), zircon (or "white sand"), and monazite (or "yellow sand"). Tinstone is often found in gold placers, and may be a valuable by-product. Platinum (gray) and osmiridium (silvery) should not be overlooked; they are more valuable than gold.

249. Occurrence of Placers.—It is a good rule to look for gold veins in placer regions; but the prospector should remember that valuable placers may have been formed from deposits too lean to work, and also that erosion may have completely removed the vein. On the other hand, some first rate gold ore has its metal so finely divided that it does not concentrate, but washes away. Such ore, when set free by erosion, would not form a placer.

In glaciated regions, placers may have been scattered by the ice-action; or, as at Cedar Creek, B.C., the placer

may have been left undisturbed, but covered with glacial gravel. In the Cariboo district this covering is so deep in some parts that valuable placers long escaped discovery. While the time since the close of the glacial period has been too short for the formation of important placers by erosion, some payable placers have been formed by re-sorting of the gravels that have been scattered by the glaciers.

Gold placers have sometimes been buried by lava flows, as in Australia and California. In gold districts, the beds and valleys of streams that have cut down through lava flows of the later geological eras should be carefully examined.

250. Gold in Conglomerate.—As might be expected, *conglomerate* occasionally contains gold nuggets, representing old placers; this is a suggested explanation of the South African gold fields; but the gold may have been deposited by circulating solutions, after consolidation of the conglomerate. An interesting case of an old placer now converted into conglomerate is found in the Black Hills, South Dakota, where basal conglomerate of the Cambrian age lies *unconformably* on pre-Cambrian schists and gold-bearing quartz veins, the erosion of which supplied the material for the ancient placer. In some places, this conglomerate has the rounded grains of gold that are characteristic of placers. Several paying mines have been worked in this rock.

251. Gold Veins and Other Gold Deposits.—Nearly all workable gold deposits (except placers) are veins, lodes, shear zones, stock works, saddle reefs, and replacement ore-bodies, which are connected with intrusions of

granite, syenite, diorite, and other igneous rocks of an acid or intermediate variety.

252. Country Rocks.—Gold deposits are found in a great variety of rocks; but, as might be expected from the close connection with igneous intrusions, the most favorable rocks are of the metamorphic kind, particularly mica schist, quartzite, and slate. Limestone is not as favorable; but some of the B. C. copper-gold deposits are in limestone

252. Gold in Ontario.—In Ontario gold has been found with mispickel in quartz veins in schists near intrusive granite (Deloro); with pyrite, bismuthinite, and magnetite in quartz veins in crystalline limestone (Frontenac); with pyrite, pyrrhotite, copper pyrites and galena, in quartz veins in a zone of chlorite schist in a mass of gabbro, which is cut by many granite dikes (Belmont); with pyrite, copper pyrites, and galena, in quartz veins in an altered sheared granite, *protogine* (Mine Centre); with pyrite in quartz lenses in gneiss (Sultana, Lake of the Woods); in veins in schist near intrusive masses of granite (various parts of Western Ontario); with pyrite, copper pyrites, bismuthinite, and molybdenite in a quartz vein cutting through a granite intrusion in trap, the trap being largely altered to schist (Mikado, Lake of the Woods); with pyrite, copper pyrites, zinc blende, galena, scheelite, graphite, calcite, dolomite, sericite, and chlorite in a system of quartz veins roughly parallel, in grey sericite schist near intrusive quartz porphyry (Hollinger, Poreupine); with pyrite, copper pyrites, molybdenite, graphite, tellurides, calcite, ankerite, chlorite, and sericite, in shattered

quartz veins and feldspar-porphyry in Timiskaming conglomerate and graywacke, and in feldspar-porphyry, near intrusions of lamprophyre, granite, and porphyry (Tough-Oakes, Kirkland Lake); with pyrite, ankerite, feldspar and sericite, in zones of porphyry and schist (altered basalt) traversed by small veins and veinlets of quartz (Matachewan Gold Mines); with pyrite, copper pyrites, zinc blende, tourmaline, bornite, and pyrrhotite in quartz veins in volcanic flows near granite and porphyry intrusions (Goudreau Gold Mines); with pyrite, copper pyrites, pyrrhotite, galena, mispickel, tellurides, and talc, in quartz veins cutting porphyritic syenite and chlorite schist near intrusive granite (McKellar-Longworth, Schreiber). The producing gold mines of Ontario are in Timiskaming and Keewatin formations, near intrusions of granite, syenite and porphyry. It is believed that the best field of prospecting is around the smaller bodies of granite, etc., which show more or less of the porphyry texture.

254. Gold in Quebec, Nova Scotia, and Manitoba.—

Quebec has been very little prospected for gold of late years. Northern Quebec, where it borders on Ontario, has the same general geology as that part of Ontario, and it should give results, if carefully prospected. Several promising discoveries have already been made in Rouyn and adjoining townships. Geological surveys have shown the existence of a belt of sedimentary rocks of the same age as the Timiskaming in Ontario. The discoveries have been made where these rocks are intruded by Algonian granite, or near such intrusions. The belt is about 120 miles long, and is apparently a continuation

of that in which the Kirkland Lake area lies. In the Hurricana district, gold has been found with pyrite, copper pyrites, zinc blende, galena, stibnite, scheelite, and tourmaline (abundant), in quartz veins in grano-diorite, quartz porphyry, green schist, and syenite. The quartz is shattered, and the gold values are deposited in the cracks.

In Nova Scotia, the ore is in saddle reefs, in anticlines of folded quartzite and slate at places where cross-folds cause a dome shape.

In Manitoba, gold deposits have been found in Keewatin greenstone, schist, and volcanic rocks near granite intrusions.

255. Gold in British Columbia.—In British Columbia, the gold veins occur in replacement deposits at or near contact of metamorphic with dioritic igneous rocks, the gangue being garnet, epidote, calcite, etc., and the "minerals" mispickel, pyrite and copper pyrites (Hedley); in quartz fissure veins in *phyllite*, (a rock intermediate between slate and mica schist,) (Lardeau); in quartz veins and schisted diabase (Poplar Creek); with copper ores in large replacement deposits in tuff and limestone near grano-diorite (granite-diorite) and syenite (Boundary); with copper ores in veins or replacement deposits in a porphyritic rock (augite-porphyrity) near bodies of grano-diorite and syenite (Rossland); with copper ores in shear zones at or near contact of *monzonite*, (a rock intermediate, between diorite and syenite) with sedimentary rocks (Princeton); with copper ores in mineralized zones in quartz-sericite schist (Britannia mine, Howe Sound); with copper ore in lenses in schist

(Vancouver Island); with copper ore in replacement deposits in limestone near granite contact (Texada Island); with pyrite, limonite, native antimony, and tellurides in quartz veins cutting shale, slate, and graywacke of brown and greenish colors (Engineer mine, Atlin); with pyrite, copper pyrites, zinc blende, galena, tetrahedrite, native silver, argentite, etc., in quartz veins and wall rock replacements at contact between quartz porphyry and andesite tuff, and partly in the quartz porphyry, gold and silver values being about equal (Premier mine, Cassiar).

256. Alterations in Rocks.—The neighborhood of igneous intrusive rocks is characteristic of all the deposits above mentioned. The country rocks near the ore deposits are usually altered in a noticeable way which must be studied in each district. Some of the changes are schisting, fracturing, rusty appearance from weathering of disseminated pyrite, bleaching of dark rocks, the occurrence of calcite and other carbonates, and the appearance of minerals characteristic of contact metamorphism, such as garnet and epidote. Of these appearances, probably schisting and extensive mineralization with pyrite, or the rusty capping resulting from its weathering, are the most useful guides to the prospector.

257. Mineralization.—The commonest mineral is pyrite. In Ontario, where banded iron formation is so common, prospectors may be led to waste time over the siliceous bands, often highly mineralized with pyrite, but usually barren of gold. Still, gold has been found in a banded iron formation that has been much folded

and shattered, the gold being in veinlets of secondary quartz. Copper pyrites is next in importance as a mineralization; and, as it is of value in itself, where it is plentiful, it should be assayed for both copper and gold. However, much copper pyrites in a gold ore causes difficulties in extraction with cyanide. Other minerals found in gold deposits are galena, zinc blende, mispickel, stibnite, bismuthinite, and the sulphur-arsenic and sulphur-antimony compounds of lead and copper; also molybdenite, and pyrrhotite. In some districts, tellurides are the mineralizers, and gold tellurides may be the chief or even the only gold minerals. All soft minerals of metallic luster, and of a silvery or lead-gray or yellow color, should be tested. The manganese minerals rhodochrosite and rhodonite are "signs" in some telluride districts. The quartz is apt to be fine-grained ("hornstone"), and not milky or glassy. The weathering of gold tellurides leaves the gold as a brown powder; if this be rubbed hard, it shows the yellow color of gold.

258. Panning.—(See Art. 246). In panning vein matter for gold, the mortar and pestle are indispensable, as the sample must be well ground up before being panned, and every grain must go into the pan. As the gold in some deposits is so locked up in pyrite and other minerals that it does not separate in the pan, a sample should first be roasted (this can be done on a shovel) and ground before being panned. The sand and gravel of rivers that have crossed gold fields may pan gold, and, in this way, give an indication for prospecting upstream.

259. Platinum.—The high value and usefulness of the platinum family of metals suggests a careful search

for new sources. Small quantities are produced from gold placers and as a by-product in the refining of the copper from the ores of the Sudbury District; but the main supply still comes from the placers of the Ural Mts., Russia, and South America (Columbia and Brazil). In those countries, it has also been found in place, associated with chromite in serpentine and peridotite rocks. Some large masses of platinum have been found, one weighing 23 lbs. It should be looked for in serpentine, wherever the rock is mineralized, and particularly where chromite is found. Olivine gabbro should also be sampled and assayed. As platinum is very heavy ($G = 15$ to 19), it will easily show in panning.

SILVER, LEAD, AND ZINC

260. Silver.—The silver production of Canada is mostly from two classes of deposits: (1) those of the Cobalt district where the silver is largely native and associated with cobalt and nickel arsenides; and (2) the silver-lead deposits of British Columbia. Silver is likewise produced in considerable quantities in British Columbia from certain gold and copper ores; and some mines, like the Dolly Varden, are essentially silver ore deposits, with very little galena and zinc blende.

261. Silver in Ontario.—In Ontario, silver ores have been found in veins in pre-Cambrian sedimentary rocks and Keewatin greenstone, intruded by diabase sills and dikes; silver veins are found also in the diabase. The vein matter in the Cobalt area is mostly calcite, and the silver minerals (native, argentine, dyscrasite.

and others) are usually associated with cobalt-nickel minerals, of which smaltite and niccolite are the commonest. In South Lorrain, there are ore shoots that are evidently the result of pre-glacial enrichment. The Elk Lake and Gowganda silver veins are in the same formation as those of the Cobalt area. In the Port Arthur region, the veins are similar to those of the Cobalt area, but quartz is more plentiful as a gangue mineral. It is possible that other areas of this kind may be discovered in Ontario. The prospector in the Cobalt country found the pink "bloom," *erythrite*, a valuable guide, but sometimes disappointing, as several smaltite veins were found that were barren of silver. Cobalt minerals in small quantities are not uncommon in other districts where no silver is found and the bloom is very conspicuous. Diabase intrusions are numerous in the pre-Cambrian rocks of Ontario, Quebec, and Manitoba. Silver should be searched for in areas where the intruded rocks are of the Cobalt (Animikie) series.

262. Silver in British Columbia.— The most important sources of silver in this province are the silver bearing galena deposits, which contain more or less zinc blende and other sulphides. The separation of zinc from lead with the recovery of the silver has been a serious problem in the case of ores high in zinc; but such ores can be treated by modern processes. In prospecting for these ores, it should be remembered that pyrite is a common associate; on weathering, it will leave a rusty capping (limonite). Zinc blende high in iron also leaves a rusty mass on weathering, but the color may be somewhat reddish. Galena is most likely to weather to cerussite or

anglesite, both of which are white, but may be gray at the surface. Thus, the St. Eugene Mine, Moyie, is in a fissure zone consisting of two main fissures roughly parallel, connected by cross veins, which usually join the main veins at a small angle. The best ore bodies are found at the junctions. The vein minerals are coarse-grained galena, zinc blende, pyrite, pyrrhotite, magnetite, and a little copper pyrites. The gangue minerals are pink garnet, actinolite, quartz, and calcite. The sulphides fill the cracks in and between the other minerals, and there is a rusty capping, sometimes several feet deep. The country rock is pre-Cambrian quartzite. At the Slocan Star, silver-bearing galena, zinc blende, tetrahedrite, copper pyrites, pyrite, mispickel, argentite, native silver, and gold occur in a fissure vein, with quartz, siderite, calcite, and barite as gangue. In the Slocan district, the country rock is slate, intruded by dikes of granite, quartz porphyry, and lamprophyre. Silver lead deposits are found in sheared zones in crystalline limestone on the east side of Kootenay Lake. At the Dolly Varden Mine, Alice Arm, native silver, argentite, ruby silver, etc. occur with pyrite in quartz veins in gray and green volcanic breccia, near the edge of the great Coast Range batholith of *grano-diorite* (granite with the kind of feldspar characteristic of diorite). The ore is believed to be the result of surface enrichment, as very coarse native silver was found at the surface, and wire silver and thin sheet silver at greater depths. In the Moose and some other properties in this district, the silver value is in galena and tetrahedrite, and is therefore more likely to persist in depth. So far, all the veins in this district have been found in green and

gray breccia; purple and red breccia seems to be barren. Surface enrichment is irregular, so that a discovery should be examined as completely as possible by stripping.

263. Silver in Yukon Territory.—The great granodiorite batholith extends northward into the Yukon, and, as was expected, ore deposits have been found around its edges in that territory. In the Keno Hill area are two systems of fissure veins of quartz, mineralized with mispickel, galena, zinc blende, manganese, and a silver mineral not identified. The veins cut through schists and quartzite (probably pre-Cambrian) which are intruded by quartz porphyry and granite porphyry. The principal ore shoots are in the transverse veins that cut across the great fault, and especially at the junctions. The galena is high in silver. The veins are easy to locate by galena, manganese, and iron float, usually not far removed from the veins.

264. Lead and Zinc.—Lead and zinc ores are found so often mixed that they are described together. In addition to galena and zinc blende, pyrite is generally present and often in considerable quantities, and copper pyrites is generally present. By weathering, the latter may leave green and blue stains. The ore deposits are of two principal kinds:

(a) *Veins and replacement deposits near igneous intrusions.* These are discussed under Silver, Arts. 261-263, as they are quite generally silver-bearing and sometimes very rich in that metal.

(b) *Deposits in sedimentary rocks* not intruded by igneous rocks; these are usually not silver-bearing. The deposits are found mostly in limestone and dolomite,

also in chert (derived from limestone) and in limey shale. The ore bodies are in brecciated zones, in crevices (gash veins) or joints enlarged by the dissolving action of water; sometimes scattered in limestone or dolomite along certain lines of stratification; in Ontario and Quebec, they occur frequently in fissure veins, which should be found to persist in depth. The others are shallow deposits.

265. Ore Minerals of Lead and Zinc.—The principal ore minerals are galena and zinc blende, but there may be considerable quantities of cerussite, anglesite, calamine, and smithsonite in the zone of oxidation. Pyrite is usually present, and marcasite nearly always. The rusty weathering of these two minerals may have left an iron cap. The zinc blende weathering is apt to be low in iron and of a light brown, red, or yellow color.

Galena is a conspicuous mineral, usually very easily "spotted", although occasionally so fine-grained as to appear steel-black ("steel galena") instead of lead-gray. The carbonate (cerussite) and sulphate (anglesite) are sometimes found in quantity, as a result of oxidation of galena. Zinc blende weathers easily, and if high in iron, leaves a rusty capping.

266. Lead-Zinc Deposits near Igneous Intrusions.—Examples of the British Columbia and Yukon lead-zinc ore deposits, all of the kind near igneous intrusions, are described in Arts. 261-263. The high-temperature minerals, garnet, epidote, pyroxene biotite, and pyrrhotite are found in some but not all of these deposits, and the silver and gold values are sometimes great enough to put the ore in the precious metals class. The

deposits are fissure veins, contact replacement bodies, or sheared and brecciated mineralized zones; they are of a kind that has a good chance of continuing as the depth increases.

267. In Ontario.—Dark colored zinc blende, with pyrite, pyrrhotite, copper pyrites, and a little native copper, irregular lenses in much altered and schisted diorite, is found at Zenith Zinc Mine, Rosspoint. At Zinc Prospect, near Ruel, occurs a fine-grained mixture of galena and zinc blende with pyrrhotite and copper pyrites in mineralized zones in greenstone and iron formation. Pyrrhotite was first discovered, the galena and zinc blende being found later, as the depth of sinking increased. In Barrie Tp., Frontenac Co., is found galena, zinc blende, pyrite, and copper pyrites with quartz and calcite in stringers and lenses, running with the strike of the country rock, which is crystalline limestone and mica schist. The galena is high in silver; the ore bodies are near granite intrusions. At McKinnon Vein, Steep-rock Lake, Atikokan, occurs silver-bearing galena and zinc blende, with pyrite and copper pyrites, in a vein of white, sugary quartz, near contact of greenstone schist with granite. At Victoria Mine, Garden River, Algoma, galena with zinc blende, pyrite, and copper pyrites in stringers, grains, and small bunches, is found in green schist; the ore carries gold and silver.

268. In Quebec.—At Notre-Dame-des-Anges, Portneuf Co., zinc blende is found with galena, pyrite, pyrrhotite, and copper pyrites, in gash veins in mineralized zones running with the strike of the rocks, in micaceous quartzite and crystalline limestone; garnet, biotite, pyroxene,

hornblende, and quartz are the gangue minerals. The ore carries silver and gold. The ore bodies are near igneous intrusions of pyroxenite. At Calumet Island, Ottawa River, zinc blende and silver-bearing galena is found with pyrite, copper pyrites, magnetite, pyrrhotite, and occasionally native silver, in mineralized zones that have gash veins running with the strike of the quartzite, crystalline limestone, and gneiss, which form the country rock. The lenses pinch out and take up again both along the surface and vertically. The gangue minerals are quartz, calcite, garnet, etc. There are intrusions of granite and gabbro in the crystalline limestone not far from the ore deposits. Near the ore-zones the quartzite is sericitic. In Lemieux Township, Gaspé Peninsula, zinc blende and galena with a little pyrite, marcasite, and copper pyrites, occur in veins and crushed zones cutting across the strike of shale and limestone, which is folded, faulted, jointed, and brecciated, and which has been intruded by porphyry and syenite. Gangue minerals are quartz (both white and amethystine), dolomite, ankerite, and calcite. At the surface, there is, in some places, a white coating of zinc silicate (calamine), and zinc carbonate, formed by weathering of zinc blende. Discoveries have been made by finding pieces of float galena, sometimes weathered to a rounded brownish mass, and trenching up-hill from these finds. The vein-outcrops usually show only white or brownish quartz, from which the zinc blende and most if not all of the galena have been weathered out, leaving the quartz in a cellular condition. Where galena has been left in the quartz, it may have a reddish-brown coating.

269. Lead-Zinc Deposits Independent of Igneous Intrusions.—These are well-defined fissure veins of galena and zinc blende in a gangue of calcite with pyrite, marcasite, and copper pyrites. Quartz is usually not plentiful, and the silver values are low. Barite and fluorspar are sometimes abundant. The veins are in faults and brecciated zones, cutting across the strike of the country rock. As the fault fissures are often of considerable length, these veins may in some cases persist in depth. The presence of fluorspar in some of them suggests the influence of igneous intrusions and also a probability of depth. Found in Ontario and Quebec.

270. In Ontario: The Frontenac Lead Mine is a fissure vein in gneiss. The vein is filled with calcite through which galena is scattered, with smaller amounts of zinc blende and pyrite. The country rock is gneiss and crystalline limestone. The Galetta Lead Mine on Chats Island, Ottawa River, is a fissure vein in a fault that broke through the flat-lying limestone of the district. The country rock is limestone and gneiss. The gangue is mostly calcite, with some barite. Galena is scattered through the calcite with small quantities of zinc blende and pyrite. A large number of lead veins of this kind are known in Eastern Ontario, all low in silver, and most of them with very little zinc blende; they are found in limestone country.

271. In Quebec: In Hull Township, Ottawa, Co., in Buckingham Township, Labelle Co., at Baie St. Paul, and at the east end of the Gaspé Peninsula are lead

veins in limestone, the gangue being calcite, barite and fluorspar.

MERCURY, ANTIMONY, AND ARSENIC

272. Mercury.—The principal ore of mercury is cinnabar, HgS , known by its bright red color (vermilion-red when powdered), its great weight, and its softness. Cinnabar is found in irregular veins, breccia zones, stockworks, and disseminations in rocks of all kinds and ages in regions of present or past volcanic activity; the deposits are often near hot springs. The valuable deposits of cinnabar have been found along lines of great disturbance, such as extensive mountain ranges. This mineral has been mined in Canada near Kamloops Lake, B. C. where it is found in irregular veins in lava flows, and also disseminated in sandstone.

The accompanying minerals are pyrite (sometimes marcasite), and stibnite, but not often any of the other common sulphides. The gangue is usually quartz, especially the opal and chalcedony varieties, calcite, and dolomite.

Mercury is found in small quantities in the silver ores of Cobalt and Silver Islet, Ontario.

273. Antimony.—The principal ore of antimony is stibnite, Sb_2S_3 , which is found in commercial quantities in veins, with a quartz gangue. Stibnite veins are found in connection with igneous intrusions in gold regions, and may carry paying quantities of gold; they are also found in shale and sandstone. Replacement deposits in limestone and shale are frequent.

When well crystallized, the stibnite is easily recognized by its lead-gray color, its softness, and its bright cleavage surfaces in streaks. At the surface, the ore may be weathered to oxides of yellowish or white color, which may however be hidden by rusty weathering products of pyrite.

274. Arsenic.—Most of the white arsenic (As_2O_3) of commerce is obtained as a by-product from ores of silver, cobalt, nickel, gold, and copper. But *mispickel* (FeSAs) is sometimes found in veins, with quartz gangue, in sufficient quantity to be a paying proposition for arsenic alone. The mineral is easily recognized by its great weight, its bright silvery or lead-gray color, its hardness, and the smell of garlic when the mineral strikes fire with steel.

COPPER, NICKEL, AND COBALT

275. Copper.—Copper ores are found in a great variety of formations. *Native copper* occurs in trap, particularly the amygdaloidal variety; it is deposited in the amygdules and in veinlets and joints. At the surface, the copper may show its presence by the green and blue stains of the carbonates, malachite and azurite.

The neighborhood of intrusive basic rocks is favorable for copper ore deposits, which may be found at or near the contacts as replacement deposits or mineralized zones. In the eastern townships of Quebec, the sulphides, copper pyrites, bornite, and chalcocite, are found in lenses in schistose porphyry and andesite, the lenses following the strike and dip of the schist. Other irreg-

ular ore bodies are found in limestone, where it is in contact with intrusive diabase. In the Parry Sound District, Ontario, bornite, chalcocite, and copper pyrites are found in disseminated zones in schistose diorite and garnetiferous gneiss. Copper pyrites and bornite in veins of quartz and dolomite are characteristic of the Bruce Mines district, Ontario. In Nova Scotia and New Brunswick, chalcocite is found in nodules in sandstone. In British Columbia, most of the important copper ore deposits are of the contact kind, and are found where sedimentary rocks (limestone and tuff) are metamorphosed by igneous intrusions. The presence of garnet and magnetite in the ore zone shows the influence of heat.

Copper pyrites and bornite contain iron; on weathering, they leave limonite as an insoluble product, of a rusty color. The conspicuous green carbonate, malachite, is another weathering product, and also the less common, blue carbonate, azurite. Since the sulphides of copper weather more quickly than iron pyrites, and since all these sulphides are apt to occur together, any rusty capping should be carefully examined, even though at first nothing but iron pyrites is found beneath it; the copper minerals may come in at greater depth. A large, lean copper deposit, which would not pay to work for copper alone, may carry enough gold and silver to make it of value.

276. Nickel and Cobalt.—The arsenical ores of nickel and cobalt are referred to under Silver, Art. 260; but it should not be forgotten that such ores occur barren of silver. To be workable for the cobalt, nickel, and ar-

senic contents, the veins would have to be larger than the great majority of the silver veins of the Cobalt area.

The most plentiful nickel ore at present known is that of the Sudbury area, Ontario. It is a mixture of pyrrhotite and copper pyrites, with smaller quantities of pentlandite (a sulphide of nickel and iron) and polydymite (a sulphide of nickel). The pyrrhotite itself is believed to carry part of the nickel content of the ore, which averages about 3.5 per cent. In addition, the ore carries about 1.5 per cent. copper as copper pyrites. The ore bodies are found at the contact of a great norite laccolith with granite. The prospector's guide has been the gossan or iron cap, left by the easily weathered minerals. Attempts have been made to discover pyrrhotite ore bodies by means of the magnetometer, pyrrhotite being magnetic; but since the magnetic attraction of pyrrhotite varies, and since magnetite may be present in granite and other igneous rocks in sufficient quantity to cause considerable attraction, these attempts have been only partially successful. The large ore body at Levaek was found in this way. As the majority of pyrrhotite deposits outside of the Sudbury area do not carry a paying quantity of nickel, an assay should always be made before any newly discovered pyrrhotite is looked upon as nickel ore. The Alexo nickel ore deposit, in the Timiskaming District, Ontario, is a body of pyrrhotite, carrying 6 to 8 per cent nickel; it is at a contact between pillow lava and serpentine. It is possible that other ores, the green silicates, garnierite, genthite, etc., may be found in serpentine or peridotite.

IRON

277. Iron Ores.—The iron minerals that are at present used as ores are hematite, magnetite, limonite, and siderite; also, occasionally, ankerite, göthite, and turgite. Hematite is the most important iron ore.

The iron content of the pure minerals is as follows:—

<i>Mineral</i>	<i>Formula</i>	<i>% of Iron</i>
Hematite	Fe_2O_3	70.0
Magnetite	Fe_3O_4	72.4
Limonite	$2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	59.8
Siderite	FeCO_3	48.2

Ankerite is a carbonate of lime, magnesia, manganese, and iron. It is of variable composition, carries only 14 or 15% of iron, and is used more for its lime and magnesia as a flux than for its iron content. *Göthite* and *turgite* come between hematite and limonite in composition, and are found with both, but are comparatively rare.

Iron ores cannot be profitably mined unless they occur in large bodies. The discovery of a few thousand tons or a vein-like body four or five feet wide is usually unimportant. To be worth while, the tonnage must be counted in hundreds of thousands or, better, in millions of tons.

278. Impurities in Iron Ores.—There are certain *impurities* that lower the value of iron ores or may even make them valueless. Sulphur in the ore goes partly into the iron and steel and makes them brittle. While it is possible by roasting the ore and by other means to remove the sulphur, the presence of any considerable

amount is objectionable. Phosphorus in steel makes it brittle. For steel-making the limit for phosphorus is one hundredth of one per cent for ten per cent of iron in the ore; this is the so-called **Bessemer limit**. A Bessemer ore carrying 52% of iron must not have more than .052% of phosphorus and the sulphur should not exceed .04%. But since the presence of phosphorus in pig iron increases the fluidity and tends to make sound castings, ores high in phosphorus are used in making foundry pig iron. Titanium is objected to by users of iron ores, because it is said to make a pasty slag and to interfere in other ways with the safe running of the blast furnace. At present, ores containing more than 5% or 6% of titanic acid (TiO_2) are not saleable.

The per cent of iron in the ore as mined must be not less than 50%, if it is to be used without being first improved (beneficiated) by cobbing, washing, calcining, or magnetic concentration. Leaner ore is found in very large quantities; and in a favorable situation, it may be workable by some concentrating process.

279. Hematite is sometimes found in vein-like deposits which are not usually large enough to be important. Such ore-bodies have been found near Kitchener, B. C. and in the Matachewan area, Ontario. Deposits of considerable size have been found at the contacts of igneous intrusions, generally basic, with crystalline limestone, dolomite, and limey shale; the ore is usually of the specular variety, and it is apt to be partly magnetite. The most important hematite deposits are of a sedimentary origin, the ore forming beds in stratified rocks. The hematite beds of the Wabana Mines, Newfoundland,

extend for miles under the ocean. They are found in sandstone and shale of Ordovician age. In Nova Scotia, smaller deposits have been found in Devonian and Silurian stratified rocks. The hematite deposits of the Lake Superior region are of sedimentary origin, but the rich ores have undergone natural concentration from the lean ores of the iron formations. These formations are wide spread in eastern Canada and the United States; but in only a very small part of the known areas (about 2% in the U. S. A.) have merchantable ores been discovered.

280. Iron Formations.—Iron formation consists of iron ore such as siderite, magnetite, and hematite, with silica in the form of chert, jasper, etc., generally in bands, but sometimes not distinctly so. The bands of iron ore are at times high-grade, but are often mixed with a good deal of silica, the whole making an ore too lean for use without concentration. Iron formation is believed to be of sedimentary origin. In Ontario three epochs of deposition are known: (a) Keewatin-Grenville, as in the Michipicoten and Moose Mountain areas; (b) *Timiskamian*, as in the Porcupine area; and (c) *Animikean*, as in the Thunder Bay area.

There are some expressions in common use in discussing these formations which it will be well to define:

Jaspilite, iron formation with the quartz layers colored red (jasper) and the rock crystalline, due to metamorphism.

Ferruginous chert, chert and ore in bands irregularly mixed of a dark gray, greenish or reddish color, not plainly crystalline.

Greenalite, a hydrated silicate of iron of a green color.

Taconite, another name for ferruginous chert.

281. Origin of Iron Ore-Bodies.—The ore-bodies, consisting of hematite and limonite, with sometimes a little magnetite, have been formed by two distinct processes: (a) the weathering of siderite into limonite and hematite, as at the Helen Mine, Michipicoten area; (b) The leaching out of the silica, leaving the concentrated ore in place, as in the Mesabi and other Minnesota ranges.

Only one deposit of the second kind has so far been found in Ontario, that at Loon Lake, east of Port Arthur. In the United States, they have been found mostly in hilly regions and toward the bottom of the slopes. Another common condition is a tight trough, or basin, formed by the iron formation, and an intruding dike. Important ore-bodies have been found that were completely without, or almost without, outcrop, in some cases being covered by slate. The hematite is sometimes mixed with enough magnetite to make possible a discovery by means of a magnetic survey. It is quite possible that somewhere in the large areas of the Ontario iron formation, the right conditions existed for enrichment. A great many of the valuable ore-bodies now being mined in the United States have been discovered without the aid of outcrops, the ore having been located by the magnetic needle and diamond drilling.

All varieties of hematite become red or reddish-brown when powdered. Outcrops can be easily "spotted" by striking with a pick or scratching with a knife.

282. Magnetite.—Magnetite is found in three kinds of deposits:

(a) Those formed by *magmatic segregation*; these are to be looked for in areas of syenite-porphyry, gabbro, anorthosite, and diorite. Deposits of this class are apt to be high in phosphorus, owing to the presence of apatite. Titaniferous magnetite is found as concentrations from gabbro and anorthosite, sometimes in vein-like bodies, often in irregular masses.

(b) *Contact deposits* of magnetite are to be looked for at the contacts of igneous rocks of the intermediate kind (diorite, etc.,) or the basic kind (diabase, etc.,), with crystalline limestone, dolomite, or limey shale. The ore bodies are usually irregular and not very large. They are apt to be high in sulphur, from the presence of pyrite and copper pyrites. Garnet, epidote, pyroxene, and apatite are found in the wall rock as well as in the ore.

(c) *Sedimentary deposits* are represented by the lean siliceous ore of the iron formation, as at Moose Mountain and Temagami, Ontario, and by magnetic black sand; both of these may prove to be important. They can be concentrated magnetically, and this is being done in Minnesota with an ore carrying only 25% of iron.

Magnetite is easily spotted by its weight, hardness, black powder, and attraction for the magnet.

283. Limonite.—Limonite, or brown ore, is to be found at the bottom of some bogs and shallow lakes, in favorable situations, where the weathering rocks have yielded iron to the water draining into these basins. The limonite accumulates so fast in some places that a

lake bottom can be cropped every seven or eight years, as at Radnor Forges, Quebec. Considerable deposits of limonite have been found in places where there is no standing water at present. The Helen Mine ore was largely brown ore. Limonite is sometimes formed in large quantities by the weathering of the sulphides of iron; such gossan has occasionally been used as an iron ore. At Bannockburn, in the Madoc area, a pyrite deposit was discovered below the limonite, which was being mined as iron ore; this gossan capping of the pyrite was from eight to fifteen feet deep.

Limonite varies a great deal in its appearance. In color, it may be light rusty, brown, dark brown, or even black on a fresh fracture. It is sometimes in round grains (shot ore), or in porous round lumps or flat cakes. When ground fine, it forms a yellow powder.

284. Siderite.—Siderite, or **spathic iron ore**, is usually gray or white; but at the surface it weathers to limonite, and the weathering may extend to a considerable depth. A rusty capping may cover a deposit of siderite. Where the ore forms the face of a cliff, the limonite may wash away as fast as it forms, leaving the siderite clean. The ore is found in vast quantities in the iron formation of the Michipicoten District, Ontario; the quantity around the Helen Mine is estimated at not less than 100 million tons; the ore is high in sulphur, owing to the presence of pyrite, and requires to be roasted.

METALS USED IN STEEL ALLOYS

285. Titanium.—The ores of titanium are rutile (TiO_2), and ilmenite (FeTiO_3).

Rutile has been found in quantity in gabbro-pegmatite along with apatite; also with ilmenite in anorthosite. The red or reddish-brown crystals (Fig. 39) of rutile are not likely to be overlooked; it is used mostly in electrodes of arc lamps. The market price for rutile is 10 cents a pound (1923).

Ilmenite, often called titanite iron ore, although not used as an ore of iron, is found in gabbro and anorthosite, usually mixed with magnetite, which it very much resembles in appearance. But pure ilmenite is non-magnetic or only slightly magnetic. It contains over 52% titanite acid (TiO_2), and the market price (1923) is one cent a pound. An ilmenite-magnetite containing 40% or upwards of TiO_2 is saleable. Deposits of pure ilmenite are not common; but there are very large quantities of the ilmenite-magnetite mixture in Quebec, Ontario and Alberta. Sometimes the percentage of titanite acid is high, on account of the presence of rutile. Every discovery of titanite iron ore should be assayed for titanium; it may be high enough to use as an ore of titanium. For uses, see Art. 61.

286. Manganese.—Manganese, like iron, is present in all rocks, but not so plentifully as iron. In the weathering process, manganese is more easily dissolved than iron; but, on the other hand, the iron is more easily precipitated from the solution. These differences account for the separation of manganese ores from iron ores in sedimentary deposits. Nearly all manganese deposits of importance have been formed by sedimentation, or through enrichment by leaching (*residual deposits*).

The principal ores of manganese are:

Pyrolusite	MnO_2	63.2% manganese
Psilomelane	MnO_2 , etc.	49 to 62% manganese
Wad	MnO_2 , etc.	varies.

Less common ores are braunite containing about 70% manganese, manganite ($\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$) with 62%, and rhodochrosite (MnCO_3) with 48%. Rhodonite, (MnSiO_3), is sometimes found mixed with other manganese ores.

Bog Manganese (also called *wad*) is of variable composition. It is like bog iron, but is darker, often quite black. As it is much more valuable than bog iron, any black, earthy, or glossy, fairly heavy mineral, should be assayed for manganese.

Pyrolusite may be found as a surface deposit. The greatest known manganese deposit, in Trans-Caucasia, consists of layers of pyrolusite in clay, marl, and sandstone. In Nova Scotia and New Brunswick, it has been found in veins, pockets, and large masses in limestone. In Nova Scotia, it occurs along with manganite and psilomelane in veins in granite. Workable deposits have been found in and above slate.

Psilomelane often accompanies pyrolusite, from which it can be distinguished by its greater hardness. In prospecting in regions where there are sedimentary rocks, particularly limestone, these minerals, of a black or dark brown color, should be looked for on the surface. To be merchantable, a manganese ore must carry at least 40% of manganese; but iron ores high in manganese may sometimes be profitably mined as manganese ores, even when the manganese content is much less.

287. Chromium.—The only important ore of chromium is chromite or chrome iron ore, FeCr_2O_4 . It is found in peridotite and in serpentine rock derived from peridotite. It occurs in irregular bunches, in vein-like masses, and often mixed with magnetite. The discovery of masses of black, hard, heavy metallic mineral in serpentine or peridotite is not necessarily a find of chrome iron ore; it may be magnetite. On the other hand, chromite that is mixed with a little magnetite might be mistaken for magnetite. In Quebec, chromite is found in serpentine, in the asbestos district. In Ontario and British Columbia, it has been found in peridotite, in both cases with microscopic diamonds. In South Africa, chromite has been found in norite near its contact with granite, and in the neighborhood of extensive deposits of titaniferous magnetite. It is possible that chromite may be found in Ontario, as a segregation at the edges of norite or gabbro intrusions.

To be merchantable, chrome iron ore must contain not less than 40% of chromium oxide (Cr_2O_3), but leaner ores are sometimes concentrated.

288. Tungsten.—The chief ores of tungsten are: (a) Wolframite, an iron-manganese tungstate, $(\text{Fe}, \text{Mn})\text{WO}_4$. The parenthesis enclosing Fe and Mn and the comma between them mean that the iron and manganese in the mineral vary in proportion, the sum being equal to what would amount to Fe alone or Mn alone. When it has little or no iron, the mineral is hübnerite, MnWO_4 , much like wolframite, but of a reddish-brown color, and yellowish-brown when powdered. Wolframite is black or brownish-black, and is red-brown when powdered. Both are very heavy, $G = 7$ or more.

(b) Scheelite, calcium tungstate, CaWO_4 . It is white, cream-yellowish, or brownish in color; easily scratched by knife; Heavy, $G = 6$; easily mistaken for quartz, but good cleavage and softness distinguish it; also, when a piece is obtained that is large enough to try its weight, it is found to be much heavier than quartz.

(c) Tungstite, H_2WO_4 , is a weathered product of wolframite or scheelite, of a canary or golden-yellow color. At the Kootenay Belle Mine, it is found in considerable quantities; but usually it occurs only in small quantities with the original minerals.

Tungsten ores are found along with tinstone, and in quartz veins in gold regions. In Nova Scotia, the quartz veins in which the tungsten ores are found are mostly barren of gold; but in the Porcupine area, Ontario, scheelite has been found in considerable quantities, closely associated with the gold; and the tungstite of the Kootenay Belle, B. C., carries gold values. The quartz veins in gold regions should be carefully examined for tungsten minerals, especially those veins of "bull" quartz which appear to be unmineralized. Scheelite, even in considerable quantities, is easily overlooked. Wolframite is more easily spotted.

In panning for gold, a very heavy white or yellowish tail may be scheelite, or a dark brown tail may be wolframite. Where gold is being concentrated on Wilfley or other tables, scheelite or wolframite would appear with the other heavy minerals. It is always possible that, in some exceptional case, it may pay to save the tungsten mineral as a by-product. A tungsten ore containing 3% or 4% of WO_3 , or about 4% or 5% of

tungsten mineral, could probably be worked for its own sake.

Tungsten ores are also found with tinstone in the vein-like pegmatite and quartz bodies which cut through slate, schist and intrusive granite.

289. Molybdenum.—The principal ore of molybdenum is the sulphide, molybdenite, (MoS_2). This may be changed by weathering into the yellow oxide, molybdate (MoO_3) or to molybdic ocher, a yellow molybdate of iron. Where galena and molybdenite occur together, *wulfenite* (PbMoO_4), of a bright orange color, may be a product of weathering; and it is sometimes plentiful enough to be of importance. Another product of the weathering of molybdenite is *powellite* (CaMoO_4), of a grayish-white color.

Molybdenite is found in the contact zone of pegmatite granite with crystalline limestone, where it is commonly associated with pyrite, pyrrhotite, pyroxene (diopside), and scapolite. It is also found in the pegmatite dikes themselves and, sometimes, in aplite dikes. Ores containing as low as 1% of molybdenite can be worked at a profit since the oil flotation process has been applied to the mineral.

Molybdenite and graphite are very much alike, but molybdenite is blue-black, while graphite is gray-black. Molybdenite is very much heavier than graphite. When the marks made on rough porcelain are compared, the molybdenite shows a greenish tint, while the graphite mark is pure gray; this difference can be seen when the marks are made on paper and rubbed until they are spread out thin.

290. Graphite¹.—Graphite is found; (a) in fissure veins in granite, gneiss, crystalline limestone, pegmatite and other intrusive rocks; (b) in lenses and irregular masses following the stratification of shale, slate, limestone, or gneiss; (c) *disseminations* in gneiss, crystalline limestone, mica schist, and similar rocks, generally near their contacts with intrusive igneous rocks, such as granite, diorite, or porphyry. Most of the workable deposits in Canada are of this kind.

Of the hundreds of graphite deposits known in Canada, very few have proved to be of economic value. The difficulty lies in separating the graphite from the other minerals, such as quartz and mica. For the finer grades, for use as a lubricant, in lead pencils, and for crucibles and electrotype making, everything of a gritty nature must be removed, and also all minerals that would tend to lower the fusion temperature of crucibles. This concentration is easy in the case of "flake" graphite disseminated in crystalline limestone. Fine-grained or "amorphous" graphite is not so easily purified.

OTHER METALLIC ORES

291. Tin.—The chief ore of tin is cassiterite, or tinstone, SnO_2 . Most of the world's tin production comes from placers. While Canada, on account of extensive glaciation, is not in a favorable position in this respect, placer tin may be discovered in prospecting for gold placers. Tinstone being very hard and very heavy, accumulates with gold in gravel and sand, and in panning will show as a heavy tail of black or dark brown grains,

¹ Included here because of resemblance to molybdenite.

which turn light brown or nearly white when finely powdered.

Tinstone is found in pegmatite dikes (often called veins) and in quartz veins in intrusive granite, and in quartz-porphry. These veins are also found in the slate, and other stratified rocks intruded by the granite. The granite in the neighborhood of the veins is altered to *greisen*, a white or gray rock composed mostly of white mica and quartz. Other ore minerals found in tinstone veins are molybdenite, wolframite, scheelite, mispickel, bismuth, and bismuthinite; pyrite, copper pyrites, galena, and zinc blende may be present. The greater part of the gangue is quartz, but lithium mica, fluorspar, topaz, tourmaline, axinite, and apatite are commonly present. In Cornwall the tourmaline is very plentiful in large masses, called *schorl*. Silver and gold may occur in important amounts, as in Bolivia.

292. Uranium and Radium.—Uranium ores are the source not only of uranium, but also of the very valuable element radium. The principal ores are pitchblende and carnotite.

Pitchblende, or uraninite, consists mostly of uranium oxides. It is a pitch-black, greenish or brownish-black mineral, green or brown when finely powdered; it has a smooth or conchoidal break, and is very heavy. Pitchblende is found in pegmatite dikes, sometimes, as in Cornwall, England, associated with tinstone. Other uranium minerals of similar appearance, *euxenite* and *samarskite*, are found in the same formation. Pitchblende is also found in veins of silver-cobalt-arsenic ore, as in Joachimsthal, Bohemia, and in quartz veins asso-

ciated with gold, as in Colorado. Uranium ores are apt to be covered with yellow spots, or crusts, of uranite or uranium ocher. Other uranium minerals of a bright yellow color are known. So far, the most promising discoveries of uranium minerals in Canada have been in pegmatite dikes, in areas of eruptive granite. The feldspar in the neighborhood of pitchblende is usually darkened. Sometimes a dull green stain on the feldspar or quartz indicates the presence of pitchblende.

The Colorado pitchblende veins are in gneiss and mica schist. They were first worked for gold; but the gold values disappeared where the pitchblende came in. The veins are found in the neighborhood of intrusive granite and andesite. In Germany and Austria, the pitchblende is associated with silver-cobalt ores in veins in mica schist and slate. Dolomite is a common gangue mineral; and in the neighborhood of the pitchblende, it is of a brownish-red color, changing to dirty gray where in contact with pitchblende.

293. Vanadium.—The ores of this important steel-alloy metal are:

Patronite, vanadium sulphide, found with a mineral pitch in Peru. The ash of coal is sometimes rich in vanadium. Bitumen from several localities in the United States has been found to contain vanadium, the ash carrying from 4% to 20%.

Carnotite, an ore of uranium, radium, and vanadium, found as a bright yellow, powdery mineral in sandstone in Colorado and Utah. It has also been noticed as a yellow incrustation on ilmenite. Most titaniferous iron ores contain a small percentage of vanadium and it

is possible that some such deposit may be discovered unusually high in vanadium.

Roscoelite, or vanadium mica, is a clove-brown, greenish brown, or greenish mineral, like mica in appearance, but more like chlorite in its softness and lack of elasticity. It has been found in commercial quantities in sandstone in Colorado.

294. Minerals of the Rare Earths.—There is a group of minerals known as *rare earths minerals*, called by that name because they contain uncommon oxides of an earthy nature; they are found in granite, and particularly in pegmatite dikes. Since they are hard, heavy substances, they become concentrated in the sand and gravel formed by the weathering of these rocks, and they may be noticed in panning for gold. A heavy tail of red, yellow, orange, black, or white, color should be tested for these minerals.

The principal minerals of this group are:

Zircon, brownish red, grey, green or white (Figs. 10, 11, 59).

Monazite, red or yellowish brown, of resinous luster.

Thorite, black; brown when powdered.

Gadolinite, black, greenish-black, or brown.

Allanite, or **cerium epidote**, black, dark brown, or gray.

Columbite and **tantalite**, brownish-black or iron-black; powder, brownish-black.

From these minerals are extracted substances used in the manufacture of mantles for gas burners, electrodes for arc lamps, *ferro-cerium* for gas lighters, and *mesothorium* which is similar to radium and used for

the same purposes. Columbite and tantalite yield the metal tantalum, worth \$18 an ounce. From monazite and zircon is extracted the metal zirconium, used as a hardener for steel. Zircon concentrates sell for \$100 to \$400 a ton. Used largely for making a *refractory*, that is, a material to stand high temperatures and other conditions of furnace operations.

295. Aluminum.—The only ore of aluminum at present in use is bauxite, a hydrated oxide of aluminum. It is found as superficial deposits, rarely in veins, resulting from the weathering of syenite and other aluminous rocks. Bauxite is usually found in or at the edge of clay deposits, and is sometimes very like clay in appearance; but oftener it has a *pisolitic* structure, that is, made up of small rounded masses. Since it is believed to have formed under tropical conditions, and since the climate of Canada has been temperate since glacial times, the chances are not good for finding a bauxite deposit in this country.

NON-METALLIC MINERAL DEPOSITS

THE COMMON NON-METALLIC MINERALS

296. Remark.—A number of minerals are mined because of their use for other purposes than as ores of metals. Some of these minerals are of such importance as to warrant special mention.

297. Pyrite.—Pyrite, or iron pyrites, FeS_2 , is found in workable deposits as follows:

(a) At or near contacts of quartz-porphyry, diorite, syenite, gabbro, and other igneous intrusions with crystalline limestone, quartzite, and other metamorphic rocks.

(b) In vein-like bodies or lenses in Keewatin and other schists; for example, the Holdsworth deposit in the Goudreau area, Michipicoten district, Ontario.

(c) In the iron formation, as in the Michipicoten district, Ontario, where the majority of the pyrite deposits are found in the iron ranges; they are there associated with banded silica and siderite or limestone. Since the pyrite weathers more easily than the rocks bounding it, it tends to form hollows between the rocks. Deposits of iron pyrites often contain enough copper to make them valuable as copper ores, and sometimes gold and silver add to the value of the ore; but the presence of other sulphides may decrease the value. Galena, zinc blende, stibnite, and mispickel are detrimental, if present in the ore.

In prospecting for pyrite, it should be remembered that, by weathering, the mineral forms a rusty brown or sometimes reddish mass of *gossan*; and since much of the material is washed away, this action often results in a hollow above the deposit. Reddish or rusty soil is an indication of pyrite. Sometimes there is a lack of vegetation, owing to the acid formed by the weathering of the pyrite. On digging down in places where these indications appear, the gossan will increase, and will become solid with increasing depth. Sulphate of iron of a whitish color and a decided taste may also appear. If the gossan is located on a steep hillside, the ore may be found uphill.

To be workable on its own account, a pyrite deposit must be practically free from gangue, so as to assay not less than 40% sulphur; it must be large enough to mine with no deadwork, and must be capable of producing a large tonnage. The low price of the mineral does not allow large cost for transportation to points where it is to be used. Competition of Louisiana sulphur makes it difficult to mine pyrite with profit.

237. Apatite.—Apatite or "phosphate" is found in Eastern Ontario and Western Quebec in bunches, pockets, or large vein-like masses associated with mica, pink calcite, pyroxene and scapolite. These deposits are found in dikes of pyroxenite, particularly at their contacts with gneiss, mica schist, and crystalline limestone. Where the mica is plentiful and of good quality, the phosphate is apt to be scarce. On the other hand, the presence of a large quantity of apatite in the mica deposits is found to give a poor quality of mica.

The discovery of very large sedimentary deposits of phosphate in the Southern States of the United States killed Canadian phosphate mining. The only chance of its revival lies in the possible, but not very probable, discovery of an unusually large and regular body of the mineral that could be mined more cheaply than the pocketty masses so far found. Some deposits in the Lièvre area, Quebec, are fairly large.

Sedimentary phosphate has been found near Banff, Alberta, but it is too lean to be merchantable. No. 1 phosphate carries at least 80% of phosphate of lime. The best found in Alberta does not go much above 30%.

298. Fluorspar.—Fluorspar, or fluorite, (CaF_2) is found in veins in limestone, shale, and sandstone, sometimes in the neighborhood of igneous intrusions; but often, as in the Madoc area, Ontario, not obviously connected with intrusive rocks. When well crystallized (Figs. 70 and 73), the fluorspar is easily recognized; but when granular or sugary, it may escape notice. While often white, it may show green, blue, pink, yellow, or purple colors. It is apt to be mixed with barite and celestite, only a small percentage of which is permissible when the fluorspar is to be used in the iron and steel industry. Quartz may be present in injurious quantity. "No. 1 ground" fluorspar is specified to contain not over 1% silica. No. 2 is allowed "less than 4% silica"; but for refining steel, the requirements with regard to silica may be even stricter. Fluorspar to be used for enamels must be free from minerals, like pyrite, that would give a color to the enamel.

299. Cryolite.—Cryolite (Na_3AlF_6) is found in pegmatite dikes. The only workable deposit known, in Greenland, is in a vein-like deposit in coarse-grained granite; it is probably to be classed as an unusual pegmatite. Near the cryolite is pegmatite, carrying tin-stone. Pure cryolite is white, and it might easily be passed over as barren-looking quartz, if not carefully examined. But it is much softer than quartz, having the same hardness as calcite. Used principally in the manufacture of aluminum, forming a molten bath in which the purified bauxite is dissolved.

300. Barite.—Barite (BaSO_4) is found in veins in a great variety of rocks, but most frequently in limestone

and dolomite; also, in slate, gneiss, syenite, diabase, hornblende schist, and other igneous and metamorphic rocks. It is a fairly common vein matter in regions where veins of metallic ores are found; but to be useful as a white paint, it should be free from mineral that would give a color to the ground product. Its weight and softness should call attention to it in the field. When crystals are noticed the "crested" appearance is characteristic (see Art. 116).

301. Celestite.—Celestite (SrSO_4) is commonly called "strontium" by the miner, which name is also applied to the much rarer mineral, *strontianite* (SrCO_3). Celestite is found in veins, commonly in crystalline limestone, but also in sandstone and shale. It resembles barite in appearance, weight and softness, but is sometimes of a pale blue color and of a somewhat fibrous structure. It has been used in place of barite in the manufacture of the paint, *lithopone*; it has been largely used in the manufacture of sugar, and fireworks.

302. Asbestos.—Serpentine asbestos is the most valuable of the fibrous minerals to which the name asbestos is applied. As produced in the Province of Quebec it has a soft silky fiber which makes it easy to spin and weave. It is found in veins in serpentine rock.

Asbestos was first discovered in Quebec by being turned up by a plow, the fibers having stood the weathering longer than the serpentine rock. In prospecting serpentine areas, parts of which are covered, some attempt should be made to find asbestos fibers in the overburden, where not too deep. Small quantities of asbestos are sometimes seen in serpentine formed in the

contact zone of limestone with an igneous intrusion. In such a situation, the quantity is not likely to be of commercial importance. When discovered, its quality can be roughly tested by spinning it with the fingers. On account of the high price of asbestos, a small percentage in the rock may pay under favorable conditions. At Thetford, Quebec, where the fiber is unusually fine and pliable, rock averaging only 3% or 4% of asbestos is profitably mined. With a rather poorer quality of fiber, rock containing 5% or 6% is payable. For further information see Art. 109.

303. Magnesite.—Magnesite, $MgCO_3$, is found in serpentine rock as a hard, non-crystalline mineral, with a fracture like broken porcelain; it is also found in talc schist and other magnesian rocks. The crystalline variety is found in dolomite rock that has been changed by intrusions of gabbro and other basic and intermediate rocks. The magnesite deposits are crumpled, banded and fractured. The rock varies from dolomite, which is carbonate of lime and carbonate of magnesia — roughly 50-50 — to fairly pure carbonate of magnesia, or magnesite; but the general appearance is much the same in all these varieties. As dolomite dissolves in rain water more easily than magnesite, the surface of the mixed rock is pitted. Dolomite areas that are partly magnesite show serpentine, talc, pyroxene, mica, etc.

The principal uses of magnesite are for linings and hearths of steel furnaces, or magnesia bricks, and for the manufacture of the metal, magnesium. For the manufacture of magnesia bricks, magnesite should be

low in lime, not carrying more than 2%. Although the Quebec magnesite carries about 8% or 9% lime, it is stated that, in spite of the high lime content, good magnesia bricks can be made from it. A certain percentage of iron helps the sintering in making the bricks. The European magnesite has this naturally; and where it is wanting, it is easy to supply the lack by adding blast furnace slag.

Hydromagnesite is a hydrated carbonate of magnesia. It has been found in Atlin, B. C. in the bottom of dried-up lakes, as a powdery deposit; it can be used for the same purposes as magnesite.

304. Talc.—The best talc deposits have been found in crystalline limestone of the dolomite kind, in the neighborhood of igneous intrusions. It is also found in association with serpentine, talc schist, chlorite schist, peridotite, and other magnesian rocks. It is easily "spotted" by its softness and soapy feeling. Talc is a cheap mineral not worth attention unless it is near transportation. But a good deposit of either pure talc or soapstone that is near a railway or water transportation, may be of value.

For its principal uses, — as filler and surface coating for paper (fibrous talc preferred), filler for white cotton, toilet powders, soaps and enamel paints, — the talc must be free from harder minerals, such as calcite and pyroxene, which would give the finely ground product a gritty character. For most of these purposes, it must also be free from color when ground. Lower grades of ground talc are used as foundry facing, in

rubber manufacture, in magnesite flooring, and to prevent sticking of roofing paper.

Soapstone is fine-grained, impure tale, which is quarried and used for laboratory table tops, electric switchboards, sinks, wash tubs, hot plates, stove linings, acid tanks, and other apparatus where its qualities of easy shaping, resistance to heat and acids, and non-conductivity for heat and electricity make it valuable. Good deposits have been discovered near Dryden and Mine Centre, Ontario.

305. Feldspar.—The useful feldspars are chiefly orthoclase and microcline, which have the same composition:

Silica (SiO_2)	64.7%
Alumina (Al_2O_3)	18.4%
Potash (K_2O)	16.9%
Total	100.0%

Soda (Na_2O) may take the place of part of the potash, and sometimes a little lime (CaO) does the same. *Albite* is sometimes used; it is soda feldspar of the following composition:

Silica (SiO_2)	68.6%
Alumina (Al_2O_3)	19.6%
Soda (Na_2O)	11.8%
Total	100.0%

Potash and lime usually take the place of part of the soda.

For industrial purposes, feldspar must be free from minerals, like tourmaline, garnet, hornblende, and black

mica, which give a gray color to the glaze or enamel, for making which, feldspar is largely used; also it must not have much quartz mixed with it, some users specifying "not more than 2%"; and it must likewise be free from hematite and other iron minerals. These requirements rule out the great bodies of granite and syenite that might, otherwise, be available.

Commercial feldspar is obtained from pegmatite granite and syenite dikes, where the coarse crystallization has caused the separation of the feldspar in large masses of the pure mineral. In some of these dikes the quartz and feldspar are crystallized together as graphic granite (see Art. 193); and if the quartz is not too plentiful (as much as 25% is allowable), the material is merchantable, if of good quality otherwise. Potash feldspar has the lowest temperature of fusion, a desirable property for its use in pottery manufacture; the fusion point is still lower if a small percentage of soda is present. Albite is sometimes mixed with a pure potash feldspar, to lower the melting point. Lime in feldspar causes a higher melting point, and it also causes the articles to shrink a little on firing.

The main uses of feldspar are in the manufacture of china-clay products. (The clay industries are often alluded to as the *ceramic arts*.) Ground feldspar is mixed with the clay, as a binder, and it is also used as a glaze for the surface, for which purposes a low fusion temperature is desirable. Feldspar is used in enamelling bricks and metal ware, as a binder in the manufacture of emery wheels and other abrasive wheels, etc., for opal glass, in scouring soaps and polishes, as surfacer for some roofing materials, and in the surface layer of

artificial stone to give it an attractive appearance. For most of these purposes, low-grade feldspar may be used. The finest grade of pure potash feldspar is used in the manufacture of artificial teeth. This *dental spar* brings a high price.

Pegmatite dikes are very common in regions where intrusive granite and syenite are plentiful. But very few of these dikes fulfil the requirements for a good feldspar quarry, namely; nearness to transportation, freedom from certain minerals mentioned above, large tonnage, and low cost of quarrying.

305. Mica.—Muscovite, or *white mica*, and phlogopite, or *amber mica*, are the principal commercial micas.

White mica is to be looked for in pegmatite granite dikes. To be merchantable it must be in large crystals or "books", the larger the better, other things being equal. It must split into very thin sheets, which will bend without breaking, and snap back when bent and released. The sheets must be free from checks and crinkles. Spots of hematite and other dark minerals lower the value, as does any stain or strong coloring. Muscovite is sometimes distinctly colored, that mined in India being usually wine-colored or purplish.

Amber mica is found in pockets with pink calcite, pyroxene (diopside), scapolite, and sometimes apatite in dikes of "pyroxenite" (a rock composed of pyroxene with more or less feldspar), mostly at or near the contacts of these dikes with crystalline limestone, gneiss, or mica schist. Three kinds of amber-mica deposits are here described:

(a) *Fissure deposits*, with calcite (generally pink) as the gangue; the walls are well-defined and often

lined with crystals of pyroxene. The mica crystals are usually found most abundantly near one or both of the walls; and when the calcite is white, the crystals of mica are apt to be larger.

(b) *Contact deposits*, found along the contacts of the pyroxenite dikes with the gneiss, etc., etc. Calcite is the vein matter.

(c) *Pockets*, or irregular bodies of mica with calcite, in the pyroxenite dikes. Pyroxene crystals are common, and also apatite crystals. Since calcite weathers away faster than mica, apatite, and pyroxene, these minerals are often found lying in the covering over mica deposits; but if the deposit is on a hillside the loose material may have been moved down hill a considerable distance. There are often a number of such pockets connected by stringers of calcite. For these irregular deposits, surface prospecting by trenching and stripping is the best way.

306. Corundum.—Corundum (Al_2O_3) is found in nepheline-syenite, peridotite, pyroxenite, and amphibolite, and sometimes in gneiss and chlorite schist. It is easily spotted by its six-sided crystals (Figs. 37 and 38), which are harder than quartz. The common colors are gray, white, and brownish. While the crystals have no true cleavage, they usually show a clean break (parting) at intervals across the length of the crystal.

Corundum has been found plentifully in Eastern Ontario, usually in nepheline-syenite, and at one time considerable quantities were mined for the manufacture of corundum wheels and other grinding instruments. Being close to diamond in hardness, corundum is a first

rate abrasive, that is, a material suitable for grinding and polishing. The severe competition of carborundum (SiC) and alundum (artificial corundum) has made it hard to mine corundum with profit.

307. Garnet.—The common red garnet, almandine, silicate of iron and aluminum, is the one commonly used as an abrasive. It is found in gneiss, mica schist, and crystalline limestone, — sometimes in granite and other igneous rocks, — but in commercial quantity and quality, it should be looked for in gneiss and mica schist. The common variety is easily recognized by its red color, hardness, and the rounded shape of the crystals (Figs. 3, 5, 60, 61). Only a small proportion of the deposits are of satisfactory quality. **Shell garnet**, that is, garnet in crystals scattered through the rock, is the best; **pocket garnet**, that is, the mineral occurring in round bunches, comes next; **massive garnet**, or garnet in fine-grained masses, is not so good, being usually mixed with other minerals. The garnet crystals are often coated on the outside with mica and other soft minerals, so that their true color is not seen, but the rounded shape is noticeable.

Garnet is used mostly for making garnet sand-paper. It is harder than quartz, and the grains easily break and keep a fresh cutting edge, whereas quartz grains wear smooth. Garnet sand paper is in demand for polishing leather, wood, and brass. Garnet is not quoted in market reports, but the concentrates were selling at \$25 to \$40 a ton in 1914.

308. Tripolite.—Other names for tripolite are *tripoli*, *infusorial earth*, *diatomaceous earth*, and *fossil*

flour. It is impure silica made up of the very small shells or cases of minute plants that live at the surface of the water or on larger plants, in seas and lakes. The bottoms of lakes may become covered to a considerable depth with a fine sediment of this material. Although like flour in appearance, the grains are hard enough to scratch glass; consequently tripolite is used as a polish particularly for metals. It is also used as a filler for rubber and wood, as a covering for steam pipes, for water filters, and a number of other purposes. Tripoli and diatomaceous earth are quoted separately in market reports, the former at \$16 to \$27, the latter at \$8 a ton. The low price is due to impurities.

309. Rottenstone.—This is a porous rock, composed mostly of very fine-grained siliceous material (quartz) and oxide of iron, left by the weathering of siliceous limestone or limey mica-schist; its reddish or rusty color is noticeable. It is used in finishing the varnished surfaces of furniture, pianos, etc., and in polishing celluloid and plate glass.

310. Fuller's Earth.—This is a clay-like material, gray, dark green, or brownish in color; a silicate of alumina, etc., differing from clay in having little or no *plasticity*, that is, the property of making with water a sticky mass that can be shaped, as is done in the manufacture of pottery. Fuller's earth is formed as a sedimentary deposit in the younger geological formations, and also, sometimes, as a product of the weathering of basic dikes. It is used for purifying fats and oils, and in the refining of petroleum. It is quoted at \$7 to \$18 a ton.

311. Clay.—The properties which make clay valuable are its plasticity (see Art. 310), and the formation of a hard, durable material when it is dried and burned. It is a secondary mineral, formed by the weathering of rocks, particularly those rich in feldspar. The most plastic clay is that which has been worked on by water for a long time; and this condition is fulfilled by clay that has been carried by running water and deposited in still water. *Brick clay* is plentiful in Canada; but, in limestone districts, it must be carefully selected, as many beds are useless on account of the presence of nodules of limestone. When the clay is burned, these nodules form quicklime, which slowly slakes, at the same time swelling and bursting the brick or tile. *China clay*, is the most valuable variety; it may be found as a residual deposit above granite or other rocks that are rich in feldspar, or as a sedimentary deposit in places that have once been the bottoms of lakes or other bodies of still water. *Fireclay* is a variety which stands a very high temperature without melting. It is sometimes found in coal deposits, but is by no means confined to the coal beds.

312. Deposits from Evaporation of Lakes or Inland Seas.—The present existence of salt lakes, such as that in Utah, makes it fairly certain that in past geological ages, similar bodies of water have dried up and left, as sedimentary deposits, substances that the water had in solution. In this way beds of gypsum, salt, and potash salts are accounted for, and possibly, also, Chile nitrate. All of these substances, except gypsum have a decided taste; and the prospector who has formed the

habit of tasting minerals is not likely to pass these by unnoticed.

In the regions of Western Canada where the rainfall is scanty, there are lakes and old lake bottoms in which deposits of Epsom salts ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$), mirabilite ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$), and hydromagnesite have been found. Of these the first two have a decided taste. Borax and similar minerals may be found in such localities.

313. Gypsum.—Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is found as a deposit in sedimentary rocks of many ages, with shale, sandstone, and limestone; it is often found with rock salt. The almost valueless mineral, anhydrite (CaSO_4) is found with gypsum, and may be mistaken for it; but it is harder, heavier, and breaks into square pieces. Gypsum is easily recognized by its softness, its whiteness (sometimes gray or reddish from impurities), and the very perfect cleavage of its crystals (Fig. 77), when they are large enough to observe. While a cheap mineral, it is easily mined, and is apt to be in large quantities. It should not be forgotten that gypsum and anhydrite may be accompanied by rock salt and the much more valuable potash salts.

314. Salt.—The solid material found in the earth's crust as rock salt has been doubtless deposited by the evaporation of salt lakes or other bodies of water that had no free outlet into the ocean. Rock salt may be found in sedimentary rocks of many ages; its presence is sometimes shown by salt springs, the water of which in its underground course has dissolved the salt.

315. Potash Salts.—Potash salts are found in the same situations as rock salt, with which they are

associated in the known deposits in Germany and France. Their great value for agricultural fertilizers would justify a careful search for deposits in Canada. Small quantities have been found in the salt beds of Malagash, Nova Scotia.

316. Nitrate.—Sodium nitrate (NaNO_3) is found in large quantity in a desert region in Chile, where it is associated with rock salt, gypsum, mirabilite, etc. This deposit is the principal source of nitrate for the world's supply. It is used very largely in agriculture, and also in numerous chemical manufactures. It is possible that the counterpart of this rare South American deposit may be found in some rainless arid region of North America.

317. Coal, Petroleum, Natural Gas.—The search for these very important materials by modern methods is a specialty requiring thorough knowledge of geology and an extensive field experience. Coal has never been found in important quantities in rocks older than the Devonian age, and not very much has been found in rocks of that age.

Oil and natural gas have been found in important quantities in sedimentary rocks of all ages from the Cambrian to the youngest, usually associated with salt water.

Some information about coal and oil will be found in Arts. 35 and 36.

PRECIOUS AND SEMI-PRECIOUS STONES

318. Remark.—A few notes on this interesting subject may lead to a more careful watch for precious and

semi-precious stones. Most gems are crystals of unusual quality in regard to transparency and color; they are to be looked for in those rocks which have crystallized slowly, or in cavities which have been slowly filled by the growth of crystals. Pegmatite dikes are therefore apt to yield gems. Vugs and rounded masses which may be vugs should be carefully examined for gem crystals.

The weight of gems is given in carats. A *carat* is 205 milligrams, or 3 1-6 grains, very nearly. One ounce Troy equals 151 3-4 carats, very nearly.

It should always be remembered that crystals of unusual beauty and perfection may have considerable value as mineral specimens.

319. Diamonds.—Diamonds are found in peridotite and serpentine, and in the soft material formed by the weathering of these rocks. In Brazil, they are found associated with a peculiar flexible sandstone, *itacolumite*. Small diamonds have already been found in British Columbia and Ontario, associated with chromite. In the productive diamond fields of South Africa, the gems are found in weathered rock in volcanic necks. Diamond placers occur in South Africa, India, and Brazil; and small diamonds have been found in California placers. Diamonds of merchantable size and in considerable quantity have been taken out of weathered peridotite near Murfreesboro, Arkansas. As diamonds of considerable size have been found in the glacial drift of some of the Northern States, there is a chance of finding a diamond field in Ontario, from which much of the drift was derived. In panning for gold, diamonds should be watched for. They can be recognized

by their rounded form, the curved faces of the crystals (Figs. 26 and 27), and their extreme hardness. Diamond scratches quartz easily; quartz scratches glass; therefore the ability to scratch glass is not a test for diamond.

320. Rubies and Sapphires.—Rubies and sapphires are corundum crystals of red and blue color respectively. They may be found in syenite, nepheline-syenite, anorthosite, peridotite, serpentine, and other basic igneous rocks, particularly when these rocks are pegmatite. In New York and New Jersey, rubies have been found in crystalline limestone that is banded with gneiss. In North Carolina, these gems have been found in chlorite, mica, and talc, in a dike of olivine and serpentine. In Burmah, long the producer of the finest rubies, they are found in crystalline limestone and gneiss, but are mostly obtained from placers formed by the weathering of these rocks. Sapphires are found in a peculiar lamprophyre in Montana, and also in andesite in the same state.

Gem corundum crystals, on account of their great hardness and freedom from weathering, have survived the wear and tear of the years; they should be watched for in panning for gold. They can be recognized by their hexagonal form (Figs. 37 and 38), and they scratch quartz easily.

321. Emerald.—Emerald is a green gem variety of *beryl*, bound in pegmatite dikes, in calcite veins in carbonaceous crystalline limestone, and sometimes in slate and mica schist. *Aquamarine* is a blue-green variety. Beryl crystals (Figs. 62 and 63) look like crystals of

apatite, but are very much harder ($H = 7.5$ to 8). Its specific gravity is 2.7 . Valuable beryl crystals have been obtained as a by-product in mining muscovite mica.

322. Spinel.—Spinel is a compound of magnesia and alumina ($MgO \cdot Al_2O_3$). Some varieties contain iron or chromium. The common color of gem spinel is ruby-red, but other colors may give value to good transparent crystals; $H = 8$; $G = 4$. The crystals are in the cubic system, usually octahedrons. Ruby spinel is sometimes found with the true ruby, the crystals of which are hexagonal. Spinel is found in crystalline limestone, serpentine, peridotite, etc. Fine, blue spinel crystals have been found in Daillebout, Quebec.

323. Diaspore.—Diaspore ($Al_2O_3 \cdot H_2O$) is hydrated alumina. The common color is white; crystals of a yellowish color, like topaz, are found; also some of a brownish tint; $H = 6.5$ to 7 ; $G = 3.4$. Crystals, in the orthorhombic system, shaped a good deal like those of topaz; but topaz is harder than quartz, while diaspore is a little softer or equal to quartz in hardness. It is found with corundum.

324. Chrysoberyl.—Chrysoberyl is oxide of beryllium and aluminum; it is of considerable value when in clear, golden-yellow crystals. The crystals are orthorhombic; $H = 8.5$; $G = 3.5$ to 3.8 . Chrysoberyl is oxide of aluminum and beryllium. Jewelers call the yellow variety *chrysolite*. The green variety, *alexandrite*, is valued as a gem. *Cat's eye* is green chrysoberyl showing a peculiar play of colors, the *chatoyant effect*. A variety of quartz that is also called *cat's eye* owes its name to

the same peculiarity. Chrysoberyl is found with tourmaline, garnet, and beryl.

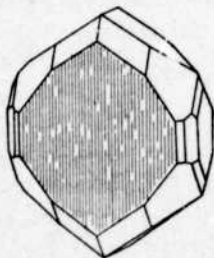


FIG. 134.—Chrysoberyl crystal.

325. Phenacite.—Phenacite is similar to beryl in composition, silicate of beryllium, while beryl has aluminum in addition. Phenacite is found in colorless crystals, which are among the most brilliant gem stones known; $H = 8$; $G = 3$. It looks a good deal like quartz but is harder, and the crystals are of a different shape,

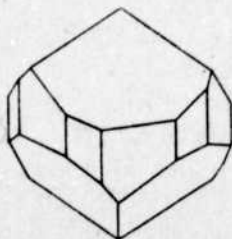


FIG. 135.—Phenacite crystals

roughly, like the cleavage pieces of calcite. Phenacite is found with beryl, emerald, amazonstone, and topaz, in granite pegmatite.

326. Peridot, or Olivine.—Peridot is the jeweler's name for olivine. Clear transparent olive-green crystals (Fig. 64) are of value as gems, $H = 6.5$ to 7 ; $G = 3.5$. It is found in the basic igneous rocks and in certain metamorphic rocks, such as impure dolomite.

327. Topaz.—Topaz is used as a gem when the crystals are clear and perfect. The prevailing color is honey-yellow. It is found in vugs in granite pegmatite, rhyolite, and other acid rocks, also in the surrounding schist, etc. Its hardness ($H = 8$) and brilliancy make it of some value as a gem. The crystals are in the orthorhombic system, and are apt to be long with a pointed end. A broken end shows good cleavage across the length. The finest crystals sell for as much as \$100 each.

328. Garnet.—Garnet crystals are sometimes perfect and clear enough to be of value as gems. Most of the varieties of garnet are used as gems when transparent crystals are found. Jewelers use red and yellowish brown garnets under the name *hyacinth*. Garnet crystals can be recognized by their roundish shape (Figs. 3, 5, 60, and 61) and hardness ($H = 6.5$ to 7.5). Garnet is a rather heavy mineral ($G = 3.15$ to 4.3). Good crystals may be found in schists, particularly mica schist and chlorite schist, in slate, in crystalline limestone and serpentine near contacts with igneous rocks, in pegmatite, and in gneiss. Beautiful crystals are found in mica schist along the Stickeen River, B. C. Green chrome-garnet of gem quality has been found in Orford, Ontario, in vugs in crystalline limestone.

Very fine gem garnets have sold for as much as \$50

each. Good crystals of one carat weight have been valued at from \$1 to \$5 each.

329. Tourmaline.—Tourmaline, when in fine pink, red, or green crystals, is of value; $H = 7$ to 7.5 ; $G = 3$. Gem tourmaline may be found in pegmatite dikes, and at the contact of intrusive granite with such metamorphic rocks as schists, gneiss, and crystalline limestone. Clear, finely colored crystals (Figs. 67 and 68) may be of considerable value. Transparent tourmaline crystals are *dichroic*, that is, the color is different when the crystals is viewed lengthwise and across its length. Crystals of brown tourmaline of gem quality have been found in crystalline limestone in Ross, Ontario, and at Calumet Falls, Clarendon, and Hunterstown, Quebec.

330. Hyacinth, or Jacinth.—Hyacinth, or Jacinth, is zircon, of a rich red color; Orange and brown crystals when transparent may be of value. Zircon crystals (Figs. 10, 11, and 59) can be recognized by their square build and their hardness ($H = 7.5$). A colorless variety may be mistaken for diamond, but it is heavier ($G = 4.7$) and not so hard. Crystals suitable for gems may be found in pegmatite dikes, and at contacts of igneous intrusives with metamorphic rocks, particularly crystalline limestone and nepheline-syenite. Fine zircon crystals are found in Sebastopol and Brudenell Townships, Renfrew County, Ontario.

331. Turquoise.—Turquoise is hydrated phosphate of aluminum and copper, of a sky-blue, green, or greenish-gray color, and a waxy luster; it is translucent or opaque; $H = 5$ to 6 ; $G = 2.6$ to 2.9 . It is brittle. It is

found in veins and in irregular masses in acid and intermediate volcanic rocks that are more or less altered. In Persia, it is found of gem quality in brecciated acid-volcanic rocks and in slate in contact with them. In New Mexico, it is found in very much decomposed volcanic tuff. Turquoise is apt to change colour, but Persian turquoise retains its colour indefinitely.

332. Quartz.—The varieties of quartz used as gems and ornamental stones are described in Art. 75. Rock crystals, amethyst, cairngorm or smoky quartz, sagenite or fleche d'amour (quartz crystals with needle-like crystals of rutile shot through them) are some of the varieties of quartz crystals used as gems. They are found in pegmatite dikes and other acid rocks. They are to be looked for in vugs (geodes) in these rocks. Cavities in sandstone and quartzite have yielded very fine quartz crystals. *Opal* is silica combined with water. Precious opal shows a beautiful play of colors. Fire opal is red to yellow with a gleam like fire when it is turned. Opal is found filling cavities and seams in trachyte, porphyry, basalt, etc. *Agate* is found mostly as rounded masses in basalt and serpentine. Where these rocks have weathered and broken down extensively, the hard, rounded masses of agate, and other similar varieties of quartz, are found on the shores of lakes and rivers. *Jasper* particularly when red and banded with other colors, is a fine ornamental stone.

333. Miscellaneous.—*Jade* is the name given to varieties of pyroxene and hornblende, of a green color, valued as an ornamental stone.

Spodumene belongs to the pyroxene group; it is a

silicate of aluminum and lithium. The variety, *hiddenite*, contains a little chromium which perhaps gives it the green color for which it is valued; it resembles emerald, but is yellowish green, while the emerald is pure green. When first put on the market about 1880, a $2\frac{1}{2}$ -carat stone cut from hiddenite sold for \$500, but the values have decreased considerably since that time. Another member of the pyroxene group, *diopside*, has been found in fine, emerald-green crystals, which are of value as gems.

Smaragdite, is a bright emerald-green variety of hornblende; is considered of value as an ornamental stone.

Rhodonite, a silicate of manganese, is sometimes found as pink or rose-reddish crystals, which have some value as precious stones. Large masses of rhodonite have been found in Russia, where it is used as a gem and also as a decorative stone.

Crocidolite, a silicate of iron, magnesium, calcium, and sodium, is a kind of asbestos of a blue color. By oxidation and addition of silica it has sometimes been changed into a hard stone of a bright yellow or brown color, with the peculiar luster called *chatoyant*; it is known as **tiger-eye**. Its fibrous structure gives it the look of petrified wood.

Epidote sometimes occurs in transparent green crystals of gem quality.

Sodalite. See Art. 95.

Moonstone is the name given to varieties of feldspar, albite, and orthoclase, which have the chatoyant play of colors, usually very delicate blue and green shades.

Sunstone, or **aventurine**, is a variety of feldspar showing peculiar fiery reflections probably due to small crystals of hematite, etc. A variety of quartz showing this effect is also called aventurine.

Amazonstone is a feldspar, *labradorite*, which is valued as an ornamental stone because of its fine, blue chatoyant effect. It is found in large quantities and of good quality in Labrador. Another feldspar, *microcline*, is sometimes chatoyant and of a beautiful green odor; the amazonstone, of Pike's Peak, Colorado, is of this kind.

Perthite is a mixture of, two feldspars, *orthoclase* and *albite*, laminated in such a way as to give the internal reflections of light that are characteristic of aventurine. The color of the mineral found at Perth, Ontario, the first discovery, is flesh-red.

Chlorastrolite is found as pebbles on the shores of Isle Royale, and on the North Shore of Lake Superior. They have been weathered out of the amygdaloid basalt (trap) of those regions. It is of a mottled opaque-green color and hard enough to take a good polish. It is sometimes chatoyant.

Thomsonite, a hydrated silicate of alumina, lime, and soda, is found in the Lake Superior amygdaloid basalt (trap), and as rolled pebbles on the beaches. It owes its value to its concentric layers of flesh-red, white, yellow, and green.

Fluorspar, when in fine colors and in large masses, is used as material for vases and other ornamental objects; also as decorative stone.

Serpentine of rich green color is used for ornamental purposes. When found in large enough quantity, it may be used as a decorative building stone.

Lazulite is a hydrated phosphate of alumina and soda. It is of a fine, opaque, blue color, like that of lapis lazuli.

Sphene or titanite is prized as a gem when found in transparent crystals. Sebastopol and Brudenell Townships, Renfrew Co., Ont., are localities famous for sphene crystals. The crystals are mostly opaque and not of gem quality.

PRACTICAL PROSPECTING

INTRODUCTION

334. Necessity of Thorough Knowledge.—The prospector's chief equipment for his business is his knowledge of rocks and minerals; and the more thorough, complete, and practicable is this knowledge the better his preparation for the discovery of mineral deposits. Bearing this in mind, the foregoing descriptions of minerals and rocks have been accorded a rather more extended treatment than is usual in treatises on prospecting. Whenever the matter under discussion has had some special application to prospecting, the attention of the reader has been directed to this fact. In this manner, a great deal of the discussion of prospecting has been distributed through the body of this book.

335. Ground Previously Covered.—In Part 1 and in the preceding pages of this part (Part 3) special information is to be found regarding each valuable mineral; as to its properties, the rocks with which it is associated, and the "signs" of its presence. For example, in Arts. 26 and 246-255, gold has been thus discussed; and, in addition, the use of *panning* in searching for gold, Art. 258, has been described. In Part 2, which deals with Rocks and Rock Structures, there is occasional reference to those features of the rocky surface of the earth that are of special interest to prospectors.

It nows remains to discuss some details of the *art* of prospecting that are not covered in the preceding pages.

336. Definite General Directions Impracticable.—The size of the prospecting party, its composition, and the equipment required, are matters that vary so much with the nature of the country, the method of travel, the time to be spent in the field, and the special objects in view, that it is not possible to give any useful directions of general application. The method of search must be chosen to suit the conditions, which vary for different regions and minerals; but there are a few general hints that may be usefully taken.

PROSPECTING DETAILS

337. Systematizing the Work.—The work should be made systematic. While discoveries are sometimes made by men who wander around with little or no method, the most fruitful work is done by those prospectors who

search in accordance with pre-arranged plans. Prospecting in a field where important discoveries have already been made should be begun by visiting some of these discoveries, to study the mineral deposits and the rocks in which they are found. There are often peculiarities in both minerals and rocks that are valuable "signs" for the guidance of the prospector.

388. Value of Work by Geologists.—The Government geologists have usually examined thoroughly the rocks, minerals, prospects, and mines of any field where important discoveries have been made; and they have prepared a geological map and a report giving most of the information about this special area that is likely to be of use to a prospector. In reports written during recent years, geologists have paid particular attention to the requirements and needs of the prospector; and these reports will usually inform him concerning the rocks that are likely to be barren of mineral wealth, those that are more likely to contain valuable deposits, and the particular association of rocks in which he is likely to make a discovery. In many cases, for instance, the deposits have been caused by large intrusions of granite; and the area most liable to contain veins is a strip of some other rock, along its contact with the granite.

339. Miners will Co-operate with Prospectors.—Those who have made discoveries, or have developed them into mines, are nearly always anxious to have more mines discovered and developed near them; the more mines there are in the camp the better the chances for good roads or a railway. On this account, as well as by reason of the spirit of good fellowship that marks miners and

prospectors alike, the men in an established mining camp will usually take great pains to show a prospector over the ground they occupy, giving him the information they have that is likely to be most beneficial to him in his search of this field.

340. Prospectors should Travel in Pairs.—In general it is advisable that prospectors travel in pairs, whatever may be the size of the whole party. This is particularly desirable in Canada, where most of the ground to be prospected is covered with forest and is rough or mountainous, with many chances for getting lost, or for breaking a leg or arm, or being otherwise seriously injured. To avoid waste of effort by walking close together, it is well to follow approximately parallel paths, but remaining within hailing distance of each other. If the ground is well known to the prospector, or if the woods are full of men, as in the case of a "rush," this precaution is, of course, unnecessary.

341. Outfit for a Pair.—When prospectors travel in pairs, it is advisable that each pair have an independent outfit, even in a large party. A tent $7\frac{1}{2}$ by 10 feet, if of fairly light cotton or silk, is a good size for two men and their provisions; it should always be fitted with a sod-cloth around three sides and a loose cheese-cloth netting in front, to keep out mosquitoes, sand flies, and other winged pests, which would otherwise make life almost unbearable. It may here be noted that a good way to keep off black flies and mosquitoes during the day is oil of citronella; this, mixed with the same amount of sweet oil, should be rubbed sparingly on the hands and face every half hour or so, when the pests are bad. Some

prospectors like to carry a heavy, water-proof tarpaulin or ground cloth, to sleep on and to use when travelling, to wrap around the blankets, tent, and the odds and ends, such as spare socks and the indispensable "housewife", which contains needles and thread, yarn, and tacks, for mending clothes, boots, and canoe. A water-proof box, holding a supply of matches should never be omitted from each prospector's personal outfit.

342. Food Supply.—The most important item of the outfit to any prospector, and one that often receives less attention than it deserves, is his food. Unless it is certain that the gun and fish line will furnish a part of the food (and it is seldom that this can be guaranteed) the prospector should carry food sufficient to last until he can reach the place where provisions can be obtained. If the trip is to be far from the "jumping-off place", it is well to take only dessicated foods (those that do not contain water), such as flour, sugar, rice, beans, bacon, oatmeal, dried apples, raisins, and dessicated (dried) potatoes. This food is the prospector's very life; it should be contained in a heavy, water-proof bag or pack sack, to protect it from the weather. In order to avoid breakage and waste of food, it is well to put each kind in a small cotton bag, tied at the mouth with a tape or string attached to the bag. These same little bags, by the way, often come in handy for holding samples of ore. If it comes to a pinch, such as when you are lost, or your pack horse dies, or your canoe is smashed, and you have to lighten your outfit, throw away your blankets, your tent, your ore samples, your pick, but do not throw away your food; if you do, you may throw away your life at the same time.

343. Importance of Well-Cooked Food.—Some prospectors think it does not matter much how their food is cooked, so long as they can get outside it; but they are wrong. Good cooking is one of the most important details of the prospector's outfit. It used to be the habit amongst "old timers" to live on bacon, bannock, beans, and tea, the last being so strong as almost to float an egg; added to this, would be a little apple sauce, as a luxury, and meat and fish when they could get them. These men would become actually ill from this half-cooked, monotonous diet, and they would have to come out to town every few months, usually for a spree, without any eating, which physicked them and gave their stomachs a new start when they went back. It is quite unnecessary for the modern prospector to waste time, money, and effort in this way; it is much better for him to take lessons in good camp cooking whenever he can get them, and thus keep himself fit during his whole season in the field. It is a comparatively simple matter to prepare good, sound, wholesome food, including the making of yeast bread, in the nest of small pails, frying pans, and reflector oven, which make up a complete cooking outfit, and which weigh but a few pounds. As this is not a cookery book, the subject must be left where it is, important though it may be.

344. The Prospector's Tools.—What should constitute the prospector's tools depends entirely upon the stage of his work and the nature of the ground over which he is working. The old, accepted prospector's pick, pointed at one end and with a hammer at the other, is a good tool, and it is better yet if it have a long handle fitted in an extra large eye. In this country, the rock

is almost invariably covered to a large extent with a thin coating of moss; and to scratch this moss away, some prospectors like to have instead of the hammer-pick, a light, long-handled mattock or grub-hoe, which has a pick on one end and a hoe or grub, about $2\frac{1}{2}$ inches wide, on the other end; this is very effective for scraping off moss and light soil and in cutting small roots. Another tool, not so common, but very effective, has a grub on one end and a hammer on the other, these two being used oftener than the pick.

345. Landmarks for Camp.—Good drinking water is indispensable to the prospector; and in few, if any, parts of Canada where prospecting remains to be done is this difficult to obtain. The prospector sets up his tent beside the supply of water, whether it be lake, stream, or spring. If the camp be on a lake or stream, it will form a landmark, by which to find the camp when returning in the evening; a stream or a large lake is best for such a landmark. A small hill is most deceptive in appearance, as it is likely to look quite different when viewed from various angles. It is likewise easy to confuse two valleys. One must be very cautious when locating a camp, unless he has had considerable experience, in which case, it will have become second nature with him.

346. The "Canoe Prospector".—It is the easiest thing in the world for the prospector to get accustomed to staying too close to his camp, either through fear of getting lost or through laziness. The "canoe prospector" of the lake country of Quebec, Ontario, and Manitoba is a man who may become very expert at traveling and an adept at making a comfortable camp

on the portage, but who seldom leaves the shore of the lake or the portage trail to conduct a real search for mineral deposits. It is a good thing to examine the shores and rock exposures along a portage; but it is likewise well to remember that all who have gone before him have examined these very places. The prospector that is most likely to make a "find" is the one who works forward systematically in unexplored territory, or in ground that has been traversed at wide intervals by the geologist, using every expedient that wood craft and scientific study can suggest to him. A half-day's steady walking through the woods in fairly level country will take him five or six miles from his camp; by returning by another, and practically parallel route, a half mile or mile from the former, he can size up a block of land from two to six square miles in extent in a single day. This of course, gives him only a look at the rocks, such as a geologist would take. But if he find anything of particular interest, as a promising belt of rock, a contact zone, a mineralized outcrop, it may take him weeks to examine this area as closely as is warranted.

347. Use of the Pocket Compass.—When traveling through the woods, whether it be in a mountainous or a flat country, a good pocket compass is a necessity to every prospector; and learning how to use the compass surely and rapidly is one of the young prospector's first duties. When the sun is visible, it is an excellent guide for direction, and it may be used instead of a compass. Its direction in the sky may be estimated by the time of day, bearing in mind the season of the year. It should be remembered that in midsummer in these northern

latitudes, the sun rises in the northeast, approximately, and it sets in the northwest; at the equinoxes, in March and September, it rises in the east and sets in the west, and it is much lower in the sky during the day. Thus it is well to check up even the sun with the compass as the seasons progress, lest one forget its changes in direction. On a dull day, when the sun is obscured by clouds, the compass is indispensable, and it must be consulted frequently enough to determine landmarks by which to travel. In a country where hill tops or mountain peaks are visible, this is a comparatively simple matter; but when deep in the woods of a valley or in a flat country, it is necessary frequently to check one's course with the compass.

348. Judging Distances.—While it is a comparatively simple matter to determine the direction of travel, it is more difficult to judge the distance covered; hence, the young prospector should take advantage of every opportunity to perfect his judgment of distance. After years of practice, a prospector is able to judge how far he has traveled, and the direction, without giving much thought to the matter; that is, he has recorded in his unconscious mind the path he has taken, the distance traveled, and the direction, and he can make a good guess as to the distance to the camp and in what direction it lies. But the young prospector cannot do this; and he should travel at first with the aid of a map, on which distances can be scaled. It is a good plan, when on a lake, to estimate the distances from point to point, and note the times taken to cover these distances; then check up the distances by scaling a map, or from in-

formation obtained from some reliable source. Calculate the speed of travel in both cases, and it will not be long before you will be able to judge quite accurately the speed of travel on still water. Four miles per hour in a loaded, two-man canoe is unusually fast paddling, as actual measurement will prove. Once the actual speed of travel in a canoe has been determined, it will be a good gauge of distance over still water; and by allowing for the speed of the current, the distance along a stream can also be gauged.

Noting the time it takes to pass over a portage or trail of known length will afford a good means of measuring the speed of walking. When proper allowance is made for the slowing up where there is no trail, the speed across country can be judged roughly. In thick woods, in level country a mile an hour is good average speed, when off the trail; this allows a little time when scratching among the rocks. When traveling a mountainous country, with much climbing, the speed will, of course, be much less.

For accurate measurement of distance, counting paces is a valuable method, after having noted how many paces are required to cover a distance equal to the surveyor's chain (66 feet), to 100 feet, to 100 yards, or to any measured distance, such as between the mile posts on a railway or across a measured portage. It is best to take your *natural* stride when counting, instead of three-foot steps, as is customary. Due allowance must also be made for the shorter steps that are taken when walking over rough ground or through thick woods, and for the crooked path that is followed in avoiding trees and other obstructions. Geologists commonly use this

method of measuring distances; with practice, surprisingly accurate results are obtained.

349. Notebook and Diary.—A notebook is required for systematic prospecting; and it is useful, though not essential, to keep in it a daily record, or diary. Sketches should be made of the ground examined; these should show streams and lakes, trails, survey lines, prominent hills, the kind of rocks seen, and all special features, such as mineralization, faulting, shearing, or folding, together with such other facts as it may be desirable to remember. If claims are staked, all the particulars should be carefully recorded in the notebook; this will help the official mining recorder to place the claim on his map, and will be valuable evidence in case of a dispute concerning the ownership of the claim.

350. A Typical Day's Work.—Taking notes of a day's journey and recording the observations made, is a simple matter when once understood; but it must be learned, like anything else. An example will now be given of a day's work, the time being early in July, with the observations and notes taken, and the manner of recording them.

Suppose the prospector is to travel several miles north from his camp, turn and go eastward for about a mile, then go south, and finally west to his camp. (See Art. 340.) Assuming that he starts at about 8 o'clock, the sun, if visible, will be seen directly on his right, when he faces north. If the sky be overcast, he must use his compass. He marks a point at the bottom of the page in his notebook to indicate the position of his camp; and since he intends to move toward the east later, he puts

this point near the lower left-hand corner. (See Fig. 136.) It is always assumed that the bottom of the page is south and the top is north, a vertical line being always

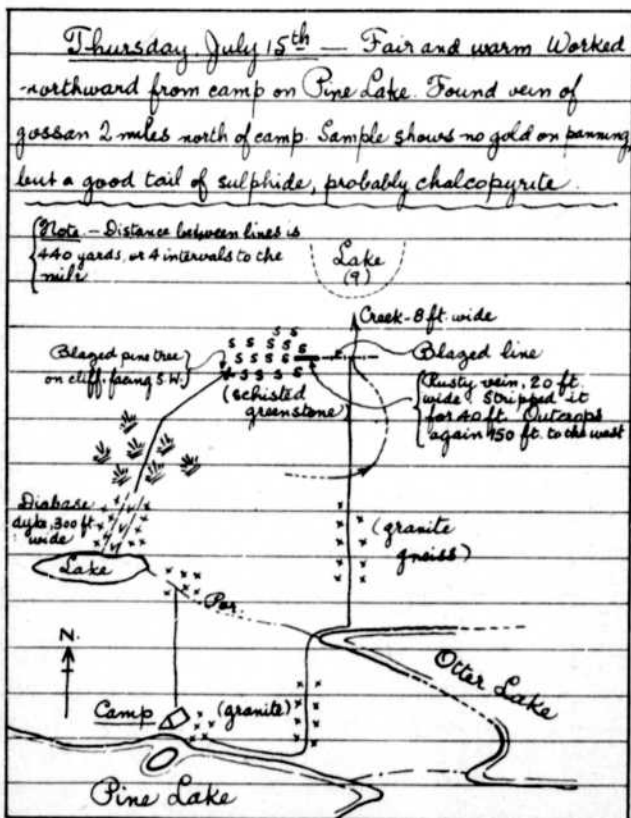


FIG. 136.—Page from prospector's notebook.

a north and south line. The notebook should be ruled with faint blue or red lines, as indicated in Fig. 136; the

distance between these lines may be used to measure distances. In the present case, this distance (interval) is assumed to be 440 yards = $\frac{1}{4}$ mile, as noted on the sketch. Near the camp, some granite rock is exposed, which is indicated by some small $\times$'s, and the notation (granite). After a $\frac{1}{2}$ -hour's easy walking to the north, he crosses, a portage trail, which he makes note of as being $\frac{3}{4}$ mile from camp, the distance it is judged to be, or 3 intervals from his camp point on the sketch. He follows this trail, in a generally northeasterly direction, and finds more granite rock, which he also marks. After walking about 300 yards (ascertained by pacing), he comes to a small lake or pond, which he sketches in. He estimates its length as $\frac{1}{2}$ mile, east and west, and its width as $\frac{1}{4}$ mile, and notes a prominent pine-covered cliff on its north side. Passing round the edge of the lake he finds that this cliff is the end of a ridge of diabase rock, and he follows it northward for $\frac{1}{4}$ mile, marking it in the book with a series of little v's. The rock on either side is found to be granite (indicated on the sketch by little $\times$'s), and the diabase is in the form of a dike, 300 feet wide; it terminates at the north end in a swamp, through which progress is difficult and very slow. The width of the swamp is noted, and the swamp is marked down in the note book, being indicated by a conventional sign that represents a tuft of marsh grass. From the open space on the north side of the swamp, he sees, toward the northeast, a hill top and a cliff, which he proceeds to investigate. On reaching it, he finds it to be greenstone — a convenient name for a number of fine-grained, greenish rocks, whose real nature it is impossible to determine in the field. This is the rock that the geologists have

indicated as favorable to the occurrence of mineral deposits in this locality. He therefore examines this rock outcrop very carefully; and before he realizes it, it is noon. By this time, the sun is high in the heavens, and is practically in the south. At this time of the day, however, the sun changes its direction so rapidly that the compass is the only reliable guide.

After eating his lunch by a tiny stream in a gully, the fire, over which he has boiled some water for his tea, is put out very carefully, and the search is resumed by walking over the bare outcrop and scratching down at intervals the moss that covers the rock. Presently, he finds an outcrop that is composed, half of schisted greenstone and half of rusty-looking material. He ascertains that this *gossan* runs under the moss; so he strips off the moss, and the gossan is found to be a band, 20 feet wide, running east and west, with the strike of the schist, for a distance of at least 40 feet. When picked into, it is found to contain specks of blue and green color, which suggests the copper minerals; and it is covered at both ends with boulder clay. Following eastward, in the direction of this band, or vein, the rusty-material outcropping is again found at the foot of a sloping outcrop of schisted greenstone.

The sun is now getting low, giving warning that the prospector has spent more time than he thought on this interesting outcrop. So at intervals across the outcrop, he digs up with his pick some of the rusty material, puts it in a handkerchief, and mixes it thoroughly; he then divides it roughly into quarters, throwing away two diagonally opposite quarters, to reduce it to two or three pounds in weight. The remainder he ties up secure-

ly in the handkerchief, to grind up and pan when he gets back to camp, in order to see if it contains any gold or other heavy minerals. Since he knows he will want to return to this spot, he blazes a prominent tree on the cliff he first saw (see Fig. 136), and then blazes a line eastward for a few hundred yards, so that he can cross out and pick it up again. He finds a stream, 8 feet wide, flowing northward across this line, so he records this on his sketch; he also notes that there appears to be a large

lake, about $\frac{1}{2}$ mile to the north; this he also records, using a dotted line to show that he is not certain of this. (In fact, whenever he records something he is not sure of, he uses a dotted line; note the dotted line between the portage he first crossed and the one he crosses on his return trip. He assumes that they are both the same portage, connecting the small lake with Otter Lake.)

The notebook now comes in handy. If he has recorded properly, and to scale, the distances traveled, and the directions are accurate, he can readily determine the direction and distance to his camp. His sketch map shows that the camp is almost directly south, and that it is about $2\frac{1}{4}$ miles away. Therefore, he strikes south, the sun now directly on his right again, in the *west*, and again crosses a stream, flowing to the east. He suspects that it is the same stream that is the end of his blazed line, and that it drains the big swamp he crossed in the morning. On the way south, $\frac{1}{4}$ mile away, he strikes outcrops of granite-gneiss, and then spies a large lake in front, at the end of which, he finds a portage trail, which he is almost certain is the one he crossed in the morning. He knows pretty well where he is now; so he continues southward, and soon comes to his own lake,

which he recognizes because of the pine-covered island in front of his camp, $\frac{1}{4}$ mile westward along the shore. The prospector's work of exploration and prospecting for the day is now finished.

351. Using the Pocket Compass.—The following brief description will be found of value to those who have never traveled with the aid of a pocket compass:

When the compass is so held that the needle is level and turns (swings) freely in a horizontal plane, the needle will always point to the north *magnetic* pole. The end that points north is usually blued, or else it is marked with a letter N, or it has a little cross bar. Under the needle is a card, marked to indicate the various points of the compass and also in degrees. The magnetic north pole is seldom in line with the observer and the true north pole, and the deviation between the true north and the magnetic north is called the **magnetic variation**, which varies, of course, with the position of the observer east or west of a meridian through the two poles. The magnetic variation is marked on the maps for the particular map area in which the prospector is located, usually *east* when prospecting in Canada. This variation must always be taken into account when determining true directions by means of a compass, as when staking a claim.

Suppose it is desired to go due north, and the map states that the magnetic variation for that locality is 15° east. Hold the compass steady, so the needle swings freely in a horizontal plane; then turn the compass (still keeping the needle horizontal) until the needle falls over the 15° mark to the right (east) of the point mark-

ed N; this point N is now due north. Look in this direction and see if there is any landmark in line with it. Assuming that the point N is in line with a large, dead pine tree, about 200 yards away, walk to this tree. On arriving there use the compass again, in the same manner as before, and locate another landmark directly from this tree, which may be a bare peak of rock in the distance; on arriving there, another landmark is located as before. It is evident that in a densely wooded country, the landmarks must be determined more frequently than in a more open country.

Suppose the prospector having gone north as far as he wishes now desires to go east. He sets the compass with the N point of the card pointing due north, as before; keeping the compass steady, preferably resting it on some convenient stationary object, he sights (looks) along the line passing through the points marked W and E, and picks up a landmark beyond E. toward which he goes, and then repeats the operation. If he wishes to go southeast, he sets the compass so the N point indicates true north; then he sights along a line passing through N W and S E, and picks up a landmark beyond the S E point. In a similar manner, any desired direction can be found and followed. It is necessary, of course, to estimate as closely as possible, all distances traveled in any particular direction, and both directions and distances should be marked on the sketch map. Care should be taken to be sure that the selected landmarks are directly in line with the direction it is desired to go; and these should be verified whenever there is reason to suspect a mistake has been made, or when it

is necessary to go around an obstruction and the landmark selected is difficult to locate.

352. Prospector's License, Staking, and Recording.

The mining laws regulate prospecting as well as mining, as might be inferred from the mention of the mining recorder in Art. 349. These laws vary in the different provinces, and the details must be learned for each; but, in general, they agree on certain main points. For instance, a prospector must take out a license (by payment of a few dollars), to give him the legal ownership of what he finds. He must then stake his claim in accordance with certain regulations, which are designed for his own protection. He must make a record of his staking at a Government office, again for his own protection, and also to let those in charge of the public lands know what part of these lands has been claimed as private property by right of discovery. Afterwards, it will be necessary to perform a stated amount of work on each claim, in order that he may retain its ownership. The prospector will gather information concerning these points as he pursues his calling and mixes with his fellow prospectors.

353. Geological Survey Reports and Maps.—Prospecting is gradually becoming systematized through the use of geological surveys, by means of which the country is mapped in such a way as to indicate the areas where valuable minerals are likely to be found. The prospector's initial discovery may call attention to some particular area, which the geologists then survey, map, and perhaps extend. Co-operation between the geologist

and the prospector is becoming more and more hearty and productive.

Geological reports and maps may be obtained from the Geological Survey, Ottawa, and from the various provincial surveys. Those who are preparing to prospect in Canada are advised to write first to The Chief of the Geological Survey, Information and Distribution Division, Ottawa, stating where the proposed prospecting is to be done, and asking for maps, reports, and other information. The purpose for which the maps are to be used should also be specified.

354. What the Maps Show.—Geological maps show the rock formations, and also such features of the country as streams, swamps, hills, sand plains, etc. Topographical maps do not show the geology of the country, but they show streams, lakes, etc., and, in addition, by means of so-called contour lines, the variations in elevations above sea level.

If a great deal of country is to be gone over, a small-scale map, is best; but if a relatively small area is to be carefully prospected, a large-scale map is advisable.

355. Map Reading.—Aside from those who make maps or who have used them consistently, few realize what a vast amount of information can be placed on a single sheet. This result is accomplished by the use of conventional signs and symbols, whose meaning must be well understood before a map can be fully utilized. The prospector should learn how to interpret a map drawn to scale; the use and meaning of the conventional signs for rivers, lakes, hills, roads, railways, etc.; and

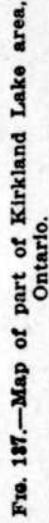
all other information that the map conveys to one who can read it properly. In addition to the foregoing, geological maps have signs to indicate a portage, rapids and falls, the different kinds of rocks, veins, shafts, and other features of interest to the prospector; all these are explained in the *Legend*, which is placed on one side of the map. Usually, the different kinds of rock are marked on the map by use of various colors. Sometimes, on the smaller maps, signs are used for this purpose, much like those shown on the sample sheet from a Notebook, Fig. 136.

356. Sample Map. A sample map showing a small part of a gold-mining camp is illustrated in Fig. 137. In the lower left-hand corner is a *Scale of Feet*, by the aid of which, distances may be measured on the map. The part of the scale to the left of 0, between 0 and 500, is subdivided into 5 equal parts; hence, each of these small intervals represents $500 \div 5 = 100$ feet, while the long intervals represent 500 feet. By means of this scale, it is ascertained that the area represented by the map (area plotted) is 4,000 feet long and 2,300 feet wide. As there is no arrow or other mark to indicate north, it is assumed that the end boundary lines run north and south, and that the *upper* edge of the map is the north boundary (see Art. 350).

The legend gives the key to the conventional signs used on this map. Two classes of rock are shown; and since the Timiskamian sediments are the *lower* of the two kinds mentioned in the legend, these rocks are at once known to be the older. When more than one kind of rock is indicated in a legend, the oldest is put at the

bottom, the next older just above this, and so on, the youngest being at the top. The map itself shows a quartz diabase dike, an olivine diabase dike, and a number of dikes of feldspar-porphyry and syenite porphyry.

357. Contour Lines.—It will be noticed that the map is covered with a large number of irregularly curved lines; these are the contour lines, and each such line has a number marked on it. Assuming that every contour line represented a path, and that one were to walk along one of these paths, he would be always at the same elevation above sea level, so long as he did not step out of the path. According to the legend, the contour interval is 10 feet; this means that the difference of level between any two consecutive contour lines is 10 feet. Evidently, then, when the lines are close together, as in the lower right-hand, or southeast, corner, the slope must be quite steep. Thus, if one starts from the line marked 1120 and goes north until he reaches line 1070 he will descend $1120 - 1070 = 50$ feet while walking a horizontal distance of about 270 feet. This will land him on a small plain, as indicated by the absence of any contour lines. Consequently, the farther apart the contour lines the more level the country; and the closer together they are the more hilly it is. Again, referring to the map, note that the ground between the words "Main Ore" and "Teck", which has a length of about 900 feet and a width of about 350 feet (as measured with the scale of feet), contains no contour lines; but, on the north side, it is bounded by the 1070 contour line and on the south side by the 1080 contour line. From this



it is known that this piece of ground is almost level, with a gentle rise to the south of 10 feet in a distance of 350 feet. Toward the east, at the word "Ore," the contours come close together; here the 10-foot rise takes place in a shorter horizontal distance, and the slope is steeper.

358. Sections.—This little map was made to show a part of the main ore zone of Kirkland Lake. Below the map, and to the right of the "legend," is a section taken along the line *HJ* of the Main Ore Zone, and following the dip. This section shows how the ground would look if a thin vertical slice were taken to a depth of 300 feet above sea level (the depth is shown by the scale on the left of the section and also by the note, Datum 300 feet above sea level, in the sectional view). The scale indicates that at *H*, the elevation is about 1125 feet, and that it is about 1040 feet at *J*; note that these heights agree with the elevations indicated by the contour lines near these points. At the left of the map is another section, which has been taken along the line *KL*, very nearly at right angles to the other section. This section shows the angle that the dip makes with the horizontal. As will be noted, the dip is nearly vertical, or 90° . Referring to the longitudinal section, a note thereon states, the longitudinal section dips 80° south; this means that the thin slice forming the section is not situated perfectly vertical, but slopes toward the south. The other section (cross section) is vertical, which fact is indicated by the wording. "Vertical Section *K-L*," which means a vertical section taken in the direction of the line *KL*.

359. Irregularities in Staking Claims.—When a claim is laid out by locating the directions of the bounding lines with a compass, and determining their lengths by pacing off the desired distances, the results obtained may differ considerably from the true lengths and directions, as is well exemplified by the two claims here shown, Fig. 137. The prospectors who staked them intended that both these claims, the Kirkland Lake and the Orr, should be square claims, 1320 feet (one-quarter mile) on each side. The east and west sides were intended to run true north and south, and the north and south sides were intended to run true east and west; but a glance at the map will show how far they came from attaining their object.

SURFACE INDICATIONS

360. Geology of the Area.—The search for mineral deposits can be made to produce better results if special attention is given to certain surface appearances. Experience has shown that minerals sought for in a known area are distributed in definite relations to the rocks of that area. The valuable deposits should be searched for in the zones thus determined by the geologist. The geological map should be carefully studied by every member of the party who is competent to do this. The mineral belts, or zones, are exceptional tracts of country; outside of these tracts, the country may be barren. For example, the gold belts of Northeastern Ontario and Northwestern Quebec are cut off on the east by a wide stretch of barren granite. In British Columbia, there is

a great granite batholith, around the edges of which are found many valuable mineral deposits, but within which, the country is mostly barren; although mineral deposits have been found around "islands" of sedimentary rocks, which are inside the general contact line of the granite and sediments. This matter is further discussed in Arts. 368 - 371.

361. Veins.—Many of the mineral deposits found in Canada occur in veins or similar structures. These often show at the surface, with the characteristic minerals visible; or, the minerals may be seen on breaking the surface material. Examples are: gold-bearing quartz veins; the calcite veins of the Cobalt silver area; the fluorspar veins of the Madoc area; and some lead and zinc ores in British Columbia.

The first discoveries are usually made by reason of such easily seen outcrops; after these have been staked, comes the harder task of finding veins not so easily visible. This is accomplished by uncovering rock in the most likely places, by removing moss, and by trenching. Since most of the veins in any one area usually run in the same general direction, trenching should be done systematically across this general direction. If the vein material were such as to be easily removed by weathering, the position of the vein may be marked by a longish hollow, which may be somewhat ditch-like. On the other hand, veins with quartz as filling may stand up as straight ridges or dikes. The covering of hidden veins, as well as of ore bodies of other descriptions, often gives indications of what is beneath, see Art. 362.

362. Capping and Stains.—The materials constitut-

ing capping, or gossan, and stains are secondary minerals that are formed by the weathering of the valuable minerals sought for or of minerals that accompany them. The commonest of these products of weathering is iron rust or limonite, which results from the weathering of pyrite, pyrrhotite, copper pyrites, zinc blende, and other sulphides containing iron. It should not be forgotten, however, that a rusty stain or capping may be due to the weathering of carbonate of iron, or even of basic rocks high in iron. Pyrite, pyrrhotite, and copper pyrites weather most rapidly; hence, iron capping, or gossan, as this material is called, is most likely to cover these minerals or the valuable ore deposits associated with them. The color of gossan is usually brown, but it is sometimes yellowish or reddish. The Sudbury copper-nickel ore bodies, the Anyox, B. C., copper ore body, and the Flin Flon ore body in Northern Manitoba, were discovered by means of gossan.

Other useful stains are: green carbonate of copper, malachite, and the less common blue carbonate, azurite; erythrite, or cobalt bloom, a pink or red mineral formed by the weathering of cobalt arsenides; and annabergite, or nickel bloom, the corresponding nickel mineral, which has a green color. In the silver areas of Northern Ontario, cobalt bloom has been the prospector's guide to many valuable discoveries; but, in a number of cases, the veins thus located have proved to be poor in silver. Cobalt bloom is often found in mineral districts that yield no silver; for example, it has been found in the Madoc area and has been noticed in the Rainy Lake district. In the Bird River area, Northern Manitoba, it is the surface indication of cobalt-nickel ores.

363. Float.—**Float** is mineral or rock that has been moved from its original position: (a) by sliding or rolling down hill; (b) by the action of streams; (c) by glacial action. In unglaciated country, float is traced back to its source by working up-hill or up-stream. In glaciated country, the source must often be sought in the direction from which the ice came, as indicated by glacial grooves. This information is often given on geological maps. Two or all three of these means of transportation may have been used in carrying a piece of float.

The float should be followed back until no more is found. If, at that point, the ore body is not discovered as an outcrop, a trench should be started and run in the same direction until the ore body is reached. The condition of the float gives some indication of the distance it has travelled. If sharp-edged and fresh-looking, it is probably not far from the ore body; if rounded and worn-looking, it may have traveled a long distance. Still, a piece of pyrite or other easily weathered material may owe its shape and appearance to weathering, and may be quite near its source. Float found in the beds of streams may have come from the steep banks or it may have been swept down stream by a swift current; it should be followed up stream and its banks should be examined at and above that point.

“In Nova Scotia, the gold-bearing veins and saddle reefs are in a district that has a wide-spread mantle of drift. The discoveries are made by first finding float, i. e., loose blocks of gold-bearing quartz in the drift; then, tracing back toward the direction of glacial advance, finding more float, until a point is reached where this ends (this distance is usually measured in hundreds

of feet, not miles); then trenching to bed rock, and finding the ore in place." (From "Notes by Members of the Geological Survey, Compiled by T. L. Tanton.")

In Gaspé, Quebec, lead-zinc ore bodies have been discovered by tracing float up-hill to its source. The higher parts of the Gaspé Peninsula escaped glaciation; so any movement of loose blocks of rock or mineral that has occurred there has been due to other causes. "The country is covered by heavy overburden, and, in consequence, outcrops are few. The presence of ore is usually detected by finding pieces of galena in the float. These sometimes form large rounded masses, weathered brownish; as a rule, they have not traveled far, and by trenching up-hill from such float, vein outcrops can usually be uncovered. In other cases, actual outcrops of veins are exposed. Most of these outcrops consist of chambered quartz, from which the zinc blende and often, also, the galena, has been leached. The quartz is white, or perhaps stained brownish; the amethystine variety, common underground, is usually bleached white in the surface exposures." (F. J. Alcock, Geological Survey, Summary Report, 1921, Part D, p. 89 D.)

364. Panning.—Panning is used in tracing back fine grained material to its source. "This is quite analogous to float tracing. There are some special features about this, however, that require mention, particularly, since two different kinds of information may be sought by the method: first, tracing the transported material back to its source in ledge; and, second, the discovery of placer, that is, ore in the loose material. In the first case, the method is to work back along the direction of

glacial advance or up-hill, as the case may be, until the showing ceases; then dig, as in the case of float tracing. By this method, the tungsten deposits of the Yukon are found. In the second case, the most favorable surface indication is rusty-looking gravel in which the pebbles are well weathered, in the bed of old streams in known mineralized districts. The prospector is not so much concerned with the surface gravel, but attempts to do his panning on the bottom, or lower, bed near bed rock. Even if gold or platinum be not found by the preliminary panning operations, it is considered a favorable indication to find a residue of galena, garnet, or other heavy minerals. In the Cariboo district, B. C., the gold-bearing gravels have a pronounced rusty appearance." (T. L. Tanton.)

365. Magnetic Attraction.—If the prospector's compass varies to a considerable extent from the magnetic north, this may indicate the presence of bodies of magnetite or pyrrhotite. A special instrument, the **magnetometer**, has been devised to measure the attraction that is exerted by such bodies. "As yet, however, no important iron-ore body is known to have been found in Canada by the aid of this guide, though information of a potential value regarding occurrences of magnetite and titaniferous magnetite has been obtained. In mineralized areas, where the sought-for ore is known to be associated with pyrrhotite, magnetometric surveys have been used as prospecting guides in the drift-covered areas. The results of these surveys indicate the positions where concentrations of magnetic minerals occur; and if there is reason to believe that the mineral which

causes the abnormal variation is pyrrhotite, the position of such concentration is a desirable place to search for the associated ore. In the Sudbury district, the Mond Nickel Co. met with notable success in thus exploring for copper-nickel ore in Levack Township. Elsewhere, in the same general area, however, many unsuccessful attempts have been made to locate copper-nickel ore, on the basis of magnetometric surveys over drift-covered areas." (T. L. Tanton.)

366. Topographic Features.—By topographic features is meant the appearance of the surface of the country as made by hollows, hills, trench-like depressions, ridges, etc.

The asbestos veins of the Thetford-Black Lake district usually occur in the small shallow trenches that crisscross through serpentine rock. These trenches should be examined very carefully, because the asbestos may be hidden by the dirt that fills them.

Large natural trenches sometimes show the position of weathered-out veins in the Cobalt district and South Lorrain areas. Fault-line scarps, that is, precipices or cliffs formed by faulting, are favorable places to search for veins, which are often found at the base of the scarp or cliff. Examples of this are seen at Thunder Cape and other places in the Silver Islet area, Ontario; the Casey-Cobalt is another example.

The talc deposits of the Ottawa Valley are found in smooth-sided pits, which are characteristic topographic features.

The fluorspar veins of the Madoc area often occur in depressions; and on the surface of the veins, there is a

gravel composed of granular fluorspar, barite, and calcite.

In all these cases, the depressions are caused by the easy weathering of the vein matter. In other cases, the vein filling may resist weathering to a greater extent than the country rock does, and thus form a ridge.

367. Rock Associations of Minerals.—Some valuable minerals are found usually or exclusively in particular rocks. Thus, serpentine rocks are the home of asbestos, chromite, magnesite, diamonds, and platinum. Asbestos and chromite are found in workable quantities in the serpentine rocks of the Black Lake-Thetford area, Quebec. "The serpentine rock where asbestos is found is rusty on the weathered surface, and is traversed by depressions of lighter-colored material; in these depressions are found the veins of asbestos. Commonly, there is a fluff on the asbestos, which causes dirt to cling; but at certain places, where the covering is very thin, the characteristic silky luster shows through, when viewed at the proper angle. In certain localities, the serpentine rock is but slightly weathered, and the green or yellowish-green color of the rock is a striking feature. On this slightly weathered rock, the asbestos is recognized by its peculiar physical properties. There are no distinctly colored gangue minerals, such as quartz or calcite, in asbestos veins. The "slip-fiber" asbestos occurs along certain joints of the serpentine rock; and should this be the first observation of the prospector, — it is a guide in the search for the transverse-fiber asbestos." (T. L. Tanton, Geological Survey, Ottawa.)

Attention should be given to rocks other than those

associated with the valuable minerals that are being specially searched for. For instance, in Northeastern Ontario, serpentine rocks are frequently met with in the gold fields; these rocks may be productive of asbestos, chromite, nickel ore, magnesite, platinum, or diamonds. The prospector in that region should therefore be acquainted with serpentine rock and with the valuable minerals that may be found in it.

368. Geological Relationships.—Geological relationships are a guide to prospecting; and since these are determined by the study of outcrops, they should be included in the study of surface indications. Examples: A number of valuable minerals are found in the Ottawa Valley region, at the contact between crystalline limestone and intrusive rocks, such as pegmatite. "The graphite deposits occur in masses and zones in the Grenville limestone, at the contact with gabbro, anorthosite, pegmatite, and rocks of intermediate type. The mineral association in the deposits are pyrite, pyrrhotite, pyroxene, scapolite, calcite, and sphene. The deposits are commonly in a rusty-colored depression, in which there is usually loose, granular, rust-coated pyroxene, and calcite. At Calabogie, the fresh unaltered material appeared on the glaciated surface." (T. L. Tanton, Geological Survey, Ottawa.)

369. "Magnesite is found in Grenville limestone in large irregular masses, more or less intimately associated with dolomite. The associated minerals in the deposits are serpentine, white diopside, and phlogopite in fine flakes. On the weathered surface, it appears white or buff, and shows a peculiar pitting due to the

removal of the associated dolomite." (T. L. Tanton, Geological Survey, Ottawa.)

370. "Molybdenite occurs as pegmatite segregations in syenite and quartz-syenite. At Quyon, Quebec, it is associated with pyrite and fluorite in syenite. On that part of the surface which appears freshly glaciated, these minerals appear in their unaltered state; elsewhere, the deposit has the appearance of a greenish-gray, rusty rock. The surrounding rock is pink. Molybdenite also occurs at the margins of Grenville limestone, in granite, gneiss, or pegmatite. These concentrations of molybdenite are disseminated along with pyrite and pyrrhotite through a deep-green pyroxenite." (T. L. Tanton, Geological Survey, Ottawa.)

Commercial deposits of feldspar are in coarse-grained pegmatite dikes, which appear white on the surface, the quartz glassy, and the feldspar porcelain-white by weathering. These dikes sometimes cut through granite or gneiss, in which case, the feldspar is pink beneath the surface. Other dikes are in crystalline limestone; the feldspar in these is white throughout.

371. The gold veins of Northeastern Ontario and Northwestern Quebec are found at or near the contact of Timiskaming sedimentary rocks, with intrusive porphyry, granite, and syenite. "Gold deposits, which are found in numerous localities in the province, from the Quebec boundary on the east to that of Manitoba on the west, are, in many cases at least, genetically connected with granites to which the name Algoman is applied. In a few cases, the granites are represented by more basic rocks. The gold deposits are found chiefly

in Keewatin schists, but a few occur in Timiskamian elastics¹. It is worthy of note that the only gold deposits of the province that have been proved to be of great economic importance are found in, or in the vicinity of, these Timiskamian fragmental rocks." (Miller and Knight, Report Ontario Department of Mines. Vol. XXIV, Part I, 1915, p. 245.)

"The gold deposits of Boston Creek supply another example of gold being derived from acid intrusions of the Algonian age. The granite, syenite, and feldspar-porphry exposed in this area by erosion are probably different facies [variations] of a plutonic rock that underlies the whole area. The gold generally occurs near these acid rocks. The presence of a number of gold-bearing veins along the contact of the intrusive porphyry and older rocks at Boston Creek, as in many other parts of central Canada, and the frequent occurrence of auriferous quartz veinlets in the porphyry and granite, suggest the relationship between the intrusives and the veins." (A. G. Burrows and P. E. Hopkins, Report Ontario Department of Mines, Vol. XXX, Part VI, 1921, p. 9.)

HANDLING DISCOVERIES

372. Sampling and Assaying.—A prospector sometimes fails to reap the full advantage, or even *any* advantage, from a discovery, because of his manner of handling it. The first step is to ascertain the value of the mineral deposit; in most cases, this must be done

¹ Composed of broken pieces; the word refers to conglomerate, etc.

by having assays made. As a preliminary, a selected sample of the best looking material may be sent to the assayer, the object being to find out if the discovery is of any value; but if the result of this assay be favorable, no more sampling should be done with specially selected samples. Samples should correctly represent the entire body of ore, and it is a waste of time and money to have selected pieces assayed.

373. Channeled Samples.—Channeled samples should be taken, when possible. This is done by cutting a channel across the ore body, about 2 inches wide and $\frac{1}{2}$ inch deep, using a sharp-pointed steel tool, called a **moil**. A tarpaulin or a piece of canvas (oilcloth is best) should be kept spread out, so as to catch the flying chips. The whole sample so made is then crushed with mortar and pestle, thoroughly mixed, spread out on the cloth, divided into quarters, and the diagonally opposite quarters are taken out and crushed finer; this operation of crushing and quartering is repeatedly performed, until the sample is reduced to a size that is convenient to send to the assayer. The samples should be marked with a number, and a record kept concerning them. A duplicate sample should be retained, in the case it be desired to have the assay repeated. When the valuable mineral is mostly invisible, as in the case of gold-bearing quartz, many assays are required to thoroughly test the value of the discovery.

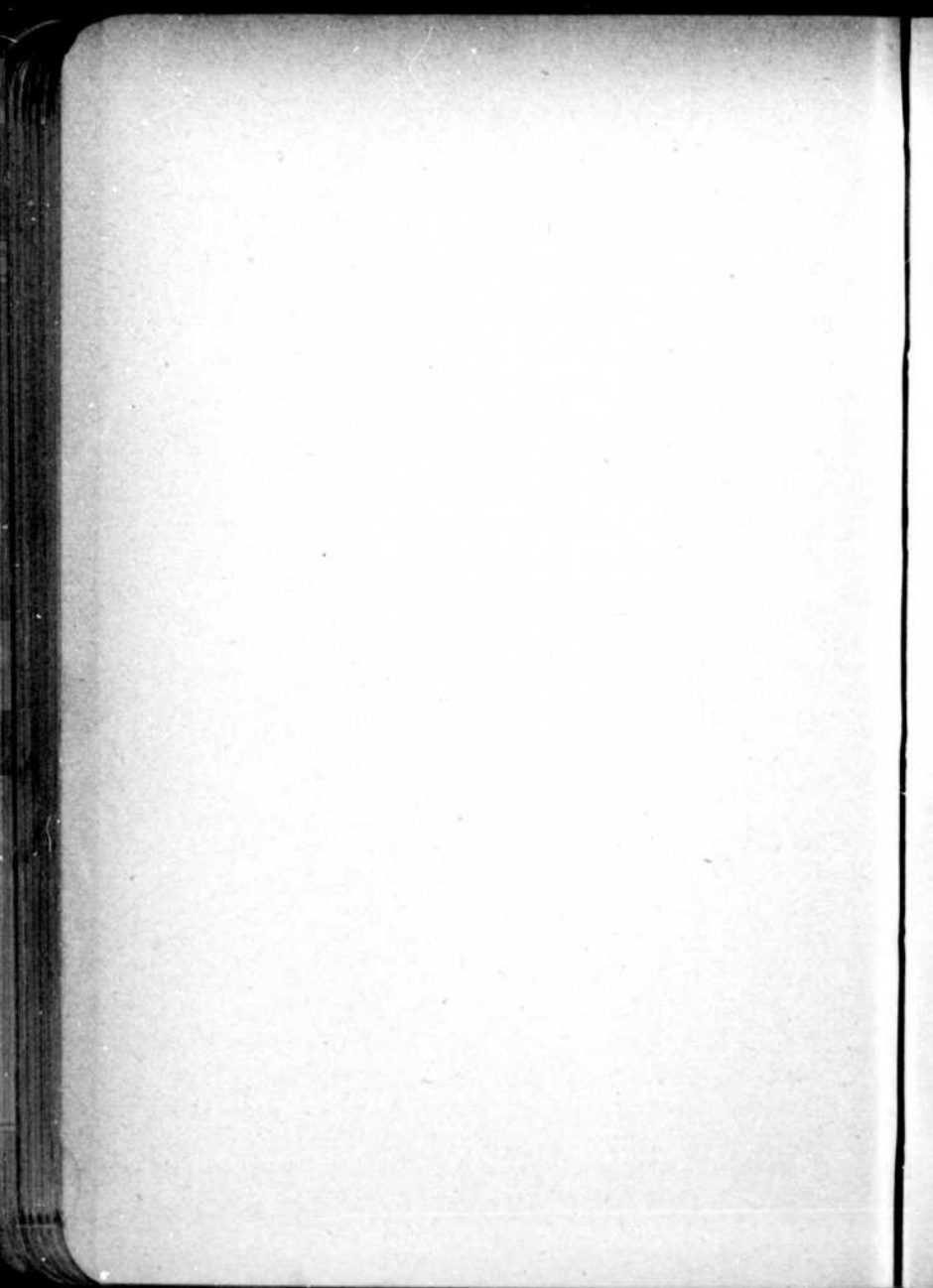
On the other hand, the mineral may, perhaps, be easily seen and its quantity judged, and assays to determine the richness of the ore may, at first, be unnecessary. For instance, a discovery of galena can often be

judged quite closely by the eye, as to the proportion of ore to rock. The first thing to find out through assays of the galena is the number of ounces of silver in a ton of the ore; this will show whether the ore is simply lead or silver-lead. Again, if iron ore is discovered, its richness can be fairly well judged by its weight; but its freedom from sulphur, phosphorus and other objectionable impurities must be determined by the chemist.

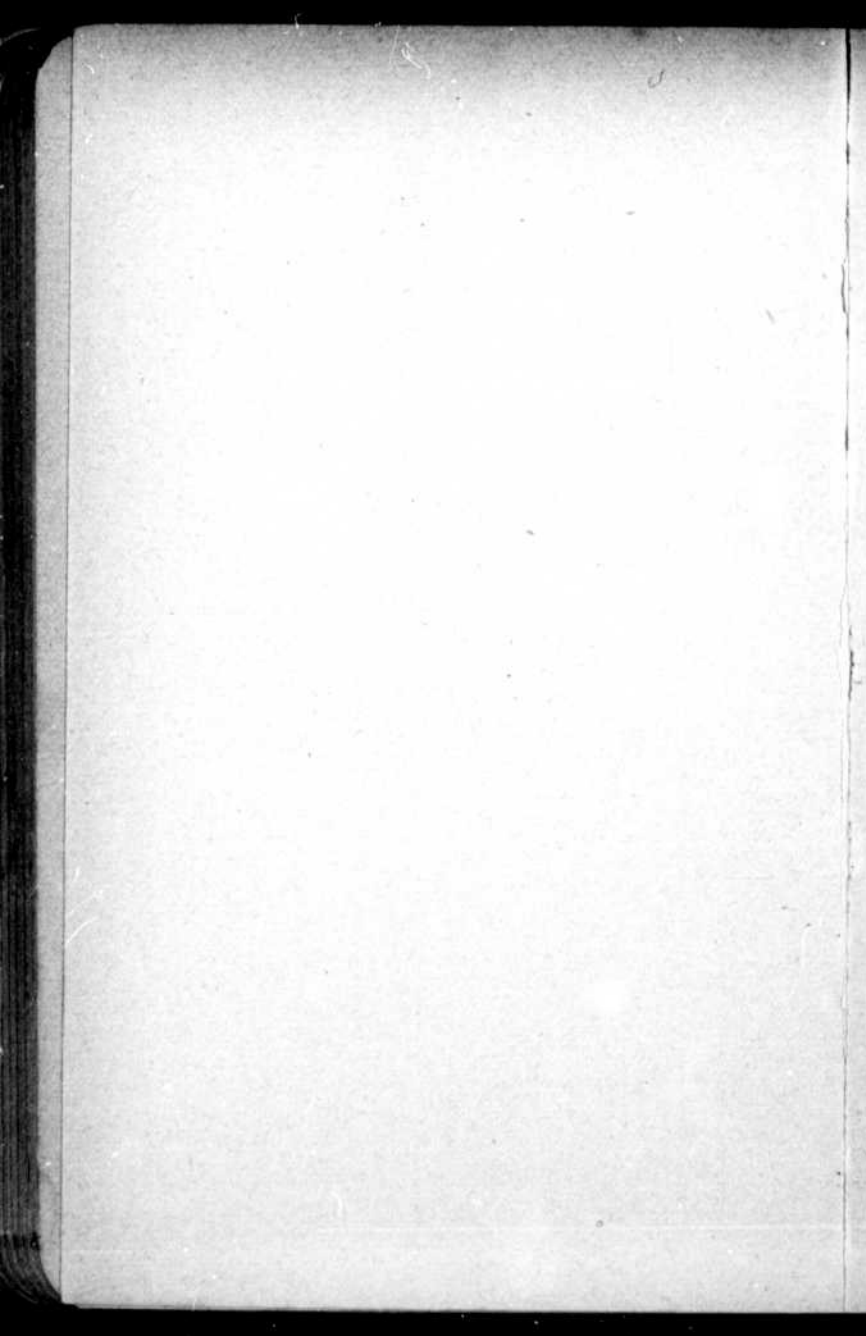
374. Duplicate Samples.—Prospectors sometimes do injustice to assayers by sending samples as duplicates that are not really such. Two pieces of ore obtained by breaking from a larger piece are not necessarily of the same value; pieces of gold ore that look exactly alike may have different values in gold. In fact, samples are not really duplicates unless prepared as described in Art. 373.

375. Development of a Discovery.—Whenever a discovery of valuable mineral has been made, surface development should be carried on to as great an extent as is possible. It is easier and cheaper to get information in this way about the extent and value of the ore body, than to get it by sinking a shaft. The vein, or other ore body, should be stripped as far as it can be followed. Where the overburden is too deep for such work, cross trenches at intervals may be practicable; and other veins may be discovered while trenching. It can be assumed as a general rule, to which, however, there are exceptions, that the ore body will show the same variations in size and values along the surface that will be found when going down through it. There are cases where a vein shows only its apex at the surface, sometimes as a mere

thread of quartz or other gangue, which expands from the surface down. In other cases, the discovery may be the opposite of this, the bottom or root of an ore body that pinches out at a small depth. Even in these cases, the chances of getting reliable information by stripping or trenching are good. A safe method of procedure is to strip, trench, sample, and assay. Test pits may be sunk, to show what the ore is like below the action of weathering; but, generally, the sinking of a shaft should be left to the investor. By surface work, the prospector puts his property in condition for examination by an engineer; and it should be remembered that the engineer has no greater ability to see through the overburden than the prospector has. It is the prospector's work not only to discover valuable minerals but also to prepare the surface of his property for examination by the engineer.



Era or Group		Period or System	Great Events
Cenozoic	Quarternary	Recent Glacial (Pleistocene)	Extensive glaciation of northern part of North America.
	Tertiary	Pliocene	
		Miocene	Lignite in B. C., Alta., Sask., Man.
		Eocene	Mercury in B. C. Rocky Mts. uplifted.
Mesozoic, or Secondary	Age of Reptiles	Cretaceous	Lignite in Alta, Sask. Anthracite and bituminous coal in B. C.
		Jurassic	Folding in Rocky Mts.; Selkirk and Purcell ranges formed. Intrusions of granite. Silver-lead ores deposited in pre-Cambrian.
		Triassic	
Paleozoic or Primary	Age of Amphibians	Permian	
		Carboniferous	Oil shales and coal in N. B. and N. S. Gypsum in N. B. and N. S.
		Devonian	
	Age of Fishes		Construction of Appalachian Mts. in eastern Canada, and intrusion of granite batholiths in B. C. and Alberta.
			Granite intrusions and formation of gold veins in N. S. Zinc-lead deposits in Gaspè. Gypsum in Man. Iron ore in N. S.
Eozoic, or pre-Cambrian	Age of Invertebrates	Silurian	Salt, gypsum, and petroleum in Ontario.
		Ordovician	
		Cambrian	Long period of erosion.
	Dawn of Life	Keeweenawan	Sedimentation and igneous activity. Deposition Sudbury copper-nickel ores; cobalt-silver ores; gold in Ontario.
		Animikean	
		Algoma	Deposition of Cobalt series, Ontario, and of iron formation, Ontario.
		Timiskamian	Intrusion of granite and gneiss. Deposition of gold in N. E. Ontario and in Quebec.
		Grenville	Deposition of Timiskamian series in Ontario and Quebec.
		Keewatin	Deposition of Grenville limestone, etc. and of extensive iron formation, Ontario.
			Extensive lava flows, Ontario.



PROSPECTING

(PART 3)

EXAMINATION QUESTIONS

(1) (a) What is an ore? (b) Give three examples of mineral deposits that are not ores.

(2) (a) What are the principal valuable substances found in pegmatite dikes? (b) Account for the large size of the crystals often found in these dikes.

(3) Define: (a) vein; (b) hanging wall; (c) foot wall; (d) gouge; (e) vug; (f) vein matter; (g) gangue; (h) fault; (i) shear zone.

(4) How is the direction of fracture influenced by the kind of rock?

(5) (a) Describe the way in which ore is supposed to have been deposited in veins. (b) Mention some of the minerals that indicate by their presence the deposition of ore at high temperature.

(6) Define: (a) lode; (b) vein system; (c) bedded vein; (d) stock; (e) saddle reef.

(7) What is the nature of contact-metamorphic deposits, and where are they found?

(8) (a) What is a placer deposit? (b) What valuable minerals are found in placer deposits?

(9) Describe the two ways in which an ore body may be enriched by weathering, and give six examples.

(10) Mention six minerals that are commonly found in gold veins.

(11) Define (a) strike-fault, and (b) dip-fault. Make sketches showing how such faults may affect an ore body.

(12) (a) Describe how gold placers are formed. (b) Account for the fact that rich placers are sometimes found much above the present level of streams. (c) What are the principal minerals found with placer gold? (d) What properties of these minerals account for their presence with the gold?

(13) (a) What class of rocks are most favorable for gold veins? (b) With what kinds of igneous intrusive rocks are gold veins usually associated? (c) In what way are the country rocks usually altered near the veins?

(14) Describe the two principal classes of silver ore found in Canada.

(15) Give the names and composition of the principal ores of copper, and account for the fact that some of them form a rusty capping by weathering.

(16) (a) What is the composition of pyrrhotite? (b) discuss it as an ore of nickel. (c) What other ores of nickel have been mined in Canada?

(17) (a) Name the ores of iron, and state their composition. (b) How large must be an iron-ore body

to be of importance. In your answer, refer to tonnage, and compare it with a gold or silver vein.

(18) What important minerals are found in serpentine and peridotite?

(19) (a) In what rocks is molybdenite found? (b) In what rocks is graphite found in quantity? (c) How can these two minerals be distinguished.

(20) In what rocks is tinstone found? make your answer as complete as you can.

(21) (a) In what kind of ore body is fluorspar usually found? (b) For what is fluorspar used. (c) State the requirements as to impurities.

(22) Describe the commercial varieties of talc, and mention their uses.

(23) (a) In what rock formation is feldspar of merchantable quality found, and what are its chief uses? (b) What are the requirements for a feldspar quarry?

(24) (a) Describe the two kinds of commercial mica; (b) in what rocks are they found?

(25) In what age of the earth did important beds of coal begin to be formed? (b) Is coal likely to be found in rocks of an earlier time?

(26) (a) Write a short account of diamonds, mentioning the rocks in which they are found. (b) State why they should be looked for when panning for gold, and how they may be identified.

(27) How may glacial grooves be used as an aid in the discovery of mineral deposits?

(28) Describe the surface appearances that may indicate the presence of a vein.

(29) Mention the ores that may underlie a capping of gossan.

(30) Describe: (a) copper stains; (b) cobalt bloom; (c) uranium ocher.

(31) If you found a piece of valuable float, how would you proceed to search for the mineral deposit from which it came?

(32) In what way is it useful to the prospector to have a knowledge of geology of the district in which he is prospecting?

INDEX

A

Acid dikes, 160
 Actinolite, properties of, 67
 Adularia, 63
 Agate, 54, 270
 Alabaster, oriental, 59
 Alamandine, 71
 Albite, 64
 composition of, 255
 Alexandrite (gem), 266
 Allanite, 247
 Altaite, 38
 Aluminum, ore of, 248
 Alundum, 51
 Amazonstone, 64, 66, 272
 Amber, properties and occurrence, 30
 Amber mica, properties and occurrence, 76
 sources of, 257
 three kinds of deposits of, 257
 Amethyst (gem), 270
 Amphibole, 66
 Amphibolite, 167
 Amygdaloid basalt, 171
 Andalusite, properties, 74
 Andesine, 64
 Andesite, 172
 Anglesite, 84
 Anhydrite, 85
 mistaken for gypsum, 262
 Ankerite, 61
 as an ore of iron, 233
 Annabergite, 39
 Anorthite, 64
 Anorthosite, 167
 Anthracite, 29
 Anticline (def.), 150
 Antimony, gray, 36
 ores of, 229
 Antimony glance, 36

Apatite, Properties and uses, 31
 sources of, 250
 Aplite, 165
 Aquadag, 28
 Aquamarine, 265
 Argentite, properties, 38
 Arkose, 145
 Arsenic, properties and occurrence, 26
 sources of, 230
 Arsenide (def.), 31
 Arsenopyrite, 40
 Asbestos, sources of, 252
 where found, 303
 Asbolite, 52
 Asphalt, 30
 Assaying ores and minerals, 306
 Atomic weights (def.), 17
 Augite, properties of, 67
 Aventurine, 54, 272
 Azurite, properties of, 62

B

Barite, or barytes, properties, uses, etc., 83
 sources of, 251
 Basalt, 170
 amygdaloid, 171
 ellipsoidal, origin of, 157
 Bases (def.), 63
 Basic dikes, 160
 Batholiths (def.), 162
 Bauxite, properties and occurrence, 50
 sources of, 248
 Bedded vein (def.), 200
 Benches, river, 116
 Beryl, gem, 265
 properties, 70
 Bessemer limit (def.), 234
 Biotite, 77

- Bismuth, properties of, 26
 Bismuthenite, properties and uses, 37
 Bituminous coal, 29
 shale, 145
 Blackjack, 41
 Black lead, 28
 mica, 77
 Bloodstone, 54
 Blue billy, 32
 Bog manganese, 52, 240
 ore, 46
 Bornite, 34
 Bort, 27
 Boss (def.), 162
 Bournonite, 36
 Bowlder clay (def.), 107
 Braunite, 240
 properties, 53
 Brazilian pebbles, 54
 Breaks (def.), 152
 Breccia, 143
 veins, 203
 Breithauptite, 41
 Brick clay, 261
 Bridges, natural, 113
 British Columbia, gold in, 218
 silver in, 222
- C
- Cairngorm, 270
 Calamine, 74
 Calaverite, 39
 Calcareous marl, 59
 Calcite, properties, 58
 uses and varieties, 59
 Calcspar, 58
 Camp, landmarks for a, 279
 Canoe prospector, 279
 Carnotite, where found, 246
 Canyon, 112
 Cape diamonds, 54
 Capping (gossan) as mineral indications, 297
 Carbonado, 27
 Carbonates (def.), 58
 formation of, 134
 Carbonic acid, effect of, in weathering, 134
 Carnotite, 81
 Cassiterite, 48
 Cat's eye, 64, 266
 Caves, 116
 Celestite, 84, 251
 Cerargyrite, 56
 Cerium epidote, 247
 Cerussite, 62
 Chalcedony, 54
 Chalcocite, 35
 Chalcopyrite, 33
 Chalk, 59, 146
 French, 79
 red, 45
 Channeled samples, 307
 Chatoyant effect, 266
 Chemical weathering, 133
 Chert, 55
 ferruginous, 236
 Chimney (def.), 202
 China clay, 79, 261
 Chloanthite, 39
 Chlorastrolite, 272
 Chlorite, 77
 Chromite, 47
 Chromium, 241
 Chrysoberyl, 266
 Chrysolite, 71, 266
 Chrysoprase, 54
 Cinnabar, 38
 Cinnamon stone, 71
 Claims, development of, 308
 irregularities in staking, 296
 staking and recording, 290
 Clay, bowlder, 107
 China, 79, 261
 ironstone, 61
 origin and use, 261
 Copper, properties and occurrence, 25
 Copper glance, 35
 ore, deposits of, 230
 gray, 35
 red, 53
 pyrites, 33
 Coral, 146

Corundum, 49
 Country, or country rock
 (def.), 194
 Crater (of volcano), 153
 Crocidolite, 271
 Crush zone (def.), 195
 cause of, 202
 Cryolite, 57
 Crystalline limestone, 176
 Crystal systems, 11
 Crystals, cubic (or regular)
 system, 11
 hexagonal system, 13
 how formed, 10
 monoclinic system, 14
 orthorhombic system, 13
 tetragonal system, 12
 triclinic system, 14
 Cuprite, 53

D

Dark-red silver ore, 38
 Deep weathering, 137
 Dental spar, 65
 Derbyshire blue john, 57
 spar, 84
 Diabase, 167
 Diallage, 68, 167
 Diamond (gem), 264
 Cape, 54
 properties and occurrence, 27
 Diary, importance of keeping
 a, 283
 Diaspore (gem), 266
 Diatomaceous earth, 259
 Dichroic (def.), 269
 Dikes (def.), 159
 basic, acid, granite, 160
 Diopside, 68
 Diorite, 166
 Dip (def.), 150
 (of fault), 210
 (of vein), 194
 Dip-fault (def.), 210
 Distances, judging, 230
 Dog-tooth spar, 59
 Dolerite, 167

Dolomite, 59
 Dolomitic limestone, 176
 Drag ore, 211
 Drift (def.), 107
 Druse (def.), 194
 Dunite, 168
 Duplicate samples, 308
 Dyscrasite, 40

E

Earth, origin of, 103
 structure of, 103
 surface of, 104
 weight of, 104
 Earthquake, one cause of, 152
 Earth's crust, movements
 of, 146
 Electrum, 23
 Elements, chemical (def.), 16
 list of, 90
 native (def.), 19
 Ellipsoidal basalt, 157
 Emerald, 70, 265
 Emery, 50
 Enstatite, 68
 Epidote (gem), 271
 properties, etc., 72
 Epsom salts, deposits of, 262
 Epsomite, 85
 Eras, life, 109
 Erosion, forces causing, 110
 by glaciers, 125
 by waves, 118
 Erythrite, 39
 Eskers (def.), 127
 Euxenite, 81

F

Fahlband (def.), 202
 False topaz, 54
 Fault (def.), 153
 strike of, dip of, 210
 oblique, normal, reverse, 210
 Faults (def.), 195, 210
 Feldspar, commercial deposits
 of, 305
 commercial, source and uses
 of, 256

- requirements of, for industrial uses, 255
 uses of, 65
 Feldspars, acid and basic, 65
 composition of, 255
 plagioclase, 64
 properties of, 63
 Feldspar-porphry, 173
 Felsite, 169
 Ferro-cerium, 247
 -manganese, 51
 Ferruginous chert, 235
 Fireclay, 261
 Fissure veins, 199
 Flats (def.), 203
 Flexible sandstone, 55
 Flint, 54
 Float, tracing to source, 299
 Fluorite, 56
 Fluorspar, as ornamental stone, 272
 properties, etc., 56
 (or fluorite), where and how found, 251
 Folding (of earth's crust), 149
 Food, well-cooked, importance of, 278
 supply, importance and amount of, 277
 Footwall (def.), 194
 of fault, 210
 Foraminifera, 145
 Fossil (def.), 109
 flour, 259
 Fracture (def.), 14
 conchoidal (def.), 15
 uneven, hackly, or granular, 15
 Fractures, cause of, 195
 direction of, 196
 Franklinite, 45
 French chalk, 79
 Fuller's earth, 260
- G
- Gabbro, 167
 Gadolinite, 247
 Galena, 35
 Gangue (def.), 191
 Garnet (gem), 268
 (def.), and properties, 70
 occurrence, 71
 sources and commercial uses, 259
 Garnierite, 79
 Gas, natural, where found, 263
 Gash veins, 203
 Geological relationships, importance of, in prospecting, 304
 survey reports and maps, 290
 Gerdorsfite, 39
 Geysers, 157
 Glacial drift, 128
 period, 128
 streams, work of, 127
 Glacials, deposition by, 127
 erosion by, 125
 front end of, 125
 motion of, 124
 origin of, 122
 practical results of, 129
 work of, 125
 Glauber's salt, 85
 Gneiss, 178
 Gold, minerals associated with, 214
 panning for, 220
 placer deposits of, 212
 properties etc., 23
 Gold in British Columbia, 218
 in conglomerate, 218
 in country rocks, 216
 in Ontario, 216
 in Quebec, Nova Scotia, Manitoba, 217
 veins, 215
 location of, 305
 Gossan, formation of, 135
 G  thite, 47
 as an ore of iron, 233
 Gouge (def.), 194
 Granite, 165
 graphic, 65, 166
 dikes, 160
 -porphry, 173

Graphite, properties, 28
 uses and sources of, 244
 Gray antimony, 36
 copper ore, 35
 Graywacke (def.), formation
 of, 143
 Greenalite, 236
 Greenstone, 167
 Greisen, 49, 166, 245
 Ground moraine, 127
 Group I—Native elements, 23
 II—Sulphites and arsen-
 ides, 31
 III—Oxides, 42
 IV—Chlorides, fluorides,
 etc., 56
 V—Carbonates, 58
 VI—Silicates, 63
 VII—Phosphates, etc., 81
 VIII—Sulphates, etc., 83
 Gypsum, properties, etc., 84
 sources of, 262

H

Hackly fracture (def.), 15
 Halite, 56
 Hanging wall (def.), 194, 210
 Hard manganese ore, 52
 Hardness (def.), 6
 scale of, 7
 testing for, 7
 Heat and cold, weathering
 effects of, 131
 Hematite, micaceous, 45
 properties, etc., 45
 specular, 45
 where found, 234
 Hemimorphite, 74
 Hercynite, 50
 Hiddenite, 68, 271
 Hornblende, 66
 common, properties, etc., 66
 Hornblendite, 167
 Horn silver, 56
 Hornstone, 54
 Hübnerite, ore of tungsten, 241
 Hyacinth (gem), 269

Hydraulic limestone, 59
 Hydroamagnesite, 60, 254
 Hypersthene, 68, 167

I

Ice, changes caused by, 122
 Iceland spar, 59
 Igneous rocks (def.), 108
 characteristics of, 163
 classes of, 164
 color of, 163
 Ilmenite, properties, etc., 44
 ores of, 239
 Infusorial earth, 55, 259
 Intruders (def.), 159
 Iridosmine, 26
 Iron capping, formation of, 135
 formations, 235
 ore-bodies, origin of, 236
 ore, spathic, 238
 ore, titanite, 44
 ores, 233
 ores, impurities in, 233
 pyrites, properties, 31
 pyrites, white, 32
 spar, 60
 Ironstone, clay, 61

J

Jacinth (gem), 269
 Jade, 270
 Jadeite, 68
 Jamesonite, 36
 Jasper, 54, 270
 Jaspilite, 235
 Joints (def.), 195
 Judging distances, 280

K

Kalgoorlite, 38
 Kaolin, 79
 Kaolinite, 79
 Kettles (def.), 112
 Kidney ore, 45
 Knife, manner of using point
 of, 20

L

- Labradorite, 64
- Laccoliths (def.), 161
- Lamina (def.), 140
- Lampadite, 52
- Landmarks for camp, 279
- Lapis-lazuli, 69
- Lateral moraine, 127
- Lava, 153
 - pillow, origin of, 157
 - flows, 155
- Lazulite, 69
- Lead and zinc, 224
 - ore minerals of, 225
 - in Ontario, 226, 228
 - in Quebec, 226, 228
- Lead ore, white, 62
- Leucoxene, 44
- License, prospector's, 290
- Life eras, 109
- Lignite, 30
- Limestone, 59, 145
 - composition of, 146
 - crystalline, 176
 - dolomitic, how formed, 176
- Limonite, properties, etc., 46
 - sources of, 237
- Lines, contour, 293
- Lithographic stone, 59
- Lithopone, 252
- Local metamorphism, 175
- Lode (def.), 200
- Loadstone, 42
- Luster (def.), 6
- Lydian stone, 55

M

- Magma (def.), 192
 - rock, 104, 157
- Magmatic segregation, 192
- Magnesite, occurrence of, 304
 - properties and uses, 60
 - sources and uses of, 253
- Magnetic (def.), 9
 - pyrites, 34
 - used in two senses, 42

- variation, allowance for, 288
- Magnetism, testing minerals
 - for, 9
- Magnetite, contact depos-
 - its, 237
 - magmatic-segregation depos-
 - its, 237
 - properties, etc., 42
 - sedimentary deposits, 237
- Magnetometer, 301
- Malachite, 62
- Manganese, ores of, 240
 - where found, 239
- Manganese ore, 51
 - ore, hard, 52
 - spar, 61
 - steel, 51
- Manitoba, gold in, 218
- Map, sample, 292
- Map reading, 291
- Maps, geological survey, 290
 - what they show, 291
- Marble, 59
 - onyx, 59
 - serpentine, 78
- Marcasite, 32
- Marl (def.), 80
- Massive garnet, 259
- Mechanical action of winds, 131
- Mercury, where found, 229
- Mesothorium, 247
- Metallic luster (def.), 6
- Metamorphic deposits, con-
 - tact, 202
 - rocks, 108, 175-181
- Metamorphism (def.), 174
 - local, regional, contact, 175
- Meteoric waters (def.), 203
- Mexican onyx, 59
- Mica, amber, properties, etc., 76
 - muscovite or white, 75
 - two classes of, 257
 - black, 77
 - vanadium, 247
 - white or amber, 257
- Mica plate, 76
- Micaceous hematite, 45
- Microcline, 64

Micanite, 76
 Mineral (def.), 1, 4
 pure, 16
 testing a, for hardness, 21
 for weight, 31
 Mineral deposits, 191
 age when formed, 208
 classification of, 192
 connected with intrusive
 igneous rocks, 197
 Mineral tables, 91-97
 how to use, 87
 purpose of, 86
 Mineralization, 219
 Minerals, characteristics of, 4
 chemical changes in, 18
 color of, 5
 division into groups, 19
 in igneous intrusions, 198
 of the rare earths, 247
 primary and secondary, 77
 streak of, 5
 testing, for magnetism, 9
 testing weight of, 8
 Mirabilite, or Glauber's salt, 85
 Mispickel, properties, etc., 40
 sources of, 230
 Molybdenite, occurrence of, 305
 properties, etc., 37
 resembles graphite, 243
 Molybdic ocher, 243
 Molybdite, 243
 Monazite, 247
 properties, etc., 81
 Moonstone, 271
 Mountain ranges, how formed,
 149
 Movements of earth's crust, 146
 Moraine (def.), 127
 Muscovite, properties, etc., 75
 requirements of, for use, 257

N

Nail-head spar, 59
 Native elements, 19
 Natural bridges, 113
 Natural gas, where found, 263

Nepheline-syenite, 68, 166
 Niccolite, 41
 Nickel, sources of, 231
 Nigrine, 53
 Nitrate, sodium, where found,
 263
 Norite, 167
 Normal fault (def.), 153, 210
 Notebook and diary, 283
 Nova Scotia, gold in, 218

O

Oblique fault (def.), 210
 Obsidian, 169
 Ocher, red, 45
 Offset (def.), 210
 Oil (petroleum), where found,
 263
 Oil shale, 145
 Oildag, 28
 Oligoclase, 64
 Olivine, properties, 71
 Olivine-diabase, 167
 -gabbro, 167
 -norite, 167
 -rock, 168
 Osmiridium, 26
 Ontario, gold in, 216
 lead and zinc in, 226, 228
 silver in, 221
 Onyx, 54
 marble, 59
 Mexican, 59
 Opal (gem), 270
 properties, 55
 Ophitic (def.), 167
 Orangeite, 70
 Ore (def.), 191
 deposition of, 197
 drag, 211
 Ore bodies, concentration of,
 by weathering, 205
 depth at which found, 199
 iron, origin of, 236
 residual, 205
 Ore deposition, great periods
 of, 208

- minerals of lead and zinc, 225
 - Ore deposition from solution, 206
 - by water from surface, 203
 - Ores, associated, 206
 - chemical deposition of, 204
 - mechanical deposition of, 204
 - Oriental alabaster, 59
 - Orthoclase, properties, 63
 - Outfit for two prospectors, 276
 - Outwash plain, 127
 - Oxygen, action of, in weathering, 127
- P
- Panning (in prospecting), 300
 - for gold, 213, 220
 - Parargyrite, 38
 - Parting (def.), 15
 - Patronite, 246
 - Peacock copper ore, 34
 - Peat, 30
 - Pegmatite, 165
 - dikes, 193
 - Peridot (gem), 268
 - Peridotite, 167
 - Perthite, 272
 - Petroleum, properties, 30
 - Petzite, 38
 - Phenacite (gem), 267
 - Phenocrysts, (def.), 169
 - Phyllite, 177
 - Phlogopite, 76
 - Phonolite, 169
 - Pillow lava, origin of, 157
 - Pisolithic structure (def.), 248
 - Pistacite, 72
 - Pitchblende, 81, 245
 - Pitches (def.), 203
 - Pitchstone, 169
 - Placers, gold occurrence of, 214
 - origin of, 213
 - Plagioclase feldspars, 63
 - Plasticity (def.), 260
 - Platinum, properties, etc., 25
 - sources of, 220
 - Plumbago, 28
 - Plutonic rocks, 165-168
 - Pocket garnet, 259
 - Porphyritic rocks, 172-174
 - Porphyry (def.), 28
 - Potash salts, where found, 262
 - Potholes, 112
 - Potstone, 79
 - Primary minerals, 77
 - Prospecting, necessity for thorough knowledge of, 273
 - systematizing the work of, 274
 - Prospector, the canoe, 279
 - typical day's work of a, 283
 - Prospectors, cooperation of
 - with miners, 276
 - outfit for two, 276
 - Prospector's license, 290
 - notebook and diary, 283
 - tools, 278
 - Proustite, 38
 - Psilomelane, properties, etc., 52
 - where found, 240
 - Pumice, 169
 - Pyrite, occurrence, 32
 - properties, 31
 - prospecting for, 249
 - sources of, 248
 - Pyrites, cock's comb, 33
 - copper, properties, etc., 33
 - magnetic, 34
 - Pyrolusite, properties, etc., 51
 - where found, 240
 - Pyromorphite, 83
 - Pyrope, 71
 - Pyroxene, 67
 - Pyroxenite, 167
 - Pyrrhotite, 34
- Q
- Quartz (gem and ornamental stone), 270
 - properties, 54
 - secondary, 177
 - value and uses, 55
 - varieties of, 54

white, 54
 Quartz conglomerate, 55
 sandstone, 55
 Quartzite, 55, 177
 properties, 178
 Quartz-porphyry, 173
 Quebec, gold in, 217
 lead and silver in, 226, 228

R

Radium, 245, 246
 Rapids, 113
 Recording claims, 290
 Red chalk, 45
 copper ore, 53
 ocher, 45
 zinc ore, 53
 Reddle, 45
 Regional metamorphism, 175
 Reports, geological survey, 290
 Reverse fault, 153, 210
 Rhodochrosite, 61, 240
 Rhodonite, 75, 240, 271
 Rhyolite, 169
 Rivers, underground, 116
 River terraces or benches, 116
 Rock associations of minerals, 303
 Rock crystal, 54
 crystals (gem), 270
 flour (def.), 127
 intrusions, 158
 magma, 194, 157
 salt, 56, 262
 series, 147
 specimens, examination of, 181
 Rock-making processes, 138
 Rocks, alterations in, 219
 country, 194
 country, gold in, 216
 igneous, color of, 163
 characteristics of, 163
 classes of, 164
 intrusive, mineral deposits in, 197
 metamorphic, 175-181

porphyritic, 172-174
 plutonic, 165-168
 sedimentary, classification of, 141
 origin of, 139
 stratified and unstratified (def.), 107
 stratified, relative ages of, 207
 table of, insert facing p. 109
 table for identification of, 181
 three classes of, 108
 volcanic, 155, 168-172
 Roscoelite, 247
 Rose quartz, 54
 Rottenstone, 260
 Ruby (gem), 265
 Runs (def.), 203
 Rutile, ores of, 239
 properties, 53

S

Saddle reef (def.), 206
 Salt, common, properties, etc., 56
 rock, where found, 262
 Samarskite, 81
 Samples, channeled, 207
 duplicate, 308
 Sampling ores and deposits, 306
 Sand, sharp, 107
 Sandstone, 143
 color of, 144
 Sanidine, 63
 Sapphire, 265
 Sardonyx, 54
 Satin spar, 59
 Scale of hardness, 7
 Scapolite, 69
 Scheelite, properties, 86
 ore of tungsten, 242
 Schists, 179
 Schorl, 245
 properties, 73
 Scorlaceous (def.), 156
 Scrap mica, 76

- Secondary minerals (def.), 77
 quartz, 177
 Sections (on map), 295
 Sediment, deposition of, 139
 Sedimentary rocks (def.), 108
 classification of, 141
 origin of, 139
 Selenite, 85
 Selvage (def.), 194
 Sericite, 75
 Serpentine, 179
 decorative stone, 273
 fibrous, 78
 marble, 78
 noble, 78
 properties, etc., 77
 Shale, 145
 Sharp sand 107
 Shear zone (def.), 194
 cause of, 202
 Shell garnet, 259
 Siderite, properties, etc., 60
 sources of, 238
 Silica (def.), 63
 Siliceous sinter, 54
 Sills (def.), 160
 Silver in British Columbia, 222
 Ontario, 221
 Yukon Territory, 224
 Silver lead (def.), 35
 ore, dark red, 38
 Sink-holes, formation of, 137
 Sinter (def.), 198
 Slate, how formed, 176
 properties, 177
 Slip (def.), 210
 Smalt blue, 39
 Smaltite, 38
 Smaragdite, 271
 Smithsonite, 74
 Smithstone, 62
 Smoky quartz (gem), 270
 Soapstone, 79
 composition, etc., 180
 uses, 255
 Sodalite, 69
 Sodium nitrate, where found, 263
 Soft coal, 29
 Spar (def.), 58
 Spathic iron ore, 238
 Specular hematite, 45
 Sphalerite, 41
 Sphene (gem), 273
 properties, etc., 80
 Spiegeleisen, 52
 Spinel (gem), 266
 Spodumene, 68, 270
 Stains as indicators, 297
 Staking claims, irregularities
 in, 296
 Staking and recording claims, 290
 Stalactites (def.), 59
 how formed, 137
 Stalagmites (def.), 59
 how formed, 138
 Staurolite, 74
 Steatite, 79, 180
 Steel, Hadfield's manganese, 51
 Stellite alloy, 48
 Stibnite, 36
 Stock (def.), 162, 202
 Stratification, 140
 Stratified rocks (def.), 107
 Stratum (def.), 140
 Stream tin, 48
 Streams, glacial, work of, 127
 Strike (def.), 151, 194, 210
 -fault (def.), 210
 Strontianite, 252
 Sulphite (def.), 31
 Sulphur, properties, etc., 26
 Sunstone (gem), 272
 Surface indications, importance
 of, 296
 Syenite, 166
 -porphry, 173
 Sylvanite, 38
 Sylvite, 56
 Syncline (def.), 150
 Systems, crystal, 11

T

- Table of atomic weights, 90
 minerals, 91-97
 rocks, 184-187
 Taconite, 236
 Talc, properties, etc., 79
 sources and uses, 254
 Talus (def.), 133
 Tantalite, 247
 Tellurides, list of, 38
 Tennantite, 35
 Terminal moraine (def.), 127
 Terraces, river, 116
 Testing for hardness, 7
 Tetradymite, 38
 Tetrahedrite, 35
 Thomsonite, 272
 Thoria, 70
 Thorite, 69, 247
 Thrust fault, 153
 Tiger eye, 54, 271
 Tin, sources of, 244
 stream, toad's eye, and
 wood, 48
 Tinstone, properties, etc., 244
 uses, etc., 48
 Titanic iron ore, 44
 Titanite (gem), 273
 properties, etc., 80
 Titanium, effect of, in iron
 ore, 44
 ores of, 238
 Toad's eye tin, 48
 Tools, prospector's, 278
 Topaz, 72, 268
 Topographic features, impor-
 tance of, 302
 Topography (def.), 2, 149
 Touchstone, 55
 Tourmaline, precious stone, 269
 properties, etc., 73
 Trachyte, 169
 Trap, 170
 Tremolite, 67
 Tripolite, 55
 or trioli, origin and uses,
 259

- Tungsten, ores of, 241
 Tungstite, 242
 Turgite, 47
 as an ore of iron, 233
 Turquoise, 269
 Twinning (def.), 15

U

- Unconformity (def.), 148
 Undertow (def.), 121
 Unstratified rocks (def.), 107
 Uraninite, 81
 Uranium, ores of, 245
 Uranium ocher, 246

V

- Vanadium, 81
 ores of, 246
 Vanadium mica, 247
 Vein (def.), 194
 matter, 194
 system (def.), 200
 Veins, breccia, 203
 discoveries of, 297
 fissure, 199
 formation of, 137
 gash, 203
 gold, 215
 gold, location of, 305
 Verde antique, 78
 Volcanic agglomerate, ash, tuff,
 1143
 eruptions, 154
 necks, 161
 rocks, 155, 168-172
 Volcano, 153
 Vug (def.), 194

W

- Wad, 52, 240
 Walls (of vein), 194
 Water, changes caused by, 111
 leveling effect of running, 116
 underground, 117
 Waterfalls, 113

Water table (def.), 117
Wave action, resultant effect
of, 121
effect of, on rocky shore, 120
Waves, erosion by, 118
Weathering, action of carbonic
acid in, 134
action of oxygen in, 135
chemical, 133
deep, 137
general effects of, 136
Weathering effects of heat and
cold, 131
forces, 130
Weight, atomic (def.), 17
of minerals, testing the, 8
Wernerite, 69
White iron pyrites, 32
lead ore, 62
mica (see muscovite)
quartz, 54
Winds, mechanical action
of, 131
Witherite, 62
Wood tin, 48

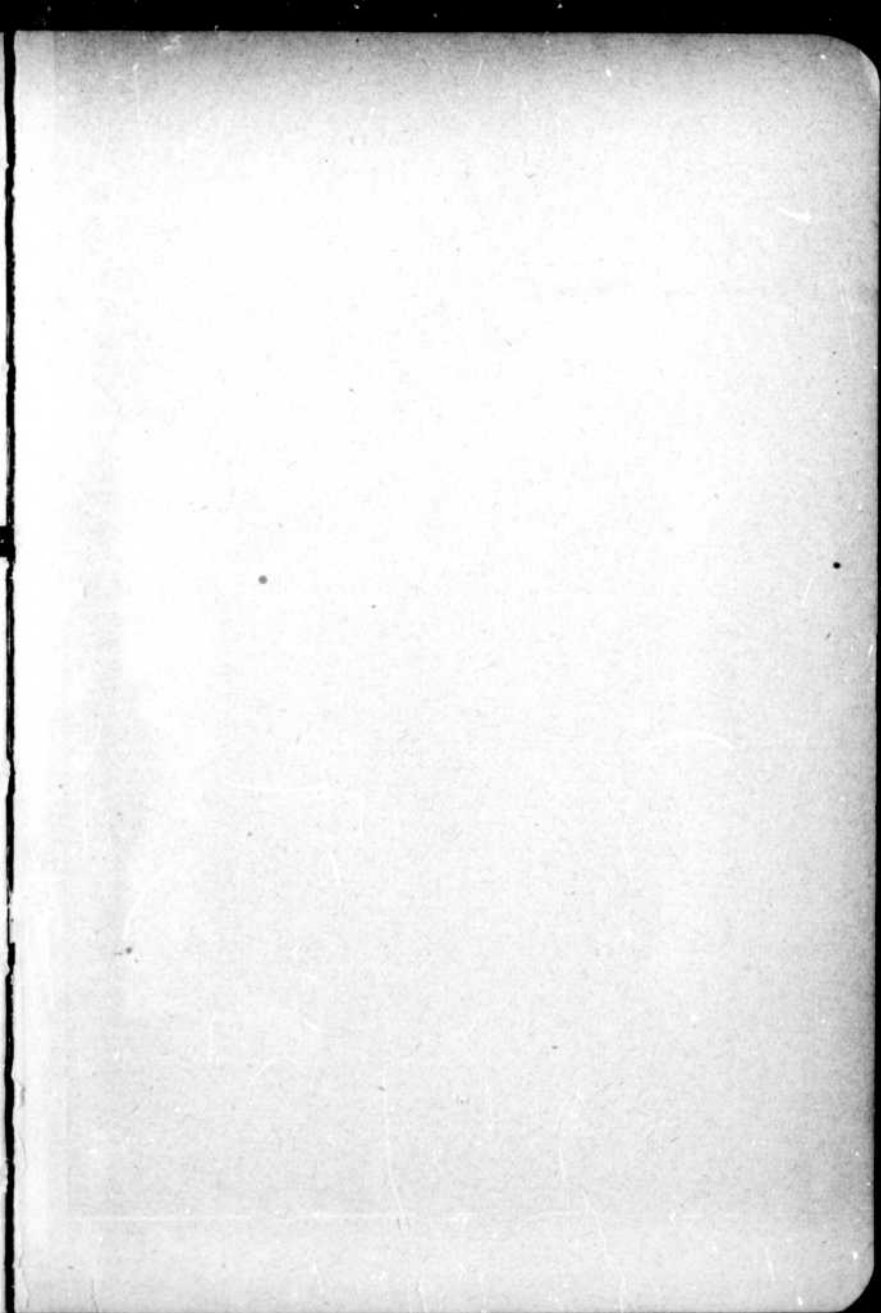
Wolframite, ore of tungsten, 241
properties, etc., 86
Wrinkling (of earth's crust),
149
Wulfenite, 243

Y

Yellow ore, 46
Yukon Territory, silver in, 224

Z

Zinc and lead, ore minerals
of, 225
in Ontario, Quebec, 226, 228
Zinc blende, 41
ore, red, 53
Zincite, 53
Zinc-lead deposits near igneous
intrusions, 225
Zircon, 69, 247
Zircon crystals, 269



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