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THE PROSPECTOR'S

FIELD-BOOK AND GUIDE

IN THE

SEARCH FOR AND THE EASY DETERMINATION OF ORES AND OTHER USEFUL MINERALS.

BY

PROF. H. S. OSBORN, LL.D.,

AUTHOR OF "THE METALLURGY OF IRON AND STEEL," "A PRACTICAL MANUAL OF MINERALS, MINES, AND MINING."

ILLUSTRATED BY SIXTY-SIX ENGRAVINGS.

EIGHTH EDITION, THOROUGHLY REVISED AND ENLARGED.

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PREFACE TO THE EIGHTH EDITION.

THE remarkable sale of seven editions of THE PROSPECTOR'S FIELD-BOOK AND GUIDE, unmistakably indicating the firm hold which it has on the confidence of Prospectors, has rendered necessary the preparation of this, the eighth edition. In doing this, the book has been carefully revised throughout, and where considered desirable, it has been enlarged. These revisions and amplifications add greatly, as it is believed, to the value and usefulness of the volume, and bring it fully up to date.

The work of revision has been undertaken by the same competent hand that so satisfactorily edited the second, third, fourth, fifth, sixth and seventh editions. As now presented to the public, it is felt to be a complete and thoroughly reliable guide and companion to the intelligent and enterprising searcher after ores and other useful minerals, including gems and gem-stones; the very best that has ever been published in any language. It has been provided with a thorough Table of Contents and an Index, rendering reference to any subject in it prompt and easy.

In conclusion the publishers would add that this edition is in number more than twice as large as the first edition, and that the book now leads the entire literature of this important subject throughout the world ; and the reason for this leadership is not far to seek. With each new issue the type has been set up anew from title to the last page of index. Thus no new issue has been an exact reprint of a previous one, and thereby the book has always been up-to-date on day of publication. In the long experience of the publishers covering a period of over three score years, they have never known the type of any other book to be set up throughout eight times as has been done with THE PROSPECTOR'S FIELD-BOOK AND GUIDE.

H. C. B.

PHILADELPHIA, 1910.

PUBLISHER'S PREFACE TO THE SECOND EDITION.

The death of Dr. Osborn, two years ago, renders it necessary that the Publisher should prepare the preface to this revised edition of The Prospector's Field-Book and Guide.

The fact of a second edition of this book having been called for so soon after the publication of the large first edition, justifies the belief that it has supplied a public requirement. The task of revising the work has devolved upon thoroughly competent hands; and whilst it has been aimed, by the insertion of further information regarding the subjects treated in the original edition, to make it still more acceptable to those for whom it was prepared, a new chapter has also been added on Petroleum, Ozocerite, Asphalt and Peat, together with a Glossary of Terms used in prospecting, mining, mineralogy, geology, etc.

While the work of revision has been done with conscientious care, under the supervision of the Publisher, it can hardly be hoped that it has been so well done as if Dr. Osborn, with his profound knowledge of the subject treated, had been alive to direct it for himself, and in his own manner.

Henry Stafford Osborn was born in Philadelphia, August 17, 1823, and died in New York City, February 2, 1894. He was graduated at the University of Pennsylvania in 1841; went abroad in 1843 or 1844; studied at Bonn, Germany, and at the Polytechnic Institution of London. Before the civil war he held the chair of Natural Science at Roanoke College, Va., and in 1866 accepted a professorship at Lafayette College, Easton, Pa. Leaving Lafayette in 1870, he became, in 1871, Professor in Miami University at Oxford, Ohio. In 1865 he received from Lafayette College the degree of LL. D.

In 1869 he published "The Metallurgy of Iron and Steel;" in 1888, "A Practical Manual of Minerals, Mines and Mining;" in 1892, the first edition of THE PROSPECTOR'S FIELD-BOOK AND GUIDE, the success of all of which books has been pronounced.

Personally, Dr. Osborn was charming, full of information on a wide range of subjects, which he had studied thoroughly; enthusiastic, amiable and just; and the relations of his publisher with him during a quarter of a century will ever be among the brightest and best recollections of that publisher's long career in business.

HENRY CAREY BAIRD.

PHILADELPHIA, January 15, 1896.

PREFACE TO THE FIRST EDITION.

In the following pages we have attempted to present such a view of the whole subject of prospecting for the useful minerals that any liberally educated reader may fully comprehend our meaning. We have therefore explained special terms where we have thought it convenient to use them, and where the technically educated student would not need an explanation.

It must be understood that the subjects of chemistry, mineralogy, and metallurgy are introduced only for their practical bearing upon the ores in hand, or those sought for, and not for theory, or the philosophy of the operation, much as such theory or philosophy would please and instruct. The prospector must, therefore, refer to larger works if he desire to be instructed in the principles governing the sciences, the teachings of which we have frequently made use of.

We would suggest to any one intending to use this volume for practical work, to become acquainted with the whole book before attempting to use any special part alone. The object and construction have made it necessary to treat some special topics without repeating principles and methods already given in some part of the work, but which bear some relation to the topic under immediate consideration.

The Table of Contents and Index have both been carefully prepared, and being very full, will make reference to any subject in the volume easy and satisfactory.

Oxford, Ohio, Jan. 5, 1892.

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CHAPTER I.

PREPARATORY INSTRUCTION.

It is well known that much disappointment and loss accrue through lack of knowledge by prospectors, who, with all their enterprise and energy, are often ignorant, not only of the probable locality, mode of occurrence and widely differing appearance of the various valuable minerals, but also of the best means of locating and testing the ores when found. It is a well established fact that most of the important mines of the world have been discovered by accident; and in many cases by people who have been quite ignorant and wholly unversed in the value of minerals. Many valuable discoveries have been delayed, or, when made, abandoned as not paying from the same cause—ignorance of the rudiments of mineralogy and mining. Hence in preparation for skilled work, an accurate knowledge of the nature of ores and the ability to recognize those which are worthy of attention are of the utmost importance. Such knowledge places the prospector at a considerable advantage, and enables him to utilize chance discoveries made by others who are not so qualified. His very first study should therefore be that of

TECHNICAL MINERALOGY.

By a *mineral* is meant any chemically homogeneous substance which neither forms, nor retains any traces of having formed, part of an organized body, and which has not been produced by the application of physical forces by man. The properties of minerals are numerous. Some, such as the form, bulk, hardness, color, etc., are readily perceived; while others such as the chemical nature, crystalline structure, behavior towards light and heat, are not so apparent, and can only be determined by means of a systematic investigation. The value of these properties in affording distinguishing characters differs greatly, but the most important are chemical composition, crystalline form, and density.

When two or more minerals occur together and form large masses, they constitute *rocks.*

The minerals which are the principal constituents of rocks are the following:

1. *Those containing silica:* as quartz; the feldspars; the micas; hornblende; pyroxene; talc; serpentine; chlorite.

2. *Carbonates:* as carbonate of lime or calcite; carbonate of lime and magnesia or dolomite.

3. *Sulphates:* as sulphate of lime or gypsum.

The special characteristics of these, and of other less frequent mineral constituents may be learned from a text-book on mineralogy. The following are the prominent characters of the most common kinds concerning the prospector:

QUARTZ. Occurs in crystals; also massive with a glassy luster. It is too hard to be scratched with a knife. It varies in color from white or colorless to black, and in transparency, from transparent quartz to opaque. It has no cleavage, that is, it breaks as easily in one direction as another like glass.

There are many varieties of quartz, of which may be mentioned: *Limpid quartz*, clear and colorless; *amethyst*, violet crystals; *agate*, presenting various colors arranged in parallel bands, straight, curved, or zigzag; *chalcedony*, transparent or translucent, and varying in color from white to gray, blue, brown and other shades; *flint*, massive, dark and dull color, edges translucent; *hornstone*, resembles flint, but differs from it in being more brittle, in breaking with a splintery, uneven fracture, and in not being so hard as quartz; *basanite, Lydian stone, or touchstone*, velvety black, more opaque than hornstone. It is used for trying the purity of gold.

Opal is also a form of silica.

FELDSPAR. This name is given to a group of minerals which are inferior to quartz only as a constituent of rocks. They have a luster nearly like quartz, but often somewhat pearly on smooth faces, are very nearly as hard as quartz, with about the same specific gravity (2.4 to 2.6); and in general have light colors, mostly white or flesh-colored, though occasionally dark-grey, brownish or green. They differ from quartz in having a perfect cleavage in one direction, yielding under the hammer a smooth lustrous surface and another nearly as perfect in a second direction inclined 84° to 90° to the first; also in being fusible before the blowpipe, though not easily so; also in composition, the feldspars consisting of silica combined with alumina and an alkali—this alkali being either potash, soda, or lime, or two or all of them combined. Included in this group are a number of distinct kinds or species. These species differ in the proportion of silica (the acid) to the other ingredients (bases), and in the particular alkali (potash, soda, or lime) predominating.

The most important kinds are:

Orthoclase, or common feldspar, a *potash* feldspar. The cleavages make a right angle with one another, whence the name, signifying cleaving at a right angle.

In the following kinds the cleavages make a right angle with one another of 84° to 87° and hence they are sometimes called *anorthic* feldspars or *plagioclastic* feldspars.

Albite, a *soda* feldspar, colorless and transparent, or translucent, and various shades of red, yellow, green and gray.

Oligoclase, a soda-lime, the soda predominating. Color, generally whitish or grayish with shades of green and yellow.

Labradorite, a lime soda, often iridescent. Color, usually ash or greenish-gray, but frequently various shades of green, yellow, and red, and sometimes the smaller crystals are colorless.

Anorthite, a lime feldspar, transparent and colorless, or translucent and grayish or reddish.

Feldspars are essentially constituents of volcanic and crystalline igneous rocks, orthoclase being typical of granite, syenite, gneiss and trachyte, usually in association with quartz.

Labradorite is the feldspar of basalts and dolerites in microscopic crystals, and it also forms enormous rock-masses in Labrador. Oligoclase may be associated with orthoclase in granite, and is the feldspathic constituent of *diorite* and *diabase*. *Andesite* is the feldspar of the trachytes of the Andes. *Albite* is chiefly found in crystalline schists and also in granite veins. Anorthite is best developed in the crystalline limestone blocks of Vesuvius, and also occurs in some basalts.

MICAS. This embraces a group of minerals whose most marked common feature is a highly laminated structure, and they admit of being split into leaves even thinner than paper. They are colorless to brown, green, reddish and black, and occur either in small scales disseminated throughout rocks—as in granite—or in large plates. The micas are silicates of alumina with either potash, magnesia or iron and some other ingredients.

The most important species of mica are:

Muscovite. This is the common mica which in the form of clear or slightly smoky colored plates is used in the doors of stoves and lanterns. In Russia it was used for the windows of houses and this gave the name to the mineral of *Muscovy glass*, whence the mineralogical name of muscovite.

Muscovite is a potash mica usually occurring in rhombic or six-sided tabular crystals. In many rocks the crystals are but poorly developed or only represented by irregularly shaped scales; cleavage basal and very perfect; color, mostly silvery-white, seldom, but occasionally, dark brown or black. Before the blowpipe it whitens and fuses on thin edges to a gray or yellow glass. Muscovite is not decomposed by sulphuric or hydrochloric acid.

Phlogopite, a magnesia mica of light brown, or copper-red, and sometimes white, color. It is common in limestone or in serpentine rocks and in dolomites.

Biotite. This includes most of the magnesia-iron mica. Color, black or dark green. Very thin laminæ appear brown, greenish or red by transmitted light. Luster pearly, hardness 2.5 to 3, specific gravity 2.7 to 3.1. The basal cleavage is highly perfect and the laminæ are flexible and elastic as in other members of the mica group. It is only slightly acted upon by hydrochloric acid, but is decomposed by sulphuric acid, leaving a residue of glistening scales of silica. Biotite is the second most important mica.

Lepidomelane is an iron-potash mica. It occurs in small six-sided tabular crystals, or in aggregations of minute scales. Color, black ; luster adamantine or somewhat vitreous. Easily decomposed by hydrochloric acid, leaving a fine scaly residue of silica.

Lepidolite or lithia mica resembles muscovite in crystalline form and many of its physical properties. Its color is white, yellowish or rose-red, the last being very prevalent. It fuses before the blowpipe more readily than muscovite, and is decomposed by hydrochloric and sulphuric acids but not so readily as the magnesian micas. Lepidolite is most commonly met with in metalliferous veins, especially those containing tin, and is nearly always associated with other minerals which contain fluorine, such as fluorspar, topaz, tourmaline, and the emerald ; it is also frequent in many kinds of granite.

AMPHIBOLE, often called HORNBLENDE. The most common kind is an iron-bearing variety, in black cleavable grains or oblong black prisms cleaving longitudinally in two directions inclined to one another 124° 30′. It occurs also in distant prisms of this angle, and of all colors from black to green and white.

Actinolite is the name applied to the green variety, and besides lime and magnesia, contains also iron. It occurs often in fibrous or columnar masses, sometimes with a radiated structure.

Tremolite is a lime-magnesia hornblende. The pure crystals are white, but the impure ones are yellowish or greenish-gray owing to the presence of protoxide of iron. There are several varieties of tremolite. Thus the substance known as

Asbestus * is in most cases tremolite containing a little water. It generally occurs in fine fibers which may be isolated or packed closely together with their principal axes parallel.

Mountain leather is a similar mineral, but the fibers are finer, closer and intermixed.

Mountain cork is a spongy, elastic asbestus, with the fibers interlaced together.

Mountain wood is like the last, but denser, far less elastic and capable of taking a high polish.

Nephrite or oriental *jade* is a compact variety much used by the Chinese as a figure stone. The color is sometimes light-green as in the *white jade;* and olive-green, as in the *green jade.* It has an uneven, fine-grained fracture, and a greasy luster.

Tremolite is found in many places, but nearly always in the older dolomites and saccharoidal limestones.

PYROXENE, including AUGITE. Like hornblende in most of its characters, its varieties of colors and its chemical composition. But the crystals, instead of being prisms of 124° 30′, are prisms of 87° 5′. Black and dark-green pyroxene in short crystals is called *augite.* It is an iron-bearing kind, and is common in igneous rocks.

The minerals of the amphibole group closely resemble pyroxene in chemical composition, while they also crystallize in the same system. They

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* Most of the asbestus mined for use in the arts is a fibrous variety of serpentine, and is easily distinguished because it contains about 14 per cent. of water.

differ, however, in the angular measurements of the oblique rhombic prism, which, as already shown, in hornblende is 124° 30′, and in augite 87° 5′ to 92° 55′.

They are all bisilicates of protoxides and sesquioxides, the former being lime, magnesia, soda, potash, and the protoxides of iron and manganese, while the latter are represented by alumina and the sesquioxides of iron and manganese.

Crystals of amphibole differ from those of pyroxene, not merely in the angular measurements of their oblique rhombic prisms, but also in the angles at which their cleavage planes intersect. This circumstance is of considerable value to the mineralogist, since it is often difficult or impossible to measure the angles of the actual crystallographic faces, but it is generally possible to measure the angles of cleavage. The crystals of minerals belonging to the amphibole group usually exhibit a fine longitudinal striation.

Color affords no safe means of discriminating between pyroxene and amphibole, since the members of both groups exhibit greenish and brownish tints. The augites and hornblendes which occur in basalt are mostly brownish in color.

The hornblende in syenite is also generally brown, but that which occurs in phonolite is mostly of a greenish tint, while the augite in leucite lavas is, as a rule, also green.

The minerals of the amphobile group frequently show a tendency to develop long, blade-like crystals.

This tendency is in a very marked degree shown by actinolite, one of the principal varieties of amphibole, the crystals arranging themselves in radiate groups.

Both hornblende and augite occur together in the same rock; but as a rule the former mineral is found in those rocks which contain a large percentage of silica, the associated minerals being usually quartz and orthoclase, while augite is generally found in rocks of a basic character containing triclinic feldspars, and with little or no free silica.

CHLORITE occurs sometimes in thin, foliated plates like mica, but inelastic, more often granular, massive; sometimes in green crystals and scales. These kinds of chlorite are found in rocks, and form the mass of chlorite rock and chlorite slate.

The chlorites are silicates of alumina, iron and magnesia with water, the average percentage of magnesia being about 34, and that of water over 12.

Chlorite is a very soft mineral, and is essentially a product of the decomposition of other minerals.

When heated in a glass tube it gives off water. Before the blowpipe it exfoliates, whitens and melts with difficulty into a grayish enamel. It is soluble in hydrochloric acid when powdered, and after long boiling.

TALC. A hydrated silicate of magnesia from which the water is only driven off at a high temperature. It generally occurs in broad pale-green, or silvery-whitish plates or leaves, looking like mica, but the cleaved plates, though flexible, are much softer and not elastic. It is easily scratched by the nail, has a pearly luster and is soapy and unctuous to the touch. Before the blowpipe it turns white and exfoliates. It is neither before or after ignition soluble in either hydrochloric or sulphuric acid, thus differing from chlorite.

Serpentine. This is also a hydrated silicate of magnesia. It is usually compact, massive, not granular at all, of a dark green color, but varying from pale green to greenish-black. The most peculiar variety is a fibrous kind occurring in seams in massive serpentine, which is called *crysotile*, popularly called *asbestus*.

Minerals are composed of chemical elements, which are substances which cannot be further separated. A table of the chemical elements, their symbols, equivalents and specific gravities, is given in the Appendix. When these elements unite together and form a compound, they always do so in fixed proportion and in definite weight. Therefore, in any pure mineral, whose composition is known, the amounts of the elements going to make up any given mass of it can be calculated by a rule-of-three sum.

For example, in galena (PbS) we have lead (Pb) = 207 and sulphur (S) = 32, total 239. Therefore, in 239 lbs. of pure galena we will find 207 lbs. of lead ($86\frac{1}{2}$ per cent.), and so on in proportion.

Thus any mineral that is pure enough to be weighed directly, or which can be concentrated pure and then weighed, can be estimated in this way, and the percentage content of the ore calculated.

The combination of two or more of these elements together gives rise to three classes of substances, namely, *acids, bases, and salts.*

Oxides of non-metallic elements are acids.

Oxides of metallic elements are bases.

Where an acid and a base unite, one exactly neutralizing the other, a substance is produced having neither acid nor basic tendency. It is known as a *salt.*

Most minerals are salts. There is only one common acid mineral, namely, quartz (SiO_2), or the oxide of the non-metallic element silicon.

There are many minerals which are basic, such as hematite (Fe_2O_3) and magnetite (Fe_3O_4), the oxides of iron, and cuprite (CuO), the oxide of copper.

Among the many minerals which are salts are: common salt or sodium chloride (NaCl); limestone or calcite ($CaCO_3$), formed from the union of the oxide of calcium (metal) and carbonic acid gas; gypsum ($CaSO_4 2H_2O$) formed by the union of the oxide of calcium (metal) and sulphuric acid; apatite, a phosphate of lime [$Ca_3(P_2O_4)_2$] formed by the same base as above, uniting with phosphoric acid.

There are a great many minerals, the acid member of which is silica, with one or more metallic oxides forming the basic member. These are known as *silicates*, and feldspar, mica, hornblende, pyroxene, talc, serpentine, etc., are examples.

These facts are important to remember, because whole families of minerals and rocks are classified as acid or basic, according to the greater or lesser quantity of silica present in them.

The COLORS of minerals are either essential to them, as in the sulphides, oxides and acidiferous compounds of most metals, and in those species of which they are essential constituents; or they are the effect of casual intermixture of these substances in species which, when pure, are naturally colorless. Of the latter sort are the colors of feldspar, calcspar, rock salt, marble, and jasper, in which the various tints of red and yellow are generally due to the oxide and hydrous oxide of iron. Other minerals derive a brilliant green color, some from carbonate of copper, others from the oxide of nickel or of chrome. In species of which the color is a permanent character, its intensity is often so far varied by a difference of texture or confused crystallization, that red, brown, and green substances appear, in a mass, to be black; but on being pulverized, their true color will be seen. It is therefore advisable, in describing a mineral, to state what its color is when reduced to powder.

The intermixtures of coloring matter, which are merely mechanical, render a mineral more or less opaque; thus the red and yellow jasper are chalcedony—which when pure is highly translucent, or even semi-transparent—colored by minute particles of oxide of iron, which are themselves opaque. But colors, which, though they may not be essential to a species, are the result of *chemical combination*, do not impair its transparency; such is the violet tint of amethyst, which is derived from a minute portion of the oxide of manganese combined with the quartz ; and the green of the emerald, which may in some cases be due to oxide of chrome.

In consequence of the variable quantity of coloring matter, whether chemically combined or otherwise, many substances present various tints and shades of color, so that they are particularized as blood-red, flesh-red, chestnut-brown, lemon-yellow, sky-blue, etc.

Accidental colors being unequally distributed, often produce parallel bands, either straight or curved, and clouded forms, as in agates. Sometimes the color takes the form of leaves and moss, or runs through the mass in veins, as in marble.

There are still other colors, which are neither essential to minerals, nor yet produced by intermixture. Some, as the sulphide of antimony, exhibit a brilliant superficial tarnish, in which the prismatic colors are regularly arranged. In transparent substances, prismatic colors are perceived in the interior, and arise from minute cracks or fissures containing films or particles of air ; these are often movable by slight pressure.

A very curious peculiarity of color called *polychroism* is connected with the phenomenon of double refraction. Some minerals, placed between the eye and the light, transmit different colors in different directions. Tourmalines, viewed parallel to their axis, are generally opaque ; perpendicularly to it, they appear to be green, red, brown, etc.

This difference is not observable in all double-refracting substances; but in some which have two axes of double-refraction three different tints have been observed. Minerals crystallizing in the cubic system never transmit more than one color, if their composition and texture be homogeneous throughout.

In some minerals a peculiar light is produced either by friction or heating them, which is called *phosphorescence.* On rubbing together two fragments or pebbles of quartz, a faint greenish light will be perceived, and the same effect can be produced with certain marbles. Other substances when placed on a heated shovel, emit a brilliant phosphorescence, which in some is green; in others pale violet. The best mode of conducting this experiment, if the specimen is powdered, or in small fragments, is to strew it over a shovel heated nearly to redness; but if it be an inch or two in length, it is better to heat it slowly, and not beyond the necessary degree, by which means the operation may be frequently repeated without injuring the specimen.

Some metals are found native and in some degree of purity, as in the cases of gold, silver, copper, mercury, and platinum, and when so found are readily determined at once by any one who is at all acquainted with those metals as they occur in general use. But frequently native metals appear under such colors, and even forms, that the discoverer must possess more knowledge than any one usually possesses who has seen the metal in the arts only. Gold, as an illustration, is frequently found in various shades of yellow, in accordance with the amount of silver or copper it may contain, and yet to the practiced eye of a true mineralogist it never loses the true gold hue.

Iron pyrites, which is composed of sulphur and iron, and called "pyrite," mineralogically, has a color somewhat similar to that of gold, and so also has a mineral called "chalcopyrite," or copper pyrites, which contains copper, iron and sulphur. These, with others, vary in the yellow shade and degrees of color, but by the practiced eye are instantly detected. Of course the brittleness of these minerals is unlike the softness of native gold, and this would instantly reveal the fact that they were not gold; but we are now speaking of the practiced eye alone, and therefore of the benefit of cultivating a knowledge by sight of minerals. The mode in which a mineral breaks when smartly struck with a hammer, or pressed with the point of a knife, is a character of importance. Many minerals can only be broken in certain directions, for instance, a crystal of calcspar can only be split parallel to the faces of a rhombohedron; many crystals break more readily in one direction than in others. Whenever a mineral breaks with a smooth, flat, even surface, it is said to exhibit

CLEAVAGE, which always depends upon the crystalline form. But minerals often break in irregular directions, having no connection whatever with the crystalline form, and this kind of breaking is called

FRACTURE. The nature of the surface given by fracture is often a character of importance, especially in distinguishing the varieties of a mineral species. Thus quartz and many mineral species show a shell-like fracture-surface which is called *conchoidal*, or if less distinct, *small conchoidal* or *sub-conchoidal*. More commonly the fracture is simply said to be *uneven*, when the surface is rough and irregular. Occasionally it is *hackly*, like a piece of fractured iron. *Earthy* and *splintery* are other terms sometimes used and readily understood.

STREAK. The color and appearance of the line of furrow on the surface of a mineral, when scratched or rubbed, is called the streak, which is best obtained by means of a hard-tempered knife or a file. The color of a mineral and its streak may correspond, or the mineral and its streak may possess different colors, or the mineral may be colored while its streak is colorless. For instance, cinnabar has both a red color and a red streak; specular iron has a black color, but a red streak; sapphire has a blue color, but a white, colorless streak. The streak of most minerals is dull and pulverulent, but a few exhibit a shining streak like that formed on scratching a piece of lead or copper. This kind of streak is distinguished by the name of *metallic*. In judging the streak of a mineral, much-weathered pieces should be rejected.

HARDNESS is another character of great importance in distinguishing minerals; it is the quality of resisting abrasion. The diamond is the hardest substance known, as it will scratch all others. Talc is one of the softest minerals. Other minerals possess intermediate degrees of hardness. To express how hard any mineral is, it becomes necessary to compare it with some known standard. Ten standards of different degrees have been chosen, and are given in order in the following scale:

1. *Talc*, easily scratched by the finger-nail.
2. *Gypsum*, does not easily yield to the finger-nail, nor will it scratch a copper coin.
3. *Calcite*, scratches a copper coin, but is also scratched by a copper coin.
4. *Fluorite*, is not scratched by a copper coin, and does not scratch glass.
5. *Apatite*, scratches glass with difficulty; is readily scratched by a knife.
6. *Feldspar*, scratches glass with ease; is difficult to scratch by a knife, but is scratched by a well-tempered steel.
7. *Quartz*, cannot be scratched by a knife, and readily scratches glass.
8. *Topaz*, } harder than flint or quartz.
9. *Corundum*, }
10. *Diamond*, scratches any substance.

In describing minerals, their hardness is always expressed by numbers. Thus, if on drawing a knife across a mineral it is impressed as easily as calcite its hardness is said to be H3. If a mineral scratches quartz, but is itself scratched by topaz its hardness is between 7 and 8.

In testing the hardness of a mineral a sound portion of it should be chosen, and the scratch should be made on a smooth clear surface and with a sharp edge or angle of the mineral used for scratching. A streak of dust on scratching one mineral with another may come from the waste of either, and it cannot be determined which is the softer until after wiping off the dust, when it will be easily seen that no scratch has been produced on the harder mineral, and that the edge of the other has been blunted. This is what would happen if an attempt were made to scratch topaz with quartz, or corundum with topaz.

By the test of hardness, clear distinctions may be drawn between minerals which resemble each other. Iron pyrites and copper pyrites, for instance, are similar in appearance, but copper pyrites can easily be scratched with a knife, while iron pyrites is nearly as hard as quartz and the knife makes no impression upon it.

FLEXIBILITY AND ELASTICITY. Some minerals can be readily bent without breaking, for instance, talc, mica, chlorite, molybdenite, native silver, etc. Minerals which after being bent can resume their former shape like a steel spring, are called elastic, for instance, mica and elaterite. A remarkable instance of flexibility, even combined with elasticity, amongst the rocks, is that of a micaceous sandstone called itacolumite, which in Brazil is the matrix of the diamond.

SMELL. A few minerals only, like bitumen, have a strong smell which is readily recognized, but specimens generally require to be struck with a hammer, rubbed, or breathed upon before any smell can be observed. Some black limestones have a bituminous odor, while some have a sulphurous, and others a fetid, smell. Hydraulic limestone has a smell of clay which can be detected when the mineral is breathed on. Some minerals containing much arsenic, for instance mispickel, smell of garlic when struck with a hammer.

Taste. Only soluble minerals have any taste, and this can only be described by comparison with well-known substances, for instance *acid*, vitriol ; *pungent*, sal ammoniac ; *salt*, rock salt ; *cooling*, nitrite ; *astringent*, alum ; *metallic astringent*, sulphate of copper ; *bitter*, sulphate of magnesia ; *sweet*, borax.

Malleability. Malleable substances can be hammered out without breaking, and it is on this quality that the value of certain metals in the arts depends, for instance, copper, silver, gold, iron, etc.

A few minerals are malleable, and at the same time sectile, *i. e.*, they can be cut with a knife, for instance, silver glance, horn silver, and ozokerite.

Mineral caoutchouc (elaterite) is sectile, but like india rubber, can only be shaped when hot. The elasticity of elaterite is so characteristic that the mineral will be readily recognized.

Ductility, or the capability of being drawn into wire, is a property which is confined exclusively to certain metals. It is possessed in the highest degree by gold, which can be drawn into the finest wire, or rolled into leaves of such fineness that 30,000 of them are not thicker than an eighth of an inch.

LUSTER. The term luster is employed to describe with certain adjectives the brilliancy or gloss of any substance. In describing the luster, well-known substances are taken as the types, and such terms as *adamantine luster*—diamond-like—and *vitreous luster*—glassy—are used. The luster of a mineral is quite independent of its color. When minerals do not possess any luster at all they are described as "dull." The kinds of luster distinguished are as follows:

Metallic: The luster of a metallic surface, as of steel, lead, tin, copper, gold, etc.

Vitreous or *glassy* luster: That of a piece of broken glass. This is the luster of most quartz and of a large part of non-metallic minerals.

Adamantine: This is the luster of the diamond. It is the brilliant, almost oily, luster shown by some very hard materials, as diamond, corundum, etc. When sub-metallic it is termed *metallic adamantine*, as seen in some varieties of white lead ore or cerussite.

Resinous or *waxy:* The luster of a piece of rosin, as that of zinc blende, some varieties of opal, etc. Near this, but quite distinct, is the *greasy luster*, shown by some specimens of milky quartz.

Pearly or the luster of mother-of-pearl. This is common where a mineral has very perfect cleavage. Examples: Talc, native magnesia, stilbite, etc.

Silky, like silk. This is the result of fibrous structure, as the variety of calcite (or of gypsum) called satin spar, also of most asbestus.

Fusibility. Some minerals can be easily fused; others only with difficulty; while some resist the highest heat which can be applied to them. There are such wide differences between the various degrees of fusibility of minerals that this character helps greatly in distinguishing them. The fusibility is most readily tested by holding a small splinter of the mineral with a forceps in a candle flame, urged by the blowpipe; or the mineral may be laid upon a piece of charcoal and the flame directed upon it by the blowpipe. Some minerals fly to pieces when heated; others swell up or give off peculiar and characteristic odors. For further information regarding fusibility, see Chapter II, The Blowpipe and its Uses.

Specific Gravity. By specific gravity is meant the comparative weight of equal bulks. Water is taken as the standard of comparison; the specific gravity of a mineral is a number showing how many times it is, bulk for bulk, heavier than water.

Rule. The specific gravity of water is called 1, of gold 19, implying that if equal bulks of gold and water were taken, the gold would weigh 19 times as heavy as water. The specific gravity of a mineral can be found by weighing it first in the air in the usual manner, and then observing how much of its weight it loses when suspended from the arm or pan of a balance, and allowed to hang freely in water. If a piece of quartz weighing 26 grains is attached by a horse hair or fine silk thread to the scales—and weighed whilst hanging in water—it will be found to weigh only 16 grains; it thus loses 10 grains, or $\frac{10}{26}$ of its entire weight. Similarly gold would lose $\frac{1}{19}$ of its weight.

Minerals differ very widely in the proportion of weight which they lose in water, but the same mineral invariably loses the same proportion, for instance: Quartz loses $\frac{10}{26}$ of its weight; topaz $\frac{10}{35}$; sapphire $\frac{10}{40}$; zircon $\frac{10}{45}$; tin ore $\frac{10}{70}$.

These proportions depend upon the specific gravity of these minerals. The specific gravity of water is called 1, of quartz 2.6, of topaz 3.5, of sapphire 4.0, of gold 19, signifying among other facts that quartz loses $\frac{10}{26}$ of its weight in water, topaz $\frac{10}{35}$, sapphire $\frac{1}{4}$, gold $\frac{1}{19}$.

In determining how much weight a mineral loses in water, a very delicate balance is required when the weight in air is under 10 grains; but for portions weighing heavier than this, a common balance turning readily to a grain, may be used for practical purposes. The mineral must be sound throughout, and free from any pores or cracks, and its surface should be rubbed over with water before immersing it, to prevent bubbles of air adhering, which would falsify the result. A trial of specific gravity can have no value unless it is made on a pure portion of a mineral, quite free from any adhering foreign matter.

The rule for finding the specific gravity is to divide the weight of the mineral in air by its loss of weight in water. *Example:* A piece of quartz weighed 1,398 grains in air and 862 grains in water;

hence the loss of weight is 536, and the weight in air divided by this number is 2.6, which is the specific gravity of quartz. Some rules for finding weights by specific gravity are given in the Appendix.

However, while the specific gravity of a mineral can be ascertained with great accuracy in the laboratory where delicate balances are available, it is not always possible to do so in the field, and the most that can be undertaken is to class minerals roughly within certain broad limits. Prospectors soon acquire some proficiency in testing the weight of minerals by handling them. A lump of pyrite, for instance, can readily be distinguished from gold by its weight, since a mass of gold of the same size would weigh at least three times as much, and a little practice with well-known substances will enable the prospector to class most minerals within certain broad limits by weighing them in the hand.

A rough idea of the specific gravity of minerals can be arrived at by washing in a tin dish. This process in the hands of an experienced prospector will give sufficiently accurate results for the determination of the most common minerals. The sorting in a tin dish is effected by picking out the larger stones by hand, but in testing the specific gravity of minerals, they should be divided, in the first instance, into regular sizes by sifting. For this purpose two sieves will be sufficient, one with eight holes, the other with sixteen holes to the linear inch; then all which will pass through the coarser sieve, but not through the finer, will be of sufficiently uniform size for the tests required.

The lighter portions will first be separated by washing; these will consist of shale, ferruginous quartz, brown oxide of iron, pebbles of tourmaline, etc., mostly of a lower specific gravity than 3.5, and the heavier minerals which remain in the dish, will be zinc blende, magnetite, pyrites, hematite, mispickel, tinstone, wolfram, gold, platinum, etc.

By a careful manipulation of the dish generally adopted by miners when showing the gold, these heavy minerals can be easily enough separated into three groups, namely: Gold, platinum, copper, bismuth, silver, mercury, etc.; tinstone, wolfram, galena, cinnabar, etc.; and zinc blende, magnetite, haematite, mispickel, etc.

Some of these minerals, mispickel for instance, can be readily recognized, and where this is the case, those which lie upstream and those below can be subdivided as being of greater or less specific gravity respectively than 6.3, which is the specific gravity of mispickel. Where the minerals in the dish cannot be readily recognized, a few fragments of metallic antimony, or zinc, or tinstone painted white—all of which have a specific gravity of about 7—should be introduced into the dish to serve as a gauge.

What has previously been said of color may also be said of *weight* and *form*. A lump of pyrite in the hands of a skilled mineralogist would be distinguished from gold by its weight, since as above mentioned, a mass of gold of the same size would weigh at least three times as much. Three crystalline pieces, the one of barite, the other two of lime carbonate and of quartz, may to the unskillful eye appear equally transparent; but the form of the first is tabular, that of the latter two is in six-sided crystals, but the lime carbonate crystals terminate in three sides, while the quartz always (like the sides) in six.

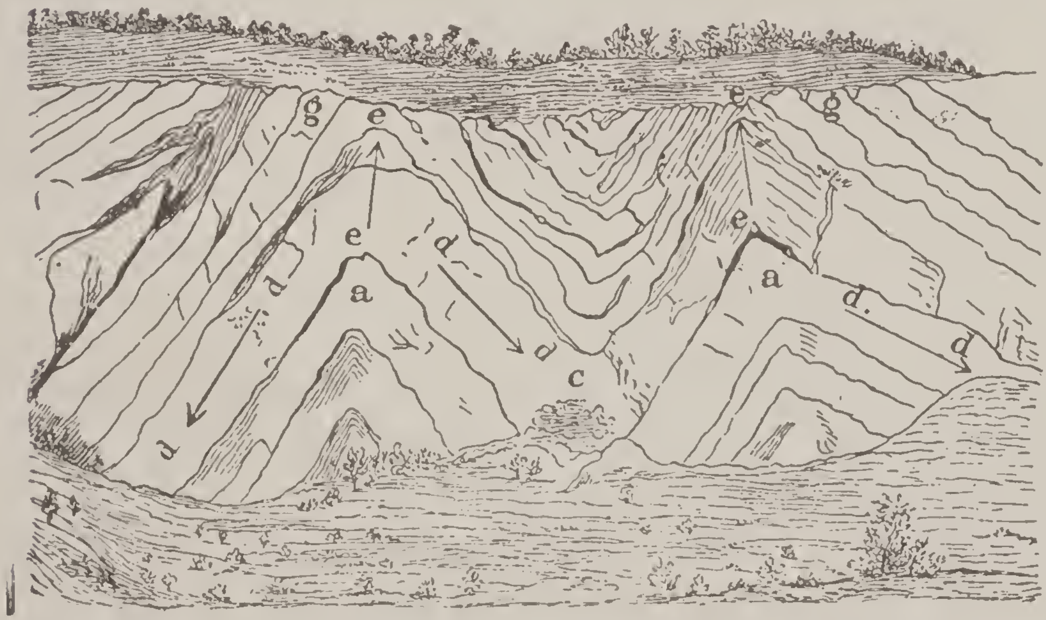
Besides a knowledge of the forms under which the minerals we seek present themselves, it is also necessary to learn the characteristics of some of the rocks which are generally associated with those minerals. The object of this knowledge is to serve in directing us to those regions where we may with greater probability discover the minerals we seek. It also serves to warn us out of a region where we should not expect to find what we desire.

To illustrate, we may not expect to find iron ores of a certain kind, brown hematites for instance, in a granitic country. On the other hand, we may find the magnetic ores in such a region, and it is useless to explore a granitic region for black band iron ore, although it may be the proper region to discover red hematite.

It is, therefore, important that the prospector should be able to distinguish many of the geologic rocks to help in guiding or in checking him, in his explorations.

A general knowledge, therefore, of the manner in which the geologic rocks are "laid down," their order, or succession, in the earth, is important, and the distinction between sedimentary and that which has been, and is usually called "igneous rock," but more properly "azoic rock," that is, rock which does not exhibit any remains of fossil or organic life. For often the only signs by which we can, with any degree of certainty, determine what is the name of the sedimentary rock is by finding the remains of former life, that is, the kind of fossil it contains. Prof. Dana says (The Amer. Journal of Science, Nov. and Dec., 1890) that it is settled that the kind of rock in itself considered is not a safe criterion of geological age.

Fig. 1.



SECTION SHOWING CONTORTED STRATA DUE TO LATERAL PRESSURE: *aa*, "anticlinal axis; *c*, the "synclinal axis." The direction of the arrows, *ee*, *ee*, is that of "the strike." That of the arrows, *dd*, is that of "the dip" of the strata, always measured from the horizon; *gg*, are the out-crops.

If all the rocks in the world had been laid down in regularly horizontal sequence and had always remained in their own separate "horizons," as every rock of the same age is called, not only should we find them all parallel, one over the other, but we might readily determine to some extent what were the exact order and distance of any one horizon, or geological age. But, although there is a general order, the same in all parts of the world, there have been upheavals and sinkings, dislocations and erosions, during the ages, so that it is necessary that the prospector should become acquainted with the various changes probable in the order and forms of the vast rocks which carry the minerals for which he is seeking.

Some of these movements of the earth's crust are represented in Fig. 1.

PRACTICAL GEOLOGY.

It may be repeated that it is of considerable importance that the prospector should have at least some general knowledge of those geological horizons with which his work is specially associated. As has been intimated, useful minerals do not always confine themselves to one horizon; but there are certain ranges of rock which indicate their vicinity. There are also limits which are never overpassed by some useful minerals, and experience has shown that some horizons are always sterile in ores, and it is therefore useless ever to expect to find them in paying quantities, in certain rocks or beyond them in certain directions.

Gold often occurs where it will not pay to open and work the strata, so also with lead and copper. It is well to learn the relations of such barren regions, or horizons, as the strata are called.

In the following table chief place has been given to these horizons which have been found in our own country to abound in the useful minerals, and we advise the possession of small specimens of the principal rocks mentioned and the special examination of the specimens under a good lens, so as to become thoroughly acquainted with their appearance and their minute constituents.

All rocks may be classed as—

1. Igneous.
2. Metamorphic.
3. Aqueous.

A rock may be defined as a mineral aggregate possessing a more or less persistent geological character. However, speaking geologically, not only the hard consolidated massive and stony substances are called "rocks," but any natural deposits of stony material such as sand, earth, or clay, when in natural beds, are geological rocks. Very few of the rocks of this earth, at any rate so far as examined, are in their original and primal condition. Even the granites and volcanic rocks are composed of other and more ancient material disintegrated, ground up, or worn down, settled, buried, and compressed by ages of enormous pressure, or consolidated by cementation. Some have been "laid down" under water, having been disintegrated into dust, carried by the winds of ages out over the oceans and seas, and settled down into the form of the present rocks, which afterward have been lifted up into mountains and plains above the seas. But by the transporting power of rivers or currents in ancient oceans, and because of unequal upheaval of some regions where subterranean forces were greater than at distant places, very large differences in the nature of the deposit have occurred, even in limited regions. These special and limited forces will account for the fact that although, taking the geological horizons throughout the world, there is a general sameness, differences do occur, and important members of the order of succession are omitted in some regions, and exceptions to general rules occur.

In the table following are therefore given those universally accepted relations of certain rocks, one to another, in the great geologic arrangement of the world, omitting some of the subsidiary, limited and unimportant horizons.

1. IGNEOUS ROCKS are such as owe their origin to the action of fire, having been subjected to sufficient heat to melt the ingredients. They form the smaller, but still a very large, part of the crust of the earth. They are not sedimentary, but are due to upheaval. They are not stratified and not fossiliferous. Some geologists divide them into *plutonic* and *volcanic* rocks, the former being crystalline, older, deeper in origin;

and the latter non-crystalline, and comparatively recent and superficial. In the case of the plutonic rocks the rate of cooling has been slow, and the consolidation gradual, and has taken place under great pressure. The rate of cooling of the volcanic rocks has on the other hand been fast, and the consolidation rapid, as with lava, etc.

Trachyte: A grayish rock of rough fracture; the same specific gravity as quartz, but mainly constituted of grains of glassy feldspar. It is essentially a unisilicate of alumina, with 10 to 15 per cent. potash, a little soda and lime: differs from quartz in that it fuses before the blowpipe, while quartz remains unfused except when soda is used.

Basalt: Blackish or dark brown. *Traps, greenstone, dolerite, amygdolite;* these latter four are only modifications, being all unisilicates with smaller amounts of potash than in trachyte, a little more soda and lime, and some traces of iron and magnesia, varying in color and form.

Obsidian is a volcanic glass, something like bottle glass, of a dark shade, and translucent.

All these are compact in texture except where some holes have been worn in by steam or gases. They are frequently found penetrating several strata, having been forced up in columns almost vertically, and sometimes spreading out horizontally for many miles between the strata or on the surface, and are called volcanic dykes, or intrusive rocks or lava.

It is not certain that granite rocks are of igneous origin, but they seem to belong to the metamorphic series.

2. METAMORPHIC ROCKS. The term *metamorphic* as applied to these rocks, implies that they are the product of the metamorphosis of rocks originally sedimentary. They are of igneous origin, subsequently to the time when they were of aqueous origin, and have undergone a change through pressure and heat, and, perhaps in connection with steam and water. All the rocks of this class are to be distinguished from the igneous by their foliated texture and yet more by their alternate bedding in parallel layers or strata, and the traces which they often very distinctly show of internal stratification. All the metamorphic rocks are silicates and acid silicates. They contain from 42 to 75 per cent. of silica, and they all contain aluminium, magnesium, iron, calcium, in the above quantitative order, and all but talc schist contain small quantities of potassium and sodium. Of this class of rocks are the following:

GNEISS, having a composition of small pieces of feldspar, mica, and quartz, like some granites, but laminated or foliated in form, and not equally solid, homogeneous, and continuous throughout its structure as granite is.

MICA SCHIST. This term is given to those

STRATIFIED ROCKS.

	GENERAL DIVISIONS.	SUBDIVISIONS.	CHARACTERISTICS.
	RECENT, PLEISTOCENE, OR QUATERNARY.	All its shells and bones are of existing species.	
TERTIARY OR CENOZOIC.	PLIOCENE.	About 50 per cent. of existing species of shells.	Tertiary rocks, yield brick and other clays, gypsum, sand, phosphate of lime deposits such as are in Florida, South Carolina, and elsewhere. GOLD in the drift and alluvial, also PLATINUM (Iridium, *see text*), and TIN. Coal fields (brown or lignite) of this Period, occur in India, Indian Archipelago, Japan, New Zealand, Vancouver's Island, and in Europe; also in California, Washington, Oregon, Colorado, etc. The true coal (anthracite and bituminous) belongs to the Carboniferous only. A very hard lignite exists at Gay Head, Martha's Vineyard, in this formation.
	MIOCENE.	Contains 80 per cent. of extinct species.	
	EOCENE.	Contains fresh water and marine strata, animals all extinct.	
SECONDARY OR MESOZOIC.	CRETACEOUS.	Upper. Middle. Lower.	Upper Chalk with flints, but the lower Chalk without flints. } The whole formation contains sea-shells, sponges, sea-urchins, etc. Contains Greensand in England and in New Jersey, used as a marl and fertilizer. There is a supposed Cretaceous lignite in Alaska, Colorado, California, Utah, etc.
	JURASSIC.	Whealden.	Consists of sand, clay, or marl, the sand used in glass-making.
		Portland Stone. Oxford Group. Stonesfield Slate.	Some English coal is found in the Oolite. Kimmeridge clay is found in upper Oolite; the fine Bavarian lithographic stone in the middle Oolite.
	Lias	Limestone in horizontal strata.	Conspicuous for the number of ammonites and nautilus shells. Furnishes building and paving stone.
	TRIASSIC.	Keuper. Muschelkalk. Bunter-sandstone.	Called by the Germans TRIAS. Connecticut river sandstone with footprints. Red clays, marls, shales and sandstones. The New Red Sandstone of England. In Europe great salt beds.
PRIMARY OR PALEOZOIC.	PERMIAN.	Dark red sandstone. Magnesian limestone. Conglomerates, Breccias, Marls in all three.	Mostly sandstones and marlytes, some impure magnesian limestone and gypsum. Thin seams of coal, unworkable. With exception of BROWN HEMATITE iron ore and the metals mentioned above, all the other metals are found in the formations below.
	CARBONIFEROUS.	Seams of Anthracite and bituminous coals of varying thicknesses. Millstone grit. Subcarboniferous.	The black band iron ore. Limestone from the same mines with the coal in Great Britain, but not so frequently in America. Anthracite, cannel, and bituminous coal in seams in limestone, sandstone, and shales, forming "The Coal Measures." Affords PETROLEUM in Pennsylvania, Ohio and elsewhere, and salines in Michigan. It is the MOUNTAIN LIMESTONE of England. Largely of corals.
	DEVONIAN.	Catskill Period. Chemung Period. Hamilton Period. Corniferous Period.	Includes the OLD RED SANDSTONE OF ENGLAND. Hamilton black shales produce oil, the Hamilton beds afford excellent flagging stone. Corniferous called also upper Helderberg group.
	SILURIAN. Upper	Oriskany Sandstone. Lower Helderberg Period. Salina Period. Niagara Period.	Salina Period supplies the salt waters of Salina and Syracuse, N. Y.
	Lower	Trenton Period. Canadian Period. Potsdam Sandstone.	The LEAD MINES of Iowa and Wisconsin are in the Magnesian Limestone of the Canadian Period.
		Cambrian. Laurentian. ARCHÆAN.	

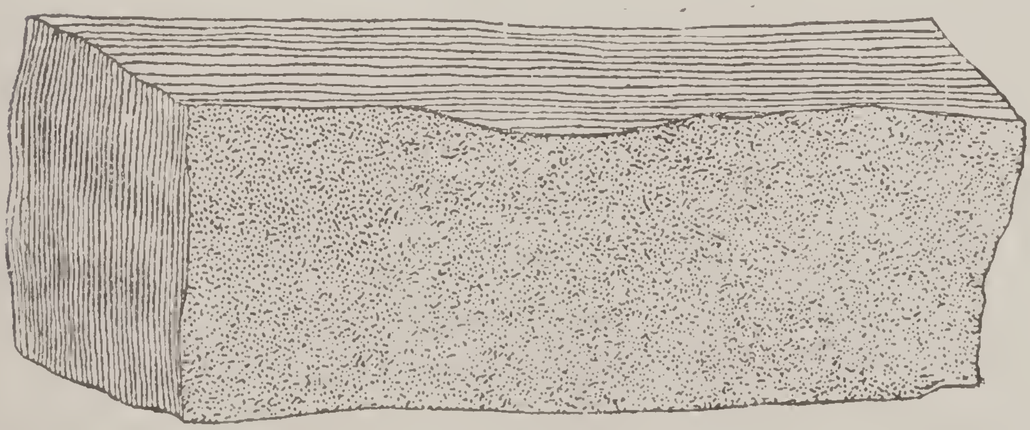
(Between pages 32 and 33.)

laminated rocks composed of mica and quartz in small particles, easily broken up, but more easily broken into tabular or leaf-like pieces, because the mica has been deposited in planes allowing of cleavage.

3. THE AQUEOUS ROCKS are simple water rocks—that is, rocks composed of sediments from the dust or ground-up remains of other rocks. The presence of such sediments is due to the transporting power of rivers, floods, or currents, and also of winds and storms and other agencies, carrying the dust to the ocean waters where it was arrested and became a sediment.

These rocks are, as a rule, stratified, or made up of successively deposited strata. They are almost in all cases fossiliferous.

FIG. 2.



Sandstone.

In sandstone (Fig. 2), the grains of sand are rounded, having no sharp edges as in granite.

Where the sedimentary material was exceedingly dust-like, it sometimes is laid down as fine mud and frequently in laminae, as in shale (Fig. 3).

Granite is a term descriptive of rocks generally composed of quartz, feldspar and mica, in grains (hence the name) of a crystalline form. But the granites are not all alike in the amount of either of the above-mentioned minerals, nor are they alike in color. Some granites contain no mica, as in *graphic* granite, only quartz and feldspar, and the quartz in the feldspar resembling written characters. Others contain hornblende as well as mica, or in the place of mica; the hornblende being in dark or black crystalline specks, pieces, or crystals, and consisting essentially of silica, magnesia, lime, and iron. This granite is called *syenite* granite. Where the feldspar is in distinct crystals in compact base, and sometimes lighter than the base, which is frequently reddish, purple, or dark green, it is a *porphyritic* granite. The granites are sometimes whitish, grayish, or flesh-red. They are considered as metamorphic and not igneous (Dana), although some

Fig. 3.

Shale.

authors still consider them to be igneous. They always present a crystalline grain in varying degrees of fineness and prominence. One form is given in Fig. 4, from a specimen in the author's possession.

This specimen contains two kinds of mica, one black, *biotite*, the other white of silvery appearance, *muscovite*. The biotite presents in spots the appearance of hornblende, and only the pen-knife point shows the scaly lamination of mica under the lens. It also contains crystalline forms of potash feldspar (*orthoclase*), distinguishable from the quartz by their sides only, by the lamellar fracture of its edges, and its peculiar vitreous glimmer, for practically the hardness appears the same, although feldspar is (6.6 and quartz 7) slightly softer. It would be well for the prospector to gather many forms of granite and examine them under the lens until he becomes thoroughly used to the variations.

Fig. 4.

Granite with black mica and feldspar crystals, with quartz as chief base.

The rocks have since their formation been subjected to numerous changes. Some have been raised from the sea without being lifted to any extent from their original horizontal position; others have been folded into most fantastic shapes; and others again have been completely inverted. In other cases, movements which have taken place since the rocks became solidified have caused fractures, and by the rocks on one side of the crack sliding on those of the other, *faults* have been produced.

Where the rocks have been folded in the form of an arch, they are said to form an *anticlinal,* and where they occupy a basin, they are spoken of as forming a *synclinal.*

In examining the surface of a country in which the rocks are of sedimentary origin, it will be found, as a rule, that the beds are inclined at varying angles to the horizon, and in making a geological survey of any special district it is necessary to note the *strike* of the rocks at every available point. When any well-marked bed occurs, its line of outcrop should be carefully followed and mapped; the boundaries of any eruptive rocks should also be clearly delineated on the plan.

The *strike* of a rock is the direction of a horizontal line in any of the beds, or, in other words, the direction in which a level drive would be put in on the floor of the bed. The *dip* is a line at right angles to the strike on the plane of the beds, and the angle is to be measured in relation to the horizon.

When any particular bed is followed on the surface, it is often found that it does not continue with the same strike for any great distance; that, in fact, it gradually veers round, the direction of the dip changing at the same time. The boundaries of rocks are sometimes rather obscure in consequence of the variable movements which have taken place, but the tracing of them on the surface is made most difficult by the occurrence of faults and dykes. The displacement due to faults may be only an inch or so, or may be several hundred feet, while in exceptional cases it may be as much as two or even three miles.

A study of faults is of great importance, more especially on account of their close association with mineral lodes.

The first indications of a deposit possessing economic value are, as a rule, to be met with among the materials forming the beds of streams, and wherever water-courses have seamed and furrowed the rocks. Metalliferous deposits should be looked for in hilly districts as a general rule, though alluvial accumulations may be found in comparatively flat country. A close study of natural phenomena will often help in the discovery of mineral wealth. Thus the form and color of the surface; stained patches; springs of water whether sweet or mineralized; scum floating on water (petroleum, etc.); accumulations of earth brought to the surface by burrowing animals; changes in vegetation; behavior of the magnetic needle. These, however, only serve to indicate existence without reference to quantity or quality.

The valuable minerals and metal-bearing deposits of the earth occur as

Lodes. By a lode or vein is generally meant a fissure in the rocky crust of the earth which is filled

FIG. 5.

FORMATION, CROSS-SECTION.

I, I, I, I, country rock enclosed in lode on *horse*, surrounded by auriferous quartz. A, A, hanging wall; B, B, foot wall; C, C, casing; D, D, D, D, *country* rock.

with mineral matter. In Australia a vein is called a *reef* and in California a *ledge.* The course of a lode in a horizontal direction is called its *strike,* while its descent is spoken of as its *dip.* Very often lodes are distinctly marked off from the rocks enclosing them by straight and sharp divisions on either side of the lode as if cut with a knife. These divisions are called the *walls* of the lode. When the lode inclines in its dip to either one side or the other, which is nearly always the case, the upper division is called the *hanging-wall,* and the lower the *foot-wall.* The incline of the load in its dip is its *underlie.* The barren rock through which the lode passes is known amongst mining men as the "country." Lodes may be all widths from a thin thread-like film to 100 feet or more in width. Lodes often contain large blocks of the country rock barren of ores or metals, which are therefore waste. Such occurrences are spoken of as *formations* or *horse,* and are generally of great width between the two walls. See Fig. 5.

Lodes nearly always carry *casing,* which is country rock ground very fine, converted into clay by moisture and mixed with quartz and free native gold. The casing mostly occurs on the foot-wall, and is often very rich in metal. Fig. 6.

When an outcrop of mineral has been found and the strike, in case of a lode, has been determined, it is advisable to test it along the surface at various points to prove its continuity and comparative richness at different points. It must not be assumed because a lode is rich where found that it will be equally so at all points where it is intersected ; and equally, because a lode is poor where first discovered, there is no reason to suppose that further prospecting along its course may not disclose parts in which valuable minerals occur.

When surface prospecting has given as much information as possible, some sinking and driving should be undertaken to prove the continuity and value of the deposit in depth. To acquire the greatest amount of information at the minimum cost, the point for sinking a shaft should be selected on the surface where the ledge is at its best and, having

Fig. 6.

Showing solid quartz lode, with casing. Tranverse section.
1, 1, solid quartz lode without *horse* ; 2, 2, casing of soft dig; 3, hanging-wall ; 4, foot-wall ; 5, 5, country rock.

determined the extent along the strike, as nearly as possible, which carries payable mineral, the shaft should be placed about the center and sunk on the underlay to a depth of 100 feet, or less, if the water level is reached sooner ; and from the bottom levels should be driven along the course of the lode as long as the mineral is of sufficient value to pay.

It will be seen that by these means a plot of ground can be cheaply opened, in which a certain quantity of ore can be measured and sampled, and an accurate idea of its value obtained. In measuring up quartz it is usual to estimate 13 cubic feet to the ton, in the solid, so that a vein 3 feet wide proved to a depth of 100 feet and for 100 feet along its line of strike would contain $\frac{100\times100\times3}{13}=2307$ tons.

The stone should be sampled every few feet and taken from wall to wall in order to arrive at a fair estimate of its value.

In following up other minerals than gold, it must be borne in mind that many of them have a tendency to decompose when exposed to the action of the weather and, consequently, that the nature of the ore at the outcrop may be very different to what will be found in depth. Copper ores, for instance, are very liable to decompose and, forming sulphates which are soluble, to be carried away in solution by running water. As most copper ores are associated with a greater or less quantity of iron, the outcrop of copper lodes are very frequently represented by a porous ironstone which is called *gossan*, and no sign of copper is found until some depth has been sunk. Generally speaking an outcrop of porous gossan may be looked upon as a very good indication for mineral in depth ; whereas, a dense ironstone seldom leads to rich deposits of other mineral below.

Beds and layers. The most common of bedded deposits are those of coal. Many kinds of iron ore are found in beds, also some copper ores in shale, silver and lead ore in sandstone, etc. Beds and layers are also known as *strata*, *measures*, *sills*, *mines*, *bassets*, *delfs*, *girdles*.

Irregular deposits, such as *pockets*, etc., which lie sometimes in various formations. Contact deposits, net-work of veins, and where mineral is diffused through rocks, or in small cracks.

Many of the irregular deposits are of great value and some of the rarer minerals, such, for instance, as sulphide of bismuth and native bismuth are found in them. These irregular deposits are not only irregular in their mode of occurrence but vary much both in size and shape so that no one by surface indications is able to form any opinion regarding their extent. It is even more important in testing these deposits when an outcrop has been found, than it is in the case of a ledge, to follow them carefully in the workings. Any drives or shafts which may be commenced should follow the direction of the ore after its extent has been proved as far as possible by these prospecting works.

Surface deposits. By surface deposits are understood the beds of alluvium which more or less cover the face of every country. These beds have been chiefly created by various mechanical agents, which, after having degraded the higher rocks, carry the material which has thus been formed down to lower levels. By this process of degradation most mineral deposits are so comminuted that by their exposure to the atmosphere they are decomposed and destroyed. However, substances like cassiterite, platinum, gold, etc., not being so readily subject to decomposition, have, in consequence, been more or less preserved and buried among these superficial deposits. In observing deposits of this kind notice has to be taken of their general situation, area, thickness and richness. Often several beds may be ranged one above the other, in which case their relative values have to be determined. In tracing any particular deposit, as, for example, whilst ascending a valley, if the particles of ore increase in size and number, the prospector may expect that he is approaching their common origin. Another indication that he is near this point of origin will be that he shall find the mineral less worn.

Comprehensively speaking, all metals are found in the oldest rocks only, and the latter form the backbone, so to speak, of the main ranges of metalliferous countries. Therefore, the prospector in making his road towards the mountains will have to select a spot for starting actual operations. For this purpose a locality should be chosen where the rocks are neither too hard or too soft, nor should they be of too uniform a character. The country most deeply indented with gullies, cañons and gulches running parallel to one another offers the best chances of success. The region near the sources of the main rivers is generally the richest in metals and always the most easily prospected, requiring less labor and time in its examination, the loose debris and wash being of much less depth on account of the greater fall in the river and creek beds than at other portions of the courses.

Auriferous lodes are most likely to be met with near the headwaters of river systems, and very frequently the alluvial gold begins at or near the locality where a number of auriferous lodes exist. This is a very common occurrence, and may be in the great majority of cases relied upon.

When a river forks at its head into two or more branches, it is strange to say, the source of the gold will nearly always be found in the right-hand branch, geographically speaking. It may be mentioned that in determining the right- and left-hand branches or banks of a river or stream, you are supposed to stand at the head of the river or stream looking towards its mouth or outlet. Amongst miners this is very often reversed, and quite a number of branches are named left-hand which, properly speaking, ought to be right-hand branches.

This right-hand theory is an old mining superstition for which science has offered no explanation, but the almost unfailing applicability of the theory is fully established by practical experience. Speaking of mining superstitions, it may be added that the spots upon which the sun shines before noon are held by miners to be richest in metal. Every old gold-miner will pin his faith to this theory. What makes these observed facts—for they really amount to that—all the more remarkable is, that they may be applied with an equal degree of liability to the Northern and to the Southern hemispheres, which makes these superstitions appear in a paradoxal light. However, they have survived the test of hundreds of years in Cornwall and on the Continent of Europe, and have been confirmed by further observation in California and Australia. The latter instance, *i. e.*, the spots upon which the sun shines before noon, may find an explanation in the fact that landslides and elevations of rock of all kinds are of more frequent occurrence upon the sunny than upon the shady side of valleys, the greater amount of disintegration of the rocks leading to a greater accumulation of the metals. However this may be, the theory forms one of the golden rules of the prospector.

The color of the rocks also serves as a guide to the prospector. Rocks of a pinkish-reddish color alternating with rocks of a deep bluish tint streaked with drab are generally very favorable to metallic deposits. Another good indication is when the faces of the precipices are covered with a black ooze caused by manganese, the presence of which always indicates a mineralized district. These are simply general indications.

Although color is always a good guide to the location of metallic deposits, it is of special service to the prospector in unexplored districts. Thus copper is indicated by greenish, bluish or reddish stains upon the rocks in the neighborhood of the lode; tin and manganese by dull, black tints; manganese shows itself also in pinkish streaks. Gold, being always accompanied by iron, manifests its presence in red, yellow or brown shades; lead and silver reveal grey or bluish-grey tinges; blende dyes the rocks yellowish-brown, and iron disports itself in all the hues of red, yellow-brown, and even dun-black.

The *wash of rivers and creeks*, and even more so that deposited upon terraces (if any) flanking the streams, must claim the close attention of the prospector. By wash is meant the diluvial drift in which gold or tin—the only metals mined in diluvial deposits—is found. The colors in connection with the different metals mentioned above apply also to stones and the wash generally, though in a modified degree. Stones streaked with pinkish lines, and lines indicating manganese, are always found in wash conveying gold. Green stones, which are universally found in the wash, are always a good indication of gold if they are of a bright sea-green or even pea-green, but they must be smooth, hard, well-polished and very heavy. In many districts such stones are considered the "pilot stones" to gold. Quartz stones must be always present in goodly numbers in every gold-bearing wash, and if they are in a decaying state, they are all the better as a favorable indication.

A very large portion of the gold which has come into the possession of men has been obtained from superficial deposits called *placers.* Deposits of placer gold are always found adjacent to and lying below districts traversed by auriferous veins, and nowhere else. The areas where the quartz veins occur have suffered great erosion, which has tended to break down and comminute the quartz, and to liberate and wash the contained gold.

Placer gold is found mingled with rolled fragments of quartz and in the irregularities of the surface of the bed rock, where a washing process on a large scale has been active.

The nuggets and coarsest gold are found nearest the outcrops of the quartz veins that have supplied them, while particles become gradually finer and finer as the line of drainage is followed from this point.

Pebbles and fragments of gold-bearing quartz which have been derived from the neighboring veins are commonly found in the placer deposits, and most of the nuggets have more or less quartz, like that of the veins still adhering to them. The gold is found in scales, grains, pebble-like nodules and round, battered masses or nuggets.

Such alluvial deposits demand very careful attention. They are of the greater importance because alluvial gold and tin are in many cases found under conditions which require no capital to work them and, consequently, immediate returns can be obtained when discovery has been made. River beds and creeks should be carefully examined, a pick and a shovel, a tin dish and a large knife being all the equipment necessary. In the first place the gravels of the stream should be washed carefully with the object of determining whether any gold at all exists. Next certain beaches along the course of the stream should be selected and shallow pits sunk through them until bed-rock is met with, and all the material raised should be panned, bearing in mind that the best gold is generally found on the bed-rock.

A further test should be made by carefully following up the stream, especially when it is low, and cleaning out with a knife all crevices in the rocks in which gravel and sand have accumulated, and this should all be panned. In some cases large quantities of gold have in a short time been saved by prospecting in this manner.

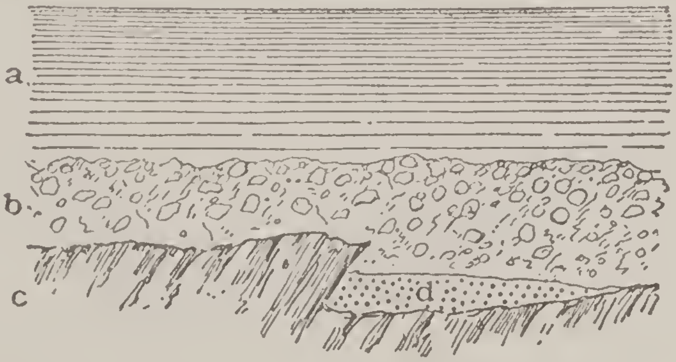
However, the gold which is found in rivers and streams does not necessarily point to the close proximity of the ledges from which it was derived ; still less does the occurrence of alluvial gold in buried river beds indicate the proximity of ledges. A careful prospector will often notice that a river or stream which he is testing appears at certain points to have altered its course, having, in fact, found it easier to cut a channel in a different direction to that which it originally followed, it has done so leaving its former channel, with the gravels and sands it had deposited, high and dry.

In cases such as this, it is generally worth while to sink prospecting shafts through the gravel until bed-rock is reached and, if the first is not successful, others should be sunk towards the upper part of the channel as defined by the inclination of the bed-rock where it is met with. There are, of course, comparatively few prizes and many blanks in prospecting such as this, but the value of the deposits found at times offers inducements to prospectors to continue trying, even when but small success has attended their earlier efforts.

The domain of the prospector lies in hilly ground. Flat plains have little attraction for him except under special conditions, because, though valuable minerals may be present, they are certain to be covered by an enormous deposit of soil.

In character, placer diggings manifest almost as great variety as vein deposits. The following illustrations show in section some forms of these alluvial deposits:

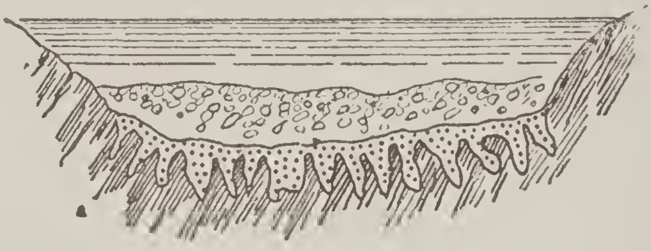
Fig. 7.



The stream (Fig. 7) flows across the strike of the rocks, and the gold is found below a hard bar; *a*, surface of stream; *b*, mud and gravel forming bed of stream; *c*, bed-rock; *d*, auriferous gravel retained by the projection of the bed-rock.

In Fig. 8 the stream flows as in Fig. 7, across the strike of the rocks, but the gold is found on one side of the creek. *a*, bank of stream; *b*, mud and other worthless matter lying on the pay dirt; *c*, auriferous gravel accumulated in the deepest parts of the stream.

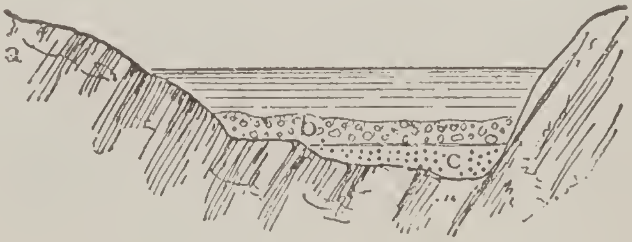
FIG. 8.



In Figs. 9 and 10, *a* represents the stream; *b*, mud and gravel at bottom of stream; *c*, bed-rock; *d*, pot-holes in bed-rock where auriferous material has lodged.

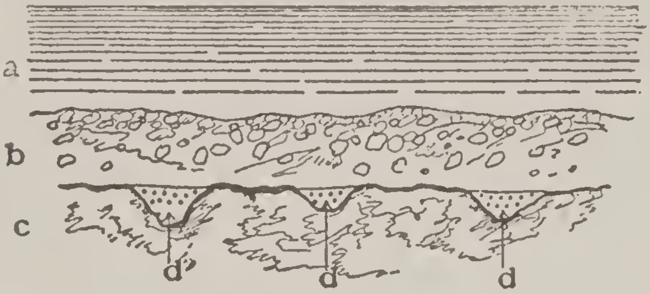
In Figs. 9 and 10 the stream generally runs with the strike of the rocks, or at a slight angle; but the dip is nearly perpendicular in those instances where pot-holes have been known to occur.

FIG. 9.



In estimating the value of alluvial claims it is of the utmost importance to consider the cheapness and abundance of the water supply and, what is of no less importance, the facilities afforded by the surrounding levels for the disposal of the debris of the mining operations or waste material, called *tailings*, from which the gold has been excavated or removed, so that the gold-bearing layer may be reached.

FIG. 10.



Beach placers. On the Pacific shores of America, extending in patches for a considerable distance, as far up as Alaska, are a number of auriferous deposits known as beach placers. They appear to be surface concentrations due to wave action, and an enrichment of this type seems to take place after heavy storms. Under such conditions the waves cut back into the coastal-plain sediments and concentrate the heavy material as a surface layer. The occurrence of these deposits is of interest, because they indicate that certain regions are auriferous. The richest deposits of this character are the famous beach placers at Nome, Alaska.

INDICATIVE PLANTS. From very early times it has been noticed that the soil overlying mineral veins is favored by special vegetation, and though the occurrence of such vegetation cannot be taken as an infallible indication of the existence of such veins, it will be interesting to record the results of past observations, so that they may serve for a guidance to further observation in future.

Indication of lead. The lead plant (*Amorpha canescens*) is said by prospectors in Michigan, Wisconsin and Illinois to be most abundant in soils overlying the irregular deposits of galena in limestones. It is a shrub one to three feet high, covered with a hoary down. The light blue flowers are borne on long spikes, and the leaves are arranged in close pairs on stems, being almost devoid of foot-stalks.

Gum trees, or trees with dead tops, as also sumac and sassafras, are observed in Missouri to be abundant where "float" galena is found in the clays.

Indication of iron. A vein of iron ore near Siegen, Germany, can be traced for nearly two miles by birch trees growing on the outcrop, while the remainder of the country is covered with oak and beech.

Indication of limestone. The beech tree is almost invariably prevalent on limestone, and detached groups of beech trees have led to discoveries of unsuspected beds of limestone.

Indication of phosphate. The phosphate miners in Estremadura, Spain, find that the *Convolvulus* *althæoides*, a creeping plant with bell-shaped flowers, is a most reliable guide to the scattered and hidden deposits of phosphorite occurring along the contact of the Silurian shales and Devonian dolomite.

Indication of silver. In Montana experienced miners look for silver wherever the *Eriogonum ovalifolium* flourishes. This plant grows in low, dense bushes, its small leaves coated with thick, white down, and its rose-colored flowers being borne in clusters on long, smooth stems.

Indication of zinc. The "zinc violet," *Galmeiveilchen* or *Kelmesblume* (*Viola calaminaria*) of Rhenish Prussia and neighboring parts of Belgium, is there considered an almost infallible guide to calamine deposits, though in other districts it grows where no zinc ore has been found. In the zinc districts its flowers are colored yellow, and zinc has been extracted from the plant. The same flower has been noticed at zinc mines in Utah.

In looking for indications where superficial deposits are known to occur, the prospector may be often guided, like the Tungusians in Northern Siberia, who search for gold by first looking at the general contour of the country, and observing those places where any obstacles, like a projecting range of hills, would be likely to prevent material from being directly washed from higher to lower ground. Holes, sudden bends, or anything which would cause a diminution in the force of a current of water, are points at which it should be expected that heavy material like gold or platinum would be likely to collect. Although in Australia the most gold is generally found in *pot-holes* and behind *hard bars*, it has often been found upon the shallow bends of ancient river courses. The lowest of a series of beds is generally the richest. In California the gold-bearing beds usually consist of gravels, which may be cemented to form a conglomerate, sands, bands of tuff, clay, fossil-woods, etc.

Magnetite occurs in alluvial deposits. Bog iron and manganese ore which have accumulated by precipitation in marshy places or in lakes, usually contain too much impurity to be of commercial value. Stream tin occurs in gravels in much the same way as gold.

In examining a lode, the nature of the various minerals it contains and the proportions which these hold to each other should be observed. Sometimes it will be noticed that certain groups of minerals are often found together, the presence of one being favorable to the existence of the other. At other times the reverse will be remarked, the existence of one mineral being the sign of the absence of another. The practical advantages to be derived from a series of observations indicating such results are too obvious to be overlooked.

The following table, showing the association of ore in metalliferous veins, is given by Phillips and Von Cotta :

Two Members.	*Three Members.*	*Four or More Members.*
Galena, blende.	Galena, blende, iron pyrites (silver ores).	Galena, blende, iron pyrites, quartz *and* spathic iron, diallogite, brown spar, calc spar *or* heavy spar.
Iron pyrites, chalcopyrites.	Iron pyrites, chalcopyrites, quartz (copper ores).	Iron pyrites, chalcopyrite, galena, blende; *and* spathic iron, diallogite, brown spar, calc spar; *or* heavy spar.
Gold, quartz.	Gold, quartz, iron pyrites.	Gold, quartz, iron pyrites, galena, blende; *and* spathic iron, diallogite, brown spar, calc spar; *or* heavy spar.
Cobalt and nickel ores.	Cobalt and nickel ores, and iron pyrites.	Cobalt and nickel ores, iron pyrites; *and* galena, blende, quartz, spathic iron ore, diallogite, brown spar, calc spar; *or* heavy spar.
Tin, ore, wolfram.	Tin, ore, wolfram, quartz.	Tin ore, wolfram, quartz, mica, tourmaline, topaz, etc.
Gold, tellurium.	Gold, tellurium, tetrahedrite (various tellurium ores).	Gold, tellurium, tetrahedrite, quartz; *and* brown spar; *or* calc spar.
Cinnabar, tetrahedrite.	Cinnabar, tetrahedrite, pyrites (various ores of quicksilver).	Cinnabar, tellurium, tetrahedrite, pyrites, quartz; *and* spathic iron, diallogite, brown spar, calc spar; *or* heavy spar.
Magnetite, chlorite.	Magnetite, chlorite, garnet.	Magnetite, chlorite, garnet, pyroxene, hornblende, pyrites, etc.

CHAPTER II.

THE BLOW-PIPE AND ITS USES.

All chemical tests for minerals, whether with the blow-pipe or in the wet way, depend upon some chemical change which is brought about, thus allowing the element, base or acid, to be recognized. These changes consist either of the decomposition of the mineral or the formation of fresh compounds. The following instances will sufficiently illustrate the character of these changes.

If the oxide of a metal, copper for instance, is mixed with carbonate of soda and fused on charcoal, the copper is reduced to a metallic state, the oxygen combining with the charcoal to form carbonic acid, which escapes as a gas, and any silica which is present decomposes the carbonate of soda to form a silicate of soda, which may be looked upon as a slag.

If a hydrous mineral is heated in a glass tube closed at one end, the water is given off, and condenses as drops in the cool part of the tube.

If an arsenical mineral is heated in a closed tube a crystalline deposit of arsenic is formed in the tube; but if it is heated in the air, white fumes of arsenious acid are evolved which smell like garlic.

If a drop of hydrochloric acid be placed on a carbonate, such as limestone, the presence of carbonic acid is recognized by the effervescence which takes place; the stronger acid having combined with the lime has liberated the carbonic acid in a gaseous form. In the case of very many mineral carbonates, the acid requires to be heated for this reaction.

A great deal can be learned respecting a mineral by a few simple trials with the blow-pipe, and every prospector should learn to use it. The chief requirements are a plain brass blow-pipe about 7 to 10 inches long, a candle, a forceps or pliers, some platinum wire, a small pestle and mortar made of agate, a small sieve, a magnet, some small glass tubes, and some good firm charcoal free from cracks and openings.

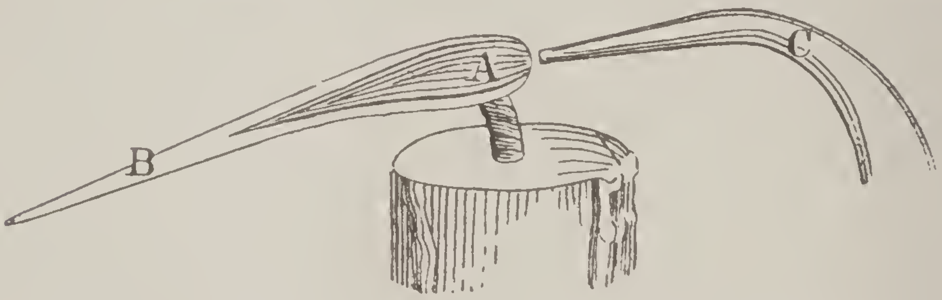
The only reagents which will be absolutely necessary are borax, carbonate of soda and, rarely, microcosmic salt, nitrate of cobalt, and a little hydrochloric and sulphuric acid. A few others are occasionally necessary, but their use is limited. The carbonate of soda should be perfectly dry, not merely dry to the touch, but quite free from water. Such carbonate of soda may be prepared from common washing soda by expelling the water it contains. Put the washing soda in a shallow, clean iron dish, and place it over a clear fire until a white, dry powder is formed; avoid too strong a heat, otherwise the dry powder might fuse. A quarter of an ounce may be kept in a well-corked bottle or tube for use. Bicarbonate of soda may be used instead without previous heating, or if the bicarbonate be moderately heated it loses weight, and becomes carbonate of soda, quite free from water, like the above.

The borax is to be dried in the same way; a quarter of an ounce will be enough. It is convenient to keep the platinum wire in the same tube. Unless these tubes are well corked, these chemicals reabsorb moisture. For testing tin ore it is useful to have a little cyanide of potassium kept in a bottle, with the cork and rim well covered with melted beeswax; it would otherwise liquefy by absorption of moisture and become useless. It is a most dangerous poison, and the greatest caution must be observed in its use.

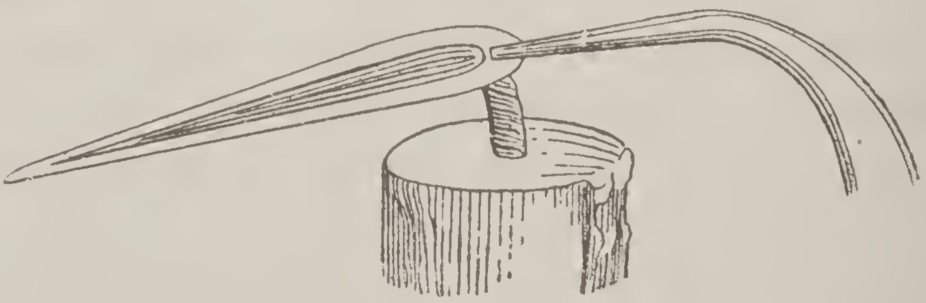
The blow-pipe should have a fine jet, or aperture, wide enough to admit of a fine needle. The mode of using it may be readily acquired by first breathing through the nostrils with the lips closed, then puffing out the cheeks (as if rinsing the mouth with water), still keeping the lips closed, and breathing as before. The blow-pipe may at this point be slipped between the lips, and it will be found that a current of air escapes through it without any effort on the part of the operator. Air flows through the pipe owing to the tendency of the distended cheeks to collapse; it must never be forced from the lungs. After a little practice the strength of the current may be increased. By breathing entirely through the nostrils, keeping the lips closed, the blast may be kept up for ten minutes or longer without exhaustion or inconvenience, except a slight fatigue of the lips in holding the blow-pipe. The beginner may practice blowing upon a piece of charcoal. The charcoal should, for convenience's sake, be cut into slices of some six inches long by three-quarters to an inch wide and half an inch thick. Place a piece of lead, or a pin-head, or fragment of pyrite (iron pyrites), near the end of the charcoal, and learn to blow the flame of a candle to a point upon the object. However awkward the blow-pipe may feel at first, practice will soon enable the learner to be expert. At first it may be necessary to gouge a small hole or recess in the coal with the point of your pen-knife, in order to prevent the specimen from being blown away. But after many trials such a command will be had over the blast that the hole may be made sufficiently deep by simply turning the point of the flame upon the coal and burning out a cavity.

Study the two colors of a sperm candle flame (Fig. 11). Notice that there is a yellow flame outside and nearer the top, and then within the flame there may be seen a bluish, probably a true blue, flame. These flames act differently on the same substance. The outer, *O F*, or yellow flame, is called the "*oxidizing flame*," the inner, the "*reducing flame*," *R F*, or *I F*. By blowing properly, these two flames may be made to turn horizontally, or even downward, and then either the *O* flame or the *R* flame may be turned on the "assay" (as the object on the charcoal may be called). Get a piece of iron ore as large as a pin-head and place it in a little cavity on the charcoal, then cover it with a quantity of soda carbonate as large as the assay. Now turn the *R* flame down on the soda and ore, and in a few seconds the ore will melt and be reduced to metallic iron, and your magnetized knife-blade will pick it and the soda up. In this experiment a piece of red or brown hematite, or a piece of *pyrite* (iron pyrites), should be used, as neither will be attracted by the knife-blade *before* the ore is reduced to metallic iron. The reason for this action on the part of the ore is that the ore is metallic iron *combined with oxygen*, and the *R* or blue flame calls for more oxygen than it possesses, so that when it is

FIG. 11.



A, the blue or reducing flame; *B*, the oxidizing flame; *C*, the end of the blow-pipe.

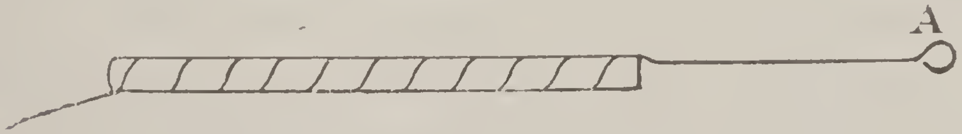


By placing the end of the blow-pipe in the flame thus, the oxidizing flame *B*, is made more efficient.

turned upon the hot oxide of iron it takes the oxygen it calls for from the ore and leaves the iron in a metallic state. But in the pyrite, which is iron and sulphur, the latter is partially driven off by either flame; and this process, on a larger scale, is called "*roasting.*" The soda absorbs a part of the sulphur and part remains in the iron, but not so much but that the magnetized knife-blade will attract it. The last experiment is good for experimental practice, but not for illustrating the two properties of the flame.

The following is an excellent practical illustration in showing the characteristic power of either flame. Get some platinum wire of the size of a large horse-hair. Wrap it around a match, leaving an end extending an inch and a half beyond the match end, then roll the end of the wire around another match until you have bent the end of the wire into a small loop (Fig. 12). Prepare a little powder of common borax, and then, heating the wire loop in the general flame, plunge it quickly into the powdered borax. It will immediately pick up a quantity of the powder, and then, by turning the flame upon the borax, you will have a clear and perfectly transparent bead filling the little loop on

FIG. 12.



Appearance and size of wire and of loop, *A*.

the end of the wire. You are now ready for the experiment of illustrating the special properties of the two flames, which will now be described.

Obtain some black oxide of manganese from any druggist, and dropping a little upon a clean sheet of letter-paper, heat your borax bead red-hot in the flame and quickly touch with the hot bead a particle of the black oxide—it will stick to the bead—then turn the outer or *O* flame upon the bead and blow till the particle of oxide of manganese has entirely dissolved—it will impart to the bead a beautiful amethystine-purple. Now turn the inner flame that is, the *R* flame, upon the bead, and in a few seconds (according to skill in keeping the *R* flame steadily on the bead) the color will disappear, but it will return when the *O* flame is used again.

These efforts will give practice, ending in sufficient skill to enable the learner to use the blow-pipe as directed in the future parts of this work.

The various reactions of different substances are given in the body of this book as they are called for when the substances are described.

A glass tube of a little less than three-eighths of an inch in diameter may be made into a blow-pipe as follows: Take a piece of such a tube, ten or twelve inches long, soften the tube by red heat in an alcohol flame, and draw it out to a small diameter—cool and scratch or file it at the smallest diameter—break it off, introduce the tube into the flame again and bend the glass to a right angle, about two inches off from the point—cool gradually—and heat the mouth end, opening it a little by introducing a small, dry, pine stick, cool it, and you have a very efficient blow-pipe when another of metal cannot be had.

Note: If your platinum loop will not hold the borax bead, then it is too large. Make a smaller loop. If it is dimmed or blackened by smoke, heat it red-hot—it will clear up.

The three principal means of chemically testing minerals before the blow-pipe are (1) with borax; (2) on charcoal, usually with the addition of carbonate of soda; (3) by holding in the oxidizing point.

In connection with this the following experiments given by Alexander M. Thomson, D. Sc., are of interest:

Experiment No. 1.—Many metals impart a color to fused borax, by which their presence can be recognized. To try this experiment, a bead of fused borax must first be obtained on the platinum wire. The end of the wire is bent into a loop or ring about the twelfth part of an inch in diameter. The wire is then heated in the blow-pipe flame, and dipped whilst hot into the borax; the portion of borax that adheres is then fused on to the wire in the blow-pipe flame, and the hot wire is again dipped; this is repeated until the loop contains a glass-like bead of borax. If the bead has become cloudy, the soot causing this may be burnt off in the oxidizing point of the flame. Having thus obtained a clear, colorless, transparent bead, the next step is to add to it a minute portion of the mineral which is to be tested. By touching a little of the finely-pulverized mineral with the borax bead, while softened by heat, enough will adhere to the bead for a first trial. The bead is then kept at a white heat in the oxidizing point of the flame for a few seconds, and on removal its color is noted, both whilst hot and when cold. If no color is imparted, a fresh trial may be made with a larger quantity of the powder; but if the bead is opaque owing to the depth of color, as is often the case, a fresh experiment must be made, using a still smaller quantity of the powder. The color can only fairly be judged in a perfectly transparent bead. If no color can be obtained in the oxidizing point, further experiment with the borax bead is needless; but if a color is obtained, it is then advisable to try the effect of the reducing flame upon the same bead. The following observations and inferences may result from this test:

COLOR OF BEAD IN		
Oxidizing	*Reducing*	*Presence of*
Green (hot); blue (cold)	Red	Copper.
Blue (hot and cold)	Blue	Cobalt.
Amethyst	Colorless	Manganese.
Green	Green	Chromium.
Red or yellow (hot) Yellow or colorless (cold)	Bottle-green	Iron.
Violet (hot); red-brown (cold).	Gray and turbid, difficult to obtain	Nickel.

This mode of testing may often be used to prove the presence of the above-mentioned metals.

It requires some practice before reliable results can be obtained in reducing. The reduced bead, if brought out of the flame at a white heat into the air, may at once oxidize; but this may be prevented by placing it inside the dark inner cone of an ordinary candle flame, and allowing it to cool partially there.

Experiment No. 2.—The mode of testing with carbonate of soda on charcoal is performed as follows: A sound piece of charcoal half an inch square is chosen, and a neat cavity is scooped out on its surface, in which is placed a mixture containing the pulverized mineral to be tested, with three or four parts of carbonate of soda, the whole not exceeding the bulk of a pea. After lightly pressing the mixture into the cavity, the blow-pipe flame may be cautiously applied to it; and afterwards when the mixture no longer shows a tendency to fly off, the charcoal may be advanced nearer to the blow-pipe, and finally be kept at as high a temperature as possible, in the reducing part of the flame.

In testing for tin ore, a piece of cyanide of potassium, about the size of a pea, may be placed upon the mixture after the first application of heat, and the further application of heat may then be continued.

This treatment is designed to extract metals from minerals; it favors in the highest degree the removal of oxygen. But, like the borax test, it is limited in its application, as it can only be used to detect certain metals. The failure of the test in any case must not be looked upon as a conclusive proof of the absence of the particular metal sought; for instance, copper can be easily extracted from carbonate of copper by this test, but not from copper pyrites. Still the test is a most valuable and indispensable one to the mineralogist. The test is complete when the metal is obtained as a globule, in the cavity of the charcoal. In many cases the globule will be found surrounded by the oxide of the metal, forming an incrustation on the charcoal; and the color of such incrustation should be carefully noted, both at the moment of removal from the flame and after cooling. By pressing the globule between smooth and hard surfaces it can be determined whether the metal is flattened out (or malleable) or crushed to pieces (brittle).

The following observations and inferences may result from this test:

Globule	*Incrustation*	*Presence of*
Yellow, malleable	None	Gold.
White, malleable	None	Silver.
Red, malleable	None	Copper.
White, malleable	White	Tin.
White, malleable	Red (hot); Yellow (cold)	Lead.
White, brittle	Red (hot); Yellow (cold)	Bismuth.
None	Yellow (hot); White (cold).	Zinc.
White, brittle, giving off fumes when removed from flame	White	Antimony.

Experiment No. 3.—In addition to these substances there are others which occur abundantly in minerals, and which may be recognized by the blow-pipe with the greatest ease; for instance, sulphur and arsenic.

These may be discovered by heating a fragment of the mineral, supported on a piece of charcoal or held in a forceps in the oxidizing point of the flame. and comparing the odor which is given off. A smell of burning sulphur indicates that the mineral contains that substance, and white fumes having a garlic odor indicate the presence of arsenic.

Mercury, antimony, and other substances may escape as fumes when heated in this manner.

Nitrate of cobalt dissolved in water, and used in exceedingly small quantity, helps to discriminate between certain white minerals, such as kaolin, meerschaum, magnesite, dolomite, etc. The mineral is reduced to powder and moistened with a drop of a very light solution, and then heated before the oxidizing flame of the blow-pipe. Kaolin and other minerals containing alumina assume a rich blue color, while meerschaum and other minerals containing magnesia become flesh-colored. Oxide of zinc, under the same circumstances, becomes green, and this can be tried with the white coating obtained on charcoal by reducing an ore of zinc with carbonate of soda.

Tests in glass tubes can be better made over a spirit lamp, so as to avoid the deposit of soot on the glass, but they can also be made with the blow-pipe flame, provided it is used carefully, avoiding too sudden a heat, which would break or fuse the glass. The presence of water in minerals will be detected in this way, as the water collects in small drops in the cold part of the tube. Some minerals containing sulphur; arsenic, antimony, tellurium and selenium often give a characteristic deposit.

Minerals containing mercury can also be tested in this way, as by adding a little carbonate of soda, sometimes with cyanide of potassium, a sublimate of metallic mercury will be formed in the cold part of the tube. A little charcoal should be added to arsenical minerals.

Organic combustible minerals generally leave a deposit of carbonaceous matter at the bottom of the tube, and the volatile hydrocarbons condense in the cooler part. The tube should, therefore, always be long enough to allow for this condensation. Minerals which yield a characteristic smell will be best tested in this way.

CHAPTER III.

CRYSTALLOGRAPHY.

THE *forms* which many minerals assume always indicate their *composition.* It is, therefore, sometimes a great help to the prospector to become acquainted with the subject of crystallography so far as to enable him to determine the system or order to which a crystal belongs.

We shall treat of the subject only so far as may be of practical application to the purposes of the prospector in the search for the useful minerals.

It is necessary to understand that nearly all mineral substances, when they appear in the crystalline condition, assume a characteristic form and do not trespass upon that of other minerals. Although, to the unaided eye and unskilled vision, this assertion may appear to be a mistake in some few cases, it appears so only because the differences are exceedingly small.

All crystalline forms have been reduced to six classes or systems, which are named as follows: I. *Isometric;* II. *Tetragonal;* III. *Hexagonal;* IV. *Orthorhombic;* V. *Monoclinic;* VI. *Triclinic.*

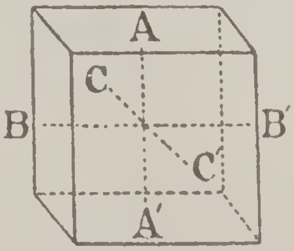
I. ISOMETRIC system. The principal forms of this system are the cube, octahedron, dodecahedron, the two trisoctahedrons, the tetrahexahedron, and the hexoctahedron.

The *cube* has six equal and square sides, as in Fig. 13. In this form lines drawn from the center of each face to the face opposite, cross each other at *right angles*, and are of the *same length*.

This system is called *isometric*, that is, iso *equal*, and metric *measure*, because these axes or lines are of equal length and at right angles to each other. It must, however, be remembered that the cube is modified in some minerals, but wherever these modifications take place the original form of the cube may always be traced. Some of the changes may be very intricate, and these especially unusual or intricate forms we shall not notice. The usual forms only are of importance, and can be treated of in so small a work as this.

The learner should take a potato and cut as perfect a cube as possible, and make himself acquainted with the common variations which may belong to the cube, as we shall show, without changing the length of the axis, and cutting so that the axis will always be the same or of equal lengths.

FIG. 13.

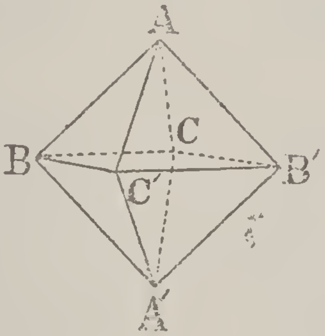


The Cube.

Fig. 13 is the cube with the three axes $A\ A'$, $B\ B'$, $C\ C'$. If, with your knife, you slice off one edge angle from A to C' and from A to C, and in like manner from A to B' and from A to B, you will have a four-sided pyramid, the apex of which will be at *A* and the four-sided base at *C B′*, *C′ B*, or around one-half the cube. Now, treat the opposite side in the same way, and you will then have the following figure, which is the octahedron (Fig. 14).

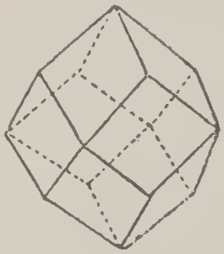
The dodecahedron (12 sides), Fig. 15, may be formed by taking off the solid angles *A*, *B*, *B′*, *A′*. In all three cases and in many others, the three axes remain the same in length, and in their angular direction where the forms have not been distorted.

FIG. 14.



The Octahedron.

FIG. 15.



The Dodecahedron.

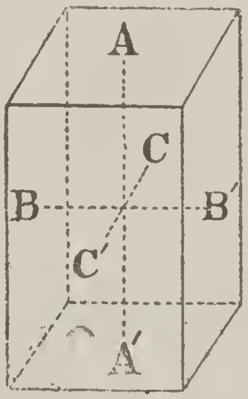
II. TETRAGONAL system. The chief forms of this system are the two square prisms and pyramids, and the eight-sided prism and double eight-sided pyramid.

The tetragonal system has also three axes as in the isometric, and they are at right angles to each other, but the vertical axis is longer than the others, as in Fig. 16.

The term *tetragonal* means "four-cornered or -angled," and is not precise, for a cube is tetragonal, but it is used to express this form because it is one word; otherwise "square prismatic" would be a more correct description, since Fig. 16 is that of a prism; for in mineralogy any crystal having parallelograms for sides is called a prism. Cut this prism as in the case of the cube, and you will have the form seen in Fig. 17.

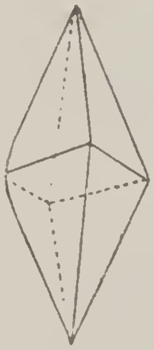
Variations upon this form may show a prism with four-sided termination at either or both ends, as in Fig. 18. This is the form of the transparent gem called the *zircon*, anciently called the *jacinth.* The zircon has been mistaken for the diamond, which it resembles in brilliancy, and somewhat in hardness.

Fig. 16.



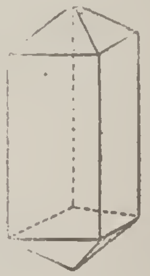
Tetragonal Prism.

Fig. 17.



Tetragonal Octahedron.

Fig. 18.



The Zircon.

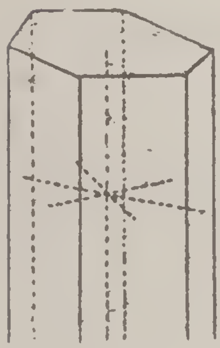
But the diamond is isometric and never tetragonal, and hence it may be distinguished readily from the zircon.

III. Hexagonal system. The chief forms of this system are the two six-sided prisms, the two double six-sided pyramids, and the twelve-sided prism and double twelve-sided pyramid. It differs from the tetragonal system in that it has three equal lateral axes instead of two; the vertical being at right angles, as in Fig. 19, with each of the three lateral.

But it must be remembered that owing to various causes in nature the hexagonal crystal always calls for hexagonal terminations; thus Figs. 20 and 21.

Owing to various causes in nature, the hexagonal crystal may be found under various modifications of the hexagonal form, but it can always be reduced to this system. The symmetry of the crystals may be by sixes, or very rarely, by cutting each angle, it may be in twelves, or the sides may be unequal in area or length, as in Fig. 20. The author once found a quartz crystal in Switzerland which was, for nearly its entire length, three-sided, but showed its hexagonal nature only at the extremity, where, having been free from its confinement in process of formation, it had assumed its normal crystallization. As has been said in another place, calcite crystals sometimes assume a hexagonal prism precisely as does quartz, but the latter shows always six-sided terminations, whereas lime or calcite crystals show three-sided terminations, as in Figs. 22 and 23. There are two sections or forms of this system, the *hexagonal* and the *rombohedral;* both belonging to

FIG. 19.



Hexagonal Prism.

FIG. 20.

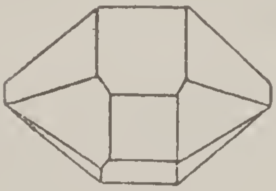
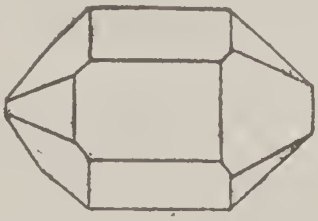


FIG. 21.

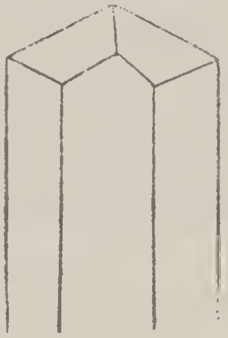


Quartz-Crystals—Hexagonal.

the hexagonal system, and distinguished as we have shown.

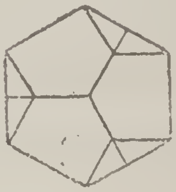
These calcite crystals belong to the rhombohedral section of the hexagonal system, showing rhombohedral forms at the end, as in Fig. 17.

FIG. 22.



Calcite hexagonal crystal—three-sided termination. Side view.

FIG. 23.



The same—end view.

IV. ORTHORHOMBIC system. The characteristic forms of this system are the rhombic prism and pyramid. There are also other forms called domes.

FIG. 24.

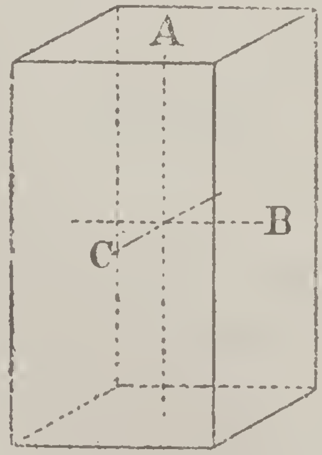
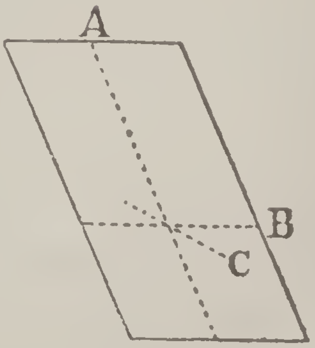


FIG. 25.



In this system the three axes are unequal and intersect at right angles, as in Fig. 24, wherein the axes, *A*, *B*, *C*, are unequal in length, but at right angles at the intersection. The terminations are flat, although frequently beveled on the surrounding edges.

V. MONOCLINIC system. The monoclinic forms are too difficult to be fully described here, but it is not hard to learn what is most essential about them. In this system two of the axial intersections are at right angles; but one is oblique, and the side of the crystal is inclined, as in Fig. 25.

Crystals of feldspar in general which contain potash (called orthoclase or potash feldspar), are monoclinic, but the soda feldspar crystals belong to the next or sixth system, as do also the lime feldspars.

VI. TRICLINIC or "*thrice inclined*" system. In this system the planes are referred to three unequal axes all oblique to each other. The only important feature in this system is that there is no right angle in any of its crystals; but it is of little use for our purposes, since with the exception of the lime feldspar and soda-lime feldspars (anorthite or lime feldspar, labradorite or soda-lime feldspar, andesite and oligoclase, both soda-lime feldspars, and albite, a soda feldspar) all the rest are of little importance, except microcline, a potash feldspar.

AS ILLUSTRATIONS OF THESE SYSTEMS the following may be stated:

Of the isometric system, or FIRST system, are gold, silver, platinum, amalgam, copper, the diamond, garnet, magnetite, pyrite, galena, alum, kalinite, all of which assume the cubic octahedral, or more allied form.

Of the tetragonal, or SECOND system, are the zircon, chalcopyrite, cassiterite (tin ore), titanic oxide, and others.

Of the hexagonal, or THIRD system, are beryl, aquamarine, the emerald, chrysoberyl, apatite (lime-phosphate), quartz.

Of the orthorhombic, or FOURTH system, are barite or sulphate of barytes, celestite or sulphate of strontia, and carbonate of strontia, also cerussite or lead carbonate.

Of the monoclinic, or FIFTH system, are borax, gypsum, glauber salt (*mirabilite* is its mineralogical name), copperas (or *melanterite*).

Of the SIXTH system we have already given sufficient illustrations.

Of the GEMS not mentioned in the above, the TURQUOIS owes its blue to copper, and is never crystallized, being in reniform or stalactitic conditions. It is a phosphate of alumina with water in composition. This mineral or gem should be carefully distinguished from LAZULITE, which, though blue, crystallizes in the *monoclinic*, or fifth system; it is a softer mineral, and contains considerable magnesia, lime and iron, of which (except a very small amount of iron) the true turquois contains none. The latter is the gem, and may be beautifully polished, and keeps its color, which is due to copper. Lazulite is found in beautiful crystals at Crowder's Mount, in Lincoln Co., N. C.; also fifty miles north of Augusta, at Graves's Mount, in Lincoln Co., Georgia.

CHAPTER IV.

SURVEYING.

THERE are a few simple measurements which are sometimes desirable, and which can be made without the labor of carrying instruments and chains. The actual work of surveying, to be of any value to the prospector, must be so accurately performed that the work should be entered upon as a specialty, and he must use a theodolite or transit and make use of logarithms. Any small work on surveying or trigonometry will give sufficient information.*

Some few measurements, however, and simple surveys with easy methods, are given here to meet cases where only a general approximation is required.

TO MEASURE HEIGHTS WHICH ARE INACCESSIBLE.

Any height of tower, stand-pipe, tree, etc., may be measured approximately by knowing your own height and taking advantage of sunlight, thus:

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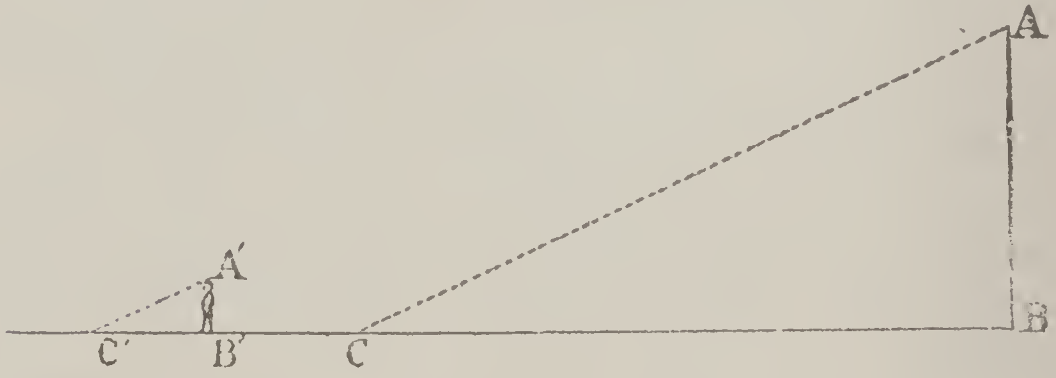
* For this purpose we would recommend the following book: The Practical Surveyor's Guide. By Andrew Duncan. A new, revised and greatly enlarged edition. Illustrated by 72 engravings. Philadelphia, Henry Carey Baird & Co., 1905. Price, $1.50.

Let *A B*, Fig. 26, be the height of the object to be measured. The dotted line is the shadow cast. Walk off into the sunlight and note on the ground the point at which your own shadow terminates; measure from the heel to that point. A calculation in single "rule of three" will give *A B* thus:

$$C' B' : B' A' :: B C : A B.$$

Heights of hills or land may be nearly enough measured by the aneroid barometer, the instructions in the use of which go with the instrument, or may be obtained with it, and approximately accurate aneroids may be had small enough to go into the side pocket, or still more accurate ones may be easily carried in a case held by a small strap around the shoulders. For hills under 2,000 feet, the following rule will give a very close approximation, and is easily remembered, because 55°, the assumed temperature, agrees with 55°, the significant figures in the 55,000 factor, while the fractional correction contains *two fours.*

Fig. 26.



Observe the altitudes and also the temperatures on the Fahrenheit thermometer, at top and bottom respectively of the hill, and take the mean between them. Let B represent the mean altitude and b the mean temperature. Then $5500 \times \frac{B-b}{B+b} =$ height of the hill in feet for the temperature of 55°. Add $\frac{1}{440}$ of this result for every degree the mean temperature exceeds 55°; or subtract as much for every degree below 55°.

TO MEASURE AREAS.

Theoretically, it is very easy to "step off lines," but practically it is very difficult thus to arrive at accuracy on uneven land. But where one is acquainted with the exact average measurement of his step on level land, he may reach some approximate accuracy on uneven land by remembering that in ascending, even slightly, his average decreases, and *vice versa* in descending. A good strong tape-measure, kept on a level in ascending and descending hills, is more convenient and more easily handled than a chain.

1. On square areas the length of the side multiplied into that of the adjacent side gives the area.

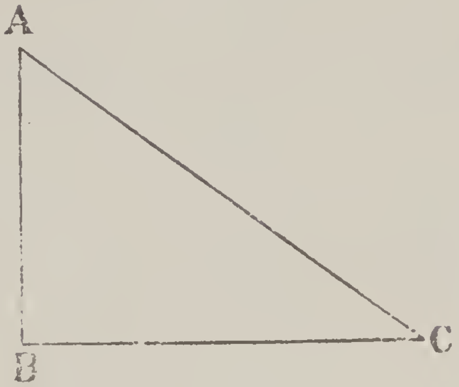
2. In the parallelogram, where all angles are right angles, the same is true.

3. In any other shape the following rules are to be observed:

First: Measure the area of a right-angled triangle thus:

Let *B*, Fig. 27, be the right angle; the area of *A B C* is equal to the length, *B C*, multiplied into half the perpendicular distance, *A B*.

FIG. 27.

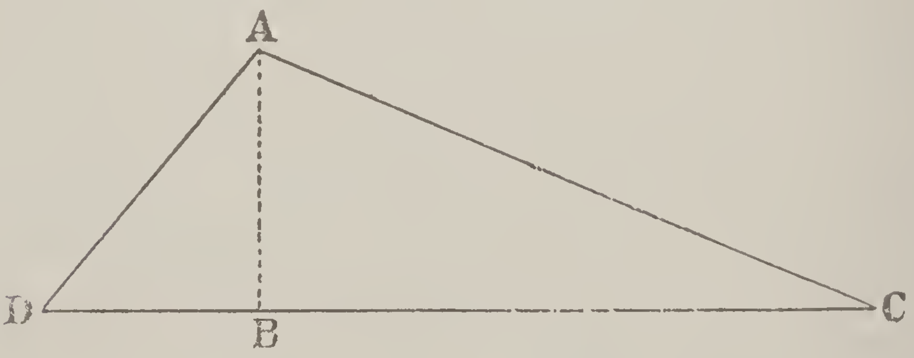


Example: *B C*=100 ft.; therefore, if *A B* = 90 ft., 100 × 45 = 4500 sq. ft. = area of *A B C*.

The same rule applies when the triangle is not a right-angled triangle: thus, the angle at *A*, Fig. 28, being obtuse.

D C=150 ft., *A B*=90 ft.; multiply 150 ft. by one-half *A B* = 45 ft., and we have 6750 sq. ft., for *A C D* is composed of two right-angled triangles, *A C B* and *A B D*, as in the previous example.

FIG. 28.



Or, when the triangle has an acute angle at *A*, Fig. 29, thus: Treat precisely as in Fig. 28, only letting the perpendicular fall from *D* upon *A C*, that is, invert the triangle.

The cases wherein the sides are more than three are treated by resolving all such areas into right-angled triangles, thus:

In Fig. 30 the area, *A C D B*, may be resolved into two triangles, *A C B* and *C D B*, of which *A B* is the base of the one and *C B* that of the other. In Fig. 31, the area, *A C D B E K*, may be resolved into the four triangles, *A C D*, *A D B*, *A B E* and *A E K*. The perpendiculars of Fig. 30 are *E D* and *C F*. Those of Fig. 31 are *C H*, *I B*, *F E* and *K G*, and the length of bases may be multiplied into half that of the perpendiculars, as in the case already given, and the feet be reduced to acres, rods, etc., or miles.

FIG. 29.

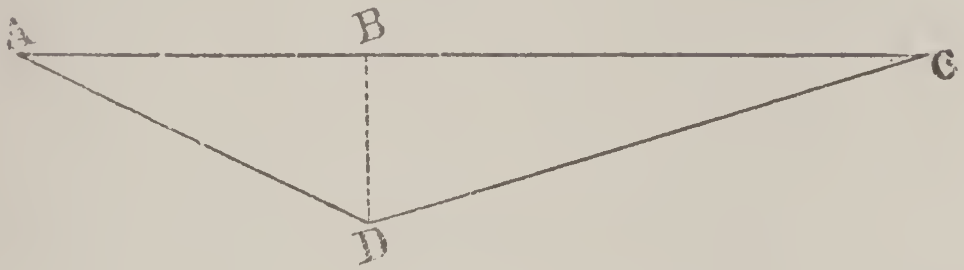
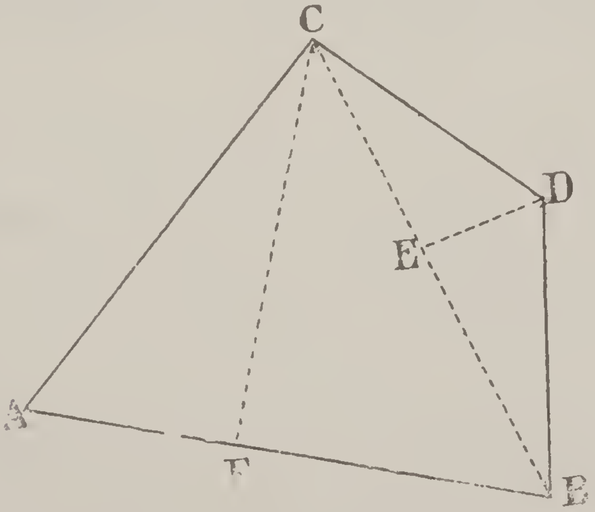
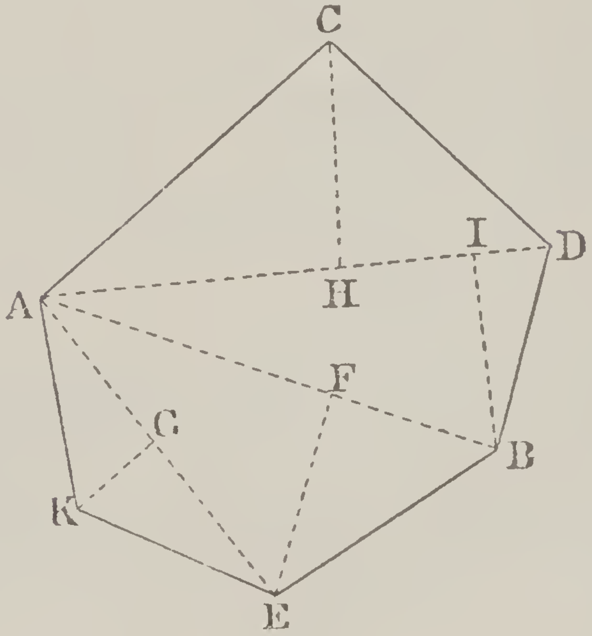


FIG. 30.



For the number of square feet in an acre, etc., see Appendix No. 3, and treat it thus: Suppose the area of Fig. 31 be 80,000 sq. ft., then according to Table No. 3, it will be 1 acre, 3 roods, 13 poles, 25 yards, 7 feet, or 1.836 + acre.

FIG. 31.

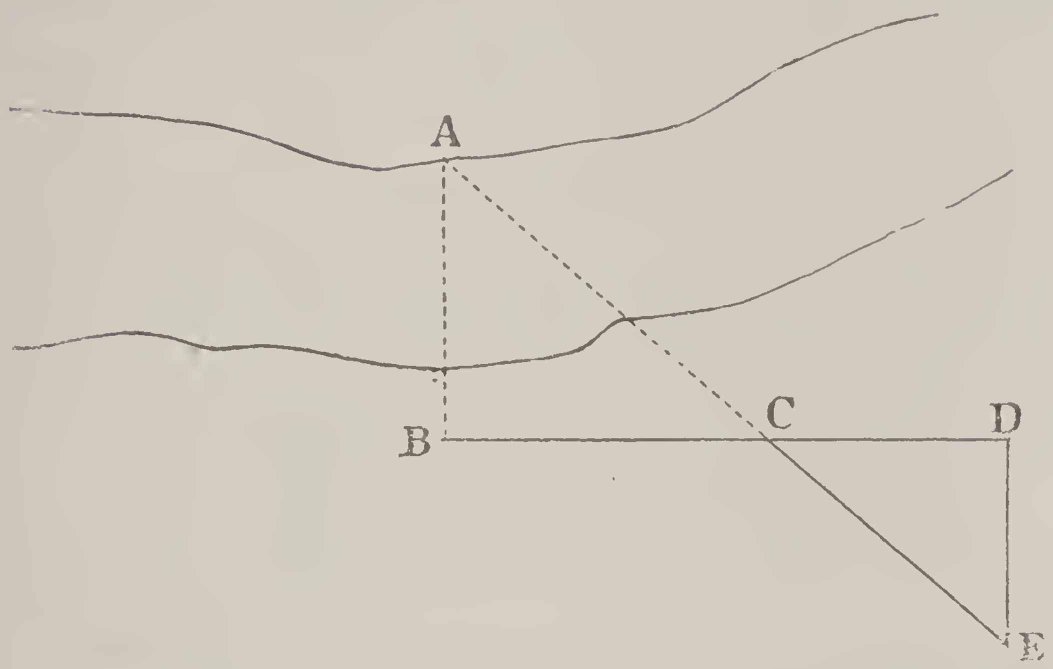


TO MEASURE AN INACCESSIBLE LINE.

Suppose we desire to measure the distance across a river, as in Fig. 32.

We want to find the distance *A B*. Measure a distance of about 100 ft., *B D*, at right angles to *A B*, and raise a pole at *C*, about half-way from *B* to *D*. Proceed in measuring at right angles to *B D*, in the direction *D E*, letting *E* be that point at which the line *C E*, if extended, would strike *A*. Now you have two right-angled triangles of the same angles, for, as every triangle has two right-angles according to geometry, and each of these triangles has one right angle, and the opposite angles at *C* are equal according to geometry, the remaining angles at *A* and *E* are equal, and the triangles are proportional, and the proportion is—

Fig. 32.



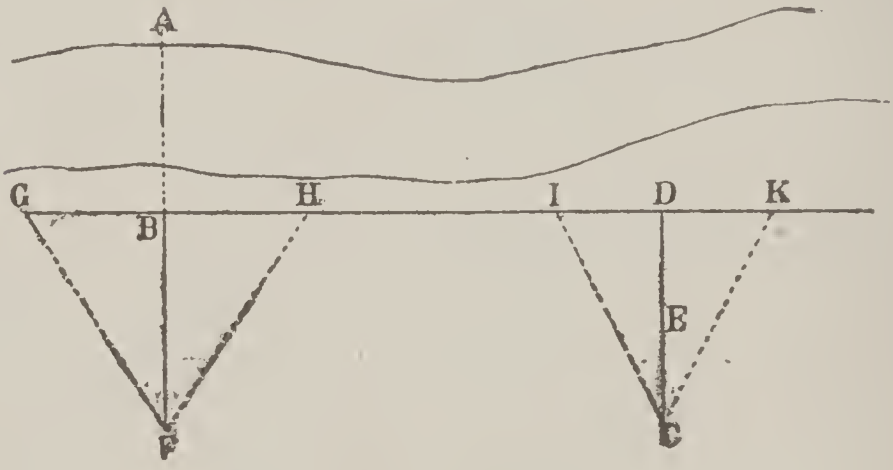
$$CD : DE :: CB : AB.$$

Then, if $CD = 40$ ft., $DE = 45$ ft., and $CB = 60$, we know that $45 \times 60 = 2700$ divided by (CD) 40 ft. $= 67\frac{1}{2}$ ft.; this is for *A B*, or the distance across the river.

The only difficulty is in measuring your angles as true right angles, and this may be done by measuring the perpendicular, thus—

Extend the line *A B*, Fig. 32, to *F*, Fig. 33, and likewise the line *D E*, Fig. 32, to *C*, as in Fig. 33. Now measure equal distances on the line *B D*, for the lines or offsets, *B C* and *B H;* also from *D C*, the offsets *D I* and *D K;* drive sticks in at *G*, *H*, *I*, and *K*. See that the distances represented by the dotted lines are equal, and if so, the lines *A B F* and *D C* are perpendicular to the line *G K*, and your work will be well done and very nearly accurate.

FIG. 33.



It is, however, well for the prospector to use a prism compass which will read to one-quarter degree. Such a compass may be had at very low rate, not more than three inches diameter, of light weight and of sufficient accuracy. The author has used one for many years, and traveled with it many thousands of miles in Asia and Africa, and can testify to the fact that by customary use it may be handled to a great degree of accuracy for horizontal angles. The needle is attached to the under side of a cord with steel engraved degrees and fractions, and read by a magnifying prism.

In almost every conceivable surveying project, especially in running adits and sinking shafts to strike adits and galleries, only the best instruments should be used. Everything depends upon the most accurate measurements, and this department of engineering is not one that can be treated approximately, because any error in measurement may result in very provoking and expensive mistakes.

We have presented all that is required on surface measurements, except where it becomes necessary to make such accurate proceedings as may only be executed by use of the finest instruments, and that with considerable practice. Otherwise accurate mathematical tables are of little importance, as their use is based upon the presence of most accurate data, and without this the best methods and diagrams are in vain.

This subject of mining engineering does not come within the range of our work, and for all mere exploring as a prospector such ground-work or digging for examination as is necessary will readily suggest itself to any intelligent workman.

CHAPTER V.

ANALYSES OF ORES.

For the examination of ores two kinds of analysis are employed, namely, the *wet method*, by the agency of liquids, and the *dry method*, in which no liquids are used, but only fluxes and heat.

Preliminary examinations may be made at first with the pocket lens and a piece of steel or a heavy-bladed pocket-knife, the *first* to see if any native metals or any sulphides, etc., are present, and the *second* to try the softness or silicious nature of the mineral. If much quartz (silex) is present it will strike fire.

Pulverize an average sample of the ore and use the blowpipe to detect *sulphur*, *arsenic*, *selenium* by the smell, on charcoal, or in the glass tube. Arsenic fumes have a garlic odor, selenium that of horse-radish.

Use a test-tube with a little nitric acid and heat over a spirit flame. Add a few drops of water and one drop of sulphocyanide of potash—an intense deep red appears, deeper according to the amount of IRON and solvency of the mineral in nitric acid.

Try another portion in the same way, but add one drop of hydrochloric acid. A dense, curdy, white precipitate indicates SILVER.

Native gold or silver is determined by color and softness, as we have elsewhere stated (*see Index*). Treat another portion in the same way with nitric acid, drop in several drops of strong ammonia water. An azure-blue color indicates COPPER.

Antimony and *tin* are detected by the blow-pipe. Place the former upon charcoal with carbonate of soda, and brilliant metallic globules are obtained; the metal fumes and volatilizes and covers the charcoal with white incrustations, and needle-shaped crystals appear. *Tin* appears when the ore is mixed with carbonate of soda and cyanide of potassium on charcoal, and the inner flame turned on—ductile grains of metallic tin and no incrustations appear.

Manganese gives amethystine beads of borax in the outer flame, *O F*, disappears with the inner, *I F*, reappears with the *O F*.

Alumina, manganese, lime, give their characteristic colors, or, in the last case, incandescent light before the blow-pipe on charcoal. *Alumina* heated on charcoal, and then touched by a half drop of protonitrate of cobalt, then heated strongly in the *O* flame, gives a blue color. *Magnesia* so treated gives a faint red or pink, seen just as it cools.

Zinc heated on charcoal with carbonate of soda in the reducing flame becomes metallic, and when oxidizing in the *O* flame gives a white oxide which is yellow when hot, white when cooled, and with protonitrate of cobalt when heated in the *O* flame a beautiful characteristic green color.

Cobalt and *nickel* give the colors which have been noticed in another place under their respective names (*see Index*).

Uranium heated with microcosmic salt (phosphate of soda and ammonia) on platinum wire in the *O* flame dissolves, producing a clear yellow glass, which on cooling becomes yellowish-green; in I F yellowish-green when hot, and green cold. But the analyst should remember that copper also produces a green bead, but *only* in the outer or oxidizing flame, and *chromium* the same, but in both outer and inner flames.

The *copper*-green becomes blue on cooling, the *chromium*-green remains green on cooling. This will always prove the metal.

Titanium in the presence of peroxide of iron, as in some titanic ores of iron and sand, gives, with microcosmic salt in a strong reducing blow-pipe flame, a yellow glass, which on cooling fades out to a delicate violet.

Vanadium, dark yellow when hot, paler on cooling; in *I. F.* brownish-red when hot, chrome-green on cooling.

Mercury may be detected in almost any of its ores by the process described (*see Index*), by heating in a glass tube and noting, under the lens, the sublimation of mercury in very minute shining particles.

Minerals which are *carbonates* may be detected by their effervescence when touched by a drop of hydrochloric acid, as in limestone and spathic iron ore. But the analyst must remember that some cyanides effervesce where neither lime nor carbonic acid is present, and chloride of lime where there is no carbonic acid. With these latter other tests must be used, but the sense of smell will show that carbonic acid does not exist, the latter having no odor.

Some sandstones have a small amount of lime carbonate and must be tried under the lens, as the bubbles are minute. But, while in these examinations great help is received, and many determinations can be made, especially in simple minerals and ores, there are compound ores so mixed in elements that the above tests fail to give satisfaction, because the colors are mixed and the action confused. Some of the elements must be moved out of the association and a separation made. This analysis is called *qualitative*, and we shall take a case of very full analysis of a compound ore.

QUALITATIVE ANALYSIS OF ORES where many elements are present.

There are many times when it becomes not only a matter of curiosity but of importance for the prospector to know the entire composition of the ore he has before him.

With a little practice the "wet method," as it is called, may be used by the prospector with all the accuracy required under the circumstances.

I. WET METHOD.

Although for one or two elements the dry method is simpler than the wet method, it may so happen that sufficient heat can not be had. Some directions whereby the wet method may prove of greater service will now be given:

1. Pulverize an average specimen of the ore as finely as possible and pass the entire quantity taken as an assay through a sieve of 80 meshes to the inch, being careful that nothing is left remaining in the sieve, as it may be a very important part.

2. Drop a little of the sifted ore into a test-tube, pour a little nitric acid upon it, add about one-eighth part water, warm it gently over a spirit flame to see if it will dissolve; if not, then add four times as much in bulk of muriatic acid (hydrochloric acid). If this will not dissolve, then proceed as follows:

3. Put the assay, after fine pulverization, into a platinum crucible. Place it in a suitably-arranged platinum wire triangle so that it will hang over an alcoholic blast lamp. When all is ready add a mixture of equal parts of sodium carbonate and of potassium carbonate, amounting in all to about four times the bulk of the assay, stir gently with a glass rod or a stiff platinum wire, and then light the lamp. Watch the assay, and when it begins to swell up withdraw the lamp, but return it when the swelling subsides, so that the alkalies do not throw your assay out of the crucible, which should be only one-half full at the beginning. With care the contents will soon subside, and under increased heat become a quiet liquid mass. Now extinguish the flame, cool the crucible, remove crucible contents to a beaker-glass or place the crucible, with its con-

tents, within the beaker, and pour a little water upon it, add some nitric acid, or a little hydrochloric acid, *but not the two acids together*, unless you have only the assay, and not the platinum crucible, in the beaker—nitro-muriatic acid dissolves platinum. Warm and stir till the assay is entirely dissolved, except perhaps some white grains of silex.

4. If the preceeding work has been properly performed, the assay is now dissolved and you are ready for work. Filter the contents of the beaker to separate any undissolved remainder, if any such is seen in the glass, and wash the filter-paper by passing an ounce or two of water through it, and now make preparations for the next step. It is not necessary, where extreme accuracy is not required, to wash the filter-paper perfectly free from the acids. But if it be necessary, then furnish yourself with a small strip of platinum ribbon; clean its surface to a polish. If a drop of the filtrate evaporated from this surface shows not the least trace of sediment or outline, even under a lens, the filter paper is sufficiently washed. When the filter-paper, is to be burned and weighed, it must be perfectly freed from the acids by continuous washing.

5. Pour ten or fifteen drops of the filtrate into a test-tube. Drop in three or four drops of hydrochloric acid. If a precipitate forms it may be of SILVER; if so, it will grow dark violet on exposure to daylight, or more rapidly and darker in sunlight. Or to test more quickly, add strong ammonia, 30 to 40 drops; it dissolves after a short time; or if it does

not dissolve, then it is LEAD; filter and test on charcoal with the blow-pipe; if it gives, with inner flame, a bead and yellow incrustation around, it is LEAD. Or, if none of the above results are seen, and yet there is a precipitate, then it is *mercury*. To prove this, add a solution of carbonate of potash and digest; it turns black; filter and place it in a glass tube, heat gently with a blow-pipe; it volatilizes and condenses on the sides; examine with strong strong lens—it is *mercury*.

6. But suppose hydrochloric acid produces no precipitate, though in excess and heated? Then there is neither LEAD, SILVER nor MERCURY in the assay, and it is not necessary to treat the ore for either, but proceed to the next step. It will be seen why we directed nitric acid to be poured on the assay, as in No. 2. Hydrochloric acid would have prevented these tests as given, but you are now prepared for the next metals, with three less to look for, or with a certainty as to the presence of one or more of the three.

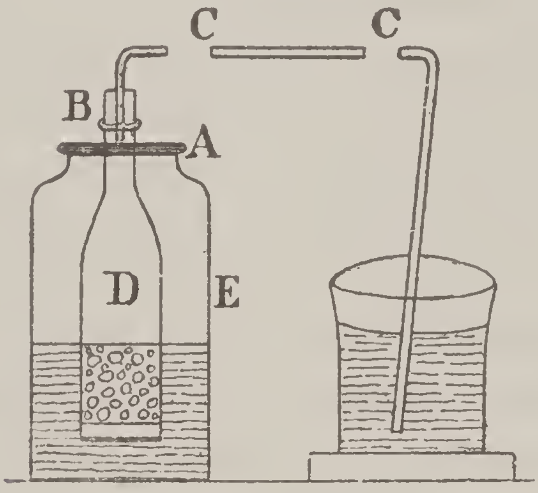
7. The whole assay, or its solution, may now be used. If any precipitate occurred in the test-tube, treat the whole assay solution with hydrochloric acid, heat to boiling, and separate the precipitated metal or metals in the whole, as in the test-tube, by filtration. Wash, set the paper (filter) aside under cover of paper to dry, and pass hydrogen sulphide slowly through the filtrate until the filtrate smells plainly of the gas.

8. As this gas is frequently used, make a simple

and cheap apparatus so that you may have a supply at any time, thus: Cut off the bottom of a long bottle * of small diameter, *D*, say about two inches, and fit it into a fruit-jar, *E*, as in Fig. 34.

The top, *A*, should be fitted loosely, so that it may be removed and let air pass through. The cork at *B* must be air-tight. Fit a small tube into the cork after bending it in a spirit-flame—a quarter-inch tube with an eighth-inch aperture is sufficiently large and is easily bent. Take an inch rod of iron, let the blacksmith heat it white-hot, and press it into a small roll of brimstone; this will give you iron sulphide—you need it in pieces as large as bullets: it melts readily against the brimstone. Place some cotton in the neck of the bottle, and

FIG. 34.



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* Cut a nick, with a large file, in the spot where you wish to start a crack near the bottom, then heat a rod, or poker, or spike-nail, nearly red-hot, place it on the nick, a crack starts; draw your hot iron and the crack will follow; when nearly cracked around pull the bottom off. A glass chimney may be used, but it is rather too small to contain sufficient iron sulphide.

having fitted a plug of wood with holes in it for the bottom of the bottle, invert the bottle and fill it half full of iron sulphide lumps, fasten the wooden plug in the bottom, not very tightly, but tightly in three or four places, so that water can pass easily, and yet the plug be well fixed in. Put the bottle in its place, resting in the jar at *A*, and somewhat loosely fastened. But this must be after you have half filled the jar with a mixture of equal parts of common hydrochloric acid and rain-water (or, next best, well-water). Hydrogen sulphide will form immediately, and if you have made all connections perfectly, as in the figure, the gas will pass from this apparatus into the solution of ore in the beaker and precipitation will soon take place. The advantage of this apparatus is that if you tie two little blocks of wood against the sides of the india-rubber tubes, *C C*, so as to press the sides together and stop the gas from flowing, the gas forming pushes the water out of the interior glass *D*, and the gas stops forming, but is ready at any moment to begin as soon as the string around the little blocks is removed.

9. After introducing the hydrogen sulphide until the filtrate smells of the gas, filter and wash the precipitate, mark the paper containing it with the letter *A*, and put this precipitate aside for the present. This is the *precipitate* from the hydrogen sulphide.

10. THE FILTRATE. If the strip of platinum shows that it contains some material after evaporation of a few drops, proceed by adding a solution of

ammonium chloride (sal ammoniac), and then aqua ammonia to the filtrate, using about one-fifteenth or one-twentieth of the bulk. Then add ammonium sulphide so long as any precipitate is apparent. Let it stand awhile. This precipitate may contain alumina, chromium oxide, zinc, nickel, manganese, cobalt and iron as sulphides. It may likewise contain phosphates, borates, oxalates, and hydrofluorates of the alkaline earths (barium, strontium and lime). The latter we may not care for.

11. Filter and wash this precipitate. Add a little water to the hydrochloric acid, now to be used in treating this precipitate. Add this diluted hydrochloric acid in sufficient quantity to dissolve the precipitate and put it aside to digest. If any part refuses to dissolve, it is because there may be present cobalt, or nickel, or both; add nitric acid and boil, for these metals dissolve in hot nitro-hydrochloric acid. Filter. Next add to the whole solution ammonium chloride, and excess of aqua ammonia. The consequent precipitate may contain alumina, chromium oxide, sesquioxide of iron, and the alkaline earths, as phosphates, etc. Dissolve the precipitate by digesting in caustic potash solution till all is dissolved that will dissolve. Filter. The solution may contain alumina and chromium oxide; boil for some time, and if a precipitate is formed, it is CHROMIUM OXIDE; confirm by the blow-pipe; it gives a green bead with borax, heightened by fusion with metallic tin or charcoal, which is the blow-pipe test for *chromium.*

12. Now supersaturate the solution with hydrochloric acid and boil with excess of ammonia; * if a precipitate is formed it is *alumina.* Confirm with blow-pipe, as has been shown. What was dissolved by digestion with potassium hydroxide (caustic potash solution) has now been treated. The precipitate may contain iron and more chromium oxide, and the phosphates, etc., of the alkaline earths.

13. We will now proceed with a portion of this precipitate by first dissolving it in as small a quantity of hydrochloric acid as is possible, filter, and add to the solution (made as nearly neutral as possible) two or three drops of ferro-cyanide of potash (yellow prussiate of potash in solution); a blue precipitate is formed, proving the presence of *iron sesquioxide.* Wash another portion and fuse it in a small crucible with potassium nitrate (pure saltpetre) and sodium carbonate about equal parts. When cold digest with water; a yellow solution results, which produces a yellow precipitate with acetate of lead, showing the presence of *oxide of chromium.* This double finding of chromium oxide (for it was found before) is due to the relative quantity of iron present as related to chromium oxide present, which will not be entirely precipitated at one time in the presence of iron under these circumstances.

14. We now go back to the solution filtered off

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* By "excess" is meant so much that after stirring with a glass strip or rod, the liquid smells strongly of ammonia.

from the precipitate treated of in paragraph 11. This solution may contain zinc, manganese, nickel and cobalt. Digest with ammonium sulphide, wash the consequent precipitate and dissolve it in nitrohydrochloric acid (aqua regia). It may be dissolved upon the filter by dropping the mixed acids and filtering through into a clean beaker, just as it could have been done in paragraph 11. This is convenient when the precipitate adheres too tightly to the filter to allow of scraping it off entirely. Digest this clear solution with potassium hydroxide (or caustic potassa) precisely as in paragraph 11. This potassa may be put into the beaker in small pieces of the stick, in which form potassium hydroxide generally is sold.

(*a*) The *solution* may contain zinc oxide.

(*b*) The *precipitate* may contain manganese, cobalt and nickel, as oxides. Pass hydrogen sulphide through the *solution* (*a*) until the precipitate (white zinc) had ceased to fall. Wash and agitate the precipitate (*b*) with a solution of carbonate of ammonia. The precipitate which now falls is the carbonate of *manganese*—confirm this by the blow-pipe. The solution from this last treatment may contain cobalt and nickel oxides. Evaporate it to dryness, redissolve in a few drops of hydrochloric acid, and again evaporate to a moist mass and divide the mass into two parts. Heat one portion with borax in the blow-pipe flame, a blue bead proves *cobalt.* Dissolve the other portion in water and add solution of cyanide of potassium slowly; a precipitate is formed which, on continued adding of the potassium cyanide, begins to redissolve. On adding hydrochloric acid it is again precipitated. It is *nickel.* Confirm with the blow-pipe.

15. In paragraph 9, paper *A* was put aside. This paper contained the precipitate holding the copper of the ore *if any was present.* Digest this with ammonium sulphide (or potassium sulphide). A solution and a precipitate are formed. The *precipitate* may contain lead, mercury, bismuth, cadmium, besides copper, as sulphides. The *solution* may contain gold, platinum, antimony, arsenic and tin as sulphides.

16. Treat the *precipitate* first, by boiling it with nitric acid. A black or brownish residue remains undissolved. Take a hard-glass tube, and having washed and dried the black residue, introduce some of it into the tube and heat it. It may act in three ways: (*a*) it sublimes without change; *mercury oxide* was present—test with blow-pipe; (*b*) it sublimes, leaving a white powder which, when moistened with ammonium sulphide, turns black, proving it to be *lead sulphate;* (*c*) it sublimes, but as a mixture of *mercury sulphide* with minute globules of metallic *mercury*, showing that through some haste or lack of care, mercury as sub-oxide of mercury still remains when it should have been entirely precipitated as *chloride of mercury* at the first (paragraph 5).

17. We now proceed with the filtrate (obtained as stated in paragraph 16), from the black or brownish residue. Treat this with solution of carbonate of

potash and wash the consequent precipitate, and then digest this precipitate in *cyanide of potassium* in excess, while it is moist. This may be done on the filter after changing the beaker, since this filtrate or solution must be kept. The *insoluble* part may contain lead and bismuth as carbonates—the *solution* may contain copper and cadmium as double salts with cyanide of potassium.

18. Proceed with the *insoluble* part by boiling it with dilute hydrochloric acid. To one part of the resultant solution add sulphuric acid ; the precipitate indicates *lead.* To the other part, after concentration by evaporation, add a large quantity of water —a milkiness is produced indicating *bismuth.*

19. Into the *solution* (paragraph 17), after digesting with potassium cyanide, pass hydrogen sulphide —the *precipitate,* if formed, indicates *cadmium*—test it with the blow-pipe. To the solution add hydrochloric acid—*copper sulphide* will be precipitated ; add a few drops of nitric acid, which will dissolve the copper sulphide, and then by adding ammonia in slight excess the solution has a blue color indicating *copper.*

20. We are now to treat the *solution* mentioned in paragraph 15. The insoluble part, paragraph 16, having been separated off as there stated, add to the solution acetic acid, and boil. If a precipitate be produced, collect a small portion, wash and heat it over a spirit-lamp upon a strip of platinum foil. If it burns with a bluish flame and leaves *no residue whatever,* it is *sulphur* and nothing more may be

done—this part of the assay is exhausted. But if it leaves some residue, then several important elements may be present. Proceed, and to one part add a solution of chloride of tin (protochloride with a drop of nitric acid added), a purple color is produced. To another part add a solution of protosulphate of iron—a brown precipitate is produced indicating *gold* in both cases.

To another part add ammonium chloride (solution); a yellow crystalline precipitate falls which marks *platinum.* *Arsenic* may be tested for by the blow-pipe in the ore, but if the presence of sulphur, in larger quantity, prevents detecting a small quantity of arsenic, it may be detected thus: Take a part of the black or brownish precipitate resulting from the addition of acetic acid, and mix it with three times its bulk of nitrate of potash (saltpetre) and carbonate of soda. Project this mixture, a little at a time, into a Berlin crucible, in which a mixture of the same substances has been placed and is in fusion over a lamp. At conclusion, digest the fused mass with pure water; filter; add excess of nitric acid and heat; now add nitrate of silver; filter when cold, and add very dilute ammonia; a brown precipitation on coloring marks *arsenic.*

Dissolve another portion of the dark precipitate or residue from acetic acid in hydrochloric acid. Place in the solution a strip of metallic zinc—a pulverulent deposit takes place on the zinc, indicating *antimony.* If more proof be wanted remove the powder to a beaker and digest in nitric acid, when a white precipitate is formed. Digest it with a strong solution of tartaric acid; only a part may be dissolved, but filter; into the clear solution pass hydrogen sulphide and an orange-colored precipitate is formed, proving *antimony.*

In the last paragraph it was found that a part of the precipitate was not dissolved in the tartaric acid; dry it; place it on charcoal with a little cyanide of potassium and carbonate of soda, and turn the inner flame of the blow pipe upon it; it is reduced to metallic *tin.*

In the above analysis provision has been made for the detection of sixteen elements. Of course, if no precipitates or signs appear at any one stage of the analysis, proceed immediately to the next, for it is not probable that any mineral will ever contain even one-half the elements mentioned in the assay, but the full number is given so as to reach any possible case.

II. DRY ASSAYS OF ORES.

The wet assay method having been described, we now give as much of the dry assay as may generally be called for.

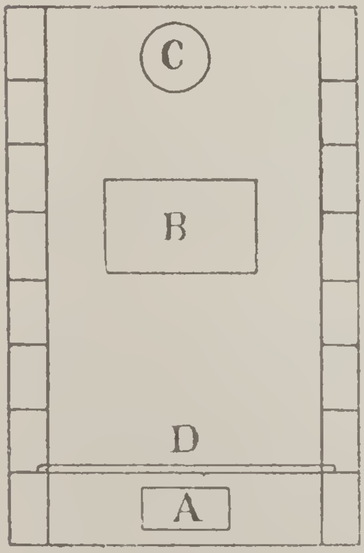
What will be first needed in the dry assay are crucibles, scorifiers and cupels. CRUCIBLES for general purposes are made of coarse material, and are called Hessian. They are sold in nests of five or more. The only sizes of much value are those holding about 6 to 8 ounces. SCORIFIERS are flat, but thick, clay saucers intended to prepare the rough ore for the finer treatment by use of the cupel and in the assay furnace. The CUPEL is a little saucer of bone-ash, intended to be used on the floor or bottom of a heated muffle in the assay furnace. The MUFFLE is a clay oven of small dimensions, intended to protect the scorifier and cupel from the coals of the furnace. They can be obtained at any chemical warehouse.

An ASSAY FURNACE may be made of sheet-iron ; it should be some 15 inches in diameter, with a grate near the bottom, and lined with either ordinary or fire brick.

In the accompanying illustration, Fig. 35, is given the general form of one which has been used for years with perfect success.

A plain sheet-iron cylinder (Fig. 35) 18 inches high and 15 inches in diameter, with draft hole at A, muffle hole at *B*, and pipe-hole at *C*, and lined, as has been said, with brick, will answer all purposes of the best assays. The hole at *C* must have a collar and pipe either for a chimney or it must enter a chimney. *B* must be provided with a flanged door, as also the draft hole *A*. The top may have, loosely laid on, only a square sheet of heavy sheet-iron, and the whole placed upon a flat stone or few bricks. Several heavy bars of iron nicked into the bricks will answer

FIG. 35.



where there is no iron foundry at hand to cast a grating *D.* Charcoal or coke may be used, or, where the draft is strong, a hard coal.

The crucible should be lined with charcoal finely pulverized and made pasty with molasses or any syrup. This process is called "brasquing." Heat the crucible before using, to dry out the syrup.

For field testing a small portable assay furnace, using preferably some form of gaseous fuel, is of great advantage. Such a furnace is made by E. H. Sargent & Son, of Chicago, Illinois. It has the advantages of only weighing 7 lbs., being about 5 by 8 inches, when set up is about 20 inches in height, and it packs in a space of 1 cubic foot with all the necessary material—the box then weighs ready packed, some 25 lbs. (without mortar and pestle); and lastly, one of the greatest recommendations is that refined petroleum is used as the fuel. This form of fuel is much more easily obtained, and is less dangerous than gasoline, which is the liquid fuel most commonly used for assaying.

If the object is to obtain the amount of an ordinary metal, such as *iron* or *lead,* pulverize the ore to about forty to the inch, weigh it, mix it with charcoal and cast the mixture, from a piece of paper, on the bottom of the crucible, cover it with charcoal an inch or two deep, drop in two or three pieces of brick, and place the crucible in the hottest part of the fire, cover all with coal and gradually increase the heat and keep it nearly at white heat for half an hour, draw it out, jar the crucible down on a stone to settle the melted button. When cool take out the contents, and the metallic iron or lead will be found with its slag attached. Clean the button and weigh it, then

$$\frac{\text{weight of resulting button}}{\text{weight of sample of ore}} \times 100 = \text{percentage of}$$

metal in the ore.

Scales, weights, etc. Any scales that weigh from $\frac{1}{4}$ oz. to $\frac{1}{2}$ lb. or a greater amount will serve for the rough work in the field. The cheapest and lightest scale is one used for weighing letters, which weighs from $\frac{1}{4}$ oz. to 12 ozs.: but a better scale is a light spring balance, weighing up to 2 lbs., and divided into $\frac{1}{2}$ and $\frac{1}{4}$ ozs.

The sample can best be weighed by laying it on a sheet of paper, turning up the edges, and tying them with a piece of string which can be hooked on to the scales.

For more delicate work, a small pair of scales weighing to $\frac{1}{100}$th of a grain is quite sufficient. Such scales may be bought at any chemical warehouse, made to pack and carry with ease and security. When in a fixed laboratory at home, the scales weighing to 0.0077 grain or half a milligram will save chemicals, time and work; but unless the analyst has an absolutely true average of the ton of ore most carefully chosen, the smaller the amount of ore used the more likely is the assay to prove deceptive when proportioned to the ton.

In weighing the ore it is well to make use of the conventional assay ton weights, as by this system the number of ounces of precious metal in a ton of ore may be known according to the amount of milligrammes, etc., the button of precious metal weighs. The assay ton (A. T.) weighs 29.166 grammes, or 29,166 milligrammes.

If 1 A. T. of ore yields a button of 1 milligramme, a ton of ore yields 1 oz. troy of precious metal.

SAMPLING AND PULVERIZING.

Sampling is of the utmost importance, especially with gold ore, as a very small amount of gold, more or less, makes a vast difference in the estimated value of the vein or deposit. Do not take selected small pieces, but an average sample of the mineral deposit. Pulverize the specimen carefully in a mortar, or, in the absence of the latter, break the ore up into a few pieces, wrap the latter in cloth or paper, and powder between two hard rocks. To prevent fragments of ore from flying out of the mortar, cover the latter with a piece of paper with a hole in the center for the pestle to pass through. Quartz and similar substances will be rendered easier to crush by first being heated and then thrown into water. Pulverization for the dry method should never be more than 50 or 60 to the inch. Smaller particles are apt to be lost or separated in the crucible. Obtain a piece of silk bolting-cloth from a flour miller or from the source from which he gets his cloth, and select two or three grades, one for "wet analysis," which may be as fine as 80 to the inch. Have a rim made by the tinner to tie on the sieving cloth, or use a cracked beaker-glass, cutting it off by the method we have already given. (*See previous note, page 93.*)

When fragments of ore adhere to the mortar, a little pulverized charcoal should be stirred about in the mortar.

GOLD AND SILVER ORES. These ores require preparation in the scorifier. Powder the ore. Take about 50 grains of the powdered ore, 500 to 1000 grains of lead shavings, according to the probable amount of silver, and about 50 grains of borax. Mix the ore with half the lead and place the mixture in the scorifier, spread the other half of lead over the contents, and finally spread the borax over all. Put the scorifier in the muffle, close the door, and heat up to fusion—then the door should be partly opened, the heat increased, until the oxidized lead (litharge) covers the scorifier. Take the latter from the muffle and pour the contents in an iron cavity or mould, separate the button and hammer it into the shape of a cube. It is now ready for cupellation, as it contains all the gold and silver.

Cupellation. By this process the lead is simply separated from the gold and silver, the separation being effected both by absorbing and oxidizing. Cupels may be made by the operator, but they can be bought so cheaply that it is seldom worth the trouble to make them.

Push a cupel into the heated muffle, place the cube of lead in the cupel with little tongs, and heat up till the lead melts; watch the lead gradually wasting away until reduced to the size of the silver it contains, when the surface will become instantaneously bright and nothing remains but the silver containing the gold. Withdraw the cupel and cool and weigh the ball. The gold and silver must be separated by the wet process, thus: Dissolve the ball in strong nitric acid and heat till the acid boils; a dark powder precipitates; filter off the dark powder, (it is the gold) and precipitate the silver by solution of common table salt or by hydrochloric acid. After all is precipitated drop into the white precipitate some pieces of zinc, add more hydrochloric acid—hydrogen gas is generated, which reduces the white silver chloride to powdered metallic silver. The gold and the silver may now be melted in separate crucibles, weighed and compared with the amount of ore used.

In these trials the lead should first be cupelled for its silver, and that subtracted from the silver found, as almost all leads contain some silver.

If it should be more convenient to melt the ore in a crucible rather than a scorifier, use the following flux: If the ore is composed chiefly of rock, pulverize, take 100 to 500 grains of ore, red lead 500 grains, charcoal powder 20 to 25 grains, carbonate of soda and borax together 500 grains—the more rock the more carbonate of soda, the more metallic bases the more borax. Place a little borax over all and melt till all is liquid, requiring about 20 minutes; withdraw, extract the button when cool, hammer up to a cube and cupel. Separate the gold and silver as before, but remember that the amount of silver must be three times that of the gold, and if there is reason to believe that there is not this amount, some silver must be melted with the button, since the separation will not otherwise be complete.

T. S. G. Kirkpatrick recommends the following process of assaying gold quartz: Take 200 grains of ore, 500 of litharge, 6 of lamp-black and 500 of carbonate of soda; or, 200 grains of ore, 200 of red lead, 150 of carbonate of soda, 8 of charcoal and 6 of borax. Mix and put into a warmed crucible, and cover with half an inch of common salt. Fuse in a hot fire 30 minutes; cool and break the pot; clean the button with a small hammer.

If the quartz is very pyritous, take 100 grains and calcine "dead" without clotting, add 500 grains of red lead, 35 of charcoal, 400 of borax, and 400 of carbonate of soda, cover with salt and proceed as above. In each case cupel the button.

As the bone-ash of which the cupel is made can absorb its own weight of metallic oxides, the cupel chosen should always exceed the weight of the button to be operated on, so as to have a margin. Boil the gold prill obtained from cupelling in nitric acid, which dissolves the silver and leaves the gold pure.

The above formulæ are open to modifications by the operator according to the apparent richness or poverty of the ore to be treated, and the presence and character of the basic impurities. In case there are oxides, a reducing agent is required; and if sulphides, an oxidizing agent. As a rule, employ a weight of litharge *twice* that of the ore, and of carbonate of soda the *same* as the ore. These reagents are added to control the size of the lead button, and to obtain one of suitable size for cupelling.

The presence of metals in the ore is indicated by cupel stains as follows: *Antimony*, pale yellow to brownish-red scoria; sometimes the cupel cracks. *Arsenic*, white or pale-yellow scoria. *Cobalt*, dark-green scoria and greenish stain. *Copper*, green or gray, dark red or brown. *Iron*, dark red-brown *Lead*, straw or orange color. *Manganese*, dark bluish-black stain. *Nickel*, greenish stain; scoria dark green. *Palladium and Platinum*, greenish stain; the button will be very crystalline. *Tin*, gray scoria; tin produces "freezing." *Zinc*, yellow on cupel; the cupel is corroded.

LEAD ORE. To ascertain the amount of lead in galena, the usual lead ore, charge the crucible with the powdered ore, carbonate of soda—two or three times the weight of the ore, three or four tenpenny nails on top to absorb the sulphur, and a covering of salt or borax. Heat to redness about 20 minutes. Pour the contents into a mold, and separate the button from the slag.

$$\frac{\text{Weight of button}}{\text{Weight of ore sample}} \times 100 = \text{percentage of metal}$$

As galena always contains more or less silver, the resulting button should be assayed for the precious metal in the cupel. As the latter does not absorb much more than its own weight of lead, the button may have to be divided into two or more portions, and each of these cupelled separately.

COPPER ORE. The wet assay is better than the dry, especially that by the burette, which will be given later on under "Copper."

TIN ORE. If it is mixed with iron or copper pyrites it should be powdered and roasted, and then mixed with one-quarter of its weight of charcoal and subjected to great heat in a crucible for about 20 minutes. Jar it as in an iron assay, let it cool, and pick out the button or buttons, or pour it out while melted.

It may be reduced otherwise by melting the powdered ore with cyanide of potassium, 100 grains of ore to 600 grains of cyanide. Cool, extract button.

This ore is very hard and may be powdered to 60 to the inch.

MERCURY. These ores are easily reduced by simply heating and condensing the vapors in a cold bath as in using a retort and cool receiver.

ANTIMONY. Place about 2000 grains of ore powdered in a crucible having a hole chipped out in the bottom, and the hole stopped loosely with a piece of charcoal. Put this crucible into another half-way down. Then lute on the lid and put clay around the juncture of the two and put live coals around the upper crucible by placing some broken bricks around the lower one on the grate, to keep the coals away from it. The antimony will melt and leave its gangue rock in the upper crucible while the lower one will receive the melted metal.

Bismuth, zinc, manganese, nickel, cobalt, and other metals should be reduced or analyzed by the "wet process" already given in this chapter.

An excellent fire lute is made of 8 parts sharp sand, 2 good clay, 1 horse-dung; mix and temper like mortar.

CHAPTER VI.

SPECIAL MINERALOGY.

GOLD.

We shall now proceed to a more definite and practical treatment of these two subjects, TECHNICAL MINERALOGY and ECONOMIC GEOLOGY, so far, only, as they may be of service in the work before us.

The first suggestion which may be made is that the best preparation for the general study of mineralogy is to gather a collection of the chief mineral substances with which the student is to come in contract. In many cases very small specimens are sufficient. As we proceed in our treatment of each substance it will occur to the reader what and how much he needs to obtain. But it should be emphasized that no amount of study on the part of the student, nor of description on the part of the instructor, can ever take the place of the actual specimen.

Gold.—Gold is one of the most widely distributed metals, but generally speaking, accumulations of larger quantities of it are found only in a few localities. Traces of it pass from various ores into artificial products, for instance, into litharge, minium, white lead, silver and copper and coins made therefrom, etc. Minute quantities of gold (about 13 grains in one ton) have been found even in sea-water, as well as in clay deposits.

In the United States the chief gold-producing localities are in California, Nevada, Arizona, Montana, Utah, Colorado and Alaska. In the last five years Alaska has averaged an annual output of gold of $20,000,000. Since 1880 its gold product has been over $140,000,000. The gold-bearing areas of Alaska are so extensive as to make it not improbable that it will prove to be one of the richest gold-producing sections in the world.

Supplies of gold are further derived from British Columbia, Nova Scotia, Mexico, and Peru and Brazil; from Australia (especially Victoria, New South Wales and Queensland), Tasmania, New Zealand, and from Africa (Natal, the Transvaal, etc.). The Ural Mountains and Siberia also yield considerable gold. In Europe, only Transylvania and Hungary are of any importance.

Gold occurs almost exclusively in the metallic state, either *in situ*, in quartz rock, especially along with quartz, pyrites and hydroferrite; also as gold sand, in dust or grains, leaflets and rounded pieces (nuggets), in the sands of rivers or in alluvial soils, consisting chiefly of clay and quartz sand along with mica, water-worn fragments of syenite, chlorite slate, grains of chrome iron and magnetic iron, spinel, garnet, etc. In the metallic state it contains always more or less silver as electrum. It may be mentioned that from numerous analyses it appears that New South Wales gold is richer in silver the farther north it occurs. Siberian, Californian and Australian golds contain not unfrequently osmiridium, palladium and platinum. Mexican rhodium-gold contains 34 to 43 per cent. rhodium. Gold amalgam is found in California and Columbia. The so-called *black gold* which occurs in nuggets in Arizona and at Maldon, Victoria, in granite and quartz lodes, is crystalline and silver-like when freshly fractured, but soon turns black in the air. It is *bismuth-gold*, with 64.211 gold, 34.398 bismuth and 1.591 gangue. Gold is often met with in native tellurium and silver telluride, sometimes in iron pyrites, copper pyrites, in blende, in arsenical pyrites and galena. To detect a content of native gold in pyrites bring a few drops of mercury into a porcelain crucible, put a perforated piece of cardboard in the crucible so that it rests a short distance above the mercury, place a small package of pyrites over the hole in the cardboard, heat the crucible for some time and watch with the pocket lens for the appearance of white stains of gold amalgam, which on rubbing with a brush or feather becomes lustrous.

Gold crystallizes in the isometric system. The occurrence of well-defined crystals is, however, rare, but they have been noted in lodes in California, Australia and Brazil. The usual forms are cubes and octahedra, with rod and plate-like forms. The crystals faces are frequently striated, and the crystals are generally rounded. Figs. 36 and 37 represent gold crystals. Twinning gives rise to dendritic and reticulated groups, but individual crystal faces and edges are usually very small. *Moss-gold*, *leaf-gold* and *wire-gold* are forms occurring sometimes. Fig. 38 shows the finest gold dust 700 times magnified, and Fig. 39 a reduced illustration of a lump of gold which was found at Forest Creek, Victoria, Australia. It weighed more than 30 pounds, and was 11.33 inches long and 5.15 inches wide. The largest nugget of gold ever found was at Ballarat, Australia. It weighed over 191 pounds, and was 20 inches long and 9 inches wide.

The specific gravity of gold is 16 to 19.5, according to the amount of alloy; hardness 2.5 to 3.0. It is the only *yellow*, *malleable* mineral found in the natural state. Its color varies from pale to deep yellow. In some localities, such as in New South Wales, Australia, and Costa Rica, it is often found of a very light color, but it presents the same color from whatever direction it is looked at, and to the prospector this is a guiding test. Indeed one of the most important and useful accomplishments for

Fig. 36.

Fig. 37.

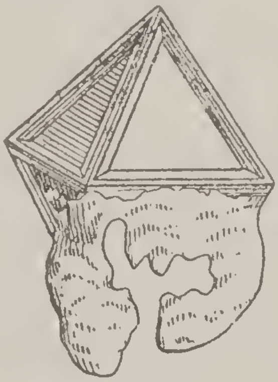


Fig. 38.

gold exploitation is "an eye for color." Native gold possesses a peculiar color which is readily recognized, although the gold may be alloyed with silver or copper, and its color will in an instant distinguish it in the eye of the expert from any condition of pyrites, whether iron or copper pyrites.

Gold grains will always flatten when struck with a hammer or between two stones, whereas other minerals similar in color will break into fragments.

FIG. 39.

Or, if the doubtful particle is coarse enough, take a needle and stick the point into the questionable specimen. If gold, the steel point will readily prick it; if pyrites or yellow mica, the point will glance off or only scratch it.

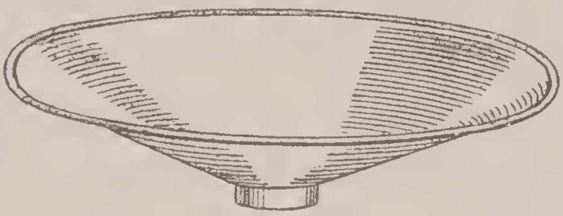
Under the blowpipe, on a piece of charcoal, gold may melt, but on cooling it always retains its color; any other mineral will lose color, become blackened, or will be attracted to the end of your pen-knife blade, if that blade has been previously magnetized, and the unknown substance contains iron.

Gold imparts no color to boiling nitric acid. It will not dissolve in nitric or hydrochloric acid separately, but it does dissolve in the two when combined, and then the acid is known as nitro-muriatic acid or aqua regia. Proportions: one nitric to four muriatic.

But it is not always a trustworthy sign that particles are gold because they will not dissolve in nitric acid. Some seemingly gold-colored particles will not dissolve in nitric acid, and yet contain not a trace of gold.

The simplest instrument for the discovery of gold and the estimation of the value of an auriferous material in which the gold is contained in a free state, is the ordinary miner's pan, a circular dish of Russian sheet-iron, about 12 inches wide and 3 inches deep, with sloping sides. There should be a slight indentation all round where the sides join the bottom, so as to afford lodging for the gold grains, and the more rusty it is the better. A frying pan free from grease will answer very well on a pinch. The South American *batea*, Fig. 40, made of hard wood in a solid piece, and hollowed out like a shallow funnel, is a superior implement when in capable hands. Another good substitute for this pan is a kind of magnified shovel without handle

FIG. 40.



made of linden wood and provided with a vertical wall on three sides. The wooden implements should be slightly charred on the surface to show up the gold grains, and should not have been used to hold mercury or amalgam.

The object of *panning out*, as the operation with the pan or batea is called, is to settle and collect at the bottom of the pan the heaviest portions of the material subjected to the test. Simple as the process of panning appears to be, dexterity is only acquired by considerable practice. In outline the operation is as follows:

A quantity of the dirt to be washed is placed in the pan, sufficient to occupy about two-thirds of its capacity. The pan with its contents is then immersed in water, either in a hole or in a rivulet, of such a depth that the operator can conveniently reach the pan with his hands while it rests on the bottom. The object of this is to give him free use of both his hands for stirring up the mass, so that every particle may become thoroughly sodden and disintegrated. Of course the pan may be held in one hand, and its contents stirred with the other, but the disadvantages of such a method are obvious.

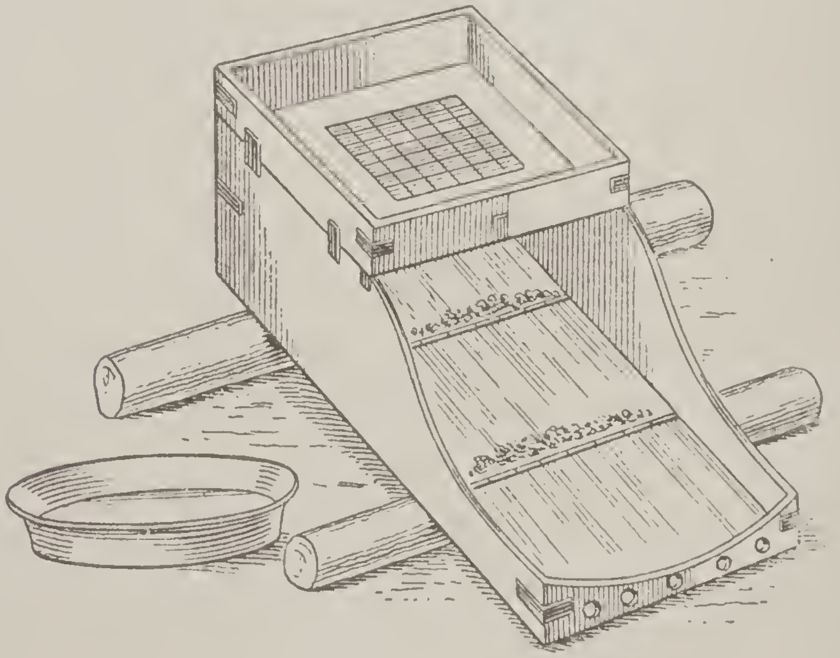
When the dirt has become thoroughly soaked and permeated by the water, the pan is taken in both hands, one on either side, and a little inside of its greatest diameter, and without allowing it to emerge from the water, it is suspended in the hands, not quite level, but tipping somewhat away from the person. In this position it is shaken so as to allow the water to disengage all the light earthy particles and carry them away. When this has been concluded there will remain in the pan varying proportions of gold dust, heavy sand, lumps of clay, and gravel stones. These last accumulate on the surface, and are picked off by hand and thrown aside. The lumps of clay must be crumbled and reduced by rubbing, so as to be carried off by the water during the next immersion of the pan. A neat turn of the wrist is required to allow the muddy waters to escape in driblets over the depressed edge of the pan, without exercising so much force as to send the lighter portion of the gold after them. At last nothing remains in the pan but the gold dust, with usually some heavy black sand and a little earthy matter. By the final careful washing with plenty of clean water, the earthy matters can be completely removed, but the heavy iron sand cannot be got rid of by any method based upon its specific gravity relatively to that of gold.

To remove the iron sand, one of two simple plans has to be adopted. If the sand be magnetic, as is usually the case, it may be eliminated to the last grain by stirring the mass carefully with a powerful magnet, care being taken that no particles of gold become mechanically suspended among the black sand.

Where this is ineffectual, recourse must be had to *blowing*. For this purpose the mass of gold dust and iron sand is allowed to become perfectly dry, and small quantities of it at a time are placed in an instrument called a *blower*—a sort of a shallow scoop, made of tin and open at one end. Holding the blower with its mouth pointed away from him, and gently shaking it so as constantly to change the position of the particles, the operator blows gently along the surface of the contents, regulating the force and direction of his breath so as to remove the sand without disturbing the gold. Where water can be had, a pan is the most efficient instrument a man can travel with in his gold-seeking journeys.

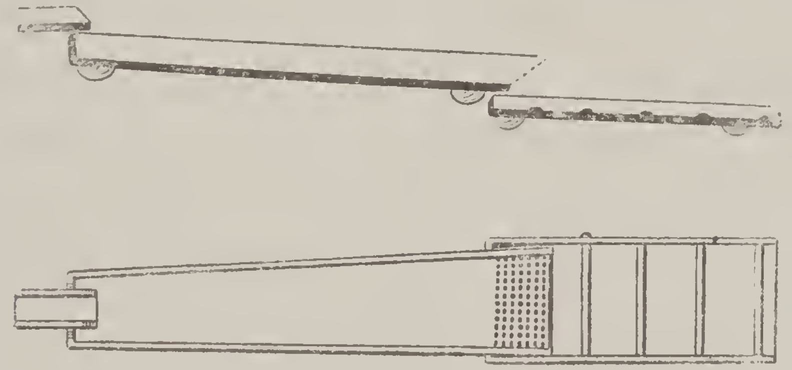
A crude apparatus formerly much used in California and Australia is called the *cradle* or *rocker*. This, as shown in Fig. 41, is a trough of some 7 feet in length and 2 broad. Across the bottom of this several bars are nailed at equal distances, and at the upper end a kind of sieve is fixed at about a foot above the bottom. This whole arrangement

Fig. 41.



is mounted upon rollers. To operate the apparatus four men are required. One man digs out the earth from the hole, a second supplies the cradle sieve with this auriferous earth, a third keeps up a supply of water which he pours upon the earth in the sieve, while the fourth keeps the machine continually moving upon the rollers. The large stones washed out are removed by hand from the sieve, and the water at the same time washes the smaller substance through, which is slowly carried towards the lower end of the trough by a slight inclination given to the whole. Thus the flow of water tends to keep the earthy particles in suspension so as to allow of their washing off, while the heavier portions of gold are obstructed in their flow, and retained against the cross bars fixed to the cradle bottom. These are removed from time to time and dried in the sun, when, after blowing away lighter particles, the metal only further requires to be melted.

Fig. 42.



A more efficient apparatus is the *long tom*, Fig. 42. A tom that will serve the purpose of the prospector can be easily manufactured on the spot where it is decided to test the ore of a newly discovered lode. A serviceable supply of tools must of course be comprised in his outfit, including one or two good adzes for giving a smooth plank surface to the side of the timber which forms the floor or sides of the tom. A rough but quite efficient apparatus can by this method be constructed in a short time.

The tom consists essentially of two separate troughs, as shown in the figure. These are placed on an incline, or given an inclination by log or rock supports. The California tom is about 12 feet long, 20 inches wide at the upper end, and widening gradually to 30 inches at the mouth. A stream of water flows in by the spout just over the place where the dirt is introduced into the upper box or tom proper. The dirt is constantly thrown in by one man, while a second is occupied in stirring it about with a square-mouthed shovel, or a fork with several blunt prongs, which is useful for pitching out the heavy boulders that sometimes occur, and for tossing back undissolved lumps of clay against the current. The lower end of the tom is cut off obliquely, so that the mouth may be stopped by a sheet of perforated iron. The sheet of iron should be closely perforated with one-half inch holes—or smaller if the pay dirt is very fine—about 20 inches square.

The apparatus being placed on an incline amounting generally to 12 inches, the materials all gravitate with the water towards this sloping grating at the mouth, everything passing through it except the large stones, which gather on the grating, and are removed as often as necessary. Beneath this grating stands what is called the *riffle box,* into which all the fine matters, including the gold, descend. The riffle box, like the tom proper, is made of rough plank, and is also placed on an incline, but only just so that the water passing over it will allow the bottom to become and remain covered with a thin coating of fine mud. In this way the gold and a few of the heaviest minerals will find their way to the bottom and rest there, especially by the help of the riffle bars, which give their name to the apparatus. Sometimes a little mercury is put behind the riffles, so as to assist in retaining the gold, and occasionally the riffle box is supplemented by a series of blankets, which are useful for catching the very fine gold.

The tom is cleaned out periodically, and the gold and amalgam are panned out. The tom employs two to four men according to the character of the dirt and the supply of water. It is applicable to diggings where the gold is coarse, it being quite incapable of saving all fine gold, of which at least 10 per cent. may be estimated as lost.

The amalgam and mercury taken out must be pressed through buckskin or canvas to remove the excess of mercury, which will run into a vessel placed to catch it. The remaining sponge-like mass of amalgam must be retorted to extract the gold.

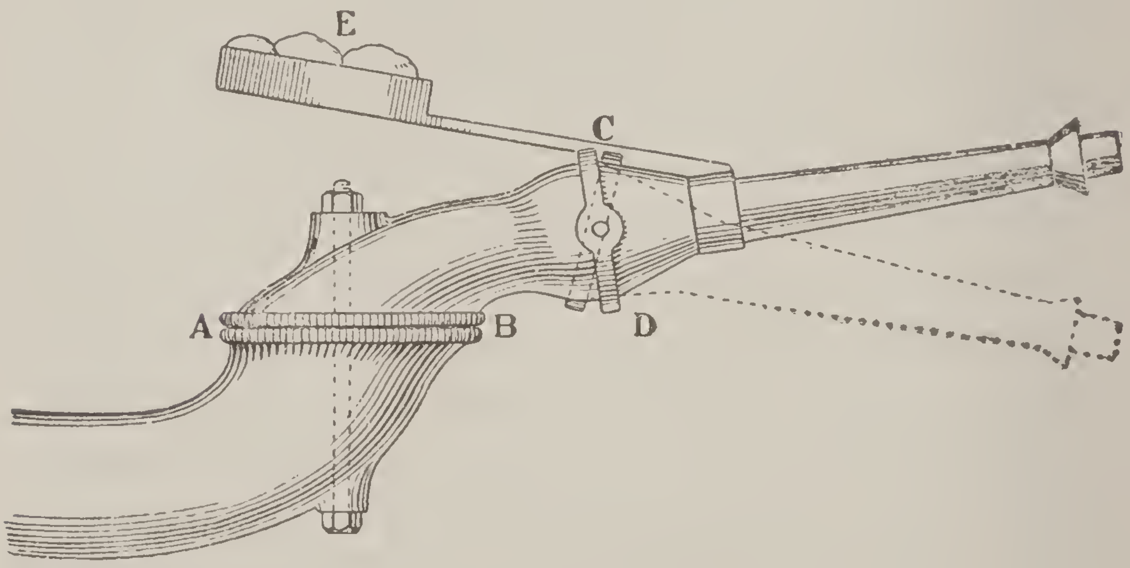
In Alaska and other remote districts primitive methods of recovering gold are employed in partly developed placer districts. The miners are obliged to make much out of little. With implements such as picks, shovels, whipsaws, and canvas hose, which they are able to carry to the place of working, they build ditches, flumes and sluice boxes and install small hydraulic plants.

Ground Sluicing. As the best pay dirt in some cases is at the bottom of creeks, it is necessary to remove the overlying gravel wash by some economical method. The stream must first be diverted into a flume built up on trestle work or running on one side of the creek. The creek bottom being freed from water, the large boulders are piled along the banks of the stream, those too heavy to move being broken by sledge hammers and powder. A narrow channel built up of boulders is thus formed which serves to confine the stream and increase its velocity, so that on being turned back into the creek bed it is able to carry off material which it could not otherwise have moved. The miners often enter this swift-flowing stream and by the use of shovels help the larger rocks down stream and off the claim. The water is from time to time diverted into the flume so that the large boulders may be thrown out or broken up. Where the creek bed is wide this temporary channel continually eating its way downward, must be moved step by step, from one side of the creek to the other, then perhaps back again in case the gravels are deep. In this way the mass of gravel is disintegrated and washed away and the gold is concentrated in a shallow deposit on bed rock. To clean up the bed rock, sluices are laid, beginning at the lowest point on the claim, and into these the enriched gravels are worked by means of wing dams and shoveling.

Sluices. The sluices consist of a series of troughs formed by planks nailed together. Each sluice box is about 12 feet in length, tapering from a width of 18 inches at the upper end to 14 inches at the lower end, thus allowing the boxes to fit into one another and a sluice of considerable length to be formed. Riffles of several sorts are used. An ordinary form is made by fitting round blocks 4 inches thick, sawed from logs a foot or more in diameter, into the boxes. Another style consists of poles placed a half inch apart lengthwise in the bottom of the sluice box. Still a third sort is made of sawed strips of wood, 2 inches or so thick, and 3 or more inches wide, placed crosswise, and set at an angle with the bottom of the box, so as to overhang on the upstream side. All of the riffles are held in place by wedges of wood, so that they can be removed for the clean-up, which begins with the uppermost set of riffles, the concentrates finally collecting on the lowest box.

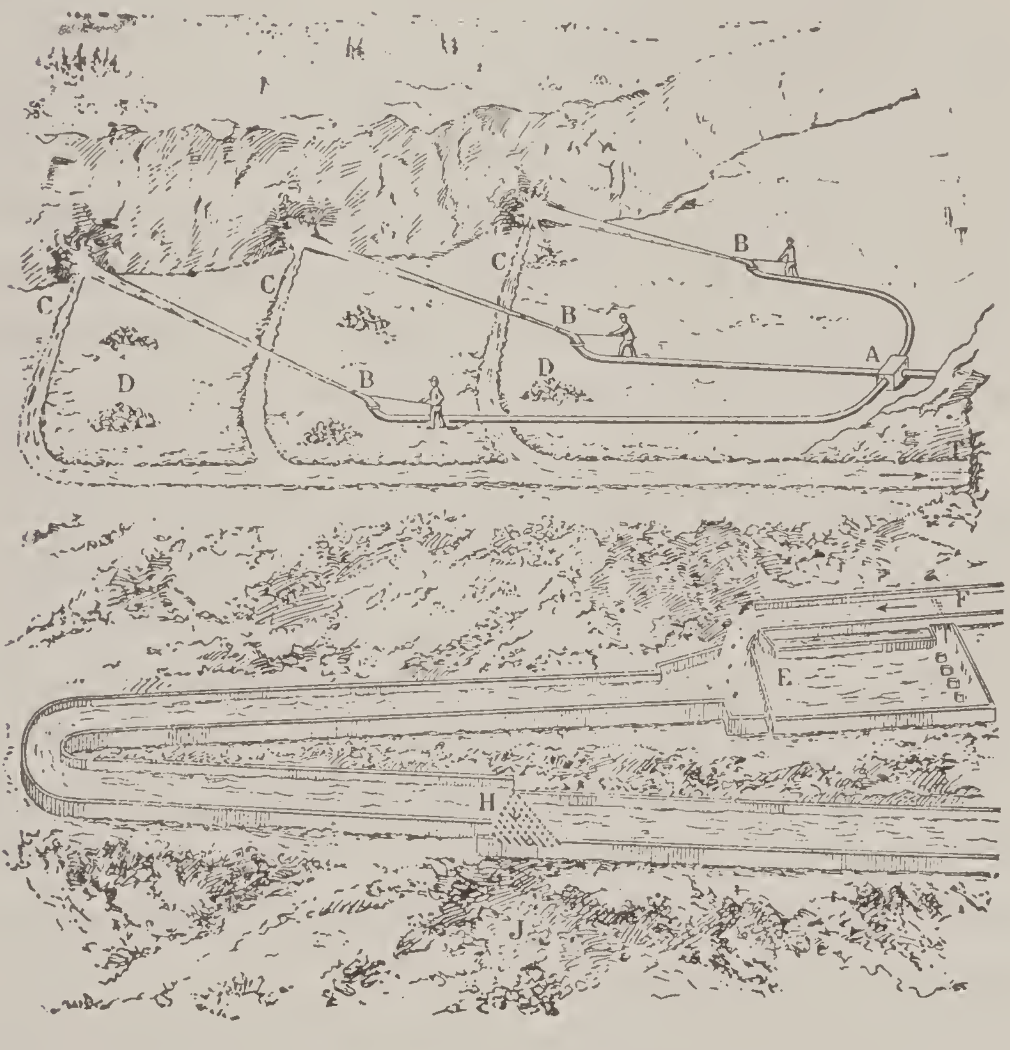
Hydraulicking or hydraulic mining. In localities where the gulches are deep, the fall of the ground rapid, and the auriferous deposits of considerable thickness, the banks of gravel are sometimes attacked by jets of water under high pressure, and the earth washed down and carried through the sluices without being touched by hand. This is called hydraulicking or hydraulic mining. This method is very effective, and under favorable circumstances, such as a plentiful supply of water with good fall, a very small amount of gold to the ton can be made to give paying returns. The water is conducted in flumes or pipes to a point where it is required, thence in wrought-iron pipes gradually reduced in size and ending in a great nozzle somewhat like that of a fireman's hose. Figs 43 and 44 show the arrangement. Fig. 43 exhibits the mouth-piece movable at *A B* in an ascending, and at *C D* in an inclined, direction. *E* is a lever loaded with weights, which facilitates the adjustment of the mouth-piece by the operator in any direction. The method of operating the arrangement will be seen from Fig. 44. *A* is the water-distributor, *B* the nozzle, *C* channels for carrying off the debris detached from the ledge; *D*, piles of larger pieces of rock which are finally comminuted. *T* is a tunnel through which the water reaches the gutter, pro-

Fig. 43.



vided with the grating *F* through which the finer stuff falls into the shallow settling basin *E*, and is distributed by blocks *G*, while the principal mass of water with the coarser material passes over the grating *F* into the principal sluice in which the grating *H* retains the larger pieces which are then thrown out at *J*. The basins *E* and the principal sluice are paved with wooden blocks or stones between which mercury is placed. The amalgam formed is freed from admixtures in a mercury bath,

Fig. 44.



pressed through sail-cloth, boiled in sulphuric acid and distilled.

One of the main difficulties in hydraulic mining is the disposal of the tailings, which may amount to millions of cubic yards in a year from a single mine.

Dredging.—Within the last few years the use of *dredges* has been rapidly extending. A dredge is a flat-bottomed boat, with machinery for raising gravel from the bottom of a stream or pond, hoisting it on board, washing it over inclined tables to save the gold, and then throwing or dumping the tailings overboard at the stern. A dredge may thus work its way up stream, or may proceed across a flat plain floating in a pond, cutting out the bank in front of it and piling up the tailings behind. The latter method is known as *paddock dredging.* A continuous supply of clear water is necessary for washing in the latter case, as very muddy water is found to interfere with the gold saving. Sometimes suction-pumps or grab-bucket dredges are used to lift the gravel, but ladder-bucket dredges similar to those used in ordinary dredging operations are much more common.

On nearly all alluvial gold fields, whether shallow placers or deep leads, is found a stratum of ferruginous conglomerate, composed principally of rounded and angular fragments of quartz of all sizes, cemented together by the oxide of iron with which the mass is impregnated, and often so hard as to resist everything but blasting. This *cement* as it is called, overlies the bed-rock, in some places resting on it, in others several inches or even feet above it. In thickness it fluctuates, from 6 inches to 8 feet or more. Its character varies but little. It is often highly auriferous, and is worthy of special attention. It should be pounded to a fine powder and tested.

Many particles of fine gold, notwithstanding their greater specific gravity, exhibit the tendency to float in water when undergoing a washing process. To save this fine flour or *float-gold*, as it is called, experiments have shown that by heating the water to the boiling-point or nearly so, these floating particles of gold will subside to the bottom of the pan or vessel.

For *lode prospecting* a pestle and mortar should be carried. The handiest for traveling is a mortar made from a mercury bottle cut in half, and a not too heavy wrought-iron pestle with a hardened face. To get the stuff to regulated fineness a fine screen is required, and the best for the prospector who is often on the move, is made from a piece of cheese cloth stretched over a small hoop. It is often desirable to heat the rock before crushing, as it is thus more easily triturated and will reveal all its gold. Having crushed the gangue to a fine powder, proceed to pan it off in the same manner as washing out alluvial earth, except that in prospecting quartz one has to be much more particular, as the gold is usually finer. Take the pan in both hands and admit enough water to cover the pulverized substance by a few inches. The whole is then swirled around and the dirty water poured off from time to time till the residue is clean quartz sand and heavy metal. Then the pan is gently tipped and a side-to-side motion given to it, thus causing the heavier contents to settle down in the corner. Next the water is carefully lapped in over the side, the pan being now tilted at a greater angle until the lighter particles are all washed away. The pan is then once more righted and very little water is a few times passed over the pinch of heavy mineral, when the gold will be revealed in a streak along the bottom. In this operation, as in all others, only practice will make perfect, and a few practical lessons are worth whole pages of written instruction.

J. C. F. Johnson * gives the following directions for making an amalgamating assay that will prove the amount of gold which can be got from a ton of a lode. Take a number of samples from different parts, both length and breadth. The drillings from the blasting bore-holes collected make the best test. When finely triturated weigh off one or two pounds, place in a black iron pan (it must not be tinned) with 5 ounces of mercury, 4 ounces common salt, 4 ounces soda, and about half a gallon of boiling water. Then with a stick, stir the pulp constantly, occasionally swirling the dish as in panning off, till you feel certain that every particle of the gangue has come in contact with the mercury. Then carefully

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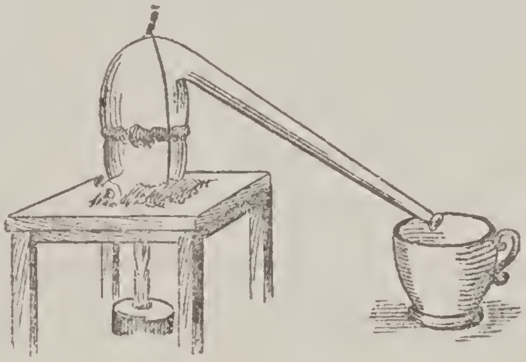
* "Getting Gold." London, 1897.

pan off into another dish so as to lose no mercury. Having got your amalgam clean, squeeze it through a piece of chamois leather, though a good quality of new calico previously wetted will do as well. The resulting pill of hard amalgam can then be wrapped in a piece of brown paper, placed on an old shovel, and the mercury driven off over a hot fire. Or a clay tobacco pipe, the mouth being stopped with clay, makes a good retort. To make such a retort, Fig. 45, take two new tobacco pipes similar in shape, with the biggest bowls and longest stems procurable. Break off the stem of one close to the bowl and fill the hole with well-worked clay. Set the stemless pipe on end in a clay bed, and fill with amalgam, pass a bit of thin iron or copper wire beneath it, and bend the end of the wire upwards. Now fit the whole pipe, bowl inverted, on the under one, luting the edges well with clay. Twist the wire over the top with a pair of nippers till the two bowls are fitted closely together, and you have a retort that will stand any heat necessary to thoroughly distill mercury. The residue,

Fig. 45.



after the mercury has been driven off, will be retorted gold, which, on being weighed and the result multiplied by 2240 for 1 pound assay, or by 1120 for two pounds, will give the amount of gold per ton which an ordinary battery might be expected to save. Thus 1 grain to the pound, 2240 pounds to the ton, would show that the stuff contained 4 ounces, 13 pennyweights, 8 grains per ton.

Darton's gold test. Darton remarks that a number of methods have been proposed to detect the minute quantities of gold occurring in rocks, etc., and having examined and tested every method, recommends the following as requiring but little time and being very trustworthy.

Small parts are chipped from all the sides of a mass of rock amounting in all to about ¼ oz. This is finely powdered in a steel mortar, and well mixed. About half of it is placed in a capacious test-tube, and then partly filled with a solution made by dissolving 20 grains of iodine and 30 grains of iodide of potassium in about 1½ ozs. of water.

The mixture thus formed is thoroughly agitated by shaking and warming. Then, after all particles have subsided, dip a piece of pure white filter-paper in it, allow it to remain for a moment, then let it drain, and dry it over the spirit lamp. It is then placed upon a piece of platinum foil held by pincers, and heated to redness over the flame. The paper is speedily consumed, and after heating further to burn off all carbon, it is allowed to cool, and then examined. If at all purple, gold is present in the ore, and the relative amount may be approximately deduced as much, fair, little or none. There is no compound which would be formed from natural products by this method which would mislead by staining the ash to a color at all similar to the distinctive purple of finely-divided gold.

A variation of this test is given by Thorpe and Muir in "Qualitative Chemical Analysis" as follows:

Five or ten grains of the finely-powdered mineral are shaken with alcoholic tincture of iodine, prepared by dissolving ½ oz. of iodine and ¼ oz. of iodide of potassium in 1 pint of rectified spirit.

The insoluble matter is allowed to settle, a piece of Swedish filter-paper is dipped into the solution and incinerated after drying. If the ash be purple in color, gold is present. To confirm the presence of gold, treat the ash with a few drops of aqua regia, evaporate to dryness at a gentle heat, and dissolve the residue in water. Pour this solution into a beaker which is set upon a sheet of white paper. A solution is now prepared by adding ferric chloride to stannous chloride until a permanent yellow color is produced. This solution is diluted, a glass rod is dipped into it, then into the gold solution. A bluish-purple streak in the track of the rod confirms the presence of gold.

Occurrence of Gold in other Forms. Besides in the condition of simple native gold, this metal is found, as previously mentioned, in intimate mixture with pyrite (iron sulphide). It does not seem to be a compound, but, as we have said, a mixture or minute association. This seems evident from the fact that when the sulphur is removed from the pyrite and the iron rusts down, the gold particles appear with their own color and characteristics in cavities of various rocks, which, when crushed or water-worn, release the particles or pieces to be washed down and mingled with sands and gravels of lower levels, or perhaps the beds and channels of rivers. This is "placer gold." Where gold has not yet been thus released, it is found in association with iron, and especially with quartz in veins. In some instances the gold in quartz is disseminated in particles so exceedingly fine as to require the lens to reveal them.

Nevertheless quartz is not the only mineral which contains gold, although it is the world's great paying source of gold. Some of the other minerals contain it. It is found in yellowish-white, four-sided prisms, and in small white grains as large as a pea, and easily crumbles. In this condition the gold is amalgamated with quicksilver in the proportion of 38 gold to 57 quicksilver, and is known as "gold amalgam." It is very easily tested by heating upon a piece of charcoal by a blow-pipe, when the quicksilver volatilizes and the gold remains.

Gold in paying quantities is found in numerous combinations, and must be discovered and extracted either chemically, by the "wet method," or by assaying in the crucible by means of the cupel and furnace, when it cannot be separated on the spot by the blow-pipe. These methods are taught in any book upon the assay of gold.

Geology of Gold. Native gold is found, when *in situ*, with comparatively small exceptions, in the quartz veins that intersect metamorphic rocks, and to some extent in the wall-rock of these veins. The metamorphic rocks thus intersected are mostly chloritic, talcose and argillaceous schists of dull green, dark grey, and other colors; also much less commonly mica and hornblende schist, gneiss, diorite, porphyry, and still more rarely granite. A laminated quartzite called *itacolumite* is common in many gold regions, and sometimes specular schists or slaty rocks, containing much foliated specular iron (hematite) or magnetite in grains.

The gold occurs in the quartz in strings, scales, plates, and in masses which are sometimes an agglomeration of crystals. The scales are often invisible to the naked eye, massive quartz that apparently contains no gold frequently yielding a considerable percentage to the assayer. It is always very irregularly distributed, and never in continuous pure bands of metal like many metallic ores. It occurs both disseminated through the mass of the quartz and in its cavities.

In studying the geological aspects of this subject and making the practical application of our knowledge to the search, it may be stated that the orginal position of gold must have been in great depths. From these depths it has been brought up by the upheaval of the granitic rocks and perhaps.

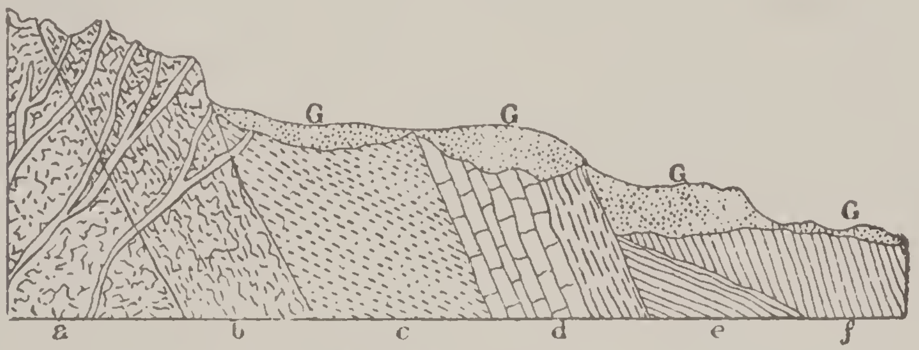
along with basaltic and other intrusions shot up from immense depths. In the course of ages the attrition and breaking-down of these higher and uplifted levels, and the long-continued floods, rains and the waves of ancient oceans and other disintegrating forces which produced the sedimentary rocks, at the same time liberated the gold which was incapable of decomposition. The gold thus found new and varied resting-places in all the sedimentary rocks of various ages, and in all the conditions which the surface might assume.

The quartz rocks are neither igneous nor sedimentary, but are supposed to have been in liquid form as solutions of silex, which, during long periods of time, gradually deposited the silex and whatever they contained, the water disappearing by evaporation or absorption.

Frequently, cellular quartz has been found with gold within the cells, the material which surrounded the gold having become decomposed, and, thus releasing the undecomposed gold, the latter is found in the cells of the quartz. Miners often judge of the character of stone by a superficial study. Quartz which is dull white in color, uncrystallized, and shows no traces of brownstone (decomposed pyrites) is called "hungry," and not expected to yield good returns. On the other hand, quartz which is well honeycombed from decomposition of pyrites, stained brown on joints and faces, and shows decomposed pyrites between the crystals, promises well.

Gold, therefore, is to be expected and looked for in granitic regions (Fig. 46), and in those rocks and from those gravels and sands which owe their origin to such regions. The auriferous belt of California extends along the lower slopes of the Sierra Nevada, which is formed of granites, flanked by crystalline schists and other rocks of the Jurassic. It consists of quartz veins striking in the same directions as the beds, and containing numerous metallic sulphides which all carry gold. It requires much judgment, general exploration, and knowledge of the region before the prospector can, with probability expect to meet with gold, or before he should begin the search. But with a full knowledge of the geologic conditions of the country and acting in accordance with the above facts, the prospector will soon come upon traces of gold, if any exist.

Fig. 46.



Section showing the two conditions under which gold is usually found in rock and drift.

The Structure of the Ural Mountains.—*a.* Granitic and gneiss rocks penetrated with greenstones and porphyrytic rocks containing gold finely disseminated. *b.* Micaceous, talcose, and argillaceous slaty rocks, supposed to be Laurentian and Cambrian. *c.* Silurian and Devonian strata. *d.* Carboniferous, limestone and grits. *e.* Coal measures. *f.* Permian and newer rocks. *G, G, G, G.* Drift, filling hollows in rocks with gold, especially at the base of the drift.

In looking for indications, the prospector should never pass an ironstone "blow-out" without examination, as, according to the German aphorism, "the iron hat covers the golden head," or as the Cornishman puts it, "iron rides a good horse." The ironstone outcrop may cover a gold, silver, copper or tin lode.

Besides the general instructions given above, considerable study should be devoted to the peculiar and seemingly irregular deposits of gold where it does not appear to have been washed down from any higher levels. For instance, in California and some other districts free gold has been found in drifts and sand and in the beds of streams which have not only been filled up, but have been buried under regions of sandstone or other rocks, but the whole country has apparently been raised, or the surrounding region has sunk so as not to show any very considerable elevation beyond where the gold deposits have been formed. But, even in this case, the general rule has been shown to be correct, for these deposits have been proved to be in the beds or channels of ancient rivers, which had either been dried up and overflowed by vast eruptions of lava or basalt, and again by floods bringing new soil and creating sedimentary rock, or the country has been raised, or subsidence of a great extent of land has taken place. In many cases, however, no subsidence has occurred, but only overflow and filling up through ages, and the actual sources still remain elevated.

Such events as we have just described do not transpire without leaving in some parts, traces or features or material, which, to the practiced eye of a skilful prospector, are evidences of some such movements and changes, and he may proceed to make a successful opening only after he has carefully examined a large tract of country, for it is from extended survey that he may the more wisely judge of the relation of superficial parts to the greater depths of even small areas.

Those rocks which lie more immediately over the granite, and which, although they owe their origin to a sedimentary condition, have been subjected to heat and heated waters, as is supposed, we have called "metamorphic rocks." But they have been, probably, first formed from the disintegration of the most ancient rocks, and have brought with them fragments of gold. These metamorphic rocks have been changed from ordinary sedimentary rock by the action of heat and by pressure, and the influence of such treatment may be suspected by their appearance being crystalline in their composition; that is, the fine grains which compose them, as well as the larger grains, are angular, whereas the materials of purely sedimentary rocks are fine without angular shape. The larger part of granite is supposed to have been metamorphic or changed, as the word means, or "altered" merely by the action of heat into a crystalline form or mass.

The igneous rocks are those whose forms are due to having been melted and driven to the surface through fissures in the overlying rocks. They are variously composed of feldspar, hornblende, a little quartz, with comparatively small proportions of other substances, and are called by various names according to the composition. The metamorphic granite contains quartz, feldspar, and mica; the igneous granite contains little or no quartz. Syenite-granite contains hornblende in place of mica. Sometimes the mica is very black, as hornblende is, and in that case may be distinguished from the latter by its more easy cleavage, as we have shown, under a sharp pen-knife; this black mica is the kind we have described as *biotite* (p. 35). There is a syenite which contains no quartz, called hyposyenite. These rocks are not the original home of gold, but at present it is very largely in these metamorphic rocks that the most paying gold is to be found, more especially in the quartz veins which have intersected these rocks. One, therefore, of the most important studies of the prospector is to acquaint himself familiarly with the appearance, the locations, and the departures of these metamorphic rocks. In many places where the alluvial gold, derived from the gold-bearing gravels, has almost ceased to be worth working, there still remain sources undiscovered, and these sources may probably be traced back even yet to some out-crop or to some ancient elevation now having subsided.

The above remarks are applicable to explorations for other metallic ores than gold. They apply to silver, and especially to tin ores, and with some modifications, to copper ores and to quicksilver, as we shall show.

GOLD IN COMBINATION. We have been speaking of gold as native and alone. But it must not be thought that this condition is the only one in which paying gold is found. The combination of gold with various oxides and sulphides of other metals are very valuable, and should be studied.

In almost all gold-bearing regions the iron sulphides carry much gold, and in some regions the paying gold is found only in this substance. Hence, it is well for the prospector to determine the presence of gold in the pyrite or whatever sulphide may present itself. We, therefore, state a method or two of determining the fact that gold exists in this substance.

1. *To separate gold in metallic sulphides, for instance, iron pyrites.* Powder the sulphide as finely as possible. Put about an ounce into a Hessian crucible and heat to a very low red heat for an hour, or until there is very little escape of sulphur fumes. Remove the crucible and put its contents into a porcelain dish. Pour over the roasted powder three fluidounces of strong nitric acid, by drops, until all violent action ceases. Add water, 8 or 10 fluidounces; the gold, if any, will appear as a very fine, black powder; filter and dry, pick out a small particle of the powder and mash it upon a hard surface, iron or agate, in an agate mortar; if it is gold, it will show the gold color. A sufficient quantity of the dried powder may be placed upon

a piece of charcoal, and by means of either *O* or *I* flame of the blow-pipe it may be melted, and both by its color and softness be proved to be gold.

There is a difficulty in this process which the prospector may not be able easily to overcome, and that is the necessity of using the strongest nitric acid. If he has a little laboratory he may readily make his own nitric acid of sufficient power, and then he possesses the simplest and quickest method of treating sulphides or any gold-bearing pyrites. The process is as follows: This acid may be made from common saltpetre and sulphuric acid of commerce. Dry the saltpetre after breaking it into small lumps of a half inch in diameter, carefully drop the lumps into a glass retort, hang the retort on a wire or stand, and introduce the beak into a glass bottle. Place the bottle in a basin of cold water and you may now apply the heat of a lamp, keeping the flame low and five or six inches off from the bottom of the retort. A coal-oil lamp with a short chimney may be used, and the heat regulated to a point at which brownish vapors appear in the retort. Keep enough acid in the retort to barely cover the saltpetre, and keep cool water in the basin, and the vapors come over and condense without much trouble.

Stop the operation when the vapors cease to come over, and the mass in the retort seems to settle down to an even surface. Then draw out the beak of the retort and put the glass stopper into the bottle, and keep the bottle away from light and heat. Wash out the retort, and if you require more nitric acid, renew the operation. The retort should be tubulated to allow of adding sulphuric acid during the operation if needed.

This acid is a yellowish-brown liquid and is known as "fuming nitric acid," and is one of those very active and convenient aids in the laboratory which cannot readily be purchased, and, therefore, must generally be made; but so little of it may be used that a small quantity goes a great way, and it will effect a result which the strongest and purest chemically-pure nitric acid fails to produce. Its effect is to release the gold from the combination of iron and sulphur by oxidizing the latter as well as the former, and rendering them soluble in water, while the gold remains in metallic form of an exceedingly fine black powder, as has been said.

2. Another method of detecting and separating the gold, where the above one cannot be used, is by pulverizing the sulphide ore very finely and mixing it with three or four times its weight of caustic potash or caustic soda, and then subjecting the crucible, which contains the mixture, to a low red heat till all the contents cease agitation and become perfectly tranquil. Then remove the crucible, wait till all is cool, and then add hydrochloric (muriatic) acid in an amount equal to three or four times the bulk of the mass. To this, after standing three or four hours in a warm place, add the usual nitric acid (about an ounce), after transferring all the liquid to a porcelain dish, or, next best, to a beaker-

glass. Let it stand in a warm place for about an hour, then add a little more nitric acid (about half an ounce), stir it well with a glass rod or strip of glass, and let it stand again for an hour or two. Examine carefully, and if it seems to have been dissolved more thoroughly than before, add a little more nitric acid and warm again, stirring well as before. If no more seems to be dissolved, then filter and wash the sediment in the filter and let it dry, and remove the filter and contents for further examination. Now precipitate the gold from the filtrate by pouring into it a solution of ferrous sulphate. [Any clear green crystals of "copperas" (sulphate of iron) of the drug-store, filtered, after saturated solution in clean rain-water and kept in corked bottles, will answer this purpose.] Let the solution stand in a warm place for an hour, drop in a few more drops, and if any further precipitation takes place, add half an ounce of the sulphate, stir it again, let it remain an hour longer in a warm place till all precipitation ceases. Decant the supernatant clear water and transfer the remainder to a filter-paper carefully, and a little at a time, to avoid breaking the filter-paper, then rinse the porcelain dish to get all particles upon the filter-paper, and when all the liquid has passed through, let it dry, and remove all the contents of the paper to a small porcelain capsule or crucible, and apply the heat of the blowpipe to burn off the paper or any organic substance which may have got into the powder; the gold remains, which may be gathered upon charcoal and melted into a globule by the concentrated flame of the blow-pipe, if in small quantity. Lastly, examine the contents of the filter which was laid aside; and, if any appearance of gold is noted, separate it under examination by a pocket lens.

The high value of gold renders even a grain of gold to the pound of ore, if that pound is an average pound in the ton, worth $80 to the ton of 2000 pounds. Hence, a pyrite which contains a half grain to the half pound may prove too valuable to neglect. In the Brazils, in deep mines, the ore yields only half an ounce to the ton of ore, and yet it is mined at a profit.* In California a continuous yield of three-eighths to half an ounce of gold to the ton of quartz is considered profitable working.†

It must be remembered, however, that the above process of extracting the gold from a pyritous ore does not extract with perfect accuracy all the gold unless conducted with more care and time than we have suggested, but it is sufficient to reveal the fact that the ore is valuable.

3. The following method requires more time and care and the use of a little furnace, but will give very accurate results. Pulverize the ore supposed to contain any gold, whether pyrites or not. Heat it in a crucible very gradually at first, increasing the heat to drive off as much sulphur as possible, frequently stirring it and increasing the heat till

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* Makins' Metallurgy, p. 227.

† Davies' Metalliferous Minerals and Mining, p. 64.

all fumes seem to have escaped. Withdraw it and prepare a crucible (clay or Hessian crucible), by dipping it in a strong solution of borax in water, and heating the crucible and repeating the dipping and heating till the crucible shows a glazed inside. Then transfer all the roasted powdered ore, after weighing it (if you desire relative quantity), into the crucible, and cover it with the following mixture (called a flux): Six times the weight of ore of litharge, one of dry borax, and about twenty grains of charcoal pulverized. Heat slowly at first, not allowing much foaming, until all is quiet and the metal button settles down at the bottom of the crucible. Cool and break the crucible to extract the button of metal, which is now ready for cupelling. (*For this process see p. 106.*)

Any one of these three methods of separating all the usual ores may readily be employed, and a little practice will enable the operator to be expert in their use. A great deal more depends upon the skill of the operator than upon the cost of his appliances.

Rule for ascertaining the amount of gold in a lump of auriferous quartz, according to Phillips:

The specific gravity of gold is 19.000.

The specific gravity of quartz is 2.600.

These numbers are given here merely for convenience in explaining the rule; they do not accurately represent the specific gravities of all quartz and quartz gold. (The quartz gold of California has not, on an average, a specific gravity of more than 18.600.)

1. Ascertain the specific gravity of the lump. Suppose it to be 8.067.

2. Deduct the specific gravity of the lump from the specific gravity of the gold; the difference is the ratio of the quartz by volume: 19.000 — 8.067 = 10.933.

3. Deduct the specific gravity of the quartz from the specific gravity of the lump; the difference is the ratio of the gold by volume: 8.067 — 2.600 = 5.467.

4. Add these ratios together and proceed by the rule of proportion. The product is the percentage of gold by bulk: 10.933 + 5.467 = 16.400. Then, as 16.400 is to 5.467, so is 100 to 33.35.

5. Multiply the percentage of gold in bulk by its specific gravity. The product is the ratio of the gold in the lump by weight: 33.35 × 19.00 = 643.65.

6. Multiply the percentage of quartz by bulk (which must be 66.65, since that of gold is 33.35) by its specific gravity. The product is the ratio of the quartz in the lump by weight: 66.65×2.60 = 173.29.

7. To find the percentage, add these two ratios together and proceed by the rule of proportion: 633.65 + 173.29 = 806.94. Then as 806.94 is to 633.65, so is 100 to 78.53. Hence, a lump of auriferous quartz having a specific gravity of 8.067, contains 78.53 per cent. of gold by weight.

CHAPTER VII.

TELLURIUM, PLATINUM, SILVER.

Tellurium. This rare element is occasionally found native, for instance, in Colorado, but more commonly in combination with gold, silver, lead and bismuth, forming minerals called *tellurides.* Native tellurium is tin-white, crystalline in structure, brittle, and therefore easily reduced to powder. Specific gravity 6, hardness 2.5. It is very fusible, volatilizing almost entirely and tinging the blowpipe flame green. White coating on charcoal. Soluble in nitric acid.

TELLURIDES. The tellurides comprise a small, but interesting group, and occur under similar conditions of association in a few widely separated localities, the more abundant ores being of great economical value, as containing a large proportion of gold and silver. Even poorer ores can be treated by roasting, and either chlorination or cyanidation. In many cases attempts to concentrate have been unsatisfactory, as the mineral frequently slimes a great deal. However, concentration is said to have been successfully applied in Boulder Co., Colorado, where gold is found as a telluride in lodes through micaceous schists, gneissic granite, and between granite and porphyry.

The presence of a telluride is recognized by the purplish-red color of the solution by heating the powdered mineral in a tube, closed at one end, together with charcoal and carbonate of soda and adding hot water.

When boiled in sulphuric acid a telluride yields a pinkish solution. The most important tellurides are:

Nagyagite, foliated or black tellurium. Streak, blackish lead-gray. Color blackish lead-gray. Luster, metallic. Specific gravity, 7. Hardness, 1. Sectile, flexible in thin laminæ. Occurs in granular or foliated masses. If the mineral is treated for some time in the O. F. a malleable globule of gold remains. This cupelled with a little assay lead assumes a pure yellow color.

Nagyagite forms a valuable gold ore in Nagyag, Transylvania.

Hessite. Streak, iron-black. Color, lead to steel-gray. Luster, metallic. Sectile, brittle. Forms cubic masses of fine-grained texture. Specific gravity, 8.5. Hardness, 2.5 to 3. Before the blowpipe fuses on charcoal to a black globule; this heated in R. F. presents on cooling white dendritic prints of silver on its surface; with soda is reduced to a globule of silver.

Petzite. Streak, iron-black. Color, steel-gray, iron-black, sometimes peacock tarnish. Luster, metallic. Sectile, brittle. Specific gravity, 8.7 to 9. Hardness, 2.5. Forms cubic masses of fine-grained texture, like hessite, which it resembles in most physical characters, but is much denser. In one locality in Colorado it forms one of the principal minerals in a group of quartz veins in porphyries traversing very coarse granites, and occurs in rounded masses, sometimes implanted on iron pyrites and irregular crystalline aggregates, which are occasionally coated with encrusting pseudomorphs of gold. Some varieties giving 18 per cent. of gold have a specific gravity of 8 to 8.3; others giving 24 to 26 per cent. of gold have a specific gravity of 9 to 9.4.

Sylvanite or *graphic tellurium*. Streak, steel-gray to silver-white. Color, steel-gray to silver-white, and sometimes nearly brass-yellow. Luster metallic. Sectile, brittle in thin laminæ. Specific gravity, 8. Hardness, 1.5 to 2. Colors the flame blue or bluish-green, giving a white incrustation and a dark-gray bead, which can be reduced alone after long blowing, or more quickly with soda, to a yellow, malleable, metallic bead of silvery-gold. The proportion of gold to silver varies. In California, sylvanite occurs in narrow veins traversing porphyry. It is called graphic because of the resemblance in the arrangement of the crystals to writing characters.

PLATINUM. Color and streak steel-gray. Luster, metallic, bright. Isometric, but is seldom found in crystals. Hardness, 4 to 4.5. Specific gravity, 16 to 19. As heavy as gold, and, therefore, easily distinguished and separated from lighter materials. Before the blow-pipe it is infusible; not affected by borax, except when containing some metal, as iron or copper, which gives the reaction. Soluble only in heated nitro-muriatic acid.

Platinum occurs in flattened or angular grains in beds of gravel or sand which resemble gold placers, and have been formed in the same way by the erosion of older deposits. The richest and most extensive platinum placers occur in or near the Ural Mountains in gravels about 3 or 4 feet thick and buried below thicker layers of barren material. Usually, but not invariably, the gravels are also auriferous, and other minerals occurring with the platinum are zircon, spinel, corundum, magnetite and osmiridium. The deposits, besides quartz grains, contain fragments of basic magnesian volcanic and metamorphic rocks, such as serpentine, olivine rock, porphyries, etc.

Platinum is occasionally found in the gold-bearing gravels of California and Oregon. Alluvial deposits of it also occur in British Columbia, Brazil, New Granada, New South Wales and in many other localities, but the quantities derived from these placers are small.

Platinum occurs *in situ* in serpentine in the Urals and elsewhere, and in other metamorphic rocks in various parts of the world, but the quantities so found are insignificant. It is also found in the form of sperrylite (arsenide of platinum associated with copper ores) in the Sudbury district of Canada. It also occurs in the ore of the New Rambler mine of Wyoming, in well-defined crystals in association with covellite and pyrite. The platinum grains occurring native are alloys containing iridium, rhodium, palladium, osmium, iron and copper. The chief impurities are iridium, which may form more than half the alloy, and iron which has been known to amount to 19 per cent. of the mass. Usually, however, the grains contain from 70 to 80 per cent. of platinum.

The greater part of the annual production of platinum is obtained from Russia. The output, in 1906, amounted to 210,318 ozs. Colombia produces about 4000 ozs. per annum, the United States a few hundred ounces, and Australia, Canada, Borneo, etc., smaller quantities. The price of platinum has risen in an extraordinary manner in the past few years.

On April 1, 1905, it was $20.50 per ounce and it remained firm at this quotation until February 1, 1906, when it jumped to $25.00 an ounce, and on September 1, 1906, leaped to the unprecedented value of $34.00 an ounce. It may be interesting to note that the name platinum is derived from *plata*, the Spanish word for silver, since it was regarded in South America at the time of its discovery (1735) as an impure ore of that metal.

Platinum, like gold, does not readily combine with other metals, and in nature the only compound known is an arsenide called *Sperrylite*, which is found in very small quantities in the Sudbury section of Ontario, Canada. Its color is tin-white; luster, bright; hardness, about 7; specific gravity, 10.6.

Platinum may be distinguished by its great weight, by its gray color, its sectile nature, and by the fact that it will not dissolve in any simple acid, and with difficulty in nitro-muriatic acid (aqua-regia). It may be distinguished from lead by its action under the blow-pipe flame, since lead melts immediately, leaving a yellowish coating, while platinum refuses to melt under the hottest flame, and leaves no coating whatever. When it exists in the alluvial soil it may be "panned out" just as gold or other heavy metals, and even more easily because of its greater gravity.

It may be found in some metal-bearing veins in crystalline metamorphic and syenite rock, from which it has been washed down, just as in the case of gold. In the latter condition it has been found more extensively than in any other.

Its chemical test is as follows: Dissolve the grains of the ore in nitro-muriatic acid (4 parts muriatic acid to 1 part nitric), preferably with gentle heat, add proto-chloride of tin (solution), also called stannous chloride ($SnCl_2$); if platinum is present a dark brownish-red color will be produced, but no precipitate.

The metal may be obtained separate from its gold, and in the presence of many other metals, by evaporating the above solution of the ore in a porcelain dish to dryness, at a gentle heat, with ammonium chloride (sal ammoniac or muriate of ammonia), and the residue treated with dilute alcohol (one-fourth part water). The gold will remain in solution and the platinum be precipitated; the precipitate is to be ignited, when the platinum will be pure. The gold, if present, may be precipitated by adding a solution of ferrous sulphate, after evaporating off the alcohol. Ferrous sulphate is proto-sulphate of iron (copperas in crystals).

Stannous chloride may readily be purchased at any chemist's warehouse, but as it is easily prepared we give the best method as follows: File a piece of tin into powder and heat very hot (nearly to boiling) with strong hydrochloric acid in a porcelain dish or beaker-glass, always keeping tin in the glass or dish, by adding tin if necessary. When no hydrogen gas is evolved (*i. e.*, no bubbles arise), dilute with four times its bulk of pure water, slightly acidulated with hydrochloric (muriatic acid, and filter. Keep the filtrate in a well-stoppered bottle in which some tin has been placed. If you have pure tin-foil, that form of tin may be used, for without the presence of metallic tin the stannous chloride ($SnCl_2$) is in danger of changing into stannic chloride ($SnCl_4$) with precipitation of a white substance (oxychloride of tin), which renders the reagent unfit for use.

SPERRYLITE. This is the only mineral known in which platinum occurs in combination with other elements. It is composed of platinum, 55.47; rhodium, 0.68; palladium, trace; antimony, 0.54, and arsenic, 43.23. Occurs in very small quantities in nickeliferous ores, containing also iridium and rhodium, of the Sudbury district, Canada.

IRIDIUM, a steel-white, extremely hard metal, next in specific gravity to osmium, is supplied partly from its alloy with native platinum and partly from the iridosmium which occurs in the platiniferous gravels. It is used for pen-points and in jewelry, and recently in metal-plating.

OSMIUM is the heaviest known metal. It comes from the same sources as iridium, and in the form of iridosmium is used for pointing tools and pens.

PALLADIUM is a brilliant silver-white metal. It also occurs with platinum, but on account of its high price is but little used.

SILVER. — NATIVE SILVER occurs in various shapes, as in small grains in the rock, as wire silver, tree-like shapes, and also in small octahedral crystals, and in other forms. Color and streak, silver-white; when found in veins is usually tarnished on the surface. Hardness, 2.3 to 3; specific gravity, 10.1 to 11.1, according to its purity. It is never found absolutely pure, but contains some gold and frequently a little copper. It is often associated with iron rocks, native copper, etc. It is always sectile and malleable, and in this respect very easily distinguished from a substance frequently mistaken for native silver, namely, *mispickel*, which is an *arsenide of iron*, having very much the appearance of silver, but is always brittle.

BEFORE THE BLOW-PIPE, on charcoal, native silver is distinguished from tin, zinc, antimony, or bismuth, by the fact thas it melts and leaves no whiteness or any other appearance of oxide upon the coal around the globule.

Tin will leave a white film, and lead a yellow, zinc a yellow which whitens on cooling. But silver leaves no film or cloud of any kind upon the coal.

Chemical Test of Silver : Dissolve the metal in nitric acid in a test-tube, preferably with the heat of an alcohol flame, but not to the boiling point. Add an equal amount of pure water (clear rain water will answer), then drop in several drops of a solution of common table salt or muriatic acid. If a cloudy white precipitate occurs which settles and blackens after exposure of a few seconds to sunlight or a few minutes to daylight, the substance is silver.

It should be remembered at this point that this test is for silver alone, since lead and mercury are also precipitated as a white cloud by the same solution, but neither blackens by exposure to the light. This distinguishes silver. If, however, further proof is needed, drop into the test-tube strong ammonia water; the precipitate is dissolved if it is that of silver; it is not if it be of lead, and it is blackened by the ammonia if it is mercury.

If there is much copper in the silver it may be detected by dipping a clean strip of polished iron or steel into the solution, for the metallic copper will immediately appear upon the surface of the iron.

It must not always be supposed that native silver is metallic or white in appearance, for it is readily tarnished by sulphur, and the proximity of sulphur in other minerals or in water may greatly discolor the native silver.

Comparatively speaking, very little of the silver of the mines is derived from native silver. Most of the silver of commerce is obtained from some of the minerals named below, which are combinations of silver with other metals, and with sulphur or chlorine, as sulphides of silver, etc., in which condition they bear no resemblance to native silver.

But in all silver minerals of any commercial value, the already mentioned tests are usually sufficient to detect the existence of silver.

Other forms in which silver is found are—

SILVER SULPHIDES are very largely associated with lead sulphides or galena, and sometimes called, when pure:

SILVER GLANCE OR ARGENTITE. This is found in masses, but when crystallized it occurs in cubes or octahedral forms. When freshly broken it has a metallic luster, otherwise it is of a dull gray or leaden appearance. It is soft and sectile, and its "streak" or the color of its powder is the same as that of the mineral itself, and rather shining. Chemical composition: Silver, 87; sulphur, 13. Hardness 2 to 2.5. Specific gravity 7.1 to 7.4.

The ore is soluble in nitric acid, and on adding common salt to the solution, a white curd is thrown down which blackens on exposure to sunlight. It is very fusible at the temperature of an ordinary flame, giving off an odor of sulphur when heated. Before the blow-pipe on charcoal, with or without carbonate of soda, it yields a white globule of metallic silver which can be flattened under the hammer.

The ore in an amorphous state is most common in earthy vein-stuff (called metal azul) or with pyritic minerals, especially galena. It is rarely recognizable by form or physical character, as rich quartz only differs from ordinary by its pale bluish-gray tint, and argentiferous galena is, as a rule, undistinguishable by sight from that containing no silver.

CERARGYRITE OF HORN SILVER. The mineral known under this name is a chloride of silver occurring in veins of clay slate with other ores of silver, usually only in the higher parts of these veins. With ochreous brown iron ore, with several copper ores, etc. Luster, waxy, resinous. Fracture, conchoidal. Color, greenish-white, pearl-gray, brownish, dirty green, and on exposure brownish or purplish. It yields a gray, shining streak. It is translucent on the extreme edges and has a waxy appearance. It cuts like horn or wax, and on an outcrop looks like dirty cement. It contains 75.3 per cent. silver, and 24.7 per cent. chlorine when unmixed or nearly pure.

A polished piece of iron may be slightly coated with silver if a piece of horn silver is moistened and rubbed upon the iron.

Horn silver is very easily fusible, melting in the flame of a candle. Heated with carbonate of soda on charcoal, it yields a globule of metallic silver.

This mineral, in various degrees of impurity, forms a very large part of the silver-bearing ores of some mines in South America, as well as in the

Western States and Territories of the United States. It is a valuable ore.

STEPHANITE OR BRITTLE SILVER ORE is a *silver sulphide with antimony*, and is found in masses and sometimes in rhombic prism crystals in veins with other silver ores. It is easily distinguished from silver sulphide (or glance) by the fact that it is brittle, while the glance, if fairly pure, may be cut with a knife into chips without breaking.

This ore is black or iron-gray, has a hardness of 2 to 2.5 and a specific gravity of 6.2 to 6.3, and when pure contains 71 per cent. of silver, the rest being antimony with some other admixtures, usually iron or copper. It is an abundant silver ore in the Comstock Lode, Nevada (Figs. 47, 48), in the Reese River and Humboldt and other regions, and at the silver mines in Idaho.

On charcoal, under the blow-pipe, it decrepitates and coats the coal with a film of antimony (antimonous acid), which, after considerable blowing, turns red, and a globule of silver is obtained.

RUBY SILVER. Several ores of silver contain arsenic and antimony as well as sulphur. The most important of these are the dark-red, sometimes black, silver ore called PYRARGYRITE, which contains 59.8 per cent. silver, 17.7 per cent. sulphur, and 22.5 per cent. antimony; and the light-red silver ore, known as PROUSTITE, with 65.5 per cent. of silver, besides sulphur, and may have a grayish appearance. Proustite has been found in masses of several hundred pounds weight at Poorman Lode, Idaho (Dana). In Mexico it is worked extensively as an ore of silver.

Both these minerals occur massive, granular or as prismatic crystals. They resemble each other closely in their characters, their hardness being 2 to 2.5, and the specific gravity of pyrargyrite 5.8, and that of proustite 5.6. Both have a red streak and an adamantine and submetallic luster.

Before the blow-pipe, pyrargyrite gives off dense antimony fumes, while proustite yields arsenical fumes easily recognized by their garlic odor. Heated on charcoal with carbonate of soda both minerals afford a globule of metallic silver.

Nitric acid extracts the silver from these ores, forming a solution, in which salt throws down a white curd, blackening on exposure to sunlight.

Bromic Silver or Bromyrite. This is a common ore containing bromine 42.6 per cent. and silver 57.4 per cent.

There are other minerals in which silver occurs, but they are only exceptions or rare, and if one is acquainted with those mentioned above, he will very likely detect the rarer silver minerals, which are not ores in the usual sense, but they may lead when discovered to valuable results.

Valuing silver ores. A simple, but rough, method is sometimes adopted of testing the value of ores from day to day when chlorides are the minerals chiefly worked, by powdering the ore in the mine, mixing it with a solution of hyposulphite of lime which dissolves the chloride, and then adding sodium sulphide, which forms a dark-colored precipitate if much silver is present. It is evidently impossible to estimate in this way the content of silver, but it affords a very good test whether the ore is of value or not.

Reference may here be made to what are called *argentiferous* minerals, comprising ores of lead or copper, in which more or less silver is present. These may be enumerated as follows: Galena (sulphide of lead); bournonite (sulpho-antimonide of lead and copper); tetrahedrite (antimonial gray copper); tennantite (arsenical gray copper); mispickel (arsenio-sulphide of iron); zinc-blende (sulphide of zinc).

These minerals will be described later under the headings where they belong. When argentiferous, they do not give evidence of the presence of silver, unless they are submitted to the process of assay. A very simple test for the presence of silver is given by Charles H. Aaron * as follows: The ore should be ground fine, and then a few ounces are mixed with about one-tenth of its weight of salt, and one-twentieth of copperas. This is placed in an old frying pan and heated gently so long as a smell of burning sulphur can be noticed, the mass being all the time stirred with a thin bar of iron. After all the sulphur has been driven off, the heat is increased for a few minutes to a light red, and the mass stirred until it swells up and becomes sticky,

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* Practical Treatise on Testing and Working Silver Ores.

care being taken not to fuse the ore. The mass is then taken out and allowed to cool on a rock, and after a little more salt has been added, and the ore mixed with water to the consistency of mortar, a strip of sheet copper previously cleaned, is inserted and left there for ten minutes. The copper strip is then removed, washed in clean water, and, if any silver is present, it will be coated with a white substance which will be heavier or lighter according to the richness of the ore and, if very rich, will appear gray and rough. The frying pan should be smeared with clay or mud, and dried before being used.

GEOLOGY OF SILVER ORES. The most valuable ores occur in the earlier or more ancient rocks, such as the granitic or gneissoid rocks, clay slates, mica schists, older limestones, and in the metamorphic rocks. The remarkable geologic conditions under which silver ores and veins occur may be understood more readily by the following diagrams than by any descriptions without them. (Figs. 47 and 48.)

In the diagrams the rocks are seen tilted up from the horizontal position to one nearly vertical, but evidently after this uplifting the trachytic dykes were shot through the masses of conglomerate. The lodes bearing silver are represented by continuous double lines, and the dykes by dotted vertical lines. The entire distance represented from Sutro to the west end of the diagram is about 5½ miles, on a course east and west, being the same as that of the Sutro tunnel upon this branch, which joins or intersects to the north and south branch of the tunnel at the Comstock lode.

In order that the superficial nature of the country may be understood, we have given the north and south sections of the same region, showing some of the mines by vertical black lines and by shaded spaces where the mines have been worked more or less extensively. (Fig. 48.)

The north and south sections exhibit the hilly surface, and fully illustrate the work of the prospector who would become acquainted with the mineral deposits of a similar region.

It will be seen in the east and west sections that all the lodes out-crop. (Fig. 47.) The non-metallic substances of these lodes are quartz, fluorspar, with, perhaps, some chlorides or sulphides ; the latter may be metallic, and there may occur some traces of gold and silver, perhaps also of antimony, lead, etc. The wisest course, therefore, is for the prospector, after having settled in which direction the strike or course of the strata runs to make an examination directly across the strata, the chief object being to learn the nature of the rocks of the region, and, at the same time, to detect the outcropping of any lodes or dykes.

His object is to become acquainted with the strata by means of the loose material, the fragments, or small outcropping rocks, where he cannot penetrate beneath the soil.

It may become necessary to traverse a great dis-

FIG. 47

Syenitic rock. Conglomerate rocks with dykes of trachytic rock. Feldspathic rocks.

SECTION ACROSS THE COMSTOCK LODE AND SURROUNDING STRATA. EAST AND WEST.

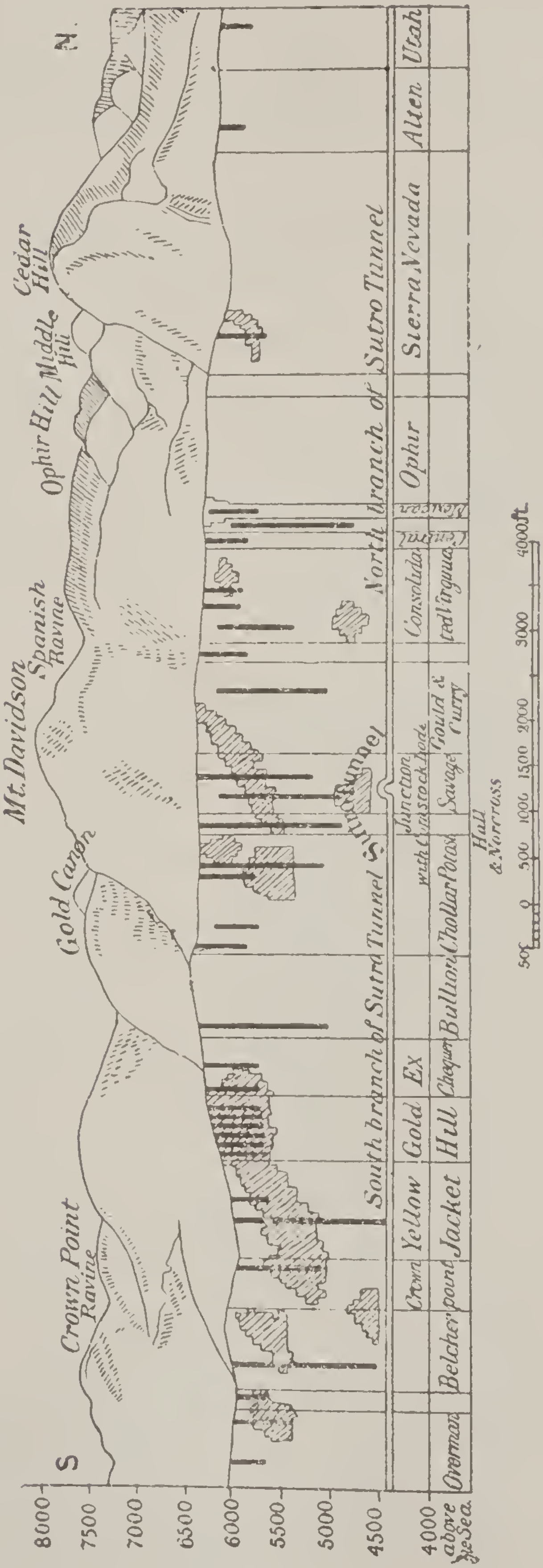
tance before any certain information may be gained, and where the hill surfaces are covered with soil, the ravines will frequently disclose the nature of the rock.

It will be noticed that the Comstock Lode begins immediately adjoining the syenite rock, and at the outcrop extends six or eight times the actual thickness of the lode below. It is also apparent that the lodes generally, at least in this region, bifurcate near the surface, even in the syenite, and when an outcrop has been discovered, the probability is that not far off another outcrop of the same lode may be found (Fig. 47).

The Comstock Lode has been traced for four or five miles north and south, but the values of the deposits are not uniform. The great bodies of ore may be seen in the north and south section where the excavations are largest, as around the Savage, and from the Exchequer to the Crown Point properties. But this whole region is filled with dykes and lodes for miles beyond the Comstock Lode, which lies on the eastern slope of a range of hills running somewhat parallel, but about fifteen miles east of the Great Sierra Nevada range, south of the Pacific Railroad, and between the lakes Begler and Carson in the western part of the State.

In the Tonopah district, the rock is apparently similar in composition to that of the Comstock, and probably of the same age. The most important veins occur in the early andesite, and do not extend into the overlying rocks. The ores are in the form

FIG. 48.



NORTH AND SOUTH SECTION OF THE COMSTOCK LODE, SHOWING THE MINES AND THE SURFACE.

of quartz veins. These veins carry gold and silver in the proportion of about 1 part of gold to 100 of silver by weight. They are usually free from base metal; no lead, arsenic, etc. has been detected. In some places there is a little copper, in others none. Silver is found in the form of chloride, sulphite (argentite), and ruby silver.

In the east of Nevada, at the Eureka Mines, the ores are found in a bed of limestone overlying the granites, quartzose slates and metamorphic rocks of great thickness. The limestone containing the ore is about 300 feet thick. But while the immediate geology varies from that of the Comstock, the general facts are the same, namely, that the silver-bearing lodes are in or very near the granites or earliest rocks. In this case the overlying rocks, though limestone, are dolomitic, containing from 36 to 46 per cent. of carbonate of magnesia, and the mineralized belt of limestone, or that containing the ores, is very much broken, and in some places apparently crushed, as if it had been subjected to a grinding process, and then partly rejoined by the cementing power of calcareous matter deposited from solution in percolating water.

A peculiarity in this last decribed limestone is found in the large caverns which occur along the course of mineral deposit. On the floors of these caverns are found beds of ore which seem to have dropped from their position in the limestone, as that has been dissolved out and carried off where the fissures easily permitted the percolating waters to pass rapidly away.

The geology of this region appears to be in the order of granites, quartzose slates and metamorphic rocks of great thickness, limestones containing segregations of ore, calcareous shales, and these surmounted by limestones also of great thickness. The special region to which this geological series refers is the Ruby Hill mines.

The Emma Mine, with many others, is situated still further east, in the Wahsatch range of mountains, which runs north and south about twenty miles east of the Great Salt Lake. This mine is about the same distance southeast of the Great Salt Lake. The adjacent rocks of this mine are granite, in massive beds, dipping from 50° to 70° eastward. This is overlaid by quartzites of a reddish color, then occurs a series of slates, upon which are thick beds of white limestone, and these pass rapidly into the carboniferous dolomitic limestone. It is in this last limestone that the ore deposits of the Emma and adjacent mines are worked.

It is a fact, however, that the ores are mainly composed of silica and lead of which there is over 70 per cent. The amount of silver is about 0.40 to 0.50 of 1 per cent. according to some analyses. A sample amount of 82 tons, gross, yielded 156 ounces of silver.

These mining districts present the general geologic conditions in which the silver ores are found in these and other States and Territories, and the prospector should expect to find surface indications accordingly, but modified more or less by exposure to weather.

Although from the preceding illustrations, silver is shown to be found both in the very early groups of rocks and in the carboniferous limestone, the latter is the exception, as it appears to be found there only when that limestone has occurred with little or no separating horizons from the earliest rocks.

CHAPTER VIII.

COPPER.

Copper occurs both native and in a compound state.

Native Copper is found in various forms, in grains, strings, plates, and even in octahedral crystals. Color, copper-red, but ofter tarnished. Ductile and malleable. Streak shining; hardness 2.5 to 3. Specific gravity, 8.5 to 8.9, according to purity. Frequently carries silver. Tested by the *blow-pipe* it yields in small quantities a blue tinge to almost black in the borax bead, according to quantity used and the kind of flame, whether inner or *R* or outer or *O*, the latter giving blue color, the former giving the copper color or metallic opaque brown.

Native copper dissolves readily in nitric acid, and if ammonia be added the solution becomes green, or greenish-blue if ammonia be in excess.

In the absence of any chemicals or a blow-pipe, the mineral, when containing native copper, or when only a compound containing copper, may be tested by heating it either in the mass, or, better, in powder, and when hot, dropping it into some salty grease and then putting it in a flame or upon burning charcoal, when the characteristic green color will appear in the flame with great distinctness.

Moreover, if the mineral contains copper in considerable quantity and it is dissolved in nitric acid, the copper will be deposited immediately upon a strip of polished iron or upon the end of a knife blade, if either be dipped into the solution.

The natural combinations of copper are almost endless. Not less than a hundred mineral species may be regarded as copper ores from the practical miner's point of view, *i. e.*, possessing economic value, and there are probably as many more which are not yet utilized. As might be expected the range of chemical associations is equally wide, embracing sulphides, antimonides, arsenides, oxides, chlorides, bromides, iodides, carbonates, sulphates, phosphates, silicates, arseniates, simple and compound, hydrated and anhydrous, in almost every degree of variety.

Below several of the more important ores of copper are mentioned, and also some copper minerals which, to the prospector, will be suggestive that the more important ores are not far off.

CUPRITE, RED COPPER ORE OR RUBY COPPER. Occurs massive, granular, and earthy. Streak, shades of brownish-red, shining. Brittle. Color, deep crimson, cherry-red. Luster adamantine or submetallic; or again it may be dull and earthy. Sometimes weathered to an iron-gray on the surface. Hardness, 3.5 to 4; specific gravity, 6. Composed of copper, 88.78 per cent., the remainder oxygen, when pure.

Before the blow-pipe, on charcoal, it yields a globule of metallic copper; with borax bead gives the indications of copper. Dissolves in hydrochloric acid, giving a brown solution which, when diluted with water, deposits white insoluble cupric chloride. In nitric acid it forms a blue solution. Sulphuric acid decomposes it into cupric oxide (CuO) and metallic copper, the former passing into solution as cupric sulphate, while the latter is undissolved.

Cuprite occurs in granite and slate with copper ores and galena and forms a valuable source of the metal. The massive variety is known as *tile ore; brick ore* is a mixture of copper and limonite. The fibrous variety is known as *plush copper ore.*

CHALCOCITE, COPPER GLANCE OR VITREOUS COPPER. Massive; slightly sectile. Color bluish-lead gray, brownish; brilliant when fresh; black and dull, on exposure to sunlight tarnishing to blue or iridescent. Streak, blackish-gray, sometimes shining. Hardness 2.5 to 3; specific gravity 5.5 to 5.8. Composed of copper 77.2; sulphur 20.6, and sometimes a little iron. It is fusible in a candle flame.

Before the blow-pipe it gives off an odor of sulphur. When heated on charcoal, a malleable globule of metallic copper remains, tarnished black, but rendered evident on flattening under a hammer. With borax bead it gives the indications of copper. Dissolves in nitric acid, forming a blue solution. These tests distinguish it from sulphide of silver. Occurs with other copper-ores.

TETRAHEDRITE OR GRAY COPPER ORE. Brittle;

steel-gray or iron-black, sometimes brownish ; streak between steel-gray and iron-black, sometimes brownish ; hardness, 3 to 4 ; specific gravity, 4.75 to 5.1. Composed of copper 38.6, sulphur 26.3, and frequently antimony and arsenic, zinc, iron, silver, etc. It frequently contains silver, and sometimes as much as 25 to 30 per cent.

Before the blow-pipe on charcoal it fuses, gives an incrustation of antimonious, and sometimes arsenious, acid, oxide of zinc and oxide of lead. Arsenic may be detected by its odor on heating the incrustation in R. F. or fusing with soda. Oxide of zinc gives a green color when heated with nitrate of cobalt solution. The iron and copper in the residue are found either by fluxes (on platinum) or by reduction with soda. Silver is determined by cupellation.

Tetrahedrite is soluble in nitric acid, arsenious and antimonious acids separating. The solution becomes blue from copper by adding ammonia in excess, and cloudy with hydrochloric acid when silver is present.

Tetrahedrite occurs with copper pyrites, galena and blende. It is worked for copper and occasionally for silver.

CHALCOPYRITE OR COPPER PYRITES. Massive. Color, brass-yellow, when fresh, gold-yellow when tarnished. Luster, sub-metallic ; brittle, slightly sectile. Streak, greenish-black, unmetallic. Hardness, 3.5 to 4, specific gravity, 4.15. Composed of copper 34.6, sulphur 34.9, iron 30.5. Before the blow-pipe it fuses with intumescence and scintillation to a rough magnetic globule. When powdered and roasted at a low heat, it is converted into a fritted mass, giving reactions of copper and iron with fluxes. With soda on charcoal, gives a globule of metallic iron and copper. It is sometimes mistaken for gold, or iron, or tin pyrites. But it is brittle, while gold is not; it will not strike fire, as does iron pyrites; and it may be distinguished from tin pyrites by the film that the latter leaves on the charcoal, while copper pyrites leaves no residue under the blow-pipe. It occurs in granite and slate in lodes or veins, and is a valuable ore of copper.

What is called *peacock ore* is only pyrites coated with oxide and exhibiting iridescent colors. By leaving a piece of clean yellow copper pyrites in water for some time it will become coated in this way.

CHRYSOCOLLA OR SILICATE OF COPPER. Accompanies other copper ores, occurring especially in the upper part of veins. It is a bright green or bluish-green mineral, scarcely worthy of being called an ore, although it contains from 35 to 40 per cent. copper and a large amount of silica. It is a secondary deposit. Its hardness is 2 to 4, and specific gravity 2 to 2.3. Its only significance to the prospector is that it may be associated with true ores. Its powder (streak) is white, while the mineral itself is green, this being due to the quartz or silex in it. When dissolved in nitric acid a precipitate is left, which distinguishes it from malachite, the latter being quite dissolved. Before the blow-pipe with soda it gives a bead of copper.

BLACK OXIDE OF COPPER is usually found on the surface. Soils the fingers when pulverulent. It is a result of decomposition of copper ores, as a deposit on surface of copper pyrites. It occurs in masses of a dark, earthy appearance, sometimes in minute, shining particles. If the dusty powder be rubbed between the fingers and dropped on a flame, the latter will be colored green. Soluble in ammonia; solution azure blue.

MALACHITE OR GREEN CARBONATE OF COPPER, has a fibrous structure nearly opaque, and is of an emerald-green color, and contains about 57 per cent. of copper. Streak, paler green than the color. Hardness 3.5 to 4; specific gravity 3.6 to 4. Commonly found near the surface of veins containing copper ores.

Before the blowpipe it becomes blackish. With borax it yields the usual blue-green bead, and on charcoal is reduced to metallic copper. It completely dissolves in nitric acid, and thus it may be distinguished from silicate of copper, which has nearly the same color and will not dissolve.

AZURITE OR BLUE CARBONATE OF COPPER is chiefly used for ornamental purposes. It is of a deep cobalt-blue color sometimes transparent, brittle. Streak bluish; hardness 3.5 to 4.5; specific gravity 3.7 to 4. Can be scratched with a knife. It blackens when heated. On charcoal it is reduced to a globule of pure copper. With the borax bead it gives the indications of copper. It is soluble in nitric acid with effervescence, forming a blue solution.

VARIEGATED COPPER PYRITES (*Bornite* or *Erubiscite*): Usually massive, of a copper-red to a pinchbeck brown color, and a blackish to lead-gray streak. Hardness 2.5 to 3, specific gravity 5.5 to 5.8. It contains about 55.5 per cent. of copper, 28.1 per cent. of sulphur, and 16.4 per cent. of iron. Before the blow-pipe it gives a bead of copper.

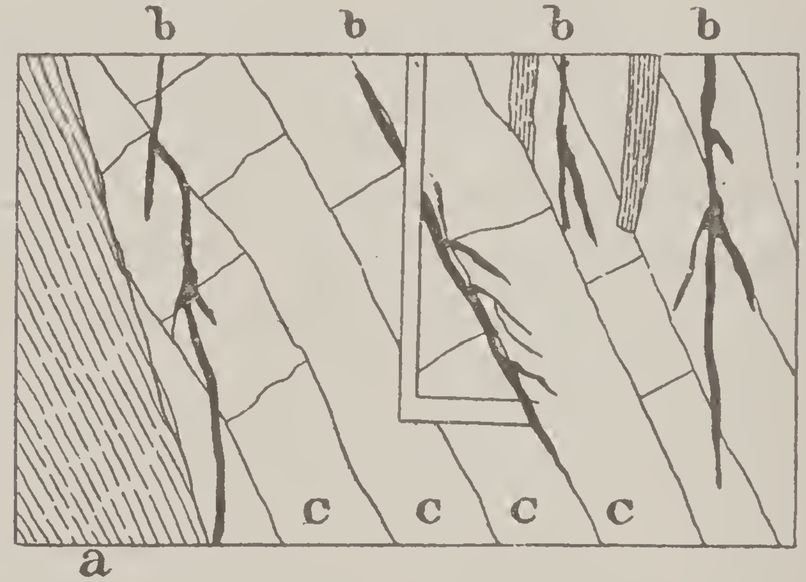
But the minerals above mentioned are by no means the most important as regards the commercial supplies of the metal; in fact, in that light they may almost be disregarded so far as affording any considerable proportion of the total yearly output, though, of course, deposits of these ores are profitable. The bulk of the world's consumption of copper is furnished by ores of the lowest grade, ranging from little more than ½ to perhaps 5 per cent., though rarely more than 3 to 3½ per cent. Thus the ores of Devon and Cornwall are worked for 1½ to 2 per cent. copper; those of Cheshire, for less than 1½ per cent.; those of Mansfeld, Germany, for little over 2½ per cent.; those of Rio Tinto, Spain, for 2¼ to 3½ per cent.; those of Maidenpec, Servia, for 2 to 3 per cent.; and, overwhelmingly the most abundant producers, those of the Lake Superior region for as little as 0.65 per cent.

Formerly the world's supply of copper was drawn from the rich ores, containing up to 40 per cent. of metal as mined, and further explorations may again reveal in the future similar deposits to replace those now exhausted; but at present and in the immediate future reliance must be placed on the enormous low-grade ore-bodies now being worked, especially in North America. Alaska is proving to be a great copper country, and in 1906 9,000,000 pounds of copper were exported from there. The best known, and probably the richest copper belt occupies a strip nearly 100 miles long and of varying width along the southern base of the Wrangell Mountains. Throughout this zone, in the drainage basins of the Chitina, the Kotsina, and the Cheshnina, there are scattered deposits of copper ores. In 1907 and 1908 Alaska produced nearly 12,000,000 pounds of copper.

The GEOLOGY OF COPPER is more varied than that of many other metals, as it occurs in rocks of almost every age. In Cornwall the slates are more productive than the granites, while in our mines in the Eastern States the new red sandstone, the carboniferous limestone, and Silurian rocks furnish copper. Also found in the metamorphic limestone, near slate (Fig. 49). In the upper peninsula of Michigan, on the shores of Lake Superior, which is the most celebrated locality for native copper, the rocks are sandstones and shales underlying greenstone or a kind of trap, and in some places seem to be igneous (Figs. 50 and 51). Ruby-copper ore occurs in Arizona between quartzose and hornblendic rocks and limestone. It occurs in both, lodes and deposits, and the best way for the prospector to prepare for actual discovery is to make himself well acquainted with the copper compounds, whether ores or minerals. They may indicate true ores, although they contain little copper.

To become ready in the detection of copper as an ore, the following facts should be kept in mind, as furnishing suggestions for skilful practice. (Figs. 49, 50 and 51.)

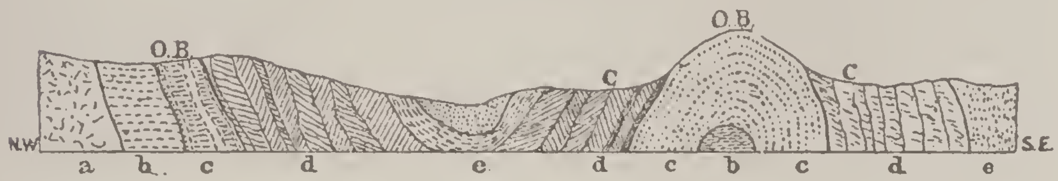
FIG. 49.



SECTION OF THE COPPER BED AT THE DOLLY HIDE MINE, MARYLAND. *a.* Slate. *b, b, b, b.* Ore beds or segregations of ore. *c, c, c, c.* Crystalline limestone (metamorphic).

It is well to remember, especially when exploring a new country, that copper is frequently associated with rocks of a dark color, which are very often green; but it must not be supposed that the color is imparted by copper, for it is generally due either to some other metal, such as iron, or to the presence of a green non-metallic mineral, such as chlorite. Serpentine and hornblendic rocks are often associated with copper ores, but green serpentines owe their color to iron, nickel or chromium, and if copper is found disseminated through some of them, it is the exception and not the rule, unless in the immediate vicinity of ore deposits. On the contrary, iron and chromium are found in all serpentines, and nickel is of frequent occurrence.

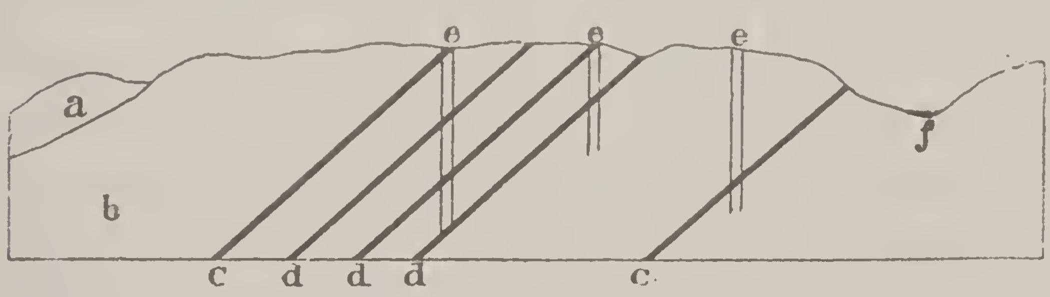
Fig. 50.



Section of strata in Lake Superior copper region: *a*. Granite. *b*. Gneissoid. *c*. Greenstone, hornblende, conglomerates with interstratified slates. *d*. Slaty rocks and traps, etc. *e*. Potsdam sandstone. *C*, *C*. Places of copper deposits. *O*, *B*. Iron ore beds. Section from *N. W.* to *S. E.*

All copper ores weigh more than quartz or limestone, and the comparative weights should be so well known by practice that there should be no hesitation in judging that the mineral you hold is more than 2.6 in specific gravity, 2.6 being that of either quartz or limestone.

Fig. 51.



Copper. Section of the Eagle vein, Lake Superior. *a*. Porphyritic rocks. *b*. Greenstone. *c*, *c*. Conglomerate. *d*, *d*, *d*. Amygdaloid bearing copper. *e*, *e*, *e*. Shafts. *f*. Montreal River.

Next examine the mineral with your pocket lens for any evidence of copper, such as green or bluish spots, or brassy points or particles; if found, chip one off and use the blow-pipe with borax bead or with soda or borax on charcoal. If the characteristic color appears, it is copper. Now proceed with other parts of the specimen. If a sulphury smell is plain, it is probably a sulphide. Place a small chip upon a depression in the charcoal, cover with soda or borax, turn the inner flame upon it and reduce to a metallic globule; if it shows the color of copper and is malleable, it is copper; if it blackens, apply your magnetized knife-blade, and if it is attracted, the mineral contains iron, and it may contain both iron and copper.

The next work is to examine the region to gather any other specimens and evidences of true ores, before attempting to know more of any particular specimen. If the surface specimens are numerous it may be well to gather some six or eight, and proceed to an examination as to the available copper. This is now the work of the chemist, and should be submitted to him. But as the skilled prospector frequently wishes to be his own chemist, where work for the desired object is not difficult nor very complicated, we give the following simple process of arriving at the per cent. of copper in an ore without regard to other elements contained therein:

TO OBTAIN THE PER CENT. OF COPPER IN AN ORE. The only chemicals needed are nitric acid, ammonia, and sodium sulphide—the colorless crystallized hydrosulphide of soda of commerce is good enough. All the apparatus needed is a glass flask or tall beaker-glass and a marked tall glass called a burette. This glass may be obtained at any chemical warehouse. The burette is marked in cubic inches or cubic centimeters, from 25 to 100. Dissolve some sodium sulphide in clear rain-water—about a half ounce to a pint. Keep the solution in a glass-stoppered bottle. Obtain some pure copper (ordinary good copper wire will answer), weigh the piece accurately and dissolve in nitric acid, add some water (twice the amount of acid used, or a little more), then add ammonia until, when stirred with a long piece of glass or glass rod, the solution smells strongly of ammonia. The ammonia must be in excess. Now fill the burette with sodium sulphide to the 100-mark, and from the burette pour into the copper solution until the blue color of copper entirely disappears; note on the burette by its marks the exact amount of sodium sulphide used. That amount represents the weight of the amount of copper used.

Now for the ore: Pulverize some of the averaged ore, weigh it, and treat it as you did the copper, with nitric acid and ammonia, and proceed with the sodium sulphide. When the ore solution has become entirely colorless, note what amount of sodium sulphide solution you have used, and you may then calculate the exact amount of copper in the ore by simple proportion. The presence of tin, zinc, lead, iron, cadmium, antimony, arsenic or bismuth in the ore does not interfere with the operation. But silver does. Therefore, a small amount of the ore must be dissolved in nitric acid (free from all muriatic acid or chlorine, as this would precipitate the silver before you would notice it), and tested by dropping into the solution a drop or two of hydrochloric acid or solution of common table salt (sodium chloride). If any silver exists in the ore a milky cloudiness will appear, of a density greater or less in accordance with the amount of silver present. If no silver appears, then you may proceed as already directed. If silver does appear, then the solution containing the weighed ore must first be treated with the salt solution or diluted hydrochloric acid, until all cloudiness or white precipitate entirely ceases. The solution of ore now contains no silver, and you may proceed as directed.

This process is sufficiently accurate for all assays, provided the following precautions are observed :—

1. Heat the copper solution, after adding the ammonia, to boiling point or little below while adding the sodium sulphide. 2. Add a little ammonia to the ammoniacal solution to keep it from losing ammonia by evaporation. 3. When the blue ammoniacal solution begins to lose its color, drop the sodium sulphide in cautiously, so as not to exceed the amount necessary to exactly precipitate the copper and no more.

Note the precipitates: The sodium sulphide first produces its black precipitate of copper sulphide, but before that takes place the ammonia will produce another precipitate, provided the copper contains any lead or tin. If the copper contains zinc, that will be precipitated immediately following the black copper sulphide, but will be white. If it contains any cadmium, that will be precipitated at the very moment the decoloration takes place, if the adding of the sodium sulphide is continued. Cadmium is known by a beautiful clear yellow precipitate. With care and skill each may be noticed.

In simply determining the amount of copper, however, no regard need be had to any of these precipitates, only pay attention to the point of decoloration.

The sodium sulphide may need proving to see if it has lost any of its strength if kept for a long time, and this may be done by a trial with a new solution holding a known amount of copper. Or, exactly the same weight of crystals of sodium sulphide to the same amount of pure water may be used as before, and the old solution thrown away. Or, by retesting the sodium sulphide the same solution may be used for a long time, and if it has become weakened, make allowance for the additional sodium sulphide required. It should be kept in a cool place, out of the sun and light also.

CHAPTER IX.

LEAD AND TIN.

I. Lead. This mineral very rarely occurs native, and then only in small amounts. It has been found particularly in Sweden. Hardness, 1.5; specific gravity, 11.3 to 11.4. The most important ore of lead is the sulphide called

Galena. When chemically pure it contains 86.6 lead and 13.4 sulphur. Specific gravity, 7.2 to 7.5, according to admixtures. Color and streak, lead-gray. Luster, shining metallic; the exposed surface may be dull from tarnish, but the fracture is brilliant. Easily recognized by the characteristic cubical cleavage, which is very easily obtained, or by the granular structure when massive. Frequently associated with other metallic sulphides, such as pyrite, chalcopyrite, arsenopyrite, blende, etc. It occurs in veins, the gangue of which is either quartz, calcite, barite or fluospar, in granite and nearly all varieties of rock, but the larger deposits are usually found either in veins or in pockets, often of great size, in limestone strata. It is also frequently found in gold-bearing lodes.

Galena almost always contains silver and hence all galenas should be tested according to the process given on p. 161. It has been stated that galenas with small crystalline facets, like coarse lump sugar, are rich in silver, while those with large cleavages are poor; but this character at the best is only local, for some galenas with large cleavages yield as much as 1,500 ozs. of silver per ton, whilst other fine-grained ores contains only 50 ozs. per ton, or even less.

The order of strata in the galena district of Wisconsin, Illinois and Iowa is shown in the annexed table.

	NIAGARA LIMESTONE.
CAMBRO-SILURIAN	Galena limestone which bears lead.
	Trenton limestone, fossils.
	Sandstones, shales, and calcareous beds.
	Lower magnesian limestones.
	Lower limit of lead.
	WHITE POTSDAM SANDSTONE.
CAMBRIAN	Upper—
	Fossiliferous slates.
	Lower—
	Dolomitic limestones.
	Dark sandstones.

Order of Strata in the Lead District of Wisconsin, Illinois and Iowa.

The geology and form of lodes of the galena ores are seen in Fig. 52.

CARBONATE OF LEAD, WHITE LEAD ORE, OR CERUSSITE. If perfectly pure its composition is, lead 83.6, carbonic acid 16.4. Hardness 3 to 3.5; specific gravity 6.4 to 6.5. Color (if freshly broken), white to gray, or even black, if it has been much weathered. Streak, colorless. Luster, glassy or adamantine; when pure is translucent, or even transparent. Very brittle. If it contains copper it is usually tinged blue or green. It has a glassy or vitreous appearance, and is easily melted before the blow-pipe, and a lead bead or globule is readily obtained.

By using a little bone-ash plastered in a hollow in the charcoal and turning the *O. F.* upon the lead, after a little skilful blowing the lead is absorbed and drawn off and a bright silver globule remains, provided the lead contains silver. This is *blowpipe cupelling.*

FIG. 52.

Lead Lode in Micaceous Slate in Mine near Middletown, Conn.

Carbonate of lead occurs in compact, earthy or fibrous masses, and is often found near the surface of a galena lode. At Leadville, Colorado, carbonate of lead has been found which contains 20 to 60 per cent. lead and 600 to 20,000 grammes of silver in a ton, the silver being present as chloride of silver (Fig. 53).

Sulphate of Lead or Anglesite often accompanies the carbonate. It somewhat resembles the carbonate, although it is of slightly less hardness, 2.75 to 3; specific gravity 6.12 to 6.3. Often in rhombic crystals. Luster, adamantine or glassy. Streak, white, gray or black. Fracture, conchoidal.

Fig. 53.

Section of strata in California Gulch, Colorado, showing portion of the carbonate of lead deposits. *a.* Porphyritic rock, 12 to 100 ft. thick. *b.* Thin bed of white clay. *c.* Carbonate of lead bed, 1 to 20 ft. thick. *d.* Oxide of iron, 1 to 6 ft. thick. *e, e.* Limestone. *f.* Clay slates. *g.* Quartzites and metamorphic rocks resting upon gneiss.

It may be distinguished from the carbonate by the fact that it *does not effervesce in an acid*, as the latter always will. It is composed of lead oxide 73.6 and sulphuric acid 26.4 in the pure specimens.

Phosphate of Lead or Pyromorphite. Composition, when pure, 89.7 phosphate and 10.3 chromate of lead, with arsenate of lead (0 to 9), phosphate of lime (0.11), and fluoride of calcium. Hardness, 3.5 to 4. Specific gravity, 6.5 to 7. Color, greenish, sometimes bright grass-green, the hexagonal crystals having a greasy luster, also yellowish, brownish, and sometimes dull violet. Luster, resinous; generally translucent. Streak, white or yellowish. Contains 78 per cent. lead. Heated on charcoal before the blow-pipe a globule is formed which takes on a crystalline appearance on cooling, leaving a yellow oxide of lead on the charcoal. With carbonate of soda in the reducing flame it yields a yellow globule. It is soluble in nitric acid.

CROCOITE OR CHROMATE OF LEAD is a yellow mineral containing protoxide of lead 68.15, chromic acid 31.85. Hardness, 2.5 to 3; specific gravity, 5.9 to 6.1. Color, various shades of bright hyacinth-red. Streak (powder) orange yellow. Luster, vitreous. Translucent, and sectile. Decrepitates before the blow-pipe. With soda on charcoal it yields a lead coating; with borax an emerald-green bead.

MASSICOT OR LEAD OCHRE. This mineral occurs massive, as a compact earth of a sulphury-yellow or reddish-yellow appearance. Hardness 2, specific gravity 8 and, when pure, 9.2. It is composed of oxygen 7.17, lead 92.83. Before the blow-pipe it fuses readily to a yellow glass, and on charcoal is easily reducible to metallic lead.

LEAD-ANTIMONY ORES. There are several compounds of lead with antimony, but they are never sufficiently plentiful to be considered as ores. One of these, *jamesonite*, contains small proportions of iron, copper, zinc and bismuth. It occurs in gray fibrous masses or small prisms, and is found in Cornwall, England, associated with quartz and bournonite. Another of these compounds, *zinkenite*, resembles stibnite and bournonite, and occurs in an antimony mine in the Hartz.

THE GEOLOGY OF LEAD. Almost all the galenas and the carbonates contain silver, and some of the latter, as in Colorado, contain large quantities of silver. The geology of lead is very much the same as that of silver.

The ores are found in veins and lodes, and also in flats and beds, and in pockets (Fig. 54). The galenas occur in limestone, called the "galena limestones," a yellowish-gray, hard, compact crystalline rock. The lowest horizon of lead ore in workable quantities lies above that of copper.

"The limestones and underlying schists are, for the most part, in a metamorphic condition, and there can be no difficulty, from the presence of porphyry above and the quartzites and gneiss below, in recognizing their position," * as in the Cambro-silurian system. It is supposed that the largest proportion of silver is contained in the ore derived from this geologic horizon.

When water has had its course, however, the condition of a mine and of its veins and beds of ore may have been changed. Robert Hunt, as regards British mines, says that the circulation of

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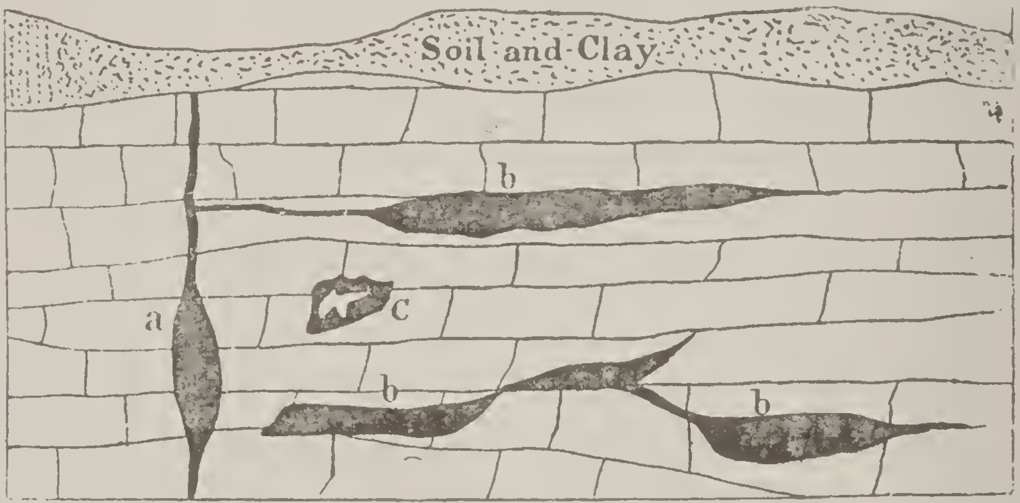
* B. C. Davies, F. G. S. A Treatise on Metalliferous Minerals, London, 1892, p. 259.

water in the veins is affected by the inclination of the strata in the direction of the vein. The richest deposits are found in that portion of strata which is the most elevated, for instance, on the side of a powerful cross vein, Fig. 55, thus:

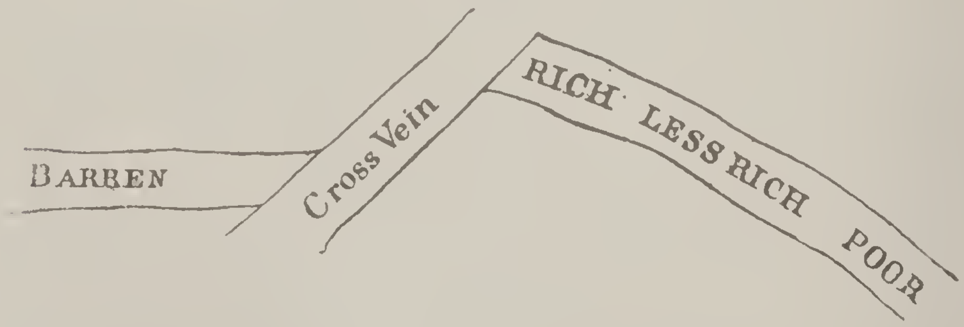
Fig. 54.



Section of Galena Limestone showing how the lead occurs in lodes, *a*, flats, *b*, *b*, *b*, and pockets, *c*, from mere threads to several feet in thickness.

The circulation of water is dependent upon an outlet at a lower level.

Fig. 55.



In the case of lead mines, it is stated that in consequence of the conditions connected with the descent of water, the richest deposits of lead are generally found at no great distance from the outcropping of the containing rock. Veins which run on the sides of a mountain in a direction nearly parallel with the valleys contain more extensive deposits of lead than those which cross the valleys at right angles.*

The prospector should keep this suggestion in mind.

The lead ores are found in the fissures where they seem to have been deposited by waters which have dissolved them out from neighboring beds (Fig 56).

In the United States the chief sources of lead in late years have been argentiferous ores and considerable from zinc ores, but a notable exception is S. E. Missouri, where galena accompanied by nickeliferous pyrite is disseminated through magnesian limestone of Cambrian age. The mines are at Bonne Terre, Mine la Motte and Doe Run. The strata lie almost horizontal, and are known to carry lead through over 300 feet in thickness.

II. TIN. When a tin-bearing mineral is heated before a blow-pipe with carbonate of soda or charcoal, white metallic tin is yielded. By dissolving this in hydrochloric acid and adding metallic zinc, the tin will be deposited in a spongy form. In the blow-pipe assay tin leaves behind a white deposit which cannot be driven off in either flame. If it be moistened with nitrate of cobalt solution, the deposit becomes bluish-green, and this test distinguishes it from other metals.

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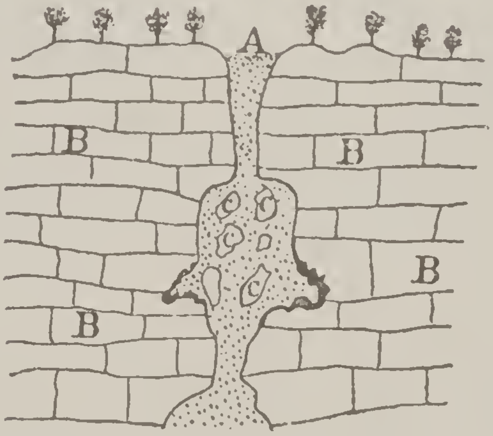
* British Mining, by Robert Hunt, London, 1884, p. 344.

Assay of tin ore. If the ore is poor it should be concentrated, the vein-stuff being got rid of as much as possible. If mixed with iron or copper pyrites, it should be calcined or else treated with acids. One method is to mix the ore with one-fifth of its weight of anthracite coal or charcoal, and expose it in a crucible to a great heat for about twenty minutes. The contents are then poured out into an iron mould, and the slag carefully examined for buttons.

FIG. 56.



SECTION OF A LEAD DEPOSIT IN A FISSURE OF THE LIMESTONE. Williams & Co.'s Mine, Wisconsin. *B, B, B, B*, limestone. *A*, the fissure running down, *C, C, C, C*, masses of ore. Metamorphic.

Another method is to mix 100 grains of the ore with six times its weight of cyanide of potassium, and expose the mixture to the heat of a good fire for twenty minutes. The contents are allowed to cool and afterwards broken to remove the slag.

CASSITERITE OR TIN STONE. This mineral forms the principal source of tin, and when pure contains 78.6 per cent. of metallic tin. It is remarkable for its hardness (6 to 7), and still more so for its specific gravity (6.8 to 7). It contains small quantities of iron, copper, manganese, tungsten, tantalic acid, arsenic, sometimes silica, and rarely lime. It is found associated with quartz, mica, topaz, tourmaline, wolfram, chlorite, iron, copper, and arsenical pyrites. It occurs massive and in crystals, also in botryoidal and reniform shapes, concentric in structure and radiated fibrous, and is then in the last form called *wood tin*, from its woody appearance. *Toad-eye* tin is the last described, but in very small shot-like grains. *Stream tin* is nothing but the ore in a state of sand as it occurs along the beds of the stream or the gravel of the adjoining region. It has been derived from tin veins or rocks.

Cassiterite yields a white, grayish, or brownish streak; has a brownish color and a dull luster. It is nearly as hard as quartz, and will scratch glass, especially if freshly broken. Pure crystals are rare. They are nearly transparent, but in the mass, as it occurs in the mines in Dakota and in many other places, the ore is of a dark brown color, and sometimes almost black; the fine powder or streak as made by a file, is light brown, however dark the mineral may be. The brown color or shade is due to oxide of iron in composition; if perfectly free from all associated impurities it would be nearly white or colorless. The usual appearance in mass or pebbles, or finer, is that of a dirty or burned-brown color with varying depths of shade.

In the pebble form it is apt to wear quite smooth, due to its extreme hardness.

It was in this form that it was discovered in Banca, in 1710, and in the neighboring island, Billiton, and traced to its source in the mountains, where the central rock is granite, covered by quartzites, altered sandstones, and slaty rock. The altered sandstone just above the granite is the most productive rock, and it is traversed in all directions with tourmaline.* The same general associations largely exist in Wyoming and Dakota tin mines.

There is another mineral containing tin which may lead to the discovery of the true ore. It requires only a short description, which is given below:

Tin pyrite (*sulphide of tin*), whose composition is, as a mineral, 29 to 30 sulphur, 25 to 31 tin, 29 to 30 copper, with iron and sometimes zinc. It has been dug as an ore of copper and called "*bell-metal.*" Its hardness is 4; specific gravity 4.3 to 4.5; has a metallic luster; color, steel-gray to black, often yellowish from the presence of copper sulphide; it is opaque and brittle.

With nitric acid it affords a blue solution, and sulphur and tin oxide separate and may be tested on charcoal, where it fuses to a globule, which, in the oxidizing flame, gives off sulphur and coats the coal with white oxide of tin.

This ore or mineral, for it does not as yet deserve the name of tin ore, is of little use, but the prospector does well to make himself acquainted with it, as it is frequently associated with the binoxide or

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* D. C. Davies, F. G. S., Metalliferous Minerals, London, 1892, p. 194.

cassiterite, or black oxide, as the true ore is frequently called.

In the United States, cassiterite occurs in small stringers and veins on the borders of granite knobs or bosses, either in the granite itself or in the adjacent rocks, in such relations that it is doubtless the result of fumarole action consequent on the intrusion of the granite. It appears that the tin oxide has probably been formed from the fluoride. The Cajalco mine in California and the Harvey Peak mines, South Dakota, have been developed, but it is questionable whether they are worked at a profit. Undeveloped deposits are reported in Alabama, North Carolina and Virginia. At Broad Arrow, near Ashland, Alabama, tin-ore is disseminated in gneiss, the ore averaging about 1½ per cent. black tin, but being very much mixed with titaniferous iron. At King's Mountain, North Carolina, cassiterite occurs very irregularly in a "greisen" or altered granite, and in limited alluvials derived from the disintegration of the same. On Irish Creek, Virginia, experimental parcels of vein-stone taken from deposits in granite have shown 3¼ to 3½ per cent. metallic tin, largely associated with arsenical pyrites and ilmenite, which increase the difficulties of concentration and lower the value of the product.

On the Seward Peninsula, Alaska, stream tin (cassiterite) has been found on Buhner Creek and on the Anikovik River, by the miners in the sluice-boxes. On Buhner Creek 2 to 3 feet of gravel overlies the bed rock, which consists of arinaceous schists, often graphitic, together with some graphitic slates. The bed rock is much jointed, the schists being broken up into pencil-shaped fragments. They strike nearly at right angles to the course of the stream and offer natural riffles for the concentration of heavier material. The slates and schists are everywhere penetrated by small veins, consisting usually of quartz with some calcite, and frequently carrying pyrite and sometimes gold. These veins are very irregular, often widening out to form blebs, and again contracting so as not to be easily traceable. The cassiterite occurs in grains and pebbles, from those microscopic in size to those half an inch in diameter, and varies in color from a light brown to a lustrous black. The production of tin in Alaska in 1907 to 1908 amounted to $20,000.

Deposits of tin occur at El Paso, Texas. The ores consist of cassiterite, with wolframite (tungstate of iron and manganese) in a gangue of quartz. Specimens of nearly pure cassiterite weighing several pounds have been found on the surface, and this mineral occurs in the quartz, either alone or associated with wolframite. The most abundant ore is a granular mixture of tin ore with quartz which resembles a coarse granite and corresponds to the greisen ore of European deposits. These ores occur in well-defined veins, which run up the slopes nearly at right angles to the direction of the range. These veins exhibit the usual characteristics of the European tin veins, their clearly defined fissures showing a central core of lead of coarse quartz, sometimes containing tin ore, and flanked on either side by altered rock in which the tin ore replaces the feldspar of the granite.

Cassiterite stands nearly by itself in its mode of occurrence and formation, as a type of a strongly marked class of deposits. It is always associated with granitic rocks, quartz-porphyries, or gneiss, all of which are of analogous composition, being rich in silica, which crystallizes as quartz, and being called in consequence "acidic" rocks. Tin lodes are nearly all of great antiquity and occur only in those of the above-named rocks which are characterized by the presence of white mica. It is only in two or three places in the world, notably Tuscany and Elba, that granites of this type have been erupted during recent times, and they contain tin in small quantity as well as some of the minerals usually associated with it, such as tourmaline, lithia, mica, and emerald.

Although this fact is of no immediate practical value, it is important, because it shows that there really are laws which govern the distribution of minerals, although these are sometimes very obscure; but by constant observation it is certain that, amongst discoveries of merely scientific interest, laws capable of practical application will occasionally be found.

Cassiterite is always associated with quartz and rarely occurs in green rocks, unless their color be due to chlorite; nor in dark-colored rocks, except where stained red by the decomposition of ferruginous minerals; neither is it found in limestone.

Those granites which are characterized by abundance of white mica have, with good reason, been termed "tin granites," and a coarse-grained rock composed of granular quartz mixed with white mica and called "greisen" occurs in all the tin fields of the world.

The minerals most commonly associated with tin, namely topaz, mica, tourmaline, fluorspar, apatite and other rarer minerals containing fluorine, seem to show that it was originally contained in the granite as fluoride of tin, and that the associated minerals have been formed at its expense. It is an established fact in the genesis of minerals that fluorine is always accompanied by silicon and boron. It is therefore natural to find silicates containing boric acid, such as tourmaline and axinite, in association with tin. Other minerals which frequently accompany this metal are wolfram, molybdenite, mispickel, garnet, beryl, etc.

It is evident that a most important aid to the prospector is a study of the characteristics of the tinstone ores, and he may find it beneficial to become acquainted with the special minerals above mentioned as associated with the ores.

These minerals include, in some mines, *wolframite*, which gives trouble in the Cornwall and other tin mines, and the following description and tests may aid in detecting it:

Wolframite is in hardness 5 to 5.5, specific gravity 7.1 to 7.55, therefore, in these features it resembles the tin oxide; though somewhat softer, yet the specific gravity is practically the same, although really heavier. So in color it frequently closely resembles tin oxide. But in the streak (or scratch powder), wolframite is a *dark reddish-brown* to black, while the tin oxide gives a white or grayish-brown powder; wolframite is opaque, while the tin oxide is translucent and sometimes transparent *on the edges;* when mixed with iron or manganese *rarely*, it looks almost opaque. Composition of wolframite: Tungstic acid about 75, the remainder protoxide of iron and manganese protoxide, more of the latter than of the former.

Wolframite is used in the preparation of some colors and enamels, and enters into the composition of some special kind of steel. Tungstate of soda, which is used as a mordant and for fire-proofing fabrics, is also prepared from it.

CHAPTER X.

ZINC, IRON, MOLYBDENUM, TITANIUM, URANIUM, VANADIUM.

I. Zinc. Zinc is never found free in nature, but chiefly occurs in combination with carbonic acid and united with sulphur. The chief ores are:

Smithsonite or Zinc Carbonate. Composition, zinc 51.44, oxygen 13.10, carbonic acid 35.46. But the composition in the mines varies because of the presence of protoxide of iron, manganese and magnesia. Color, when pure, nearly white, through various shades of yellow and gray to brown. Hardness 5, specific gravity 4 to 4.4. Streak, uncolored or white. Luster, vitreous, pearly, subtransparent to translucent. Found in veins, but more usually in irregular deposits in limestone strata.

It is easily detected by the blow-pipe, as it gives a green color when heated after being moistened with half a drop of nitrate of cobalt solution. On charcoal, with soda, it coats the charcoal with a white film, which is yellow when hot and white on cooling, but if moistened with the cobalt solution and heated in the *O F* turns green. With muriatic acid it effervesces and dissolves. In mass it is translucent and brittle.

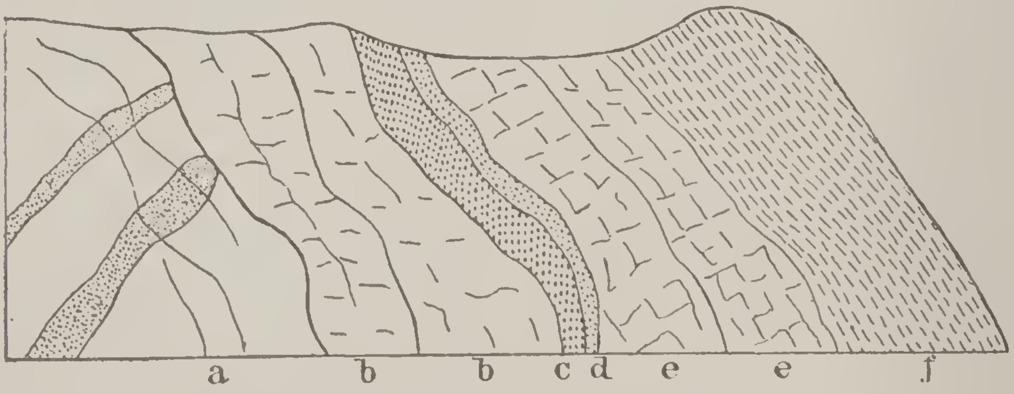
CALAMINE. This is a silicate of zinc. Composition, zinc oxide 67.5, silica 25, water 7.5. Hardness 4.5 to 5, the latter when crystallized (Dana); specific gravity 3.16 to 3.9. Color when pure, pearly white, but owing to the presence of iron oxide, etc., generally brownish, sometimes green. Streak, whitish. Luster, pearly or glassy. Acts before the blow-pipe like Smithsonite, but *does not effervesce with acids*, and gelatinizes; it is soluble in a strong solution of potash. In physical characters zinc silicate somewhat resembles zinc carbonate. An anhydrous variety of this ore is *Willemite*, which is found in New Jersey (Mine Hill and Sterling Hill). Zinc silicate is usually found in veins or in beds or in irregular pockets in stratified calcareous rocks, in association with zinc blende, zinc carbonate, iron, lead ores, etc.

ZINCITE OR RED OXIDE OF ZINC. Its composition is zinc 80, oxygen 20, varied by the presence of 3 to 12 parts of peroxide of manganese, which gives the red color, for zinc oxide, pure, is white. Hardness 4 to 4.5; specific gravity 5.4 to 5.7; color, red and yellowish-red, streak the same; luster, brilliant; translucent, brittle. Occurs in grains or masses. Is found chiefly in Sussex Co., New Jersey.

SULPHIDE OF ZINC, SPHALERITE OR ZINC BLENDE. Miners' names, *black jack, false lead, false galena.* Composition, zinc 66.8, sulphur 33.2, but varied in the mines by iron, and sometimes cadmium. Color varies from yellow to brown and almost black, having a waxy look. Streak, white to reddish-brown.

Luster, waxy. Hardness 3.5 to 4; specific gravity 3.9 to 4.2; brittle, translucent. Zinc blende is the most abundant zinc ore. It occurs in rocks of all ages, in veins, in contact deposits or in irregular pockets in limestone, etc., and is frequently associated with the ores of lead, as well as those of copper, iron, silver, gold and tin; also, frequently associated with quartz, barite, fluorite, calcite, etc. It is easily recognized if treated with hot hydrochloric acid, as it gives a smell of rotten eggs (sulphuretted hydrogen), and the same results can be obtained without heating if a small quantity of pure iron filings is added to the acid. With soda on charcoal before the blow-pipe, zinc blende gives a sulphuret which, with water on a silver coin, tarnishes or blackens it.

FIG. 57.



SECTION OF STRATA NEAR SPARTA, NEW JERSEY, ZINC MINES.

a, Slaty rock with feldspathic dykes. *b*, *b*, Limestone. *c*, Franklinite iron ore with zinc, 20 to 30 ft. wide. *d*, Red oxide of zinc, 3 to 9 ft. wide. *e*, *e*, Crystalline limestone. *f*, Feldspathic rock.

The GEOLOGY OF ZINC and that of lead are so nearly alike that what has been said of the latter will apply to the former (Fig. 57).

In New Jersey a section of strata near Sparta, Sussex Co., shows slaty rock with feldspathic dykes, then limestone adjoining the Franklinite iron ore with zinc 20 to 30 feet wide, then the red oxide of zinc 3 to 9 feet wide, then crystalline limestone, and next feldspathic rock (Fig. 57).

Enormous and extensive deposits of the sulphide are reported as occurring in Colorado, at Georgetown and Mount Lincoln, and in Montana, near Jefferson City.

The blow-pipe shows the same tests for zinc as have previously been mentioned. The fumes of sulphurous acid may be easily noticed when the mineral is placed in an open tube of glass (a test-tube with a small hole in the bottom will be sufficient), and is strongly heated.

II. Iron. This metal is one of the most abundant and widely distributed elements of the earth's crust, its distribution being materially aided by the fact of its forming two oxides of different chemical quantivalence. Native iron, or iron in the metallic state, is very rarely found in nature, it occurring almost entirely in meteoric iron.

Native or Meteoric Iron. Occurs in small grains in the platinum-carrying sand of Siberia and in larger coherent masses in rocks in Canada. However, of greater interest is the occurrence of native iron in *meteorites* which occasionally fall to the earth. As a rule they do not exceed a few pounds in weight, and only a few weighing more than 220 lbs. have thus far been discovered. In 1870, large masses weighing from 10,000 to 50,000 lbs. were discovered imbedded in basalt at Disko, Greenland. Several meteoric masses containing small black diamonds have been found in Arizona. Meteorites are distinguished by the fact that they contain nickel and traces of cobalt, copper and other metals. In fact, the presence of nickel is the criterion for the genuineness of a meteorite. Actual meteoric iron in which the presence of nickel could not be established has thus far been found only at Scriba and in Walker County, Alabama. In specimens of meteorites examined, the iron ranges from 67 to 94 per cent. and the nickel from 6 to 24. Below some analyses of meteoric iron found in this country are given :

	From Hominy Creek, North Carolina.	From Burlington, New York.	From Babb's Mill, Tennessee.	From Claiborne, Alabama.
Iron	93.225	89.752	80.594	88.04
Nickel	0.236	8.897	17.104	10.73
Cobalt		0.625	2.037	0.46
Manganese	—	—	—	0.13
Copper	—	—	—	—
Tin	0.099	—	—	0.07
Sulphur	0.543	—	—	—
Phosphor-nickel-iron	—	0.703	0.124	—
Silicon	0.501	—	—	—
Carbon	4.765	—	—	—

Meteorites may be distinguished from metallic iron of other origin by peculiar markings which are produced when the surface is polished and treated with nitric acid. These markings are due to combinations of iron with nickel, and partly also with phosphorus, which are not decomposed, or only with difficulty by acids, and are imbedded in a crystalline state in the remaining mass of iron, the latter being quickly dissolved by the acid, while the former are not attacked for a long time.

The most important ores of iron are:

MAGNETITE OR MAGNETIC IRON ORE is found in octahedral or decahedral crystals; more commonly simply massive. Streak, black; color, black. Composition, iron 72.4, oxygen 27.6. Hardness, 5.5 to 6.5; specific gravity, 5 to 5.1. The ore is always easily attracted by the magnet, and sometimes is found capable of attracting iron, and is then called *polaric* or *loadstone.* In powder or small grains it is always attractable by a magnetized knifeblade.

The usual geological position of magnetite is in the most highly metamorphic rocks, in which it probably represents the excess of iron oxide originally in the rock which was not taken up by silica. Occasionally it is found in layers, but in this country and elsewhere it forms whole mountains. Among other rocks in which it occurs the following are the most important: Crystalline limestone, chloritic, talcose, hornblendic, pyroxenic and hypersthenic schists; serpentine, diorite and basalt. Specular iron is frequently associated with it.

Magnetite is not acted upon by nitric acid, but hydrochloric acid dissolves it when in very fine powder and under long-continued heat.

Iron exists in magnetite as protoxide and peroxide, or FeO and Fe_2O_3, and upon this difference of oxides is based the action of important tests.

FRANKLINITE is an ore somewhat resembling magnetite in color, hardness, and specific gravity, but it contains manganese and zinc, and as an ore, is peculiar to Sussex Co., New Jersey. Color, dark black. Streak, dark brown. Its action on the magnet is feebler than in the case of magnetite. The iron is said to be of the composition of peroxide, or Fe_2O_3, but it is probably in part protoxide, and this is the cause of its feeble effect on the magnet.

It is easily affected under the blow-pipe. Alone, it is infusible, but with borax in the *O F* it colors the borax bead with the amethystine color of manganese, and in the *R F* it shows the bottle-green of iron. On charcoal with soda it gives the bluish-white manganate, and also the coating of zinc, especially if the soda is mixed with borax. In fine powder soluble in hydrochloric acid.

SPECULAR ORE is the peroxide of iron without the protoxide. This oxide is also called the sesquioxide, or one and a half oxide, since iron combines with oxygen in the proportion of one to one and a half parts, or Fe_2O_3, and this is the highest proportion of oxygen the iron will combine with, and hence it is the peroxide, the peroxide and sesquioxide being the same in this case.

Specular ore is called RED HEMATITE from its color, which in some masses is so intensely red as to appear nearly black, but it may always be distinguished from magnetite by its red streak, and the blacker the ore the more decided is the red of its powder or streak. It is never magnetic. It has been found that in cases where specular ore showed any magnetic attraction, it was due to the fact that the ore contained some protoxide of iron.

Hardness 5.5; specific gravity 4.5 to 5.3; composition 70 per cent. iron, 30 per cent. oxygen. Color, reddish to almost black. Streak, red. Luster, metallic, but dull and earthy in some varieties.

BROWN IRON ORE OR BROWN HEMATITE OR LIMONITE. This is the same composition as red hematite, except that it has less iron and contains water in chemical combination, generally about 14 per cent. Color, brown, yellow and coffee color. Streak, yellowish. Luster, dull or submetallic. Hardness 5 to 5.5; specific gravity 3.6 to 4. When heated red-hot it loses its water and turns to a bright red, unless largely mixed with alumina and silex, when the red color is shaded. It is not magnetic unless heated with soda under the blow-pipe, when it becomes metallic, as all iron ores do.

The amount of metallic iron in a pure specimen is 59 per cent., sometimes decreased by the presence of alumina, silica, magnesia, and other impurities, so that its average in many good mines is only about 35 to 36 per cent. iron.

SPATHIC IRON ORE OR SIDERITE is an iron carbonate, composed of iron protoxide 62 per cent. and carbonic acid, or 48 per cent. pure iron. Sometimes massive, with a crystalline structure. Hardness, 3.5 to 4.5; gravity, 3.7 to 3.9; streak, white. Color gray or cream color, unless weathered, when it is brownish. Luster glassy or pearly.

When in powder it effervesces with muriatic acid, especially when hot. Translucent on edges, and thin plates or splinters.

With the blow-pipe in a closed tube (test-tube) it decrepitates, becomes blakened, and gives off carbonic acid. Before the blow-pipe alone, held by forceps, it blackens and fuses. In the test-tube with muriatic acid it may be tested for carbonic acid, by letting a lighted thread down into the tube, when the flame is instantly extinguished. The solution in the tube may be tested for iron by dropping a drop of solution of ferricyanide of potassium into the muriatic acid solution, when it becomes instantly a deep blue. This is a test of protoxide of iron, spathic ore being iron in the condition of protoxide only.

BLACK BAND ORE is an argillaceous spathic ore of various dark colors, being largely combined with carbonaceous material. It is found extensively in Great Britain, near the summit of the coal measures. In our country the black band ores are also associated with the coal measures, both in the anthracite and bituminous regions.

CHROMIC IRON OR CHROMITE, generally with 49.90 to 60.04 per cent. of chromic oxide, 18.42 to 35.68 per cent. of ferrous oxide, 10 to 12 per cent. alumina, 5.36 to 15 per cent. magnesia, and 4 to 6 per cent.

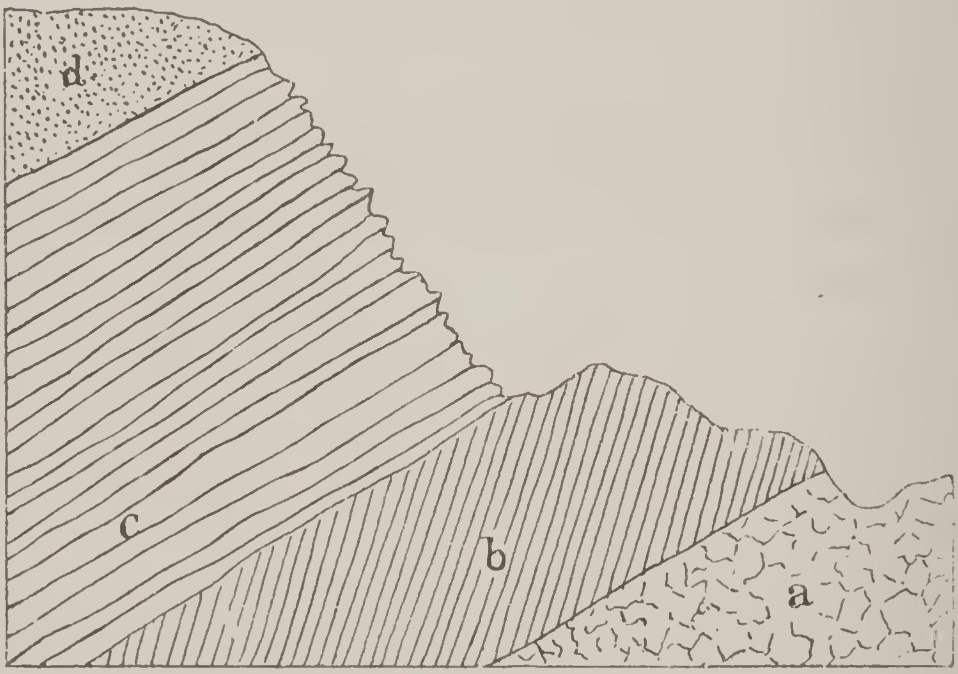
silica, occurs usually massive, mixed with other iron ores or in serpentine. Color, black to brownish-black. Luster faintly metallic. Streak or powder, dark-brown. Fracture, irregular; specific gravity, 4.4 to 4.6; hardness, 5.5, is not scratched by a knife. With borax bead it gives the characteristic indications of chromium. It is largely used in the preparation of chromium colors.

The following iron ores are not used for the making of iron and steel, but may nevertheless prove of value.

Iron Pyrites, usually in cubes and allied forms, sides often marked by fine parallel lines. Occurs also massive and contains 46.7 per cent. of iron and 53.3 per cent. of sulphur. Color, brass yellow; luster, metallic; streak, brownish-black; fracture irregular; specific gravity. 4.8 to 5.1; hardness, 6 to 6.5; cannot be scratched with a knife, but is scratched by quartz, and scratches glass with great facility. Before the blow-pipe it burns with a blue flame, giving off an odor of sulphur, and ultimately fuses into a black magnetic globule. It is found in great abundance, and is used as a source of sulphur. It is easily distinguished from copper pyrites by its hardness, the latter being readily cut with a knife. From gold it is distinguished by its hardness and in not being malleable, and in giving off sulphurous odors in the blow-pipe flame.

Arsenical Pyrites or mispickel contains 34.4 per cent. of iron, 19.6 per cent. of arsenic, and 46.0 per cent of sulphur. It occurs in flattened prisms and also massive. Color, white; luster, metallic; streak, gray; fracture, uneven; specific gravity, 6.0 to 6.3; hardness, 5.5; cannot be scratched with a knife, but is scratched by quartz. Heated before the blow-pipe, it gives off white arsenical fumes of a garlic odor, and finally fuses into a black globule. It is abundant in mining districts, and sometimes is auriferous. With the improved processes now in use, it is possible to extract the gold profitably, and hence mispickel ores should be examined for gold.

Fig. 58.



Geologial Horizons around the Iron Ores of Lake Superior.

a. Gneiss. *b.* Hornblende slates. *c.* The same with numerous thin beds of iron ore which frequently unite. *d.* Potsdam sandstone.

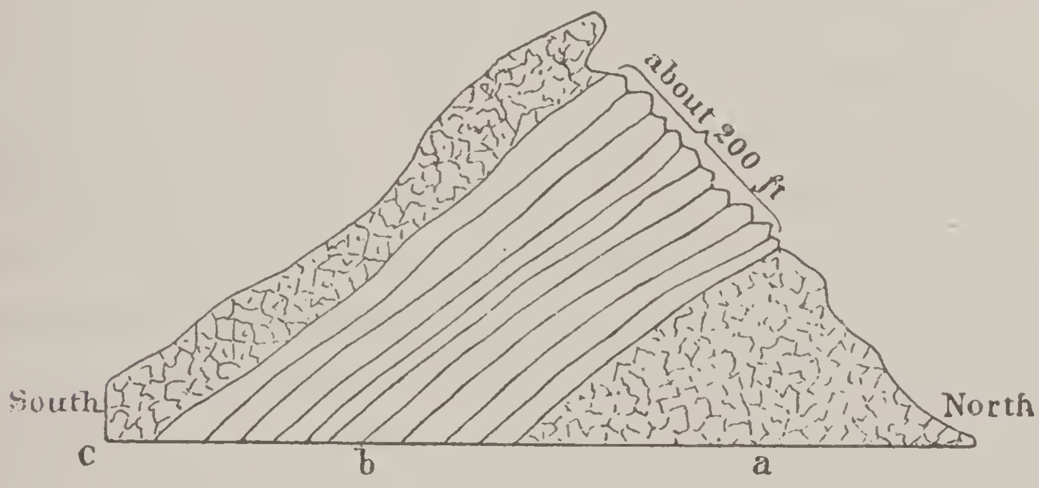
The Geology of the iron ores varies, and may be divided into that of the magnetites, which are always derived from the granite, gneiss, schist rocks, clay slates, and, rarely, the metamorphic limestones.

The red hematites seem to be only an alteration derived from the magnetites, and belong to the same more ancient rocks as the latter.

The brown hematites (limonites) are derived from both the former, and are generally sedimentary.

Very frequently in extensive magnetic regions, where the country back is mountainous, the brown ore has been formed in basins and knees and interlocked portions of the lower country, where ages of rains, storms and freshets have gradually transported and altered the magnetic ores of the upper regions and brought down these iron oxides to the low lands, where they have been arrested and settled down in beds of brown hematite. This seems to have been the history of all the hematitic limonite beds and deposits; they are on the lower levels when they were formed, although in after ages they may have been uplifted.

Fig. 59.



SECTION OF PILOT KNOB, MISSOURI.

a. Quartzite or siliceous rock. *b*. Red hematite iron ore alternating with siliceous matter. *c*. Siliceous rocks.

Iron ores are, therefore, to be found in three general geologic regions: (1) in the earliest rocks; (2) in the carboniferous, and (3) in the more recent or sedimentary rocks, and in accordance with their composition as magnetites and specular ores, as carbonacous or black band and spathic ores, or as brown ores of the limonite order.

One of the most peculiar geologic condition is found in the Pilot Knob Mountain, wherein the iron strata have been thrown up as in Fig. 59.

THE USE OF THE MAGNETIC NEEDLE IN PROSPECTING FOR IRON.

In ordinary cases, where the surface is covered with loose earth, it is common to search for magnetic iron ore with a magnetic needle or a miner's compass, and for preliminary examinations it is now the chief reliance. In using this instrument considerable practice is required; but this joined to good judgment gives indications of the presence of ore which are almost infallible. There has been very great improvement, within a few years past, in the methods of searching for magnetic ore as well as in the instruments to be used for that purpose, and the work is now well done by many persons.

In the Annual Report of the State Geologist of New Jersey for 1879, W. H. Scranton, M. E., makes a report, accompanied by a map, upon a magnetic survey made at Oxford, Warren Co., New Jersey, to determine the location of a vein, and the proper places to sink shafts. Mr. Scranton finds Gurley's

Norwegian compass the best, though the slowest to work with. He sums up the indications from the magnetic needle in searching for ore, as it usually occurs in New Jersey, as follows:

" An attraction which is confined to a very small spot and is lost in passing a few feet from it, is most likely to be caused by a boulder of ore or particles of magnetite in the rock.

"An attraction which continues on steadily in the direction of the strike of the rock for a distance of many feet or rods, indicates a vein of ore; and if it is positive and strongest towards the southwest, it is reasonable to conclude that the vein begins with the attraction there. If the attraction diminishes in going northeast, and finally dies out without becoming negative, it indicates that the vein has continued on without break or ending until too far off to move the compass needle. If, on passing towards the northeast, along the line of attraction, the south pole is drawn down, it indicates the end of the vein or an offset. If, on continuing further still in the same direction, positive attraction is found, it shows that the vein is not ended; but if no attraction is shown, there is no indication as to the further continuance of the ore.

" In crossing veins of ore from southeast to northwest, when the dip of the rock and ore is as usual to the southeast, positive attraction is first observed to come on gradually, as the ore is nearer and nearer to the surface, and the northwest edge of the vein is indicated by the needle suddenly showing negative attraction just at the point of passing off it. This change of attraction will be less marked as the depth of the vein is greater, or as the strike is nearer north and south. The steadiness and continuance of the attraction is a much better indication of ore than the strength or amount of attraction is. The ore may vary in its susceptibility to the magnetic influence from impurities in its substance ; it does vary according to the position in which it lies—that is, according to its dip and strike ; and it also varies very much according to its distance beneath the surface.

" *Method of Using the Compass in Searching for Ore.* —It is sufficient to say that the first examinations are made by passing over the ground with the compass in a northwest and southeast direction, at intervals of a few rods, until indications of ore are found. Then the ground should be examined more carefully by crossing the line of attraction at intervals of a few feet, and marking the points upon which observations have been made, and recording the amount of attraction. Observations with the ordinary compass should be made and the variation of the horizontal needle be noted. In this way material may soon be accumulated for staking out the line of attraction, or for constructing a map for study and reference.

" After sufficient exploration with the magnetic needle, it still remains to prove the value of the vein by uncovering the ore, examining its quality, measuring the size of the vein, and estimating the cost of mining and marketing it. Uncovering should first be done in trenches dug across the line of attraction, and carried quite down to the rock. When the ore is in this way proved to be of value, regular mining operations may begin.

"In places where there are offsets in the ore, or where it has been subject to bends, folds, or other irregularities, so that the miner is at fault in what direction to proceed, explorations may be made with the diamond drill."

MOLYBDENUM. The sulphide occurs native as MOLYBDENITE in crystallolaminar masses or tabular crystals, having a strong metallic luster and lead-gray color, and forming a greenish-black streak which is best seen by drawing a piece across a china plate. Specific gravity, 4.5 to 4.6; hardness, 1 to 1.5; easily scratched by the nail. It contains 58.9 of molybdenum and 51.1 per cent. of sulphur. It occurs sparingly in granite, syenite and chlorite schists, and is sometimes mistaken for graphite, from which it is, however, readily distinguished by the streak, that of graphite being black. Before the blow-pipe it is infusible, but tinges the flame faint green. Heated on charcoal for a long time it gives off a faint sulphurous odor and becomes encrusted white. Its chief use is in the preparation of a blue color.

IV. TITANIUM occurs in nature in the form of titanic oxide. The most important minerals containing titanium are:

Rutile. This mineral resembles cassiterite, but has a lower specific gravity, is red by transmitted light, and crystals are more prismatic. It occurs in striated prisms, many times twinned; in eight-sided prisms with flat pyramidal termination, rarely compact massive. Hardness, 6 to 6.5. Specific gravity, 4.2 to 4.3. Color, reddish brown to black, by transmitted light deep red. Streak, yellowish brown. Luster, adamantine. Occurs in granite, gneiss, syenite, mica schist, and granular lime-stone. It generally contains enough iron to give a reaction in the borax bead. With salt of phosphorus in *R. F.* the strongly saturated bead is purplish violet. It is used for preparing some enamels and when pure for coloring artificial teeth.

Octahedrite, occurs in elongated octahedrons sometimes so splendent as to be mistaken for diamonds. Black or brown, yellow, sometimes fine blue. Reactions same as for rutile.

Brookite. Brown to black, crystals often tabular, generally distinctly orthorhombic, always readily distinguished from tetragonal. Reactions same as for rutile.

The mode of occurrence of the last two minerals is frequently the same as rutile, and they, like rutile, frequently accompany gold. Their luster is adamantine, and they are likely to attract the eye when found in alluvial deposits, in which they are frequently associated with the diamond.

V. URANIUM. Uranium ores are comparatively rare. They occur generally associated with other minerals, especially silver and tin ores, in veins in the older rocks—granite, mica schist, clay slate, porphyry. The most important mineral containing uranium is *pitch-blende* or *uraninite.* It does not occur pure but always mixed with other ores—silver, tin and zinc ores, galena, pyrites, cobalt, nickel and bismuth ores, etc. Color, pitchy black to grayish black. Streak, brownish black. Hardness, 5.5. Specific gravity, 9 to 9.7. Luster, pitch-like to dull. Crystals are rare, generally massive, compact, with a conchoidal to uneven fracture.

Hydrochloric acid does not attack pitch-blende, but decomposes carbonates and silicates which may be present, as well as metallic sulphides, sulphuretted hydrogen being evolved. In a pure state pitch-blende is soluble in nitric acid, the color of the solution being yellow. It dissolves with difficulty in concentrated sulphuric acid, the solution being green. The solution in nitric acid gives with ammonia a sulphur-yellow precipitate. When boiled with phosphoric acid an emerald-green solution results.

The pure ore is next to infusible, colors borax yellow in the *O. F.*, green in the *R. F.*, while microcosmic salt gives a green color in both flames.

It may here be noticed that the element *radium* having great radio-activity and closely resembling barium in character has been detected in pitch blende.

The chief use of pitch-blende is for the preparation of an orange color for painting porcelain and coloring glass to which it imparts a greenish yellow, foggy or opaline appearance.

VI. VANADIUM is quite widely distributed in nature, but is not found anywhere in large masses. The principal minerals are

Vanadinite. In hexagonal prisms, with basal pinacoid, also in reniform aggregates of fine columnar to fibrous texture. Color red to brownish red. Streak white. Luster, adamantine, on fracture resinous. Hardness, 2.5 to 3. Specific gravity, 6.6 to 7.23. Dissolves readily in nitric acid. Decrepitates strongly before the blowpipe, gives in the tube a slight white coating, fuses on charcoal to a globule which separates lead and give a lead coating and produces in *O. F.* of the borax globule a glass, red yellow when warm, yellow green when cold, and in the *R. F.* a beautiful green glass. The ore occurs in lustrous red and yellow hexagonal crystals in Arizona; in green crystals with calcite at Charcas, Mexico, and in Chile.

Descloizite. Pyramidal, resembling octahedrons, drusy. Color, olive green to black. Luster, adamantine to resinous. Hardness, 3.5. Specific gravity, 5.839. Gives water in a closed tube. The coating on charcoal reacts for zinc with cobalt nitrate. It occurs with lead and silver ores.

Dechenite. Color red, reddish yellow. Streak yellowish to orange. Transparent on fracture and edges. Occurs in Leadville lead ores.

Volborthite. Hexagonal. Color, olive green, grass green, and yellow. Hardness, 3 to 3.5. Specific gravity, 3.45 to 3.55. Streak yellow. Gives water in a closed tube and becomes black. On charcoal a black slag is formed.

While vanadium was formerly considered only of scientific interest, it has during the past few years sprung into the position of a metal which has practically marked an epoch in the history of the steel trade, its alloys with iron known as vanadium steel forming a highly valuable material in the construction of automobiles, locomotives, etc.

CHAPTER XI.

MERCURY, BISMUTH, NICKEL, COBALT, AND CADMIUM.

I. Mercury or Quicksilver. At ordinary temperatures it is fluid, a character which no other metal possesses. The usual properties of a metal are, however, highly developed in it, and when solid it has much resemblance to silver, especially in its high metallic luster, ductility, malleability, its capability of being cut with a knife, its granular fracture, and its high degree of conductibility of heat and electricity.

Mercury readily combines with most of the other metals, and the compounds thus formed are called *amalgams*. The amalgams with the heavy elements are generally easy of decomposition, and hence it is exceedingly useful for the extraction of gold and silver from their ores or matrices. The mercury picks up the almost invisible specks of gold, and in this way the gold is concentrated into a comparatively small space. By heating the amalgam the mercury is driven off and the gold is separated in nearly pure form.

Native Mercury. Occurs occasionally as globules disseminated through the rocks. Color, bright white. Specific gravity, 13.6 at 50° F., and about

15.6 when solid. It contains sometimes a little silver, but generally occurs associated with cinnabar, the proportion of the latter being, however, very inconsiderable. In more recent formations it occurs generally, without cinnabar, in porous rock, sometimes associated with small quantities of chloride and iodide of mercury. In California such rock is subjected to distillation, if warranted by the price of mercury.

With a higher percentage of silver or gold, mercury is changed to

NATIVE AMALGAMS. As in all alloys the proportions of the constituents vary, and the properties of a specimen will vary according as the silver, the gold, or the mercury predominates. The native amalgam most frequently found is a mixture of silver and mercury, and when pure contains from 64 to 72 per cent. mercury. Color, silver-white; hardness, 3 to 3.5; specific gravity, 10.5 to 14. Soluble in nitric acid. On charcoal before the blow-pipe, the mercury evaporates, and the silver remains.

Amalgams of gold and mercury have been found in Utah.

SELENIDE OF MERCURY with 72 per cent. of mercury occurs at Marysvale, Utah, and in Mexico. It is of steel or lead-gray color and metallic luster.

CINNABAR OR SULPHIDE OF MERCURY. The chief supply of commercial mercury is obtained from this ore. It is found in granular, fibrous, dense and earthy masses, and sometimes also in small rhombohedral or prismatic crystals. Specific gravity, 6.7 to 8.2. Hardness, 2 to 2.5. Streak, scarlet-red. Fracture, uneven, splintery. Luster, adamantine. Color, generally cochineal-red, also brown, brownish-black, etc. Contains, mercury 86.2, sulphur 13.8, when pure. Before the blow-pipe in the closed tube it yields a black sublimate of the same composition as the original mineral. In the open tube, if carefully heated, it yields sulphurous acid and mercury globules, together with a small quantity of black sublimate. On charcoal it volatilizes completely. Insoluble in sulphuric acid, hydrochloric acid and potash lye; soluble in aqua regia, sulphur being separated.

There is also a black sulphide, called *metacinnabarite*, found in one locality in California; and, in California and Mexico, a sulphoselenide named *guadalcazarite* (81½ per cent. mercury, 10 sulphur, 6½ selenium) is sometimes encountered.

The quicksilver deposits at Almaden, in Spain, have a far remote history, for in the time of Pliny 10,000 lbs. were sent annually to Rome from these mines. They occur in upper silurian slates, sometimes interstratified with beds of limestone; but the ordinary slates themselves, which are much contorted, rarely contain cinnabar. The enclosing rock usually consists of black carbonaceous slates and quartzites alternating with schists and fine-grained sandstones.

At Idria, Austria, cinnabar is found in impregnated beds and stockworks, in bituminous shales, dolomitic sandstones and limestone breccias of triassic age, dipping 30° to 40°, and covered by carboniferous sandstones and shales in a reversed position. This deposit has been worked for nearly 400 years, and is said to become richer as the depth increases.

The quicksilver-bearing belt of California extends along the coast range for a distance of about 200 miles. According to a report by M. G. Rolland, these deposits are generally impregnations in the cretaceous and tertiary formations. They seem to be richer when the beds are more schistose and transmuted. They are more or less closely in relation with serpentines, which are themselves sometimes impregnated with oxide of iron, sometimes in quartzose schists, in sandstones, more rarely in limestone rocks, limestone breccias, etc. Native mercury is found in some magnesian rocks near the surface. There are no defined fissures nor veins proper. The cinnabar with quartz, pyrites, and bituminous substances is sometimes disseminated in the rock in fine particles and spots, sometimes forms certain kinds of stockworks or reticulated veins and nests. The parts thus impregnated congregate and form rich zones, the size of which occasionally reaches 80 fathoms, and the percentage 35 per cent., and flat-like veins or lenticular deposits, the strike and dip of which agree with those of the schists of the country generally. These rich zones without defined limits gradually merge into poor stuff containing half a per cent., or mere traces, and are of no value.

Sulphur Bank, one of the principal mines, was originally worked as a sulphur deposit. Sulphur in workable quantities is known to exist in some volcanic countries, and volcanic rocks are abundant at the California cinnabar mines.

II. Bismuth. This metal occurs native, of a reddish silver-white color. Brittle when cold; hardness, 2 to 2.5; specific gravity, 9.7. Malleable and sectile when heated, but breaks under the hammer. It carries, sometimes, traces of arsenic, sulphur, tellurium and iron. On charcoal before the blow-pipe, it fuses and entirely volatilizes, leaving a coating which is orange-yellow while hot and lemon-yellow on cooling (this is the trioxide of bismuth). It dissolves in nitric acid, but subsequent dilution causes a white precipitate.

Very little bismuth has been found in our country. The metal occurs on the Continent of Europe, associated with silver and cobalt, also with copper ores. Although there is but little call for it in the arts, a deposit or lode of bismuth would be valuable.

Where it has been found in the United States it has been associated with wolfram (tungstate of iron and manganese), also with tungstate of lime, with galena and zinc blende in quartz.

Its Geology is the same as that of copper; it occurs in veins in gneiss and other crystalline rocks and clay slate, accompanying ores of silver, copper, lead and zinc.

III. Nickel. It does not occur native except in meteorites.

Under the blow-pipe, the test for nickel requires care and some pratice. On charcoal, with soda in the inner flame, it gives a gray metallic powder, attractable by the magnet. In the borax bead in the outer flame it gives a hyacinth-red to violet-brown while hot, a yellowish or yellow-red when cold. In the reducing or inner flame, a gray appearance is given. These appearances are modified by the impurities and the amount of nickel in the mineral. The wet process is the only method of determining the true value of a nickel-bearing mineral.

Its chief ores are:

SMALTITE, which is a combination of cobalt, iron and nickel, and arsenic in varying proportion. It will be more fully referred to, later on, under COBALT.

NICKEL ARSENIDE, COPPER NICKEL or NICOLITE. Composition: Nickel, 44.1; arsenic, 55.9. It looks somewhat like pale copper, but contains no copper. Hardness, 5 to 5.5; specific gravity, 7.2 to 7.8; streak, pale brownish to black; luster, metallic; brittle. It frequently contains a little iron, and sometimes a trace of antimony, lead and cobalt. Dissolves completely in aqua regia; also in nitric acid; crystals of arsenious acid being separated by cooling.

If carefully treated under the blow-pipe with borax, it will show the iron if present, in the bead, and the cobalt and nickel by successive oxidations (see under Smaltites later on). But the nickel requires special treatment, the detection of which we shall speak of in this chapter.

There is another mineral, not properly an ore, called:

EMERALD-NICKEL, a carbonate of nickel, containing 28.6 water when pure. It forms incrustations on other minerals, like another called

MILLERITE, a sulphide of nickel forming tufts of very fine acicular, brassy-looking crystals, in cavities of the red hematite of Sterling Iron Mines in Northern New York, and velvety incrustations on ores in the Gap Mine, Lancaster Co., Penna., where nickel was found and worked. In the former place no nickel abounds, but in the latter it has in the past been found in paying quantities; the mine is now exhausted. But the sulphide forms at the latter place vary very much, as examined under the microscope, from the acicular crystals found in the ores at Sterling, N. Y., and yet they are of the same chemical combination. The ore upon which the tufts of velvety covering were found at the Gap Mine, is pyrrhotite or sulphide of iron, holding 4 to 5.9 per cent. nickel in composition; that of Sterling, N. Y., is the red hematite.

The sources of nickel discovered in Sudbury, Canada, north of Georgian Bay, yield nickel in *pyrrhotite* (sulphide of iron), and apparently also in *chalcopyrite*, whose typical composition is copper 34.6, iron 30.5, sulphur 34.9. It is a mineral of brass-yellow appearance, and one which furnishes the copper of commerce at the Cornwall Mines

(Eng.) and at the copper beds in Fahlun, Sweden. In the latter place it is imbedded, as it appears to be in the region of the Sudbury Mines, only that the Sudbury ore is imbedded in pyrrhotite and the Swedish in gneiss.

The chalcopyrite does not mix intimately with the nickel ore so as to form a homogeneous mass; it occurs by itself in pockets or threads, etc., but inclosed with massive pyrrhotite, which, while it may have more than 30 per cent. of nickel present, does not show any sign of the changed composition.*

This per cent. is far above the average of nickel in the pyrrhotite, which seldom carries less than 2½ per cent. or more than 9 per cent. of nickel.

The following new ores of nickel are reported by Dr. Emmons from Sudbury, Canada:

Foleyrite, of a bronze-yellow color, grayish-black streak, and metallic luster. It occurs massive and contains 32.87 per cent. of nickel. Its specific gravity is 4.73, hardness 3.5.

Whartonite contains 6.10 per cent. of nickel. It has a pale bronze-yellow color, black streak and metallic luster. Specific gravity about 3.73; hardness about 4.

JACK'S TIN OR BLUEITE contains 3.5 per cent. of nickel. It is of an olive-gray to bronze color, metallic luster and black streak. Specific gravity, 4.2; hardness, 3 to 3.5.

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* Dr. E. B. Peters, Manager of the Canada Copper Company.

ANALYSIS OF ORES FOR NICKEL AND COBALT.

As this analysis requires care, we give the following method in full:

1. Reduce finely 50 grains of the ore. Put it in a dry beaker-glass and pour over it a mixture of one part sulphuric acid with three parts nitric acid, both pure and concentrated, or 40 to 50 c. c. to 2 grams of ore.

2. Heat the covered beaker on a sand-bath to near 212° Fahr. for two hours. Then partly uncover, and evaporate the nitric acid entirely.

3. Cool and add 100 or more c.c. of water and let it stand for four hours; the insoluble residue is LEAD sulphate, silex, etc.

4. Filter off the soluble part and place the moist lead sulphate in a beaker and dissolve it by first pouring in ammonia (20 to 25 c.c.), and next acetic acid till it is decidedly acid. The sulphate now dissolves if kept warm for some twenty minutes. Filter and wash, and if any residue remains (silex, etc.), reserve for future examination.

5. The LEAD is now separate, but if the amount is sought, pass a current of hydrogen sulphide through the solution till the lead is entirely precipitated. Filter, dry, place the residue in a porcelain crucible and heat to a low red heat, passing a current of dry hydrogen into the crucible while heating, to prevent any oxidizing of the sulphide. When the crucible and contents remain the same in weight, the last weight of the lead sulphide is the correct amount. Of this weight, 86.61 parts in 100 are lead, 13.39 are sulphur.

If the ore has no lead in it, the above work is omitted entirely. The likelihood of lead may be tested qualitatively from a small quantity dissolved, precipitated by hydrogen sulphide, and the precipitate determined by the blow-pipe on charcoal giving the lead coating, and with soda, the metallic globule.

6. To SEPARATE THE COPPER. The filtrate remaining after the insoluble lead sulphate was filtered off, as in No. 4, now contains whatever the mineral is composed of, copper, iron, nickel, cobalt, etc. Dilute the filtrate to about 500 c.c., heat to nearly boiling, and pass hydrogen sulphide through it, and thus precipitate all the copper after adding 1 or 2 c.c. of hydrochoric acid. Filter, wash, dry, and ignite the precipitate in an atmosphere of hydrogen. The result will be pure Cu_2S, from which the copper may be ascertained as 79.85 parts of the whole weight of Cu_2S.

7. Concentrate by evaporation the filtrate of No. 6 remaining after the copper was separated, add 1 or 2 c.c. of nitric acid, and boil the filtrate two or three minutes, let it become nearly cold, add an excess of ammonia, and let it stand in a warm place half an hour.

8. Filter the precipitate into a porcelain dish and redissolve the iron oxide (hydroxide) with hydrochloric acid poured slowly into the filter, complete washing of the filter with hot water, reduce the free acid in the filtrate with ammonia, then very nearly neutralize it carefully with sodium (metallic) or ammonium carbonate; the solution must remain

clear, though dark red, if much iron is present. Now add a strong neutral solution of ammonium or sodium acetate (not in large excess), and then boil a short time. When rightly performed the iron oxide precipitate will settle rapidly, and the supernatant liquor will be clear. Wash rapidly with boiling water, and, at first, separate the clear part by decantation, and then filter. If great exactitude is required, redissolve in hydrochloric acid, and once more precipitate with the acetate just as before. Add this filtrate to the ammoniacal filtrate mentioned at the beginning of No. 7 paragraph.

The iron is now separated as basic ferric acetate, and it is almost, if not entirely, separated from all nickel and cobalt which are yet in solution.

9\. The first filtrate, No. 7, contains all the nickel and cobalt. It must now be concentrated to about 250 c.c. If it is slightly acid, proceed; if not, then add muriatic acid until it is very slightly acid. Now heat the filtrate in a beaker to gentle boiling, and pass hydrogen sulphide through the liquid. A black precipitate follows; if nickel sulphide with cobalt sulphide, they are together.

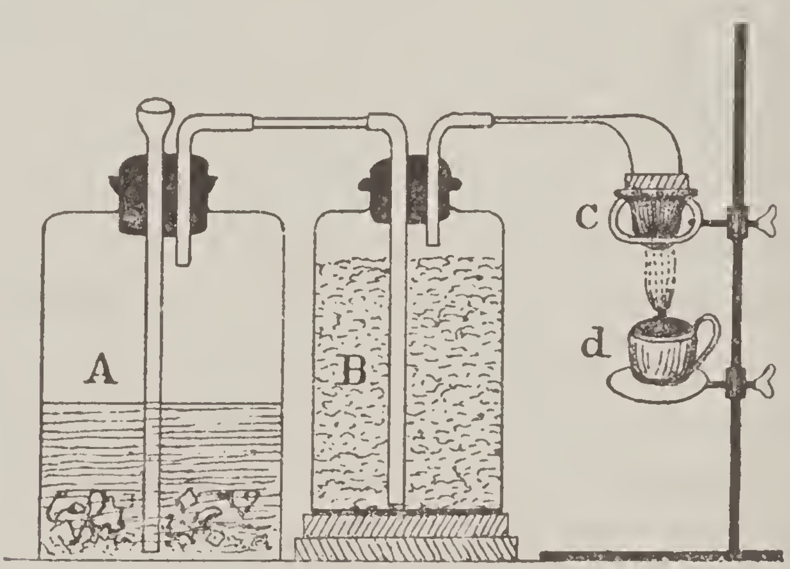
10\. Filter, wash, and dry; incinerate the filter-paper with the precipitate if very small in quantity, otherwise separately; heat in porcelain crucible. Dissolve in aqua regia (nitro-muriatic acid), and treat it till only yellow sulphur remains, evaporate and expose the residue to a heat of 180° Fah. to make any silica insoluble. Moisten with a few drops of muriatic acid, add 20 c.c. of water to dissolve the salts, add some solution of hydrogen sulphide to separate any copper or lead which may have escaped separation, filter into a porcelain dish and concentrate all to about 100 c.c.

11. Boil gently, and while boiling add *pure* sodium carbonate solution until the liquid is slightly alkaline. Continue boiling a few minutes, add a few grains of pure soda solution (sodium hydroxide). This is best prepared freshly by dropping a small ball of metallic sodium into a half ounce of water in a platinum dish or crucible, or not so well, in a porcelain dish. Heat to boiling again a few minutes till all the nickel and cobalt are precipitated, wash the precipitate with boiling hot water by decantation, and finally on the filter, until a drop on polished platinum shows no residue. After drying the precipitate remove it to a piece of glazed paper; cover with a bell-glass. Then incinerate the filter till the carbon has entirely disappeared, add it to the precipitate already obtained, place all in a crucible, cover it and expose to heat to redness, and, finally, if desired, reduce the oxides to the metallic condition by ignition under a stream of hydrogen.

12. As this process of reduction to metal is sometimes very useful, we give a simple plan of apparatus for this purpose. Get a half-pint wide-mouthed pickle bottle and introduce two glass tubes of a quarter-inch diameter into a cork fitting the mouth, after having nicely adjusted the cork to the mouth of the bottle. The tubes may be easily bent and blown as in *A B*, Fig. 60, over the flame of an

alcohol lamp, before permanently fastening them in place. To blow a funnel end, heat the end of the tube to softness and mash it together, hermetically seal, then reheat rapidly, roll it between finger and thumb while gently blowing at the other end until swollen large enough, then with pincers, break it or chip it off; if enlarged twice or three times the diameter, it is large enough for the purpose. The tubes intended to be bent should be rapidly rotated in the enlarged flame until red-hot, and then bent to the right angle and gradually cooled.

Fig. 60.



It is well to make another of these bottles for drying the hydrogen, as in *B*. Introduce the tube as shown in the figure, wherein *B* represents the drying bottle in which is placed a quantity of fragments of chloride of calcium of the size of peas or even smaller. In putting the cork with tubes into this bottle, the bottle should be on its side and rolled while introducing the longer tube into the calcium chloride, so that the fragments may not obstruct the tube as it is pushed down. The exit-tube may be bent or straight, and properly-sized india-rubber tubing may be fitted over the ends so as to make connections. A common clay-stem smoking pipe arranged as in the figure, with the bowl inverted into the crucible which is placed on a wire support on a retort stand, *c*, is quite sufficient. The usual alcohol blast-lamp, *d*, is required for this operation. To put the apparatus to work it is only necessary to introduce some three or four ounces of broken-up pieces of zinc into *A*, together with water sufficient to half fill the bottle, cork up with the tubes arranged as above, and pour into the funnel-shaped tube common oil of vitriol gradually, until the gas begins to come over, then stop as the water becomes heated, and the gas will increase without further addition. You may now prepare your crucible, and, when in place, and the tubes all arranged, the gas may be made to come over more rapidly by adding a little more oil of vitriol, drop by drop.

13. The crucible should be weighed after cooling and replaced, the flame of the blast-lamp relighted, and red heat renewed under the hydrogen apparatus until the crucible, when again weighed, shows no alteration in weight. The oxide has now been reduced to the pure metal form, and it may then be cooled.

In the case of the analysis we are now upon, the metallic reduction will be that of both nickel and cobalt, and they will appear as a dark powder in the bottom of the crucible.

When the hydrogen apparatus is no longer to be used, the generator bottle *A* should be washed thoroughly and the zinc also; the latter may be left in the bottle and the cork replaced loosely, but the cork must be removed from bottle *B*, and a tight-fitting cork be used in its place, as the chloride may be used again. All is ready for another operation by simply replacing and adding water and acid as before.

4. SEPARATION OF NICKEL AND COBALT. The two metals should be weighed in order that, if the cobalt be found, the nickel may be known by the difference. Dissolve the two metals in nitric acid and evaporate them till there is no free nitric acid. Next add about 6 to 8 grams (100 grains) potassium nitrate dissolved in 10 to 15 c. c. of hot water. If any flocculent particles appear, add a little acetic acid, just sufficient to dissolve them, and now a precipitate of cobalt (as tripotassium cobaltic nitrate), takes place slowly. The whole volume should now be 15 to 20 c.c. Cover the beaker containing it with glass, and set it aside in a warm place for twenty-four hours. Filter, wash with a solution of potassium acetate (which may be made by neutralizing acetic acid with crystallized potassium bicarbonate, leaving the solution slightly acid), and proceed to more efficiently separate the cobalt as a metal, as follows:

Dilute the filtrate, heat, and precipitate with caustic soda (sodium hydroxide), wash the greater part of the saline matter out, and then dissolve the precipitate in nitric acid, evaporate to dryness, add two or three drops of nitric acid and dissolve in a small volume of water, filter, concentrate the filtrate, and repeat the process of separation of potassium nitrate as before. Put this precipitate, with the filter-paper, into a beaker, add about 100 c.c. of water, heat, add muriatic acid to dissolve it, separate the filter-paper, wash it in a funnel, evaporate the solution on a water-bath, and let it remain on the water-bath two or three hours to render the silica insoluble, then moisten with muriatic acid, add water, filter, and convert the cobalt to metallic form, as was done before for both nickel and cobalt, namely, as in paragraph No. 11. The cobalt is now entirely separate from the nickel. Weigh it, and by difference from the weight of the two determine the weight of nickel as suggested in No. 14. The amount of nickel is now known by weight, and readily compared with the whole amount of the original weight of ore employed at the beginning.

If the above process is carefully followed out, in a mineral containing lead, copper, iron, cobalt, and nickel, the cobalt and nickel are separated with great exactness.

However, the main ore of nickel is pyrrhotite, and as found in the Sudbury Mines, Canada, it contains only iron and nickel, seldom cobalt enough to notice. So that much less work is required, as follows: Pulverize, dissolve in muriatic acid in a flask. If very much free acid is present, nearly neutralize with sodium or ammonium carbonate; the solution should be clear, but, if there is much ferric chloride, it should be of a deep-red color; now do as directed in No. 8, to add the ammonium acetate, and proceed as before.

In addition to the nickel ores already given may be mentioned a hydrated silicate of nickel found in New Caledonia and named after its discoverer.

GARNIERITE. It contains from 8 to 10 per cent. of nickel. Color, light or dark green. Streak, light green. Specific gravity, 2.2 to 2.86. Hardness, 2.5. Fuses in borax before *R. F.* and gives the ordinary nickel bead. It is found in lodes and pockets in serpentine rock. It has also been found in Oregon.

IV. COBALT. Cobalt does not occur in native form. The following are the minerals of importance:

SMALTITE seems to be composed of cobalt, nickel, iron and arsenic; the typical form is arsenic 72.1, cobalt 9.4, nickel 9.5, iron 9 = 100. Hardness, 5.5 to 6; specific gravity, 6.4 to 7.2. Color, tin-white, sometimes iridescent. Streak, grayish-white. Brittle. Before the blow-pipe, on charcoal with soda, the arsenious acid fumes are given off, and the garlic smell is plainly observed. With borax for the bead the assay may be made to show (with successive heatings) the reactions, first of iron, then cobalt, and nickel, provided the operator is skilful in oxidizing the powdered ore by cautious degrees; when one borax bead shows iron reaction by a certain amount of carefully applied *O F* to the bead, try another with increased degree of oxidation until you perceive the cobalt blue and nickel brown, if both are present.

COBALTITE is composed of sulphur, arsenic and cobalt in the typical proportions of 19.3, 45.2, 35.5 = 100, but it frequently, as a mineral, contains iron. Hardness, 5.5; specific gravity, 6 to 6.3. Under the blow-pipe, in an open tube, it sends off sulphurous fumes and a sublimate of arsenious acid. With borax bead gives the blue of cobalt. Dissolves in warm nitric acid, separating the sulphur and arsenic.

Cobaltite and smaltite are valuable as affording the greater part of the smalt of commerce, and the former is used in porcelain painting.

ERYTHRITE is a soft (1.5 to 2.5) peach-red mineral of specific gravity 2.9, transparent or translucent, sometimes pearl- or greenish gray.

Composition, typical, arsenic, 38.43, cobalt oxide, 37.55, water, 24.02 = 100.

In a closed tube, under blow-pipe, it yields water and turns bluish. Gives the usual blue for cobalt in the borax bead.

Valuable for the manufacture of smalt. It is sometimes known as "*cobalt bloom.*"

LINNÆITE. This is valuable for the large amount of both cobalt and nickel it sometimes contains. Hardness, 5.5; specific gravity, 4.8 to 5; metallic luster; color, pale steel-gray, tarnishing to red. Composition, sulphur, 42, cobalt 58 = 100, but cobalt is replaced by large amounts of nickel, and sometimes copper. Some specimens from Mineral Hill, Maryland, and from Missouri, have yielded as high as 29.56 and 30 per cent. of nickel, with 21 to 25 per cent. cobalt in the same specimen, but with a small amount of iron (3 per cent.).

EARTHY COBALT OR COBALT WAD (*Asbolite* is the mineralogical name), occurs as a bog ore, with manganese, iron and copper, and nickel. It is blue, black at times, has a hardness of 1 to 1.5, and specific gravity of 2.2 to 2.6. It sometimes contains up to 35 per cent. of cobalt oxide.

The geological position of cobalt is in the earlier rocks, as the chlorite slates with chalcopyrite, blende, and pyrite, as in Maryland. Sometimes the ore is found in cavities in the limestone of the carboniferous age, as in Great Britain. The tin-white cobalt is found in the gneissic and primitive rocks as in Norway. Linnæite is found at Mine la Motte, Mo., in masses, sometimes in octahedral crystals among its rich ores of lead and nickel.

IV. CADMIUM. Of this mineral but one ore is known, namely, the sulphide, or GREENOCKITE, with 77.7 per cent. cadmium. Color, honey- to orange-yellow and brick-red ; in hexagonal prisms ; hardness 3 to 3.5 ; specific gravity 4.5 to 4.908. Before the blow-pipe, on charcoal with soda, it yields a red-brown deposit. Cadmium is frequently associated with zinc ores, some varieties of sphalerite or blende containing 3.4 per cent.

Metallic cadmium is white like tin, and shares with it the property of emitting a crackling sound when bent. It is so soft that it leaves a mark upon paper.

CHAPTER XII.

ALUMINIUM, ANTIMONY, MANGANESE.

1. Aluminium. The distribution of aluminium in nature is very wide, rivaling that of iron, yet three are but few minerals which serve as sources of the metal. These are : *Bauxite,* a limonite in which most of the iron is replaced by aluminium. It occurs in earthy masses resembling clay ; also in compact form. The color varies from white to gray, yellow also to brown or red, especially in the impurer kinds. It contains 50 to 75 per cent. alumina. Corundum, generally quite pure but too valuable for abrasive purposes to be used as an ore. It will be more fully described in Chapter XV, Gems and Precious Stones, this mineral species including some of the most important precious stones. *Diaspore* hard and crystalline, specific gravity 3.4, with 64 to 85 per cent. alumina, and ordinarily quite pure. *Gibbsite,* stalactitic, specific gravity 2.4, containing, when pure, 65 per cent. alumina. *Aluminite,* specific gravity 1.66, a sulphate of aluminium found in large beds, chiefly along the Gila River, in New Mexico, containing about 30 per cent. alumina, and easily soluble in water. *Cryolite,* specific gravity 2.9, easily fusible, and when fused its specific gravity is about 2. It contains 40 per cent. aluminium fluoride

and 60 per cent. sodium fluoride. All clays contain a large percentage of aluminium, but always in the state of silicate, and the difficulty of removing this silica has so far prevented the employment of clay as an ore of aluminium.

Of the ores above named the most important is

BAUXITE, of which there are vast deposits at Baux, near Arles, in France, in Ireland, and in Alabama, Arkansas, the Carolinas, Georgia, Tennessee and Virginia.

The Arkansas deposits are said to cover a large area, and to reach a thickness of 40 feet, forming an interbedded mass in ferruginous Tertiary sandstone.

The Alabama deposits are better known, and all occur in the lower Silurian formation. The district has been badly broken up by sharp folds and great thrust faults, and the mineral occurs as pockets in close association with brown iron ore (limonite) and clay.

Bauxite has to undergo purification for the purpose of the aluminium manufacturer. Several methods are used:

1. It is chosen as free from iron as possible, and is roasted at a low red heat, and afterwards treated with sulphuric acid, which combines with the alumina present, forming sulphate of alumina. This is readily dissolved by water, leaving the great bulk of silica and iron behind. The solution of sulphate of alumina is allowed to settle, the supernatant liquid is siphoned off into an evaporating tank and

evaporated to dryness. The dry sulphate of alumina is calcined at a red heat, driving off the sulphuric acid, leaving as a residue anhydrous alumina.

2. The bauxite is treated either by fusing with carbonate of soda and dissolving in water, or by boiling it with a strong solution of caustic soda. In either case a solution of sodium aluminate is obtained, which is filtered from the residue of silica and ferric oxide, and decomposed into aluminium hydrate and carbonate of soda by pumping carbonic acid gas through it. After a thorough washing, the hydrate is calcined at a high heat, and the resulting alumina is finely ground.

If not too darkly colored, due to iron, bauxite gives the blue-colored mass characteristic of aluminium when ignited after moistening with cobalt nitrate.

The ore next in importance is

Cryolite, of which there is practically only one productive mine, that at Ivigtut, South Greenland. The mine is worked as a quarry, and has been opened 450 feet long, 150 feet wide and 100 feet deep, while diamond drills have proved the permanence of the ore for a further depth of 150 feet. The vein appears to widen with depth, but the quality of the mineral becomes inferior. About 10,000 tons of cryolite annually are shipped to the United States.

With the blowpipe, on charcoal, cryolite fuses to a clear bead, becoming opaque on cooling. After long blowing with O F the assay spreads out, the fluoride of sodium sinks into the charcoal, and the suffocating odor of fluorine is given off and the aluminium remains as a crust which, if touched with a little cobalt solution and gently heated, gives a blue color of alumina. If some of the cryolite is powdered and placed near the open end of a glass tube and the flame from the blowpipe turned carefully on it, the fluorine will be freed and will etch the glass, showing corrosion and proving the presence of fluorine. Besides, as a source of the metal aluminium, cryolite is used as a flux, and largely for the manufacture of alumina of soda.

While the older processes of aluminium manufacture, dependent on the reduction of the double chloride of aluminium and sodium, must always have a scientific interest, they have been beaten out of the field of commercial industry by the newer electrolytic methods, of which there are four varieties. In England and America Cowles' and Hall's patents are followed; on the Continent, Heroult's and Minet's. They are all virtually modifications of the original Deville-Bunsen process, maintaining fusion by the heat of the electric current.

II. ANTIMONY. This metal occurs in three forms, namely, the oxide, *senarmontite*, containing 83.56 per cent. antimony; the sulphide, *stibnite*, *antimonite* or *antimony glance*, affording 71.8 per cent.; a sulphoxide, *kermesite*, giving 75.72 per cent., in addition to some unimportant combinations with silver, etc. While it may be said that antimony is somewhat widely distributed in nature, yet, owing to cost and difficulties in extraction, only comparatively few mines affording a rich ore can be profitably worked. Beyond the considerable quantities of oxide coming from Algiers and of kermesite from Tuscany, almost the entire output is in the form of

Stibnite, which contains 78.8 per cent. antimony and 28.2 sulphur. Hardness, 2; specific gravity, 4.5. Color, lead-gray; streak blackish lead-gray, rubbed streak is pale yellowish-brown. Luster, metallic; sectile. Occurs in rhombic, generally in radiated or divergent bunches; massive with columnar or fibrous structure. Soluble in hydrochloric acid giving a slight crystalline precipitate of lead chloride if lead be present.

Before the blowpipe, on charcoal, it fuses, spreads out, gives sulphurous and antimonious fumes, coats the charcoal with white oxide of antimony; this coat, treated in *R F*, tinges the flame greenish-blue.

Foremost in antimony production stands Portugal, due principally to the mining district of Oporto. The geological formations of Portugal are chiefly igneous and old sedimentary. The most favorable rocks for good antimony ore are bluish gray argillaceous Silurian shales.

Among the other European centers of production, the Bohemian mines are in granite and mica schist; the Hungarian in granite—sometimes auriferous; the Styrian in dolomite, and the Turkish also in granite. Victoria, New South Wales, and Western Australia are large producers of auriferous stibnite.

In New Brunswick, antimony is mined in a quartz and calcite gangue in clay-slates and sandstones of Cambro-Silurian age.

Within the United States stibnite has been found in a number of places, all in the West. At San Emigdio, Kern Co., California, it is contained, with quartz gangue, in a vein in granite. The vein varies in thickness from a few inches to several feet. Several other small deposits occur in San Benito Co. and elsewhere in California. Stibnite has also been discovered in Humboldt Co., Nevada, and in Louder Co., not far from Austin, in a quartz gangue. Some remarkable deposits occur in Iron County, Utah, as masses of radiating needles, which follow the stratification planes of sandstone and fill the interstices of a conglomerate. Stibnite is found in Sevier Co., Arkansas, filling veins, with a quartz gangue, in sandstone.

III. MANGANESE, The ores of manganese are divided into three general classes:

1. Manganese ores.
2. Manganiferous iron ores.
3. Argentiferous manganese ores.

WAD is the name given to manganese oxide. It is found in earthy, compact masses of a dark brown color, chiefly oxide of manganese and water.

Easily recognized under the blow-pipe, as it gives (in minute quantities) in the borax bead, a violet color in the *O F*, but disappears when the *R F* is turned upon it, and reappears when the *O F* is repeated.

It is found in beds varying from several inches to a foot or more in thickness. Hardness, 0.5 to 2.5; specific gravity, 3 to 4. Color, generally some shades of dark-brown; streak umber-brown. Generally soft and earthy, compact. Fracture smooth, sometimes sub-conchoidal. Wad is used as a flux in iron smelting, and in a lixiviated state as a paint.

Pyrolusite. This is the peroxide or dioxide, with 63.2 per cent. of manganese and 36.8 per cent. oxygen. Its crystalline form is the rhombic prism and it generally occurs in the form of minute crystals grouped together and radiating from a common center. It has an iron-black or steel-gray color, a semi-metallic luster, and yields a black streak. Specific gravity, 4.7 to 4.86; hardness, 2 to 2.5; infusible before the blow-pipe, and acquires a red-brown color. On heating it generally yields some water and loses 12 per cent. of oxygen. With borax, soda and microcosmic salt it shows manganese reaction. It dissolves in hydrochloric acid, when heated, with vigorous evolution of hydrogen.

Psilomelane occurs massive, occasionally shelly, seldom fibrous; color, iron-black to bluish-black streak bluish-black and shining; fracture, conchoidal to smooth. Specific gravity, 3.7 to 4.7; hardness, 5.5 to 6. Before the blow-pipe it yields manganic oxide, giving off oxygen. It is soluble in hydrochloric acid, chlorine being evolved. The powdered ore colors sulphuric acid red. Psilomelane contains from 40 to 50 per cent. of manganese, and some baryta and potassa. A solution in hydrochloric acid of the variety containing baryta gives a heavy white precipitate with sulphuric acid.

RHODOCROSITE OR MANGANESE CARBONATE occurs in spherical and nodular aggregations of cauliform texture or in compact masses of granular texture. It is rose-red to raspberry-red in color, by weathering frequently brownish, with a glassy or mother-of-pearl luster. It cleaves like calcite. It contains 61.4 per cent. of manganese protoxide and 38.6 per cent. of carbonic acid, with part of manganese frequently replaced by calcium, magnesium, or iron. Specific gravity, 3.3 to 3.6; hardness, 3.5 to 4.5. Before the blow-pipe it is infusible and becomes black. From similar minerals it is distinguished by its rose-color and the manganese reaction with soda and borax; and from silicate of manganese by its inferior hardness, its effervescence with acids and its non-fusibility.

The manganese in ores of the third class is valuable, even when the silver alone is sought, as it facilitates the work whereby the silver is extracted; this it does because of its fluxing quality.

In the United States the most important mines of manganese are located in Virginia, Arkansas and Georgia. The chief production in Virginia is at the Crimona mines, in Arkansas in the Batesville district, and in Georgia in the Cartersville district. In the latter district extensive deposits of manganese are closely associated with deposits of iron ore. All the iron ore contains traces of manganese, but the main deposits of the latter are quite distinct from the iron. The ore occurs like the brown hematite, embedded in a heavy mantle of residual clay, associated with chert and angular fragments of quartzite. The proportion of clay to ore is generally larger than in deposits of brown hematite. The ore occurs as small concretions scattered through the clay, and also in the form of veins, penetrating the clay in an irregular manner. It has the appearance of having been deposited by solutions percolating through the residual mantle. The original source of the manganese was probably the Beaver limestone, although some of it may have come from the Weisner quartzite. The deposits occur with about equal frequency in the residual material derived from the two formations.

In California manganese is produced in a small way for use in the manufacture of chlorine for gold-smelting purposes.

Colorado produces two classes of manganese-bearing ores, a manganiferous iron ore used to some extent in the production of spiegeleisen, and a manganiferous silver ore used as a flux in the smelting of silver-lead ores.

A deposit of manganese has also been opened in the Chickasaw Nation, Indian Territory.

The greater portion of manganese and manganiferous ores serves for the preparation of iron manganese alloys—spiegeleisen and ferro-manganese, as well as other manganese alloys. Considerable quantities are used as coloring matter in the manufacture of pottery and glass.

Manganese, when heated in the air, gives a good brown paint, and when moderately heated a black paint. Both paints may be directly produced from the residues resulting in the manufacture of chlorine.

Manganese is also used as a coloring matter and mordant in dyeing and calico printing, in the manufacture of oxygen, as a material in the manufacture of disinfectants, and in electrical batteries.

CHAPTER XIII.

VARIOUS USEFUL MINERALS.

Alum. This name is applied to a group of minerals which are hydrous sulphates of aluminium with potash, soda, ammonia, magnesia, etc. They all crystallize in the regular system, are soluble in water and have an astringent sweetish taste. Hardness, 2 to 2.5; specific gravity, 1.8. *Potash alum* is the most common, and is usually found in the form of an efflorescence or an incrustation, with a mealy and sometimes a fibrous structure. It is abundant in clays, argillaceous schists, which, when largely impregnated with alum, are called *aluminous schists* or *shales.*

Soda alum has a general resemblance to potash alum but is rather more soluble in water. *Magnesia alum* occurs in silky-lustered fibrous masses. *Iron alum* forms yellowish-white silky masses. It differs somewhat from the other alums in turning red when heated.

Alum is used in dyeing and calico-printing, candle-making, dressing skins, clarifying liquids, and in pharmacy.

Apatite, Phosphate of Lime, occurs in six-sided prisms, also in masses. It is transparent or opaque; colorless, white, yellowish, green, violet, with a glassy luster, and yields a white streak. Fracture, conchoidal or uneven. Specific gravity, 3.16 to 3.22. Hardness, 5. In thin laminæ it is fusible with difficulty before the blowpipe; when moistened with sulphuric acid, it tinges the flame greenish. It is soluble in hydrochloric and nitric acids without effervescence. From beryl it is distinguished by its inferior hardness and its solubility in acids. It occurs in rocks of various kinds, but more frequently in those of a metamorphic crystalline character, as in Laurentian gneiss, which is usually hornblendic, granitic or quartzose in character, in Canada, and in association with granular limestone. It is also found as an accessory mineral in metalliferous veins, especially those of tin, and beautifully crystallized and of various colors in many eruptive rocks. It also occurs in veins by itself, mostly in limestone, but sometimes in granites and schists. In these deposits apatite is also found as concretions, sometimes showing a radiated structure, but of an earthy appearance externally.

In sedimentary formations where a considerable accumulation of fossils has provided the phosphate of lime it occurs in two principal forms, namely, *coprolites*, which are excreta of large animals, especially saurians, and concretions formed at the expense of the same coprolites, together with shells, bones, etc. The richest of these deposits are from Lower Cretaceous to Lower Jurassic in age, but phosphatic deposits are found and worked in sedimentary deposits of all ages.

The principal use of apatite is as a source of phosphoric acid and phosphorus, and before the discovery of the phosphate-rock deposits in Florida was largely sold to the manufacturers of fertilizers.

The Tennessee *white phosphates* occurs in Perry and Decatur counties. The lamellar variety is the highest grade and the most easily prepared for market. It also appears to be most abundant. Selected specimens of the thin plates contain 85 to 90 per cent. of lime phosphate. The less dense greenish material, which is associated with the white and pink plates, contains some ferrous iron and runs slightly under 80 per cent. of lime phosphate.

Arsenic is found in the mineral kingdom partly in a metallic state, partly in combination with oxygen, sulphur and other bodies.

1. *Native Arsenic* occurs seldom distinctly crystallized, but usually in fine granular, spherical or nodular masses. Specific gravity, 5.7 to 5.8 ; hardness, 3.5 ; brittle ; uneven and fine-grained fracture ; metallic luster ; color, whitish lead-gray, usually with a grayish-black tarnish ; evolves an odor of garlic on breaking ; contains occasionally more or less iron, cobalt, nickel, antimony and silver.

Before the blow-pipe it quickly volatilizes before fusing, giving off white fumes having an odor of garlic. Native arsenic occurs especially in veins in crystalline slates and transition rocks in subordinate quantities associated with ores of silver, lead, cobalt and nickel.

2. *Realgar*, with 70.029 per cent. of arsenic and 39.971 per cent. sulphur. Color, red; crystallizes clinorhombic; fracture, conchoidal to splintery; hardness, 1.5 to 2.0; specific gravity, 3.4 to 3.6. It is but slightly affected by acids; soluble with a deposit of sulphur in aqua regia, and in concentrated potash lye with separation of dark brown sulphuret of arsenic. From ruby silver and cinnabar, it is readily distinguished by its inferior hardness, slighter specific gravity and orange-yellow streak, the streak of the two above-mentioned minerals being cochineal-red.

3. *Orpiment*, with 69.9 per cent. of arsenic and 39.1 per cent. of sulphur; occurs in nature, but for industrial purposes is mostly artificially prepared. The mineral has a lustrous lemon-yellow or orange-yellow color, is cleavable into thin, flexible, transparent laminæ; hardness, 1.5 to 2; specific gravity, 3.4 to 3.5; soluble in nitric acid, potash lye and ammonia.

ASBESTUS. Fibrous. Color, green or white. The asbestus of commerce is practically a finely fibrous form of serpentine, that is to say, it is essentially a hydrated magnesium silicate. Every deposit of serpentine is a possible repository of asbestus. It occurs in seams half an inch to several inches in width, running parallel to or crossing one another, the width of each seam making the length of the fiber. Canada furnishes at present a large portion of the world's supply of asbestus. The profitable mining, however, is at present confined to a small area in the great serpentine belt of the Province of Quebec, that lies to the south of the St. Lawrence River. In the form of a rough cloth, asbestus is used for covering steam-pipes and for many purposes requiring an incombustible material.

Barytes, or *barium sulphate*, commonly called *heavy spar*, occurs in tabular, glassy crystals, and also in dull masses in veins of various rock formations. Color, white or tinted; transparent or translucent; luster, vitreous or pearly. Specific gravity, 4.3 to 4.7. Hardness, 3 to 3.5. It is readily distinguished by its great comparative weight. When heated in the blowpipe flame splinters fly off the crystals. It fuses with difficulty, and imparts a green tinge to the flame. After fusion with soda, it stains a silver coin black. It is not acted upon by acids.

In the United States barytes is found in many places, it being mined in Virginia, Missouri, New Jersey, and other states. It frequently occurs in connection with lead and zinc deposits, forming the gaugue of the metal-bearing vein. The best varieties of barytes are the white and gray. The chief use of barytes is as a pigment, as a cheap substitute for white lead. It is also used as a make-weight by paper manufacturers, etc.

The carbonate of barium, *witherite*, is a much less common mineral than the sulphate. It sometimes occurs in crystals, but the more common form is that in fibrous masses. It occurs in veins. It fuses easily in the forceps, and gives a yellow-green flame.

In hydrochloric acid it dissolves with effervescence, the solution yielding a heavy white precipitate (barium sulphate) if a little sulphuric acid is added. Witherite is used in the refining of sugar, and also in the manufacture of plate glass.

BORAX. Monoclinic. Hardness, 2 to 2.5; specific gravity, 1.7. Fracture, conchoidal. Luster, vitreous to resinous. Color, white, sometimes grayish, bluish, or greenish. Streak, white. Taste, slightly alkaline and sweetish. Translucent to opaque. The occurrence of deposits of borax in the United States is, so far as known, limited to California, Nevada, and Oregon. In the early seventies, borax in large quantity and in a very pure condition was discovered on many of the alkaline marshes of western Nevada and eastern California. Refining plants were established and flourished for a time, but the increased production of borax in this country, together with the importation of large amounts from Italy, so reduced the price that in a few years most of the plants were abandoned.

In 1890 it was found that the borax crust on most of the marshes is a secondary deposit, being derived from the leaching of beds of borate of lime in the Tertiary lake sediments that abound in the region. The marshes were abandoned and a mine was established on a bedded deposit at Borate near Daggett, San Bernandino County, California. The value of this deposit led to the discovery in Death Valley * of

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* Death Valley received its sinister name from the fact that, in 1849, a band of emigrants wandered into the valley and most of them perished from thirst before an avenue of escape was discovered.

enormous deposits that far exceed those now being worked near Daggett.

The borax of Death Valley, as well as that near Daggett, occurs in a regular stratum, interbedded with the semi-inducted sands and clays that make up the bulk of the strata. These beds are generally regarded as of Tertiary age, and they are supposed to have been deposited in inclosed bodies of water.

The principal deposits of boron salts occurs at Borate near Daggett in the vicinity of the old Calico mining district. The mineral found here is *borate of lime*, or *colemanite*, and it occurs as a bedded deposit from 5 to 30 feet in thickness, interstratified in lake sediments. These lake beds are composed of semi-indurated clays, sandstones and coarse conglomerates with intercalated sheets of volcanic tuff and lava. The rocks are severely folded, the axes of the folds lying in an east-west direction.

Borax is used in medicine and as an antiseptic by meat packers and others. Its chief use, however, is as a flux in metallurgical operations, in enameling, glazing of pottery, and in the manufacture of glass.

CLAYS. The clays are all products of alteration from other minerals. Their composition is variable and they do not crystallize. The true clays are all plastic and refractory to a greater or less degree, and on these properties their value for industrial purposes depends. Pure *kaolin* is the type of all the clays.

The presence of alkalies in clays is objectionable, as it renders them fusible, as also do many other oxides. Iron is not only objectionable on the score of fusibility, but also as coloring matter. The presence of too large a proportion of water, carbonic acid or organic matter, causes clay to contract under the action of fire, and the same result will ensue if the clay is partially fusible.

The soft clays are divided as follows:

Kaolin, porcelain clay or China clay. This is a product of decomposition of feldspar and other minerals, and never occurs in any crystalline form. Its composition varies somewhat according to the source from which it has been derived. In all cases it is a hydrated silicate of alumina, and its usual source is feldspar. It is a friable, soft substance of a white yellow, or flesh-red color, and capable of resisting the highest heat of a porcelain furnace. It usually contains more or less silica in an uncombined state. Its specific gravity is 2.2. Kaolin is almost entirely from the older feldspathic rocks, while clays are generally derived from younger rocks.

Pottery or plastic clay is not so pure as kaolin, containing a large percentage of iron.

Bole is a hydrated silicate of alumina and iron, of a somewhat variable composition, but generally containing about 42 per cent. of silica and 24 per cent. of water. It also contains a large amount of ferric oxide, which gives it its yellow-red or brownish-black color. It is soft and greasy, translucent or opaque, adheres to the tongue, and falls to pieces with a crackling noise when immersed in water. The hardness is 1.5 and the specific gravity 1.4 to 2. It fuses with facility into a greenish enamel.

Fuller's earth is a kind of clay composed, when pure, of 45 per cent. silica, 20 to 25 per cent. alumina, and water. It was formerly largely used as an absorbent in fulling or freeing woolen fabrics and cloth from fatty matters, but in modern times other substances have been substituted, and the consumption of it has greatly fallen off.

Extensive deposits of Fuller's earth occur in Decatur County, Georgia and in Gadsden, Leon and Alachua Counties, Florida. With the exception of the Alachua County deposits, they are all of Upper Oligocene age, and equivalent with the Alum Buff beds.

COAL (MINERAL). Massive, uncrystalline. Color, black or brown; opaque. Brittle or imperfectly sectile. Hardness, 0.5 to 2.5. Specific gravity, 1.2 to 1.80. Coal is composed of carbon with some oxygen and hydrogen, more or less moisture, and traces also of nitrogen, besides some earthy material which constitutes the ash.

The greater part of the coal formations originally consisted of peat or vegetable materials washed together; usually sand and clay were likewise contained in the deposit, and sometimes hydrated oxide of iron or ferrous carbonate. These deposits, in the course of time, with pressure, were formed into strata of alternate sandstone (usually gray) and slate clay or shale; and between these strata, beds of brown or black coal or anthracite and clay-ironstone were formed, subordinate, however, in extent and thickness to the sandstone, slate, and shale. Coarse conglomerates, marl, or limestones very rarely occur in these formations. The Carboniferous period and the Tertiary period furnish the most characteristic examples of these formations, but the carbonaceous deposits of other periods are associated with similar rocks, and are so like the genuine coal formations that, petrographically, they are hardly to be distinguished from them.

Recent surveys, still incomplete, show that Alaska has coal in abundance and of the finest quality.

Anthracite (*Glance coal, Stone coal*). Luster high, not resinous, sometimes submetallic. Color, gray-black. Hardness, 2 to 2.5. Specific gravity, if pure, 1.57 to 1.67. Fracture often conchoidal. Anthracite consists almost entirely of carbon, and contains very little hydrogen, oxygen, or nitrogen. It contains earthy admixtures in various quantity. The normal position of anthracite appears to be in the transition formations.

Bituminous coal. Color, black. Luster, usually somewhat resinous. Hardness, 1.5 to 2; specific gravity, 1.2 to 1.4. Contains usually 75 to 85 per cent. of carbon.

Cannel coal. Very compact and even in texture, with little luster, and fracture largely conchoidal.

Brown coal (often called *lignite*). Color, black to brownish-black. Contains 52 to 65 per cent. of fixed carbon.

Jet resembles cannel coal, but is harder, of a deeper black and higher luster. It takes a brilliant polish and is set in jewelry.

DOLOMITE is composed of carbonic acid, lime, magnesia. It occurs in rhombohedrons, faces often curved. It is frequently granular or massive: white or dull tinted; and glassy or pearly. Specific gravity, 2.8 to 2.9; hardness, 3.5 to 4. Effervesces in nitric acid and dissolves more slowly than calc spar. Yields quicklime when burnt. Occurs in extensive beds of various ages like limestone. It is used as a building-stone and in the manufacture of Epsom salts. It is difficult to distinguish from calcite without chemical analysis.

FELDSPAR, ORTHOCLASE, is composed of silica, 64.20; alumina, 18.40; potash or soda (lime), 16.95. Crystallized or in irregular masses. Opaque; usually flesh-red or white, or of various dull tints. Luster, glassy or pearly; fracture, irregular, but in some directions it splits with an even, glimmering cleavage face. Specific gravity, 2.3 to 2.8; hardness, 6. Before the blow-pipe it fuses with difficulty; is not touched by acids. Where found in sufficient quantity to be of industrial value, it is usually obtained from veins in granite or pegmatite. The minerals associated with feldspar are chiefly quartz and mica; while tourmaline and topaz also occur commonly. Feldspar is, to a limited extent, employed in the manufacture of glass, but the chief use for it is as a china glaze and as a glass-forming ingredient in the body of the porcelains.

One of the finest varieties of feldspar is that known as *Adularia*, from Mount Adula, near the St. Gothard Pass, where it is found redeposited from the rock mass in veins and cavities. It consists of silica 64, alumina 20, lime 2, and potash 14. *Moonstone* is another variety, with bluish-white spots of a pearly luster. *Sunstone* is another, with a pale yellow color with minute scales of mica. *Aventurine*, feldspar sprinkled with iridescent spots from the presence of minute particles of titanium or iron. The last three varieties are employed as gem-stones, being occasionally set in brooches, but are too soft for rings.

A beautiful variety of orthoclase known as *Amazon stone* occurs in large green crystals near Pike's Peak, in Colorado, in Siberia and elsewhere.

FLINT consists of silica, which in a very fine condition has been separated from the surrounding rock, and which, attracted to some organic or inorganic nucleus, and sometimes only to itself, has grown in successive layers or bands, often of different colors. *Hornstone* or *chert* is allied to flint, but it is more brittle and it takes its color—dirty grey, red, and reddish-yellow, green or brown—from the rocks in which it is found. It occurs in portions of sandstone rocks usually containing a little lime, the fine silica being seemingly collected into one spot.

FLUORSPAR, FLUORITE, consists of 48.7 per cent. of fluorine and 51.3 per cent. of calcium. Its usual mode of occurrence is massive and granular. It is also found as cubic crystals in vuggs or coating the walls of small fractures in the country rock. It is generally translucent, though rarely transparent; its color is white or light violet, blue, purple, and occasionally yellow; sometimes layers of different tints in the same piece. Luster, glassy. It breaks with smooth cleavage-planes parallel to the octahedral faces. Specific gravity, 3 to 3.2; hardness, 4. Before the blowpipe it is fusible with difficulty to an enamel. It is used in the manufacture of hydrofluoric acid, with which glass is etched, and also as a flux for copper and other ores. Sometimes it is employed for ornaments, especially massive pieces, they taking a high polish. It occurs in veins with lead and silver ores.

GRAPHITE, PLUMBAGO, BLACKLEAD, consists essentially of carbon, in mechanical admixture with varying proportions of siliceous matter, as clay, sand or limestone. It occurs in hexagonal crystals, but usually in foliated or massive layers. Color, steel-gray to bluish-black. Hardness very slight, 0.5 to 1. Soils the fingers, makes a mark upon paper, and feels greasy. The specific gravities of different kinds of graphite vary according to the content of foreign admixtures, but lie within the limits of 2.105 and 2.5857. Graphite is not affected by acids and strongly resists other chemical agents. It is largely used in the manufacture of pencils, crucibles, stove polish, and lubricants for heavy machinery. It is found in various parts of the world, chiefly in crystalline limestone, in gneiss and mica schists, frequently replacing the mica in the latter so that they become actual graphite schists. Two distinct varieties are noticed: The one fine-grained, or amorphous; the other foliated, or compounded of numerous little scales; sometimes also it appears as an impregnation of other rocks rather than as a distinct rock in itself. Geologically, it is confined to the oldest formations, and is usually, if not universally, associated with metamorphic action. The chief source whence the bulk of the mineral has for many years been derived is the Island of Ceylon. The soil and rocks of the island are almost everywhere impregnated with graphite, so that it may be seen covering the surface in the drains after a recent shower. The supply is practically inexhaustible, the mineral existing in such quantities in the gneiss rocks that, upon their decomposition, it is seen in bright silver-like specks throughout. Ceylon graphite is particularly remarkable for its purity, containing as it does very small proportions of siliceous ash.

Graphitiferous rocks of the Laurentian system are widely spread throughout Canada and some parts of the United States. The graphite in these rocks usually occurs in beds and seams varying in thickness from a few inches to 2 to 3 feet. Perhaps the most important and extensive of the Canadian deposits is that near the township of Buckingham, where the graphite occurs both in beds or veins or disseminated.

Considerable deposits of graphite are found in Chester County, Pennsylvania, Essex County, New

York, and near Sonora, California. In the latter place the lode from which the mineral is obtained runs about 4,000 feet in a N. E. and S. W. direction, and ranges from 29 to 40 feet in width. It is much broken up and mixed with the surrounding rock and earth to a depth of about 30 feet, but below this it is well defined between walls of sandstone and clay-slate. The lode is frequently divided by lenticular masses of clay-slate, from a few inches to several feet in thickness.

Close to the village of Ticonderoga, Essex Co., New York, graphite is obtained from a mountain, locally known as the Black-lead Mountain. The graphite beds are interstratified between gneissic rocks. The beds dip at an angle of 45°. The ore in them is chiefly of the foliated variety, and is mixed with gneiss and quartz in the beds in veins or layers from 1 to 8 inches in thickness, some of the deposits being richer than others. One of these has been followed to a depth of 350 feet. It is found of varying thickness and it opens out at times into pockets.

Graphite is said to occur in great purity in different localities in Albany Co., Wyoming, in veins from 1 foot 6 inches to 5 feet thick. At Pilkin, Gunnison Co., it occurs massive in beds 2 feet thick, but of impure quality. It is also found in the coal measures of New Mexico, in Nevada, in Utah, and in the Black Hills of South Dakota.

The value of graphite depends upon the amount of its carbon. To test the purity of graphite, pulverize and then dry at about 350° F. 20 grains of it; then place it in a tube of hard glass 4 to 5 inches long, half an inch wide, and closed on one end. Add twenty times as much dried oxide of lead and mix intimately. Weigh the tube and contents, and afterwards heat before the blow-pipe until the contents are completely fused and no longer evolve gases. Ten minutes will suffice for this. Allow the tube to cool, and weigh it. The loss in weight is carbonic acid. For every 28 parts of loss there must have been 12 of carbon.

Gypsum is a hydrous sulphate of lime, and is composed of sulphuric acid, lime and water. It occurs in prisms with oblique terminations, sometimes resembling an arrow-head. It is transparent or opaque, white or dull tinted, with a glassy, pearly or satin luster. Cleavage occurs easily in one direction ; specific gravity, 2.3 ; hardness, 2 ; can be readily cut with the knife. In the blow-pipe flame it becomes white and opaque without fusing, and can then be easily crumbled between the fingers. Nitric acid does not cause effervescence. It occurs in fissures and in stratified rocks, often forming extensive beds. When pure white it is called Alabaster ; when transparent, Selenite ; and when fibrous, Satin Spar. When burnt, gypsum loses its water and falls to powder. This powder, called Plaster of Paris, which is perfectly white when free from iron, possesses the property of reabsorbing the water lost, and in a very short time of assuming again the solid state, expanding slightly in so doing. It is this last property that renders plaster of Paris so valuable for obtaining casts. It is also used as a fertilizer.

INFUSORIAL EARTH is an earthy, sometimes chalk-like siliceous material, entirely or largely made up of the microscopic shells of the minute organisms called *diatoms.* It occurs in beds sometimes of great extent, sometimes beneath peat beds, and is obtained for commerce in Maine, New Hampshire, Massachusetts, Virginia, California, Nevada, Missouri. It feels harsh between the fingers and is of a white or grayish color, but often discolored by various impurities. Infusorial earth is used as a polishing powder, electro-silicon being the trade-name of one kind much used for polishing silver. It is also used for making soda silicate and for purposes of a cement. Being a bad conductor of heat, it is applied as a protection to steam boilers and pipes. It is also employed for filling soap.

LITHOGRAPHIC LIMESTONE. The only stone yet found possessing the necessary qualifications for lithographic work is a fine-grained homogeneous limestone, breaking with an imperfect shell-like or conchoidal fracture, and, as a rule, of a gray, drab or yellowish color. A good stone must be sufficiently porous to absorb the greasy compound which holds the ink, soft enough to work readily under the engraver's tool, yet not too soft, and must be firm in texture throughout and entirely free from all veins and inequalities. The best stone, and indeed the only one which has yet been found to fill satisfactorily all these requirements, occurs at Solenhofen, Bavaria. These beds are of Upper Jurassic age, and form a mass of some eighty feet in thickness. The prevailing tints of the stone are yellowish or drab.

In the United States materials partaking of the nature of lithographic stone have been reported from various localities, but it is believed all have failed as a source of supply of the commercial article, though it is possible that ignorance as to the proper methods of quarrying may in some cases have been a cause of failure.

MEERSCHAUM OR SEPIOLITE is a manganese silicate. When pure, it is very light; and, when dry, it will float upon water. It will be recognized by its property, when dry, of adhering to the tongue, and by its smooth, compact texture. It is generally found in serpentine, in which rock it occurs in nodular masses; but it is also found in limestones of tertiary age. It is of a snowy-white color and a useful substance when found in quantity, being much employed for the bowls of tobacco pipes, and for this purpose is mined in Asia Minor.

MICAS. These are silicates of alumina with potash, rarely soda or lithia, also magnesia, iron and some other elements. Always crystallized in thin plates, which may be split into extremely thin, flexible layers. Transparent in thin layers. Color, white, green, brown to black. Specific gravity, 2.7 to 3.1. Hardness, 2 to 2.5; very easily scratched with a knife. Before the blowpipe mica whitens, but is infusible except on thin edges. When it can be obtained in large sheets, it is very valuable. It is sometimes used in the place of window-glass on board ship, for stoves and for lamp-chimneys. The ground material is used as a lubricant and in making ornamental and fire-proof paint.

Biotite, or black mica, contains more magnesia than alumina. It is often present in eruptive rocks, especially some granites. *Muscovite*, or white mica, on the contrary, contains more alumina than magnesia, and as it also contains potash in small, but appreciable, quantities, it is sometimes called *potash mica*, and biotite *magnesian mica.* Muscovite is an important mineral to the tin miner, since it is always found in that class of granite in which tinstone occurs, and with quartz alone forms the rock called *greisen*, which is very generally associated with tin. The rock in which large sheets of mica are found is called by some geologists *pegmatite*, and has the same composition as granite itself, but the crystals are of a larger size.

NITRE OR SALTPETRE is white, inodorous, not deliquescent; at a red heat it is decomposed with evolution, first of oxygen. It has a cooling saline taste, a vitreous luster, a hardness of 2, and specific gravity of 1.9. It is readily soluble in water. Before the blowpipe it fuses easily on platinum wire, tinging the flame green.

Nitre occurs as a separate formation in the caverns of several limestone mountains in Ceylon, Calabria and elsewhere, as an efflorescence from the surface on the ground, especially in hot weather after rain, also in springs.

Chile saltpetre occurs in crystals and crystalline grains. Hardness, 1.5 to 2. Specific gravity, 2.1 to 2.3. Colorless or light colored. Transparent to translucent. Taste saline, cooling. Soluble in water; deflagrates in glowing charcoal, but less vividly than niter. It fuses before the blow-pipe, tinging the flame yellow. It is found in grains mixed with the sand, and associated with gypsum, rock salt, and Glauber's salt, occurring in many parts of the coast of Chile.

ROCK SALT has the character of ordinary table salt, but is more or less impure. Occurs in beds interstratified with sandstone and clays, which are usually of a red color and associated with gypsum. Specific gravity, 2 to 2.25, hardness 2 to 2.5. It contains 39.30 per cent. of sodium and 60.66 per cent. of chlorine, but most samples contain clay and a little lime and magnesia. The surface indications of rock salt are brine springs supporting a vegetation like that near the seacoast, also occasional sinking of the soil caused by the removal of the subterranean bed of salt by spring water. Rock salt is obtained by sinking wells from which the brine is pumped and evaporated in large pans, or by mining, the same as for any other ore.

Salt deposits occur in the strata of all ages, from the Silurian to those now forming. In North America a chain of mountains extends along the west bank of the river Missouri for a length of 80 miles by 45 in breath, and of considerable height.

These mountains consist largely of rock salt. The same formation extends into Kentucky, where the deposits are called "licks," because of the licking of the rocks and soil by the herds of wild cattle that once roamed there. In Michigan, in the neighborhood of Marine City, a well was sunk to a depth of 1,633 feet, when a deposit of rock salt was entered and penetrated to a depth of over 1,500 feet without the tools passing through it. The deposit seems to increase in thickness, but it is reached at an increasing depth as it trends in a southwesterly direction by Inverhuron, Kincardine, and Warwick.

An extraordinary superficial deposit of rock salt occurs in Petite Anse Island, parish Iberia, Louisiana. The island is about two miles in diameter, and the salt deposit on it is known to extend under 165 acres. It is covered with 16 feet of soil. It has been proved to a depth of 80 feet. The salt occurs in solid masses of pure crystals, and it is taken out by blasting.

The bulk of the manufactured salt in North America is obtained from brine springs. Valuable and productive springs are worked in the Syracuse and Salina districts, New York, and in Ohio. Some of these arise from a red sandstone whose geological place is said to be below the coal measures.

Rock salt has been discovered in Nevada. The southern termination of the deposits is about seven miles from the uppermost limit to the navigation of the Colorado river. Some of the specimens are sufficiently pure and transparent to allow of small print being read through them. In the same state there is an interesting salt lake, the water of which contains about two pounds of salt and soda to every gallon. It is several hundred feet deep. Soda and salt have been obtained from this lake for several years by natural evaporation. The water is pumped into tanks at the beginning of the summer season. It is left in these tanks during the warm summer months until the frost sets in. When the first frost comes the soda is precipitated in crystals. The water is then drained off into a large pond, where slow evaporation goes on, and a deposit of common salt is obtained.

The famous salt mine of Wieliezka, near Cracow, in Galicia, has been worked since the year 1251, and it has still vast reserves of the mineral.

SLATE is an argillaceous shale easily recognized by its cleavability, and varies in color from light sea-green and gray to red, purple and black. It has been formed by sedimentary deposits, and now constitutes extensive beds in the Silurian formation.

SULPHUR. Native sulphur or brimstone occurs crystallized or massive in volcanic regions and in beds of gypsum. Color, yellow; luster, resinous; specific gravity, 2.1; hardness, 1.5 to 2.5. It is fusible and burns with a blue flame and well-known odor. It is frequently found contaminated with clay or pitch. Italy and Sicily together furnish the greater part of the sulphur of commerce, the major portion coming from Sicily. The most important deposits of brimstone in the United States are found in Utah at Cove Creek, 22 miles from Beaver, while there are other deposits at a point about 12 miles southwest from Frisco. Large deposits of sulphur are known to exist in Wyoming, California and Arizona, but none of them is at present available for working at a profit.

A scarcity of brimstone has led to greater attention being paid to native pyrites, especially for the manufacture of sulphuric acid. While there are many deposits of iron pyrites in most parts of the world, they are not always accessible to mining at a low cost, and situated so that transportation of the low-valued product is easy and cheap. These primary conditions are essential to the industrial usefulness of any pyrites bed. The production of pyrites on a commercial scale in the United States is at present confined to Massachusetts and Virginia.

As a rapid and accurate method of estimating the sulphur available to the acid-maker in a sample of pyrites, J. Cuthbert Welch has published the following in the *Analyst:* Place 5 grammes of pyrites in a porcelain boat in a combustion tube, heat to redness, pass oxygen* over till combustion is complete, and absorb the gas formed in about 30 cubic centimeters of a solution of bromine in a mixture of equal parts of hydrochloric acid (specific gravity,

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*The oxygen should be prepared from pure potassium chlorate in glass vessels, or at any rate in an iron one, kept especially for the purpose, and the gas should be passed through a strong solution of potash in the bulbs, through a U-tube containing calcium chloride, and lastly, either through another calcium chloride tube or, preferably, over phosphoric anhydride before use.

1.1) and water, in potash (or preferably nitrogen) bulbs. Wash out the solution into a beaker, boil, precipitate by boiling solution of barium chloride, cool, filter and wash, dry and ignite the barium sulphate.

TALC OR SOAPSTONE, called STEATITE when massive, is a hydrated silicate of magnesia, from which the water is only driven off at a high temperature. It usually occurs in foliated laminar masses, like mica, but differs from the latter in not being elastic, in being softer and readily marked by the nail, in yielding an unctuous-feeling powder, and in not containing alumina as an essential ingredient. The laminated variety of talc has been adopted by mineralogists as representing 1 in the scale of hardness; its specific gravity is 2.7. The color is white, sometimes tinged with green, and the luster pearly. When heated in a matrass, it undergoes no appreciable loss of water or transparency ; when subjected to a high heat it exfoliates and hardens, but does not melt. Acids have no effect upon it, either after or before ignition. Talc is quarried and employed for various purposes. It is mixed with clay to increase the translucency of the finished porcelain ; when powdered it is used for diminishing the friction of machinery, and as a basis for colored cosmetic powders. Pencils are made from it for removing grease from silks and cloths, and for marking out the patterns of clothes.

CHAPTER XIV

GEMS AND PRECIOUS STONES.

Although many varieties of gems and precious stones are known to occur in the United States, systematic mining for them is carried on only at a few places, and the annual output is still very small in comparison with the prospective extent of the field. Not many persons are familiar with the appearance of gem stones in their native state, so that while quartz pebbles are often mistaken for rough diamonds, garnets for rubies, ilmenite for black diamonds, etc., on the other hand it is quite probable that many valuable occurrences have escaped notice.

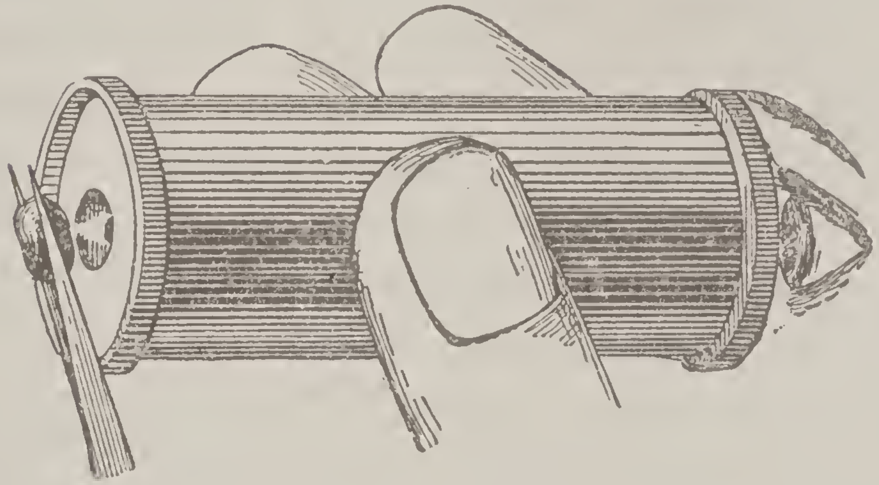
Many of the gems are of comparatively little value, so that it is not always profitable to pay much attention to their discovery unless the quantity of them is great, for the cost of polishing is an important factor in assigning a value to them. Many colored transparent and translucent kinds of quartz colored by metallic oxides fall under this category. But it is so easy to prospect a stream, for instance, in a country of crystalline, igneous, or metamorphic rock, that a search for precious stones and gems of all kinds should be made much more frequently than is usually the case. With regard to the precious varieties, it is well to bear in mind that the valuable specimens may be associated with all sorts of worthless specimens, all of which, though impure in quality, may really be sapphires, spinels, chrysoberyls, tourmalines, zircons, etc.

Though many are translucent rather than transparent, many dark in outward appearance, and all water-worn, more or less, and with surfaces not at all glass-like, and the majority not apparently transparent or translucent unless held up to the light, yet here and there a good specimen may be found. For all that, a knowledge of the general appearance of such impure specimens is probably of as much importance as that of the good ones, for the prospector who comes across them has an encouragement in his search for valuable ones.

For some reason or other, diamonds and gold are often found in the same alluvial deposit, and auriferous beds should therefore be examined for this precious stone. The specific gravity of the diamond —higher than that of quartz or most pebbles—and that of gold are so very different that it does not follow that, for instance in a stream bed, these two minerals are always found close together.

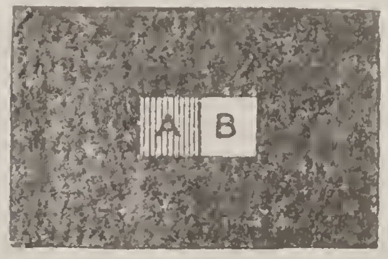
Whilst certain characteristics of precious stones, such as hardness and specific gravity, given in the table later on, may be useful to the prospector, yet it is not always an easy matter to distinguish a certain precious stone from one which may be similar in appearance though perhaps of much less value. To assist any one in doubt, and in many instances to settle the point, the dichroiscope, Figs. 64 and 65, is very useful, taking for granted that some practice with the various kinds of translucent or transparent stones of various shades and colors has been acquired. The dichroiscope is in the shape of a cylinder 2 inches long and 1 inch in diameter, and thus easily carried about.

Fig. 64.



EXAMINING A GEM THROUGH THE DICHROISCOPE.

Fig. 65.



When a transparent or semi-transparent stone is examined through the dichroiscope, the color of the square A is different or of a shade different to that of the square B when dichroism exists.

Placing by means of tweezers a translucent or transparent stone close to the one end of the instrument where the two square images are seen when the instrument, held skywards, is looked into, and turning it about in various directions, and at the same time turning the instrument round, the observer will notice whether the color of the two squares is one and the same. If the stone is amorphous, such as flint, obsidian, etc., or crystallizing according to the cubic system, such as diamond, spinel ruby, garnet, etc., the two squares will be of the same color to that of the other when the colored stone is examined in certain directions, though it may be the same in certain others.

Thus a true ruby, which affords two shades of pink, can be distinguished from a spinel ruby or garnet without dichroism, or from a pink tourmaline, which gives two colors but somewhat differently to those of ruby ; so, too, a sapphire, which gives a blue shade in one square, and a light shade of color without any shade of blue in the other, can be distinguished from an amethyst, which affords two shades of purple, or from a blue spinel, which does not show any twin coloration, or from an iolite (or water sapphire), in which the coloration is of its own kind.

A tourmaline, either the green or brown variety, can be recognized directly by the color of the one square being quite dark compared to that of the other.

An emerald affords two distinct shades of green (one bluish), easily remembered ; so a green garnet, which does not show twin colorations, cannot be mistaken for it.

With the dichroiscope and two or three minerals, such as the sapphire, topaz and rock crystal to test for hardness and a little practice, and a slight knowledge of the crystallization of minerals which, though frequently found water-worn, not uncommonly retain traces of the original crystal edges and faces, the prospector can examine his specimens with a very much easier mind than he would without them. Frequently neither the hardness of a gem stone nor its behavior before the dichroiscope is sufficient to enable its identity to be reliably known. In such a case its specific gravity may settle the question, but this may require a more accurate balance than the prospector may possess, and the advice of an expert may be necessary.

Diamond. Diamonds are usually met with in alluvial soil, often on gold-diggings. In some Indian fields a diamond-bearing conglomerate occurs which is made up of rounded stones cemented together, and lies under two layers, the top one consisting of gravel, sand and loam, the bottom one of thick clay and mud. In the neighborhood of Pannah, between Sonar and the Son river, diamonds are found in ferriferous pebble conglomerate and in river alluvium. The most beautiful crystallized specimens are, however, found on the west side of the Nalla-Malla mountains, near Banganpally, between Pennar and Kistnah, in a diamond-bearing layer between beds of primitive conglomerate.

In Borneo the diamond is found associated with magnetic iron ore, gold and platinum, in alluvial deposits consisting of serpentine and quartz fragments as well as marl.

In Brazil the province Minas Geraës is rich in diamonds, the most important occurrence being at Sao Joao do Barro, where they are found in an entirely weathered talcose slate. In other parts of the same country the diamond is also obtained from a conglomerate of white quartz, pebbles and light-colored sand, sometimes with yellow and blue quartz and iron sand. In the province of Bahia occurs a substance known as *carbonado* or *black diamond.* It is an allotropic form of carbon closely related to the diamond, and is found in small, irregular, crypto-crystalline masses of a dark gray or black color. Although its density is not so great as that of the diamond, it is very much harder; in fact, it is the hardest substance known. At first it was used only in cutting diamonds, but since the invention of the core-drill for boring in rocks it has found a greatly extended use, and is now employed for the so-called "diamond crown" of this drill. The *bort* of the South African mines finds a similar industrial application, being worthless as a gem.

In South Africa the diamond occurs associated chiefly with garnet and titanic iron ore, as well as with quartz opal, calcareous spar, and more rarely with iron pyrites, bronzite, smaragdite and vaalite. According to St. Meunier the South African diamond-bearing sands are composed of an exceedingly large number of constituents, eighty different varieties of minerals and rocks having been found in them. Of minerals occur, for instance, diamond, topaz, garnet, bronzite, ilmenite, quartz, tremolite, asbestus, wallastonite, vaalite. zeolite, iron pyrites, brown iron ore, calcareous, spar, opal, hyalite, jasper, agate, clay. Of rocks are found, serpentine, eklogite, pegmatite and talcose slate. At the Kimberley mine, which more or less represents others in the neighborhood, the diamond-bearing ground forms a "pipe" or "chimney" surrounded by formations totally different from the payable rock. The encasing material is made up of red sandy soil on the surface, underneath which is a layer of calcareous tufa, then yellow shale, then black shale, and below this, hard igneous rock. The diamond-bearing ground consists of "yellow ground" (really the decomposed "blue ground"), which is comparatively friable; and deeper down the "blue ground" (hydrous magnesian conglomerate), which needs blasting by dynamite. The "blue ground" is of a dark bluish to a greenish-gray color and has a more or less greasy feel. With it are mixed portions of boulders of various kinds of rock such as serpentine, quartzite, mica-schist, chlorite-schist, gneiss, granite, etc. All this "blue ground" has evidently been subjected to heat. The gems are in the matter which binds these rocks, not in the rocks themselves.

Diamonds are also found in the Ural, various parts of Australia, New Zealand and in the United States. In the latter country diamonds have frequently been found since 1850, when the first one was discovered in the alluvial workings for gold in California. Since this time they have been found at intervals both in the recent alluvium and also in the ancient detritus covered by lava flows. The California localities include, in Amador Co., Volcano, where an association with garnet and chalcedony is seen; Fiddletown, with gold and lead and copper ores; in Butte Co., the Cherokee ravine, with zircon, chromite, etc.; in Dorado Co., at Forest Hill. In North Carolina, at Brindletown Creek in Rutherford Co.; at Portis Mines, in Franklin Co., with gold in placer workings; at Dysortville, in M'Dowell Co. Diamonds have also been found sparingly in Idaho and Oregon, and in Hall Co., Georgia. The garnet districts of Arizona and New Mexico may also be looked upon as favorable for the occurrence of this gem. One stone of 23¾ carats was found at Manchester, Virginia in 1855. It is of interest to note that much of the rock of North Carolina consists of a schistose rock, and that a flexible sandstone similar to the itacolumite of Brazil is also found. Many experienced geologists hold to the opinion that since so many associations of the diamond are present in North Carolina, they have hopes of their being eventually found there. In Wisconsin diamonds have been found in glacial deposits with quartz, garnet, ilmenite and magnetite.

The natural surface of the diamond is often unequal; its sides are lined, somewhat convex, and generally appear dulled, or as they are commonly called, *rough*, by the evident action of fire. The diamond breaks regularly into four principal cleavages. It does not sparkle in the rough, and the best test is its hardness and its becoming electric when rubbed before polishing. The color of the diamond varies through all tones of the color-scale, from absolute colorless through all shades of yellow, red, green, blue to intense black. Some colorless diamonds acquire on heating a reddish shade, which disappears on cooling.

The occurrence of diamonds of different colors affords a remarkable illustration of what has been said about the colors of minerals. As pure carbon, diamond is colorless, as are also the microscopic diamonds artificially produced by an electric current, but in nature the stones are of different colors, which are imparted to them by a very small proportion of foreign matter. The yellow and gray tints decrease the value of the diamond, but red, blue and green varieties, on the contrary, are so rare that when diamonds are so colored their value is considerably greater than if perfectly colorless. For instance, the best blue diamond known is estimated at double the calculated value of a good colorless diamond of the same size.

In Borneo a kind of black diamond is found which is very highly prized in consequence of its exceptional luster and rarity. It is even harder than the ordinary diamond.

The specific gravity of the pure diamond varies from 3.5 to 3.6 ; that of the black diamond is from 3.012 to 3.255.

One of the most beautiful qualities of the diamond is its power of refraction; that of water is 0.785; that of the ruby, 0.739; that of the rock crystal, 0.654; that of the diamond, 1.396. The refraction of the diamond is single in the entire crystals; when broken it possesses double, but imperfect, refraction in the thin layers.

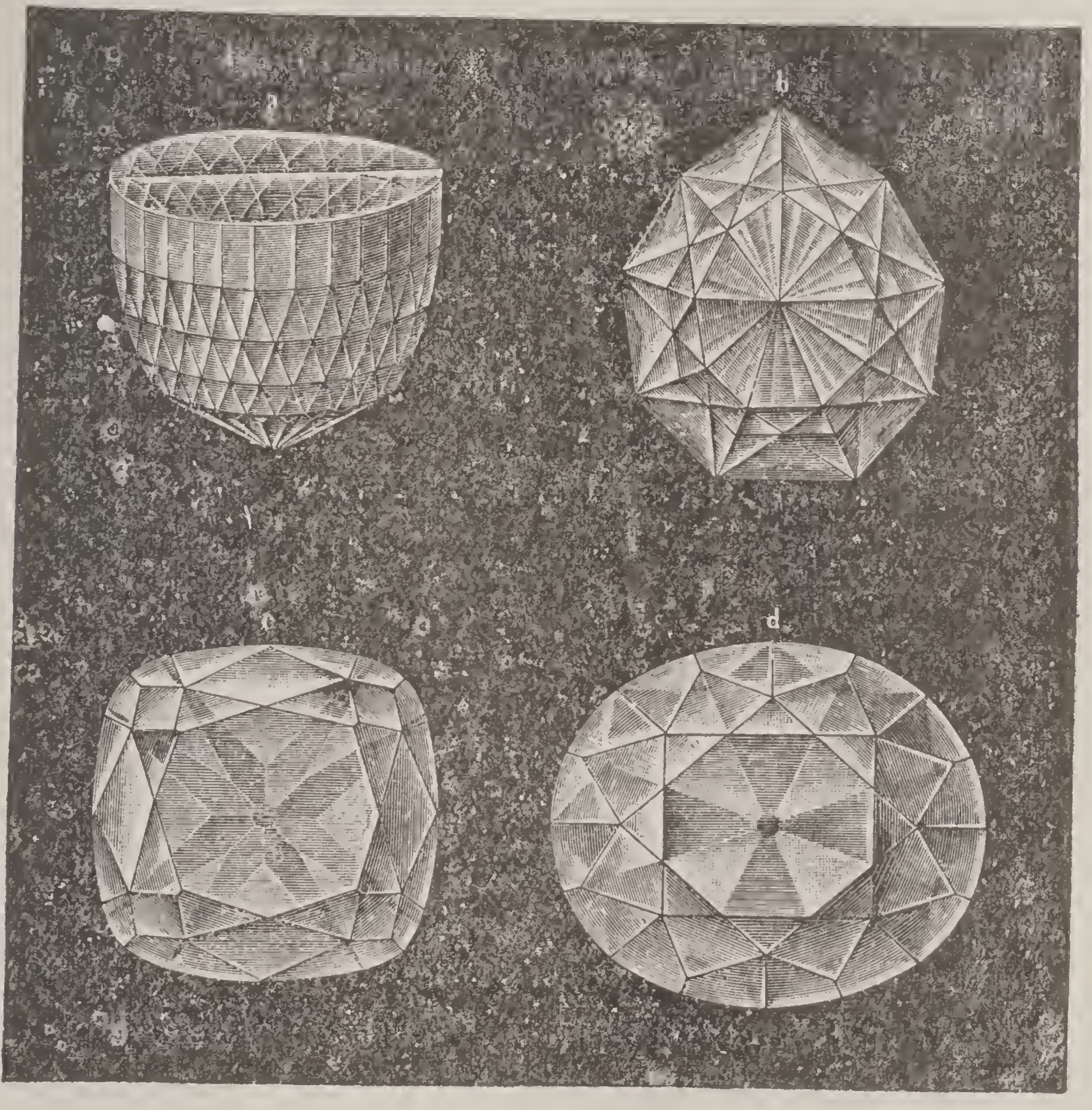
The value of the diamond is dependent on its color, its size, and the finish given to it by working. Perfectly colorless stones bring the highest price, and next, stones with a reddish, greenish and bluish shade, which, however, are quite rare. Yellowish diamonds are of less value, the price paid for them being the lower the more the yellow color plays into brown.

Of the largest diamonds each has its own name and its own history. Of these may here be mentioned the *Koh-i-noor or mountain of light*, Fig. 66, *d*.

It passed from the Mogul Empire at the conquest of it by the Persians in 1739. Later it was in the possession of Runjeet King and, on the annexation of the Punjab it passed to the East India Company, by whom it was presented to Queen Victoria in 1850. It originally weighed 186½ carats, but was recut in 1852, and in its present state weighes 106 $\frac{1}{16}$ carats.

The Orlof, Fig. 66, *a*, weighs 194¾ carats, and is as large as half a pigeon's egg. It is claimed to have formed an eye for an idol in a Brahmin temple at Seringham, to have been stolen by a French soldier, and passed by the hands of an English sea captain to Amsterdam, where it was bought for Catherine II of Russia by Prince Orlof; it now adorns the Imperial sceptre of Russia. It has been

Fig. 66.



supposed that a diamond know as the *Great Mogul* was divided into three stones of which the Koh-i-noor and Orlof are two. This diamond is said to have weighed 560 to 787½ carats in the rough; it is not definitely known what became of it.

The *Grand Duke of Tuscany or Florentine*, Fig. 66, *b*, is one of the most beautiful diamonds. It is a yellow diamond, and weighs 139⅘ carats. It belongs to the House of Austria. The *Pitt* or *Regent*, Fig. 66, *c*, is usually considered one of the finest and most perfectly cut stones in existence. It was found at the Partial Mines in India, and was bought by Governor Pitt for £20,400; later on it was bought by the French Regent for £80,000. It was stolen in 1792, but recovered, and still remains the property of the French nation. In the rough it weighed 410 carats; when cut it was 137 carats. The *Hope* diamond is of a rich sapphire blue with great fire and brilliancy. It weighs 44¼ carats. It is considered an unlucky stone, and has seemed to pursue to misfortune or the grave those who have possessed it. It came mysteriously out of the East and was acquired by Louis XIV of France. The gem was still in the crown of France when Louis XVI died by the guillotine amid the storms of the great revolution. Then the jewel vanished for a time, and it was not until 1830, that a London dealer, purchasing it from a stranger, sold it to the banker Henry Thomas Hope. The *Star of South Africa* was found in 1869 in river diggings. In the rough it weighed 83½ carats; cut as a brilliant it weighs 46½ carats. The *Victoria* is also a South African stone; its weight in the rough was 457½ carats. In 1893 a stone 917¾ carats was found at the Jagersfontein Mine. From it a perfect brilliant of 239 carats was cut, and this is known as the *Excelsior* or *Jubilee* diamond. A stone of 655 carats was found at the same time in 1895.

But by far exceeding all the specimens previously found is the diamond found at New Premier Mine, near Victoria, South Africa, January 25, 1905. It was found in the yellow ground, about 18 feet below the surface. It was named the *Cullinan* after the chairman of the Premier Company. Its weight is 3,024¾ carats, and in size it may be roughly compared with a man's tightly-clenched fist, its longest measurement being rather over four inches. This famous diamond has been presented to King Edward VII of England.

CORUNDUM. This mineral species includes some of the most important precious stones. The blue crystalline variety is called *sapphire*, the red, the *ruby*; the light-yellow *Oriental topaz*, the bright-green *Oriental emerald*, and the bright-violet *Oriental amethyst*. One variety exhibits a six-rayed star inside the prism, and is called the *asterias*.

Considerable activity in corundum mining has sprung up within the last few years, and several new occurrences of corundum in quantity have been brought to light, those of special note being in Ontario, Canada, where the corundum occurs in a syenite, and in North Carolina and Georgia, where it occurs in a gneiss or a quartz-schist.

The corundum localities in the United States are, with the exception of those in Montana, Colorado and California, limited to the Appalachian region, the mineral having been found at various points throughout nearly its entire length. The emery vein or bed at Chester, Mass., has furnished a large quantity of the mineral, but the chief American source is a narrow section of the southern portion of the Appalachian region extending from southwestern North Carolina into Georgia.

Corundum was formerly regarded as occurring sparingly in nature, and in only a few types of of rocks, but it is now known to occur rather widely, and instead of being in quantity in the basic magnesium or periodite rocks only, it has been found in abundance in syenites, in gneisses and in schists. Although occurring in many of the crystalline rocks it has been observed as a rock constituent in only a few of them. In some cases it is an original constituent of the rock, and in other cases it has been formed later, during the process of metamorphism.

Corundum, as it is mined for abrasive purposes, occurs as sand, crystal, or gravel, and block corundum. Sometimes all three types are found in the same deposit. The sand corundum consists of small grains or fragments of the mineral scattered through the vein. The crystal corundum consists of crystals up to three inches in length. The block variety often occurs in masses of almost pure corundum from 10 to 1000 pounds in weight. Again, it occurs in large masses intimately associated with hornblende, feldspar, etc., making a rock which is tough and is difficult to work. Frequently, the only way to break the masses is to build fires over them, and then suddenly to cool them by pouring water upon them.

It is the hardness of corundum which makes it of so great a value as an abrasive. Next to the diamond it is the hardest mineral known, having a hardness of 9 while the diamond has a hardness of 10. Specific gravity 3.9 to 4.2. Luster, glassy, sometimes pearly. Fracture, uneven or conchoidal. Infusible before the blowpipe, and not affected by acids nor by heat. It is almost pure alumina containing but a small percentage of other constituents, principally silica, water and ferric oxide.

Emery is a granular impure form of corundum consisting of a mechanical admixture of corundum and magnetite or hematite. It is of great commercial value as an abrasive, though now carborundum is displacing it in this use to a large extent. Until recently the only emery known to occur in the United States was that at Chester, Mass., and Peekskill, N. Y., but it has now been found in North Carolina in a very promising prospect. The chief foreign sources of emery are the Greek island of Naxos and Asiatic Turkey.

Sapphire. This is the blue variety of corundum in its purest crystalline state. Its general composition is alumina 92, silica 5.25, oxide of iron 1.0. The color most highly valued is a highly transparent bright Prussian blue. More frequently the color is pale blue, passing by paler shades into perfectly colorless varieties. The paler varieties are frequently marked by dark blue spots and streaks which detract from their value. But these paler varieties lose their color when subjected to great heat, a fact which has some times been taken advantage of by unscrupulous dealers to pass them off as diamonds.

The principal form of the sapphire is an acute rhomboid, but it has many modifications and varieties. On being broken it shows a conchoidal fracture, seldom a lamellar appearance.

In the United States there are two areas of importance as producers of sapphires. One is the Culsagee Mine in Macon County, North Carolina, where the mineral occurs with spinel, tremolite, tourmaline, magnetite, rutile, chromite, olivine and mica, in gneiss. The other district is in Montana. Near Helena is a glacial moraine known as El Dorado Bar and in this sapphire has been found with topaz, garnet, cassiterite, quartz and cyanite. In addition it has been found *in situ* in Montana in a dyke with pyrope, at Yago Creek, near Judith River, of a fine corn-flower blue. At Santa Fe, New Mexico, in southern Colorado and Arizona, sapphires occur in the sand associated with peridot, pyrope and almandine garnet.

Ruby. The ruby is the red variety of corundum and in composition varies from almost pure alumina to a compound containing 10 to 20 per cent. of magnesia, and always about 1 per cent. of oxide of iron. The ruby is subdivided into several varieties according to color, which in its turn is affected by mineral composition, *spinel ruby* occurring in bright red or scarlet crystals, *rubicelle* of an orange-red color, *bala ruby* rose red, *almandine ruby* violet, *chlorospinel* green, and *pleonast* is the name given to dark varieties.

The crystals are usually small and when not defaced by friction they have a brilliant luster, as has also the lamellar structure, with natural joints which it shows on being broken. It exhibits various degrees of transparency. The color most valued is the intense blood red or carmine color of the spinel ruby. When the color is a lilac blue, the specimen was formerly known as the *Oriental amethyst*, and was regarded as a connecting link between the ruby and the sapphire. In the United States ruby is found in various localities. It occurs in gneissic and metamorphic rocks and in granular limestone. In North Carolina ruby of gem quality is found at Corvee Creek, a tributary of the Little Tennessee River in a decomposed garnetiferous basic rock. Many much-weathered specimens have been found, which have led to the conclusion that rubies of very large size have been formed here. The associated minerals are garnet, spinel, monazite, rutile, ilmenite, different micas, staurolite, gold, etc., and the rubies often show inclusions sometimes so minute as to give the gem a " sheen."

Ruby ranks above diamond in point of value for good stones of rich deep color. It has been stated that $100,000 has been paid for a very fine ruby of $38\frac{9}{16}$ carats.

The garnet is sometimes mistaken for the East Indian ruby, which is the most precious variety, but the garnet is *isometric*, and even when cut and mounted may be distinguished from the oriental ruby by the superior hardness of the ruby, the latter being next to the diamond, while the garnet is only as hard as quartz, or not quite so hard, So that a garnet of the most precious kind if worn will, under the strong lens, show the lines of wear, especially on the edges, which are absent in the true oriental ruby.

TOPAZ is composed of silica, alumina and fluorine. The fluorine may be detected before the blow-pipe in the open tube by powdering a little of the topaz and mixing it with a small quantity of microcosmic salt (a salt of phosphorus). The heat of the blow-pipe will liberate the fluorine aud its strong pungent smell, as well as its corrosion of the tube will prove its presence. With the cobalt (nitrate) solution on charcoal, it gives a fine blue color in proof of alumina. This is the best test of the topaz, as the color of the mineral is not always the same, nor is it always perfectly transparent.

The topaz crystallizes in the orthorhombic section of the hexagonal or fourth system. The finest are generally in prismatic form, showing a flat plane at the extreme end, even when the end of the crystal has several inclined faces. The crystals break easily across with smooth brilliant cleavage. Transparent or semi-transparent. White, yellow, greenish, bluish, pink. Luster glassy, specific gravity, 3.5. Hardness, 8. Scratches quartz; is scratched by sapphire. Infusible, but often blistered and altered by heat. When smooth surfaces are rubbed on cloth they become strongly electric, and can attract small pieces of paper, but rough surfaces do not show this. The brilliant cleavage of topaz distinguishes it from tourmaline and other minerals. Topaz occurs in gneiss or granite with tourmaline, mica, beryl; also cassiterite or tin-stone, apatite, fluorite. The white topaz resembles the diamond, but unlike the latter it can be scratched by sapphire. The pale blue variety is of value for cutting into large stones for brooches; specimens are occasionally found of several pounds weight. Topaz of a beautiful sherry color occurs in Brazil. Specimens of this when heated become pink, when they are known as burnt topaz. The yellow varieties are cut as gems. Although not very valuable, they are quite brilliant and look very well.

Topaz is usually found, when *in situ*, in attached crystals in cavities in granite. It is also frequently associated with beryl, tourmaline and feldspar. Topaz is resistent to most forms of weathering, and hence is often found in rolled pebbles in the detritus of granite and other rocks.

In the United States, yellow crystals are found in Connecticut, blue ones in granite in Maine, colorless ones in Utah, and both colorless and pale blue occur with Amazon stone at Florissant in the Pike's Peak district in Colorado.

BERYL OR EMERALD is composed of silica, alumina and beryllium or glucinum. It is almost always found in distinct crystals, and usually in forms easy to recognize. The crystals are hexagonal prisms, usually green, transparent or opaque. Luster, glassy. Fracture, uneven. Specific gravity, 2.7. Hardness, 7 to 8. Infusible or nearly so, but becomes cloudy by heating. Occurs in granite rocks with feldspar and quartz. Valuable for jewelry when transparent and rich grass-green (emerald) or sea-green (aquamarine).

Both emerald and aquamarine are found in Alexander Co., North Carolina. Green and golden beryl occur in Oxford Co., Maine, and beryl of a sapphire blue is found at Royalston in Massachusetts. Emerald also occurs at Haddam in Connecticut. In Colorado, on Mount Antero, very fine aquamarines are found associated with phenacite.

A productive emerald mine is that of Muso, in New Granada, Mexico. The emerald occurs in veins and cavities in a black limestone that contains fossil ammonites. The limestone also contains within itself minute emeralds and an appreciable quantity of glucina. When first obtained the emeralds from this mine are soft and fragile; the largest and finest emeralds could be reduced to powder by squeezing and rubbing them with the hand. After exposure to the air for a little time they become hard and fit for the jeweler's use.

Phenacite is a silicate of beryllium or glucinum. Its hardness is about the same as topaz, and its specific gravity 3.4 to 3.6. It occurs in glassy rhombohedral crystals, and its hardness, beautiful transparency and color make it valuable for cutting as a gem, since it is capable of extreme polish.

Phenacite has been found at Pike's Peak, Colorado, in crystals of sufficient size and quality to furnish fair gems. It also occurs at Topaz Butte with topaz and Amazon stone in granite; also at Mount Artero, in Colorado with quartz and beryl.

Zircon is composed of silica and zirconia. It is found in square prisms terminated by pyramids, and in octahedrons, but often also in pebbles and grains. Transparent or opaque. Wine or brownish red, gray, yellow, white. Luster, glassy; fracture, usually irregular, but in one direction it can be split so as to exhibit a smooth even cleavage-face having an adamantine luster like the diamond. Specific gravity, 4.0 to 5.0; hardness, 7.5; scratches quartz, is scratched by topaz. Infusible; the red varieties, when heated before the blow-pipe, emit a phosphorescent light, and become permanently colorless. Zircon occurs in syenite, granite, basalt. In some regions it occurs in the rock so abundantly that when the rock has been worn down by the weather, it is left unaltered in considerable quantities. It may then be obtained by washing the gravel in the manner of the gold miner. Clear crystals are used in jewelry, in jeweling watches, and imitation of diamond. It may be distinguished from the latter by its inferior hardness, and in not becoming so readily electric by friction. Fine crystals are obtained in New York and Canada; and good specimens also come from North Carolina and Colorado.

Garnet is composed of silica, alumina, lime, iron, magnesia, manganese. It is found almost always in distinct crystals, and as these crystals are commonly isolated and scattered through the rock, it is not difficult to recognize them. The crystals are usually twelve-sided, having the form of a rhombic dodecahedron. They are transparent or opaque; generally red; also brown, green, yellow, black, white. Luster, glassy or resinous; fracture conchoidal or uneven; specific gravity, 3.5 to 4.3; hardness, 6.5 to 7.5; cannot be scratched with a knife. Fusible with more or less difficulty. Red varieties impart a green color to borax bead owing to presence of chromium. Garnet usually occurs in crystals scattered through granite, gneiss or mica-schist, also in crystalline limestone; with serpentine or chromite; also in some volcanic rocks. Fine-colored transparent varieties (carbuncle, cinnamon stone, almandine) are used in jewelry. The garnets found in Arizona, New Mexico and Southern Colorado, and there called "rubies," are as fine as those from any other locality, the blood-red being the most desirable. Very fine crystals of cinnamon stone, cinnamon garnet or essonite have been found in New Hampshire, Maine, and at many other points in the United States.

TOURMALINE is composed of silica, alumina, magnesia, boracic acid, fluorine, oxides of iron (lime and alkalies). It is found in prisms with three, six nine or more sides, furrowed lengthwise, terminating in low pyramids. Commonly black and opaque, rarely transparent, and of a rich red, yellow, or green color. Luster glassy ; fracture uneven ; specific gravity, 3.1 ; hardness, 7 to 8 ; cannot be scratched with a knife. When the smooth side of a prism is rubbed on cloth it becomes electric and can attract a small piece of paper. Tourmaline occurs in granite and slate. Only the fine-colored transparent varieties, which are used as gems and for optical purposes, are of value. The principal source of tourmaline in the United States is the locality Mount Mica, at Paris, Maine. In Massachusetts, Chesterfield and Goshen yield good green tourmalines, and also a rose-red but opaque variety. Tourmaline is also found in New York. In California, at Mesa Grande, both the red and green varieties occur.

EPIDOTE is a silicate of alumina, iron and lime, but varies rather widely in composition, especially as regards the relative amounts of alumina and iron. It is usually found in prismatic crystals, often very slender and terminated at one end only ; they belong to the monoclinic system. Luster, vitreous; color, commonly green, although there are black and pink varieties. Epidote is found in many localities in the United States and in very large crystals ranging from brown to green in color, but as a rule the crystals are only translucent or semi-opaque, though some stones of considerable value and great beauty have been found in Rabun county, Georgia.

OPAL is composed of silica and water. It is never found in crystals; but only in massive and amorphous form. Fracture, conchoidal ; specific gravity, 2.2 ; hardness, 6 ; can be scratched by quartz and thus distinguished from it. It is infusible and generally milk-white. The most beautiful variety of opal is that called *precious opal*, which exhibits a beautiful play of colors and is a valuable gem. One kind of precious opal with a bright red flash of light is called the *fire opal*, and another kind is the *harlequin opal.* Common opal does not exhibit this play of colors, and it varies widely in color and appearance. *Milk opal*, as one variety is called, has a pure white color and milky opalescence, while *resin opal* or *wax opal* has a waxy luster and yellow color. *Jasper opal* is intermediate between jasper and opal; *wood opal* is petrified wood, in which the mineral material is opal instead of quartz. Opal is commonly met with in seams of certain volcanic rocks ; sometimes it occurs in limestone and also in metallic veins. Precious opal is rare in the United States, though some of high value is said to have been found in Creek Co., near John Davy's River, Oregon.

The precious opal found in Hungary occurs in fissures in a weathered andesitic lava with other forms of opal. Hungarian opals show the finest fire, and their colors deteriorate least with exposure.

In Mexico precious opal occurs in the State of Queretaro in volcanic rock and associated with other forms of opal. The colors are intense, but in larger patches than the Hungarian specimens show, and the colors do not change so much when the stone is moved.

Turquois is a hydrated phosphate of aluminium, containing also a little copper phosphate, which is probably the source of the color, which in the most precious variety is robin's-egg blue, and bluish-green in less highly prized varieties. It occurs only in compact massive forms, filling seams and cavities in volcanic rock. Specific gravity 3.127. Turquois has been found in the Holy Cross mining region, thirty miles from Leadville, Colorado, and of late years a number of mines have been opened in New Mexico, at Los Carillos and in Grant County. The latter mines produce stones having a faint greenish tinge, which is either due to a partial change or metamorphism, which has taken place while the turquois was in the rock, or it may be a local peculiarity. Turquois occurs also in Arizona and at a point in Southern Nevada. At the latter place it is found in veins of small grains in a hard shaly sandstone. The color of this turquois is a rich blue, almost equal to the finest Persian, and the grains are so small that the sandstone is cut with the turquois in it, making a rich mottled stone for jewelry.

Agate is found in almost every part of the world, and the difference of the constituent parts makes the specific gravity vary from 2.58 to 2.69. The agate, properly so called, is naturally translucent, less transparent than crystalline quartz, but yet less opaque than jasper. It is too hard to be even scratched by rock crystal. It takes a very good polish. It is never found in regular forms, but always either in nodules, in stalactites, or in irregular masses *Eye agates* consist of those parts of the stone in which the cutting discovers circular bands of very small diameter arranged with regularity round one circular spot. These circles are frequently so perfect that they appear to be traced by the compass. The first round is white, the second, black, green, red, blue or yellow; most rare are those whose circles are at equal distance from the center. *Moss agate* contains brown-black, moss-like, or dendritic forms distributed rather thickly through the mass. These forms consist of some metallic oxide (as of manganese). Of all the American stones used in jewelry there is no other of which so much is sold as the moss agate. The principal sources of supply are Utah, Colorado, Montana and Wyoming.

CHALCEDONY is a semi-transparent variety of quartz of a waxy luster and varying in color from white through gray, green and yellow to brown. It is translucent or semi-transparent. It occurs in stalactite, reniform or botryoidal masses which have been formed in cavities in greenstones and others of the older rocks. Into these cavities, as into miniature caverns, water-holding siliceous matter has penetrated and deposited its solid contents, consisting almost exclusively of silica tinged by the presence of other minerals. Some of these cavities are several feet in diameter, and besides the coloring of the encircling mass there are often, in the interior of the concretions in them, cavities or central nuclei which contain sometimes as many as twenty-four different substances, as silver, iron pyrites, rutile, magnetite, tremolite, mica, tourmaline, topaz, with water, naphtha, and atmospheric air.

Carnelian is chalcedony colored by the oxide of iron hematite; it is sometimes called *sard.* It has the same properties as chalcedony and occurs either as an ordinary agate, or in fissures as vein agate. Although of wide distribution, only two localities, both in India, are known. The name carnelian was given to the stone on account of its flesh color.

Chrysoprase is a variety of chalcedony colored green by oxide of nickel. In a warm dry place its color is destroyed, but it can again be restored by keeping it damp.

Jasper is quartz rendered opaque by clay, iron and other impurities. It is of a red, yellow or green color. Sometimes the colors are arranged in ribands, or in other fantastic forms. It is used for ornamental work.

Wood Jasper is a fossil wood silicified. It is found at Chalcedony Park, Arizona, and Yellowstone Park.

Bloodstone or Heliotrope is green jasper, with splashes of red resembling blood spots.

Rock crystal is pure, transparent, colorless quartz, and is found at a great many localities in the United States. In Herkimer County, at Lake George, and throughout the adjacent regions in New York state, the calciferous sandstone contains single crystals, and at times cavities are found filled with doubly terminated crystals, often of remarkable perfection and brilliancy. These are collected, cut and, often uncut, are mounted in jewelry and sold under the name of "Lake George diamonds."

AMETHYST is a transparent variety of quartz of a rich violet or purple color due to the oxide of manganese which it contains. It crystallizes in the form of a hexagon, terminated at the two heads by a species of cone with six facets. These crystals are often in masses, and the base is always less colored than the top. Amethysts are generally found in metalliferous mountains, and are always in combination with quartz and agate. They occur in many localities in the United States, for instance, near Greensboro, in North Carolina, and in the districts around Lake Superior, especially in the northwest, but not in so fine or large specimens as in Ceylon or Siberia.

ROSE QUARTZ is pink, red, and inclining to violet-blue in color. It usually shows a vitreous luster, and small conchoidal fracture. It is as a rule not crystallized and but rarely transparent. It is liable to fade on exposure, though it may to some degree be restored by moistening the specimen.

YELLOW QUARTZ OR CITRINE OR FALSE TOPAZ occurs in light yellow translucent crystals. It much resembles yellow topaz in color, and hence is often called *Occidental topaz* or *Spanish topaz*. It is often set and sold for topaz, but may be distinguished from it by its want of cleavage and by being softer.

SMOKY QUARTZ OR CAIRNGORM varies in color from a pale sherry tint through all degrees of smoky brown to almost black. It occurs in crystals identical in all respects, except color, to rock crystal. Its commonest mode of occurrence is in fissures in granite and allied rocks, sometimes in spaces in the outer parts of a granite mass, probably due to shrinkage on consolidation ; in such cavities sometimes associated with beryl, topaz and crystals of feldspar.

ONYX and SARDONYX. A variety of quartz having a regular alternation of strata more or less even, and variously colored in black, white, brown, gray, yellow and red. When the onyx has one or two strata of red carnelian, it is more valued and takes the name of sardonyx. In the onyx the dark strata are always opaque and contrast strongly with the clear, which, when thinned, become almost translucent.

CAT'S EYE consists of a quartz mixed with parallel fibers of asbestus and amianthus. It is found in pebbles and in pieces more or less rounded ; it has a concave fracture ; is translucent and also transparent at the edges. It has a vitreous and resinous light. It is generally either green, red, yellow or gray. It marks glass. Its specific gravity is from 2.56 to 2.73. When exposed to a great heat it loses luster and transparency, but does not melt under the blowpipe unless reduced to minute fragments.

Many other gem stones are known to occur in the United States, and the following list compiled by Mr. George F. Kunz * is here given :

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* Mineral Resources of the United States, Washington, 1883.

List of gem stones known to occur in the United States.

Achroïte (tourmaline).
Agate (quartz).
Agatized wood (quartz).
Almandine (garnet).
Amazon stone (microlene).
Amber.
Amethyst (quartz).
Aquamarine (beryl).
Asteria.
Beryl.
Bloodstone.
Bowenite (serpentine).
Cairngorm (quartz).
Catlinite.
Chalcedony (quartz).
Chiastolite.
Chlorastrolite.
Chondroite.
Chrysolite.
Danburite.
Diamond.
Diopside (pyrozene).
Elæolite (nephelite).
Emerald (beryl).
Epidote.
Essonite (garnet).
Fléche d' amour (quartz).
Fluorite.
Fossil coral.
Garnet.
Grossularite (garnet).
Heliotrope.
Hematite.
Hiddenite (spodumene).
Hornblende in quartz.
Idocrase.
Indicolite (tourmaline).
Iolite.
Isopyre.
Jade.
Jasper.
Jet (mineral coal).
Labradorite.
Labrador spar (labradorite).
Lake George diamonds (quartz).
Lithia emeralds (spodumene).
Macle.
Malachite.
Moonstone (feldspar group).
Moss agate (quartz).
Novaculite (quartz).
Obsidian.
Olivine (chrysolite).
Opalized wood (opal).
Peridot (chrysolite).
Phenakite.
Prehnite.
Pyrope (garnet).
Quartz.
Rhodonite.
Rock crystal (quartz).
Rose quartz (quartz).
Ruby (corundum).
Rubellite (tourmaline).
Rutile.
Rutile in quartz (quartz).
Sagenite (quartz).
Sapphire (corundum).
Silicified wood (quartz).
Smoky quartz (quartz).
Smoky topaz (quartz).
Spinel.
Spodumene.
Sunstone (feldspar).
Thetis hair stone (quartz).
Thomsonite.
Tourmaline.
Topaz.

CHAPTER XV.

PETROLEUM, OZOCERITE, ASPHALT, PEAT.

CRUDE petroleum occurs only in the higher strata of rocks, it being never found in metamorphic rocks or crystalline formation. The Pennsylvania oil strata belong to the Devonian age, the anticlinal ridges being more favorable, it is said, than the synclinal ones. Sandstones saturated with oil form the reservoir, and this sandstone appears to be lenticular in form, and of varying texture, sometimes passing into conglomerates. The following facts appear to have been ascertained with reference to the Pennsylvania oil region: 1. The thicker the cover the more the oil, large accumulations being seldom found under light covers. 2. The coarser and more open the sand the more the oil. 3. The sandstones buried in shales must form the reservoir. 4. Underlying shales must exist which form the source of the oil.

In the Ohio district the Trenton limestone which is struck at a depth at from 1,100 to 2,200 feet below the surface, and is covered by 400 to 1,000 feet of shales, appears to be both the producer and reservoir. The principal accumulation both of oil and gas, are always the uppermost beds of the limestones and generally not more than 20 or 30 feet below its upper surface. The oil rock continues to a lower level but below the oil the rock is charged with brine containing unusual quantities of chloride of calcium and magnesium; when this is struck the well is frequently lost, although it is sometimes possible to plug it near the bottom. The limestone appears to be quite porous in parts, but this porosity seems to be due to dolomitization, the change having resulted in recrystallization, which has left innumerable microscopic cavities, in which the oil has accumulated.

In Kentucky petroleum occurs near the base of carboniferous limestone. In California it is found in strata belonging to the tertiary age, in Colorado and other western States, in those belonging to the cretaceous. and in North Carolina to those belonging to the triassic. In West Virginia it occurs in strata belonging to the coal measures. The Gulf Coastal Plain oil field of Texas includes a belt of country from 50 to 75 miles wide, bordering the Gulf of Mexico and extending from the vicinity of the Mississippi River in Louisiana westward about two-thirds of the distance across Texas. The oil rock is a crystalline dolomitic limestone, having an extremely porous structure; associated with it is considerable selenite or crystalline gypsum. Another abundant crystalline accessory mineral is native sulphur. In southwestern Alaska petroleum is known to occur at two localities—in the Enochkin Bay district and in the vicinity of Cold Bay. The Enochkin Bay oil seepages and so-called gas springs are in an area of shales and sandstones of Jurassic age, which are thrown up into a long anticline. At Cold Bay the rocks are chiefly Jurassic shales and sandstones.

Crude petroleum is a fluid of a dark color, sometimes black, and contains 84 to 88 per cent. of carbon, the rest hydrogen.

In prospecting for petroleum, the prospector, besides the customary outfit, should carry a stick provided with a long iron point. It is best to follow the courses of rivers and creeks upward, because the progress of the work will not then be impeded by the turbidity of the water. It is also advisable to make such excursions in the warm season of the year, because the oil exudes more freely at that time than in cooler weather, when especially heavy oils and mineral tar, or maltha, are readily converted into a butyraceous mass. It is also best to wait until the water in the rivers and creeks is low.

Observe whether the surface of the water exhibits variegated iridescent figures, this being especially the case in places where the water stands quietly or moves very little, for instance, in coves. Such an iridescent film, when found, may be due to petroleum, but also to iron oxides and similar substances. However, by touching the surface of the water, for instance, with the iron-pointed stick, a film of oxide of iron may be disintegrated in angular pieces and very small flakes, which can be moved in any direction, while oil films, when separated, reunite, and can be readily distinguished from allied indications by the many changes in color and figures. To be sure, films of very heavy oil may occasionally be met with which can be separated into angular pieces, behaving in this respect like iron oxides, but they almost invariably exhibit variegated movable rings of color. In swamps other substances may produce a phenomenon similar to crude oil.

When indications of oil have in this manner been discovered in a quiet part of a water-course, try to remove the iridescent film of the water-course, and turn up the bottom by several times driving the iron-pointed stick into it. If films of oil, together with bubbles of gas, reappear, and this phenomenon occurs regularly after repeated experiments, there may be an outcrop of oil which deserves further examination.

However, if the work with the iron-pointed stick yields negative results, the oil must have floated down from above, and the examination of the water course has to be continued until by means of the iron-pointed stick the source of the traces of crude oil has been found. This source will usually be in sandstone or other porous rock, and pieces knocked off with a hammer will exhibit the oil generally in the form of drops, partly upon the surfaces of the strata and partly also in small cavities. Instead of petroleum, mineral tar—a black, smeary mass—will frequently be found.

The rock itself is occasionally impregnated, which may be recognized partly by the odor and partly by the so-called *water-test.* For this purpose place a piece of the rock in quiet water, if possible exposed to the rays of the sun; if the rock contains oil the characteristic iridescent colors appear, as a rule, upon the surface of the water.

The fresh fracture of oil-bearing sandstone is, as a rule, of a darker color than that of adjoining rock.

After rain, drops of water adhere to out-crops of oil sandstone in a manner similar to that observed on other fatty substances.

If in prospecting in water-courses oil-bearing sandstone has been found, the question has to be answered whether the prospector has to deal with contiguous rock or simply with an erratic block. This question can, as a rule, be decided without much difficulty, from the position of the stratification and the petrographic character of the rock in question as compared with the surroundings. However, if there is still a doubt, examine, by means of the water-test, the portions of rock in the natural continuation of the block.

Should the oil-bearing rock actually turn out to be an erratic block, the rock from which it has been derived will be found above, either on the slopes or in the water-course itself. Knowing the petrographic character of the oil-bearing block, it will not be difficult to find in the neighborhood the rock from which it is derived. In the above-described manner the water-courses are traced to the limits of the territory. In carrying on the work of prospecting, it is advisable to examine specimens of all the sandstone by means of the water-test, since the latter frequently shows the presence of petroleum, though there may be no external indications of it.

It may be mentioned that in cooler weather the traces of oil upon the surface of the water do not yield blue, red, yellow, etc., figures, or at least not very vivid ones, but a milky coloration, which possibly may also be due to other causes, so that determination is more difficult and less certain. This is another reason why it is advisable to select warm days for prospecting. That oil may also be detected by its odor need scarcely be mentioned.

In *swampy puddles* iridescent films, which do not consist of iron oxides, but of hydrocarbons formed by decomposition, are occasionally met with. If due to the latter cause, they do not reappear, or at least only to a slight extent when removed with the iron-pointed stick from the surface of the water. However, in examining the bottom, gas-bubbles generally rise to the surface. Such puddles are examined first in the centre, and then by detaching pieces from the edges with the iron-pointed stick.

SALSES (*mud volcanoes*), as well as abundant exhalations of natural gas, if not derived from coal measures, are promising indications of the presence of petroleum in the territory.

It need scarcely be mentioned that porous rock —if oil-bearing—justifies greater expectations than compact rock, and that larger quantities of oil may be looked for in oil-bearing sandstones of greater thickness.

Although, generally speaking, a rich occurrence of oil may be inferred from abundant indications in the outcrop, the reverse is not always correct; in many oil-fields, now productive, the indications when first found were not especially encouraging.

If the oil occurs in definite geological horizons, the latter must be particularly searched for and traced, and carefully examined in the water-courses crossing them, not only because the strata are there most denuded so as to allow of the best view of their geological structure, but also because the oil, since the restraining covering is wanting, has the best chance of exuding there, and the cut of the water-course is generally one of the lowest points of the outcrop, where the most abundant exudation takes place in consequence of the greater head of pressure.

A very important question is whether the oil occurrs in beds or in veins. In answering this question the following particulars may serve as guiding points:

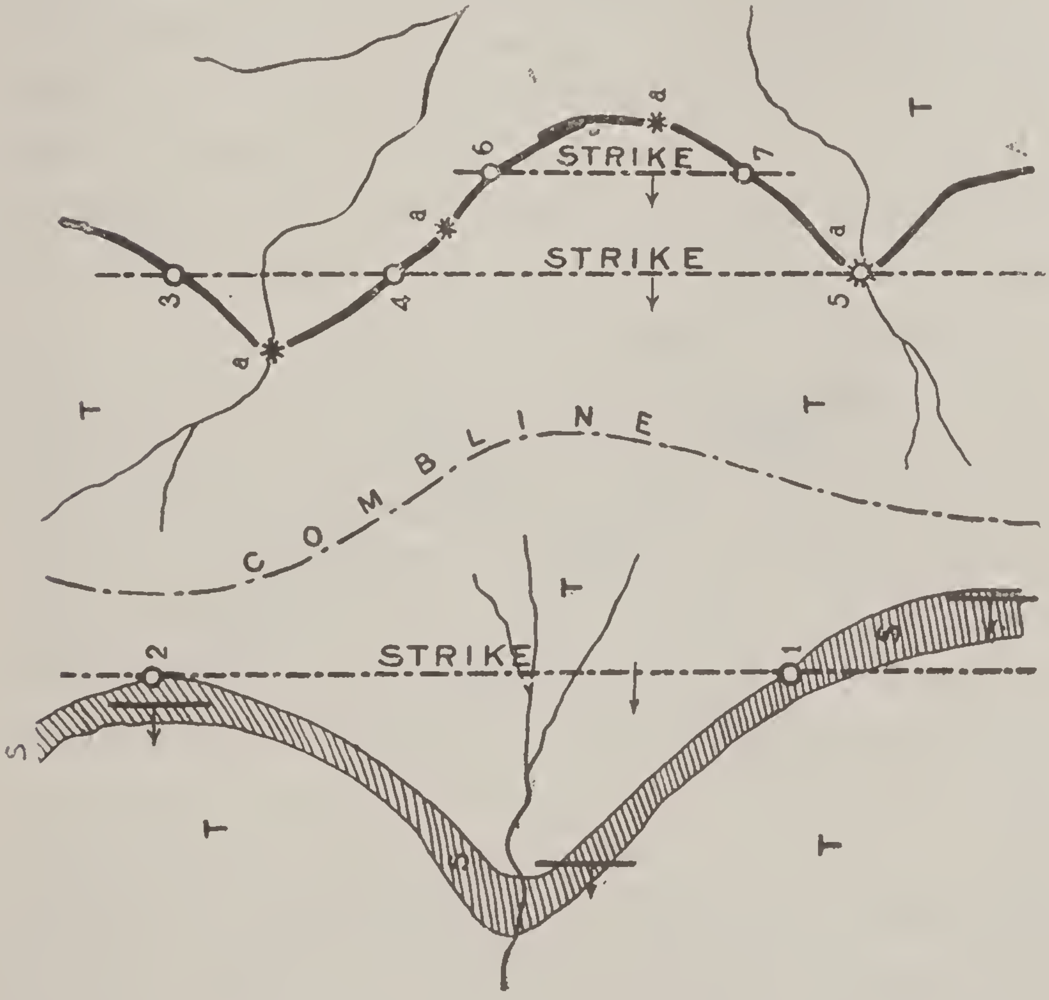
With proportionately greater denudation of the oil-bearing rock, it is sometimes possible directly to decide this question by observation, whereby the prospector, however, must take into consideration that even with a bed-like occurrence the oil will collect in small fissures. With a vein-like occurrence a fissure may be traced to where it assumes larger dimensions in the strike and dip.

If the prospector has to deal with a thick seam or stratum of sandstone, recognized as oil-bearing, imbedded in another rock, for instance, shale, such seam should be traced and pieces freshly cut from it examined as to their content of oil by the water-test. If positive results are obtained, it may be inferred that the sandstone is the bearer of the oil, and that it is a bed-like occurrence.

In a large mass of sandstone several outcrops of oil may sometimes be found at quite a distance from each other. If in tracing the stratum of the first outcrop according to its strike, the second, third, etc., outcrops are encountered, we have to do with a bed-like occurrence. This tracing of the stratum is effected by means of a compass, however, always with due consideration to the configuration of the ground. Suppose the cross-section of the sandstone bed with the declivity—the so-called outcrop-line—construed and traced. The outcrop-line will deviate the more from the straight line of strike, the flatter the strata and declivities lie. In tracing the same stratum, it must be observed whether its strike does not change, which, of course will necessitate a change in the route of the prospector.

If some promising outcrops of oil have been found, which will justify the execution of more extensive and more expensive prospecting work, it is advisable to mark accurately in the sketch-map, in addition to the outcrops, the relative heights, generally determined by an aneroid barometer, the strike and dip of the stratum reduced to the astronomical meridian, and the outcrops of well characterized concordant strata, for instance, imbedded in shale S, Fig. 61, no matter whether they lie in the upcast or downcast of the outcrops of oil, *a*. The relative heights of one of these strata are determined in several places, selecting points which can be readily found upon the map, and, if possible, lie at the same height, which can be readily effected without essential error with the assistance of an aneroid barometer by taking observations in rapid succession. The points of same height, for instance, 1 and 2, give the strike of the stratum for a greater distance.

FIG. 61.



By connecting the outcrops of oil *a* by a line *AA*, and again determining in the latter several points of the same height, for instance, 3, 4 and 5, the general strike is again obtained. If the latter runs parallel with the general strike of the characteristic stratum *S*, previously traced, one is justified in inferring a bed-like occurrence of oil, even if the construed dip of the outcrop line of oil corresponds with the observed local dip of the strata.

In these investigations it is presupposed that the oil is recognized as exuding from the solid rock, an error regarding the outcrop of it being, therefore, excluded. Such an error may, however, occur when the outcrop is covered with loose masses of earth and rock, to the base of which the oil exuding above flows down hidden, and escapes further below by some accidental cause.

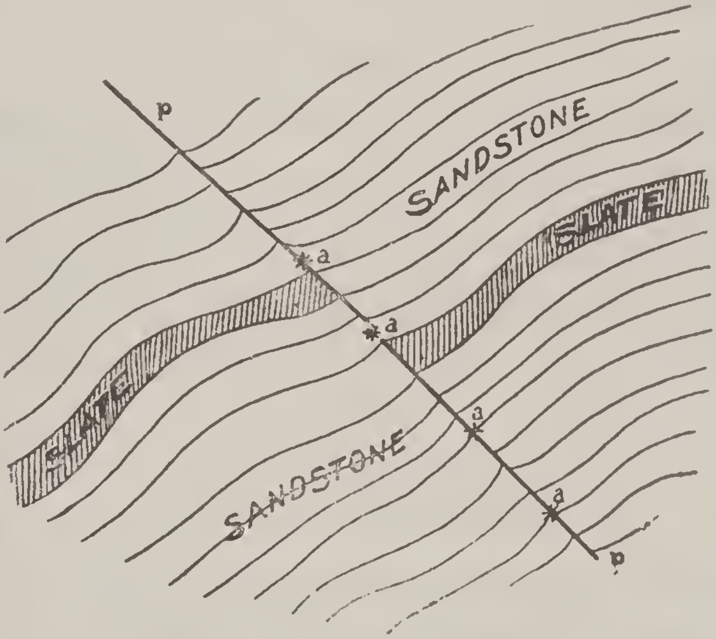
A vein-like occurrence of oil will not show the above-mentioned conformities with the characteristic concordant strata. Such an occurrence presupposes a fissure, which is generally connected with a throw of the strata. This is most frequently established by the fact that a characteristic stratum suddenly ends and does not reappear in its natural continuation but either to the right or left, or higher or lower. If two or more such points of disturbance have been found, their connecting line is the outcrop line of the fissure, Fig. 62. If this line passes through the outcrop *a*, or if several outcrops lie in it, a vein-like occurrence of oil must be inferred.

However, sometimes the oil occurs in a maze of smaller and large fissures. This is shown in the construction by the fact that in the presence of several outcrops a linear distribution of the same cannot be recognized, and that the combinations yield the most varying results, according to whether exploration is carried on from the one or the other outcrop. Such occurrence presents uncommon difficulties in prospecting.

It need scarcely be mentioned that in prospecting for oil, it is of great importance to hunt up and map the anticlinals and their saddles, as well as faults.

The use of a contour map of an oil sand to locate new pools in unprospected territory will materially aid the prospector, but cannot be absolutely relied upon, as the other conditions necessary for an accumulation can only be learned by actual test.

Fig. 62.



The directions here given for prospecting may have to be modified according to local conditions. With a sufficient preliminary knowledge of geology, any difficulties will, as a rule, be readily overcome by thoroughly digesting the principles of the directions given.

As regards the quality of the surface oil, it must be remembered that it is not a criterion for the oil occuring at greater depth. The oil thickens on the surface of the earth, and with increasing density becomes viscous and dark. If pale, limpid, and specifically lighter oil is found at the outcrop, it is sure evidence of oil of excellent quality at greater depth. In every case it may be expected that the quality of the oil at greater depth is superior to that at the outcrop.

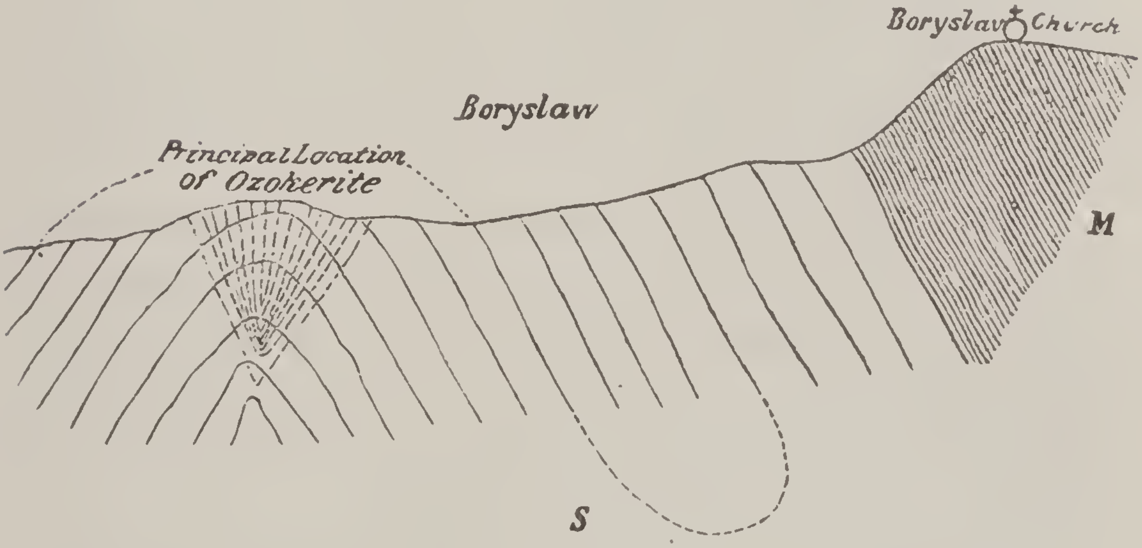
OZOCERITE is a mineral paraffine or wax, and occurs generally in fissures and cavities in the neighborhood of coal-fields and deposits of rock salt, or under sandstone pervaded with bitumen. It is found in various localities in Africa, America, Asia and Europe. In the United States it occurs in Arizona, Texas and Utah.

The most interesting deposit is in East Galicia, Austria. The ozocerite occurs there in a saliferous clay belonging to the miocene of the most recent tertiary period, and forming a narrow, almost continuous strip on the northern edge of the Carpathian Mountains. This miocene group of saliferous clay consists chiefly of bluish and variegated clays, sands and sandstones, with numerous occurrences of gypsum, rock salt and salt springs. In Boryslaw, the strata of saliferous clay form a perceptible saddle as they sink on the south below the so-called menilite slates, which are very bituminous and foliated, and form here the most northern edge of the Carpathian Mountains. The principal deposit of ozocerite converges with the axis of the saddle as shown in Fig. 63, *S* being the strata of saliferous clay, and *M* menilite slate.

Closely allied to ozocerite are the following mineral resins:

Retinite, generally of a yellowish-brown, sometimes of a green-yellow or red color. It is found with brown coal in various localities.

Fig. 63.



Elaterite or elastic bitumen, of a blackish-brown color, subtranslucent, and occuring in soft, flexible masses in the lead-veins of Castleton, in Derbyshire, in the bituminous sandstone of Woodbury, Connecticut, etc.

Pyropissite occurs in strata in brown coal.

Ozocerite occurs in various shades of color, from pale yellow to black; when melted it generally shows a dark-green color. The pale varieties are chiefly found in places containing much marsh gas. The dark-green, heavy variety is the best, while the black kind, or asphaltic wax, is the poorest; it contains resinous combinations of oxygen, and is intermediate between mineral oil and ozocerite.

The odor of ozocerite is, according to its purity, agreeably wax-like. In consistency it is soft, pliable, flexible to hard; the mass in the latter case showing a conchoidal fracture, but softens on kneading. The boiling-point lies between 133° and 165° F., and of the so-called " marble wax " even as high as 230° F. The specific gravity is from 0.845 to 0.930.

Ozocerite is readily soluble in oil of turpentine, petroleum, benzine, etc., and with difficulty in alcohol and ether; it burns with a bright flame, generally leaving no residue. Its elementary composition is about that of petroleum, 85 per cent. of carbon and 15 per cent. of hydrogen.

Native Asphalt or Bitumen is solid at the ordinary temperature, of a black to blackish-brown color and a conchoidal facture with glassy luster. Hardness, 1 to 2; specifie gravity, 1 to 2. It melts at 90° F., and is very inflammable. It appears to be formed by the oxidation of the non-saturated hydrocarbides in petroleum. The most remarkable deposits are in Cuba, Trinidad and Venezuela. Other noted localities are the Dead Sea, Seyssel, (France), Limmer, the Abruzzo, and Val de Travers. It occurs also of every degree of consistence, and in immense quantity, along the coast of the Gulf of Mexico, chiefly in the States of Tamaulipas, Vera Cruz and Tabasco, where not unfrequently it is associated with rock salt and "saltpeter." It also occurs in Utah in widely-separated places. It has been found associated with ozocerite and more extensively as melted out of sandstone. California includes a large area which furnishes asphalt, much the larger proportion being the product of the decomposition of petroleum, while the remainder occurs in veins that are evidently eruptive, the former occuring in beds of greater or less extent on hillsides or gulch slopes, below springs of more fluid bitumen. These deposits are scattered over the country between the bay of Monterey and San Diego, but are chiefly observed west and south of the coast ranges, between Santa Barbara and the Soledad pass. Asphalt occurs also in other localities in the United States, for instance in Connecticut, in thin seams and veins in eruptive rock; in New York in the region of eruptive and metamorphic rocks, in Tennessee in the Trenton limestone, etc. In some American specimens sulphur has been found to the extent of 10.85 per cent. Asphalt is in great request for paving purposes; it is of increasing value, and deposits are eagerly sought for.

Peat. Peat is not a mineral, but consists of the cumulatively resolved fibrous parts of certain mosses and graminaceæ. It gradually darkens from brown to black with increasing age. It occurs in beds or in bogs. As a fuel it is most economically used at the place where it is grown. Good peat yields about 3 to 6 per cent. of tar proper, which is comparatively easy to purify by the usual method.

The examination of a peat bog is very instructive with reference to the formation of coal as affording examples of vegetable matter in every stage of decomposition; from that in which the organized structure is still clearly visible, to the black carbonaceous mass which only requires consolidation by pressure in order to resemble a true coal.

APPENDIX.

PROSPECTING BY MEANS OF ELECTRICITY.

Mr. Leon Draft and Mr. Alfred Williams have invented a method of finding ore by means of electricity, by which they claim to be able to detect the presence of certain mineral ores invisible to the eye and undiscoverable by mining engineering. It is claimed that by this method not only can deposits be located, but that the extent and depth of the lode can be determined with an accuracy that is quite impossible with any existing system of prospecting.

In working this method there are two stations, the transmitting and receiving. At the former there is a battery of 12 volts, giving 4 amperes and 50 watts; a special form of break works in methylated spirits, and is driven by a motor, which is supplied with current by a special local battery and a primary condenser. The current is next led through the primary by an inductor, a special form of induction coil having a large core and a very heavy winding on the secondary circuit. The current now passes through a secondary condenser to adjustable series and parallel spark-gaps. The electric waves generated by this arrangement are taken to earth by means of two iron spikes driven two to three inches into the ground.

The receiving set comprises two similar iron spikes, driven into the ground to a depth of an inch or two, and connected up to a tripod on which are placed a series parallel and with a transformer and two delicate receivers or resonators. The interrupter breaks contact 700 times a minute.

By adjusting his earth connections the operator can focus the waves on any field that he may wish to explore ; the lines of force travel outward and onward until they reach the iron spikes, in the receiving set. When this occurs, the observer can by means of the resonators detect their presence by hearing the noise of the break, or by the sparking across the gaps.

Now, in a normal condition, *i. e.*, if the ground be of a homogeneous character, the prospector should hear the noises loudest when exactly opposite the center of the base line of the transmitting station.

The existence, however, of a vein or reef containing metal has the tendency of throwing the waves out of normal course, by reason of the fact that it has a different conductivity from the material by which it is surrounded. The prospector must therefore make his earth connections in different places, and shift his position until he can detect the presence of the waves. When directly over the lode, the noise in the resonators will be loudest.

Condenser-discharges from lodes manifest themselves as overtones in the receivers, and at certain spots or nodal points the noise will cease altogether owing to the influence of the waves.

The condenser-discharges can be heard over some lodes when the distance from the inductor is so great that the noise of the break or of the spark-gap cannot be heard ; thus they form a great assistance to prospecting, helping to determine not only the position and depth of a mineral deposit, but also, to a great extent, its nature and characteristics.

The area to be energized by the electrical waves may be as small as 300 square feet and as large as 30 square miles, and the terminals may be placed hundreds of yards apart.

It will, of course, be necessary to train mining engineers and prospectors in the use of the instruments and in the detection of the presence of the waves. The whole outfit is, however, simple and easy to work with. Its development during the next few years will be watched with interest by all interested in mining operations.

WEIGHTS AND MEASURES.

British weights and measures, and those used in our country are based upon the weight of a cubic inch of distilled water at 62° Fah., and 30 inches height of the barometer, the maximum density. This was decided by Parliament, in the reign of George IV., to be 252.458 grains. Recent experiments, however, show that a cubic inch of water at the temperature of maximum density is 252.286 standard grains. On this account scientists are urging the readjustment of the gallon, bushel, etc., but at present the tables below are correct. *See also No. 8.*

Weights and measures of various nations :—

No. 1.—English Length.

3 barleycorns = 1 inch.
12 inches = 1 foot.
3 feet = 1 yard.
5½ yards = 1 rod, pole, or perch (16½ feet).
4 poles or 100 links = 1 chain (22 yards or 66 feet).
10 chains = 1 furlong (220 yards or 660 feet).
8 furlongs = 1 mile (1760 yards or 5280 feet).

A span = 9 inches; a fathom = 6 feet; a league = 3 miles; a geographical mile = 6082.66 feet, same as nautical knot, 60 being a degree, *i. e.*, 69.121 miles.

Particular Measures of Length,

A point, $\frac{1}{72}$ of an inch.
A line, $\frac{1}{12}$ of an inch.
A palm, 3 inches.
A hand, 4 inches.
A link, 7.92 inches.
A pace, military, 2 feet, 6 inches.
A pace, geometrical, 5 feet.
A cable's length, 120 fathoms.
A degree (average), 69⅛ miles.

No. 2.—Surface Measure.

144 square inches = 1 square foot.
9 square feet = 1 square yard.
30¼ square yards = 1 pole, rod, or perch (square).
16 poles (square) = 1 chain (sq.) or 484 sq. yds.
40 poles = 1 rood (sq.) or 1210 sq. yds.
10 chains or 4 roods = 1 acre (4840 sq. yds.).
640 acres = 1 sq. mile.

No. 3.—Surface Measure in Feet.

9 square feet = 1 square yard.
272¼ " " = 1 pole, rod, or perch.
4,356 " " = 1 square chain.
10,890 " " = 1 square rood.
43,560 " " = 1 acre.
27,878,400 " " = 1 square mile.

No. 4.—Solid Measure.

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

16½ feet long, 1 foot high, and 1½ feet thick = 1 perch stone = 24¾ cubic feet.

No. 5.—Troy Weight.

Platinum, gold, silver, and some precious stones are weighed by Troy weight, diamonds by carats of 4 grains each.

24 grains = 1 pennyweight.
20 pennyweights = 1 ounce (480 grains).
12 ounces = 1 pound (5760 grains).

No. 6.—Avoirdupois Weight.

16 drams = 1 ounce (437½ grains).
16 ounces = 1 pound (7000 grains).
14 pounds = 1 stone.
2 stones = 1 quarter.
4 quarters = 1 hundredweight.
20 hundred-weight = 1 ton (long ton) (2240 pounds).

No. 7.—Weight by Specific Gravity.

Frequently the weight of masses is required where it it very inconvenient, or, perhaps, impossible to use scales. The following method may be sufficiently accurate :—

Find the average specific gravity of the mass either by actual weight of a piece or by the following table. Then measure the cubic contents of the mass as nearly as possible and multiply by the weight of a cubic foot. Thus, a mass of limestone (as good marble) measures 40 cubic feet. The specific gravity of good marble is 2.6, that is, it is 2.6 as heavy as a cubic foot of water, which weighs 62.5 pounds. Therefore

$$\begin{array}{r} 62.5 \\ 2.6 \\ \hline 3750 \\ 1250 \\ \hline 162.50 \end{array}$$

A cubic foot of good marble weighs 162.5 pounds and the 40 cubic feet will weigh

$$\begin{array}{r} 162.5 \\ 40 \\ \hline 6500.0 \end{array}$$

or, about 3¼ tons. Of course, all rock masses have not plane sides, and the irregularity requires some calculation, and various allowances which the prospector must make, and can easily do with a little consideration.

When greater accuracy of specific gravity and of bulk is desired for small masses, and no scales are at hand, the following plan may be very satisfactorily adopted. Fill a tub or hogshead or large box with rain water, after having inserted a tube or piece of tin pipe into the upper edge. Pour in more water until it will hold no more without running out of the spout. Introduce the mass of rock and catch all the water which runs out of the pipe. Now measure the overflow; this represents the exact cubic measure of the rock introduced.

1 gallon	contains	231 cubic inches.
1 quart	" . . .	87.75 or 57¾ cubic inches.
1 pint	"	28.87 or 28⅚ " "
1 gill	"	7.21 or 7⅕ " "

See Appendix, No. 8.

Suppose the overflow was 8 gallons, 1 quart, 1½ gills, and that the specific gravity of the rock or ore was 6.5 by the table below. Then the mass will cause an overflow of 1936.99 cubic inches, and this is 208.99 more than one cubic foot, or about 1.120 of a cubic foot for the mass.

Since 6.5 was the specific gravity of the ore, 6.5×62.5 pounds = 406.25, which would be the weight of a cubic foot of the ore, and 406.25×1.120 =455 pounds, the exact weight of the mass you introduced into the water.

No. 8—Special Weights, etc.

One cubic foot of water is equal to 7.475 U. S. gals. of 231 cubic inches each, or 7½ gallons nearly; or 6.2321 imperial gals. of 277¼ cubic inches each. This, with what follows, is important in the construction of tanks, pools, etc., where contents, weight, and pressure are to be considered.

It should be remembered that, although the English imperial gallon is 277¼ cubic inches = 10 lbs. avoir. of distilled water at 62° Fah., bar. 30 inches, and equal to 277.274 cubic inches, the United States standard gallon is 231 inches, or 58372.1754 grains, or 8.3389 lbs. of distilled water maximum density. This is almost exactly = to a cylinder 7 inches diameter, 6 inches high. The beer gallon = 282 inches.

One gallon = 8.3389 lbs.. one quart = 2.0847 lbs.; one pint = 1.0423 lbs. ; one gill = 0.2606 lb., U. S. standard measure. One cubic foot of water =62.310 lbs., British weight ; recent and correct, 62.278.

No. 9.—French Measures.—Length.

Millimetre ($\frac{1}{1000}$ of a metre)	=	.03937 inch.
Centimetre ($\frac{1}{100}$ " ")	=	.3937 "
Decimetre ($\frac{1}{10}$ " ")	=	3.937 "
Metre (the unit of length)	=	39.3708 " or 3.2809 ft.
Decametre (10 metres)	=	32.809 ft. or 10.9363 yds.
Hectometre (100 metres)	=	109.3633 yards.
Kilometre (1000 metres)	=	1093.63 yds. or .62138 mile.
Myriametre (10,000 metres)	=	6.2138 miles.

Surface.

Centiare ($\frac{1}{10}$ of an are or sq. metre)	=	1.1960 sq. yds.
Are (unit of surface)	=	119.6033 sq. yards or .0247 acre.
Decare (10 ares)	=	1196.033 sq. yards or .2474 acre.
Hectare (100 ares)	=	11960.33 sq. yards or 2.4736 acres.

SOLID MEASURE.

Decistere ($\frac{1}{10}$ of a stere) = 3.5317 cubic feet.
Stere (cubic metre) = 35.3166 " "
Decastere (10 steres) = 353.1658 " "

WEIGHT.

Milligramme ($\frac{1}{1000}$ of a gramme) = .0154 grain.
Centigramme ($\frac{1}{100}$ " ") = .1544 grain.
Decigramme ($\frac{1}{10}$ " ") = 1.544 grains.
Gramme (unit of weight) = 15.44 grains.
Decagramme (10 grammes) = 154.4 grains.
Hectogramme (100 ") = 1,544 grains. { 3.2167 ozs. Troy or 3.5291 ozs. Avoir.
Kilogramme (1000 ") = $32\frac{1}{4}$ ozs. or 2.2057 pounds.
Myriagramme (10,000 grammes) = 22.057 pounds.

NO. 10.—SPECIFIC GRAVITY OF METALS, ORES, ROCKS, ETC.

Platinum	16–21
Gold	16–19.5
Mercury	13.5
Lead	11.35–11.5
Silver	10.1–11.1
Copper	8.5–8.9
Iron when pure	7.78
Iron, cast, average	6.7; foundry 6.9 to 7

ORES: associated with gold and silver.

(Gold) Iron pyrites	4.8–5.2
Copper pyrites	4.0–4.3
(Silver) Galena	7.2–7.7
Glance (silver)	7.2–7.4
Ruby silver (dark)	5.7–5.9
" " (light)	5.5–5.6
Brittle silver (sulphide)	5.2–6.3
Horn silver	5.5–5.6

Other Ores.

Zinc blende	3.7–4.2
Mercury (Cinnabar)	8.8–9.9
Tin, tinstone, cassiterite	6.4–7.6
Tin pyrites	4.3-4.5
Copper—Red or ruby copper	5.7–6.15
Gray	5.5–5.8
Black oxide	5.2–6.3
Pyrites	4.1–4.3
Carbonate (Malachite)	3.5–4.1
Lead—Sulphide (Galena)	7.2–7.7
Carbonate (White lead)	6.4–6.6
Zinc—Blende	3.7–4.2
Calamine	4.0–4.5
Iron—Hematite (red)	4.5–5.3
Magnetic	4.9–5.9
Brown hematite	3.6–4.0
Spathic (carbonate)	3.7–3.9
Pyrites (mundic)	4.8–5.2
Antimony—Gray sulphide	4.5–4.7
Nickel—Kupfer nickel	7.3–7.5
Cobalt—Tin-white	6.5–7.2
Glance	6.0
Pyrites	4.8–5.0
Bloom	2.91–2.95
Earthy	3.15–3.29
Manganese—Black oxide	4.7–5.0
Wad, Bog manganese	2.0–4.6
Bismuth—Sulphide	6.4–6.6
Oxide	4.3

Minerals of Common Occurrence.

Quartz	2.5–2.8
Fluorspar	3.0–3.3
Calc spar	2.5–2.8
Barytes	4.3–4.8
Granite Gneiss	2.4–2.7
Mica slate	2.6–2.9

Syenite	2.7–3.0
Greenstone trap	2.7–3.0
Basalt	2.6–3.1
Porphyry	2.3–2.7
Talcose slate	2.6–2.8
Clay slate	2.5–2.8
Chloritic slate	2.7–2.8
Serpentine	2.5–2.7
Limestone and Dolomite	2 5–2.9
Sandstones	1.9–2.7
Shale	2.8

Other minerals are mentioned in the text with their specific gravities.

No. 11.—A Ton Weight of the Following will Average in Cubic Feet:

Earth	21 cubic feet.	Pit sand	22 cubic feet.
Clay	18 " "	River sand	19 " "
Chalk	14 " "	Marl	18 " "
Coarse gravel	19 " "	Shingle	23 " "

Assay of Gold by the Touchstone.*

This is a rough and rapid method of approximately ascertaining the quality of a gold alloy without injury to the article, as is the case in dry and wet assaying.

An experienced person may determine the correct standard within 1 per cent. of the truth. The method is based on the fact that the richer an alloy is in gold, the more clearly does a streak drawn with it on a black ground exhibit a pure golden-yellow color, and the less it is attacked by a test acid.

The touchstone is a hard siliceous stone of a black color, its surface being prepared and left so that it

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* From Hiorns's "Practical Metallurgy and Assaying."

will just abrade the metal from any sharp angle of the alloy when the latter is drawn over the stone.

In order to ascertain the quality of the alloy, its streak is compared with streaks drawn by alloys of known fineness, called *touch needles,* of which five series are required.

1. *Red series,* consisting of gold and copper, the gold increasing by half carats in successive needles.
2. *White series,* contains gold and silver.
3. *Mixed series,* in which the quantities of silver and copper alloyed with the gold are equal.
4. *Unequal* mixed series, in which the silver is to the gold as 2 : 1.
5. Series in which the silver is to the copper as 1 : 2.

Besides these, special needles are prepared for different kinds of work.

The mark left on the stone by the alloy having been matched with the corresponding mark of one of the touch needles, it is assumed to have the same composition. To confirm this assumption, a drop of acid is placed on each streak, allowed to work for some time, and its effect observed in each case, then wiped off to see if the mark is left unchanged.

The *test acid* consists of: 98 parts pure nitric acid, 2 parts hydrochloric acid, 25 parts distilled water.

The first streak made by a body is discarded, as in the case of colored gold, for example, the surface having a different composition to the general mass.

The above test mixture has no effect on alloys of 18 carats and upwards, so that streaks made by these alloys will not be wiped off with a linen rag after treating with acid. Pure nitric acid has no effect on alloys of 15 carats upwards.

ESTIMATION OF GOLD IN ALLOYS (HIORNS).

In places where a large number of assays have to be conducted a special set of weights is employed, as with silver, the unit quantity being termed the *assay pound*, which is subdivided into carats, carat grains, eights, and excess grains. The amount taken as a unit may be 10 grains or half a gramme = 7.716 grains. The relation of the parts are well shown in the following table by Prof. Roberts-Austen:

				Excess Grains.	Decimal Equivalent.
			Eights.	1	.1736
		Carat Grains.	1	7.5	1.3021
	Carats.	1	8	60	10.416
Assay Pound.	1	4	32	240	41.6
1	24	96	768	5760	1000.

The excess grains in one assay pound are the same as the number of grains in the troy pounds.

Gold is reported to the trade according to the above table, in carats or the decimal equivalents. Thus pure gold is 24 carats or 1000 fine; standard gold, 22 carats $= \frac{22 \times 1000}{24} = 916.66$ fine.

When an alloy is slightly "worse" than the standard, it is said to be "worse so much." When above the standard, the alloy is called "better so much," the difference being expressed in carat grains, eights, and excess grains, or in its decimal equivalent. In both cases the excess grains represent gold present in excess of the report.

STANDARD VALUES OF GOLD IN DIFFERENT COUNTRIES.

COUNTRIES,	1000 (24 carats).	916.66 (22 carats).	900 (21.6 carats).
England (one troy ounce)	£4 4 10	£3 17 10	£3 16 6
United States (one troy ounce)	$20.67	$18.95	$18.60
France (Kilogramme)	Fr. 3,444.44	Fr. 3,157.40	Fr. 3,100
Germany "	Mk. 2,790	Mk. 2,474.16	Mk. 2,511

POWER FOR MILLS.

As the Pelton wheel seems to find the most frequent application in California, it may be convenient to have the following rule, applicable to this wheel:

When the head of water is known in feet, multiply it by 0.0024147, and the product is the horse-power obtainable from one miner's inch of water.

The power necessary for different mill parts is:

For each 850 lbs. stamp, dropping 6 inches 95 times per minute	1.33	H. P.
For each 750 lbs. stamp, dropping 6 inches 95 times per minute	1.18	"
For each 650 lbs. stamp, dropping 6 inches 95 times per minute	1.00	"
For an 8-inch by 10-inch Blake pattern rock-breaker	9.00	"
For a Frue or Triumph vanner with 220 revolutions per minute	0.50	"
For a 4-foot clean-up pan, making 30 revolutions per minute	1.50	"
For an amalgamating barrel, making 30 revolutions per minute	2.50	"
For a mechanical batea, making 30 revolutions per minute	1.00	"

BORING.

Rock is bored with jumpers of 10 to 18 lbs., used alone or with boring bars and hammer. The former are more effective, but can only be used perpendicularly, or nearly so, and with rock of moderate hardness; they require more skill.

18 lb.	hammers	are used	for 3 inch boring bars.
16 lb.	"	"	" 2½ inch boring bars.
14 lb.	"	"	" 2 and 1¾ inch boring bars.
5 to 7 lb.	"	"	" 1 inch boring bars.

The boring bars may be made of 1⅛-inch bar iron of various lengths, with steel bits up to 3 inches. A bit should bore from 18 to 24 feet with each steeling, and requires to be sharpened once for every foot bored.

DIAMOND DRILL.

This drill is applicable to sinking a bore-hole for prospecting for minerals or water, shafts, etc., or blasting under water.

It consists of a circular row of "carbonados," a species of diamond, set in a circular steel ring. This is attached to a hollow steel tube, which is kept rotating at about 250 revolutions per minute, pressed forward by a force varying from 400 to 800 lbs., according to the nature of the rock. Water is supplied through the tube, which washes out the debris and cools the diamonds.

Granite and the hardest limestones are penetrated at the rate of 2 or 3 inches per minute, sandstones 4 inches, quartz 1 inch.

The diamond drill is not effective in soft strata, such as clay, sand and alluvial deposits.

THE CHEMICAL ELEMENTS, THEIR SYMBOLS, ATOMIC WEIGHTS * AND SPECIFIC GRAVITIES.

Name.	Symbol.	Atomic Weight.	Specific Gravity.
Aluminium	Al.	27.5	2.56
Antimony	Sb.	120.4	6.70
Arsenic	As.	75.0	5.70
Barium	Ba.	137.4	4.00
Bismuth	Bi.	208.1	9.7
Boron	B.	11.0	2.63
Bromine	Br.	79.95	5.54
Cadmium	Cd.	112.4	8.60
Caesium	Cs.	132.9	1.88
Calcium	Ca.	40.1	1.58
Carbon	C.	12.0	3.50
Cerium	Ce.	139.0	6.68
Chlorine	Cl.	35.5	2.45
Chromium	Cr.	52.1	6.81
Cobalt	Co.	59.0	7.7
Columbium	Cb.	184.8	6.00
Copper	Cu.	93.7	8.96
Didymium	Di.	96.0	6.54
Erbium	E.	166.0	—
Fluorine	F.	19.05	1.32
Gallium	Ga.	70.0	5.9
Glucinum	Gl.	9.5	2.1
Gold (Aurum)	Au.	197.2	19.3
Hydrogen	H.	1.008	0.069
Indium	In.	114.0	7.4
Iodine	I.	126.85	4.94
Iridium	Ir.	193.1	21.15
Iron (Ferrum)	Fe.	55.9	7.79
Lanthanum	La.	138.6	11.37
Lead (Plumbum)	Pb.	206.92	11.44
Lithium	Li.	7.03	0.59
Magnesium	Mg.	24.3	1.75
Manganese	Mn.	55.0	8.01
Mercury (Hydrargyrum)	Hg.	200.0	13.59
Molybdenum	Mb.	96.0	8.60
Nickel	Ni.	58.70	8.60
Niobium	Nb.	93.7	6.27

* According to the Committee of the American Chemical Society (Clarke).

THE CHEMICAL ELEMENTS, THEIR SYMBOLS, EQUIVALENTS AND SPECIFIC GRAVITIES.

Name.	Symbol.	Atomic Weight.	Specific Gravity.
Nitrogen	N.	14.04	0.972
Osmium	Os.	191.0	21.40
Oxygen	O.	16.0	1.105
Palladium	Pd.	107.0	11.60
Phosphorus	P.	31.0	1.83
Platinum	Pt.	194.9	21.53
Potassium (Kalium)	K.	39.11	0.865
Rhodium	Ro.	103.0	12.1
Rubidium	Rb.	85.4	1.52
Ruthenium	Ru.	101.7	11.4
Selenium	Se.	79.2	4.78
Silicon	Si.	28.4	2.49
Silver (Argentum)	Ag.	107.92	10.5
Sodium (Natrium)	Na.	23.05	0.972
Strontium	Sr.	87.6	2.54
Sulphur	S.	32.07	2.05
Tantalium	Ta.	182 8	10.78
Tellurium	Te.	127.5?	6.02
Thallium	Tl.	204.15	11.91
Thorium	Th.	232.6	7.8
Tin (Stannum)	Sn.	119.0	7.28
Titanium	Ti.	48.15	4.3
Tungsten (Wolfram)	W.	184.0	17.6
Uranium	U.	239.6	18.4
Vanadium	V.	51.4	5.50
Yttrium	Y.	89.0	—
Zinc	Zn.	65.4	7.14
Zirconium	Zr.	80.4	4.15

The figures indicating the proportions by weight in which the elements unite with one another are called the combining or atomic weights, because they represent the relative weights of the atoms of the different elements. Since hydrogen is the lightest element, it is taken as the standard, and its combining or atomic weight = 1.

To find the proportional parts by weight of the elements of any substance whose chemical formula is known :

RULE.—Multiply together the equivalent and the exponent of each element of the compound ; the product will be the proportion by weight of that element in the substance.

Example.—Find the proportionate weight of the elements of alcohol, C_2H_6O :

Carbon C_2 = equivalent 12 × exponent 2 = 24
Hydrogen H_6 = equivalent 1 × exponent 6 = 6
Oxygen O = equivalent 16 × exponent 1 = 16

Of every 46 lbs. of alcohol, 6 lbs. will be H ; 16 O ; 24 C.

To find the proportions by *volume*, divide by the specific gravity.

COMMON NAMES OF CHEMICAL SUBSTANCES.

Common Names.	*Chemical Names.*
Aqua fortis.	Nitric acid.
Aqua regia	Nitro-hydrochloric acid.
Blue vitriol.	Sulphate of copper.
Cream of tartar.	Bitartrate of potassium.
Calomel.	Chloride of mercury.
Chalk.	Carbonate of calcium.
Caustic potash.	Hydrate of potassium.
Chloroform.	Chloride of formyl.
Common salt.	Chloride of sodium.
Copperas and green vitriol.	Sulphate of iron.
Corrosive sublimate.	Bichloride of mercury.
Dry alum.	Sulphate of aluminium and potassium.
Epsom salts.	Sulphate of magnesium.

Ethiops mineral.	Black sulphide of mercury.
Galena.	Sulphate of lead.
Glauber's salt.	Sulphate of sodium.
Glucose.	Grape sugar.
Iron pyrites.	Bisulphide of iron.
Jeweler's putty.	Oxide of tin.
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