

# ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. XII

SEPTEMBER, 1917

No. 6

## GENETIC CLASSIFICATION OF UNDERGROUND VOLATILE AGENTS.

REGINALD A. DALY.

### CONTENTS.

	PAGE.
The Problem .....	487
Individual Terms Already Suggested .....	489
Ground-water .....	489
Juvenile .....	489
Resurgent .....	491
Magmatic .....	492
Epigene and Meteoric .....	492
Vadose .....	494
Phreatic .....	494
Seepage .....	495
Connate .....	495
Older Classifications .....	496
Proposed Classification .....	498
Proposed Classification in Practice .....	501
Summary .....	502
References .....	503

### THE PROBLEM.

Many changes in rocks and minerals below the earth's surface are controlled by the presence of subsurface waters, vapors, and gases—substances of highly varied composition, yet sharing the attribute of being volatile at relatively low temperatures and pressures. Of these fluids water is the most striking and, in the earth's crust as a whole, probably the most important. It is

never pure, but is regularly in mutual solution with other volatile compounds or with gaseous elements. Similarly, carbon dioxide or chlorine or any of the sulphur gases is seldom or never the only gaseous phase affecting a rock mass of even small volume. Complex and protean as these volatile associations may be, their components tend to act together in significant geological processes. In company they lower the fusion or solution temperatures of silicates. In company they cause gaseous tension in heated rocks. In company they help to direct the march of lithification, rock weathering, vein formation, or ore deposition. Because of the close cooperation of these fluids, the students of diagenesis, metamorphism, weathering, volcanology, plutonic rocks, vein formation, and ore deposits have generally no choice but to regard each concrete solution as a unit. Most of the solutions are chiefly composed of water; hence the name "waters" is commonly used to designate them, and that whether the water is liquid, vapor, or gas.

This figurative use of "waters" is likely to persist, since in most geological discussions it involves no obscurity of meaning. However, the principal volatile component of limestone or dolomite is not water, and it is a question whether the carbon dioxide doing geological work within the carbonate rock or, as an emanation, outside it, can be regarded as one of the crustal "waters" without stretching metaphor too far. There is needed a more appropriate term which shall signify not only well waters, spring waters, waters buried with sediments, the primitive water in live magma, the water of constitution or of solid solution in minerals, but also such magmatic constituents as chlorine, fluorine, the sulphur gases, the carbon gases, and the gases essential in calcite, sodalite, apatite, gypsum, etc., and the rocks containing these minerals. Neither "underground fluids" nor "underground solutions" is appropriate because magma is both a fluid and a solution. The expression "volatile substances" or "*volatile agents*" is less equivocal. The one word "*volatiles*," employed as a noun, is suggested as a convenient, short equivalent. If "waters" were used in the same sense, its metaphorical char-

acter, as the whole named from a part, might be shown by always enclosing the word in quotation marks. That convention cannot be ultimately satisfactory.

Economic geologists, concerned with ore-bearing solutions, have been specially interested in the technical vocabulary required for a scientific classification of volatile agents. Yet it is manifestly advisable, if possible, to have developed a system of terms which shall be available for all kinds of geological specialists or for the general geologist. The purposes of this article are: to indicate how nearly the technical terms invented or adapted by the economic geologists fill the needs of the general geologist; on the other hand, to suggest to the student of ore deposits the value of certain inventions or technical adaptations of volcanologists and others; and to offer a general classification of underground volatile agents, founded on older classifications but somewhat more extended than any of these.

Unfortunately, most of the terms now commonly employed, though of modern origin, have not uniform definitions among authoritative writers, and it is essential, after reviewing sample variations of usage, to choose the definitions that are most warranted by custom and by the logic of a systematic scheme.

For bibliographic assistance the writer owes hearty thanks to his colleagues, Professors Graton and Lindgren.

#### INDIVIDUAL TERMS ALREADY SUGGESTED.

*Ground-water.*—While “ground-water” is a popular and engineering expression for seepage water at and below the water-table (the subsurface, so-called water-level) and is thus the equivalent of Daubrée’s “phreatic water,” some authors, like Kemp (1902, reprint, p. 2; 1906, p. 219), have definitely considered magmatic water as ground-water.

*Juvenile.*—Suess (1902, p. 141) introduced this word: “With the vadose waters of the earth’s surface are associated new supplies (Mengen) which, reaching daylight for the first time and before our eyes, may be called *juvenile* waters.” Again (1909, p. 630): “On the other hand, *juvenile* waters are those that

originate when hydrogen, emanating from the earth's interior under very high pressure and at very high temperature, combines with the oxygen of the atmosphere." There are obvious difficulties, of a quantitative nature, in the way of accepting Suess's speculation as to the manner in which juvenile hydrogen has been oxidized, and many geologists agree that the oxygen of primitive (magmatic) water is also largely juvenile. Chlorine, fluorine, sulphur, arsenic, and carbon are, according to Suess, other juvenile elements. He regarded the sea water, sea salts, and the atmosphere as all juvenile in the final analysis, as juvenile in former geological periods; but for practical purposes he grouped all these emanations of the past as "vadose" substances. Juvenile fluids are those in the act of appearing first at the earth's surface, or those of primary nature, arrested in the rocks on the way to the surface. Once delivered to atmosphere, river, or ocean, the emanations cease to be juvenile in a technical sense. In other words, Suess and his followers agree that proximate, rather than ultimate, origins should be emphasized in any useful classification. That view and the main principle of Suess's definition are reflected in the "juvenile" of the scheme to be proposed.

Gautier (1910, p. 437) and Clarke (1916, p. 213) use "virgin" as a synonym for "juvenile."

Though Suess attributed volcanic temperatures to the heat of primary hydrogen and other gases locally streaming out from the earth's interior, he nowhere states that all magmatic gas or vapor is directly of juvenile origin. On the contrary, a passage on page 655 of the third volume of "*Das Antlitz der Erde*," zweite Hälfte (1909), implies that he believed magmatic gas to be in part of meteoric origin. Nevertheless, a number of authors—including Lane (1908a, p. 502), Keilhack (1912, p. 73), Beyschlag, Vogt, and Krusch (1913, p. 135), Lawson (1914, p. 220), Pirsson (1915, p. 212), Leith and Mead (1915, p. 243), and Ries and Watson (1915, p. 594)—have used "magmatic" and "juvenile" as synonymous descriptions of emanations from magma. Spurr (1905, p. 256) writes of "magmatic or primitive

water"; Irving (1911, p. 668), of "'juvenile' or hot ascending waters." Ransome (1909, p. 198) is more nearly accordant with Suess and with the facts of nature in defining "juvenile" as "original magmatic." Kemp in 1908 (p. 706) recognized the possibility of magmatic gases other than juvenile, but in 1914 (reprint, p. 5) gave "magmatic" and "juvenile" as synonyms, thus aligning himself with the majority of the above-mentioned writers. This treatment of the two words is of course largely due to conscious or unconscious adhesion to a widely entertained speculation as to the origin of magmas, that they are composed entirely of primary matter.

Juvenile fluids may be: actually present in, or emanations from, hot or cooling rock-melts; in the fluid inclusions characterizing primary igneous minerals; in the gaseous components of some solid solutions; in the hydroxyl and other primary molecules chemically combined in primary crystallized rocks; or in emanations from re-heated igneous rocks. Thus, a juvenile fluid may belong to any one of Lincoln's (1907, p. 259) four classes of "emanations"—actual, fossil, repressed, and potential.

*Resurgent.*—"Resurgent" was adapted by the writer (1908, p. 48; 1910, p. 113; 1911, p. 57; 1914, p. 249) to signify the magmatic emanations of secondary origin, that is, those absorbed from country rock, either directly or during the solution of country rock in magma. Von Wolff (1914, p. 118) has accepted the word in the sense given and (p. 387) extends it to describe also certain pyroclastic deposits. As just noted, most authorities on the genesis of ore deposits appear to be opposed to the concept, and the very few authors who have seriously considered the origin of the ore-depositing solutions at or near igneous contacts generally regard "magmatic" and "juvenile" as of equivalent meaning. The sanction for the use of "resurgent" in the proposed classification is found in the many facts showing the reality of syntexis and profound endomorphic changes of primary magma. A great number of field observers have described such facts and they can no longer be explained away as the product of wild speculation. In any case, no geologist can afford

to ignore the possibility that resurgent gases have powerfully contributed to the development of ore deposits at igneous contacts.

Resurgent fluids naturally resemble the juvenile in their modes of occurrence, whether as constituents of live magma, as actual emanations, or as prisoners in frozen magma.

*Magmatic.*—The quantitative importance of secondary magmas is a matter of controversy, but no geologist with even minimum skill and experience in field interpretation doubts that locally sediments and schists have been absorbed by primary magma, which has therefore become charged with some resurgent volatile matter. Hence, in the interests of clear thinking, "magmatic waters" will here be held to include both "juvenile waters" and "resurgent waters"; more generally, "magmatic volatiles" (with "*hypogene* volatiles" as a synonym) will include "juvenile volatiles" and "resurgent volatiles." Either of the respective subdivisions may include volatile agents of "volcanic" origin or those of "plutonic" origin.

*Epigene and Meteoric.*—Frequent synonyms for "meteoric water" are "atmospheric water," "rain-water," "waters of infiltration," and "water of superficial origin." Few authors have considered the point whether sea-water, seeping into the earth's crust (as it obviously does at some points<sup>1</sup>), is properly included under "meteoric." In one passage Gautier (1910, p. 436) seems to answer this question in the negative; elsewhere (p. 438) he logically includes ocean-water seepages in meteoric waters, since he uses "*eaux d'infiltration*" as a synonym for "*eaux météoriques*." Lane (1908a, p. 503) puts both fresh and marine waters in the connate division of meteoric waters. Like every lake and river, the ocean is a part of the great circulatory system affecting atmospheric water and certainly very little of the actual sea-water has failed to make at least one complete journey in the cycle of the rains. Further, it may be recalled that the Greek root of "meteoric" means "things lifted up, on high, in air," and that much of the oceanic solution has been

<sup>1</sup> Sea-mills of Cephalonia, Hawaii (proved at borings), etc.

"raised" from the earth's interior by volcanic processes. From the standpoint of etymology, therefore, the geologist has the right to call ocean water meteoric and so recognize the close genetic kinship with the water of atmosphere, river, and lake.

Nevertheless, the tradition that proximate origins should be emphasized and the fact that "meteoric water" and "atmospheric water" are commonly employed as synonyms make it seem wiser to use some expression other than "meteoric" for underground waters of surface origin in general. Such a word is *epigene*, the correlative of Lyell's "hypogene." Geikie (1882, p. 316; 1903, p. 430) employed "epigene" in the sense of "produced on the surface of the earth" (see the New English Dictionary) and made it cover the activities of both fresh and marine water. Geikie's "epigene" is thus broader in scope than the same word used merely in describing underground volatile agents, but contexts should prevent any uncertainty of meaning on that account.

A possible objection to this technical adaptation is that "epigene" is liable to be confused with the "epigenetic" employed in classifying ore deposits. In reply one may urge that "epigene" is an older word than the "epigenetic" of classifications of ore deposits, and is the invaded, not the invader.<sup>2</sup> Only a little care is needed, while reading, writing, or translating, to prevent the imagined confusion.

"*Epigeal*" (lit. "on the earth"; accent on the penultimate syllable) might also be used to include atmospheric, fluvial, lacustrine and marine waters.

<sup>2</sup> Gürich (*Zeit. für prakt. Geol.*, 1899, p. 175) states that Stelzner, in a then unpublished course of lectures, first applied "epigenetic" to ore deposits. Bergeat (*Centralblatt für Mineralogie*, etc., 1901, p. 84) notes 1894 as the year of its appearance.

It is worthy of mention that "epigenetic" has long been used: in mineralogy as a synonym for "pseudomorphic"; in physical geology (Richtshofen and others) as a name for valleys eroded by superimposed rivers; and in biology as a name for a theory of germ evolution. Stelzner thus adapted an already overloaded word. A permissible equivalent might be "apogenetic." According to strict etymology, "hystero-genetic" would perhaps be a still better word for the idea he wished to express, but this term had been pre-empted by Zirkel to describe the later-formed schliers in igneous rocks.

Epigene waters become underground waters either by sinking through the rocks (seepage water) or by being buried with sediments or extrusive lavas or pyroclastics (connate water).

*Vadose*.—Posepny (1894, reprint, pp. 17, 24) invented the word "vadose" to signify "that part of the subterranean circulation bounded [below] by the water-level [water-table]." He contrasted it with the "deep underground circulation," below the water-table. In this sense Kemp (1906, p. 224; 1907, p. 2; 1914, reprint, p. 2) and W. H. Emmons (1913, p. 28, and 1917, p. 48) use the term.<sup>3</sup>

Suess (1902, p. 134; 1909, p. 630) consciously extended the meaning so that "vadose" should include all seepage water, above and below the water-table, and, as well, all oceans, rivers, clouds, rain, and snow. He even regarded as vadose the hydrogen sulphide bacterially generated in the Black Sea. Delkeskamp (1906, p. 33), Lindgren (1913, p. 82), Beyschlag, Vogt, and Krusch (1914, p. 135) and Lincoln (1911, p. 257) also appear to employ "vadose" as including all seepage water. Omitting any reference to the water-table, Spurr (1905, p. 256) describes vadose water as "surface-derived descending water"; Ries (1916, p. 441), as "descending surface water"; Doelter (1906, p. 14) and Clarke (1916, p. 213), as "superficial" water or "waters of infiltration."

Lane (1908a, p. 505) and von Wolff (1914, p. 118) make "vadose" a synonym of "phreatic." Keilhack (1912, p. 73) makes "vadose" cover all waters other than magmatic (his "juvenile").

The present writer (1914, p. 249) has used "vadose waters" as equivalent to "seepage waters" or "waters of infiltration," but now believes it better to adhere to Posepny's original definition, which in general gives a clear mental picture. In an arid region where there may be no distinct water-table,<sup>4</sup> all the seepage water is to be classed as vadose.

*Phreatic*.—Daubrée (1887, p. 19) invented "phreatic" from

<sup>3</sup> In a foot-note (1917, p. 46) Emmons erroneously states that "Posepny includes in the 'vadose' circulation water below the 'permanent water level.'"

<sup>4</sup> According to a verbal communication from Professor W. Lindgren.



a Greek expression for "well." Referring to what is popularly called ground-waters, he wrote (in free translation): "It will be convenient if they bear a cosmopolitan title, like *phreatic*, which expresses the fact that they supply *ordinary* wells and which is a term that would be understood by the Greeks." Originally, then, the word meant seepage water and particularly that below the water-table. It was so used by Hay (1892, p. 8) and McGee (1894, pp. 16, 42). The new English Dictionary (1909) defines it "of or pertaining to a well."

Suess (1909, p. 655) appears to have included in "phreatic water" that of connate origin as well as seepage water. Lane (1908a, p. 505) makes "phreatic" a synonym of "ordinary spring" or "vadose" water. Von Wolff (1914, p. 118) regards "vadose or phreatic" as including connate waters, in spite of their very definite distinction by Lane, the author who first suggested "connate" as a technical term in geology.

The writer believes that the history of the word and practical expediency should make "phreatic" mean the infiltrated waters which are bounded above by the water-table.

Phreatic waters are typically migratory, being driven by gravity and vapor pressure. The heat for changing density or vapor pressure may be derived from the earth's general supply, or developed in dynamic metamorphism, or derived from intrusive magma. Locally, however, seeping water may be arrested in its movement and, as free water, occluded water, water in solid solution, or water in chemical combination, remain stationary for an indefinite time.

*Seepage.*—Thus, all *seepage* waters or waters of infiltration, fresh or marine, are divisible into two physical parts, separated by the water-table: vadose above and phreatic below.

*Connate.*—In 1908 Lane (1908b, reprint, p. 1) wrote: "Such waters laid down with the strata when they were laid down may be called connate waters, for short"; and (1908a, p. 502) again described them as "buried with the beds in the first place." Though he stated magmatic water to be "in a sense connate in the magma," Lane's various papers appear to show that he in-

tended his new term not to apply to water and other volatile substances trapped in igneous rock at the time of its crystallization from magma. He gave "syngenetic" as an alternative expression for "connate." Connate water may be marine or fresh.

A considerable number of geologists, including Clarke, Lawson, Leith and Mead, Lindgren, von Wolff, and the writer, have found "connate" very useful in published descriptions and discussions. In the sequel the word will be used according to the Lane definition, with the additional notes: That epigene water buried in the cavities of surface lavas or in tuffs or other pyroclastics are also, like the epigene water buried in ordinary sediments, regarded as connate; and, secondly, that volatile substances typified by the carbon dioxide of limestone or the sulphur trioxide of gypsum are also connate in a technical sense. Typically, connate water or gas is stagnant. At first it may be free or combined. If initially in the free state, it may, through diagenesis or metamorphism, become occluded, go into solid solution, or become chemically combined. However, enormous volumes of connate water have obviously been expelled and set moving through the rocks either by diagenetic settling of sediments or pyroclastics, or because of the new crystallizations involved in static or dynamic metamorphism, or because of mere orogenic pressure, or because of the generation of heat with consequent increase of vapor tension. The heat concerned may be from the earth's general supply, from a zone of dynamic metamorphism, or from intrusive magma.

#### OLDER CLASSIFICATIONS.

Systematic discussion of the origin of underground "volatiles" has been largely confined to the writings of workers in the problems of ore deposits, and these authors have specialized on the waters, seldom considering those volatile solutions chiefly composed of material other than water. Among the authors who have recently given attention to the matter are: Posepny; Kemp; Lane; Ransome; Gautier; Beyschlag, Vogt, and Krusch; Lindgren; Lawson; and von Wolff.

Posepny recognized only two classes of waters, corresponding to his "vadose underground circulation" and "deep underground circulation."

Kemp (1902, reprint, p. 2) notes two classes: those derived "from eruptive rocks" and those derived "from meteoric sources, possibly during sedimentation." He finds the heat essential to promote circulation in: (1) dynamic crushing or chemical reactions; (2) the normal increase of temperature with depth; and (3) igneous intrusions.

Lane (1908a, p. 503) offers the following scheme:

I. Meteoric group.

- (a) Rain, vadose, or *pluvial* waters.
- (b) Buried or *connate* waters.

II. Juvenile or volcanic.

- (a) Magmatic.

Lindgren (1913, p. 82) classifies underground waters as: (1) vadose, (2) magmatic, (3) connate, and (4) "water originally of surface origin and contained in the pores of the rock, or in chemical combination, has by subsidence of the crust been carried to deeper and warmer levels and ascends from these by a sort of distillation."

The present writer (1911, p. 57) has reviewed "in tabular form, the whole group of gases and vapors which are engaged in volcanic and subvolcanic activities," publishing this table:

Magmatic fluids (volcanic; internal)	Juvenile .....	<ul style="list-style-type: none"> <li>{ Emanations directly from abyssal injection.</li> <li>{ Emanations from primary solid abyssal country-rock.</li> </ul>
	Resurgent ....	<ul style="list-style-type: none"> <li>{ Vadose and connate fluids absorbed in the syntectic process.</li> <li>{ Vadose fluids absorbed independently of rock assimilation.</li> </ul>
Phreatic fluids (subvolcanic; external)		<ul style="list-style-type: none"> <li>{ Vadose.</li> <li>{ Connate.</li> </ul>

In the table "vadose" is used in the broader meaning of seepage waters; therein the writer followed Suess and certain

authors on ore deposits. In the classification now to be proposed the word is employed with Posepny's definition.

Von Wolff (1914, p. 118) recognized among the volatile substances important in volcanology:

- I. Vadose oder phreatische Bestandteile.
- II. Magmatische Bestandteile.
  - (a) Juvenil magmatische, d. h. primäre.
  - (b) Resurgent, d. h. vadose oder konnate Fluida.

He adds the note (translated): "Of the vadose substances Lane called those 'connate' which are enclosed in sediments at the time of the formation of the latter." Evidently von Wolff's use of "vadose" and "phreatic" does not in either case correspond to the original definition.

#### PROPOSED CLASSIFICATION.

The following table represents the writer's attempt at a systematic grouping of underground "volatiles" on the basis of proximate origins. Classification on the basis of ultimate origin would have no practical value, since most, if not all, of the earth's surface water and gases were once probably juvenile.

#### UNDERGROUND VOLATILE AGENTS.

##### A. MAGMATIC or HYPOGENE (includes volcanic and plutonic).

##### I. JUVENILE (primitive, virgin, original-magmatic).

- a. In liquid magma.
- b. In crystallized igneous rocks and minerals, as occlusions, solid solutions, and chemical compounds.
- c. *Expelled*, from magma or igneous rock by crystallization or heat; may remain free or go into solid solution or new chemical compounds.

##### II. RESURGENT (secondary-magmatic).

- a. In liquid magma.
- b. In crystallized igneous rocks and minerals, as

occlusions, solid solutions, and chemical compounds.

- c. *Expelled*, from magma or igneous rock by crystallization or heat; may remain free or go into solid solution or new chemical compounds.

B. EPIGENE or EPIGEAL (includes underground atmospheric and marine water and associated gases).

I. SEEPAGE (fresh or marine waters of infiltration)..

1. *Vadose* (above the water-table).
2. *Phreatic* (below the water-table).
  - a. *Arrested* (free, occluded, in solid solution, or in chemical combination).
  - b. *Migrating*, because of gravity, the earth's general heat, the heat of orogenic crushing, or the heat of igneous intrusion.

II. CONNATE (fresh or marine waters buried with sediments or surface volcanics).

- a. *Stagnant* (free, occluded, in solid solution, or in chemical combination).
- b. *Expelled*, by diagenetic settling, crystallization during metamorphism, orogenic stress, the earth's general heat, the heat of orogenic crushing or metamorphic changes, or the heat of igneous intrusion.

C. MIXED TYPES.

The primary divisions (magmatic, epigene and mixed) and the secondary divisions (juvenile, resurgent, seepage and connate) are directly founded on origin. The finer divisions are descriptive of the actual locations and states of the "volatiles." Moving "volatiles" are specially significant in geology and the causes of their movement are briefly indicated. Both classes of seepage waters are typically in movement, but a juvenile, resurgent, or connate fluid will not migrate from the place of its proximate origin unless driven by some particular, powerful force or forces. This quality of emanation is symbolized by the

word "expelled." Thus, expelled juvenile, expelled resurgent, and expelled connate "volatiles" are all to be recognized.

Subjects for debate in connection with this table may be: (a) the emphasis on resurgent "volatiles"; (b) the inclusion of seawater in the meteoric class or its exclusion; (c) the definition of phreatic water as seepage water below the water-table, with corresponding definition of "vadose"; and (d) the use of "epigene" as proposed.

Most of the terms already have international currency—a desirable feature if a classification is to follow an elementary rule in scientific procedure. Men of six different nations have introduced these terms. The objective quality of the concepts underlying the leading words of the table is suggested by the fact that, without any violent changes in the original definitions, the terms make up a comprehensive mental scheme of underground volatile agents.

In offering the classification the writer's purpose is to show that the vocabulary of underground "volatiles" has been developed by the geological profession to the point where unequivocal statement and therefore clear thinking are possible. Both advantages are gravely endangered by such careless usages, definitions, and synonymies as are illustrated in the foregoing historical sketch. Misled by high authority the writer has, for example, employed "vadose" in too broad a sense. Still higher authority is Posepny's original definition coupled with the necessity of fitting together the established words "vadose," "epigene," "seepage," and "phreatic" in a logical scheme. Closer study of the subject has thus led to a conviction of sin and the suggested new classification is in part a confession of it. The need of a common language in science is absolute. No less certain is the advisability of constant revision of the verbal stock-in-trade of science. It is an ungrateful task, but the reviewer may be well repaid if criticism of his product is constructive.

## PROPOSED CLASSIFICATION IN PRACTICE.

Of course the scheme outlined is in no sense a classification of the *criteria* for the different kinds of underground "volatiles." That is a quite distinct problem, superlatively important and very difficult. It can be wisely attacked only if its investigator goes into the field already provided with a logical picture of all the known kinds of underground fluids. A knowledge of their relative amounts in the earth's crust is not his first care. He may prefer or believe that resurgent fluids or free-concrete water do not exist at all, but just because of his preference or belief he should keep his eyes specially sharp for field evidences that just these kinds of volatile agents do exist. In other words, a classification, as complete as the *experience* of the geological profession can make it, is an indispensable friend and mentor for the best type of field worker. He is ready to mend his classification as experience compels its improvement; he will never go without some kind of a classification. He needs it as an aid to intellectual integrity, to clear sight, to *complete* observation in the field. He will not make a fetish of it, but use it as a tool of high scientific value.

In view of the present lack of criteria for identifying each kind of underground volatile agents, there is little ground for wonder that so few students of springs, volcanoes, or ore deposits have ventured to classify actual, concrete solutions with a great degree of refinement. As a matter of fact, a given example is likely to be of mixed origin. Juvenile gases are liable to be mixed with small or large amounts of resurgent gases or vapors. Pure resurgent emanations are practically impossible. Any gaseous emanation from an igneous intrusive can hardly fail to mix with epigene water. Seepage water may dissolve a small percentage of connate water. Probably in most cases the utmost the investigator of a field problem can do is to determine the origin of the dominant ingredient in the underground solutions involved and secure a more qualitative notion regarding the other ingredients.

Hence, a number of descriptive terms other than those of a complete genetic classification are required for the field worker.

Such familiar expressions as "ascending waters," "descending waters," "oxidizing solutions," "acid waters," "alkaline waters," etc., may often be more directly useful in a scientific way than any term in the proposed classification.

A specially important illustration is found in the connection between metalliferous ore deposits and igneous intrusions. The field data may suffice to show that a primary concentration of ore was effected by magmatic emanations, without declaring what proportion was juvenile and what resurgent. On the other hand, the field data may be so incomplete that the observer cannot decide whether the ore-depositing solution was magmatic "water" or seepage or connate water heated by the igneous mass, though the fact shows the solution to have become capable of depositing ore because it has moved in the hot aureole about the intrusive. In such a case the fluid may be called an "*aureole* solution." Aureole fluids may, then, be juvenile, resurgent, phreatic, or connate, or any mixture of two or more of these kinds. As a class they are to be contrasted with phreatic waters which have not been thermally or chemically affected by any igneous intrusion.

Analogous general terms must be employed in the field study of metamorphism, volcanology, and other phases of geology. Indefinite expansion of the working vocabulary is thus possible and advisable; yet no necessary disturbance of the genetic classification of underground "volatiles" is thereby occasioned. Each of the two sets of terms, the universal and the special, has its own place in the equipment of every thorough investigator of the subject. The proposed classification is, of course, not universally acceptable, but its future editions, showing the confirmation or improvement dictated by the experience of geologists, may possibly serve as a general guide to research.

#### SUMMARY.

A review of geological literature since 1894, the date of Posepny's notable paper on ore deposits, shows the necessity of stock-taking in the matter of words to be used in describing and



thinking about underground volatile agents. The scope of "juvenile" has been variously defined. The synonymy of "magmatic emanation" has correspondingly varied. The idea underlying the term "resurgent" needs new emphasis; certainly the reason for the concentration of many ores by "aureole" solutions should be considered in terms of the high probability that the chemical nature of those solutions is a function of the resurgent material contained. The technical meanings of "meteoric" and "epigene" should be fixed in terms of a systematic scheme. The definitions and synonymies of "vadose" and "connate" have varied fundamentally. The value of "phreatic" in geology partly depends on a proper definition of "vadose."

Lack of uniformity in definition has interfered with general adhesion to any one of the older classifications of underground "volatiles." The writer has found that, if the original definitions of the established terms connected with this subject be accepted nearly or quite without change, a logical and formally complete scheme can be formulated. The resulting classification, constructively criticized, may have value as an automatic control in the making of field observations and as the embodiment of a universal language in dealing with underground solutions. Alongside it a much more elastic, working or field vocabulary should be developed. After the ability to speak and write about underground solutions with unequivocal meaning has been attained by geologists, they are more likely to attack with success the field criteria for recognizing the different kinds of volatile agents—a truly momentous and pressing problem.

## REFERENCES.

- F. Beyschlag, J. H. L. Vogt, and P. Krusch**, "The Deposits of the Useful Minerals and Rocks," translated by S. J. Truscott, London, 1914, vol. 1, p. 135.  
**F. W. Clarke**, Bulletin 616, U. S. Geol. Survey, 1916, p. 213.  
**R. A. Daly**, *American Journal of Science*, vol. 26, 1908, p. 48; *Bulletin, Geol. Soc. of America*, vol. 21, 1910, p. 113; *Proc. Amer. Acad. Arts and Sciences*, vol. 47, 1911, p. 57; "Igneous Rocks and their Origin," New York, 1914, p. 249.

- A. Daubrée, "Les eaux souterraines a l'époque actuelle," Paris, vol. 1, 1887, p. 19.
- R. Delkeskamp, *Zeit. für prakt. Geologie*, vol. 14, 1906, p. 33.
- C. Doelter, "Petrogenesis," Braunschweig, 1906, p. 14.
- W. H. Emmons, Bulletin 529, U. S. Geol. Survey, 1913, p. 28; Bulletin 625, U. S. Geol. Survey, 1917, p. 46.
- A. Gautier, *Comptes Rendus*, vol. 150, 1910, p. 436.
- A. Geikie, "Text-book of Geology," London, 1st ed., 1882, p. 316; 4th ed., 1903, p. 430.
- R. Hay, Final Report to Secretary of Agriculture, Senate Exec. Doc. 41, pt. 3, 52d U. S. Congress, 1st sess., 1892, p. 8.
- J. D. Irving, *ECON. GEOL.*, vol. 6, 1911, p. 668.
- K. Keilhack, "Lehrbuch der Grundwasser- und Quellenkunde," Berlin, 1912, p. 73.
- J. F. Kemp, *Trans. Amer. Inst. Mining Eng.*, 1902, reprint, p. 2; *ECON. GEOL.*, vol. 1, 1906, p. 207; *ibid.*, vol. 2, 1907, p. 2; *Min. and Sci. Press*, vol. 96, 1908, p. 705; Bulletin 79, Mining and Metall. Soc. America, reprint, 1914, p. 2.
- A. C. Lane, (a) *Bulletin Geol. Soc. America*, vol. 19, 1908, p. 502; (b) *Proc. Lake Superior Min. Inst.*, vol. 13, 1908, reprint, p. 1.
- A. C. Lawson, *Bulletin Dept. Geol. Univ. of California*, vol. 8, 1914, p. 219.
- C. K. Leith and W. J. Mead, "Metamorphic Geology," New York, 1915, p. 243.
- F. C. Lincoln, *ECON. GEOL.*, vol. 2, 1907, p. 259; *ibid.*, vol. 6, 1911, p. 257.
- W. Lindgren, "Mineral Deposits," New York, 1913, p. 82.
- W J McGee, 14th Ann. Rep. U. S. Geol. Survey, pt. 2, 1894, pp. 16, 42.
- L. V. Pirsson, "A Text-book of Geology," New York, pt. 1, 1915, p. 212.
- F. Posepny, *Trans. Amer. Inst. Min. Eng.*, vol. 23, 1894, reprint, p. 17.
- F. L. Ransome, Prof. paper 66, U. S. Geol. Survey, 1909, p. 198.
- H. Ries, "Economic Geology," New York, 4th ed., 1916, p. 440.
- H. Ries and T. L. Watson, "Engineering Geology," New York, 2d ed., 1915, p. 594.
- J. E. Spurr, Prof. paper 42, U. S. Geol. Survey, 1905, p. 256.
- E. Suess, "Verh. der Gesell. deut. Naturf. und Aertze," 1902, pp. 133-150; "Das Antlitz der Erde," Wien, Bd. 3, 2te Hälfte, 1909, pp. 630, 655.
- F. von Wolff, "Der Vulkanismus," Stuttgart, 1914, pp. 118, 387.