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ON THE CLASSIFICATION OF ROCKS.

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No. 13. — *On the Classification of Rocks.** *By* M. E. WADSWORTH.

THE results sketched in this paper, which will be given in greater detail elsewhere, were derived from the study of collections made in California, Lower California, Arizona, Nevada, Oregon, the territory covered by the Exploration of the Fortieth Parallel, the Lake Superior Region, New England, Costa Rica, and in Europe. The consecutive western area represented by these collections includes some three hundred thousand square miles, extending over one thousand miles in each direction. As this comprises one of the most extensive volcanic regions on the globe, which also contains old crystalline and sedimentary rocks, it affords a wide field for generalization.

Knowing the tendency of the human mind to fall into error, I can but feel that in avoiding the mistakes of others I may have committed greater ones myself. However this may be, my duty is none the less plain to give the facts as I understand them, let the result be what it will.

This work has been done at the private expense of Professor J. D. Whitney, in continuation of his work upon the State Geological Survey of California, and will be published in full in the Memoirs of the Museum of Comparative Zoölogy at Harvard University. If this paper has any value, the credit belongs to Professor Whitney, as without his generous liberality the work could not have been done; if valueless, the blame rests upon me, as I have had entire freedom in this work, and no one but myself is responsible for a single sentence contained herein.

My thanks are due to Mr. Clarence King, for his great courtesy in allowing me to examine, for some weeks, the rocks and slides belonging to his former Survey, which had been studied and reported upon by Professor Zirkel, and for his placing at my disposal his microscope during the examination; to the officers of the American Museum of Natural History in New York, in whose building the collection was deposited, for their efforts to facilitate my work; also to Mr. George W. Hawes of Yale College, for the privilege of examining his New Hampshire collection.

* Abstract of a thesis presented for the degree of Doctor of Philosophy in Harvard University, March 25, 1879; also given before the Boston Society of Natural History, May 7, 1879. The references and the numbers of the sections, which are fully given in the original, are omitted here.

The thin sections belonging to Professor Whitney's collections were prepared by Mr. J. H. Huntington, late Assistant Geologist on the Geological Survey of New Hampshire, whose preparations have been far superior to the other American work on rock sections that I have seen, and are fully equal, if not superior, to the German work sent to this country.

All classifications of rocks in vogue at the present time are, with one exception, confessedly artificial, as one can readily see by examining those proposed by Naumann, Blum, Von Cotta, Zirkel, Dana, Lang, Lasaulx, Rosenbusch, Roth, and scores of other writers of more or less note. The one exception is that scheme for the Tertiary volcanic rocks given by Baron Richthofen in the Memoirs of the California Academy of Sciences (Vol. I. Part II., 1868), in which he announces that, beginning with the Tertiary age, volcanic rocks succeed one another in massive eruptions in the following order: propylite, andesite, trachyte, rhyolite, and basalt. Having laid down this order, his classification then becomes largely artificial.

The usual classifications have been based on structure, age, mineralogical composition, chemical composition, and upon almost every part of the rock separately, but never on the entire rock as a unit. But little attention has been paid, when the scheme was based on mineralogical characters, whether the minerals were foreign, original, or alteration products. If the same minerals existed in two rocks, no matter if the minerals in one were products of the crystallization of the cooling magma, and in the other alteration products, both rocks were classed as the same, even if there existed a difference of silica amounting to over twenty per cent.

If we adopt the mineralogical classification, we are met by the fact that the feldspars cannot be distinguished from one another, in spite of the method of Des Cloizeaux, and its ingenious modification by Professor Pumpelly, — methods that fail exactly where they are most needod.

Furthermore, our best chemists and mineralogists are not agreed as to what are the species of feldspar, — a point that it would be well to settle before the classification of rocks is made wholly dependent on the feldspathic constituent.

Quartz, hornblende, augite, monoclinic and triclinic feldspars, and magnetic iron are found extending through rocks of every age and of every percentage of silica. The quartz and hornblende exist as foreign, as indigenous, and as alteration products, — distinctions that should be noted in employing these minerals in classification.

No natural distinction can be drawn between rocks of the Tertiary and Pre-Tertiary ages, since the glass and fluidal inclusions, crystalline texture, and the various other characters fail, exactly where they are most needed, to divide the rocks into older and younger, as is done by the majority of lithologists.

The writer believes that rocks should be studied, by beginning with their most compact or glassy state, and by then tracing them through to the most crystalline form, following every alteration, whether it be chemical or mechanical. Every rock that can be traced in this way forms a distinct species, whatever may be its state, — whether amorphous, glassy, crystalline, fragmental, tufaceous, or otherwise, — and whatever may be its age. The modifications, if of sufficient importance, form varieties simply, which should be included under the specific name. A natural classification of rocks must be empirical, and must be based on the rock as a whole, while a natural mineralogical classification is an impossibility, as it is based on part of the characters only.

If we except the veinstones and the majority of those rocks that are composed of one mineral, the species of rock forming the crust of the globe are very few. Believing that this earth is a cooling globe, all manifestations of internal heat giving rise to rocks (the only thing with which we are at present concerned) are here termed volcanic, and all such products are styled volcanic rocks. The testimony of the rocks is that all sedimentary forms came primarily from volcanic ones, volcanic energy having been more active than now in the past ages of the globe. This derivation is consonant with that which we see taking place at the present time, and agrees with the law of dissipation of energy; while the reverse view, at present popular, — that eruptive rocks were derived from sedimentary ones, — is contrary to the positive testimony of the rocks themselves, to the facts that are observed in nature, and to physical laws.

Taking the consolidation of any rock as its initial point, the minerals and rock fragments contained therein fall naturally into three classes: 1. Minerals and fragments of prior origin; 2. The products of that consolidation; 3. The products of alteration and infiltration.

These three classes are most marked in the volcanic rocks, as is natural; the first two predominating in the younger and least altered, the latter in the older and more altered ones, while the first and third classes predominate in sedimentary rocks. These alterations apparently take place through the agency of the ordinary percolating waters, which are not necessarily hot. The minerals and fragments of the first class, I find, fall into two divisions in the volcanic rocks: 1. Those that are characteristic of the rock species, and which were probably derived from the re-fusion of this species, that had crystallized at the depth at which it was prior to the eruption; 2. Those that are accidental, probably caught in the passage upward or during the outflow. Similar divisions are found, to a greater or less extent, in the sedimentary rocks, according as they were derived from one or more rocks, and also according to the preponderance of different rock fragments and minerals in them. Details of these occurrences will be given in the final publication.

Believing that new names should not be employed, except in cases of absolute necessity for filling gaps in the classification, the effort has been made to retain all the old names that are necessary, in their most general use, and to reject all needless ones, that can be so dealt with.

Starting with the basic rocks, I shall pass from the glassy states to the most crystalline, from the least altered to the most altered, and from the massive to the clastic, keeping on a similar range of chemical composition, and tracing the various gradations step by step. I shall also, in like manner, trace the gradations from the basic to the more acidic rocks, showing the gradual changes that exist in that direction as well. Since, owing to the necessities of the case, both in the use of these observations in a thesis and in giving a post-graduate course in lithology in this Museum, my work was made public before it was entirely completed, it has been deemed necessary to publish this abstract in advance. Several matters of detail yet remain to be worked out, which may modify some of the general views. All that is liable to be so modified must, therefore, be withheld for the present.

Commencing with the basalts, we find a bluish-black glass, giving in the thin section a yellowish-brown glassy base, holding a few crystalline secretions. This glass passes in the same specimen into a dense black, globulitic base, with the same mineral secretions. We then pass on to specimens that contain less of the globulitic base and more and more of the crystalline minerals, plagioclase, a little sanidin, magnetite, olivine, and augite. As the rocks become more crystalline the feldspars take positions diverging more and more from one another, holding cuneiform masses of the globulitic base between them, which base, as we proceed, is replaced by grains of augite, olivine, and magnetite. The feldspar is chiefly plagioclase, and is usually in narrow, ledge-like forms.

The olivine is mostly in rounded and broken crystals and fragments, showing oftentimes a blackening of its edges by the heat of the molten magma, which has torn and eaten its way into the olivine substance. Occasionally we see only little heaps of black grains left from the destruction of the olivine, every gradation being traced from these to the only slightly attacked olivine. Similar grains are scattered through the groundmass, giving rise to the belief that part of the magnetite found in the basalt was derived in this way, as the crystals of olivine are often found to be magnetic. The augite, unlike the olivine but like the feldspar, is a direct product of crystallization from the cooling magma. It is found to vary inversely with the olivine, and to crystallize with that mineral in such a manner as to lead to the conclusion that the augite is derived from the crystallization of the olivine material mixed with a certain proportion of the base. The olivine is very rarely the product of crystallization of the magma, but belongs to the minerals of the first class. The more coarsely crystalline of the basalts are known as dolerites and anamesites; the same general characters also hold good in the leucite and nephelite varieties.

The basaltic rocks are more subject to alteration than any others, the variety of alteration products diminishing as the silica increases. This alteration affects the olivine and base first, the latter often becoming somewhat fibrous, forming a base called by the German lithologists "micro-felsitic." Under this term they have utterly confounded the original micro-felsitic base of the unaltered andesites, and of some allied rocks, with the alteration and devitrification products in the basalts, andesites, trachytes, rhyolites, felsites, etc. Further alteration obliterates the base, and, one after another, the minerals in the rock, the feldspar usually being the last to disappear. These changes give rise to the presence of hydrous oxides and silicates, carbonates, etc. The chief proportion of quartz in these altered rocks is a direct product of alteration, derived from the base and the silicates in the basalt. The fine-grained, compact basalts through their alteration give rise to the variety known as melaphyr, while the coarser-grained ones, like the dolerites, in like manner form the diabases and the great majority of the basic rocks known as diorite, — a name that is at present the most abused one that occurs in lithology, as it is made to cover, not only old basalts, andesites, etc., but also the granites of the Sierra Nevada. May it soon be dropped! The still more coarsely crystalline varieties, when altered, give rise to the gabbros and peridotites. Under the former of these should be placed the majority of the euphotides, in which the saussurite is an altered feldspar. For the special descriptions and the tracing out of these changes, reference must be made to the original paper. The percentage of silica in all these basalts lies usually between 45 and 55 per cent, generally averaging about 49 per cent.

The unaltered fragmental forms of the basalts, as well as of the other volcanic rocks, are called tufas, while I have denominated all the altered and old fragmental forms as *porodites*, since at present we have no name in the science that covers that class of rocks. The poroditic forms, of course, closely resemble the rocks from which they were derived, and separation is often impossible in the field, the true character being told only by microscopic examination. To this difficulty of distinction is owing the often repeated assertion that sedimentary rocks pass into eruptive ones, — an assertion that has not proved true in the few cases that have come under my observation. It fails, in like manner, under the examination of other investigators, if recent petrographical literature is to be taken as a guide. Classing the various forms given above as varieties under the species basalt, the scheme is as follows: —

Basalt	Feldspar Leucite Nephelite	Basalt Dolerite	Melaphyr	Tufa.
			Diabase Gabbro Peridotite	Porodite.

Serpentine, when derived from the alteration of a peridotite, as is the case with some from California, would be classed under this variety.

Passing on to the more acidic species, the rocks usually known as andesites come next in order, ranging in silica usually from about 55 to 65 per cent, but generally averaging about 61 per cent. We have a gradual passage from basalt, with its globulitic base, rough groundmass, and accompanying minerals, into a rock having a dark to light-brown glass for its base, filled with microlites, and generally somewhat globulitic. Olivine is rarely seen in this; augite becomes abundant, in well-formed crystals; plagioclase predominates, but sanidin is more abundant than in the basalt. The color is a blackish-brown or gray, somewhat lighter than in basalt, and the structure of the rock is more porphyritic. The next form, usually classed as andesite, including also some so-called trachytes, has a gray micro-felsitic base, filled with microlites, enclosing similar minerals, and is of like structure but usually of a lighter gray color. Both contain, oftentimes, more or less hornblende, which plays here the same rôle that the olivine does in basalt. This hornblende is a mineral of the first class; its edges are often blackened, the crystals rounded, broken, blackened on the broken parts, and gnawed into by the molten magma. Sometimes this blackening and destruction extend so far that only little heaps of black grains are left, while similar grains are also scattered through the groundmass.

The blackened parts of this brown hornblende are magnetic, and it is probable that much of the magnetite scattered through the groundmass came from the destroyed hornblende. Often these hornblendes, occurring in the andesites that have a reddish color, have been torn into ferritic fibres, which have been heaped up or else scattered throughout the groundmass. These changes have apparently been produced by the remelting of pre-existing rocks of the same kind. The augite varies inversely with the hornblende, and in its relations to that mineral leaves no doubt that it comes from a recrystallization of the hornblende material dissolved in the magma.

The feldspar and augite are here products of crystallization of the magma. These rocks are subject to alteration, but in a less degree than the basalts, the changes being somewhat similar, and giving rise to several varieties now classed by lithologists as distinct species, some of the most important of which are propylite, porphyrite, hornblende-porphyry, black porphyry, part of the felsite or felsite porphyry, diorite, etc. No distinction can be legitimately drawn between the hornblende and augite andesites, on account of their mutual relations, as given above; as well might we have olivine and augite basalts.

We next pass into that most obscurely defined of the volcanic rocks, trachyte, which has been made to include the rhyolites on one side and the andesites on the other. The range of silica here is perhaps from 65 to 70 per cent. The base is a light-gray, almost colorless glass, somewhat micro-felsitic; sanidin begins to predominate, the plagioclase diminishes, biotite appears, and the hornblende is partly now a mineral of the first class and partly of the second. Augite rarely occurs, while quartz, which has been occasionally seen as a mineral of the first class in the basalts and andesites, begins to be more abundant. This, like the others, has its old and altered forms.

Next we pass on to the rhyolites, which contain from about 70 to 80 per cent of silica, possessing a clear, glassy base, which is, however, often colored by foreign materials, holding crystals and fragments of quartz belonging to the minerals of the first class, and more abundant sanidin, biotite, and hornblende, crystallizing out of the magma. The base is most prominent in the compact rhyolites, and its devitrification gives rise to the various structures that characterize them. This devitrification gives rise in the older and more altered rhyolites to the feldspar, quartz, and micro-felsitic (so-called) base, that has so puzzled lithologists in the study of the felsites. The rhyolites of all volcanic rocks pre-eminently show lamination produced by flowing, a fact which is doubtless due to their base being so siliceous. This structure and their devitrification enable us to trace a direct connection between the rhyolites and felsites, which are simply the older and more altered rhyolites. One of the best illustrations of this is to be found on Marblehead Neck, Mass., where at least two distinct flows of felsite occur, one cutting the other. They show the fluidal structure so characteristic of rhyolites, — a character that has been mistaken for lines of sedimentation by geologists, while the enclosed crystals of orthoclase have been taken for pebbles.

These felsites are not stratified, and, contrary to the positive assertion of Dr. T. Sterry Hunt, they are younger than the granite on the Neck, and cut it; also dikes of the felsite are seen cutting the granite. Furthermore, there is no passage of a conglomerate into a felsite in this locality, as macroscopic and microscopic observations prove. While to the naked eye and under the microscope this rock shows the fluidal structure of a rhyolite, in polarized light it is seen that the base has been completely devitrified, a process that is carried to a great extent in many known modern rhyolites.*

The various old rocks, designated by a multiplicity of names, fall into one and sometimes two or more of these species, according to the exactitude with which the name has been used in the past. The derived rocks can be referred to the parent ones with greater or less difficulty according as they were derived from one or more species, and also according to the changes that they have suffered. The tracing out of the natural relations and history of rocks is the most valuable and philosophical work to be done at present in this department of study, — work which never can be finished until the sum of human knowledge is complete, but which, as far as lies in my power to do with the collections now at my disposal, I hope to place before the public next year.

It is found in those rocks which show signs of long-continued cooling that the base diminishes and the crystalline minerals increase, the base occupying the interspaces between the crystals. When this process was carried to sufficient extent, as it was in the deeper-seated and older rocks, the chemical bases crystallized out of the rock base, leaving the superfluous silica in the form of quartz occupying the same interspaces. This process has taken place not only in the acidic granites but also

* Mr. J. S. Diller, who has been studying lithology under my direction, has undertaken, as a subject for his thesis, the field and microscopic relations of some of the felsites of Eastern Massachusetts. He has already made some important observations, and I hope his work will solve the vexed question of their relations.

in some of the basic gabbros. No inference, it seems to me, can be drawn regarding the heat to which a liquid has been exposed from either the pyrognostic or thermo-optical characters of the minerals that crystallize out on its cooling, or from the order of this crystallization. Thermo-optic and pyrognostic observations will prove to be of value, doubtless, when applied to those minerals that belong to the first class in volcanic rocks.

As far as my own observation has gone, and as far also as can be told from the observation of others, no sulphide, no carbonate, nor any hydrous mineral whatsoever, is the direct product of crystallization of the fluid magma, but all these are the products of alteration and infiltration after the consolidation of the lava, as are also part of the feldspar and quartz, as well as all of the epidote, etc.

Cases of envelopment are of constant occurrence among the minerals of the second class, but they bear no resemblance to those cases of alteration that Dr. Hunt has endeavored to place under the head of envelopment, and which are so abundantly seen in the altered rocks.

The alterations that take place are not usually attributable to extraneous material brought in by infiltrating waters, but are rather molecular changes brought about by the percolating waters within the rock mass. Except, therefore, on the weathered portions or in some rocks exposed to abnormal conditions, while the mineral constituents change through chemical rearrangement, the ultimate chemical constitution of the rock, as a whole, remains nearly constant.

The microscopic and chemical characters of volcanic rocks are opposed to the idea that they came from sedimentary ones, as the inclusions of the first division of the first class are nearly constant for each species, — a thing which could not happen if they were derived from the fusion of sediments, since a heat which has not obliterated hornblende crystals was certainly not great enough to destroy all the materials of which our sedimentary rocks are composed. While the chemical composition of these rocks indicates a somewhat uniform origin, that of the sedimentary ones shows generally a mixed one, as we know is the case with the majority of them.

The materials of the first division of the first class, too, in each species are only of such rock species as itself or of those that we know have preceded them in order of time; as, for instance, in rhyolite we find fragments of rhyolite, trachyte, andesite, and melaphyr or diabase, but, so far as I have seen, never an unaltered basalt. Rhyolite, being the most refractory of the volcanic rocks, is usually the most brecciated; and those geologists who hold that conglomerates have been metamorphosed into felsites, have forgotten that conglomerates are usually mixed rocks, while in the cases cited by them the pebbles are felsites, the same as the felsite into which they are said to be changed. We should expect, when an outflow takes place, that there would be a re-heating and breaking up of the old lava in the vent, which would naturally give us this brecciated material. However old the rocks may be, the materials of the first class in each species remain the same in character, from the earliest ones that I have examined down to those of the present time. The alterations to which volcanic rocks and their derived sediments are subjected make it often difficult to distinguish one from the other; but this difficulty arises, not from the sedimentary rock assuming, under any agency to which it is naturally subjected, the form of a volcanic one, except so far as it retains the characters and alterations belonging to its parent rock, but from the volcanic one taking from alteration, characters closely like those of sedimentary rocks. I have never found, under the microscope, the sedimentary characters obliterated in the most highly metamorphosed rocks that were known to have a sedimentary origin; and, furthermore, the minerals and mineral varieties of the third class in sedimentary rocks are, with possibly one or two exceptions, never like the minerals arising from the crystallization of any lava. The supposed passage of a sedimentary rock into an eruptive one can only be considered proved when it is shown positively that the observer knows the nature of the rocks in question, and that he has examined every inch of the portion lying between them, so as to be able absolutely to prove that no line of junction can exist. One such case worked in that way would prove the entire question in favor of the popular geological school.

The Geological Exploration of the Fortieth Parallel adopted, with modifications, Richthofen's classification of the Tertiary and recent volcanic rocks, and Mr. King, in his report, states that each of these rocks shows always a basic, mean, and acidic form. He classes rhyolite as the acidic form of basalt, placing both under the head of neolite. As my examination of Mr. King's collections convinces me that his system is based on errors, it is well to point out briefly some of these, taking, of course, the report of Professor Zirkel as the basis, and following, in a measure, its order.

The mica schist that Professor Zirkel calls a paragonite slate, like that from St. Gotthard, is similar to many mica schists in New England, and, except that its color is grayish-white, has no resemblance to the paragonite schist from St. Gotthard. It is, furthermore, destitute of disthene, although he says it contains "excellent large crystals of pale-blue disthene."

His granite porphyries belong in part to granites and gneisses and in part to the felsites, and his syenites are old and much decomposed andesites, in which the quartz is an alteration product.

The diorites are partly sedimentary rocks, partly granites and felsites, partly old andesites, and the rest are old basalts.

The so-called hornblende porphyries are somewhat altered andesites, and the diabases are mainly altered basalts, but a few are unaltered ones, the remainder being altered old andesites. The melaphyrs are all old, altered basalts, except one, which is an old andesite.

The propylites are all altered andesites, with which species their chemical composition agrees; and the diagnostic distinctions that Professor Zirkel has placed between the andesites and propylites do not hold good even in the specimens that he described, as would have been readily seen had he given complete descriptions instead of the very imperfect and often inaccurate ones that have been published. The distinction between these rocks is simply in the degree of alteration, and they pass directly into each other. With but two exceptions, the quartz propylites are old granitoid, felsitic, and fragmental rocks, while the two exceptional ones are altered andesites, in which the quartz is an alteration product. Rejecting, then, the so-called propylites that are not propylites, the range in silica is from 58.66 per cent to 64.62 per cent, or about 6 per cent, as shown by Mr. King's list of analyses.

No line can be drawn between the hornblende and augite andesites, but both form one continuous series, Professor Zirkel being mistaken in his statement that the augite andesites are younger than the rhyolites. Beginning with the andesites, the volcanic rocks have been described and arranged very indiscriminately, rhyolites being described in his report as trachytes, trachytes as andesites, and rhyolites and basalts as trachytes, etc. Only a few of these cases can be pointed out here. All the dacites, with one exception, are rhyolites, felsites, and fragmental rocks not belonging to andesites. The exception is an altered andesite, in which the quartz is an alteration product. Referring again to Mr. King's tables of analyses, we find the range of silica in the undoubted andesites to be from 58.33 per cent to 62.71 per cent, or a little over 4 per cent. Analysis 140 is that of a rock referred with doubt to the andesites.

The analyses of the trachytes seem best to bear out Mr. King's idea; but on looking over the list of analyses, and omitting those of rocks which were not described since they lay outside of his district, only two or three remain that can be considered as trachytes, viz. Nos. 154 and 155, and possibly 153. The rest belong to quartz-bearing basalts and to andesites. The basalts that have been described as trachytes are not doubtful ones, that might naturally have been classed with the trachytes, but are well-marked specimens, identical with some that have been described under the head of basalt in the same report. Attention should also be called to the fact that, contrary to Mr. King's theory, the quartz-bearing trachytes of Professor Zirkel's report are basic rocks (true basalts), and his typical augitic trachytes are acidic ones.

Regarding the union of the basalts and rhyolites, it should be remembered that they have not a single character in common, and also that the highest analysis of basalt published by Mr. King differs by fourteen per cent of silica from the lowest analysis of rhyolite. Professor Zirkel's method leaves the presence of nephelite very doubtful, certainly not proved. My examination shows that part of his nephelite-bearing rocks are andesites and the remainder basalts, in all of which the presence of nephelite is very doubtful. His supposed haüyne seems to be nothing but some grains of ultramarine rubbed off the boxes and enclosed in the balsam used in mounting. After careful study of the reports and collections of the Fortieth Parallel Survey, and of collections of the same rocks in the same and adjacent regions, I am unable to find any basis for Mr. King's classification, or for his theory of the genesis of volcanic rocks. In studying propylite I have not only examined the collections mentioned above, but have also had constantly at hand Baron Richthofen's collection made in California and Washoe. Placing propylite under andesite, as an altered form of the latter, Richthofen's law of succession seems then to be an observed order of occurrence in a comparatively brief geological period, and as such is hardly at present entitled to be considered a law. When it will express the order of succession during all time, and the reasons for that succession, then, and not till then, will it rank as one of nature's great laws.

We need more accurate field, microscopic, and chemical work on unaltered rocks, and a more careful study of our rock species in all their relations, since the best descriptions are at present so imperfect as to be of but very little value.

It is to be noticed that only so many minerals form in a lava as can crystallize during the time of cooling, and the interchange of chemical elements between two points not in juxtaposition is very slow in such a pasty mass. The crystallization will then be imperfect, as will also be the removal of the chemical elements from the base in rapidly cooling magmas. These facts, together with the diverse origin of the rock minerals, have served to render futile all attempts to determine by chemical analysis the minerals and the percentage of each in rocks.

In those rocks which contain an unaltered base, I find that the base is a surer index of the chemical composition, if we must be restricted to one thing, than the enclosed minerals are.

Exact field, microscopic, and chemical investigations are needed upon the vein-stones, ore deposits, and sedimentary rocks, as well as upon the eruptive ones, — work which promises a fruitful harvest for the earnest laborer. If the signs of the times are read aright, the day is not far distant when the battlefield of that all-embracing science, geology, will be transferred to the domain of petrography; and no young geologist who desires to stand in the front can afford to be ignorant of the modern lithological methods.

CAMBRIDGE, May, 1879.