Sir William Dawson
with the respects of
G. K. Gilbert

Author's Edition.

THE WORK OF THE

INTERNATIONAL CONGRESS OF GEOLOGISTS.

BY
G. K. GILBERT.

[Vice-Presidential Address, read to Section E of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, at New York, Aug. 10, 1887.]

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(Extracted from the American Naturalist, September, 1887.)

The Address of Vice-President G. K. Gilbert before Section E; A. A. A. S., Columbia College, New York, August 10, 1887.

Mr. Gilbert's address was a well-written composition, which bore the same title as the pamphlet published by the undersigned, under the auspices of the American Committee,—"The Work of the International Congress of Geologists." The easy and flowing style of the address was to have been expected by those who had read any of Mr. Gilbert's previous productions; but it must not be supposed that his fecundity of expression led him into saying too much. He has not been betrayed, for instance, into any general mention of the past work of the American Committee delegates to the Congress; nor even into any particular mention of that part of it which furnished the greater part of the material on which his address was based.

In speaking of the need for a word "to denote indefinitely an aggregate of strata," since to the word *formation*, formerly used in this manner, the Congress has attached a specific meaning, he says,—

"I suggest that we may advantageously enrich our language by the permanent adoption of *terrane*, a word whose English meaning has not been well established."

This is a singular, though doubtless inadvertent, plagiarism, since the two international committees (see "Report of Am. Com.," p. 43, etc., *a*, *c*, *d*, and pp. 50, 9, etc.) have employed the word in just this way. In the debates of the Congress also (*ibid.*, p. 22) "Professor Renevier proposed the term *terrane* (*terrain*) to avoid prejudging the rank in the classification of these rocks" (Archean). "He objected to the use of the term in any systematic sense, but believed it might be employed in a general sense." This, of course, inferred the use of the French word, with whatever pronunciation and spelling, in other tongues.

His suggestion as to the use of the termination "al" to convey ideas of time, as in Archeal, Cretaceal, Laramal, Belly Riveral, Bitter Creekal, if it will induce the local-taxonomy geologists of Mr. Gilbert's school to admit, through its employment, any generality in geological classification, will probably be easily introduced. Still, after having conceded to him an unusual command of his mother-tongue and great skill in its use, one cannot help regarding his innovations as usually more *logal* (as perhaps he himself would have phrased it of another) than logical. Nevertheless, let us hasten to observe that they are always euphonious; and, in fact, in reading his well-rounded periods, one may imagine them the agreeable cadence of word-drops caught up by some sprite of the river of language, and with the added glory of hue and tone from the intellectual light which floods them, falling back into their native bed.

In the serious matter of the address there are some passages to approve and some to disapprove. For example, in speaking

of the Congress's suggestions as to the terminations to be added to indicate groups, systems, series, etc., Mr. Gilbert says,—

"It would be impossible for a geologist to name or allude to a terrane without declaring its rank," etc.

To this it may be said that schemes of classification are not made for systematizing what we do not know, but what we do know. Nevertheless, it would not be an insuperable obstacle to speak of the "blankary, blankic, or blankian terrane." Equally ill-founded is the fear that by too systematic a classification—

". . . Taxonomy would be conceived by many geologists as an end instead of a means, . . . and energy would be wasted in taxonomic refinement and taxonomic controversy."

Energy is wasted now, and a great deal more than if there were some fixed principle to guide the controversialists.

One line of objection, curious in one who must be assumed to have accustomed himself to take broad views of things, is this:

"A committee appointed for the purpose formulated rules for the establishment of the names of genera and species, and their report was adopted by the Congress. I have no opinion to express as to the wisdom of the rules, but it is a matter of surprise that a body of geologists assumed to speak with authority on the subjects. From one point of view palæontology is a part of geology; from another point of view it is a part of biology. In so far as it names genera and species it is purely biologic, and it would seem proper that students of fossils unite with students of living animals and living plants in the adoption of rules of nomenclature."

Is it forgotten by Mr. Gilbert that the field of palæontology has been occupied almost exclusively by students of living plants and animals on account of its rich promise of results in determining those questions of derivative origin with which the address of this year's president of the Association was concerned? These geologic-biologists specially equipped to prosecute new inquiries are the very members of the Congress who have attempted the classification to which he alludes. He adds:

"The same is true of mineralogy, in regard to which no action has been taken. The most intimate relations of systematic mineralogy are with chemistry."

The last sentence would hardly secure Mr. Gilbert's critical approval were he aware that, from the earliest dawn of the science of mineralogy up to the present time, some of the most pre-eminent among mineralogists have denied this. But, even if it were so, some of those best able as chemists to grapple with petrological problems have entered the field of geology for the purpose of devoting themselves to it. Towards the close of the address he touches again upon this point, as follows:

"When a matter is proposed for regulation by the Congress, the first question which should be asked is whether it falls within the legitimate purview of a convention of geologists."

But what does not fall within such purview which bears, however indirectly, upon the riddles they are trying to unravel? Is the science of geology to be classed with those occupations

which relate solely and exclusively to one thing? (Perhaps Mr. Gilbert would call them *monotaxic.*) Or is it not rather a campaign requiring for its prosecution the infantry, artillery, cavalry, pontoon-trains, sappers and miners, engineers, and all the various departments of the largest army of science? If civil engineers with a little experience in camp become among the best military engineers, if our frontiersmen make the best scouts, why may not biologists, chemists, and crystallographers whose ambition urges them to seek a wider field than their laboratories become the very leaders which geology demands? In point of fact, they do; and if Mr. Gilbert will observe in the debates of the Congress, or of any other body which discusses these questions, who take the principal parts, and whose influence is most felt, he will find men eminent in the domains of special knowledge before they ventured to advise in that realm where it was applied to the attainment of a particular purpose.

It would seem, from certain parts of the address, that Mr. Gilbert half fears and half denies that the Congress possesses infallibility, but thinks that it should never pronounce in favor of a classification until all knowledge relating to the subject has been exhausted. He says, in regard to the acceptance by the Congress of a classification of the eruptive rocks,—

"With the rapid growth of knowledge and ideas, classifications are continually remodelled, and the best is in danger of becoming obsolete before it has been printed and circulated."

This evinces a curious view of the purpose of science. Is the same not equally true of philology, of ethnology, and of anything else which can be made the subject of investigation and transformed into organized knowledge? Does Mr. Gilbert expect that the heavens will fall if the classifications of the Congress need remodelling when time and further study have given more light? Are we to wait for omniscience before we attempt to classify? Or will not, rather, the changes which the future is certain to require, however great, be easier and less distracting when the whole enlightened world can take them at once by mutual agreement?

But perhaps Mr. Gilbert does not consider the co-ordination of knowledge in geology essential; one would judge so, at least, by his remark that

"—every system and every group is local. . . . If I have properly characterized stratigraphic systems, if they are both natural and local, it goes without saying that the classification of the strata of all countries in a dozen or so systems . . . is impossible."

Were that qualifying "if" not there one would be tempted to remark that, though the writer thinks it goes *without* saying, very few will concede that this statement goes *with* the saying, and in the absence of any proof. It is a thing which Mr. Gilbert cannot possibly know enough to deny, although he may think

that none of the supporters of the proposition know enough to assert it.

In parts of the address there is some appearance of unfairness in stating the position of the Congress. Take this, for instance:

"There can be no doubt that those who originally organized the work contemplated the *enactment* of a stratigraphic classification to be applied to the entire earth, and the selection of a color scheme for use either in all geologic maps or in all general geologic maps. But at the Berlin session the committee in charge of the work on the map of Europe pressed the Congress for the determination of questions on which hung the completion of the map, *and many hasty decisions were reached, while not a few disputed points were referred to the Map Committee.* The debates indicate that much *or* all of this work was provisional or of merely local application, but the *resolutions* adopted show little qualification. It should be added that the official minutes of the meeting are still unpublished."

—[It might, with grace, also have been here added whence his knowledge of the unofficial minutes came.]—The use of "enactment" in this sense conveys an impression the reverse of the fact. The Congress assembled to consult, to compare notes, and recommend; not to enact. Of course, it was, and is, hoped and believed that some plan will be arrived at of universal application. Without this, geology would be simply a more intellectual pastime than collecting postage-stamps or measuring property lines; but the implication of the entire succeeding sentence is, that the Congress, being pressed, "enacted" certain things, and left other things to be "enacted" by a subordinate committee. That all the points decided had reference to an experiment which was to be made the subject of future criticism is rendered unclear by the "much *or* all," and by the little qualification which it is said the resolutions have.

Yet this should have been understood by Mr. Gilbert, for he says, farther on,—

"By a series of resolutions a partial scheme has been selected, one color at a time, and the completion of the plan has been left to the Committee on the Map of Europe."

This certainly implies that the Map Committee has consulted the Congress as to certain portions of the former's task, and not that the latter has "enacted" colors for the world. Further:

"It is understood, in a general way, that the Congress reserves final action, and that the published legend not only belongs specifically to the map of Europe, but is provisional; still, as the map, *if generally approved*, will unquestionably be declared by the Congress an authoritative pattern for the guidance of map-makers, the plan should be freely criticised at its present stage."

If the map is open to much criticism it cannot be generally approved, and if not, it is quite proper that it should be declared a pattern. The Congress has quite abundantly shown its aversion to dictating or enacting contrary to the judgment of qualified objectors. Mr. Gilbert

. . . "cannot too strongly nor too earnestly insist that a System which is universal is artificial."

Of course, all human systems are artificial; but if Mr. Gilbert means inapplicable, and if any considerable number of competent geologists agree with him, it must be admitted that the very idea of an international congress is an absurdity. It may be doubted, however, whether this be the case, when one considers the many eminent men who have interested themselves in the Congress. Passing over his statement that no strata in the Eastern United States are pronounced Jurassic with confidence (as one in which he differs from at least as good an authority as himself), he objects to separating "a continuous rock system" (conformable strata?) which contains fossils resembling forms of the lower Jurassic at the top, and lower down others resembling forms of the Triassic, into those two systems, and says, "A Jurassic system thus established would be necessarily artificial." But in Great Britain the beds from the bottom of the Primordial to the base of the Upper Silurian make a single conformable sequence; and many other examples in Europe and this country might be cited. Indeed, it is strongly insisted by the Director of the United States Geological Survey that "systems or divisions of the second order (above the Archean) should be based primarily on biology and secondarily on physical structure." Mr. Gilbert's definition of a System as

"a great terrane separated from terranes above and below *by great unconformities*, or great life-breaks, or both,"

differs from that of his chief, as well as from the common usage.

But Mr. Gilbert prefers his

"own definition of a system, making it natural, and consequently local;"

and he opposes

"any attempt to coerce the geology of one country in a rigid matrix formed over and shaped by the geology of another country."

As to the latter, so do all geologists; but it is a different proposition to make a matrix by combining the "geologies" of all countries and fitting as much as there happens to be of each into the general mould, leaving the others to complete the gaps.

He objects to the provisional color scheme of the Map Committee, that

"—it is adjusted to the rock systems of Europe exclusively, and makes no provision whatever for the systems of other parts of the earth. The geologists of Wisconsin, for example, cannot use it without calling the Keweenawan either Cambrian or Archean," . . . if they believe that "it belongs to neither of these two categories."

The above, to be intelligible, needs a note explaining that certain eminent geologists have lately come to the conclusion that the term Archean should be restricted to the lower part of what up to the present time the world has understood it to define, and that another term should be applied to the rocks between its upper portion, as thus defined, and the base of the Primordial.

This criticism, then, assumes the form of a serious sort of pun, or a puzzle based upon the ambiguity of a word. As the greater number of the world's geologists have not yet accepted this new use of "Archean," the criticism is not fatal. Of course, if the new group be accepted, the Keweenawan will be interpolated between it and the Paleozoic.

It is not the purpose of this article to criticise the plan of the spectrum proposed by Mr. Gilbert. As he says, it has been very fully discussed in the proceedings of the Bologna Congress; but it may be said that one of his canons—viz., that the groups of "hues and tones," called by the vulgar simply colors, which are to serve as a scale—

"... must be so chosen that the degree of separateness of adjacent colors shall be everywhere the same, as judged by the *normal* human eye."

will be very difficult to carry into effect, in default of the discovery of, and agreement upon, that normal eye. To no two eyes of the ordinary kind would the "separateness" be likely to appear the same. It ought also to be mentioned that, in adding the hues of purple to one end or the other of the spectrum to increase the range of the time-scale colors, he violates his own rule, and renders it impracticable to assign by its wave-length a color to an intermediate rock-mass.

The portion of the address, however, most open to objection is the end of it. He says,—

"A classification is a generalized expression of the facts of observation outside the domain of the voter. If it comprises all the essential facts its sufficiency will be eventually recognized, whether its authority is individual or collective. If it does not comprise them it will inevitably be superseded, by whatever authority it may have been instituted."

This argument savors somewhat of Oriental fatalism, but no exception need be taken to the words beyond the fact that a vote of competent men is a good way to arrive at a conclusion whether a certain formulative statement be or be not the desired generalized expression. The conviction that such a vote carries will be strong in proportion to its unanimity, but, in any case, it will have to stand the test to which Mr. Gilbert alludes. He proceeds:

"For this reason I am opposed to the classification by the Congress of the sedimentary formations, and likewise to the classification of the volcanic rocks; and I also regard it as ill advised that the Congress undertook the preparation of a map of Europe, for that, if more than a work of compilation, is a work of classification."

Poor Congress! About to be bereft of the power to consider the objects for which it was created, why was it called into purposeless being? Suppose that when Lavoisier and his coadjutors assembled the famous congress to decide upon a system of nomenclature and to agree upon a theory of chemistry (then largely through his efforts emerging from chaos to order) some one had said, "Your congress should consider no questions of science,

but only questions of names. Within the field of names it should only comprehend what Stahl and the phlogistonists understand by them. It should therefore not attempt the classification of the elements, nor the classification of compounds made by combining elements. It should discuss no analysis unless the data be compiled from existing authorities. It should not regulate the nomenclature of somatology, for that belongs to physics and mechanics; it should not regulate the nomenclature of reactions, for that belongs to magic,—in fact, it should not meddle with names at all, for that is the domain of philology:"—would we ever have had a science of chemistry at all, or would Lavoisier and his colleagues have persisted in their reckless course of counselling and devising?

In this connection the words of the great Berzelius are very applicable:

"In every science a systematic nomenclature is necessary, but in none more than in chemistry. The confusion which reigned prior to the happy idea of Guyton de Morveau is a proof. The nomenclature which chemists have employed since 1780 is the fruit of his labors, sustained and directed by Lavoisier, Berthollet, and Fourcroy. The advantage that it presents is that whoever learns to recognize a compound can give it its true name without knowing it beforehand, so that it is unnecessary to charge the memory with a large number of different terms. . . . Furthermore, scientific nomenclature is in itself the expression of a complete theory, so that if, on the one hand, the theory furnish the name, on the other the name indicates the theory. It has been objected to this relation of a nomenclature to theory that it obliges the names to be changed with the theories, which would not be necessary in the employment of purely technical terms, that are always preserved without alteration. But as these changes are ordinarily the results of progress in the direction of clearer notions, the change of nomenclature, far from injuring, is, on the contrary, another means for facilitating the march of ideas. *In general, nothing which contributes towards rendering any part of a science stationary is advantageous:* everything must advance equally in proportion to the multiplication of discoveries and knowledge." (Berzelius, "Treatise on Chemistry," vol. i., Introduction, 1829.)

It is tolerably sure that if Mr. Gilbert expects the International Congress of Geologists to eschew all questions of science in its debates, and devote itself to the employment of playing at logograms exclusively with old data, he will be disappointed.—*Persifor Frazer.*

Sept. 24, 1887.

ADDRESS

BY

G. K. GILBERT,

VICE PRESIDENT, SECTION E.

THE WORK OF THE INTERNATIONAL CONGRESS OF GEOLOGISTS.

ELEVEN years ago the Association met at Buffalo. It was the year of the Centennial Exhibition, and we were honored by the presence of a number of European geologists. This naturally opened the subject of the international relations of geology, and the proposition to institute a Congress of geologists of the world took form in the appointment by the Association of an International Committee. The project thus initiated found favor elsewhere, and there resulted an international organization, which up to the present time has held three meetings. It convened first at Paris in 1878, then at Bologna in 1881, and at Berlin in 1885. Its next meeting will be held in London next year, and an endeavor will be made to secure for the United States the honor of the fifth meeting. The original committee of the Association has been continued, with some change of membership, and has sent representatives to each session of the Congress.

The work of the Congress as originally conceived and as subsequently undertaken has for its scope geologic nomenclature and classification, and the conventions of geologic maps. The particular classifications attempted are the establishment of the major divisions used in historic and stratigraphic geology and the subdivision of volcanic rocks. In nomenclature three things are undertaken: first the determination of the names of historic and stratigraphic divisions; second the formulation of rules for nomenclature in paleontology and mineralogy; and third, the establishment and definition of the taxonomic terms of chronology (period, epoch,

etc.,) and of stratigraphy (system, series, etc.). The map conventions most discussed are colors, but all signs for the graphic indication of geologic data are considered. The Congress has also undertaken the preparation of a large map of Europe, to be printed in forty-nine sheets.

The work was for the most part planned at the Paris meeting, and committees were appointed to formulate subjects for action by the Congress at subsequent sessions. Briefly stated, the work accomplished to the present time is as follows: Agreement has been reached as to the rank and equivalence of the taxonomic terms employed in chronology and stratigraphy, a set of rules for paleontologic nomenclature has been adopted, and many sheets of the map of Europe have been prepared for the engraver. A partial classification of stratified rocks has been agreed to and also a partial scheme of map colors, but the reports of proceedings indicate that action in these matters is tentative rather than final.

It is understood that both of these subjects will have prominent place in the proceedings at the London meeting, and the American committee is endeavoring to prepare itself for representative action at that meeting by ascertaining the opinions of all American geologists on the various subjects. It has asked this Section to set apart a day for the discussion of some of the more important questions, and it can hardly be doubted that the Section will realize the mutual advantage of thus assigning the time requested. I am personally so impressed with the importance of the possible work of the Congress that I shall devote the present hour also to its consideration.

The first thing the Congress did was to select names for a set of categories to express the taxonomic rank of stratigraphic divisions, on the one hand, and of chronologic divisions on the other. In the terminology of zoölogy and botany the words kingdom, class, order, family, genus, species, etc., however difficult of definition they may severally be, nevertheless are used always in the same order of inclusion. No systematist in those sciences would think of grouping orders together and calling them a family, or of styling a group of families a genus. But in geology there is no such uniformity of usage. With some writers a group is larger than a series, with others it is smaller. With some an age includes several periods, with others a period includes several ages. There are even writers who ignore the distinction between stratigraphy and chronology;

and among the classifications submitted to the Congress is one in which an age is subdivided into systems. There is a manifest advantage in bringing order out of this chaos, and so great is the utility of uniformity and perspicuity that the decisions of the Congress in this regard will unquestionably be followed by future authors. The terms and the order adopted by the Congress are as follows: Of stratigraphic divisions that with the highest rank is *group*, then *system*, *series* and *stage*. The corresponding chronologic divisions are *era*, *period*, *epoch* and *age*. This order of rank is strange to most English readers and writers, and so is one of the terms — *stage* — but the strangeness is only a temporary disadvantage and will not seriously retard the adoption of the convention. The fact that we have previously used the words in a different sense, or that their etymology might warrant a different meaning, need not deter us, for we know from frequent experience that the connotations of a word transferred from one use to another quickly disappear from consciousness, leaving it purely denotative. The introduction of the word *stage*, which can hardly be said to have had an English status heretofore, or at least the introduction of some new word for that part of the column, was necessitated by the restriction of the word *formation* to a special meaning, — the designation of mineral masses with reference to their origin.

The same restriction vacated another office that had been filled by formation, and to this office no appointment was made. I refer to the use of the word to denote indefinitely an aggregate of strata —as in saying, This formation should be called a series rather than a system. This is an important function, for which some provision must be made. I suggest that we may advantageously enrich our language by the permanent adoption of *terrane*, a word whose English meaning has not been well established.

The fixation of the chronologic terms creates a similar difficulty. We have crystallized out of our magma the terms *era*, *period*, *epoch* and *age*, and there remain in the ground-mass only *eon*, *cycle* and *time*. Of these, *eon* has a poetic connotation which seems to unfit it for this particular use; *cycle* implies repetition or recurrence; and *time* has been so generally applied to unlimited duration that it is difficult to apply it also to limited duration, even though the nature of the limitation be indefinite. On the whole, *time* seems open to the least objection, but I cannot help regretting that either *period* or *age*, both of which have heretofore passed current

in the indefinite sense, was not reserved by the Congress for that function. With English-speaking peoples the word *eon* could have been better spared for the definite series.

But while the terms selected by the Congress are not beyond criticism, the benefits to be derived from an agreement in an orderly system are so great that I for one shall unhesitatingly adopt them as they stand,— provided, of course, that the Congress makes no effort to improve its selection. A small reform of this nature yields its profit to this as well as future generations, and I hold it a duty to favor even those reforms which involve so much effort and pains that their blessings cannot be realized by those who initiate them. Such are the exchange of our English spelling for a rational system, and the exchange of decimal notation in arithmetic for a binary notation. My application of the new nomenclature begins with this address, in the preparation of which I have experienced its utility. That you may have no difficulty in interpreting my reformed language, I have placed the taxonomic legend on the wall, with the addition of the complementary indefinite terms, terrane and time.

Terranes.	Times.
Group.	Era.
System.	Period.
Series.	Epoch.
Stage.	Age.

There are propositions before the Congress to distinguish the names of individual groups, systems, series and stages by means of terminations, those of the same rank having the same termination. Thus it is proposed by a committee that every name of a group shall end in *ary*,— Tertiary, Primary, Archeary; it is proposed that names of systems end in *ic*,— Cretacic, Carbonic, Siluric; it is proposed that names of series end in *ian*,— Eifelian, Laramian, Trentonian; and it is proposed that stage names terminate with *in*. Another committee suggests that *ic* be used for stages instead of systems. The adoption of such a plan would enable a writer or speaker to indicate the taxonomic rank of a terrane without adding a word for that purpose. If he regarded a certain terrane taking its name from Cambria as a system, he would call it the Cambric; if he esteemed it only a series, he would say Cambrian; and there would be no need of adding the word system, or series in order to express his full meaning. Conversely the reader or hearer would always learn its taxonomic rank, or supposed

rank, whenever a terrane was mentioned. These I conceive to be the advantages derivable from the change, but they would not be the only effects. It would become impossible for a geologist to name or allude to a terrane without declaring its rank, and the consequences of this would be evil in many ways. In the first place one could not discuss terranes from any point of view without expressing an opinion as to their taxonomy, and the change would thus contravene one of the most important rights of opinion — namely, the right to reserve opinion. Again, geologists who differed as to the rank of a terrane would necessarily terminate its title differently, and a needless synonymy would thus be introduced. In the third place the created necessity for taxonomic discrimination on all occasions would tend to direct undue attention to taxonomic problems. Taxonomy would be conceived by many geologists as an end instead of a means, just as correlation has been conceived, and energy would be wasted in taxonomic refinement and taxonomic controversy. It is convenient for purposes of description and comparison to classify the strata that constitute a local columnar section in phalanges of various magnitude or rank, but the criteria on which we depend for discrimination are in the nature of things variable and offer ground for endless difference of opinion; and it would be extremely unfortunate to have such differences perpetually brought to the foreground.

Another subject considered by the Congress is the nomenclature of paleontology. A committee appointed for the purpose formulated rules for the establishment of the names of genera and species, and their report was adopted by the Congress. I have no opinion to express as to the wisdom of the rules, but it is a matter of surprise that a body of geologists assumed to speak with authority on the subject. From one point of view paleontology is a part of geology; from another point of view it is a part of biology. In so far as it names genera and species it is purely biologic, and it would seem proper that the students of fossils unite with the students of living animals and living plants in the adoption of rules of nomenclature.

A similar remark applies to the nomenclature of mineralogy, in regard to which no action has yet been taken. The most intimate relations of systematic mineralogy are with chemistry.

Yet another projected work of the Congress is the classification of eruptive rocks. Up to the present time action has been deferred,

and it may reasonably be hoped that no scheme of classification will be adopted. If there existed a system of classification which gave general satisfaction and had stood the test of time, there would be little harm — and little or no advantage in giving it the official stamp of approval. If the main features of a classification were well established and the residuary discrepancies were recognized as unessential, it is conceivable that some benefit might be derived from the submission of the matter to an assembly of specialists. But the actual case is far different. Not only is there wide difference as to the classification of volcanic rocks, but there is no agreement as to the fundamental principles on which their classification should be based, for we still lack an accepted theory of volcanism. At the same time observation is being pushed with great vigor, and with the aid of new and important methods. With the rapid growth of knowledge and ideas classifications are continually remodelled, and the best is in danger of becoming obsolete before it has been printed and circulated. Should the Congress enter the lists, one of two things would occur. Either its classification would be treated like that of an individual and ignored as soon as a better one was proposed, or it would be regarded as more authoritative, and new facts would for a time be warped into adjustment with it. In either case the reputation of the Congress would eventually suffer, and in one case science would suffer also.

There remain to consider the two most important undertakings of the Congress, the classification of terranes and the unification of map colors. The Congress is attacking these subjects indirectly by means of a third undertaking, the preparation of a geologic map of Europe, and this method of approach has had the effect of making it difficult properly to interpret its action. There can be no doubt that those who originally organized the work contemplated the enactment of a stratigraphic classification to be applied to the entire earth and the selection of a color scheme for use either in all geologic maps or in all general geologic maps. But at the Berlin session the committee in charge of work on the map of Europe pressed the Congress for the determination of questions on which hung the completion of the map, and many hasty decisions were reached, while not a few disputed points were referred to the map committee. The debates indicate that much or all of this work was provisional or of merely local application, but the resolutions adopted show little qualification. It should be added

that the official minutes of the meeting are still unpublished. In view of the uncertainty thus occasioned I shall not attempt to characterize the attitude of the Congress on the subject of classification, but shall merely develop my individual view.

It is the opinion of many who have discussed the general classification of terranes by convention of geologists that the smallest unit of such classification should be the stratigraphic system. What is a stratigraphic system? The Congress implies a definition in saying that a system includes more than a series and less than a group, and that the Jurassic is a system; but this gives only a meagre conception and we need a full one. As the problem of classification demands a true conception of a system, and as there is reason to believe that a false conception is abroad, it is proper that in seeking the true one we begin with the elements.

The surface of the land is constantly degraded by erosion, and the material removed is spread on the floor of the ocean, forming a deposit. This process has gone on from the dawn of geologic history, but the positions and boundaries of land and ocean have not remained the same. Crust movements have caused the submergence of land, and the emergence of ocean bottom, and these movements have been local and irregular, districts here and there going up while other districts went down. The emergence of ocean bottom exposes the deposit previously made on it and subjects it to erosion. In this way every part of the known surface of the globe has been the scene of successive deposition and erosion, and in many districts the alternations of process have been numerous. It is manifestly impossible that either erosion or deposition should have ever prevailed universally, and it has been established by the study of stratigraphic breaks that a time of erosion has often interrupted deposition in one region while deposition was uninterrupted in another.

In transportation from its region of erosion to its place of deposition detritus is assorted, and it results that the simultaneous deposits on the bottom of an ocean are not everywhere the same. Equal diversity is shown in the ancient deposits constituting geologic formations. It is a general fact that synchronous formations have not everywhere the same constitution.

Many of the variations in deposits are correlated with depth of water and distance from shore, and it results that elevation and subsidence in regions of continuous deposition produce changes in the nature of the local deposit.

The animals and plants of the earth are not universally distributed, but are grouped in provinces. In the geologic past similar provinces existed, but their boundaries were different, shifting in harmony with the varying geography of the surface. From time to time the barriers separating contiguous provinces have been abolished, suffering them to coalesce; and conversely new barriers have arisen, creating new provinces. From the earliest paleozoic to the present time the species of animals and plants have been progressively modified, the nature of the modification depending on local conditions. The faunas and floras of different provinces thus become different, and the longer the provinces remain distinct, the greater is the divergence of life. The removal of a barrier either produces a new fauna by the fusion of the two previously separated, or else obliterates one and extends the area of the other. In either case there is a change toward the unification of life, and in either case there is an abrupt change in a local fauna. Thus the secular evolution of species, combined with the secular and kaleidoscope revolution of land areas, leads to two antagonistic tendencies, one toward diversity of life on different parts of the globe, the other toward its uniformity. The tendency toward uniformity affords the basis for the correlation of terranes by comparison of fossils; the tendency toward diversity limits the possibilities of correlation.

If now we direct attention to some limited area and study its geology, we find that under the operation of these general processes it has acquired a stratigraphic constitution of a complex nature. Its successive terranes are varied in texture. Breaks in the continuity of deposition are marked by unconformities. The fossils at different horizons are different, and when they are examined in order from the lowest to the highest, the rate of change is found to vary, being in places nearly imperceptible and elsewhere abrupt. It is by means of such features as these — that is, by lithologic changes, by unconformities, and by life changes — that the stratigraphic column is classified into groups, systems, series and stages. A system is a great terrane separated from terranes above and below by great unconformities, or great life breaks, or both. Smaller unconformities, smaller life changes, and lithologic changes are used for the demarcation of series and stages; and on the other hand, exceptionally great unconformities and life breaks are used to delimit groups. As the same criteria determine groups, systems and series, differing only in degree, the precise definition of

the term system is impossible, and in many cases the gradation of a terrane as a group, a system or a series is largely a matter of convenience. From this point of view a system is somewhat artificial, but there is a more important sense in which it is natural. It is limited by stratigraphic or paleontologic breaks above and below, and these breaks are natural. The taxonomist is not warranted in dividing systems where no such break exists.

Transferring now our attention to some other area, distant from the first, and studying its stratigraphy, we find that the same principles enable us to divide it independently into stages, series, systems and groups. Its fossils are not the same, but they are to a certain extent similar, and the sequence of life is approximately parallel. We cannot compare stage with stage, nor series with series perhaps, but we can compare system with system, and making the comparison we discover that the breaks are at different places. While one area was upraised and subjected for a time to erosion, the other received continuous deposition. While life in one area, enjoying constant conditions, was almost unchanged for long ages and even epochs, it was revolutionized in the other by the irruption across some obsolescent barrier of strong and aggressive faunas and floras. The systems of one area, therefore, do not coincide with the systems of the other in their beginning and ending. They may differ in number, and they may differ greatly in magnitude and in the duration they represent. They are in fact a different set of systems.

The case I have described is ideal but not false. It represents the common experience of those who have developed the geologic histories of remote districts and attempted to correlate them with the geologic history of Europe. There does not exist a world-wide system nor a world-wide group, but every system and every group is local. The classification developed in one place is perfectly applicable only there. At a short distance away some of its beds disappear and others are introduced; farther on its stages cannot be recognized; then its series fail and finally its systems and its groups.

If I have properly characterized stratigraphic systems — if they are both natural and local — it goes without saying that the classification of the strata of all countries in a dozen or so systems, as proposed by some of the members of the Congress, is impossible.

I hasten to add that from the point of view of these gentlemen what they advocate is not necessarily impossible, for they have a

different conception of a system. They regard it not as local but as universal. It is their privilege to define their terms as they please, and we will not dispute about mere words, but I cannot too strongly or too earnestly insist that a system which is universal is artificial. It may be natural in one geologic province, but it is artificial in all others. Take for example the Jurassic. It is a natural system in Europe. In the eastern United States no strata are called Jurassic with confidence, and at the west the rocks called Jurassic merge with those called Triassic. In India, Medlicott tells us, a Jurassic fauna occurs at the summit of a great natural system containing a Permian fauna near its base. In New Zealand, according to Hutton, a continuous rock system, dissevered by great unconformities from other systems, bears at top fossils resembling those of the lower Jurassic and lower down fossils of Triassic facies. To establish a Jurassic system in either of these countries it is necessary to divide a natural system, and a Jurassic system thus established would be necessarily artificial.

This is the sort of classification implied by the assumption that systems are world-wide. It is not impossible, but it is highly unadvisable. It is classification for the sake of uniformity, and its uniformity is procrustean. The natural systems of a region are the logical chapters of its geologic history. If you group its strata artificially according to the natural divisions of another region, you mask and falsify its history. The geologic history of the earth has as great local diversity as its human history. As in human history there are interrelations and harmonies and a universal progress, but these are perceptible only in the general view; and the student whose preconceptions lead him to exaggerate the harmonies and ignore the discrepancies perverts the meaning of every page.

I prefer therefore my own definition of system, making it natural and consequently local, and I earnestly oppose any attempt to coerce the geology of one country in a rigid matrix formed over and shaped by the geology of another country.

The ideas I oppose have arisen in connection with the work of correlation. Some geologists appear to regard correlation as the determination in distant localities of identities; the more philosophic regard it as the determination of the actual relations, whether they be of identity or difference. With the former the basis of correlation is the universality of geologic systems; with the latter it may be said to be the universality of geologic time.

Now in the comparative study of local geologic histories, just as

in the comparative study of local human histories, it is a matter of convenience to have a common scale of time. It is not essential, but it is highly convenient. In human history we use an astronomic scale of equal parts, designating each unit by a number. In geology no scale of equal parts is available, and we employ the eras and periods, and to some extent the epochs, of the local geologic history first deciphered — that of Europe. These time divisions bear the same names as the groups, systems and series of strata whose deposition occurred within them.

So far as the science of geology is concerned the selection of Europe as its first field of study was a matter of chance, and the adoption of the European time scale as a general standard may therefore be said to have been accidental. Though the local rock scheme on which it is based is natural, the time scale, considered as universal, is arbitrary. Another locality would have afforded a different scale, but its authority would neither be greater nor less. The scale being recognized as arbitrary, and a mere matter of convenience, it is legitimate to modify and fix it by formal convention. The Congress can do good service to geologic technology by putting it in the best possible shape and giving it an official status. In my judgment only a small number of divisions should be admitted, not more than the number of periods of the European scheme. In a general way the durations represented by the coördinate divisions should be as nearly equal as practicable, but a certain concession might be made to chronologic perspective on account of our superior opportunities for studying the later history. Some of the shorter periods might perhaps be united under new names. Each line of division between periods should be defined by means of a stratigraphic plane of division, and this can be done with precision if a locality is made part of the definition.

Especially should pains be taken to declare the arbitrary nature of the scale. Even with this precaution it will be misconstrued by many, for there is a tendency of the mind to attach undue weight to classification. Wherever we draw lines of separation we lose to a certain extent the power to recognize continuity. When, for example, the clock strikes twelve on New Year's Eve time seems to stop and begin again. We speak of the achievements of the nineteenth century — and despite ourselves we think of them, too — as though a new industrial epoch began in A. D.

1800. And so it is easy for the beginner in geology to accept as discontinuous the eras and periods of which his text-book treats, and it is hard for him afterward to unlearn the lesson.

There is reason to believe that confusion of ideas in regard to geologic classification has been fostered by the employment of the same set of names for the divisions of the time scale and for the local terranes on which they are founded. It might be well to furnish the time scale with names suggesting time — such names as the brothers Rogers applied to the terranes of Pennsylvania — but so radical a change is hardly feasible, especially as we should thus lose the mnemonic connection of times with corresponding terranes. I propose as a means of accomplishing the end with the least inconvenience, that a set of time words be derived from the terrane names by modifying the final syllables. The time words should all have the same termination, and that should differ from any terminations occurring in the terrane names. I suggest for the ending of time words the syllable *al*. With such a nomenclature Jurassic and Devonian would denote only certain European rock systems, while Jural and Devonal would denote periods of the standard time scale; and we could speak of the Chico-Tejon series as partly Eocenal and partly Cretaceal without seeming to imply the existence in California of the Eocene and Cretaceous systems of Europe.

A few minutes ago I opposed the differentiation of words by terminations because it abrogated the power of indefinite expression; I now favor it for the same reason. It is well to be indefinite as to the taxonomic rank of terranes while their characters are imperfectly known, but it is not well to confuse terranes with times.

It is not to be assumed that a time scale adopted now as the best possible will continue indefinitely to be the best possible; the day will inevitably come when it can be improved. In the fuller light of the future we may recognize as very unequal periods that we now deem equivalent, and the possibilities of defining pre-Cambrial periods are unlimited. Even now there are announced beneath the lowest fossil-bearing terranes of the Lake Superior region two systems of clastic rocks limited above and below by great unconformities, and Irving demands their recognition as a group, distinct from the Archean. If his voice is heard, the time scale

will include an era between the Paleozoal and the Archeal, and this era will supply the needs of the systematist until great additions have been made to our present knowledge of the older rocks.

My only remaining subject is the representation of terranes on maps by means of colors. At present no two organizations and scarcely two individuals use colors in the same way, and it is probably true that every organization and individual publishing many geologic maps has at different times employed the same color for different terranes and different colors for the same terrane. It results that the map user can gain no information from the distribution of colors until he has studied the legend; before he can read a new atlas he must learn a new alphabet. The advantage to be gained by substituting a universal language for this confusion of tongues is manifest and great, and has justified the application of much time and attention by the Congress and its committees. By a series of resolutions a partial scheme has been selected, one color at a time, and the completion of the plan has been left to the committee on the map of Europe. That committee has prepared a color legend which is accessible to American geologists in the volume of information published by the American committee. It is understood in a general way that the Congress reserves final action, and the published legend not only belongs specifically to the map of Europe, but is provisional; still, as this map, if generally approved, will unquestionably be declared by the Congress an authoritative pattern for the guidance of map makers, the plan should be freely criticised at its present stage. The selection of uniform colors is a far more delicate and important matter than the arrangement of taxonomic terms; for while ill-chosen words may quickly fit themselves to new uses, the adoption of an ill-arranged color scheme must entail continual loss.

In my judgment the scheme provisionally chosen is defective in several particulars, to which I shall presently call attention, but it is necessary to introduce the discussion by a statement of the conditions to be satisfied by a standard color scheme and a statement of the practical means available. The following are the principal conditions, arranged in an order embodying my estimate of their relative importance:

(1) The map must be clearly and easily legible. Each color must be so distinct from each other color that it can be identified,

whatever its surrounding; and all other conventions must be readily discriminated.

(2) The cartographic scheme must be adjustable to the geologic facts; it must not require that the facts be adjusted to it.

(3) The same scheme should serve both for general maps, as, for example, those representing only systems, and for detail maps, representing numerous smaller divisions.

(4) Undue expense should be avoided. The amount and consequent utility of color cartography is largely limited by its cost.

(5) It should be easily fixed and retained in the mind. This is best accomplished by making it orderly.

(6) Other considerations permitting, the map should please the eye. Since the arrangement of color areas cannot be foretold, this can only be accomplished by admitting a certain range of choice. If allowed sufficient latitude in the selection of tones, an expert colorist can ameliorate an offensive combination of hues.

(7) Other considerations permitting, the establishment of a universal system should involve the least possible inconvenience. But as the inconvenience of change is temporary, while the inconvenience of a bad system is lasting, this consideration should yield to every other.

The art of mapping geologic terranes by means of color is well developed, and its methods, viewed from the geologist's standpoint, admit of easy characterization. Color may be varied in two distinct ways — in hue and in tone. Hues differ in quality, as yellowish green and bluish green. Tones differ in strength, as pale green and dark green. A color is printed either solid or broken; it is said to be broken when applied in a pattern, as in lines or dots, or when it is interrupted by a pattern. The difference between solid and broken colors is a difference of texture. The primary discriminations in mapping are through hue, tone and texture.

The map engraver produces texture in three ways. In the first way a single impression is made with a broken color. The white of the paper, displayed where the color is interrupted, combines with the color in the general effect, producing a paler tone of the same hue. In the second way two impressions are made, one with solid color the other with broken, and the two impressions have the same hue; they may or may not differ in tone. This is

monochromatic overprinting, and its general effect agrees in hue with the single impression, but differs in tone, being darker. In the third way two impressions are made, one solid, one broken, and their colors differ in hue. This is bichromatic overprinting and its general effect differs in hue as well as tone from each of the colors combined in it. The first and second ways produce texture monochromatically and do not yield a new hue; the third way produces texture bichromatically and yields a new hue. It is practically impossible to obtain a texture effect without modifying the original tone.

The natural gradation from hue to hue is absolutely continuous and the number of hues is infinite; the number of tones of each hue is likewise infinite. The number of hues and tones the eye can discriminate is finite, but very great; it is stated that one thousand hues have been distinguished in the solar spectrum. But the number of hues and tones that can be combined in a map is small. As a matter of perception, every color is modified by the colors adjacent to it. The same hue affords different sensations when differently surrounded, and different hues may afford the same sensation. The same is true of tones; and there is a certain interdependence of hues and tones in this respect. In a geologic map each color is liable to fall into various combinations, and two colors little differentiated occasion confusion. There is, therefore, a somewhat narrow limit to the employment of hues and tones. The matter has not been fully worked out, but it is probable that twenty is as large a number of hues as can be safely employed in connection with tones. Texture admits of very great variation. The various color schemes submitted to the Congress and printed in the report of the Bologna meeting afford, with their manifest permutations, about two hundred distinct textures, and I am satisfied from a study of these and others that as many as one hundred can be chosen that are not subject to confusion. It follows that a map or atlas expressing few distinctions need use only hues, or only hues and tones, but where numerous distinctions are to be made, recourse must be had to textures.

The printing of a large number of textures of the same hue produces a greater number of tones than can be discriminated, and its effect is to confuse and nullify any distinctions (within the range of that hue) based purely on tone. The printing of a large number

of bichromatic textures causes the same result, and it also produces a greater number of hues than can be discriminated; its effect is to confuse and nullify distinctions based purely on tone, or on hue, or on tone and hue together.

In the color scheme prepared for the map of Europe thirty-eight distinctions are made. There are twenty-four hues, and the remaining fourteen distinctions are accomplished by variations of tone. While it may be possible to select twenty-four hues available for indiscriminate combination, there can be no question that those provisionally printed by the committee will fail to maintain their distinctness when variously combined upon a map. Under the influence of such chromatic environments as are sure to be encountered, the four yellow hues of the Tertiary cannot be discriminated, and the same difficulty will arise with the two hues of grey assigned to the Carboniferous, and with the hues of grey and brown assigned respectively to the Permian and the Devonian. Some of the tones likewise are not sufficiently distinguished. Two of the blues of the Jurassic, two of the browns of the Devonian, two of the rose tones of the Archean, and the two violets of the Trias are open to this criticism. A certain amount of adjustment can be made in the final selection of inks, and probably all the defects from tone can be thus remedied, but the confusion of hues is more difficult to eliminate, for the great number of the hues interferes with the separation of those that are too approximate. To strengthen one contrast is to weaken another.

In order to judge of the availability of the scheme for the production of detail maps, it is necessary to consider the resolutions of the Congress as well as the printed legend. A resolution provides that the subdivisions of a system shall be represented by shades of the color adopted for the system, or by broken color or other texture devices, and it is further provided that the shades, whether produced by solid color or by texture, shall be so arranged that the darkest or strongest represent the lower divisions of the system. The resolution is in French, and the word I have translated shade (*nuance*) is one which applies popularly to either hue or tone, while in the scientific terminology of chromatics it applies to hue only. The committee on the map has taken it in its popular sense, and has represented some subdivisions by hues, and others by tones; for example, Pliocene and Miocene are assigned

two tones of the same hue, while Oligocene and Eocene have each a separate hue. The upper Cretaceous and part of the lower Cretaceous are assigned a green hue in two tones, while the Gault and the Wealden, classed as subdivisions of the lower Cretaceous, have independent hues of green. Of the six reds assigned to volcanic rocks, two agree in hue and differ in tone, while the remainder have distinct hues. As the legend stands, both major and minor distinctions, that is to say, the discrimination of groups, the discrimination of systems, and the discrimination of divisions smaller than systems, are all accomplished by differences of hue, while the discrimination of minor divisions is accomplished indifferently by variation of hue and by variation of tone. The same means performs several functions and the same function is performed by several means.

It is stating the same thing from another point of view to say that the Congress and its committees have used the term color in its popular rather than its scientific sense. Scientifically, a color is a particular tone of a particular hue, and the number of colors is infinite. Popularly, a color is an assemblage of contiguous hues and their tones, to which a name has been given. Each hue and tone within the range covered by the name is a shade of the color. It is in this popular sense that the resolutions assign a color to each system, and assign shades of the system-color to the subdivisions of the system.

Now if in the variation of a system-color, by textures or otherwise, a single hue is adhered to, the system-color remains distinct from other system-colors throughout all its modifications and their modifications, but if hues as well as tones are varied, the inevitable result is confusion, for some of the hues of one system-color will approach too near to hues of other system-colors. With a multiplicity of minor distinctions the main distinction of system from system will be lost.

Another difficulty lies in the fact that the Quaternary and Devonian colors, while strongly contrasted in tone, are nearly identical in hue. This does not affect their use in a general map, but in a detail map the stronger tones of the Quaternary grey will approach too closely the paler tones of the Devonian brown.

These criticisms apply to those features of the scheme which affect its adoption for general and detail maps of European countries. There is one of equal or greater importance affecting its application

in other continents. It is adjusted to the rock systems of Europe exclusively, and makes no provision whatever for the systems of other parts of the earth. The geologists of Wisconsin, for example, cannot use it without calling the Keweenawan either Cambrian or Archean. If they were in doubt which division should hold it, but inclined a little one way or the other, they could express their qualified opinion in the notation provided by the map committee; but having attained an unqualified opinion that the terrane belongs to neither of these two categories, they find no means for expressing their conclusions. The scheme cannot be applied to the geology of India, of New Zealand, or of Australia, without misrepresentation. It is not universal but local, and this because it is founded on the fallacy of a world-wide unity of geologic systems.

So far as the geology of the world is concerned, it would be better to adopt no convention at all as regards map colors, than to adopt one carrying with it and promulgating a vicious classification. Uniformity is not worth purchasing at the price of falsification. If the members of the Congress cannot agree upon a plan having the flexibility demanded by the geologic facts, it will be best to limit its action to the local problems involved in the map of Europe. I believe, however, that the necessary flexibility is attainable, and before proceeding to further criticism of the committee scheme I will give the outlines of a plan which appears to me to combine the advantage of flexibility with a number of other desirable qualities.

The plan is founded on the universality of geologic time and the diversity of local geologic histories as expressed in rock systems. Geologic periods are arranged in linear order. Each one adjoins the next and together they constitute continuous geologic time, which we may conceive as represented by a straight line. The stratigraphic systems of a country have likewise an order of succession, and their arrangement is linear. They are not always continuous one with another, but the history recorded by the systems and the breaks between them is continuous and may be represented by a straight line, equal and parallel to that of geologic time. And so for each country. A color scale which shall represent each and all of these parallel lines must be itself linear and continuous, and, fortunately, we have such a scale furnished us in the prismatic spectrum.

I propose, first, that the continuous prismatic spectrum be

adopted as the standard universal scale for continuous geologic time. I propose, second, that the conventional time scale, based on the geologic history of Europe, be complemented by a color scale, prismatic but discontinuous. I would assign to each period, not a certain portion or area of the spectrum, but a specific color defined by its position in the spectrum. This color scale will also apply to the geology of Europe. I propose, third, that the students of each geologic district shall assign to the stratigraphic systems of that district a set of prismatic colors so selected from the spectrum as to properly represent the relation of each system to the time scale, provided that relation is approximately known. Under this rule a system corresponding partly with the Cretaceous and partly with the Jurassic will receive a prismatic color intermediate between those assigned to the Cretaceal and Jural divisions of the time scale. I propose, fourth, that systems whose relations to the standard time scale are not even approximately known be given tentative positions in the time scale and assigned the corresponding colors; and that such provisional colors be distinguished by a special device.

Of this device I will speak later, but before we leave this part of the subject, the capability of the plan to express the facts should be more clearly characterized. Continuous geologic time being equated with the continuous spectral band of light, each period is theoretically equated with a segment of that band including all the hues between certain limits. But, practically, the period is represented in the color scale only by the central hue of the segment, and there is nothing in the nature of this hue to indicate the length of the segment. Similarly each local system is represented only by the hue corresponding to the middle of the equivalent period, considered as a part of the continuous time-scale, and this hue gives no information as to the magnitude of the system or the duration of the corresponding period. When a non-European system is represented on a map with the Devonal color, all that is expressed is that the middle of its period coincides with the middle of the Devonal period; the whole period may equal the Devonal or may be shorter or may be longer. With this limitation the scheme is able to express the exact facts, or the exact state of opinion, in regard to correlation.

I propose, fifth, that the subdivisions of systems be represented, if their number is small, by distinct tones of the hue assigned to

the system, and if their number is great, by monochromatic textures. It having been provided that systems shall be distinguished by means of hues, it is now provided that hues shall have no other function. This secures the integrity of the distinction between systems, whatever the minuteness of subdivision.

The idea of using the spectral colors in their proper order is not novel. It has entered into half the plans submitted to the Congress, but each author has introduced other colors also, or else has undertaken to use the spectrum colors more than once, under the impression that they do not afford the necessary range or variety. This impression is based largely upon the popular meaning of the word color. It is indeed true that if we limit ourselves to those parts of the spectral series which have univocal names, we have only six or seven distinctions; and it is further true that if we have recourse to binominal designations, such as yellowish green and greenish yellow, we obtain rather indefinite conceptions; but to men of science there are better resources than those afforded by the language of every day life. The spectrum has been elaborately studied, and the relations of its dark lines to its colors have been determined. Its wave lengths have, moreover, been measured, and by such means as these we are furnished with three different scales, any one of which is adequate to the precise definition of any hue of the continuous series. What needs to be done is this. When the divisions of the time scale have been decided on, the spectrum must be studied to ascertain the best selection of hues. Their number must, of course, be that of the number of divisions of the time scale, and they must be so chosen that the degree of separateness of adjacent colors shall be everywhere the same, as judged by the normal human eye. Then define each hue by its wave length, or its position in the Kirchhoff scale, and define it also in terms of the best combination of pigments with which it can be approximately reproduced for practical use. It is of course impossible to copy the prismatic colors with accuracy, because the colors of pigments are impure, but this difficulty will not seriously interfere with the employment of the prismatic colors as a standard.

The practical question whether the spectrum will give a sufficient number of hues so far separated from each other as to be distinguishable in all the arrangements occurring on maps has received such consideration as I have been able to give it, and it is my judgment that the maximum number of hues that can safely be

used falls somewhere between fifteen and twenty. There will certainly be no difficulty in thus constructing a standard color scale with about a dozen terms.

The employment of the spectral colors in this manner leaves three groups of colors unassigned; the purples, the browns and the greys. If the spectral colors be arranged on the circumference of a circle so that each diameter of the circle connects hues that are complementary, it is found that they occupy the greater part, but not quite all, of the circumference, and the color needed to fill the vacant arc is purple. The hues of purple might then, if deemed necessary, be added to one end or the other of the spectrum, thus increasing the range from which to select colors for the time scale.

My sixth proposition is to assign the browns to volcanic rocks. I would leave the greys unassigned.

It will be observed that no intimation has been given as to whether the violet end of the spectrum should apply to the newest system of strata or the oldest. It must of course be definitely assigned to one or the other, but the particular assignment is a matter of indifference.

The main features of the proposed prismatic scheme have now been set forth and you are fairly entitled to exemption from the minor features, but there is one detail that can hardly be omitted. In one of the main propositions it was provided that some special device should distinguish colors assigned to uncorrelated systems, and I feel it incumbent to show that a suitable device can be found. Of a number that have occurred to me as about equally available, I will mention but a single one — the overprinting, in small dots, widely separated, of the complementary color. The complementary color is selected because it does not disturb the relation of the system-color to the colors of adjacent systems. Bichromatic overprinting produces a hue intermediate between the two hues combined, but the hue midway between a system-color and its complementary color is white or grey, and if only a small amount of the complementary color is added, the system-color becomes merely paler or duller, when viewed from such a distance that the colors blend.

The prismatic color scheme having been constructed for the express purpose of securing a degree of flexibility that will fit it for universal use need not be further compared in that regard with the scheme published by the European map committee. Enough has

also been said to show that its superior perspicuity is claimed both for general and for detail maps. A few words will suffice to compare the two systems in other respects.

As regards the expense incurred in the production of general maps, neither scheme has notable advantage, and they are not yet sufficiently developed to permit a comparison as regards the cost of detail maps. Their capability for the production of pleasant color effects can be best judged when maps have been actually made, but it may be said in a general way that the committee's scheme will afford more strong contrasts between adjacent color areas than the prismatic. The maps colored by the former will be relatively lively, those colored by the latter relatively quiet. It is provided by the committee that the volcanic colors shall be not merely red but strong. On a general map volcanic areas cover comparatively small spaces, and strong reds thus disposed will ordinarily add brilliancy; but the detail map of a volcanic district, thus colored, will be disquietingly suggestive of active eruption.

The alphabet of colors for the prismatic scale will be the more easily learned of the two, because it is orderly, and because its order is already familiar in the spectrum. The committee's scheme, however, has some old-fashioned mnemonic features which the prismatic lacks. The green of the Cretaceous is connected with greensand, the red of volcanic rocks with fire, and the rose of the Archean with feldspar; and the grey of the Carboniferous mildly suggests the blackness of coal.

In respect to facility of introduction the committee's scheme, being essentially a compromise of existing color scales, has the advantage that to most users it is not entirely novel. The prismatic scheme on the other hand has the advantage of being orderly. It scientifically differentiates the functions of hues and tones, and though each one of its colors may be different from what the individual geologist has previously employed for the indication of the same system, the order of the colors is already familiar to him in another way.

This closes my review of the various works undertaken by the Congress. Some of these have been favored, others opposed, and reasons have been given. But there is a general consideration or criterion applicable to all which has nearly escaped mention, although it is of preëminent importance. When a matter is pro-

posed for regulation by the Congress, the first question which should be asked is whether it falls within the legitimate purview of a convention of geologists. It manifestly does not, if it belongs to some other science rather than to geology, and objection has on this ground been made against the regulation by our geologic Congress of the nomenclatures of paleontology and mineralogy. But not all geologic matters even are properly subject to settlement by convention. This is peculiarly the case with geologic facts. Science is distinguished from the earlier philosophies of mankind by the peculiarity that it establishes its fundamental data by observation. The old philosophies were founded largely upon assumptions, and it was not deemed illogical — perhaps it was not illogical — to appeal to the authority of an assemblage of experts for the establishment of fundamental assumptions. But for science it is not merely illogical, it is suicidal, to establish facts in any other way than by observation. No vote of the most august scientific body can possibly establish a fact, and no vote can have any weight against a good observation.

Now the entire science of geology, using the phrase in a strict sense, is constituted by the aggregation and arrangement of facts, and none of its results can be rendered more true, or be more firmly established, or be prevented from yielding to contradictory facts, by conventional agreement. A classification, if it has any value whatever, is merely a generalized expression of the facts of observation, and is outside the domain of the voter. If it comprises all the essential facts, its sufficiency will eventually be recognized, whether its authority is individual or collective. If it does not comprise them, it will inevitably be superseded, by whatever authority it may have been instituted. For this reason I am opposed to the classification by the Congress of the sedimentary formations, and likewise to the classification of the volcanic rocks, and I also regard it as ill-advised that the Congress undertook the preparation of a map of Europe, for that—if more than a work of compilation—is a work of classification.

If we examine the other undertakings of the Congress — the definition and gradation of taxonomic terms, the systematization of terminations, the selection of a scale of colors for geologic maps, and the selection of other conventional signs for the graphic expression of geologic phenomena—we find that they all belong to the means of intercommunication of geologists. They affect only

the verbal and graphic technical language of the science. Of the same nature is the arbitrary time scale whose preparation I favor, — a conventional terminology for the facts of correlation. So we may say in general, that the proper function of the Congress is the establishment of common means of expressing the facts of geology. It should not meddle with the facts themselves. It may regulate the art of the geologist, but it must not attempt to regulate his science. Its proper field of work lies in the determination of questions of technology; it is a trespasser if it undertakes the determination of questions of science. It may decree terms, but it must not decree opinions.