

Calcophiles, Hygrophytes, Pelophytes, Psammophytes, and Nemo-phytes.

DRY LOVERS (XEROPHYTES)—

Daphne Laureola.
Orchis pyramidalis.
Fagus sylvatica.
Rosa rubiginosa.
Gymnadenia conopsea.
Ophrys apifera.
O. muscifera.
Herminium monorchis.
Carduus acaulis.
Thalictrum minus.
Campanula rotundifolia. (?)
Draba verna.

SAND LOVERS (PSAMMOPHYTES)—

Cytisus scoparina.
Saxifraga granulata.
Digitalis purpurea.
Betula alba.

CLAY LOVERS (PELOPHYTES)—

Lysimachia nemorum.
Alisma Plantago.
Alnus glutinosa.

LIME LOVERS (CALCOPHYTES)—

Reseda.
Onobrychis.
Specularia hybrida.
Chlora perfoliata.
Neottia Nidus-Avis.
Aquilegia. (?)
Lychnis vespertina. (?)
Campanula Trachelium. (?)
Polygala calcarea.
Hutchinsia.
Anemone Pulsatilla.
Clematis (?)

DAMP LOVERS (HYGROPHYTES)—

Caltha.
Cardamine pratensis. } on allu-
Lychnis Flox-cuculi. } vium.
Geum rivale.

SHADE LOVERS (NEMOPHYTES OR

DRYADS, Baker, p. 78)—

Lychnis diurna.
Oxalis Acetosella.
Asperula odorata.

ON THE CLASSIFICATION OF ROCKS.

By THE REV. J. F. BLAKE, M.A., F.G.S.

(Read March 5th, 1880.)

Of the three great groups of rocks, as ordinarily distinguished—the Aqueous, Igneous, and Metamorphic—the first has never given rise, nor is perhaps ever likely to give rise, to any considerable discussion, except as regards the age, which has far more interest to Geologists than the peculiarities of structure. The particular relations of the crystalline rocks to each other and their consequent grouping was for a long time the subject of exciting controversy, which, lulled to sleep for a time, seems reviving once more in a modified form. The flood of light which has been poured on the subject by the microscopical examination of thin slices has rendered several petrologists averse to the old classification by which

the Igneous rocks were divided into Volcanic, Trappæan, and Plutonic, as appearing to be inconsistent with more newly discovered facts, and several fresh arrangements have been recently proposed. The classification of such rocks may, therefore, be considered as at present *sub judice*; and on this account, without pretending to bring any fresh facts to the discussion, the present remarks are offered in the hope of showing how the newer facts may be arranged in their logical places, and the proposed schemes be, as far as possible, reconciled to each other, and to the older and time-honoured one. As there is always a tendency to the belief that the newest arrangement must necessarily be the best, it may be well to observe that the closer study of the structure of rocks, which is so marked a characteristic of our present Geological work, is but a revival, with improved means, of the mineralogy which played so conspicuous a part in rock-discrimination in the earlier days of the science; and yet the behaviour of rocks in the field was finally adopted as the basis of classification, and produced our present sub-divisions. The latter method was found to be most useful to the Geologist, and I doubt whether increased knowledge of the minute structure of rocks will do more than improve it.

In most of the newer classifications, which I propose to discuss, no notice is taken of the Geological relations of the rocks, but everything is based on what may be learnt from hand specimens or microscopic slides.

I will, in the first place, limit myself to the Igneous rock, and place side by side the older classifications, and those which have been more recently proposed.

As a representative of the former, I will take that given in the last edition of Jukes' "Manual of Geology," edited by Prof. Geikie, and dated 1872, as one of the best known and most authoritative.

PROF. JUKE'S CLASSIFICATION.

	<i>Felspathic.</i>		<i>Augitic.</i>
A. Volcanic.	Trachyte.	Trachy-dolerites.	Dolerite.
	Pearlstone.		Anamesite.
	Andesite.		Basalt.
	Phonolite.		Wacke.
	Obsidian.		
	Pumice.		
	Trachyte tuffs, &c.		Doleritic tuffs, &c.

	<i>Felspathic.</i>	<i>Hornblendic & Pyroxenic, Felspar & Hornblende, &c.</i>
B. Trappæan.	Felstone.	Diorite.
	Pitchstone.	Diallage Rock.
	Clinkstone.	Hypersthene Rock.
	Minette.	Melaphyre.
	Kersanton.	Diabase.
	Kersantite.	Aphanite.
	Porphyrite.	Wacke.
C. Granitic.	Felstone tuff, &c.	Greenstone tuff, &c.
	Granite.	Syenite & its varieties.
	Syenitic Granite.	
	Pegmatite.	
	Protogine.	
	Graphic Granite.	

The great feature of this grouping is the prominence given to the middle group, of which the author says that it is a term of convenience only to indicate some rocks that have been formed by volcanic action, some that are more essentially granitic with many intermediate or undetermined rocks between the two.

Prof. Dana's classification, which proceeds on a totally different basis, being a chemical or mineralogical one, was published in the "American Journal of Science," in 1878, and the author's summary was transferred to the pages of the "Geological Magazine" for May, 1879.

PROF. DANA'S CLASSIFICATION.

- I. Mica and Potash-Felspar Series. { Granite, Granulite, Gneiss, Protogine, Mica-schist, &c. Felsite, Trachyte and Leucite rock.
- II. Mica and Soda-lime-Felspar Series. { Kersantite and Kinsigite, and the Nephelitic kinds of Miascite, Detroite, Phonolite, &c.
- III. Hornblende Potash-Felspar Series. { Syenite, quartz Syenite, Syenitic-gneiss, Hornblende-schist, Amphibolite, Unakite, &c., Zircon-Syenite, Foyaite.
- IV. Hornblende and Soda-lime-Felspar Series. { Diorite, Propylite, Andesite, Labradorite rocks, Saussarite Rock, Euphotide.
- V. Pyroxene and Potash-Felspar Series. { Amphigenite.
- VI. Pyroxene and Soda-lime-Felspar Series. { Augite-Andesite, Norite (Hypersthene and Gabbro part) Hypersthene, Dolerite (comprising Basalt and Diabase) Nephelinite.
- VII. Pyroxene, Garnet, Epidote, and Chrysolyte rock, with little or no Felspar. { Pryoxenite, Lherzolite, Garnetite, Eclogite, Epidosite, Chrysolite, Dunite.

VIII. Hydrous Magnesian and Aluminous rocks with little or no Felspar. { Chlorite-Schist, Talcose-Schist, Serpentine, Ophiolyte, Prophyllite-Schist, &c.

In this not only the Igneous rocks, but those generally called Metamorphic are included.

The later edition of Jukes' "School Manual of Geology," edited by Jukes Browne, in 1876, contains a classification by Prof. Bonney, which is stated to be that to be used in a "Handbook of Petrology," promised by the latter, but which has not yet seen the light. This is somewhat on the same lines as that of Prof. Dana, but chemical composition gives way largely to structure.

PROF. BONNEY'S CLASSIFICATION.

	Matrix wholly crystalline.	Matrix semi-crystalline.	Matrix grassy.
I. Orthoclase Felspar. <i>a</i> , Quartziferous. <i>b</i> , Quartzless.	Granite. Syenite.	Quartz Felsite. Orthoclase-felsite, Minette.	Quartz-Trachyte Sanidine-Trachyte. Pitchstone. Obsidian.
II. Plagioclase Felspar. <i>a</i> , Oligoclase, sometimes with quartz. <i>b</i> , Labradorite or an allied mineral—no quartz.	Diorite. Gabbro. Diabase. Dolerite. Basalt.	Porphyryte. Some basalts?	Andesite. Tachylite.

The last classification which I shall cite is that of Mr. Rutley, in his golden book, entitled "The Study of Rocks;" a book which ought to be in every student's hands. The author states that the rocks named are considered as type-rocks of the respective groups.

MR. RUTLEY'S CLASSIFICATION.

- I. Vitreous. Obsidian, Pumice, Perlite, Pitchstone, Tachylite.
- II. Crystalline.
 - A. Typical groups. { Granite, Felstone, Syenite, Trachyte, Phonolite, Andesite, Porphyryte, Diorite, Diabase, Gabbro, Basalt.
 - B. Rocks of exceptional mineral composition.
- III. Volcanic ejectamenta.
- IV. Altered eruptive rocks.

On the perusal of the descriptions of these several groups, it appears that they are made to include rocks which are often separated from each other ; thus, under Granite, we have also Porphyritic Granite, Felstone, Granitite, Cordierite-granite, Luxullianite, Haplite, Granulite, Greisen, Gneiss and Cornubianite; while Syenite includes also Minette, Kersanton and Kersantite.

These several classifications I now propose to discuss *seriatim*, after first laying down some principles which we ought to follow if classification is to be of any use.

The points in which Igneous rocks differ from each other are—
1. Their mineral composition. 2. Their structure. 3. Their origin. 4. Their age. The age of a rock ought in no way to enter into a descriptive classification, still less into the name ; for then we might have to invent a new name for the same rock in each epoch, and should lose the power of stating the facts about the age of such rocks. Thus, if, as Prof. Geikie says, some “petrographers retain the name Melaphyre as a geological term for all Doleritic rocks of Palæozoic age,” the two names simply become synonymous, and we lose the power of stating that “most Doleritic rocks of Palæozoic age are melaphyres.” So of the term Propylite for Tertiary Andesites, and Felstones for ancient Rhyolites, unless these terms contain some mineralogical meaning, they are simply tautologous. In like manner to call a group of volcanic rocks traps, simply because they were erupted in ancient times, reduces the important generalization that ancient volcanic rocks are very like modern ones into the apparently self-condemning statement that trap rocks are very like volcanic ones.

The mode of occurrence, that is, whether it has flowed as a lava or has consolidated beneath the surface, cannot in itself be allowed to influence the *name* of a rock if it otherwise remains constant in character ; otherwise, if we were discussing whether some rock found intrusive beneath great piles of strata reached the surface elsewhere, we should have to ask whether *A* was elsewhere *B*. Whether we may profitably use the mode of occurrence for making the larger groups, opens up the great question between the recent and the earlier classifications. The great objection to its use is, that it makes the grouping a theoretical rather than a positive one. Certainly, when the structure and composition is ascertained, there is no difficulty in classifying the rock in the latter method—yet it tells us nothing we did not know before—and, in

point of fact, the better founded the theory, the better is it suited to be made the basis of classification, and hence it is a retro-grade step to throw a theory over without replacing it. Often, indeed, a geologist is chiefly interested in the origin of the rock, and only cares to know its composition so far as it may throw light upon that—hence, whatever mineralogists, or cabinet petrographers may do, he will always require a classification which involves the origin.

With regard to the structure of rocks—as it appears to be proved that it depends on the rate of cooling, it is an important element in their discrimination—but being certainly less essential than their composition, should be subordinated to the latter. Thus, for the naming of rocks the great guide must be their mineral ingredients. The chief difficulty to contend with here is, that rocks will pass into each other, and there is always a temptation to enlarge the definitions accordingly; but, as Mr. Rutley remarks, “sharp, or moderately sharp definitions constitute the basis of all classification, and if these be abandoned, the petrological nomenclature becomes almost worthless.”

First, now to examine Prof. Jukes' and Geikie's classification. We here find “Granitic” used as a group-name parallel to “Volcanic.” This is substituted for “Plutonic,” on the ground that it is “advisable to avoid terms that involve foregone conclusions.” The term, however, either means that they occur in such circumstances as lead us to conclude, rightly or wrongly, their subterranean origin, which is all we mean by Plutonic, or else it is the same as Prof. Bonney's “matrix wholly crystalline,” in which case structure is mixed up with origin in the classification. Since, moreover, there is so much discussion on the origin of granite, it seems inadvisable to use it as a group-name. Next we have the use of the word “Trappæan.” This is made to include all Igneous rocks not formed in the neighbourhood of modern volcanoes, and excluded from granitic without any particular reason being given. With this wide range, the group seems to me, as it has seemed to many, an absurd one; a lava which flowed in ancient times appears to have just as much right to the name “Volcanic” as a recent one; and the use of the term “Trap.” for a contemporaneous lava is certain to be rejected with the growing proof of the general identity of all lavas. It appears to me, however, that we require a name for those igneous rocks which are intrusive in long sheets

and dykes. Certain peculiarities appear to be involved in this mode of occurrence as in Pitchstone and Felstone, but these peculiarities are capable also of production in rocks which have flowed as lavas by a long process of devitrification. It is therefore improbable that any rock is exclusively a Trap rock, and the whole series may be represented also as belonging to the altered Volcanic rocks, or, in some cases, to the Plutonic. Nevertheless, the name is a useful one in the sense defined, and may therefore be retained.

With regard to the several rocks grouped under the three heads among the Volcanic—*Pearlstone* or *Perlite*, has reference to a structure induced in the rock after its formation, and therefore the name should not be placed in a parallel line with *Trachyte* and *Andesite*, which differ in their mineralogical ingredients, and the same remark applies to *Pumice*. Among the augitic rocks, *Anamesite* appears to be a useless name, as it is simply an intermediate term between *Dolerite* and *Basalt*; which latter will well cover it, as it commonly does for field geologists. Next as to the Trappæan: At present, *Minette*, *Kersanton* and *Kersantite*, appear to belong exclusively to this group, and to be the forms which *Syenite* and *Diorite* assume when found in dykes. The name *Porphyrite* seems to me a very objectionable one. It is slightly altered from porphyry, but really means the same thing, except its restriction to rocks which would otherwise be called *Andesites*, from their being essentially composed of a plagioclase felspar and hornblende, or augite. *Diorite* is essentially a plutonic rock, occurring often as a trap. With regard to such names as *Diallage Rock* and *Hypersthene Rock*, in which one mineral alone is abundant, it is scarcely logical to put these alone on a level with *Diorite*, &c., and to omit all reference to those in which some other mineral is predominant, as *Nephelinite*, *Leucitophyr*, or *Garnet rock*. As to *Melaphyr*, the term has been used in reality simply for Basalts or Dolerites of Palæozoic age. Mr. Rutley describes it under the former head, and states that it differs from ordinary basalt in containing decomposition products of compounds of iron. It is, therefore, an altered basalt, and the name should only be used when such alteration can be proved, and to indicate that it *has* been proved for the particular rock in question. *Diabase* is a name well fitted to raise all the difficulties that are possible in the nomenclature of rocks, and there is no more curious page in Mr. Rutley's valuable book than that on which this rock is described.

Compare his description of *Diabase* with that of *Dolerite* :—" *Diabase* may be regarded typically as a crystalline-granular admixture of triclinic felspar and augite, usually with more or less magnetite and titaniferous iron." "*Dolerite* . . . contains augite, magnetite and titaniferous iron, but it has, in addition, other mineral constituents . . . of these the felspars claim the most prominent place—they are triclinic." Thus they are both described in identical terms, but the order of enumeration is reversed. The real difference is that *Diabase* contains chlorite, and this is an alteration product; the rock is, therefore, an altered dolerite, as Mr. Allport has shown. It seems to be sufficient for some petrologists to prove that one rock is an altered form of a second, to justify the discontinuance of the separate names; but I cannot help thinking it a convenience to have a name to indicate the particular kind of alteration that has taken place. The additional mineral in *Melaphyr* and *Diabase* being, however, both varieties of chlorite, the first name may well be dispensed with. *Aphanite* is essentially a useless term, and nothing need be said of it—or of "*Wacke*." Among the granitic rocks, only two are really mentioned, for *Pegmatite* and *Graphic Granite* are only varieties, and *Protogine* is a metamorphic gneiss.

We now come to Prof. Dana's classification which has an entirely different basis and which may be much more debatable. He lays down as his principle that "the chemical and mineralogical composition of the *chief* constituents should be first considered and not crystalline form." In the latter part of the sentence he is striking at the use of the term plagioclase as a general term for felspar of a certain kind in rocks. The actual term plagioclase, as Prof. Bonney admits in his strictures on Dana's classification, is rendered rather of doubtful value since the discovery of microcline—a plagioclastic potash felspar, but it is usually meant as an abbreviation for "soda-lime-felspar," to which it has doubtless ceased to be synonymous. Passing this Prof. Dana lays down that the *names* should indicate no more than mineralogical composition, and not be used to separate rocks which differ only in structure. This strikes at the base of Prof. Bonney's scheme, which goes very largely upon structure, and yet so far as structure indicates origin or circumstances of formation we must agree rather with the latter, otherwise we could not separate shale from clay or grit from sandstone. These differences in texture, however, Prof. Dana allows may be indicated

as varieties, and this is perhaps enough. He argues especially against the use of the word *Porphyritic* to indicate any more than a particular condition of a rock. He makes a great difference between hornblendic and augitic rocks, in spite of the great chemical similarity of the minerals, because they may indicate geological differences of origin; it is of course on the very same principle that Prof. Bonney lays stress on structure. He regards mica and hornblende as too distinct in composition to be considered as replacing each other, and hence objects to such terms as Mica-diorite for a rock without hornblende or Hornblendic granite if no mica is present. These principles are most admirable as referring to specific rocks and deserve adoption, but his classification into groups rests in no way upon them. Surely one must conclude that accessory minerals have been confounded with essential and even composition taken no note of, while geological considerations are thrown utterly to the winds when such rocks as Granite, Gneiss, Mica-schist and Trachyte are all classed together, and one is led to ask what use such a classification can be to any one? Prof. Bonney's remarks on this are very good; he especially objects to group VII, on account of the diversity of the rocks included; this is indeed a "carpet bag" group, necessary on the method adopted, but yet unphilosophical, or a confession of our ignorance. On the whole it appears to me an artificial classification which can never assist a student seeking for a natural one.

Prof. Bonney's classification is an incomplete one, otherwise he would have to make a third sub-division of those which contain no felspar, and in this, as in Prof. Dana's group VII, "mineralogy and chemistry would have to be fairly thrown to the winds." There is no wonder that the author of this classification should dispute, *totâ vi*, Prof. Dana's objections to Plagioclase and Orthoclase when they take away the ground from beneath his feet; but however the former word may be limited, it still remains to show any just cause why the varieties of felspar should be made of so much importance. No doubt common Orthoclase is nearly confined to the more crystalline Plutonic rocks, but in the form of sanidine it occurs in many volcanic rocks as in Trachyte and Phonolite. Again even in Granite Orthoclase is very often associated with Oligoclase as in that of Leinster, and therefore the two sub-divisions can only mean "orthoclase present, orthoclase absent." That the presence of Orthoclase is of so great importance remains, I think, to be proved.

When we consider that Albite, a soda-felspar, is more highly silicated than Orthoclase and that Microcline, a potash-felspar, is triclinic, it is plain that the chemical composition is not indicated by the distinction of the felspars.

The importance of the character of the matrix is brought very prominently forward by this classification, and there can be no doubt that it is worthy of more consideration than has been given to it, though it may be doubtful whether it should occupy the second place; one point is brought out by it, which is of great interest, that is the approximation of Dolerite to the Plutonic rocks, especially to Gabbro. When it is remembered that Prof. Judd has shown that Granite may form the actual core of an extinct volcano, and Dolerite, from its crystalline character, must have consolidated under pressure, the association of the latter with the basic representative of the former cannot be very remote. Thus Dolerite may be a connecting link between the two great classes.

Mr. Rutley's grouping is, perhaps, scarcely intended for a classification, but merely for convenience of reference, otherwise one would observe that where the matrix is glassy with sporadic crystals, we have a rock more allied to a vitreous one than to a wholly crystalline one. It is remarkable that the typical groups contain the two *Porphyrite* and *Diabase*, though the author distinctly recognises all that can be said against the use of those terms. The group called "rocks of exceptional mineral constitution" is an equivalent of Dana's non-felspathic group, and the same arguments may be used against it. When rocks of this character are classed together the group becomes a mere catalogue, and it would have been far more useful if it had been shown what are the nearest allies of each. The establishment of a group under the title "altered eruptive rocks" is an admirable step, as Prof. Bonney remarks, there are probably as many altered igneous as aqueous rocks, only they are altered in a different way, the former by hydro-metamorphism, the latter by pyro-metamorphism. The only important rock, however, found in this group is *Serpentine*, and it would be still better to include in it all rocks derived by change from others, but in my opinion best to place each in connection with its unaltered representative.

These classifications belong to three great types, founded re-

spectively on the composition, the structure, and the mode of occurrence of rocks. Each embodies important elements in the history of rocks. Believing as we do that there is a cycle in the formation of rocks, that a sedimentary rock may be altered into a metamorphic, then into a plutonic, which under certain circumstances may be erupted as a volcanic rock, the chemical classification may be of use as keeping together what may be the successive forms of one and the same collection of materials. The objection obviously is that we can have no proof of the mass remaining unmixed during its changes. The classification by structure combines into groups those that have consolidated under similar conditions, but leaves out how those conditions were brought about. The third method is essentially a geological one, and however the two former classifications may commend themselves to chemists and microscopists, geologists proper will seek one founded upon this method, however much it may be modified by a consideration of the others.

One great feature in the natural history of rocks has as yet been only partially used in classification, and that is the change which rocks have undergone subsequent to their formation. In the case of sedimentary rocks which have become crystalline, this has been recognised in calling them metamorphic, but in the case of igneous rocks which have become devitrified, or otherwise changed by the long continued action of water, no special designation has been employed. One great improvement, therefore, would be the placing in parallel lines the original rocks and the altered form; thereby suggesting the question for any rock containing alteration products—what was its original form? Each rock-name might then stand for a definite mineralogical mixture of particular structure, and any introduction of a new mineral, or alteration in structure brought about subsequently, might be indicated by a definite name in the lists of altered rocks, while original differences of structure or the presence of important accessory minerals would give rise to a varietal name.

In the great groups no hard and fast line can be drawn, at all events in the geological method of classification, for a Plutonic rock may lie at the base of a volcano, and Trappæan rocks may reach the surface and thus become eruptive. So again with the Acid and Basic groups—there must always be rocks of inter-

mediate character ; but it is, I think, scarcely worth while to distinguish them as such. With regard to the Trap rocks, I define them as those which have been forced into sheets or dykes, but have not reached the surface. Since they may start from a mass of Plutonic rock and resemble that group, or be more nearly related to volcanoes, a preliminary subdivision is suggested into Volcanic Traps and Plutonic Traps. With regard to Ashes and Tufas they might be classed either with Volcanic or Sedimentary rocks, but appear most naturally as an independent group of the latter.

The following Table is not intended or imagined to be exhaustive, but it is hoped it may be suggestive; the great objection to it, which I do not quite see how to get over, is that it mixes all kinds of alteration together, whether due to pressure, water, or heat and water.

CLASSIFICATION PROPOSED.

	<i>Normal Rocks.</i>	<i>Varieties.</i>	<i>Altered Rocks.</i>
Volcanic.	Acid ...	Rhyolite ...	Felsite.
		Trachyte.	
		Sanidine Trachyte.	
		Domite.	
		Andesite ...	Propylite.
		Angite Andesite.	
		Obsidian.	
		Pumice.	
		Phonolite.	
		Trachy-dolerite.	
	Basic ...	Dolerite ...	Diabase.
		Nephilinite.	
		Leucitophyr.	
		Basalt ...	Melaphyr.
Trap.	Volcanic	Ash.	
		Tachylite.	
		Felstone.	
		Phonolite.	
		Pitchstone.	
		Basalt.	
	Plutonic	Eclogite.	
		Elvanite.	
		Minette.	
		Kersantite.	
		Lherzolite.	

	Normal Rocks.	Varieties.	Altered Rocks.
Plutonic.	Acid ...	Granite.	
		Granitite.	
		Hornblendic granite.	
		Luxullianite.	
		Syenite.	
		Quartz syenite.	
Sedimentary.	Basic ...	Diorite.	
		Gabbro.	
		Olivine Gabbro	... Serpentine.
	Sandstone	... ..	... Quartzite.
	Clay	... ..	... Slate.
	Marl.		
	Mudstone	... ..	... Gneiss.
			... Hornblende Schist.
	Sandy clay	... ..	... Mica schist.
	Limestone	... ..	... Dolomite.
			... Crystalline Limestone.
	Coal	... ..	... Graphite.

It would be too long a task to give definitions of all these; but for the sake of example we may take one of the smallest groups—the Basic Volcanic series. In this *Dolerite* is defined as a wholly crystalline mixture of *Labradorite*, *Augite*, and *Magnetite*. *Diabase* is what this rock becomes when some of the iron combines to form *Chlorite*. The varieties of *Dolerite* may be called *Nephelinite* and *Leucicophyr*, in which Nepheline and Leucite respectively take the place of the Felspar. *Basalt* consists of the same three minerals as *Dolerite*, but some part of it consists of an amorphous ground mass, and *Melaphyr* is what *Basalt* becomes when some of the iron in it forms hydrated minerals.

If this scheme were fully worked out, each rock would show its relations to others in a much more satisfactory manner than by their mere apposition in a table, and the chemical and structural peculiarities would have their due weight assigned.