bably derived form. Instead of being circular in section at right angles to the long axis, they were triangular, so that they bore a strong resemblance to the kernels of a beech-nut. The

broad end in this case also was perfectly transparent, and the sharper end banded as before.

I append three diagrams representing typical forms.

Ramnagar, Terai, January 25 C. S. MIDDLEMISS

Snowflakes

IN your issue of January 20 (p. 271) is an interesting sketch of the snowstorm of January 7, 1887, with mention of snowflakes $3\frac{1}{2}$ inches long. Without vouching for the exact details I send you some statements from a letter in the *New York World* of to-day's issue. The letter is dated Fort Keogh, Montana, U.S., February 13. "The winter of 1886–87 will be long remembered throughout the north-west for the extreme severity of the temperature and the unusual depth of snow. From January 6 to 11 the degree of cold was something frightful. Mercury thermometers were often congealed, and spirit thermometers were kept jumping from 40° to 60° below zero. Half a dozen times has the 60° notch been touched, and once this season $62\frac{1}{2}$° below zero has been scored on the Saskatchewan plains. But the authorities in weather in this country are the Indians. The oldest members of the Crow tribe say there have been few such winters as the present since they settled in the Yellowstone Valley. Curious phenomena sometimes attend a snowstorm. Near Matt. Coleman's ranch on January 28 the flakes were tremendous, some were larger than milk-pans. Some flakes measured 15 inches square and 8 inches thick. For miles the ground was covered with such bunches, and they made a remarkable spectacle while falling. A mail-carrier was caught in the same storm and verifies it." The narrative is one of great suffering, and loss of human lives and cattle. "Miss Maggie Bunn, school-teacher at Highmore, while going from the school to her house was frozen to death. The bodies of three Indians who belonged to Berthold Agency were found frozen near Ashland." And so on, in harrowing detail, for a number of whites perished. SAMUEL LOCKWOOD

Freehold, New Jersey, U.S.A., February 14

"Invisible at Greenwich"

I WRITE to note an apparent oversight which I have detected in the *Nautical Almanac* for 1888. The partial solar eclipse of August 7 is stated to be "invisible at Greenwich," but on applying a rigorous calculation I find that it will be visible there to a small extent, the times of contact being as follows :—

	G.M.T. h. m.	Angle from N. pt.	Angle from vertex
First contact ...	6 53	11° to E.	26° to W.
Greatest phase	7 3	·013 (sun's diam. 1)	
Last contact ...	7 13	30° to E.	7° to W.

the angles being for the direct image.

I am aware that this is a very insignificant eclipse, but the greatest attainable accuracy is desirable in our national ephemeris, which, indeed, inserts eclipses much slighter than the above, *e.g.* the lunar eclipse of November 26, 1890, whose magnitude is only ·002. A. C. CROMMELIN

Trinity College, Cambridge, February 15

Lunar Halos

LAST evening (February 8), about a quarter-past eight o'clock (75th meridian time), I saw around the moon a series of coloured rings lying close together. The inner one was two or three diameters of the moon from the moon and *red*, the next was violet, then red, and finally violet again, this last one being very faint. From their proximity to the moon these rings seem to constitute the coronal, but I am puzzled by the fact that the inner ring was red. Do halos ever occur so close to the moon and without an interval between the two pairs of red and violet rings?

February 12.—Since writing to you on the 9th inst. I have found that my colleague here, Prof. W. G. Brown, noticed the rings around the moon about half an hour before I saw them. He says the colour nearest the moon was *yellow*, passing into red outwards, and that immediately following the red was violet, then the colours of the solar spectrum in order from violet to red on the outside. This indicates that the first red was really outside a violet ring which for some reason was invisible, and brings the phenomenon properly under diffraction : in fact, we had a good example of the coronal with the innermost rings wanting. S. T. MORELAND

Washington and Lea University, Lexington, Va., U.S.A.

The Beetle in Motion

IF it can interest Prof. Lloyd Morgan I am in a position to communicate that I have many times observed the progressive movements of insects, spiders, and myriapods. I have not noticed the retardation of hind-legs; it seems to me that this occurs only in the case of bulky and slow-moving beetles, like the larger Melasomata. In general, I find that the mode of progression in articulates does not differ essentially from what we see in vertebrates; the process is only, at first sight, a little obscured by the plurality of the legs. If we consider only the prothoracic ring of a beetle, we find that it walks like all bipeds, alternating one leg with another. Two segments walk in the manner of quadrupeds, which are not amblers. Now the legs of the third segment must necessarily repeat the movements of the legs of the first segment, for the sake of equilibrium. The fourth ring would repeat the movements of the second, and so on.

Tashkend A. WILKINS

A Recently-Discovered Deposit of Celestine

WITH reference to Mr. Madan's letter (p. 391), on "A Recently-Discovered Deposit of Celestine," I beg to inform him that a note was read by me at the last meeting of the Mineralogical Society, describing these crystals as exhibiting a habit and size unknown till then to occur with such crystals of celestine in England. I obtained the crystals at Christmas, from Mr. Henson, of the Strand, and am expecting to receive more material, which I hope to work on at the end of Term; but, unlike Mr. Madan, I have at present been unable to visit the locality where they are found. R. H. SOLLY

Mineralogical Museum, Cambridge, February 28

The Vitality of Seeds

MAY I ask, through the columns of your widely-circulated paper, whether there is any really trustworthy evidence for the following statement made by Prof. Judd in his address to the Geological Association (p. 393 in your last issue): "The botanist cites the germination of seeds, taken from ancient Egyptian tombs, as a striking illustration of how long life may remain dormant in the vegetable world." I know that this is a popular belief, but should like to learn upon what foundation it rests. Probably it would interest other botanists besides.

February 26 N. E. P.

THE RELATIONS BETWEEN GEOLOGY AND THE MINERALOGICAL SCIENCES[1]

II.

LET us now turn from the statical aspect of minerals, their morphology, to the dynamical aspects, their physiology.

Minerals are not fixed and unchangeable entities, as they are sometimes regarded. On the contrary, they exhibit varying degrees of instability, and pass through very definite series of metamorphoses.

We have already seen that every alteration in the temperature or other conditions which surround a crystal leads to striking modifications of molecular structure, which are at once revealed by the delicate tests of optical analysis. So sensitive, indeed, are some crystals to the action of external forces, that even the passage of the

[1] Address to the Geological Society at the Anniversary Meeting on February 18, by the President, Prof. John W. Judd, F.R.S. Continued from p. 396.

light-waves through their substance leads to permanent molecular rearrangements which are evidenced by marked changes in colour, translucency, and other properties.

Many minerals have their atoms so arranged that the action of external forces causes them to fall readily into new combinations. In this way there are brought about such paramorphic changes as that of aragonite into calcite, and augite into hornblende. Excessively slight manifestations of force are sometimes sufficient to induce such paramorphic changes.

But the most significant fact of all is that every crystal possesses certain peculiarities of molecular structure, and as the result of this internal "organisation," it responds in a definite manner to the action of various external forces, undergoing in this way well-marked series of physical and chemical changes without losing its identity. As the final result of such successive changes, however, the bonds which hold the "organised" structures together are gradually weakened, and at last break down altogether. In this way the separate existence of the mineral comes to an end; but the materials of which it was composed, resolving themselves into new compounds, may go to build up the substance of other "organised" structures. Need I point out that in all these respects minerals behave exactly like plants and animals?

But in the case of plants and animals changes such as these, which are the direct outcome of external forces acting on a special organisation, are called *physiological*, and I know of no valid reason why the same term should not be employed in the case of minerals. It is true that the accomplishment of the cycles of change in minerals often requires periods of time of enormous duration, and that during incalculable intervals they may appear to be wholly suspended; but in these respects the "life" of a mineral differs from that of a plant in just the same manner as the latter does from the life of an animal.

I must ask your attention for a few moments to these peculiarities of internal organisation in minerals, and to the way in which the various physical and chemical forces act and react upon them in consequence of their special organisation.

Recent researches have shown that every crystal possesses a number of planes, all of which are related to its peculiar symmetry, along which the several physical forces operate in a marked manner to produce changes in the physical and chemical properties of the crystal. These planes have been called the "structure-planes" of the crystal.

By far the most obvious of these structure-planes of crystals are those of cleavage. When crystals are subjected to the action of mechanical force they break up along one, two, or three definite planes, with varying degrees of ease. In some cases when this separation cannot be readily effected by percussion or pressure, it may be brought about by the unequal expansion and contraction in a crystal resulting from alternate heating and cooling. We cannot arrive at the limit of this liability of a crystal to separate along its cleavage-planes; if we powder a calcite-crystal and examine the fine dust under a microscope, each minute grain will be seen to have the form of a cleavage-rhomb of the material.

Now the exquisite molecular structure of a crystal, of which this wonderful property of cleavage is the outcome, is borne witness to, not only by the perfection of the cleavage-surfaces—presenting, as they do, a lustre which no artificial polish can imitate—but by the fact that each particular set of cleavage-surfaces presents definite characteristics, analogous to those seen in the actual faces of crystals. Each exhibits striking peculiarities in its mode of reflecting light; each yields in varying degrees to a hard point drawn across it in different directions; and each, when treated with appropriate solvents, is attacked in a characteristic fashion, giving rise to the geometrical forms known as the etching-figures. Wonderful as these cleavage-surfaces are, however, it must be remembered that the power of cleavage is one that, under ordinary circumstances, remains altogether *latent* in crystals.

Cleavage-planes, however, are not the only latent structure-planes in crystals. Long ago it was shown by Brewster, Reusch, and Pfaff, that when minerals are subjected to pressure in certain directions, their molecules appear to glide over one another along certain definite planes within the crystal; and, if we examine optically a crystal which has been treated in this manner, it is actually found to exhibit a series of twin-lamellæ arranged parallel to the so-called "gliding-planes." It thus appears that in the movements set up within a crystal by the application of force from without, certain of the molecules of which the crystal is built up, lying in bands parallel to the gliding-plane, are actually made to rotate through an angle of 180°.

At one time these "gliding-planes" were regarded as being peculiar to a few minerals, such as calcite and rock-salt; but the investigations of Frankenheim, Baumhauer, Foerstner, and especially of Mügge, have shown that they exist in crystals belonging to every group in the mineral kingdom, including all those minerals which occur as common rock-forming constituents, such as the feldspars and pyroxenes.

As is the case with the cleavage-planes, so with the gliding-planes, there may exist one, two, or three in the same crystal. One of these is usually a principal gliding-plane—the slipping movement with its accompanying twin-lamellæ being produced parallel to it with the greatest facility—while the others are subordinate ones.

Strange to say, however, the particular gliding-plane along which a crystal yields appears to be determined, not only by the direction in which the force is applied, but to some extent also by the nature of that force, whether percussive, or a sustained pressure, or a violent stress; in some cases where the application of external force fails to produce the gliding movement with its accompanying lamellar twinning, it may be induced by the strains which result from unequal expansion and contraction during the heating and cooling of a crystal. Some mineralogists have, indeed, proposed to apply distinctive names to the results which follow from the application of different kinds of force—whether a blow (*Schlagfiguren*), pressure (*Reissflachen*), or the effect of heating and cooling (*Contractionrisse*).

The gliding-planes of crystals are quite distinct from the cleavage-planes, though some very curious and interesting relations have in certain cases been shown to exist between them. That the artificial formation of twin-lamellæ, like the production of cleavage, is rendered possible by complicated molecular structures, it is scarcely necessary to point out. The application of external force to such crystals is like the putting of a spark to a train of gunpowder: the molecules lying in parallel bands are in unstable equilibrium, ready, so soon as set in motion, to roll through an angle of 180°.

There is still a third and even more subtle set of structure-planes in crystals to which I must now allude, those, namely, for which the name of *solution-planes* has been proposed.

It was long ago shown by Daniell that when crystals are exposed to the action of solvents they are attacked in such a manner as to give rise to peculiar geometrical forms. The subject has been followed up by Baumhauer, Leydolt, Becke, and others, who have shown what a wonderful variety of "etching-figures" may be produced by operating upon the various faces and cleavage-surfaces of different crystals.

Quite recently, however, it has been shown by Von Ebner, as the result of his studies of calcite and aragonite, that all the complicated phenomena of the etched figures arise from the existence of planes along which solvent or chemical action takes place most readily within a crystal. It thus appears that the complicated etched figures, with their curved and striated surfaces, are indications of the combination or oscillation of tendencies to chemical action along the different solvent-planes of the crystal.

My own experiments have enabled me to show that the chemical action taking place along the solution-planes of crystals leads to the development of cavities, often assuming the forms of negative crystals, which may become wholly or partially filled with the product of the chemical action.

Although the solution-planes are quite distinct, both from the gliding-planes and the cleavage-planes of crystals, I have been able to show that some curious and interesting relations exist between them. If lamellar twinning has been already developed in a crystal, then chemical action takes place along the gliding-planes in preference to the normal solution-planes.

It is only when we study the minerals building up the rock-masses of the globe that we fully realise the importance of these molecular structures, and the wonderful changes which crystals are capable of undergoing, as a consequence of their internal "organisation." Then, and then only, do we begin to understand the significance and the far-reaching consequences of the physiological changes of which minerals are susceptible.

The crystals forming the rock-masses of the globe have been subjected to every variety of mechanical force —violent fracture, long-continued strain, steady but enormous pressure—prolonged over vast intervals of time, to which must be added the potent effects of alternate heating and cooling. Such crystals, moreover, are transfused through their whole substance by various liquids and gases acting under tremendous, and sometimes varying, pressures.

Under such circumstances it is not surprising to find that the crystals have often yielded along their cleavage-planes, and that cleavage-cracks have been produced. These, by affording a ready channel for the passage of solvents, not unfrequently determine the course of various chemical operations going on within the crystal.

Not unfrequently, too, the rock-forming minerals have yielded along their gliding-planes, and the development in them of twin-lamellæ is the result. Every crystal of calcite in an ordinary metamorphic limestone, and many of the plagioclase feldspars in igneous rocks, exhibit the secondary lamellar twinning which has arisen from the action of mechanical forces upon the mass.[1] The microcline structure in orthoclases, with many other similar structures in other minerals, must almost certainly be ascribed to the same cause.

Still more remarkable are the consequences which follow from the existence of the solution-planes in crystals. By the action of various solvents under pressure, augite is made to assume the forms known as diallage and pseudo-hypersthene, the ferriferous enstatite of bronzite or hypersthene, while the feldspars acquire their avanturine, schiller, and chatoyant phenomena. When, in addition to the statical pressures due to thousands of feet of superincumbent rocks, these solvent agencies work with those tremendous dynamical aids afforded by deforming stresses, such as make the rocks to flow during mountain-making, it is not surprising to find the molecules of the original crystals breaking from their old allegiances, and the liberated atoms uniting to form new minerals, the position of which is determined by the lines of flow in the mass.

Not a few of our gems owe their exquisite beauties to these physiological changes which have taken place in them since their first formation. The ardent glow of the sunstone and the pale watery gleam of the moonstone, no less than the lovely play of the azure tints in Labrador-spar and the bronzy sheen of Paulite, are the result of physiological processes taking place in crystals which were originally clear and translucent. In the profound laboratories of our earth's crust slow physical and chemical operations, resulting from the interaction between the crystal, with its wonderful molecular structure, and the external agencies which environ it, have given rise to new structures, too minute, it may be, to be traced by our microscopes, but capable of so playing with the light-waves as to startle us with new beauties, and to add another to

"The fairy tales of science, and the long results of time."

Yes! minerals all have a *life-history*, one which is in part determined by their original constitution, and in part by the long series of slowly-varying conditions to which they have since been subjected. In spite of the circumstance that their cycles of change have extended over periods measured by millions of years, the nature of their metamorphoses and the processes by which these have been brought about are, in all essential respects, analogous to those which take place in a *Sequoia* or a butterfly. In spite, too, of the limitations placed upon us by our brief existence on the globe, it is ours to follow in all its complicated sequence this procession of events, to discover the delicate organisation in which they originate, to determine the varied conditions by which they have been controlled, and to assign to each of them the part which it has played in the wonderful history of our globe during the countless ages of the past.

The subject of distribution, or chorology, is one of no less importance in the study of the mineral than in that of the vegetable and animal kingdoms. The relations of minerals to one another, and the manner in which they make their appearance in respect both to time and place, constitute a most instructive and suggestive field of research.

The older mineralogists paid some attention to the question of the mode of association of minerals with one another, which they described under the term "paragenesis." But this was at a time when only large and freely crystallised specimens received much attention. At the present day this question of the varied distribution of minerals in space and time, and the manner in which they are associated with one another to build up rock-masses, constitutes a most important branch of our science, that to which the name of petrology is given.

Under the name of "petrography" an attempt has been made to establish a branch of natural-history science which shall bear the same relation to mineralogy as that science does to chemistry. As minerals are formed by the union of certain chemical compounds, so rocks, it is argued, may be regarded as being built up of different minerals. But it must be remembered that while minerals possess a distinct individuality—the result of their different chemical constitution and their characteristic crystallographic form—we are quite unable to point to anything analogous to these in the case of rocks.

How is a rock-"species" to be defined? It is not enough to state its ultimate chemical composition; for rocks of the most varied character and origin may agree in this respect. Equally futile is it to take mineralogical constitution as the basis of our classification; for, in the

[1] It has often been asserted that the "striation" on the faces or cleavage-surfaces of crystals is an indication of the existence of polysynthetic twinning. But in the oligoclase of Ytterby and other localities, I have found that many crystals which exhibit striation do not affect polarised light differently in the alternate striæ. But on submitting the crystals to alternate heating and cooling, and sometimes by percussive force, the twinning may be easily developed in them. It appears from these observations that the crystals are built up of lamellæ, in which the molecules are alternately in stable and unstable equilibrium. I have in some cases found that the stresses upon a slice of feldspar which is being heated and cooled and then ground into a thin section, while cemented to a glass plate during the preparation of a microscopic slide, are sufficient to cause the rotation of the molecules in the alternate lamellæ. In some cases, I have no doubt that twin-lamellation, like cleavage-cracks, may be induced in the crystals of our rock-sections during the processes to which they are submitted in their preparation.

same rock-mass, the species of minerals which are present and their proportions to one another may, and, indeed, often do, vary from point to point. Nor does minute structure, though affording admirable criteria for distinguishing certain *types* of rock, supply a sufficiently definite means of diagnosis for all the different varieties which occur. A system of "lithology" may, indeed, be devised, if we confine our attention to the hand-specimens in our museums; but it breaks down the moment that we attempt to apply it in our researches in the field.

I have long felt assured that all attempts at a nomenclature and classification of rocks must, for the reasons just stated, be regarded as tentative and provisional only; but the careful study of rock-types is nevertheless bringing to light a number of facts calculated to profoundly modify mineralogical no less than geological thought and speculation.

Petrology forms the link between mineralogy and geology, just as palæontology does between biology and geology. Mineralogy has justly been styled the alphabet of petrology; but if the orthography and etymology of the language of rocks lie in the province of the mineralogist, its syntax and prosody belong to the realm of the geologist. In that language, of which the letters are mineral species and the words are rock-types, I am persuaded that there is written for us the whole story of terrestrial evolution.

Petrology, it is clear, could make but little progress until the improvement of microscopic methods enabled us to make accurate determinations of the minerals in a rock, even when these are present as the most minute particles. The characteristic peculiarities of the different rock-forming minerals, so carefully studied by Zirkel, their accurate optical diagnosis, at which Rosenbusch has laboured with so much success, these with the microchemical methods of Knop, Bořický, Streng, and Behrens, and the pyro-chemical method of Szabó, have already done much to render exact our methods of recognising the minerals in a rock. The contrivances, for which we are principally indebted to the French petrographers, for effecting the isolation of the minerals in rocks, so that they may be submitted to accurate chemical analysis, enable us in cases of difficulty or doubt to confirm or check the results of our microscopical studies.

But there is at present, perhaps, a tendency to confound the end with the means in such researches as these. When all the varieties of minerals in a rock have been correctly identified, the work of the petrologist is not ended; on the contrary, it is only just begun.

The relationship of the several minerals in a rock to one another, the discrimination between such as are original and those of secondary origin, and the recognition among the former of the essential, as distinguished from those that are accessory or accidental,—these are problems of even greater importance than the exact determination of the species or varieties to which each belongs. In not a few rocks it can be demonstrated that every one of its present mineral constituents is different from those of which it was originally made up; in some cases, indeed, it may be shown that the recombination of the elements of the rock into fresh mineral aggregates has taken place again and again. As well might we try to give a rational account of our English speech without taking into account the series of changes through which it has passed in its evolution from the Anglo-Saxon dialects, as to explain the nature of a rock without studying the influence upon it of the forces by which it has gradually acquired its present characters.

With respect to the geographical distribution of the different mineral species, many suggestive observations have been made. Some, like the feldspars, the pyroxenes and the olivines, appear to be ubiquitous in our earth's crust, and even make their appearance again in those bodies of extra-terrestrial origin—the meteorites. Others, like leucite, nepheline, hauyn, sodalite, and melilite, are exceedingly abundant in certain areas of the earth's surface, while they appear to be wholly wanting in others.

Still more remarkable are the relations which are found to exist between the types of rocks occurring in different geographical areas. The study of this subject is leading us to the recognition of the fact that there are distinct petrological provinces. In closely adjoining areas—such as Hungary and Bohemia, for example—widely different types of rock have been erupted during the same geological period; and this is a fact not less striking and significant than that of the meeting of two perfectly distinct biological provinces along a line which traverses the Malayan archipelago. It cannot be doubted that the prosecution of this hopeful branch of study—the geographical distribution of minerals and rocks—will lead us to results of the highest interest and value.

That there will be shown to be a distribution of rocks in time, as well as in space, I am perfectly prepared to believe. I cannot but think, however, that some of the generalisations on this subject which have been hazarded are somewhat premature. To a geologist (especially one belonging to the school of Lyell) it is equally difficult to conceive that there should be a broad distinction between the metamorphic rocks of Archæan and post-Archæan age respectively, as that the pre-Tertiary volcanic rocks should be altogether different from those of Tertiary and recent times.

The great object of all our studies—concerning the morphology, the physiology, and the chorology—of the mineral kingdom, ought to be to arrive at definite ideas concerning its ætiology; the causes by which the existing forms, capabilities, and positions of minerals and rocks have been determined.

While the *fossils* contained in rock-masses afford us the means for determining the date of their origin, the careful study of the minerals which they include may enable us to unravel the complicated series of changes through which they have passed since their first formation.

Eighteen years ago, when seeking to show how the origin of a particular rock might be elucidated by a combination of studies in the field, in the chemical laboratory, and by the aid of the microscope, I ventured to offer to this Society some general remarks on this subject. As it has been my constant endeavour since that time to apply the principles then enunciated in the case of rocks of more complicated character and more recondite origin, I may perhaps be forgiven for repeating the words I then used. Every rock since its first formation "has undergone and it still is undergoing a constant series of internal changes, the result of the action of different causes, as heat, pressure, solution, the play of many chemical affinities, and of crystallographic and other molecular forces, causes insignificant perhaps in themselves, but capable under the factor *time* of producing the most wonderful transformations. The geologist is called upon to unravel the complicated results, to pronounce what portion of the phenomena presented by a rock is due to the forces by which it was originally formed, and what must be referred to subsequent change; to discriminate the successive stages of the latter and to detect their various causes; in short, to trace the history of a rock from its deposition to the present moment."

Dr. Wadsworth has well characterised the changes which take place in rock-masses as due to the tendency of unstable mineral combinations to pass into stable ones. It must be remembered, however, that stability is a relative term, and that the arrangement of molecules which is stable under one set of conditions becomes unstable under another set. As by the internal movements and the external denudation of the earth's crust, the conditions under which rock-masses exist are undergoing slow but continual change, new adjustments of the molecular structure of the rocks are at once necessitated and brought about.

In attempting to reason as to the *original* conditions under which a rock-mass must have been formed, it is of great importance to avoid those sources of error which exist in rocks that have undergone much secondary alteration. Such rocks abound in, though they are not necessarily confined to, the older geological formations; and it is among the younger and fresher rocks, therefore, that we may most hopefully seek the key to many petrological problems.

If, for example, we concentrate our attention upon the more recent and less altered igneous rocks, it becomes clear that the degree of crystallisation displayed by them has depended on the slowness with which consolidation has taken place, and that this has in turn been determined by the depth from the surface at which they have been formed. In this way, by the study of igneous rock-masses in Scotland and in Hungary, I was able to show that there is a perfect gradation from highly crystalline rocks—granites, diorites, and gabbros—into the ordinary volcanic types—rhyolites, andesites, and basalts, respectively—and from the latter into the various kinds of volcanic glass. These conclusions have been confirmed by subsequent investigations like those of Hague and Iddings in the Comstock region, and of Lotto in Elba. Further and more recent researches have enabled me to show that certain types of structure have been determined in rocks, according to the more or less perfect absence of all movement within them during their consolidation.

Very remarkable, indeed, are the internal changes which take place in rock-masses when they are submitted to those powerful stresses which result from the movements that occur during mountain-making; and the full explanation of these is perhaps the most difficult problem which still confronts the geologist.

It was long ago asserted by Scrope and Darwin that the solid rock-masses of the globe, under such conditions as these, must have actually *flowed*, like the viscous lavas of the rhyolitic series. These geologists were even able to show that the separation and disposition of the crystalline elements in such lavas present the closest analogy with what is seen in the crystalline schists and gneisses of greatly disturbed areas.

Since these early researches, which were principally based on the study of rocks in the field, aided only by the pocket-lens, three classes of researches have served to deepen our insight into the methods by which the schistose and gneissose rocks must have been produced.

In the first place, the experiments of MM. Tresca and Daubreé have shown that solid matter under enormous pressure behaves like a viscous substance, its whole internal structure exhibiting evidence of the flowing movements to which it has been subjected.

In the second place, the studies of M. Spring have established the fact that both paramorphic change and direct chemical reaction may result from simple pressure. Thus the unstable monoclinic form of sulphur, by a pressure of 5000 atmospheres, was at ordinary temperatures converted instantly into the stable rhombic form, a transformation accompanied by change of density and of many other physical properties. Still more striking is the case of the unstable, yellow, rhombic, mercuric-iodide, which, by simple rubbing with a hard substance, passes into its stable, red, tetragonal allomorph. It is instructive to notice that the same change in both instances appears to take place "spontaneously" after a sufficient interval of time; or, in other words, small variations in temperature, pressure, and other surrounding conditions are capable, if sufficient time be allowed, of bringing about the same result as more intense pressure applied suddenly. That the similar paramorphic change of pyroxene into hornblende, which is so frequently exemplified in the earth's crust, is sometimes the result of intense pressure, and at other times follows from the repeated slight alteration of conditions during long periods of time, we have, I believe, abundant evidence.

But the experiments of M. Spring that prove that chemical reactions can result directly from pressure are of even greater interest to the geologist. By submitting mixed powders to intense pressure, he succeeded in producing metallic alloys and various binary compounds, and also in bringing about double decomposition between many salts. That similar reactions between the complicated silicates which form the minerals of rocks have resulted from the enormous pressures to which they have been subjected, we have the most ample proof. Thus in rocks where such pressure has just begun to act, such as the "flaser-gabbros," wherever the unstable olivine is in contact with the almost equally unstable anorthite, chemical reactions have been set up by the pressure, and these have resulted in the formation of zones of enstatite and anthophyllite, hornblende and biotite, which have been so well described by Törnebohm, Bonney, Adams, and Williams. Provided with the clue supplied by these results, we find little difficulty in going one step further. When the pressure has been still more intense, as in mountain-making movements, reactions are set up among all the minerals of the rock-mass; the elements of which it is composed, set free from their old engagements, enter into new alliances, and the result is the formation of a completely new set of crystallised minerals.

The third class of researches, destined, as I believe, to remove our difficulties in explaining the origin of the schistose and gneissose rocks, are those already alluded to as having been undertaken with the microscope. As yet the details of such changes have only been explained in the case of some of the simpler examples; but I am convinced that the persevering application of the same methods in the field and the laboratory will result in the removal of difficulties that now seem to be absolutely insurmountable.

Some observers in this country have been led to infer that the recrystallisation of rock-masses under pressure has in all cases been preceded by their pulverisation. Of this, I confess that I can find no evidence. That near great faults of all kinds, this reduction of rocks to powder does take place, we find abundant proof; but the evidence also points to the conclusion that such *rock-crushing*, as distinct from *rock-flowing*, is in every case local and exceptional.

There is another and totally different series of changes which takes place in rocks, when, brought near to the surface by denudation, they are exposed to the action of water, oxygen, carbonic acid, and other atmospheric agents. The breaking-up of the alkaline silicates and the deposition of secondary silica, the formation of the zeolites, the epidotes, the chlorites, and serpentine, the resolution of crystallised minerals into the isotropic mixtures, and the recrystallisation of these in new forms, all offer problems of the highest interest to the geologist.

I may venture, in drawing these remarks to a close, to indicate another point of analogy between the three natural-history sciences. It is found in the circumstance that experimental verifications of our conclusions are often difficult, if not actually impossible.

We must be content to reason from the proved variability of the existing forms of plants and animals as to the possibility of the production in time of new species. And in the same way, with our limited command of heat, pressure, and especially of time, we can scarcely hope to originate the exact counterparts of the various minerals and rocks of our earth's crust.

We may nevertheless point with satisfaction to what, in spite of such difficulty, has already been accomplished in this interesting field of research. The honour of having pushed these researches to such successful issues belongs chiefly to the chemists, mineralogists, and geologists of France. To the labours of Senarmont, Daubrée, and a host of other workers, we owe the artificial production of a very large number of the minerals of our globe; while the ingenious experiments of Fouqué and Michel Lévy have resulted in the formation of many rocks differing in no essential particulars from those which have been produced by natural agencies.

In the prosecution of his various researches the importance and value of exact mineralogical knowledge to the geologist is becoming every day more apparent. The temporary estrangement between the cultivators of mineralogy and geology is now, we may hope, for ever at an end; very heartily, indeed, do geologists recognise and welcome the aid of their brethren the mineralogists.

But if it be confessed that the benefits, past and prospective, conferred on geological science by mineralogy are vast and even incalculable, it must also be admitted that the debt is amply repaid by the beneficial influence which is being exercised in turn upon mineralogy by geology.

Some time ago a distinguished mineralogist asked me if I did not find the ordinary text-books of his science but little calculated to arouse the interest or excite the enthusiasm of students. I am sure that the energy of my assent must at least have assured my friend of the strength of my convictions on the subject.

Too long, indeed, has the accumulated mass of mineral lore recalled the grim vision of the seer of Chebar. In that gruesome valley the wail of the student, "the bones are very dry," has mingled with the sigh of the teacher, "Can these bones live?" But now from the four winds of heaven come the constructive ideas of many minds—from Scandinavia and from France, from Germany and from the United States—and in obedience to this influence behold "a great shaking" in the formless mass. Scattered facts, isolated observations, imperfect generalisations, and tentative hypotheses are falling together "bone to his bone," and are building up a sound body of mineralogical knowledge; and into this the spirit of geological thought entering, mineralogy shall stand forth a living science.

DR. WILLIAM TRAILL, OF WOODWICK[1]

THE death of this assiduous student of natural history merits more than a passing notice, since there are few surgeons who did more for the advancement of Eastern conchology than he; while his researches on the antiquities of his native county (Orkney) also claim attention. His whole career, indeed, as in the case of many an Eastern surgeon, illustrates the wisdom of placing both natural history and botany on the curriculum of every medical student.

Dr. Traill was the eldest son of Mr. Traill, of Westness, Rousay, Orkney, and he was born in Kirkwall on September 8, 1818. He proceeded to the University of Edinburgh to study medicine at the age of sixteen, and while there he had the advantage of the direction and advice of his uncle, the late Prof. Traill, who held the Chair of Medical Jurisprudence. Young Traill proved an apt student, and showed from the first a strong liking for natural history. This was fostered by his uncle (whose collection of snakes, now in the Museum of Science and Art, was well known to naturalists), as well as by his pursuits during the holidays at the family seat at Westness, in the Island of Rousay. Amongst his fellow-students were Dr. Cleghorn, of Stranthie, late Conservator of Forests in India, Sir Lyon Playfair, and Dr. Halliday Douglas.

After graduating in 1841, he proceeded to India as a surgeon in the East India Company's service. The splendid field thus opened up to the young naturalist stirred all his energies into activity, and he studied and collected various groups, but especially the land-shells of Madras. His early studies on the shores of Orkney had given him a predilection for this department, and he remained faithful to it throughout life. Thus, when shortly afterwards called to serve in China, he began the collection of those beautiful specimens of Eastern shells now so well known in many collections. His opportunities were further extended by a residence of some years at Singapore, and afterwards at Malacca and other stations. He returned to England in 1854, and his collections were much admired, both as regards the beauty of the specimens and the number of examples of each species. His acquaintance with Dr. Knapp, a retired army surgeon, and also well known as a malacologist, gave a great impetus to his studies, as also did his association with Andrew Murray, Robert Gray, Dr. Howden, Wyville Thomson, Foster Heddle, James Cunningham, Patrick Dalnahoy, and R. Greville.

His return-voyage to India in 1856 gave him an opportunity of examining the pteropods and other pelagic mollusks, and his observations, with four plates and a chart, were communicated by Sir Walter Elliott to the *Madras Journal*, then edited by his friend Dr. Cleghorn. His preparations of the delicate glassy shells of the Thecosomatous forms was remarkable. He also described some rare species, observed certain peculiarities in their structure, and made comparisons between the velum of the young Cypræa and the epipodia of the pteropods. His collection of Eastern mollusks was largely increased during his second period of duty, so that it became celebrated for certain rare types, such as *Rostellaria rectirostris*, *Trochus guilfordii*, *Trochus imperialis*, &c. He also added largely to Prof. Traill's collection of snakes formerly alluded to.

On retiring from active duty he settled at St. Andrews, and at once took an active interest in the University Museum and Literary and Philosophical Society, of which latter he was a Vice-President at his death. He spent much of his time in arranging the Mollusca in the Museum, and he enriched the collection by many interesting and rare types. In his annual trips to his estate in Orkney he also made researches on the antiquities and geology of the district, and these he embodied in papers communicated to the Edinburgh Antiquarian Society, and to the Society at St. Andrews. Amongst these papers are the following:—"Results of Excavations at the Broch of Burrian, Orkney," two plates and woodcuts; "Notice of Excavations at Stenabeck, Orkney," with woodcuts; "On Submarine Forests in Orkney"; "On the Picts' Houses of Skerra Broc"; "On the Recurrence of Boulder-Clay in Orkney"; "Notice of the Boulders in North Ronaldshay," &c.

His knowledge of botany also enabled him to acclimatise various plants in Orkney, such as *Phormium tenax*, various Veronicas, the Manuka (Capt. Cook's sea-plant), the Japanese *Euonymus*, and others.

Dr. Traill was a man of refined and cultivated mind, genial but unobtrusive, and had a large circle of friends. He enjoyed good health till eighteen months ago, when the first symptoms of the disease which ultimately proved fatal appeared. W. C. M.

[1] Abstract of Paper read at the Literary and Philosophical Society, St. Andrews, January 21, 1887.

THE EARTHQUAKE

A SERIES of shocks of earthquake has caused much havoc in the Riviera during the last week. Although it is too early to attempt to give a complete account of what has happened, the leading facts, so far as they are of scientific interest, are well summed up in the following report, issued by Father Denza, of the Montcalieri Observatory:—

"(1) The earthquake in our region has had nearly the