NO. IX.—ON THE OCCURRENCE OF TACHYLYTE AT LOCH SCREDEN,
MULL. By Professor M. FORSTER-HEDDLE, F.R.S.E., &c.
With an Illustration (Plate III.) and Two Diagrams.

[Read 11th May, 1893.]

TACHYLYTE is the black, bottle-glass selvage which is occasionally seen upon the contact surfaces of basaltic dykes.

In a paper upon the tachylytes of the Western Islands of Scotland, published in the *Quarterly Journal of the Geological Society* for April, 1883, by Professors Judd and Cole, these authors give what is termed a detailed "History of previous opinions on the subject."

In this, after showing that a variety of terms had been applied to this selvage upon the Continent, they say "Zirkel and others describe different varieties of basalt-glass under the name of tachylite, and by the same designation the Scottish examples were referred to by one of us in 1875."

Under a second heading, "Distribution and mode of occurrence," due credit is given to Dr. M'Culloch as having been the original discoverer of two, out of what are termed the "five known localities."

Under the above headings no notice is, however, taken of the observation, and very full, interesting, and accurate description, of the occurrence of this substance by Prof. Archibald Geikie at Ben Tigh in Eigg,—published in his admirable paper on the geology of Eigg in the *Quarterly Journal of the Geological Society* in 1871; nor of a chronicle of the occurrence of the same substance at the Quiraing in Skye, as submitted to the Mineralogical Society in 1880 by the present writer, and published in the *Mineralogical Magazine*.

In this latter paper the writer showed, by analysis of both, that the composition of the tachylyte, and that of the dolerite to which the vitrified skin or selvage was attached, were nearly identical; and that the former was thus probably the suddenly-chilled portion of the flow: and he also showed—by a contrasted analysis of the pitchstone of Arran—that while tachylyte is the glassy condition of a *basic* rock, pitchstone stands in the same relation to an *acidic* rock.

In a note which was appended to their paper by Professor Judd and Mr. Cole, subsequent to its reading, they credit M. Necker

with the primal recognition of the above;—"the true nature and properties of the material are very clearly defined;"—and they credit the present writer who was the analyst of both with having only brought Necker forward to receive the above award. What Necker actually did was only to affirm that the so-called "gallinace" of Beal was not pitchstone. He did not recognise it as being tachylite, which he does not even mention in this connection at all, though he notices it in his "Regne Mineral" of 1835,—placing it, as an aluminate of lime, beside obsidian and sphærolite.

As Messrs. Judd and Cole have come to the same conclusion as that previously announced by the present writer—a conclusion which indeed was inevitable after the still earlier analysis by Delesse—I have the less hesitation in passing certain other of their conclusions under review, in connection with the recording of the occurrence of tachylite sheathing a dyke at a new locality, and that in quantity altogether enormous in comparison with that seen at *all* the other Scotch localities combined.

The locality referred to is the northern angle of the entrance to Loch Screden in Mull.

While examining this part of the coast of the island, from Mr. Harvie Brown's yacht, we were attracted by the appearance of basaltic pillars, and landed at the point near Derag Skier. We here found a development of basaltic structure more diversified in its features than that seen at the not far-distant Staffa, though by no means so picturesque.

A pavement more regular in its columns than that of the Giant's Causeway, and a wonderfully fine circle or wheel, with a depressed circular axis or throat, are two of the features most deserving of being recorded. This last, though only properly seen from an overhanging cliff, very much surpasses the well-known "rock" of the Rock and Spindle near St. Andrews. The pillars greatly exceed those of the latter in dimensions, they are much more regularly disposed, and at their peripheral extremities are suddenly incurved upwards—simulating somewhat the expanded petals of a camelia.

The dyke, the sides of which are sheathed in tachylite, occurs immediately to the east of this pillared basalt, cutting some of the smaller groups both vertically and horizontally. It forms the southern limit, as it were, of a vast grass-clad slope of debris, of about 1000 feet in height, which faces the western ocean, and

which has very infelicitously been called "the Wilderness." From a concentric coronet of cliffs which crowns this slope, the dyke may be seen cutting the sward in an almost vertical sweep of 800 or 900 feet. When it reaches to within about 50 feet of the water it suddenly bends to the east, and becomes nearly horizontal in part of its course, but with a slight dip to the south-east. In the higher parts of its course it cuts bedded dolerites, melaphyres, and amygdaloids; the denser columnar basalt seems to have deflected it at the point where it meets that bed, but, at a short distance southward of this, it cuts the basalt diagonally.

As the writer did not ascend the turf-clad slope to any height, he cannot speak positively, but, so far as he could see, the tachylyte appeared only where the dyke cut basalt. The basalt of the dyke is much denser and finer in grain than that of the pillars; it is of a light grey-brown tint, that of the pillars being dark brown. It contains no druses with zeolites; in this differing from the basalt of the pillars.

The tachylyte coats both sides of the dyke, and the exposure is in all respects perfect. The pillars have been swept clean off the upper surface of the horizontal bend for a distance back from the sea-cliff of 20 or more yards; so that the upper skin of tachylyte is walked upon, and a surface, much broken-in upon it is true, but of several hundred square yards, of black-bottle-like glass, is exposed. This upper skin or selvage is thin, being from a quarter to half an inch in thickness, and the transition into the ordinary structure of the rock is, upon this surface, somewhat sudden. On the lower selvage, again, the tachylyte is from 2 to 3 inches in thickness, and the passage into basalt is very gradual.

The dyke, where cutting the basalt, has an average width of 9 feet. High up on the slope it seems to assume greater dimensions. At one spot the dyke is divided by a portion of the pillared basalt, here nearly amorphous; this crosses it diagonally, and hitches it slightly upward to the east—like a reversed fault.

The westernmost portion of the dyke thins off, so as to underlie for a short distance this apparently-included mass of basalt. The thickness of the selvage of tachylyte increases as the mass thins; and when the dyke is about 8 inches wide it appears at first sight to be all black tachylyte.

The marginal portions are all jet-black glass, so smooth in

fracture as to reflect perfectly. These margins have such eminent conchoidal fractures as to present the appearance of an agglomeration of small black bullets or egg-shaped masses. It gradually becomes pitchy in lustre, and brown in colour, towards the centre. The most perfect glass has a specific gravity of 2·728.

This portion of the tachylyte passes in a vein-like process for about 15 yards through the columnar basalt. Its average thickness is 6 to 7 inches, but it thins to 2 inches; there it is clear lustrous glass throughout, much fractured; while a short distance to the east it expands to a thickness of 22 inches. Here it is still tachylyte throughout, with a columnar structure like that of starch. The little columns are about 2 inches long by $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness. They are for the most part in a nearly vertical position—that is lying across the dyke—but are grouped in fasciculitic clusters. This patch of the tachylyte bears in miniature a very striking resemblance to the truncated western extremity of the Scur of Eigg where seen at the point of Bridianach.

In that portion of its course where this vein-like process has a thickness of less than 7 inches, its rents cause it to assume the form of balls or ovoidal masses, which are flattened on the sides by mutual contact. These balls may be extracted entire, their general length coinciding with the width of the vein. Hammer-fracture of these balls discloses a structure somewhat approaching that of banded hornstone—the brilliant velvet-black of the tachylyte passing through bands of brownish colour with a duller and more vitreous or pitchy centre.

It has been stated above that the dyke cuts the pillars somewhat diagonally: the pillars, however, have *not* been rent diagonally, but at right angles to their vertical position. The rent thus passes through the colonnade of pillars step-ways—the glassy plug of tachylyte filling up what would otherwise be angular vacuities in a similar step-like manner. So comes it that the selvage of tachylyte at one side of a rent pillar may be little more than a fourth of an inch in thickness, while at the other it may be 3 or 4 inches. This is best seen in the easternmost portion of the dyke.

From the angles of these pools of tachylyte, small branching veins of the substance penetrate the basalt, thinning off to nothing.

This proves the fluent condition of the tachylyte to have been perfect. But the once-perfect fluidity of, not only the tachylyte, but of the basalt itself, is made manifest by the structure of the balls or ovoidal masses above referred to,—as disclosed by the microscope. Sectioning shows the rock of the pillars to be one of minute crystal grain. The lath-shaped labradorite is in crystal groups of a somewhat stellar arrangement. The augite, in larger crystals of nearly uniform dimensions, is pale-green and granular or structureless. The olivines are clear. There is little or no glass. Sections of the central portion of the dyke show it to be a dolerite of fine crystal grain, in which labradorite in lath-shaped crystals is the most clearly defined ingredient; the augite is in unusually-lengthened crystals, in fact its crystals are almost as lath-shaped as those of the felspar; it is much fissured, and of a reddish-yellow tint; there is some calcite, and but little of either glass or magnetite.

Where the basalt of the dyke has narrowed down to 7 inches or less in width, its structure and its appearance are entirely altered. This alteration is progressive through three stages. In the first of these it has assumed the colour and much of the lustre of cobbler's wax, but the lens shows the colour to be unequal in intensity, and that this inequality is due to darker bands which consist of belts of contiguous, or for the most part contiguous, spheres; these have a stellar or internally-radiating structure. As the divergent rays penetrate to different extents into the magma, the term *stellar* would define this variety of basalt fully better than *spherulitic*. At the same time it has to be noted that, where these darker subcrystalline groups occur so frequently or closely as to impinge upon each other, the usual straight lines of arrested growth appear. The sections of these concretionary arrangements do not disclose a definite crystalline radiation, but one like what would be assumed by a multiplicity of tapering feathers,—as of those from the neck of a cock—tied into a ball, and viewed in section: a feather of darker tint showing broad and flat at one point and tapering to nothing at others where presented edgeways. This greater darkness along certain lines and in certain spots may be due either, wholly or partly, to difference of material, or only to difference of position. There is no definiteness of crystalline form to guide; and the polariscope merely deepens

the general tint, and upon revolution displays the dark cross without any alteration of tint at any part. The only other structure disclosed is an occasional concentric banding near the centres of the groups. To say that the darker feather or blade is probably mainly augite, and that the paler is mainly labradorite, is to introduce unwarranted guessing.*

Another stage in the alteration of structure is to be seen where, in a narrower part of the vein, the darker material predominates, while the lighter has, by comparison at least, paled in colour. Here the latter has definitely segregated apart either in distinct spherulites, or in spherulites which have played the part of nuclei to the growth of the forementioned feathered structure. These spherules, which have by a powerful transmitted light a fawn colour, have a well-developed radiating acicular growth in their peripheral portions, but their more central substance shows a confused acicular arrangement of spicules very similar to the willow-leaf structure displayed in sun-spots. Some portions of the slides show these spicules to be definite, acicular, lath-shaped crystals, free from any yellow stain, and shining up clear and colourless. They obscure at about the same angle as does labradorite. These spherules are surrounded by a clearer and somewhat yellower zone, which looks like glass, but does not act on light as such. Through this clearer zone the divergent radiations of the central spherule pass to enter into the general dark substance, which here consists of a congeries of rayed spherules which come into mutual flattening contact with one another throughout.

The third and complete stage of departure from the structure normal to basalt is that of the tachylyte itself. This is a compact, umber-brown, perfectly isotropic, glass; but it carries numbers of paler spheres with radiating acicular structure, which brilliantly display the cross, with also a concomitant darkening and paling of alternating crystalline rays, upon revolution of the beam of light.

In all three stages of this structure, perlitic fracture is abundant and open; and throughout it all, indifferently in position, minute spheres of chalcedony giving the dark cross are occasionally seen. Rarely these have a centre of quartz, and frequently they are surrounded by a pale zone. They do not act as centres to the diverging clusters of acicular crystallisations.

* See the lower figure in Plate III.

The rich brown of the tachylyte glass and of the rock throughout certainly so far encourages the belief that the opacity is due to separated magnetite.

It has in the foregoing remarks been stated that at the date at which the author made his analysis of the tachylyte of the Quiraing, he conceived it to be that portion of the lava-flow which had been solidified by coming into contact with the cold surfaces of pre-existent rock. This actual solidification *in situ* as glass seems, both before and since, to have been invariably the accepted explanation of its occurrence.

Geikie * writes—"In many examples the fineness of grain of the outer band culminates in a perfect volcanic glass. The glass doubtless represents the original condition of the rock of the dyke. It was suddenly chilled and solidified by contact with the walls of the fissure."

Professor Bonney writes—"The name of tachylyte has been applied to varieties where the material remains in the form of glass."

Professor Judd says †—"These dolerites in turn passing into basalts which when suddenly cooled assume the form of tachylyte or basalt glass. The differences between gabbro and tachylyte on the one hand, and between granite and obsidian upon the other, are not to be accounted for by a difference in geologic age, but are a consequence of the different conditions under which the rocks have solidified;" and further on—"in situations where very rapid cooling has evidently taken place, basalt-glass has been formed."

Mr. W. Muir considers that where the glass occurred the dykes could not have run for long.

Professors A. Geikie and Bonney, it will be seen in the above, and in the context of the quotations, put it that the glass when suddenly cooled has remained in its original condition; and when slowly cooled has assumed the more and more coarsely crystalline conditions of basalt, dolerite, and gabbro. Judd, again, puts it that basalt *assumes* the form of glass. There can, however, be little doubt that in the latter case the apparent difference of view is due to a less happy precision of expression. All, however, seem to consider that there has been *immediate contact-solidification*.

* *Transactions Royal Society Edin.*, vol. xxxv., pt. 1, page 35.

† *Quarterly Journal Geological Society*, vol. xlii., page 50.

*One of the above-mentioned balls of the Loch Screden dyke unmistakably disproves this.**

Its section shows a selvage of blue-black tachylyte about a fourth part of an inch in thickness. The central portions of the ball are made up of stellar concretions of basalt; towards the sides these are arranged in bands which consist of a series of these stellar spheres disposed in a single line or layer, looking in section like the links of a chain. From one of the selvages of tachylyte there projects downwards and then forwards, *i.e.*, in the direction of the flow in the rent, a process or tongue of the tachylyte, some inches in length. This process has the peculiar hooked form of the Bill of Portland. The bands of stellar arrangement are folded over this process, in conformity with its outline; and, in the bay or circular recess formed by its hooked extremity, there is clearly delineated the whirls of an eddy of the still liquid basalt (Plate III.). The tachylyte has here manifestly been dragged forward, *in a condition of plasticity, if not of fluidity*, while the flow of the more central portions was still continuing.

Two of the conclusions of Professor Judd's paper, which I desire to pass under review, are these. First, that crystals may be dissolved by their magma *under a relief of pressure*;—and second, that the cavernous condition of many porphyritically-disposed crystals results from their having been attacked and dissolved by the glass or magma which envelopes them. From the first of these I entirely dissent. The second, I think, is to be accepted in *not* the greatest number of cases, and is a subject which calls for special research.

Professor Judd enunciates the first of the above in the following words:—"The facts described point to the conclusion that crystals formed under great pressure in the midst of a fused magma may, on the relief of that pressure, be attacked and dissolved by the magma in which they were originally developed." Now this is not only exceedingly repugnant to all chemical teaching, but it is in direct antagonism to all experimental experience. The compositions and decompositions, solutions and resolutions, in Nature's laboratory, so far as we know of them, are elaborated in precise conformity with all the laws which guide us in the operations

* This ball is now deposited in "the Scottish Collection of Minerals" in the Edinburgh Museum of Science and Art.

FLUIDITY OF TACHYLYTE SELVAGE.

SECTION OF STELLAR BASALT.

of our laboratories : and it is our invariable practice, in bringing about solutions and decompositions of substances which offer unusual resistance to ordinary reagents, to seal them up in tubes of glass or iron, and subject them to increased pressure and to high temperatures. But here it is propounded that these crystals were attacked when the pressure is relieved, and the heat is departing ! The above inference or contention is all the more extraordinary from the fact that Professor Judd in his paper on the "Older Peridotites of Scotland," over and over again insists upon *increase* of pressure augmenting solvent power ; he speaks of it as "a well-known physical law" ; and refers to the researches of Daubree, Sorby, Guthrie and others, as "placing the fact beyond all doubt !" He also makes it one of the postulates of his "Theory of schillerisation."

With regard to crystals being attacked and dissolved by the glass or magma in which they lie ("have been caught up" is so far theory), I should not be prepared to offer so emphatic a dissent, though it is to be remarked that a caveat was entered, both by Mr. Teale and by Mr. Bauermann, as to this when Professor Judd's paper was read.

The "solution" of a crystal of definite composition by a molten magma of less definite composition in a rock, cannot be regarded as an example of ordinary physical or adhesion-solution, but as a chemical decomposition. And so the object aimed at, so to speak, is the formation of a new compound in the magma. And this compound would be possessed of a definite form which would disclose itself certainly to the polariscope, and even probably to the microscope. Now, inasmuch as certain of these so-called dissolved crystals are surrounded on all their margins (whether they show flat crystalline faces, or re-entering hollowed out bays), by a fibrous crystalline fringe, which radiates from these surfaces, it may be held that this fringe did not consist of any portion or ingredient of the magma, crystallising round the large crystal as a nucleus, but consisted of a substance formed by the union of the magma, or a certain portion thereof, with the dissolved outer layer of the crystal.

But where does such a contention land us, except in this—that as this fringe is a proof of attack and new formation, there can have been no attack—*i.e.*, "solution"—if the new formation is

not made manifest: and in far the greater number of cases *no* such crystalline fringe and *no* alteration in polarisation-appearances is visible in proximity to the margin of so-called “dissolved crystals.” It is certainly to be regretted that those who advocate solution of these crystals had not submitted analysis of the glass and magma, so as to demonstrate that its composition conferred upon it the solvent power claimed, and had not at the same time submitted some tangible proof of its alteration after it had exerted the solvent power claimed.

The most common of all the appearances of these “dissolved crystals” is, however, perfectly inexplicable to the writer, under the known laws of either physical or chemical solution. All who make rock-sections their study must be familiar in these “dissolved crystals” with the deep and sinuous channels which insculcate in their *terra firma*, and the deeply indenting bays with narrow entrances, which sectioning *in three directions* shows to exist.

Now, in the cases both of physical and chemical solution, the nearer the action approaches to saturation the slower is the action, and the less is dissolved. But here it must be the opposite. The bulk of the liquid is free to act upon the outside, and currents would there carry away the solution so formed, and allow the access of another quantity of the solvent; but not so with the

Fig. 1.

portion embayed. It is evident that solution is going on much more speedily here: both the deep penetration and the widening out within the entrance vouch for a far greater amount of removal of the solid. More is removed and faster. A new supply of solvent must be reduced to a minimum—diffusion alone can bring it in, as there can be no currents. With the quantity embayed—as with Hamlet's mother—“increase of appetite must have grown by what it fed on.” (See fig. 1.)

It would certainly seem to be a more probable view that some portion of the glass was simply caught up during the crystal formation.

The whole subject is obscure and calls for special research, and that in connection with what are called "negative crystals," for the one subject must bear upon the other. This name,—“negative crystals,”—is a most unfortunate one, for it is at the same time both misleading and inadmissible. It is applied to certain hollows or spaces in the body or mass of otherwise-solid crystals, which spaces, it is held, were originally vacuous, or filled with vapour or liquid, and have probably been subsequently filled more or less completely with certain products of decomposition—said products having, according as it suits theory, either been force-pumped through the solid substance of the crystal from without; or certain constituents have been force-pumped out of the substance of the crystal, by a process of selective decomposition unknown to chemists, but perfectly simple and altogether above the necessity of explanation to theoretic geologists.

In the term “negative crystals” negative is an adjective, and crystal is a substantive. The adjective qualifies the substantive. But a crystal is more than a substantive, it is a substance: and it is a substance with so definite a composition and so regular an arrangement of its parts as to possess a regular geometric form, which with flat faces and salient angles incloses that substance; which has definite lines of cleavage, a definite action on light, varying in different directions, and a hardness which varies also in different directions. *No one of which properties of crystals do these so-called “crystals” possess!*

Moreover, in the sense in which it is proposed to use the adjective here, its opposite “positive” has never been applied. But while that has not been so applied, the *whole term* has for long, and that for the purpose of defining certain properties of crystals of the highest importance in the science of optics, and in mineralogy. In *this* application the term “holds the field,” so that its application in any other sense is inadmissible. The things intended to be defined are hollows in the crystal, with boundaries which, in accordance with the crystallographic arrangement of the molecules, have flat sides *accordant with external faces of the crystal-form of the substance itself*. It has been attempted

to be made out that the hollows were formed by some mysterious agent (not condescended on) of the force-pump process; but every one engaged in the formation of regular crystalline forms is familiar with the difficulty of making, even in circumstances of no undue pressure, artificial crystals which do not contain such hollows generally holding some of the mother-liquid with all its alien solutions.

If these hollows be plugged with any solid substance, as that substance must have taken a cast of the crystal sides, it is an *endomorph*; and as in all probability an isomorphous substance would not take such a cast, but would crystallographically associate itself in or with the including crystal-substance, the plugging substance must be a *pseudomorph*. Those who desiderate correct names might be satisfied with *pseud-endomorph*, which tells that they are not imbedded crystals: the word is shorter than “negative crystals,” apart from the argument that the latter term is in all respects objectionable.

In stating above that during the artificial formation of crystals in the laboratory, there frequently occur in them vacuities of definite form with flat sides, which bear an evident relation to the crystalline form of the salt itself, there has come before us one of the objections, so far as recognised knowledge or experiment permits us to speak, to the theory that similar vacuities have been formed in nature in any *less* simple manner (as by any agent acting from without).

Every agent which produces change of form or alteration of structure in a physical existence, or alteration of chemical arrangement, or decomposition—which is the loosening of pre-existent arrangement and combination in a chemical compound—must act *along the lines of weakness present in all crystalline structures*.

Our present tabulation of these lines of weakness or “Structure Planes,” as they are termed, is (as shewn in figure 2 on the next page):—

Fig. 2.

1st. *The direction of molecular instability*, or “gliding plane”; along which direct pressure permits of a sliding of the molecules over one another, and by the polar revolution of one or more layers of molecules produces twin laminæ of excessive tenuity.

2nd. *The direction of cohesive weakness*, or “cleavage plane”; along which the crystal rends when a disruptive force is applied at certain sides and in certain directions.

3rd. *The direction of chemical weakness*, or “solution plane”; along which water or other solvent acts in preference to, and with greater rapidity than along others.

And our present knowledge of these goes only so far as to show that they lie in different directions*—the first truncating the terminal edges of the form delineated by the second; and the second truncating the terminal edges of the form delineated by the third. These directions of weakness give rise to the faces in calcite, *e*, *r*, and *f*, whose relation to each other in position is shown in the figure. This being so, great difficulty lies in conceiving how any agent of solution could force its way into a crystal to *abstract* portions thereof *locally*, and in a series of spots,—so forming the vacuities,—without at the same time

* In substances of facile cleavage,—as baryte—water holding dust in suspension occasionally is by capillarity drawn into the cleavages, and so simulates a solution plane,

disclosing the path of its entrance by a similar action; and still more, without, in accordance with the ordinary and recognised law of action of solvents, operating along the plane of chemical weakness.

Now, in an admirable paper* Professor Judd himself shows that "felspar" of an olivine gabbro, at Coruisk, contains those enclosures lying not in *one* but in *five* different directions. These directions he states to be parallel to the two pinacoid faces, the two prismatic faces, and to the basal face; all of which faces, be it observed, are usually-occurring crystal-faces of the species. It certainly then would seem to be the most direct conjecture that these pseud-endomorphs *were deposited upon its faces during the growth of the crystal*.

Professor Judd, however, takes an entirely different view. The occurrence of vacuities of various forms upon the faces of crystals during their growth is established both by observation and experiment: of the structure-planes of crystals, the first has been established by experiment; the second by experiment; and the third by observation, if not also by experiment. But these established facts do not suffice to bear out Professor Judd's view, for he writes,—“I have long felt that it is impossible to account for the characteristics presented by the minerals of deep-seated rock-masses without assuming the truth of the above postulates.” The “above postulates,” four in number, are the basis of his “Theory of schillerisation.” For this the recognised structure laws *do not suffice*, and of his adopted postulates three are hypothetical, though certain somewhat obscure facts are adduced which are held to support them.

Professor Judd writes,† “although the planes of cleavage, of gliding, and of susceptibility to chemical action in a crystal are all *distinct from one another*, yet in most, if not in all crystals there appear to be certain curious and very interesting relations between them.” Further on we find that these “relations seem to indicate the mutual interchangeability of the cleavage planes and the gliding planes. That a remarkable relation also exists between the third set of structure-planes—the solution-planes—and the gliding-planes, seems to me to be indicated by

* *Quart. Jour. Geol. Soc.*, vol. xli., page 412.

† *Mineralogical Magazine*, vol. vii., page 82.

my study of some of the rock-forming minerals in deep-seated masses." But what of *distinctness* from one another does this bear, or evidence? A "relation" which amounts to "mutual interchangeability" hardly leaves enough of "distinctness" to be of use to science!

But more indefiniteness of position follows, for we find, first, that twin-planes "become" planes of solubility; second, that pressure develops a second and then a third solution-plane; third, that sometimes one sometimes another of these is the "easiest"—easier even than the normal solution-plane; and lastly, that such planes "arise parallel to the directions along which strain is directed." Thus they may lie in *every* direction! All this is little else than the shuffling of certainty into uncertainty.

But any residual definiteness of known or discoverable position of the solution-plane is altogether done away with in considering the chemical processes by means of which these "eaten-out" hollows are regarded as having been filled; for Professor Judd writes—"It is probable that under the enormous pressures which exist at great depths in the earth's crust, *the whole substance* of such crystals is permeated by fluid and gaseous material, capable of exercising a chemical action on the materials through which they pass"; in so passing these fluids are supposed to dissolve out ferric oxide, sometimes depositing it in the "negative crystals" of the mineral which yielded it, but sometimes carrying it off and "depositing it in those of labradorite."

It is not only inexplicable to chemistry, but open to chemical doubt that a solvent should, *without interfering with the composition of a crystal in other respects*, be able to extract protoxide of iron and precipitate it as peroxide *in shut cavities*. What of the silica which was in combination with the iron protoxide; would its precipitation as a residue in the crystal not render the latter altogether opaque?

On the other hand, it is a fact, familiar to all chemists, that substances alien to the composition of a crystallising body should be *extruded from its molecules*, and be deposited in layers, or sprinkled upon its faces during its growth. This fact is equally familiar to mineralogists, being specially well seen in the "capping" of quartz, of calcite, and indeed of many crystals. If not the explanation which meets all cases, this at least is not one which jumbles up the known with the merely speculative.

That water and probably more powerful solvents permeate *rocks* is clearly shown by the formation of agates, and by the deposition of saponite, calcite, and other decomposition-products between, or among, the component crystals of a rock ; but that such solvents pass between the opposed contact-surfaces of the component crystals of the rock,—dissolving thin layers from off the said surfaces,—is surely more probable than that they burrowed to the interiors and left the surfaces unaffected. It has been maintained that many of the so-called examples of schillerisation are in truth instances of the effects of mere ordinary weathering—a somewhat bronzy lustre and darker colour being produced by surface-peroxidation of the protoxide of iron of the unaltered mineral.

Three of the best cases of schillerisation known in Scotland I have by analysis determined to be due to this chemical alteration. These are—the diallage of the Cuchullin Hills in Skye ; the so-called “bronzite” of Balhammie Hill in Ayrshire ; and the schiller-spar of Belhelvie in Aberdeenshire.

The diallage of Cuchullin, which is, when fresh, dark green and of moderately high lustre, has on its outer surface a thin skin of a brown tint, and a lustre approaching to that of paulite,—for which mineral it was for long taken. When sections of the two portions are examined, they are found to exhibit no difference in structure ; but there has been peroxidation in the crust.

The blocks of the “bronzite” of Balhammie, when broken up, display the lustrous crystals of paler and paler *green* tint the further they are removed from the surface. Analysis shows these crystals to be serpentine-pseudomorphs after enstatite ; there being peroxide of iron in the superficial crystals, but none in the deep-seated ones.

The schiller-spar of the Black Dog Rock, and of the Belhelvie Hills, is the only true enstatite schiller-spar in Scotland. At the Black Dog Rock, where the outer layer is always subject to sand-friction, the mineral is grass green ; while the exposed crystals seen at the quarries on the west side of the Belhelvie range appear as bronzy buttons. The same is seen in the pseudo-enstatite crystals which stud serpentine at many other localities, there being no structural alteration in any.