On the Processes by which a Plagioclase Felspar is converted into a Scapolite.

(With a Plate.)

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FEW mineralogical problems are of greater interest at the present time than those connected with the metamorphism of rocks. We are called upon to determine the exact series of processes by which a rock, having a particular texture and consisting of certain mineral species, is converted into a totally dissimilar rock, possessing, not only a different structure, but a distinct mineralogical constitution.

No example of the kind offers a better opportunity for studies of the class to which I refer than the celebrated "apatitbringer," or hornblende-scapolite-rock of Oedegaarden, near Bamle, in Norway. Many observations in the field go to prove that a pyroxene-felspar-rock has in this case been converted into a hornblende-scapolite-rock; and the beautiful experimental investigations of MM. Fouqué and Michel-Lévy have shown that, by fusion and slow cooling, the hornblende-scapolite-rock is, in turn, converted back again into a felspar-pyroxene-rock.

By the kindness of a friend and former pupil, Mr. Eger, who is the Director of the celebrated Apatite Mines of Oedegaarden, near Bamle, in Southern Norway, I have had placed at my disposal an interesting series of specimens, which has enabled me to carry out the investigations described in the following paper.

Attention was first called to the remarkable rock of Oedegaarden by Brögger and Reusch in 1875;[1] these authors styling the rock a "gefleckter gabbro." The rock was also described in 1877 by H. Möhl.[2] In 1878 Lang expressed a suspicion that the rock contained a mineral of the Scapolite group,[3] and in the same year the presence of Scapolite was fully demonstrated by Michel-Lévy.[4]

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[1] *Zeitschr. d. deutsch. geol. Gesellsch.* Vol. XXVII. p. 749.

[2] *Nyt. Magazin for Naturwidenskaberne.* Bd. XXIII. (1877) pp. 75-77, T. II. Fig. 4.

[3] *Zeitschr. d. deutsch. geol. Gesellsch.* Vol. XXXI. p. 503.

[4] *Bull. Soc. Min. Fr.* 1878, pp. 43-46, 79-81. See also Fouqué and Michel-Lévy, *Minéralogie Micrographique* (1879). Plate XXXVII. fig. 1.

In the following year (1879) MM. Fouqué and Michel-Lévy made the important announcement that, by fusing the hornblende-scapolite-rock of Oedegaarden with a trace of sodic fluoride, they had succeeded in producing a rock composed of pyroxene and labradorite.[1]

In 1883 Sjögren gave some additional details concerning the mode of occurrence and association of the rocks of the district, all of which pointed to the conclusion that the hornblende-scapolite-rock had resulted from the metamorphism of a pyroxene-felspar-rock.[2]

Many examples of the occurrence of scapolite in the crystalline schists have been described by Becke, Törnebohm, Dathe, Wulf, Mügge and others; and Svedmark has described a rock from Orebrö, in Sweden, having a very similar mineralogical constitution to the Oedegaarden rock;[3] while still more recently Lacroix and Baret have given an account of a pyroxene-hornblende-scapolite-rock from Point-du-Jour, near St. Nazaire, in France.[4]

At the meeting of the British Association at Montreal in 1884, Mr. F. D. Adams announced the existence of scapolite-rocks in Canada, where, however, a connection with the important Apatite-deposits of that country does not as yet seem to have been proved.[5]

In 1887 Dr. A. P. Coleman showed in his study of the Petrography of the Drift of Central Ontario that masses of scapolite-diorite-schist occur as erratic blocks in that district.[6]

Quite recently, Mr. F. D. Adams and Dr. Andrew C. Lawson have given an admirable account of the chief characteristics of the scapolite-bearing rocks in Canada; and in the sequel I shall have to refer to some very suggestive observations which they have made upon the subject.[7]

In the year 1879 Mr. F. D. Adams made the important discovery that the scapolites, as a rule, contain chlorine, though in very variable proportions.[8]

Subsequent analyses have fully confirmed this interesting conclusion; and in 1883 Tschermak, in his important monograph on "Die Skapo-

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[1] *Bull. Soc. Min. Fr.* Vol. II. 1879, p. 113.

[2] *Geol. Fören. i Stockholm Föhr.* Bd. VI. (1883) pp. 447-498.

[3] *Geol. Fören. i Stock. Förh.* VII. p. 293.

[4] *Bull. Soc. Min. Fr.* Tome X. (1887) p. 288.

[5] *Brit. Ass. R.* 1884 (Montreal), Proc. of Sect. p. 717.

[6] *Trans. Roy. Soc. Canada.* Vol. V. (1867), Sect. 3, p. 55.

[7] *Canadian Record of Science.* Vol. III. (1888), p. 185.

[8] *Am. Journ. of Sc.* 3rd Ser. Vol. XVII. (1879) pp. 315-320.

lithreihe,"[1] has shown that it is only possible to explain the remarkably discrepant results obtained by the analysis of different members of the group by assuming that the scapolites—like the felspars—must consist of mixtures, in varying proportions, of two isomorphous molecules. The Meionite molecule, as defined by Tschermak, is a basic lime-alumina silicate, and the Marialite molecule is an acid soda-alumina silicate combined with a definite proportion of sodic chloride.

In spite of the protests of Rammelsberg,[2] this view of Tschermak concerning the constitution of the scapolites has steadily gained ground, and now seems to be very generally accepted by mineralogists.

With respect to the nature of the scapolite in the interesting rock of Oedegaarden, it may be sufficient to cite the following analyses:—

	A.	B.
Silica	59·66	54·00
Alumina...	22·65	24·13
Lime	7·32	7·89
Magnesia	2·60	0·95
Soda	8·13	11·81
Potash	feeble traces	—
Phosphorus	sensible traces	—
Loss by Calcination ...	—	1·22
	100·36	100·00

A is an analysis by M. Michel-Lévy of material which had lost volatile matter by fusion, the exact amount not being ascertained, but being certainly less than 2 per cent. By long ignition the mineral was found to lose from 2 to 2·2 per cent.

B is an analysis by M. Wenghell, of the University of Christiania.

As the oxygen ratios of the mineral are 1 : 2 : 6, both MM. Michel-Lévy and Sjögren are inclined to group this scapolite with the dipyres.

By a comparison of the analyses of this and similar dipyres with those of a felspar between labradorite and andesine, it will be seen that the main chemical change required to convert the latter into the former is the introduction of a certain proportion of sodium and chlorine. I propose to show how the introduction of these elements has been effected in the case in question.

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[1] *Sitzb. d. k. Akad. d. Wissensch. zu Wien.* Bd. 88. I. Abth. (1883) p. 1142.

[2] *Zeitschr. d. deutsch. geol. Gesellsch.* Bd. XXXVI. (1884) p. 120. *Neues Jahrb. für Min. &c.* Bd. II. (1884) p. 67.

The study of a number of slices cut from the series of specimens supplied to me by Mr. Eger, shows that in some cases portions of crystals of felspar—probably the centres of large porphyritic individuals—remain tolerably unaltered in the midst of the rock; while in other cases every phase of the change from felspar to scapolite may be followed step by step.

The felspar, where freshest, presents all the optical characters of a plagioclase; and exhibits repeated twinning, both on the albite and pericline types (Plate IX. Fig. 1). But when viewed by ordinary light the crystals of felspar are seen to present a somewhat dark tint (Plate IX. Fig. 2), and with high powers the cause of this peculiarity becomes at once apparent. It is evidently due to a vast number of minute enclosures within the felspar-crystals (Plate IX. Figs. 3, 4).

A careful study of these enclosures with high powers shows that they are liquid-cavities containing bubbles, and these cavities are found to be crowded together in such enormous numbers, that in some cases they must bear a very considerable proportion to the volume of the mineral in which they are included. These cavities are of especial interest on three grounds.

First. Their distribution in the crystal has clearly been determined by a pre-existent twin-structure in the crystals in which they are developed. This is shown by the fact that wherever any of the lamellæ of either the albite- or pericline-twins appear, their place in the crystal is exactly indicated by great numbers of liquid cavities arranged along the planes which bound the lamellæ. (Compare Figs. 1 and 2, Plate IX.)

If the crystal be viewed alternately by ordinary and by polarised light, it will be seen that these planes marked by crowds of liquid-cavities *map out very exactly* the twin-lamellation of the crystal. Where one of the twin-lamellæ is interrupted or dies out, there a similar break in the continuity of the sheets of liquid-cavities can be made out. There cannot be any doubt that where twin-planes have been developed in the felspar-crystal these have become planes of chemical weakness or instability, and along these solution of the substance of the crystal has taken place, leading to the formation of cavities filled with the solvent.[1] In just the same way I have shown that the kaolinisation of felspars may take place along the planes produced by secondary-twinning of a felspar.[2] The kaolinisation of felspars along certain planes has often been asserted to be due to the solvent action following planes of cleavage. But it is only necessary to examine certain sections by ordinary and by polarised light to see that the

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[1] Compare the case of Calcite described in *Min. Mag.* Vol. VII. (1887), p. 87.

[2] *Loc. cit.* p. 89.

partial, interrupted and bent lamellation in a plagioclase felspar is—as in the case now described—exactly mapped out by the bands along which kaolinisation has taken place. (See Plate IX. Figs. 6 and 7.)

Secondly. While the cavities arranged along these planes differ greatly in form and size, there is a very general disposition among them to assume forms bounded by planes, thus constituting negative crystals. In these cases, the broadest and best-developed planes of the negative crystals are usually parallel to those in which the cavities lie—the solution planes. There is thus the closest analogy between these negative crystals in the felspar of the Oedegaarden-rock and those which are formed in the avanturine varieties of a labradorite-felspar which I described on a previous occasion.[1]

Thirdly.—In some of the largest cavities it can be perceived that, besides the bubble, there are crystals floating about in the liquid, and in certain cases these crystals can be seen to be of cubical form. That the liquids in these cavities are supersaturated solutions of the alkaline chlorides is thus shown to be in the highest degree probable; and this probability has been converted into certainty by the following experiment:—Portions of a specimen of the rock, containing these felspar-crystals with inclusions were, after careful washing with distilled water, crushed in an agate mortar and lixiviated; the presence of chlorides in the liquid thus obtained was at once shown on adding silver-nitrate.

In their interesting study of the Canadian scapolite-rocks already referred to,[2] Messrs. Adams and Lawson direct attention to three very important features, which I have also found to be equally exhibited in the Norwegian rock.

First.—Some of the grains of scapolite show traces of a lamellar twinning like that of the felspar-crystals from which they are derived,[3] though the extinction was found to be much less distinct than in the felspar.

Secondly.—In many of the grains of scapolite numerous enclosures arranged in parallel bands occur.

Thirdly.—While some of the grains of scapolite exhibit the strong double refraction characteristic of that mineral, and polarise in brilliant

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[1] *Min. Mag.* Vol. VII. (1886), pp. 85-87. Plate III. fig. 3. See also Vogelsang in *Archives Néerlandaises.* Vol. II. (1868).

[2] *The Canadian Record of Science* 1889.

[3] *Loc. cit.* p. 193.

[4] *Loc. cit.* p. 194.

tints, others lying side by side with them display only low polarisation tints, little more pronounced, indeed, than those of felspar. That the difference is not due to thickness is shown by the fact that grains with strong and weak double refraction are seen lying side by side in the same section.[1]

The authors very justly insist on the support afforded by these phenomena to the conclusion that the scapolite has been produced by the alteration of a plagioclase-felspar, and that in some cases the change is incomplete.

The study of the Norwegian rock proves, I think conclusively, not only that this is the case, but enables us to realise the several stages of the process by which the transformation from one mineral species to another is effected.

In the least altered felspar-crystals the partial and irregular distribution of the lamellar twinning may be noticed, and is strongly suggestive of its having been developed by mechanical forces. The development of cavities, many of them of the nature of negative crystals, disposed along the gliding planes, is clearly due to the fact that these twin-planes have become planes of chemical weakness. If dark-coloured, secondary products had been deposited in these negative crystals and other cavities, then a perfect "schiller" structure would have been developed like that characteristic of diallage, bronzite, and certain felspars.

That the solvent—which, under statical pressure, permeated the whole substance of the felspar-crystals and attacked them in their planes of chemical weakness—was a solution containing sodic chloride we have the clearest proof; and the problem which remains to be considered is the nature and origin of the chemical reactions by which the sodic chloride in the cavities became combined with the silicates of the felspar in which they were enclosed, so as to give rise to the formation of a scapolite.

In some cases I have found large crystals of felspar, with numerous liquid cavities developed in them, the outer portions of which have been converted into scapolite granules. Some of these granules have the characteristic double refraction of scapolite; but in other cases, while all the other optical properties are those of scapolite, the polarisation tints are but little higher than those of the adjoining felspar.[2] In a few instances but little granulation has accompanied the formation of the scapolite—

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[1] *Loc. cit.* p. 193.

[2] It is worthy of note that MM. Michel Lévy and Lacroix have found that there are great variations both in the refraction and double refraction of the different mixtures of the meionite and marialite molecules (*Les Minéraux des Roches* 1888, p. 293).

which in these cases forms broad crystalline masses replacing parts of the felspar-crystals.

In not a few cases we find the outside of the secondary granules of scapolite quite free from enclosures, while in the middle of them there are many liquid cavities, evidently those belonging to the original felspars. (See Plate IX. Fig. 5.) It is worthy of notice that the polarisation tints of the outer portions of these grains, where all trace of the cavities has disappeared, is markedly higher than those of the interior portions where the cavities still exist. The complete conversion of the felspar into scapolite appears to be attended with the disappearance of the liquid cavities.

In many cases grains, which must be referred to scapolite, exhibit more or less distinct traces of the twinning of the original felspar; that this is the true interpretation of the phenomenon is proved by the fact that in the Oedegaarden rock the traces of twin-lamellæ in the peripheral scapolite granules can be seen to be *actually continuous with or parallel to* those in the unaltered central mass of felspar. (See Plate IX. Fig. 1.)

With all these facts before us, I think that it is impossible to doubt that the formation of the scapolite-molecules at the expense of those of felspar by the addition of the sodic chloride, is one that goes on progressively in the crystals, and that we have crystalline particles in the rock which consist in varying proportions of the felspar- and the scapolite-molecules.

In his interesting investigations upon Tabasheer, Sir David Brewster long ago showed that it was possible to have such an intimate admixture of colloid silica and of air, that the resulting material possesses an index of refraction intermediate between those of the two substances in question.[1] The study of the mineral constituents of rocks often affords similar illustrations of the ultramicroscopical admixture of substances with different optical properties.

In the paramorphic and pseudomorphic changes which take place in the minerals of rocks we find many beautiful illustrations of the same kind. Tschermak's valuable researches on the felspars, the scapolites, the pyroxenes, the amphiboles and other groups of minerals have shown the possibility of the existence, with the same crystalline form, of mixtures in very varying proportions of two or more molecules of different chemical constitution. The gradual conversion of pyroxenes into amphiboles, by the process of uralitisation, and the development of certain minerals at the expense of others, during contact metamorphism, may

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[1] *Phil. Trans.* Vol. CIX. (1819), p. 283; and *Edinb. Journ. of Science*, Vol. VIII. 1828), p. 335.

prepare us for examples of the transformation of one species of mineral into another, by the progressive change of its component molecules.

We now come to the question of the *cause* of the breaking up of the felspar-molecules, and the formation from them and the sodic chloride of the scapolite-molecules.

The scapolite-rock of Oedegaarden exhibits, in hand specimens, but little evidence of distinct foliation. That it has been subjected to a certain amount of internal movement is, however, indicated by the granular character which it assumes. I have already shown that crystals of augite in ophitic dolerites become broken up into rounded granules when the rocks in which they were being found were subjected to internal movements during crystallisation; and that the rocks thus assume the granulitic structure;[1] and this observation has been confirmed by Dr. Hatch.[2]

All the evidence with respect to the Oedegaarden rock points to the conclusion that, after the felspar-crystals had become charged, along their solution-planes, with cavities containing sodic chloride the effect of internal stresses in the rock-mass was to bring about those chemical reactions by which the felspar-molecules were broken up and their materials became united with the sodic chloride to form scapolite. I find additional evidence of the action of dynamometamorphism in the gabbros of the same district, where the scapolite-rock is developed. In these gabbros the constituent minerals are all found to be surrounded by concentric zones of various secondary minerals—like those of the "flaser gabbros"—and the results of the dynamometamorphic action in these rocks appear to be worthy of very careful study. Most of the occurrences of scapolite, which have been described, are in rocks of gneissic character.

The scapolite which is found in the specimens of the Oedegaarden rock where the felspar has not altogether disappeared, is sometimes remarkable for its freshness and its almost perfectly unaltered character. One of the most striking features it not unfrequently presents is the total absence of cleavage-cracks. This character, with its wonderful clearness and fresh appearance, gives it a most deceptive resemblance to quartz. I suspect that, on account of this resemblance of the two minerals, scapolite has often been overlooked in rocks where it occurs. While the presence of characteristic cleavage-cracks is a valuable means of diagnosis in the hands of the petrographer, their absence is a character upon which we ought always to hesitate to found conclusions. Many highly cleavable minerals may, under

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[1] *Quart. Journ. Geol. Soc.* Vol. XLII. (1886), p. 76.

[2] *Trans. Roy. Soc. Edinb.* Vol. XXXV. (1883), Part 2, p. 104.

certain circumstances, fail to show the accidental cleavage-cracks upon which we ordinarily depend in our rock-sections.

It is very interesting to note that the other principal constituent of the Oedegaarden rock—the pyroxene—can be shown, during its conversion into hornblende, to have gone through a precisely parallel series of changes to those which the felspar was subjected to in passing into scapolite.

The original pyroxene of the rock appears, from portions which remain unaltered in some of the specimens, to have been a nearly colourless variety. The straight extinction, the pleochroism and the feeble double refraction of all the specimens I have been able to examine indicates that it was a rhombic pyroxene or enstatite. In almost all cases, however, the development of enclosures parallel to a pinacoidal plane has converted it into a schillerized variety—in this case bronzite.

This pale coloured bronzite is in places found acquiring the characteristic colour, pleochroism and absorption of a brown hornblende; but in these cases this pleochroism and absorption are decidedly feeble, and it is worthy of notice that the characteristic bands of enclosures belonging to the bronzite remain; nevertheless, though the cleavage still appears to be that of a pyroxene rather than of a hornblende, the extinction and double refraction are unmistakably those of an amphibole.

In the conversion of the enstatite into hornblende, the relations of the orthorhombic and monoclinic crystals are the same as is found in the intergrowths of orthorhombic and monoclinic pyroxenes; the central portion of the crystal consisting of enstatite has its macropinacoid (100) parallel to the clinopinacoid (010) of the zone of secondary hornblende which surrounds it.

In the case of many other rocks, I have met with examples of a pyroxene which has acquired the colour and pleochroism of a hornblende while retaining some of its original characteristics.

Thus in an ophitic dolerite from the Shiant Isles, and in a dolerite from a dyke at Assynt, I have found pyroxene-crystals which retain the cleavage and extinction of that mineral, but which are seen to acquire progressively, as we approach their edges, the characteristic colour, pleochroism and absorption of a brown hornblende. The pyroxenes of the rock of Penmaenmawr which, when unaltered, were shown by Rosenbusch to be a somewhat ferriferous enstatite,[1] acquire by alteration, as was noticed by the late John Arthur Phillips,[2] the characteristic colour, pleo-

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[1] *Massige Gesteine*, 1st Ed. (1887), p. 352.

[2] *Quart. Journ. Geol. Soc.* Vol. XXXIII. (1877), p. 423.

chroism and absorption of hornblende, while retaining the orthorhombic extinction. The same is true of the pyroxenes of the Eycott-Hill rock, and many similar cases might be mentioned.

The last stage of the change of the pyroxene in the Oedegaarden rock is witnessed in the case of certain crystals which, around their edges and in irregular patches in their midst, exhibit a development of the fully pronounced pleochroism, and absorption, together with the very characteristic cleavage of hornblende. The existence of two types of hornblende—the one with feeble pleochroism and absorption, and the other with very intense pleochroism and absorption—has already been noticed by Sjögren in this rock. The last stage of the change into hornblende appears to be always accompanied by a remarkable "granulation" of the crystals. The original pyroxenes crystallise in broad and thick plates, but these, before acquiring the fully pronounced characters belonging to hornblende—namely, the strong pleochroism and absorption as well as the cleavage—in all cases break up into a mosaic of more or less rounded granules—each individual granule presenting its own peculiar orientation. It may be remarked that many rock-forming amphiboles and micas undergo great changes in their pleochroism and absorption and these changes may affect the whole or, as in the formation of pleochroic halos and similar phenomena, only portions of the crystals.

While the original pyroxene-felspar-rock appears to have a perfectly *granitic* structure, the derived hornblende-scapolite-rock has a most marked *granulitic* structure. The large felspar-crystals become an aggregate of scapolite-granules; and the large pyroxene-crystals break up into a similar mosaic of hornblende-granules.

Nothing can be more striking than the parallelism of the changes undergone by the two chief constituents of this very interesting rock; and nowhere perhaps can we find more instructive illustrations of the effects produced, in the first place, as the results of chemical action resulting from statical pressures (schillerization), and in the second place, from the changes induced by the internal stresses set up in a rock during its deformation in the act of flowing (dynamometamorphism).

The effect of the statical pressure is seen in the way in which the crystals of felspar and pyroxene, respectively, yield to the solvents—which under the enormous pressure must permeate their whole substance—this solvent action taking place where planes of chemical weakness or instability exist in the crystal. In the case of the felspar-crystals, cavities, often assuming the forms of negative crystals and containing liquids, arise; in the case of the pyroxenes, these cavities become filled with various secondary solid products, which, having a submetallic lustre, give rise to the schiller of bronzite.

In the case of the pyroxene it is found that there is a marked tendency of the crystals, while retaining the characteristic cleavage, enclosures and other properties of bronzite, to acquire the extinction and double refraction, and *to a limited extent* the colour, the pleochroism, and the absorption of hornblende.

The last change is a very striking and instructive one. In the bronzite, and in the felspar (with its cavities containing a solution of sodic chloride), we have the necessary materials for forming a hornblende and a scapolite respectively—the former by a paramorphic the latter by a pseudomorphic change.

These final results seem to be clearly referable to dynamometamorphic action—and are in each case accompanied by that *granulation* of the mass which is the result of crystalline forces acting on materials that are at the same time subjected to powerful mechanical stresses. The "granulation" of the hornblende and the scapolite respectively cannot, it appears to me, be regarded as simply a mechanical crushing of the crystals—as some writers on metamorphism seem to have imagined—but must be referred to a crystallising process going on *under the influence and control of powerful mechanical stresses.*

Such appear to be the series of processes by which a perfectly GRANITIC rock, composed of *pyroxene* and *felspar*, is converted into a remarkably GRANULITIC rock made up of *hornblende* and *scapolite.*

We have, it seems to me, the most complete evidence that, alike in the conversion of enstatite into hornblende, and in the transformation of felspar into scapolite, the change takes place slowly, molecule by molecule, and the distinctive properties of the new crystalline substance are acquired gradually and by successive stages, some of which it is possible to trace.

The investigation of the nature, the relations, and the sequences of those changes which take place in the distinctive properties of a mineral—as it is gradually transformed into another species—and the determination of the causes to which these changes must be severally assigned, are problems which may worthily engage, as they will certainly demand and reward, the combined efforts of the geologist and the mineralogist.

EXPLANATION OF PLATE IX.

Alteration of Plagioclase Felspar.

Fig. 1. Crystal of plagioclase-felspar seen between crossed nicols, magnified 25 diameters. The central portion exhibits the twinning (on both the albite and pericline types), the refraction, double refraction, extinction and other characters belonging to plagioclase-felspar. The outer part of the crystal consists of a number of large grains of scapolite, in some of which a faint indication of the lamellar structure of the felspar can still be detected, though the extinction of these is never definite as it is in the felspar. In the part marked *x* we have a grain exhibiting all the optical properties of scapolite, but in which lamellæ that do not give definite extinctions can be detected,—and these lamellæ are evidently parallel to those in the unaltered felspar. Outside of these again we find a mass of scapolite-granules, some exhibiting low and others high polarisation-tints.

Fig. 2. The crystal seen with the same magnifying power by ordinary light. The felspar is seen to be traversed by bands of cavities, which are so numerous as to give the mass a dark colour. That these bands of cavities exactly map out the lamellæ of the albite- and pericline-twins becomes very obvious, if we examine the crystal alternately by ordinary and polarised light.

(A series of examples may be selected from the rock, showing felspars almost unaltered, others with narrow zones of scapolite around them, and others in which the zones of scapolite have increased till only a vestige of the original felspar remains in the centre.)

Fig. 3 shows a portion of this felspar-crystal, with its numerous inclusions, as seen with a magnifying power of 250 diameters. The development of these cavities along certain definite planes, and their tendency to assume the form of negative crystals, with their most largely developed planes parallel to planes of chemical weakness, is very clearly indicated.

Fig. 4. Cavities of the same felspar-crystal as seen with a magnifying power of 2500 diameters.

a. Large irregular liquid cavity with a bubble and two small cubic crystals.

b. Flat-sided cavity (negative crystal) with a bubble.

c. Similar cavity in which no bubble is seen.

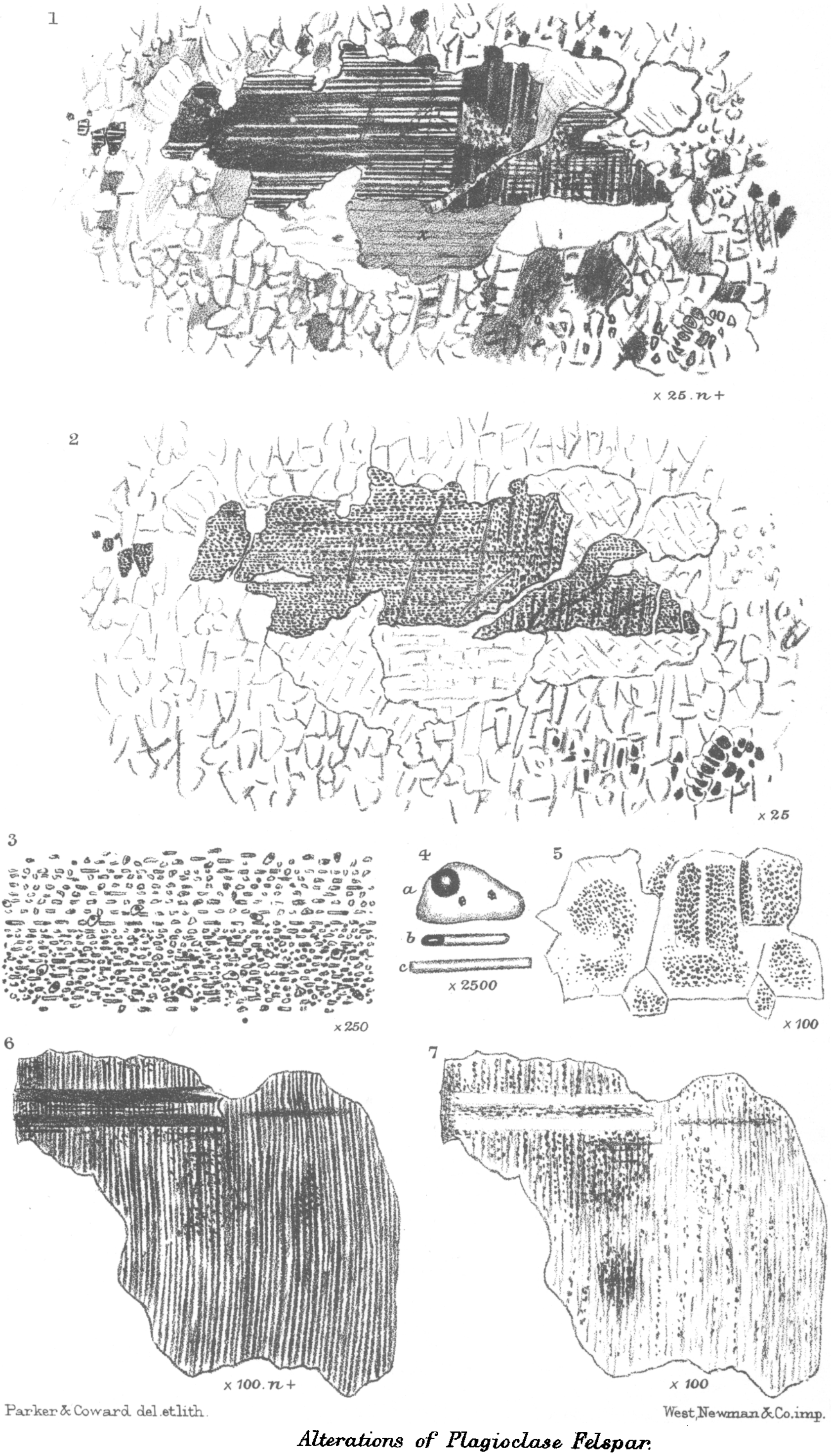
Fig. 5. Group of granules of scapolite as seen magnified 100 diameters. In the centres of those granules are seen groups of cavities arranged in

lines, like those of the felspar-crystals, from which the scapolite has been derived. By polarised light it may often be observed that the centres of the granules containing the cavities polarise in lower tints than the exterior margins which are free from cavities.

Figs. 6 and 7. Two views of a plagioclase-crystal from a diorite, Old Meldrum, Aberdeenshire, magnified 100 diameters.

Fig. 6 shows the crystal as seen with crossed nicols. The two systems of twin-lamellæ—the one system only very partially developed, and the other system exhibiting very marked curvature, are very distinctly displayed.

Fig. 7 shows the same crystal viewed by ordinary light. The kaolinisation of the felspar is seen to have been determined by the presence of the twin-lamellæ—the curvature of the one system, and the partial character of the other system being very conspicuous. In this and other similar cases, the lines of secondary inclusions or of kaolinisation, as seen by ordinary light, completely map out the twin-lamellation as seen by polarised light. It is only necessary to examine the section alternately by ordinary and by polarised light, to perceive how complete is the correspondence between the twin-structures and the planes of chemical instability in the crystal.



Parker & Coward del. et lith.

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Alterations of Plagioclase Felspar.