CHAPTER XXV.

On the rocks usually termed 'Primary'—Their relation to volcanic and sedimentary formations—The 'primary' class divisible into stratified and unstratified —Unstratified rocks called Plutonic—Granite veins—Their various forms and mineral composition—Proofs of their igneous origin—Granites of the same character produced at successive eras—Some of these newer than certain fossiliferous strata—Difficulty of determining the age of particular granites—Distinction between the volcanic and the plutonic rocks—Trappean rocks not separable from the volcanic—Passage from trap into granite—Theory of the origin of granite at every period from the earliest to the most recent.

ON THE ROCKS COMMONLY CALLED PRIMARY.

We shall now treat of the class of rocks usually termed 'primary,' a name which, as we shall afterwards show, is not always applicable, since the formations so designated sometimes belong to different epochs, and are not, in every case, more ancient than the secondary strata. In general, however, this division of rocks may justly be regarded as of higher antiquity than the oldest secondary groups before described, and they may, therefore, with propriety be spoken of in these concluding chapters, for we have hitherto proceeded in our retrospective survey of geological monuments from the newer to those of more ancient date.

In order to explain to the reader the relation which we conceive the rocks termed 'primary' to bear to the tertiary and secondary formations, we shall resume that general view of the component parts of the earth's crust of which we gave a slight sketch in the preliminary division of our subject in the 2nd chapter *.

We there stated that sedimentary formations, containing organic remains, occupy a large part of the surface of our continents, but that here and there volcanic rocks occur, breaking through, alternating with, or covering the sedimentary deposits,

* See above, p. 8.

so that there are obviously two orders of mineral masses formed at the surface which have a distinct origin, the aqueous and the volcanic.

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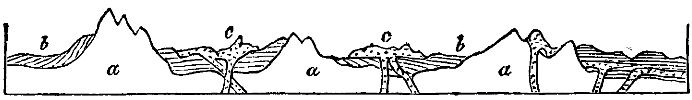

a, Formations called primary (stratified and unstratified).
b, Aqueous formations. *c*, Volcanic rocks.

Besides these, however, there is another class, which cannot be assimilated precisely to either of the preceding, and which is often seen underlying the sedimentary, or breaking up to the surface in the central parts of mountain-chains, constituting some of the highest lands, and, at the same time, passing down and forming the inferior parts of the crust of the earth. This class, usually termed 'primary,' is divisible into two groups, the stratified and the unstratified. The stratified consists of the rocks called gneiss, mica-schist, argillaceous-schist (or clay-slate), hornblende-schist, primary limestone, and some others. The unstratified, or Plutonic, is composed in great measure of granite, and rocks closely allied to granite. Both these groups agree in having, for the most part, a highly crystalline texture, and in not containing organic remains.

Plutonic rocks.—The unstratified crystalline rocks have been very commonly called Plutonic, from the opinion that they were formed by igneous action at great depths, whereas the volcanic, although they also have risen up from below, have cooled from a melted state upon or near to the surface. The theory conveyed by the name Plutonic is, we believe, correct. Granite, porphyry, and other rocks of the same family, often occur in large amorphous masses, from which small veins and dikes are sent off, which traverse the stratified rocks called 'primary,' precisely in the manner in which lava is seen in some places to penetrate the secondary strata.

Granite Veins.—We find also one set of granite veins intersecting another, and granitiform porphyries intruding themselves into granite, in a manner analogous to that of the volcanic dikes of Etna and Vesuvius, where they cut and shift each other, or pass through alternating beds of lava and tuff.

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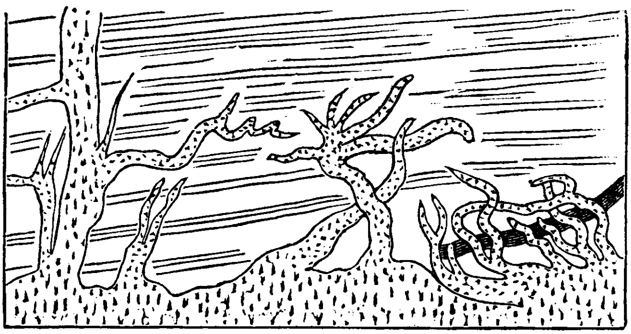

Granite veins traversing stratified rocks.

The annexed diagram will explain to the reader the manner in which these granite veins often branch off from the principal mass. Those on the right-hand side, and in the middle, are taken from Dr. Macculloch's representation of veins passing through the gneiss at Cape Wrath, in Scotland *. The veins on the left are described, by Captain Basil Hall, as traversing the argillaceous schist of the Table-Mountain at the Cape of Good Hope †.

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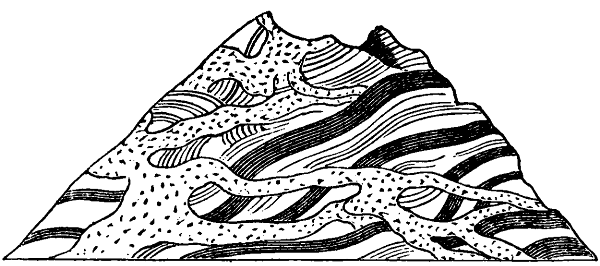

Granite veins traversing gneiss at Cape Wrath, in Scotland.

We subjoin another sketch from Dr. Macculloch's interesting

* Western Islands, plate 31.

† Account of the structure of the Table-Mountain, &c., Trans. Roy. Soc. Edin., vol. vii.

representations of the granite veins in Scotland, in which the contrast of colour between the vein and some of the dark varieties of hornblende-schist associated with the gneiss renders the phenomena more conspicuous.

The following sketch of a group of granite veins in Cornwall is given by Messieurs Von Oeynhausen and Von Dechen*.

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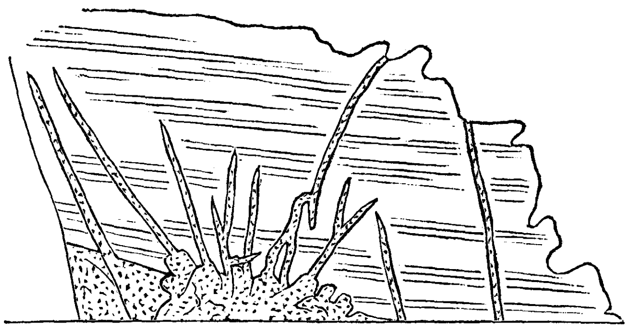

Granite veins passing through Hornblende slate, Carnsilver Cove, Cornwall.

The main body of the granite here is of a porphyritic appearance with large crystals of felspar; but in the veins it is fine-grained and without these large crystals. The general height of the veins is from 16 to 20 feet, but some are much higher.

The vein-granite of Cornwall very generally assumes a finer grain, and frequently undergoes a change in mineral composition, as is very commonly observed in other countries. Thus, according to Professor Sedgwick, the main body of the Cornish granite is an aggregate of mica, quartz, and felspar; but the veins are sometimes without mica, being a granular aggregate of quartz and felspar. In other varieties quartz prevails to the almost entire exclusion both of felspar and mica; in others, the mica and quartz both disappear, and the vein is simply composed of white granular felspar †.

Changes are sometimes caused in the intersected strata very

* Phil. Mag. and Annals, No. 27, new Series, March, 1829.

† On Geol. of Cornwall. Trans. of Cambridge Soc., vol. i. p. 124.

analogous to those which the contact of a fused mass might be supposed to produce.

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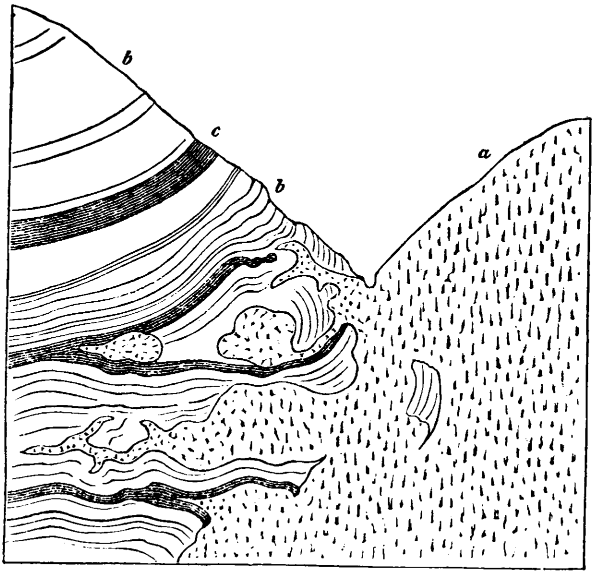

Junction of granite and limestone in Glen Tilt.

a, Granite. *b*, Limestone. *c*, Blue argillaceous schist.

The above diagram from a sketch of Dr. Macculloch, represents the junction of the granite of Glen Tilt in Perthshire, with a mass of stratified limestone and schist. The granite, in this locality, often sends forth so many veins as to reticulate the limestone and schist, the veins diminishing towards their termination to the thickness of a leaf of paper or a thread. In some places fragments of granite appear entangled as it were in the limestone, and are not visibly connected with any larger mass, while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite. The ordinary colour of the limestone of Glen Tilt is lead blue, and its texture large grained and highly crystalline; but where it approximates to the granite, particularly where it is penetrated by the smaller veins, the crystalline texture disappears, and it assumes an appearance exactly resembling that of horn-stone. The associated argillaceous schist often passes into hornblende slate, where it approaches very near to the granite *.

In the plutonic, as in the volcanic rocks, there is every gradation from a tortuous vein to the most regular form of a dike, such as we have described as intersecting the tuffs and lavas of Vesuvius and Etna. In these dikes of granite, which may be seen, among other places, on the southern flank of Mount Battoch, one of the Grampians, the opposite walls sometimes preserve an exact parallelism for a considerable distance. It is not uncommon for one set of granite veins to intersect another, and sometimes there are three sets, as in the environs of Heidelberg, where the granite of the right bank of the Rhine is seen to consist of three varieties differing in colour, grain, and various peculiarities of mineral composition. One of these, which is evidently the second in age, is seen to cut through an older granite, and another, still newer, traverses both the second and the first. These phenomena were lately pointed out to me by Professor Leonhard at Heidelberg.

In Shetland there are two kinds of granite. One of these, composed of hornblende, mica, felspar, and quartz, is of a dark colour, and is seen underlying gneiss. The other is a red granite which penetrates the former everywhere in veins †.

Granites of different ages.—It was formerly supposed that granite was the oldest of rocks, the mineral product of a particular period or state of the earth formed long antecedently to the introduction of organic beings into the planet. But it is now ascertained that this rock has been produced again and again, at successive eras, with the same characters, penetrating the stratified rocks in different regions, but not always associated with strata of the same age. Nor are organic remains always entirely wanting in the formations invaded by granite, although their absence is more usual. Many well authenticated exceptions to the rule are now established on the authority of

* Macculloch, Geol. Trans., vol. iii. p. 259.

† Macculloch, Syst. of Geol., vol. i. p. 58.

numerous observers, amongst the earliest of whom we may cite Von Buch, who discovered in Norway a mass of granite overlying an ancient secondary limestone, containing orthocerata and other shells and zoophytes *.

A considerable mass of granite in Sky is described by Dr. Macculloch as incumbent on limestone and shale, which are of the age of the English lias †. The limestone, which, at a greater distance from the granite, contains shells, exhibits no traces of them near the junction of the igneous rock, where it has been converted into a pure crystalline marble ‡.

This granite of Sky was at first termed 'Syenite,' by which name many geologists have denominated the more modern granites; but authors have entirely failed in their attempt to establish a distinction between granites and syenites on mineralogical characters. The latter have sometimes been defined to consist of a triple compound of felspar, quartz, and hornblende, but the oldest granites are very commonly composed of these ingredients only. In his later publications Dr. Macculloch has with great propriety, we think, called the plutonic rock of Sky a granite §.

In different parts of the Alps a comparatively modern granite is seen penetrating through secondary strata, which contain belemnites, and other fossils, and are supposed to be referrible to the age of the English lias. According to the observations of M. Elie de Beaumont and Hugi, masses of this granite are sometimes found partially overlying the secondary beds, and altering them in a manner which we shall describe more particularly when we treat of the changes in composition and structure superinduced upon sedimentary deposits in contact with Plutonic rocks || (see wood-cut, No. 90, p. 371).

In such examples we can merely affirm, that the granite is

* Travels through Norway and Lapland, p. 45. London, 1813.

† See Murchison, Geol. Trans., 2nd Series, vol. ii. part ii. p. 311—321.

‡ Western Islands, vol. i. p. 330.

§ Syst. of Geol., vol. i. p. 150.

|| Elie de Beaumont, Sur les Montagnes de l'Oisans, Mem. de la Soc. d'Hist. Nat. de Paris, tome v. Hugi, Natur. Historische Alpenreise, Soleure, 1830.

newer than a secondary formation containing belemnites, but we can form no conjecture when it originated, not even whether it be of secondary or tertiary date. It is, indeed, very necessary to be on our guard against the inference that a granite is usually of about the same age as the group of strata into which it has intruded itself, for in that case we shall be inclined to assume rashly that the granites found penetrating a more modern secondary rock, such as the lias for example, are much newer than those found invading strata older than the carboniferous series. The contrary may often be true, for the plutonic rock which was last in a melted state, may not have been forced up anywhere so near the surface as to enter into the newer groups of strata, and it may have been injected into a part of the earth's crust formed exclusively of the older sedimentary formations.

'In a deep series of strata,' says Dr. Macculloch, 'the superior or distant portions may have been but slightly disturbed, or have entirely escaped disturbance, by a granite which has not emitted its veins far beyond its immediate boundary. However certain, therefore, it may be, that any mass of granite is posterior to the gneiss, the micaceous schist, or the argillaceous schists, which it traverses, or into which it intrudes, we are unable to prove that it is not also posterior to the secondary strata that lie above them *.'

There can be no doubt, however, that some granites are more ancient than any of our regular series which we identify by organic remains, because there are rounded pebbles of granite, as well as gneiss, in the conglomerates of the oldest fossiliferous groups.

Distinction between volcanic and plutonic rocks—Trap.—The next point to consider is the distinction between the plutonic and volcanic rocks. When geologists first began to examine attentively the structure of the northern parts of Europe, they were almost entirely ignorant of the phenomena of existing volcanos, and when they met with basalt and other

* Syst. of Geol., vol. i. p. 136.

rocks composed chiefly of augite, hornblende, and felspar, which are now admitted by all to have been once in a state of fusion, they were divided in opinion whether they were of igneous or of aqueous origin. We have shown in our sketch of the history of geology in the first volume, how much the polemical controversies on this subject retarded the advancement of the science, and how slowly the analogy of the rocks in question to the products of burning volcanos was recognized.

Most of the igneous rocks first investigated in Germany, France, and Scotland, were associated with marine strata, and in some places they occurred in tabular masses or platforms at different heights, so as to form on the sides of some hills a succession of terraces or *steps*, from which circumstance they were called 'trap' by Bergman (from *trappa*, Swedish for a staircase), a name afterwards adopted very generally into the nomenclature of the science.

When these trappean rocks were compared with lavas produced in the atmosphere, they were found to be in general less porous and more compact; but in this instance the terms of comparison were imperfect, for a set of rocks, formed almost entirely under water, was contrasted with another which had cooled in the open air.

Yet the ancient volcanos of Central France were classed, in reference probably to their antiquity, with the trap rocks, although they afford perfect counterparts to existing volcanos, and were evidently formed in the open air. Mont Dor and the Plomb du Cantal, indeed, may differ in many respects from Vesuvius and Etna in the mineral constitution and structure of their lavas; but it is that kind of difference which we must expect to discover when we compare the products of any two active volcanos, such as Teneriffe and Hecla, or Hecla and Cotopaxi.

The amygdaloidal structure in many of the trap formations proves that they were originally cellular and porous like lava, but the cells have been subsequently filled up with silex, carbonate of lime, zeolite, and other ingredients which form the nodules. Dr. Macculloch, after examining with great attention the igneous rocks of Scotland, observes 'that it is a mere dispute about terms to refuse to the ancient eruptions of trap the name of submarine volcanos, for they are such in every essential point, although they no longer eject fire and smoke *.'

The same author also considers it not improbable that some of the volcanic rocks of the same country may have been poured out in the open air †.

The recent examination of the igneous rocks of Sicily, especially those of the Val di Noto, has proved that all the more ordinary varieties of European trap have been produced under the waters of the sea in the Newer Pliocene period, that is to say, since the Mediterranean has been inhabited by a great proportion of the existing species of testacea. We are, therefore, entitled to feel the utmost confidence, that if we could obtain access to the existing bed of the ocean, and explore the igneous rocks poured out within the last 5000 years beneath the pressure of a sea of considerable depth, we should behold formations of modern date scarcely distinguishable from the most ancient trap rocks of our island. We cannot, however, expect the identity to be perfect, for time is ever working some alteration in the composition of these mineral masses, as, for example, by converting porous lava into amygdaloids.

Passage from trap into granite.—If a division be attempted between the trappean and volcanic rocks, it must be made between different parts of the same volcano,—nay even the same rock, which would be called 'trap,' where it fills a fissure and has assumed a solid crystalline form on slow cooling, must be termed volcanic, or lava, where it issues on the flanks of the mountain. Some geologists may perhaps be of opinion that melted matter, which has been poured out in the open air, may be conveniently called volcanic, while that which appears to have cooled at the bottom of the sea, or under pressure, but at no great depth from the surface, may be termed 'trap;' but we believe that such distinctions will lead only to confusion, and that we must consider trap and volcanic as synonymous. On the other hand, the difficulty of discrimi-

* Syst. of Geol., vol. ii. p. 114. † Ibid.

nating the volcanic from the plutonic rocks is sufficiently great; for we must draw an arbitrary line between them, there being an insensible passage from the most common forms of granite into trap or lava.

'The ordinary granite of Aberdeenshire,' says Dr. Macculloch, 'is the usual ternary compound of quartz, felspar, and mica, but sometimes hornblende is added to these, or the hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of felspar and hornblende, and in examining more minutely this duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into a basalt, and at length into a soft claystone, with a schistose tendency on exposure, in no respect differing from those of the trap islands of the western coast*.' The same author mentions, that in Shetland a granite composed of hornblende, mica, felspar, and quartz, graduates in an equally perfect manner into basalt†.

It would be easy to multiply examples to prove that the granitic and trap-rocks pass into each other, and are merely different forms which the same elements have assumed according to the different circumstances under which they have consolidated from a state of fusion. What we have said respecting the mode of explaining the different texture of the central and external parts of the Vesuvian dikes may enable the reader in some measure to comprehend how such differences may originate ‡.

The same lava which is porous where it has flowed over from the crater, and where it has cooled rapidly and under comparatively slight pressure, is compact and porphyritic in the dike. Now these dikes are evidently the channels of communication between the crater and the volcanic foci below; so that we may suppose them to be continuous to the depth of several hundred fathoms, or perhaps two or three miles, or even more; and the fluid matter below, which cools and consoli-

* Syst. of Geol., vol. i. p. 157. † Ibid., p. 158.

‡ See above, p. 124.

dates slowly under so enormous a pressure, may be supposed to acquire a very distinct texture and become granite.

If it be objected that we do not find in mountain-chains volcanic dikes passing upwards into lava, and downwards into granite, we may answer that our vertical sections are usually of small extent, and it is enough that we find in certain localities a transition from trap to porous lava, and in others a passage from granite to trap. It should also be remembered, that a large proportion of the igneous rocks, when first formed, cannot be supposed to reach the surface, and these may assume the usual granitic texture without graduating into trap, or into such lava and scoriæ as are found on the flanks of a volcanic cone.

Theory of the origin of granite at all periods.—It is not uncommon for lava-streams to require more than ten years to cool in the open air, and a much longer period where they are of great depth. The melted matter poured out from Jorullo, in Mexico, in the year 1759, which accumulated in some places to the height of 550 feet, was found to retain a high temperature half a century after the eruption*. For what immense periods, then, must we not conclude that great masses of subterranean lava in the volcanic foci may remain in a red hot or incandescent state, and how gradual must be the process of refrigeration! This process may be sometimes retarded for an indefinite period, by the accession of fresh supplies of heat, for we find that the lava in the crater of Stromboli, one of the Lipari islands, has been in a state of constant ebullition for the last 2000 years, and we must suppose this fluid mass to communicate with some cauldron or reservoir of fused matter below. In the Isle of Bourbon, also, where there has been an emission of lava once in every two years for a long period, we may infer that the lava below is permanently in a state of liquefaction.

When melted matter is injected into the fissures of a contiguous rock at a considerable depth, it may cool rapidly if that rock has not acquired a high temperature; but suppose, on he

* See vol. i. p. 378, and Second Edition, p. 433.

contrary, that it has been heated, and still continues for centuries, or thousands of years, at a red heat, the vein may acquire a highly crystalline texture.

The great pressure of a superincumbent mass, and exclusion from contact with air or water, are probably the usual conditions necessary to produce the granitic texture; but the same may sometimes be superinduced at a slighter distance from the surface by slow refrigeration, when additional supplies of heat check, from time to time, the cooling process and cause it to be indefinitely protracted.

If, for the reasons above alluded to, we conceive it probable that plutonic rocks have originated in the nether parts of the earth's crust, as often as the volcanic have been generated at the surface, we may imagine that no small quantity of the former class has been forming in the recent epoch, since we suppose that about 2000 volcanic eruptions may occur in the course of every century, either above the waters of the sea or beneath them *.

We may also infer, that during each preceding period, whether tertiary or secondary, there have been granites and granitiform rocks generated, because we have already discovered the monuments of ancient volcanic eruptions at almost every period.

In the next chapter we shall endeavour to show, that in consequence of the great depths at which the plutonic rocks usually originate, and the manner in which they are associated with the older sedimentary strata of each district, it is rarely possible to determine with exactness their relative age. Yet there is reason to believe that the greater portion of the plutonic formations now visible are of higher antiquity than the oldest secondary strata. We shall also endeavour to point out, that this opinion is by no means inconsistent with the theory that *equal* quantities of granite may have been produced in succession, during *equal periods* of time, from the earliest to the most modern epochs.

* See vol. i. chap. xxii.