Capio Lumen

GRANITES

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GRANITES AND OUR GRANITE INDUSTRIES

GEORGE F. HARRIS, F.G.S.

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BY

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WITH ILLUSTRATIONS

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PREFACE.

THIS little work is not intended to be a purely geological treatise on granite, but is especially designed for the assistance of those who, being commercially or professionally interested in the granite industry, desire to look at the rock from a geological point of view.

At the same time, it will be generally acknowledged that the results of practice often subserve scientific purposes, so that the book may not altogether be without interest to the geologist. He must, however, remember that in describing various kinds of granite used in the trade, salient features only are noticed, whilst in only a few cases have I described accessory minerals. The portion bearing on the origin of granite, too, might have been considerably extended. The views brought forward appear to me to best accord with established facts, and controversial matters which do not affect main points have not been alluded to.

It should be mentioned that the greater part of the work, more particularly those chapters dealing with the quarries, has previously appeared in the *Builder*; and I am much indebted to the courtesy of the proprietors of that journal for permission to re-publish the same. Much matter, however, has since been added and the whole revised.

I must express my obligations to all those quarry owners and granite merchants who have assisted me with information. I am especially indebted to Messrs. W. G., J. A., and B. A. Freeman, of the firm of John Freeman & Sons, of Penryn, for facilitating my inquiries at their quarries in Cornwall; to Messrs. John Fyfe, A. & F. Manuelle, and A. Macdonald, Field & Co. for their assistance when I was in the Aberdeen district; and to Mr. Thos Blake, of St. Helier's, on the occasion of my visit to the Channel Islands.

To my friend Mr. Henry Fleck I must also tender thanks for aid given in examining proofs whilst the work was passing through the press.

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GRANITES

AND

OUR GRANITE INDUSTRIES.

CHAPTER I.

THE CLASSIFICATION OF ROCKS.

In order to understand the position of granite with reference to other rocks composing the earth's crust it will be necessary for us to consider briefly the classification of rocks in general.

They may be divided into three great classes, according to their modes of origin. The first of these is termed *igneous*, and comprises rocks which have once been in a molten condition, or in a state of fusion. The second is known as *aqueous*,—those that have been laid down or formed in water. The third, *metamorphic*, includes those portions of either of the foregoing divisions which have been subjected to sufficient heat and pressure to cause them to substantially change their form, but not quite enough to melt them up.

The igneous rocks fall into two groups:—1, the *crystalline*, composed wholly of crystals, such as granites, syenites, and gabbros; 2, the *non-crystalline*, those made of a substance resembling glass, such as obsidian and tachylite, or which have crystals scattered about in a glassy matrix, as exemplified by most lavas.

The different aqueous rocks might be placed into three groups:

1. *Sandstones,* being made of grains of mineral matter (mostly quartz) cemented together by materials which have, in the majority of cases, been introduced into the rocks subsequent to their deposition. They are more or less compact, according to the nature of the cementing material, extreme types being loose sand or concretionary matter, too soft for building purposes; and hard siliceous stone, breaking with a splintery fracture.

2. *Limestones,* being made wholly of calcareous organic remains in a more or less perfect state, or having been deposited chemically in the shape of little spherules, the nuclei of which are generally fragments of mineral matter or pieces of broken shells. We shall treat of dolomites under this heading, as they are magnesian limestones, having sometimes been formed in water, though occasionally by metamorphic action properly so-called.

3. *Clays,* composed mostly of silicate of alumina, which, although primarily derived from the decomposition of felspar eventually becomes impure, in a greater or less degree, by the addition of other mineral matter both at the time of deposition and subsequently.

Metamorphic rocks may be separated into four groups:—

1. *Gneiss and Crystalline Schists.*—The crystalline materials of which these are formed have arranged themselves in layers which may be composed of one or more minerals. These layers are not necessarily parallel to each other, but are frequently much twisted or contorted, especially in the schists.

2. *Quartzites,* which are sands or sandstones much altered in being greatly pressed into an exceedingly hard mass.

3. *Crystalline Limestones* (or marbles, properly so-called) are ordinary limestone rocks similarly subjected to great pressure, so that their original structure is obliterated, the calcium carbonate having entirely re-crystallised *in situ.*

4. *Slates,* which are clays also very highly pressed, so much so, that the major axes of the particles of which

they are composed have been made to assume a position at right angles to the direction of the pressure, hence their characteristic fissile structure.

The aqueous rocks are also divided into the following groups, according to their relative age:—

TERTIARY . .	Pliocene Miocene (absent in Great Britain). Eocene.
SECONDARY. .	Cretaceous. Oolitic. Liassic. Triassic.
PRIMARY . .	Permian. Carboniferous. Devonian (Old Red Sandstone). Silurian. Cambrian.
	Archæan.

In this list the oldest rocks are placed at the bottom, and the newest at the top. This age is not reckoned by years, but by means of the order of superposition of one portion with another, and also by the remains of organisms (or fossils) which they so often contain. In other words, it is proved by the lithological character, as well as by the organisms contained in them, that they were laid down in water, just as thick deposits of sand, clay, and gravel are now being laid down with shells, &c., in the sea on our coast margins and in the estuaries of rivers; the only difference being that the aqueous rocks presented for our examination have been raised by gradual upheaval, together with the floors upon which they were deposited.

Traversing the country we find that these rocks are tilted at various angles with the horizon, and their edges have been attacked and worn away by rain, frost, waves, &c., at different times. Suppose we start from Essex and travel—say, into North Wales—we shall find that, generally, we shall pass over many different kinds of sandstones, clays, and limestones, which, in succession, were observed to come up under each other.

Now, we could easily demonstrate the fact that, inasmuch as the rocks were seen to lie upon one another that the uppermost one of any two, having been laid down on top of the other, must necessarily be of younger age. Therefore, we come to the conclusion that, in such a case as the one before us, the youngest rock, or formation as it is called, is situated in Essex; and that the rocks progressively get older as we go north-westwards, until, on arriving in North Wales we are brought face to face with the oldest.

If further proofs were wanting to establish this point they may be furnished by the shells, &c. (fossils), contained in the formations. We should find that the beds at the surface in East Essex contain a very large proportion of fossils, which are absolutely identical with the genera and species now living in our seas; but as we examined the older beds going north-westwards we should discover that this proportion became progressively less, and we should not have to go so very far before we came to formations which do not contain a single species similar to those now living. These are called extinct species, and those fossils found in the oldest rocks are least like organisms at present in existence. It is clear, therefore, that certain fossils characterise certain formations; and the practical value of this fact is immense, when we reflect on the facility with which, in many instances, the proximity or otherwise of coal, or any other similar and useful commodity, may be predicted.

In the foregoing observations we have not touched upon some superficial deposits, as they do not immediately concern us. It will be understood also that since the beds were laid down they have been more or less dislocated, or faulted as it is termed. This effect is most marked on the oldest rocks, which, having been longest in existence, have naturally suffered greatest. Locally, therefore, the order of sequence may occasionally be somewhat disarranged.

We may remark that our observations extend only to the tract of ground under consideration; the rule that the older the aqueous rocks are the more unlike living things will their fossil contents be, holds good all over the world, but it is sometimes difficult to prove their age by superposition alone, because in many mountainous districts (as the Alps, &c.), whole masses of strata have been turned

completely upside down and crumpled and folded just as though they were only sheets of paper. In these contortions the rocks have been squeezed so much that clay has been turned into slate, soft rocks into hard; and many mountain ranges are formed out of comparatively recent deposits. We may easily conceive, therefore, that in such cases as these the more recent rocks may be as hard and as much dislocated as the oldest ones. In parts of northern Russia some of the oldest rocks in existence, in spite of their high antiquity, are very little altered, being almost as soft as when they were originally laid down. This, however, is quite an exception.

CHAPTER II.

THE STRUCTURE OF GRANITE.

I.—MACROSCOPIC EXAMINATION.

If we examine a piece of granite, we find that it is a very hard rock, thoroughly crystalline in structure, by which we mean that it does not possess any matrix or cementing material whatever between the crystals of which the substance as a whole is made. The rock is rendered compact by the adhesion of the minerals to one another, and a close examination shows that in typical granite three different kinds of minerals are present. The first of these is called *quartz*, and may be recognised by its clear glassy appearance. It cannot be scratched with a knife. The second, *felspar*, may exist in a variety of colours, red, grey, yellow, white or light green. It can be distinguished from the quartz by not being transparent, whilst it can be scratched with a knife. The third, *mica*, may be either white, black, brown, or light yellow, and if it occurs in large enough crystals can be split up into flakes with the knife, and so may easily be recognised from the other two minerals.

Now, these three forms are termed the *essential* minerals of granite, by which it must be understood that in a true granite they must all be present in fair proportions. If any other minerals exist, as they very frequently do, they are termed *accessory*. Sometimes these latter are in such abundance as to, in a great measure, help to form the rock, in which case the material is no longer a true granite, but receives either a compound name indicative of the nature of the addition, or a new name altogether.

One of these other minerals, very commonly found, is called *hornblende*, being either white, grey, black, brown, light, or dark green. Perhaps the last-mentioned colour is the most characteristic. It is more like mica than the other two essential minerals, but may be distinguished from it by not flaking off when urged with the point of the knife. It has comparatively a rather dull appearance also. The only other accessory mineral we need mention is *schorl*, generally very black and lustrous, existing either in small patches, isolated or radiating, needle-shaped crystals.

When the former mineral is present with quartz, felspar, and mica, the rock is termed hornblendic-granite; or, if the latter exists in an appreciable quantity with these three minerals, it is known as schorlaceous-granite.

It will be observed, however, that certain rocks find their way into the market which will not answer to the description we have given of granite, and yet they bear that name. We shall point these out in the proper place, so that it will be sufficient now to consider briefly the more prominent of them. Perchance we come across one which contains no mica, or in which that mineral is present in such minute quantities that it may not appreciably help to form the rock, and may thus be regarded as an accessory mineral only. Determining the minerals in it, we find that they are quartz, felspar, and hornblende. The name of this rock is *Syenite*, although we may mention that a rock bearing this name may sometimes be met with on the Continent in which quartz is not necessarily essential. Many British geologists would also admit the term to apply to those rocks which contain only felspar and hornblende, the former mineral being of the particular variety known as orthoclase felspar.

Sometimes a material made only of quartz and felspar is found in a granulated condition, when it is called *granulite*. Now and then the quartz is so developed that a section of the rock would exhibit Hebrew-like markings, when it is known as *graphic granite*.

Other stones occur in the market, also known as granite, but which really only resemble that rock in being crystalline, the nature of the crystals in many instances in no wise approaching those of granite. It will be understood that our observations do not apply to such stones unless it is expressly so stated.

To return to typical granite. A very close examination will show us that the crystals composing it do rather more than adhere to one another, in the ordinary sense; they are found to interlock each other. For example, we may find that the felspar is perfect, and regular in form, the mica being rather irregular, but the quartz seems to interlace and fill up all the cracks, as it were. In such a case we must irresistibly come to the conclusion that the quartz was the last essential mineral formed in the rock. This, insignificant as it may appear, has a practical bearing, considerably influencing both the durability and suitability of the material for constructional purposes, as we shall see farther on (see p. 123).

Furthermore, it will be observed that some stones containing quartz, felspar, and mica, are very different in appearance from others containing precisely similar minerals. The best known are those in which these minerals plainly occur in more or less regular layers; such a rock is known as *gneiss*, but is not often found in the London market. We frequently see granites, however, the minerals of which have an indistinct tendency to occur in layers, especially the black mica. The structure is not clearly enough pronounced to cause the stone to be called gneiss, and so it is known as *foliated granite*.

The minerals vary very much in size in the different kinds of granite, and according as they are minute, small, or large, so we shall designate the stone fine, medium, or coarse-grained, respectively. We commonly find that the ground-mass, or base, of the rock is fine-grained, but large felspar crystals, sometimes as much as six inches in length, are distributed throughout it in a conspicuous manner: such a rock is known as *porphyritic granite*. It is often necessary to see large pieces of this rock to establish its true porphyritic nature. When seen in the quarry these long crystals frequently appear to have a general direction, but this fact is, perhaps, more clearly established by observing and questioning masons on the

spot as to the method in which the stone will most readily cleave or split. Looking at a perpendicular face, say one hundred feet high, one sees that these crystals occur in wavy undulations, but that many will not conform to the general directions.

Taking into consideration these various kinds, we come to the conclusion that true granite, namely, a rock in which quartz, felspar, and mica are fairly and homogeneously displayed in a thoroughly crystalline manner, is not a common rock in the market; so that if we confined our attention to this alone our task would be a very small one. We prefer, therefore, to regard the matter in a generic sense, taking true granite as the type, and the other kinds as species or variations of that type. We shall not demonstrate the intimate relations of each species to the others, for we should then overstep the limits of this little work, but it may be stated that the rule so general in the organic world applies equally to the inorganic, namely, that nature will not allow any hard and fast lines to be drawn between the species; they merge imperceptibly into each other, and, if we chose to designate any kind of rock by a particular name, and thus make distinctions for our own convenience, it would be purely an artificial arrangement, which does not really exist in nature.

As may already have been conjectured, it is exceedingly difficult, if not impossible, to state in what proportion the minerals should exist to form true granite. Science endeavours to fix it, and theoretically does so very well, but as a matter of practice it cannot be carried out. For example, one kind of rock may show quartz, felspar, and mica, with a very small proportion of hornblende; another may exhibit the hornblende in fair proportions as a rock-former, and every gradation may be observed between the two kinds of rock. The former would be called granite, the latter hornblendic-granite (or syenitic-granite); but who could name the rocks of the intermediate stages? Our classification demands a name for them which must be either the former or the latter, but it will be seen that individual opinion must operate very prominently in the determination. Exactly the same thing occurs in regard to the gradations between hornblendic-granite and syenite by the gradual disappearance of the mica; or, in fact, between almost any two closely related kinds of rock.

II.—MICROSCOPIC EXAMINATION.

We have hitherto spoken of the common granite-forming minerals as though they were always of the same kind, and did not admit of any variation. As a matter of fact there are many kinds of felspars, micas, &c., crystallising in different systems and possessing divergent chemical compositions. The more common of these minerals are important enough, as influencing the texture and durability of the stones, for us to describe. It is not altogether easy to distinguish some of these without the aid of magnifying instruments, and so the microscope has been called into use. We shall not pretend to give even a complete outline of this branch of research, but the following observations may be useful in guiding those who may desire to study the subject. There can be no question of the value of a close and searching investigation into the minute parts of a rock, for these are almost always the first to decay, and if, therefore, we can properly understand them, we shall strike at the very root of its weakness.

The rock to be examined is ground down to transparency. The method of preparing these exceedingly thin slices of rock for the microscope is well explained by Dr. A. Geikie (*Outlines of Field Geology*, 1882, pp. 202—211; *Text Book of Geology*, 1882, pp. 182—187), and Mr. F. Rutley (*The Study of Rocks*, 1884, pp. 59—74).

The microscope required need not be of a very expensive character. A complete enough examination may be carried out with one capable of magnifying 100 diameters, whilst it is often found more convenient to use a much lower power—60 diameters.

The stages of the more expensive microscopes used in examining rocks are usually made to revolve, as there are many advantages derived; and they have also rackwork for moving the object under examination to and fro, or up

and down. A special contrivance for successively bringing various different magnifying powers to bear, without having to screw and unscrew them as required, and rack-work for fine adjustment, have been invented, but none of these are absolutely necessary for our purposes, although if they are obtained, so much the better, as they save time and trouble.

The microscope, however, *must* have a polariscope attached. The polarising apparatus commonly employed consists of two Nicol's prisms—one placed above the eye-piece of the instrument, or above the objective, which acts as the analyser; the other, fitted under the stage of the microscope, being the polariser. The polariser should always be placed so that it revolves freely when turned by the hand.

The Nicol's prism is constructed out of a rhombohedron of Iceland spar, about 1 in. in height and $\frac{1}{3}$ in. in breadth. This is bisected in the plane which passes through the obtuse angles. The two halves are then again joined in the same order by means of Canada balsam. It polarises light completely, and transmits only one beam of polarised light, the other being entirely suppressed.*

The field of the microscope appears clear and well illuminated when the shorter diagonals of the two prisms coincide in direction, but when they are placed at right angles to one another the field appears quite dark, light being totally extinguished. The intermediate positions exhibit different shades, either dark or light according to the relation of one prism to the other.

The use of the polariscope is briefly this. If the rock under examination contains any portions that are amorphous (that is, those in which no crystalline structure is developed), or crystals belonging to the cubic system, with, perhaps, two exceptions, they will be seen to become light and dark as the polariser is revolved. This is owing to their being singly-refracting, or *isotropic* substances.

If, however, the stone contains crystals belonging to any of the other crystallographic systems it will modify the

* The *polarisation of light* is well explained in Ganot's "Physics," 1883, pp. 584-606.

polarised beam of light. All such minerals or crystals are said to polarise; in other words, they exhibit double-refraction, and are called *anisotropic*.

The direction in which the sections of the crystals are cut must be taken into consideration, because, under certain circumstances, as we shall presently see, they do not affect polarised light. In cutting rock sections for our purposes of examination it would be quite an accident were many of these peculiar conditions to present themselves, as, generally speaking, the stone would be chipped at random, without any attention being paid to the direction of the blow.

Another test with the polarising apparatus, very useful in determining the mineral constituents of rocks, is in finding whether any pleochroic or dichroic mineral is present. To do this the upper Nicol prism is removed, leaving only the lower. If, as we rotate the latter, no change in tint is observed, there is no pleochroic mineral present, or at least none which shows pleochroism at the angle at which it has been bisected; but very often the hue of certain crystals is changed, and they present many different colours. This is *pleochroism*. When, during the rotation of the prism, only two colours have been observed, the minerals presenting that appearance are said to be dichroic, or to exhibit *dichroism*.

Dichroism, or pleochroism, practically never occurs in crystals belonging to the cubic system. It is exceedingly useful in the determination of some common rock-forming minerals, enabling us, in most cases, at a glance to distinguish crystals in many other respects resembling each other.

A useful accessory to the microscope is a bull's eye condenser, which is used to examine rock sections by reflected light. This is done by throwing the mirror, under the stage of the microscope, out of gear, and by means of the condenser, directing a strong light on the surface of the section. The advantage of this method is more particularly noticeable in the case of minerals, which, when examined by transmitted light, are seen as black objects —opaque.

Reflected light often enables us to discover the character of, and to define, opaque minerals.

A lamp giving a good light may also be obtained specially for microscopic purposes.

When the microscope and its few accessories are purchased, the principal expense is at an end. If the student does not care to grind down his own pieces of rock for examination, there are several lapidaries, and mounters of microscopical objects, who would be glad to do so for him at 1s. 6d. per slide, and more cheaply if several slides are required. But we would strongly recommend that at first he should grind and mount his own specimens, for he then becomes more familiar with the stones, whilst practice teaches him the peculiar features consequent on bad mounting.

We will now describe a few of the principal varieties of the common granite-forming minerals, and their general appearance under the microscope; but we would urge the student to purchase a special work on this portion of the subject.

Quartz may exist in a variety of forms, being either an original constituent of the rock, or subsequently formed, when it is called secondary quartz. In the latter state it is often found filling cracks and cavities. It may be crystalline or non-crystalline, though we rarely meet it in the last-mentioned state in granite. When pure it is practically unaffected by the acids in the atmosphere; its chemical composition is silica, the oxide of silicon. In thin transparent sections under the microscope quartz appears clear, and polarises in strong, brilliant colours. Minute enclosures of foreign substances, little specks, and thousands of minute cavities are frequently seen dotted over the crystals. Its appearance is so characteristic that it cannot easily be mistaken for any other mineral.

Felspar may also exist in many ways, and is important enough for us to describe in some detail.

The following table shows the principal felspars, and their average chemical composition :*—

* Dr. A. Geikie, "Text Book of Geology," 1882, pp. 70-72.

Name of Felspar.	Silica.	Alumina.	Potash.	Soda.	Lime.
Orthoclase	64·60	18·50	16·90	.. ..	.. ..
Albite	68·62	19·56	.. ..	11·82	.. ..
Oligoclase	63·70	23·95	1·20	8·11	2·05
Labradorite	52·90	30·30	.. ..	4·50	12·30
Anorthite	43·08	36·82	.. ..	.. ..	20·10

Orthoclase often contains small proportions of lime, iron, magnesia, and soda. Its colour is a dirty white, grey, or pink. It crystallises in the monoclinic system. The other four felspars crystallise in the triclinic system.

Felspar, as previously mentioned, is one of the essential constituents of granite, and on the power of its resistance to weathering the durability of that stone mainly depends. We are sometimes apt to consider granite as a good weathering stone, without inquiring into any particulars concerning it, and although as a rule it is exceedingly durable, as a matter of fact, unless the felspar be of a durable character, it may weather quite as easily as a bad limestone or sandstone. For instance, much of the granite used in the buildings of Dublin is of inferior quality, being so rotten as to become quite worthless.

Anorthite, the lime felspar, is unquestionably the worst form of the mineral for weathering. It occasionally exists in granites and metamorphic rocks.

In the decomposition of felspars, which may be represented as silicate of alumina combined with silicates of potash, soda, and lime, the alkali or lime is removed in combination with a portion of silica, and there remains as the final result of the process a hydrated silicate of alumina, or clay. The potash felspar orthoclase is, under ordinary conditions, much less subject to such a decomposition than the soda felspar, albite, or those which, like labradorite, contain both lime and soda. Both Mitscherlich and Bischof have remarked that where albite and orthoclase are associated, the former may be found decomposed and friable, whilst the latter is still unaltered. This change of felspar is favoured by mechanical division, which multiplies the surfaces exposed, so that when a felspathic

rock is triturated with water, small portions of silica and of alkalies are taken into solution. If the decomposing rock contains, like many granites, both potash and soda felspar, the latter, being first attacked, will be rendered friable, and eventually reduced to the condition of clay.*

Under the microscope orthoclase can be distinguished from quartz by its characteristic cleavage, and dirty turbid-looking appearance. It often presents a very irregular crystalline form, and commonly occurs in twins, which ordinarily polarise in different colours on either side of a line running lengthways down the centre, when twinned on what is known as the Carlsbad type.

Triclinic felspars in polarised light usually show a series of parallel bands, or twin lamellæ as they are called, which polarise in various colours. The student will find excellent information on the microscopic determination of felspars from Fouqué and Michel Lévy, "Minéralogie Micrographique," pp. 209—227; Rutley, *Quarterly Journal of the Geological Society* (1876), p. 479; and "Study of Rocks," pp. 86—104.

The two commonest forms of *mica* are termed muscovite and biotite. The former crystallises in the rhombic system, is optically biaxial, and consists principally of silicates of alumina and potash. Oxide of iron, soda, fluorine, and water are usually present in variable quantities. Its ordinary colour is silvery white, but occasionally dark brown or black specks of the mineral may be seen. Muscovite stands the weather very well, and little plates of it may be found on decomposed granite, apparently unaffected by the action of the weather; whilst the felspar has rotted away. Under the microscope, muscovite exhibits clear colours and is transparent. As in the case of most minerals distributed promiscuously throughout a rock, the section for microscopic examination being cut in any direction, it is not easy to give all the rules for the determination of this mica. Under ordinary circumstances the sections do not often coincide with the cleavage of the mineral, but cut the planes of cleavage at different angles, which causes thin parallel lines to appear in two different directions.

* See "Geol. of Canada" (1863), p. 570.

When, by design or accident, the section is cut parallel to the basal cleavage a tolerably strong chromatic polarisation is shown, thus differing from biotite, which, under the same conditions, appears dark between crossed Nicols.

Dichroism is faintly exhibited.

Biotite is also called the magnesian mica, and crystallises in the hexagonal system. Its chemical composition is silicate of alumina and magnesia, with a little potash and iron. Its colour may be either black or dark green. It is not so durable as muscovite, assuming a white, soft crust under the action of the weather. Ordinary sections of the crystal are strongly dichroic.

Hornblende crystallises in the monoclinic system. Its chemical composition is "silicate of protoxide of iron, magnesia, alumina, lime, and protoxide of manganese, with frequently a little hydrofluoric acid and water." *

There are two principal varieties of hornblende; one has a considerable proportion of alumina, and the other contains very little, sometimes none.

The former is generally of a dark green, black, or brown; the latter of a pale green, white, or grey colour.

The non-aluminous hornblendes do not often occur in stones largely used for building, but the aluminous kinds are found in syenite and granite, where, in weathering, the silica, lime, magnesia, and a portion of the alkalies are removed, with conversion of part of the earths and the iron into carbonates. The further oxidation of the ferrous carbonate is shown by the yellow and brown crust, so commonly to be seen on the surface, or penetrating cracks in the hornblende. The change proceeds until a mere internal kernel of unaltered mineral remains, or until the whole has been converted into a ferruginous clay.†

Under the microscope, hornblende is strongly dichroic, and this is its principal feature. It is often longitudinally striated, in addition to which the cleavage planes form a sort of lattice work. The mineral is so irregular in form that very little reliance can be placed in its determination from that point of view. It polarises in rich colours when in thin sections.

* Rutley's "Mineralogy" (1876), p. 121.

† See Geikie, *op. cit.*, p. 75.

CHAPTER III.

THE ORIGIN OF GRANITE.

Possibly no geologist could be more anxious to account for the origin of granite than are many of the quarrymen and masons who blast and work the material. They always listen with the greatest attention to anything that may be said on the subject, and most of them have their own ideas respecting it. Several of them are quite prepared to believe that granite is of igneous origin (as we have stated), but the majority do not clearly understand the facts from which such a conclusion is drawn. A certain section believes that the long felspar crystals (p. 14) are the remains of fossils; whilst another is of opinion that granites are as regularly stratified as the aqueous deposits are. All of them know of the existence of other rocks than granite, perhaps, in their immediate vicinity; but the relations subsisting between the granite and those rocks very few seem to recognise. It was the knowledge of this fact which caused us to write a rather longer account of the aqueous rocks than might, perhaps, have been considered necessary in a work of this kind.

We will now endeavour to give some idea of what the igneous rocks are like, confining our attention especially to granite. In doing so, we will firstly examine certain sections showing the junction of that rock with others surrounding it, and our illustrations will, as much as possible, be drawn from sections actually seen by us in and near the various quarries in Aberdeen and Cornwall. The quarrymen in the respective localities will then be able very easily to go and examine the evidence for themselves.

The first exposure to which we would direct attention will be found on the beach at Torry, on the opposite side of the river Dee from Aberdeen, going towards the lighthouse at the extremity of the breakwater forming the entrance to the harbour. Starting from the village and proceeding eastwards, we find that one of the first rocks met with on the beach is a schist—a metamorphic rock, *i.e.*, one the original form of which has been considerably altered by heat and pressure. This schist may be easily recognised by the manner in which it is foliated, presenting a series of lines of different thickness, and being very much twisted about or contorted in places. As this is followed up a pink granite is seen penetrating the schist. This granite vein is only five yards in thickness. It is very fine-grained, and at its junction on both sides with the metamorphic rock, the appearance of the latter is very much altered. Small veins of granite branch off from the main vein, and the general result is that innumerable pieces of schist have been broken off from the body of that rock, and are included in the granite. (See Fig. 1.)

The interpretation of the phenomena presented is comparatively easy. The granite was clearly in a molten condition when it took up the position in which we now see it. From other indications in the vicinity, it would appear that the main body of the granite is not very deeply seated nor far off; and no doubt the schist is a thin bed lying on it. As the igneous mass burst its way through the schist it broke off portions of the latter, and endeavoured to melt them up.

If we may judge from the thin lines and minute fragments of the schistose matter running parallel with the general direction of the main vein, and so closely incorporated with the granite at, and within a foot of, the junction of the two rocks, we should certainly assert that the granite had, to some extent, been successful in doing so. Many large pieces of the schist would not submit to the melting process. Some of these refractory substances

are quite angular, and, with the exception of a slight alteration of both rocks at their junction for about one inch, they look as fresh as does the main mass of schist. Not so, however, with others that seem to be the kernels of pieces, the edges of which have been melted up in the granite, portions of which are seen mixed up with it in such a manner as to make it exceedingly difficult, if not impossible, to define the limits of either.

We have by no means exhausted the interest attach-

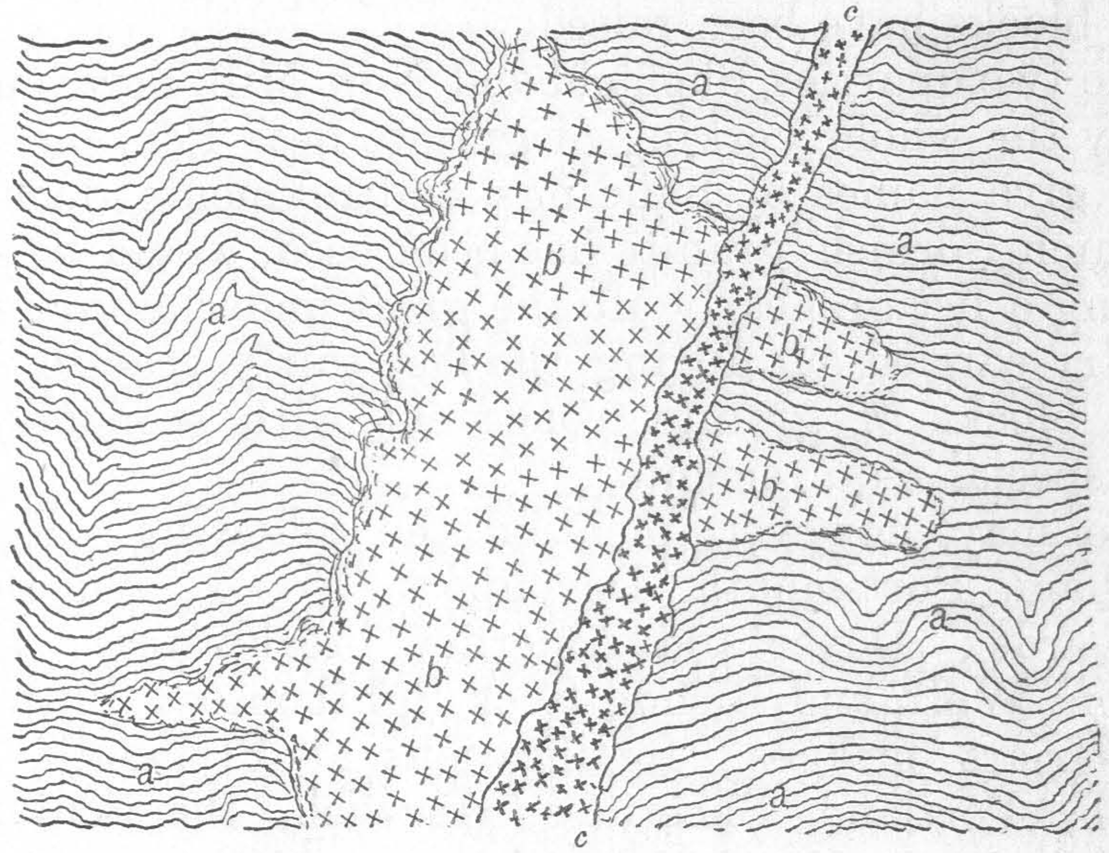

FIG. 1.—PLAN OF PART OF TORRY BEACH.
Area about 170 square yards.

a, A crystalline schist, contorted in places. *b*, Fine-grained pink granite. Pieces of *a* are caught up in it, especially near the junction of the two rocks. *c*, A vein of giant granite, penetrating both *a* and *b*.

ing to this most instructive exposure, for we find that another kind of granite has penetrated the fine-grained variety, in the shape of a vein about 4 feet across. This newer rock, in spite of its small breadth, is colossal in grain, and does not, at first sight, look like a granite. But the fact is apparent that it is composed of quartz, felspar, and mica, so there cannot be any doubt about it. The ordinary quartz crystals in this vein range in size from 6 in. to 10 in. in length; the pink orthoclase felspar from 4 in. to 18 in., and the silvery brown mica from 4 in.

to 8 in., being 1 in. or more thick. The contrast between this American-looking vein and the fine-grained rock in which it is found, is complete. At some points the former granite is also in contact with the schist.

Proceeding towards Girdle Ness, we find that a considerable portion of the beach between this vein and the point at which the long breakwater runs out into the sea is composed of schist. On nearing the breakwater, we find granite veins running through the schist in all directions (see Fig. 2), and rugged portions of them rise above the surface of the water, forming conspicuous objects. Here may be seen dozens of huge masses of schist, highly contorted, entirely surrounded by granite, presenting precisely the same phenomena at the junction of the two rocks as we have described. Just past the breakwater, the main mass of granite, of a dark grey colour, shows itself, and this is the fundamental rock of the district.

To show that these phenomena are not peculiar to this district alone, but prevail almost everywhere in granite areas whenever good sections are visible, we may mention that Dr. James Geikie, in a paper on the metamorphic origin of granite, states that in the grey granite of the southern uplands of Scotland he finds "nests" of altered rock, consisting of dark fine-grained or semi-crystalline rock, often showing traces of lamination. Sometimes there is a sharp line between the granite and the included fragments; at other times the passage is gradual. They may be remnants of thin bands or beds of shale interleaved in the original strata, from which the granite has been derived by metamorphic action; for, if they were fragments broken off, they should be more abundant near the junction, which they are not. He concludes that these granites have resulted from the alteration *in situ* of certain bedded deposits.*

The miners of Cornwall are all aware that granite veins very frequently are seen cutting the clay slates in small tortuous veins. The character of these veins is the same as the granite from which they were derived. "The veins are usually of no great length; but since at Porthleven

* *Geol. Mag.*, vol. iii. (1866), p. 529.

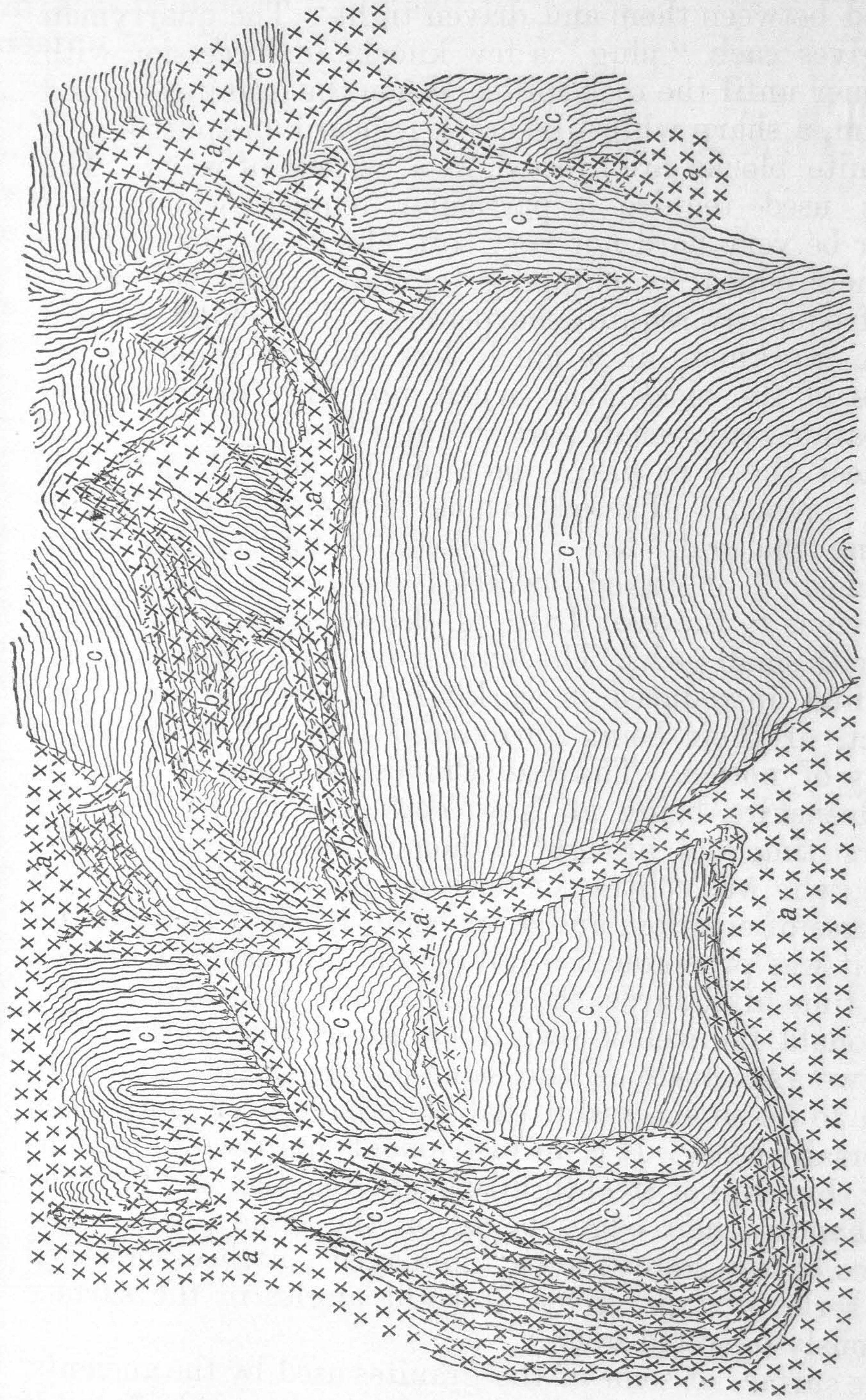

FIG. 2.—PLAN OF PART OF TORRY BEACH, NEAR THE BREAKWATER. Area about 80 square yards. *a*, Granite. *b*, Granite and schist mixed. *c*, Schist.

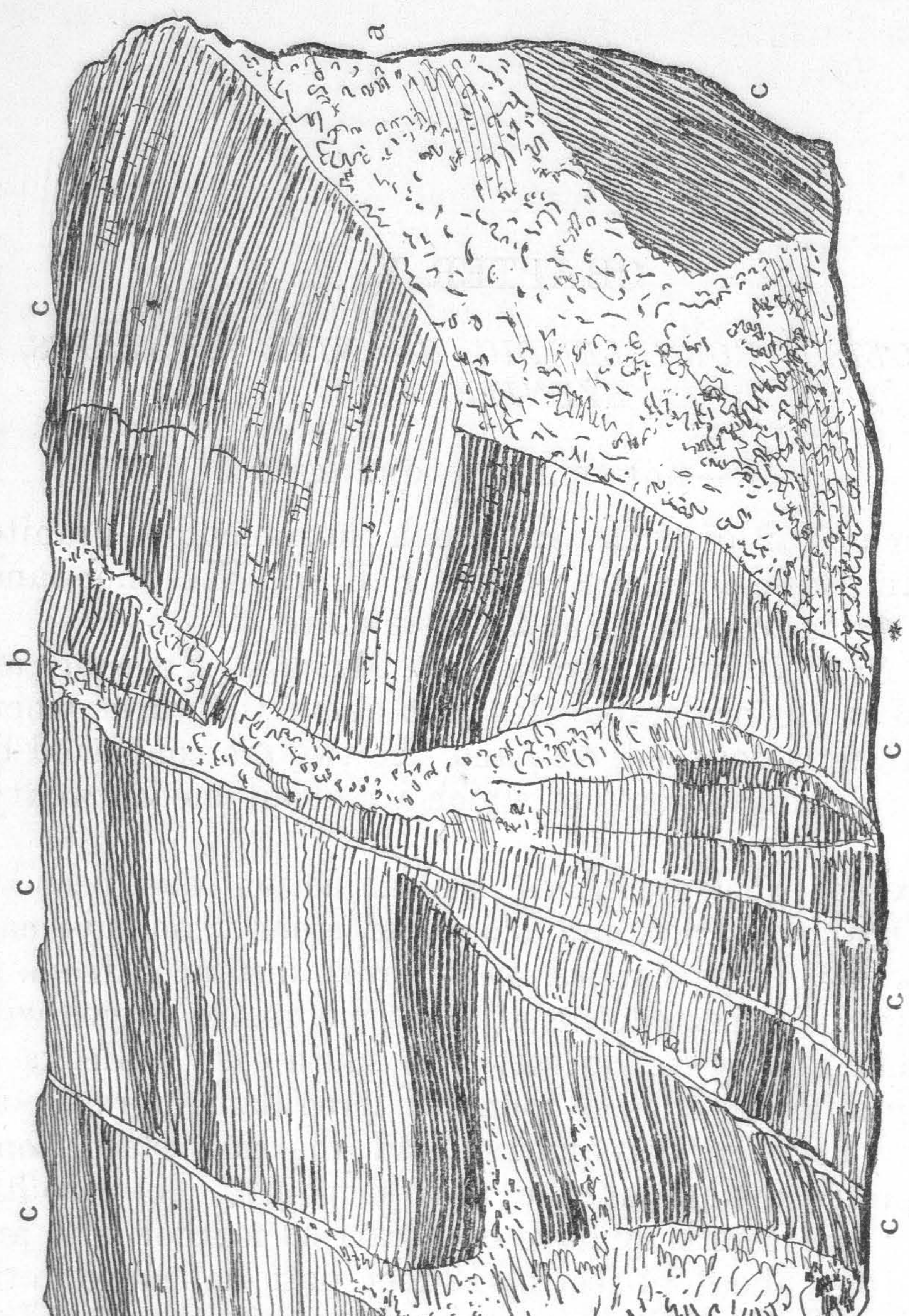

FIG. 3.—*a*, Granite. *b*, Granite and schist mixed. *c*, Schist.
Size of specimen, 1 foot by 7 inches.

Cove and other places they may be seen less than an inch thick, though of considerable length, the eruptive matter must have possessed a considerable amount of fluidity. From the numerous fragments torn from the slate and isolated in the veins, the force of the eruption must have been immense."* Granite veins are also numerous in the Lizard district.

Some of the men at Dyce quarry may remember splitting up a large block of granite for us in September, 1886, which contained a lenticular patch of schist in it nearly 6 ft. by 4 ft. by 9 in. (in broadest part).

At Dancing Cairns quarry an enormous block, showing junction of granite with schist, was also split asunder, and the diagram (Fig. 3) represents a piece of it kindly transported by Mr. W. B. Wight, the manager, to the railway station, and which we brought away. As will be seen, the schist is completely cut up by granite, and the action has faulted pieces of the former.

At Lamorna quarries, near Penzance, in company with Mr. B. A. Freeman, we saw many small pieces of metamorphic rock enveloped in the porphyritic granite.

We might easily give other examples of the association of granite with surrounding rock. Our text-books teem with them; in fact, it is, as Dr. A. Geikie† says, "Most large masses of granite send veins into the surrounding rocks, and often in such abundance as to form a complicated network."

A very beautiful example of granite veins penetrating pre-existing granitoid rock exists in the Corrennie quarry, near Tillyfourie Station, Aberdeenshire, if it has not been blasted away in the development of the quarry. The diagram (Fig. 4) represents what we saw there in September, 1886.

The red granitoid rock *a* (for description see p. 76) has been penetrated by the blue granite *b*, and it is easily seen that large masses of the latter throw out veins in many directions. At many places the junction of the two rocks is extremely well defined, and the pink

* Brenton Symons, F.C.S., "Geol. of Cornwall" (1884), p. 33.
† "Text-book of Geology" (1882), p. 552.

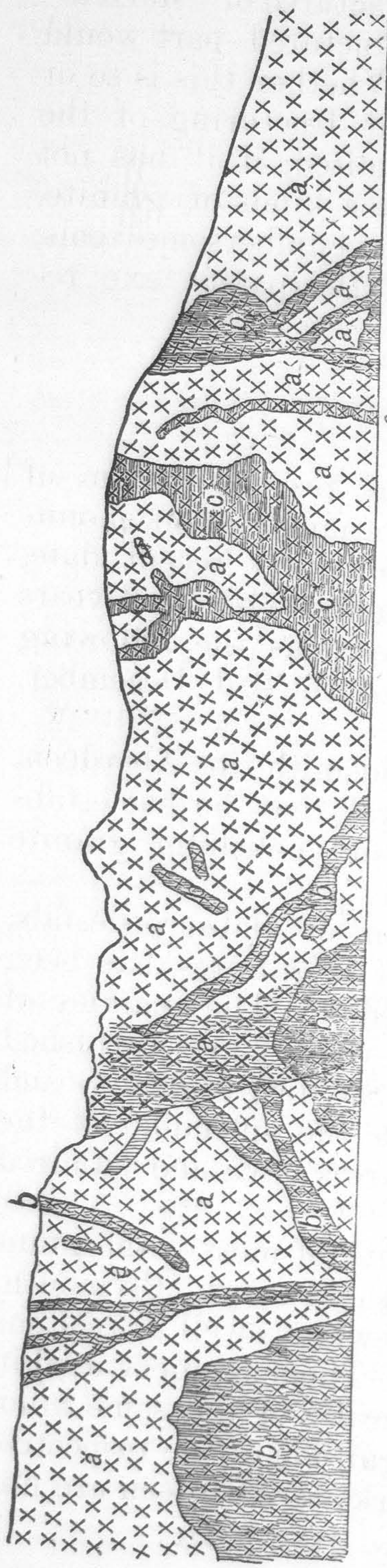

Fig. 4.—Section of the face of a Quarry at Correnie Hill. Length about 100 yards.
a, Red granitoid rock. *b*, Blue granite, throwing out veins into *a*. *c*, Bluish-red granite, throwing out veins into *a*.

orthoclase felspar in *a* has apparently re-crystallised, as much larger crystals of it exist along the line of junction than are normally found in the main mass. In other places the felspar in *a* does not seem to be so affected, but assumes a sickly yellow appearance, which gradually disappears as the rock recedes from the veins. The mass marked *c* is a bluish-red granite, and is probably only *b* with the addition of pink orthoclase felspar. It appears to shade almost imperceptibly into *a*, and many pieces of the latter are seen included in it. It is curious that whenever pieces of *a* are caught up in *b* (as in Fig. 5) they lose the pink hue and become light yellow, and we fancy we saw garnets in them when in this state. Moreover, such included pieces were frequently bordered by a thin band of black mica. The base of the hill is made of a coarser grey granite, with a large quantity of black mica in it.

The elvans in Cornwall are often seen running through the quarries, and the rock for some distance on either side of them is so much altered that the granite is of no commercial value.

We may mention, in this connection, that although many quarrymen recognise the term "elvan" as a band of dirty rock running through the quarry, a large number of them call the finer-grained elvans, when weathered, "sand courses." The latter term seems to apply principally where the vein is thin; when it is of respectable proportions they call it either a thick sand course or a "barr." When the granite is very much jointed or rotten, it is called a "horse" by Cornishmen. It is interesting to note that these terms are not constant even in the same district, except the "barr." The Scottish quarrymen round Aberdeen use the term "barr" or "burr," for any seam of rotten or bad granite which interferes with the ordinary run of the blocks. The elvans are observed to get less granitic in structure as they recede from the main mass of the granite and penetrate the surrounding metamorphosed rocks.

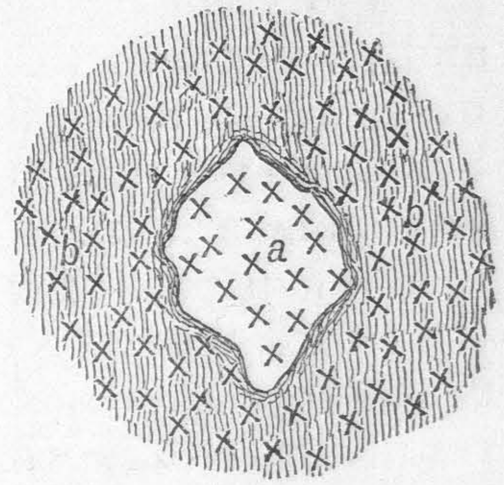

Fig. 5.
a, Fragment of red granitoid rock (4 inches in length) bordered by black mica and caught up in *b*.
b, Blue granite.

When the various points we have raised are carefully considered, we think that there cannot be the slightest doubt that the evidence is overwhelming in favour of the view that the greater part of our granites were once in a molten condition. Taking that afforded by the veins, it is quite clear that the granitic matter must in the majority of cases have existed in a highly plastic condition. From the thoroughly crystalline state of the material and from the fact that when examined by the microscope many of the crystals contain fluids which could not have been formed unless under the influence of great pressure, we are led to the conclusion that all such highly crystalline rocks have been formed at a considerable depth from the surface of the earth, that being the only place where such enormous pressure could have been exerted. Now, everybody knows that moving pressure*

* Sensitive instruments show that hardly any part of the earth's crust is ever quite still, even when no earthquake movements are visibly manifested.

causes heat, and the enormous pressure exerted by the overlying rocks, side-stresses and thrusts in mountain regions, would therefore result in tremendous heat at no very great depth within certain parts of the earth's crust. This heat would be sufficient to melt any known rock, and that it actually does melt is proved by the gradual alteration by heat exemplified in many of the rocks, the upper portions of which have been denuded or worn away (as will be referred to later on), and which are thus bared and raised to the surface for our examination. These rocks, as we have before stated, are known as metamorphic, and it has been demonstrated that there is a very gradual passage from certain of them through gneiss to granite; and we must therefore conclude that granite, in the vast majority of cases, is the result of extreme metamorphism by heat, and that it has therefore been, once at least, in a molten condition.

We will pause for a moment to consider the meaning of the words "molten condition." Although we have stated that at certain depths within the crust of the earth the heat resulting from moving pressure exerted by superincumbent rocks would be sufficient to melt any known rock, we should have added, *if this rock existed at the surface of the earth.*

Now, we have shown that the metamorphism and ultimate fusion of rocks was dependent upon the condition that they existed not at the surface of the earth, but at some distance within the earth's crust. Therefore we have no right to assume that rocks would actually *melt* when not situated at the surface. But the only thing which prevents them from becoming liquid is the weight of the superincumbent mass of rocks; in other words, the principal thing which caused them, in most cases, to become highly heated is the very same agent which deters them from becoming liquid. We therefore are led to see that rocks can exist in a highly heated condition in a solid form, and even when they, under the ordinary conditions prevailing at the earth's surface, would melt.

Such rocks are described by Professor Judd, F.R.S.,* who clearly explains this point, as being in a *potentially*

* "Volcanoes" (1883), p. 350.

liquid condition. If, by reason of earthquake action or otherwise, this superincumbent pressure be suddenly released, the potentially liquid mass would fly to the actually liquid form, and would burst through the rocks immediately above it, sending veins branching in every direction. Perchance some of these veins, bursting along the lines of least resistance, would reach the surface of the earth, and we should then get a *volcano*. The same acute observer mentioned above has demonstrated that the acid lavas (those which have a large proportion of silica in them), when traced downwards, will be found to have proceeded from granite and granitic rocks. The lavas under consideration are very frequently of identical chemical composition with the granites, and the only difference between them is their respective minerals and states of crystallisation. The granites, as we have before mentioned, are thoroughly crystalline; there is no glassy-looking cementing material binding the crystals together, but the lavas, on the contrary, contain a very large proportion of this glassy cement, and are not, therefore, thoroughly crystalline in structure.

Further, Professor Judd and other geologists have shown that the amount of glassy material present in an igneous rock is in inverse proportion to the amount of pressure under which it consolidated. For example, if it consolidated at the surface of the earth (and so under very little pressure) it would cool quickly, and there would be a greater proportion of glassy matter between its crystals than if it consolidated more slowly some distance down the throat of the volcano, and there would be still less of the material as the granite was approached. The glassy ground-mass would gradually assume a crystalline structure, and would pass from cryptocrystalline through microcrystalline to thoroughly crystalline, or a granitic state of crystallisation.

We have now shown that a rock which is indubitably in a molten condition, inasmuch as it is found exuding in that state from a modern volcano, can be traced downwards to granite. What greater proof of the once molten condition of the granite is needed? Surely the evidence is overwhelming enough to convince the greatest sceptic on the point? Of course nobody has actually descended the neck of a volcano to ascertain these things. It is all worked out by observation on denuded volcanoes, which have long since ceased to emit lavas, being now extinct; on the phenomena exhibited by the veins of granite, and on the invariable alteration of the rocks surrounding the granite. Denudation, or the action of the atmosphere, &c., in weathering or wearing down rocks, has been the greatest assistant in enabling us to solve the problem. There is no rock in existence which successfully resists the denuding agents for any very great length of time. Our building stones are weathered, no matter how well they may be selected. Even granite itself, hard though it may be, is worn away in time; and nobody would pretend to dispute this fact who has seen the many feet in depth of rotten granite which exists at the surface in many granite districts.

Our rivers are annually discharging thousands of tons of material into the sea, all of which has either chemically or mechanically been worn off from the rocks forming the river basin. If denudation was allowed to have its own way the land would eventually be planed down to a dead level, but fortunately the very accumulation of the sediment alluded to, first, by its weight, causes subsidence, thus heating its lower portions; the heat, together with the imprisoned water (high above the boiling-point), causes expansion, and the whole mass of sediment, together with its contained organic remains thus may perhaps be once more raised above the surface of the water and again attacked by the atmosphere. So the process goes on, the upheaving forces in some place or other compensating for the subsiding.

We would desire to be clear in connecting acid lavas with granites. Having seen that in time all rocks may be disintegrated, we can trace by means of a volcano, dissected in this way by the weather, the rocks from the crater downwards. We may find in one region the lava of the crater and a small portion of the neck of the ancient volcano leading down from it. We carefully collect specimens of the rock from the crater and the different levels in the neck, and if the section be sufficiently large we shall observe that the rock at the lower levels of the neck is slightly more crystalline in character than the lava in the old crater. Then we go on to another section, it may be in another district, and succeed in discovering a rock exactly like the more crystalline form from the lower portion of the volcanic neck. Tracing this rock downwards, we find that as we get to its lower part it gets indubitably more and more crystalline. Another section may, perhaps, present us with the more crystalline rock last alluded to, and on following this up we find that it leads us to a granite vein, may be one of the elvans, and so on to the main mass of the granite. The connection of the lava with the granite would thus be proved.

We see, therefore, that although there is plenty of granite now at the surface of the earth, it once existed a few thousand feet below, and it has been brought to the position in which we now find it partly by the wearing away of the rocks which were above it, and partly by the irruptive nature of the material itself when in the molten condition. Such operations would take thousands of years to carry into effect, but then geologic time is practically infinite. Reverting to the order of sequence of the aqueous rocks (p. 3), we may mention that, taking the whole world, exceedingly few granites are of Tertiary age, and even these are confined to the earlier periods of it; the majority are of Primary (or Palæozoic) age, or Archæan. This is just as it should be, for of course the longer the rocks have been in existence the greater chance they have had of being largely denuded. Granites are being formed below us at the present time, but it will be in the exceedingly remote future before the rocks overlying them will be worn down, and they will thus be brought to the light of day. Granite would not be formed at such great depths from the surface of the earth in mountainous regions as in the less corrugated portions of the crust, for the enormous lateral pressure exerted in the formation of the mountain ranges would raise the temperature sufficiently to melt rocks comparatively nearer the surface. This is how it is that granites so frequently occur along the lines of very much denuded ancient mountain chains. A good example of such a case would be the Devon and Cornwall district.

It was not so very long ago that geologists universally believed that all granites were older than any of the aqueous rocks, but it is now proved, as we have stated, that they may be of any age, except the most recent geologic periods. At the same time the granites of several areas are unquestionably amongst the oldest rocks in existence, and in many such cases it is exceedingly doubtful whether they are the products of extreme metamorphism caused in the way we have attempted to explain, or simply the cooling, at great depths, of portions of the original molten crust of the earth.

In order to simplify matters, we have spoken of granites as though they were all of igneous origin, and if we confined our attention to true granites (see p. 6) alone we should not have occasion to make any exceptions to the rule. But as we are including not only the type but the varieties in our descriptions, we would observe that there are some granites—especially those which are foliated (p. 8)—which in all probability have never actually been molten, but just one stage removed from it, and these are intermediate between true granites and gneiss. Such intermediate rocks are conveniently termed metamorphic granites. We are aware that those true granites which are known to have been formed by the action of extreme metamorphism are alluded to as being of metamorphic origin by some authors. As will have been observed, however, we have not made this distinction, for we do not see any necessity for so doing. So long as extreme metamorphism has actually melted the rock we are content to call it an igneous granite, but if it has not quite done so, and the rock exhibits foliation, we should term it a metamorphic granite, in allusion to the fact that it has not yet quite undergone the complete metamorphosis. This is assuming that the foliation is the result of metamorphism of any other rock than an igneous one. An exception would be created, for instance, if a truly igneous granite, after having consolidated, were subjected to metamorphic action, and by molecular rearrangement of its particles were to become foliated, in just the same manner as any other kind of rock might be. This would be a metamorphosed granite.

In regard to foliated granite we may observe that the lines of foliation are not necessarily the lines of the original stratification. Many granite workers who have expressed an opinion on the subject appear to think that they are. (We are not now alluding to joints, of course.) They were simply the lines of least resistance along which some of the minerals had a tendency to form, and were governed by the direction and amount of pressure exerted on them more than by anything else. If such lines correspond with the original planes of stratification it would be purely an accident, and in any case we should not have any direct proof either way, for the whole rock has been so crystallised and altered that its original structure has been completely obliterated.

We have hitherto apparently assumed that the product of any rock melted by metamorphic action and cooled is always granite, but this is not so. It is only when suitable materials have been melted that such is the case. This might have been surmised by the guarded way in which we have traced the connection of *acid* lavas with granitic rocks. There would have been no occasion to qualify the word lavas if all lavas led to granites. As a matter of fact, other rocks have been formed in a similar manner to granites; these are known by the names of syenite, gabbro, &c. Their origin is identical with that of granite; they all agree in being thoroughly crystalline, but inasmuch as they differ in the kind of minerals of which they are respectively formed and they differ in chemical composition, their respective lavas are also different from each other.

In addition to the sources of heat alluded to, we have that of the interior of the globe itself, a remnant of its past molten condition; but as to how far this has assisted in the formation of granite and other plutonic rocks, it is difficult to say. The oldest granites were probably much affected by it. The earth is said to be now giving off this heat, and, in thus cooling, is contracting. If the mountain chains and corrugations of the earth's crust were induced to form along lines of weakness produced by this contraction, pressure metamorphism would unquestionably there result; but it matters not whether the heat generated in crushing is partially due to this or any other cause, the effect in the formation of thoroughly crystalline plutonic rocks would be practically the same, provided the igneous mass resulting from it cooled slowly under sufficient pressure.

We have now said sufficient to give an outline of the origin of granite; but this is not a text-book, and we have not therefore quoted even the principal works, nor given the opinions of many different writers on portions of the subject. Of the main point—that granites have been formed by the slow cooling of suitable matter once in a more or less molten condition and under great pressure in the earth's crust—nearly all seem to agree, but the complicated nature of the subject has necessarily caused differences of opinion on minor points, and for further information we would refer to the various works of Professors Judd, Bonney, and Lapworth; Drs. Calloway, Haughton, and Hicks; Messrs. Rutley, Bauerman, Hudleston, Teall, &c., &c.; in addition to the excellent text-books of Dr. A. Geikie, Professors Prestwich and Seeley (Phillips), &c. &c.

CHAPTER IV.

ENGLISH (DEVON AND CORNWALL) GRANITE QUARRIES.

It would be impossible to state, with any pretensions to accuracy, the date when granite first began to be quarried. We know that the ancient Egyptians quarried the hornblendic granite of Syene as far back, at least, as the reign of Zestus, king of Thebes, 1,300 years before the Christian era. These quarries can even now be traced along the hillsides near that place.*

When granite was first used as a building material in the British Islands the loose blocks strewn about the surface of the ground were utilised for the purpose, and granite quarrying, as now understood, was not begun till about the middle of last century, but it was a long time before the methods of working it were such as to promise a good supply of stone.

The granites of Aberdeenshire appear to have been the first to attract the attention of engineers and surveyors, for we learn that in 1764 it was resolved to have the streets of London paved with Aberdeen granite.† From that date the export trade of Aberdeen gradually increased, especially after a lapse of a few years, when the stone at first obtained, having undergone practical tests, was shown to be of good quality. Great quarries were then opened, and the important branch of industry which to-day characterises that city was begun in earnest. Paving Streets London

It appears from a reference in "Kennedy's Annals" that the contractors for paving the streets of London began quarrying operations among the rocks on the sea-

* Trevor, "Ancient Egypt" (1863), p. 10.
† Bremner, "Industries of Scotland," p. 405.

coast of the lands of Torrie, and transported the stones roughly dressed to London. This mode of procedure was at length found to be too expensive, and the masons of Aberdeen were employed to work the stones to proper shape, according to contract, a system which in the main has survived to the present day, and will, no doubt, be likely to do so for a long time to come.

Machinery was first used in quarrying these granites about the year 1795, when stones of large dimensions were ordered by the Admiralty for the docks at Portsmouth, at that time in course of construction. This machinery, however, was very crude, and several years elapsed before much progress was made, either in keeping the quarries in good working order or in improving the instruments of labour. When a step was made in that direction steam-power was introduced, with the result that the output of stone was considerably augmented, and, worked-up material being produced at a cheaper rate, Aberdeen and other granites came to be more generally used.

Devon and Cornwall Granites.

The principal granite quarries of England are situated in Cornwall and Devon, including the Scilly and Lundy Islands.

Granite has been used in Cornwall from time immemorial for building and monumental purposes, but the process of raising it from quarries is of recent origin. Until within the last sixty years the only granite used was obtained from boulders upon the surface of the ground; but for all export purposes at least, quarrying has entirely superseded this primitive method, and is now a prominent industry in the county. The quarries produce very large blocks, whilst the fact that both fine and coarse-grained granites are obtained is sufficient to render it capable of being used for either architectural or engineering work.

We may remark, however, that the vast majority of the granites of Devon and Cornwall are coarse-grained, with large felspar crystals scattered throughout, and that fine-

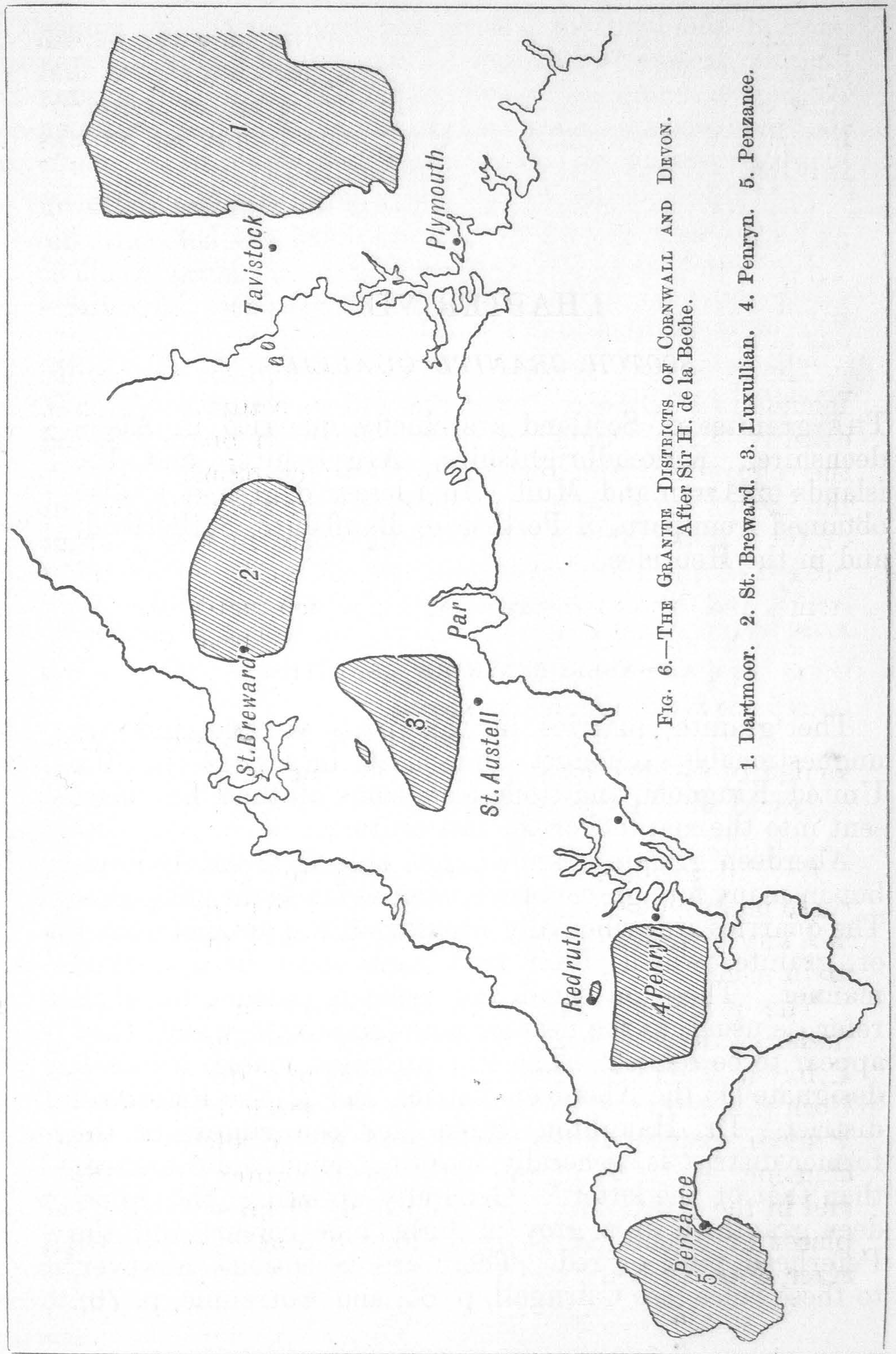

Fig. 6.—The Granite Districts of Cornwall and Devon. After Sir H. de la Beche.

1. Dartmoor. 2. St. Breward. 3. Luxullian. 4. Penryn. 5. Penzance.

grained varieties are not so common as in some of the other districts to be described. Haughton has shown that some of the white mica of the Cornish granites is lepidolite (lithia mica), whilst the black mica in the same rocks is often lepidomelane (iron-potash mica).*

Sir H. de la Beche has shown that the granites of Devon and Cornwall are of an age intermediate between the Triassic and lower Carboniferous periods. Many tracts of granite in this area rise through Devonian and Carboniferous strata, the evidence being very clear.

The principal granitic bosses range from the Scilly Islands to Dartmoor. That the various slates, sandstones, calcareous and trappean rocks, which at present bound these granite bosses, and smaller patches, existed prior to the intrusion of the granite, is shown by the displacement of these rocks by the latter, by the mode in which minor groups of them are sometimes cut off by it on the line of strike, and by the granitic matter which has been driven from the bodies of it into cracks and fissures formed in these adjoining rocks.† The strata in the vicinity of the bosses are always metamorphosed.

The granite areas of Cornwall and Devon may be conveniently divided into five districts, and a glance at the map will show their position, and the names we propose to call them.

Several patches of granite which are detached from these main masses need not here be taken into account, and any quarries in them will be referred to the nearest main mass.

The principal granite quarry-owners in the districts under consideration are Messrs. John Freeman & Sons, of Penryn. This firm alone has upwards of sixty quarries in Cornwall, situated principally in the large district near Penryn, embracing the parishes of Mabe, Stithians, Constantine, and Wendron; also in Penzance, Luxullian, and in the district north of Liskeard. There are shipping-places at Penzance, Penryn, Port Navas on the Helford river, Par Harbour, and Looe.

* "Proceedings Royal Society," vol. xvii., p. 209.

† "Report on Geol. of Cornwall, &c." (1839), p. 165.

In these quarries rocks weighing from 100 to 2,000 tons, in solid masses, are frequently detached from their native position. The process of quarrying has gradually developed from the most primitive methods, until now when steam cranes, rock-drills, and other-labour saving appliances are in use.

Other quarry-owners and granite workers are the West of England Granite Company, The Kit Hill Granite Company, Messrs. Shearer & Co., Hosking, J. Easton & Sons, Pethick Bros. & Duke, of Plymouth, Edward Story, and H.M. Government.

I.—DARTMOOR DISTRICT.

The great mass of granite in this district is coarse-grained, having quartz, felspar, and mica, the last mineral being sometimes white, at others black, and occasionally they are found together. The stone is very frequently porphyritic, and here and there schorlaceous, but the latter character is chiefly confined to the outskirts, where the granite adjoins the metamorphic rocks. Schorlaceous granite, however, is occasionally found in the interior of the mass, and there is a very gradual passage between schorl rock (schorl and quartz) and ordinary granite, in some parts. As a rule, the mica disappears as the schorl becomes abundant. Rarely, the rocks are composed of quartz, felspar, mica, and schorl in about equal proportions. After the mica has disappeared, the felspar generally goes. The mass is much more variable in composition at its outskirts than anywhere else.

The following are some of the granite workings of the district.

Trowlesworthy Quarry.—This quarry is situated in the western part of Dartmoor, and is worked by Messrs. John Freeman & Sons. The stone is of a red colour, and in this respect is quite an exception to the ordinary tint of granites in the West of England. The rather inaccessible position of the quarry, and the irregularity of the structure of the rock, render its introduction into the market on a large scale impracticable, but it is a handsome stone.

Haytor Quarries.—These are situated about fourteen miles south-west from Exeter, and are worked by Messrs. J. Easton & Son, of that city.

The earliest quarrying operations in Dartmoor "Forest" on a large scale were at Haytor, and very large quantities were sent to London by the Haytor Granite Company. The company, after several years, abandoned these workings and removed to Foggintor, near Princetown, where it carried on extensive works and raised large quantities of granite, but eventually wound up some twenty years ago. Since then, however, the quarries have been re-opened, as we have seen.

The stone at Haytor appears to have a fine-grained base, of a light greenish grey colour; the felspar is of two tints, white and light green, being distributed evenly over the stone. Mica is very plentiful, the prevailing colour being black, but it approaches brown in places. The quartz is of the ordinary clear crystalline character. Much of the rock quarried at Haytor is wholly composed as above, but a considerable proportion has, in addition, some fine large orthoclase felspars distributed porphyritically. These spars are frequently 2 in. or 3 in. in length, are white, usually exhibit twinning, and seem to lie in some cases approximately in the same direction. Very large stones may be obtained, and some time since, a piece about 45 ft. by 12 ft. by 12 ft. was shifted. It is worked principally for monumental purposes, but may also be utilised for steps, kerbs, &c., being taken to Bovey station, about four miles, and sent by rail to Exeter.

A large portion of London Bridge was built of it, and in those days the granite was shipped at Teignmouth, being carried thither on a granite tramway for five miles to a small canal, whence barges conveyed it to the ships.

We may call attention to the fact that at least two or three authors state that the Haytor quarries have ceased working,* and although the stone is not worked so extensively as formerly, it is incorrect to state that they are closed.

* See "Guide to Mus. Prac. Geol.," p. 26, quoted in Hull's "Building and Ornam. Stones," p. 35; and Rivington's "Build. Const.," part iii., Materials, p. 18.

Blackenstone Quarry.—This quarry is near Moreton Hampstead, about eleven miles west of Exeter, and has been worked by Messrs. J. Easton & Son for forty years. The stone has a fine base, composed of felspar of two colours, light pink and light green. The proportion of quartz does not appear to be very large; black mica is fairly abundant, being scattered about rather evenly. But the character of the stone is chiefly marked by the large porphyritic orthoclase felspars, of a light pink colour. In some cases these felspars do not appear to be so well defined as in the Haytor stone, occurring rather as patches of a broken-up appearance than clean crystals.

The stone splits easily with wedges, and is worked into copings, kerbs, steps, gate-posts, and rollers.

Foggintor, Great and Little *King Tor*, *Swell Tor*, *Crip Tor*, and *Inga Tor*, are quarries situated on Dartmoor, near Princetown, and worked by Messrs. Pethick Bros., of Plymouth. They are about fourteen miles from Plymouth, the port of shipment, and are connected with the Princetown railway, which runs by a siding direct into the quarries.

The granite from the Swell Tor quarry is of two colours, grey and blue; the blue appears to be a good, hard, compact stone, and is largely used for street work, kerbs, &c.

The breakwater, fort, and defences around Plymouth are built of Dartmoor granite.

Between the Dartmoor mass and that of St. Breward are some small patches of granite rising high above the level of the surrounding country. One of the most noticeable of these is—

Kit Hill, on which are situated quarries belonging to a company, of which Mr. W. J. Chalk is the manager. The grain of the rock is fine, and it occurs in large masses some hundreds of tons in weight.

Gunnislake Quarry is situated in the village of that name, on the banks of the Tamar, on the road from Tavistock to Callington. The scenery all round is magnificent. The quarry was opened in 1808, and the depth of granite worked in the main opening is 150 feet. It belongs to Mr. Edward Story, who has built houses to accommodate the machinery for working and polishing it on the spot.

The stone is grey in colour and differs from the general run of Dartmoor granite in that, normally, felspar crystals are not porphyritically developed. Masses of white orthoclase occur, some being quite an inch in length, but they do not exhibit the twinning characteristically, and are seen to be much broken up when closely examined. Quartz, transparent and clear, exists in little blebs. Both black and light brown micas occur, and schorl is present in exceedingly minute quantities. The general appearance of the stone is intermediate between that of the Dartmoor and St. Breward districts, which also closely corresponds with its geographical position.

It is noteworthy that blue, pink, and cream colours are also found in the quarry. A copper lode runs through a remote part of the working. Although the grey granite may be seen running directly against this lode, it gradually assumes a pink or cream colour as it nears it, whilst the stone is much harder than ordinarily. The alteration in colour is due to the orthoclase crystals being turned pink, perhaps by incipient decomposition. The structure of the granite near the lode is also slightly altered and the orthoclase crystals are much better defined and larger than in the main mass.

The grey granite is a nice-looking stone, and we were informed that it can be cut in any direction, there being no particular cleaving way. The master joints run N. by 10° E.; oblique W.S.W. and E.N.E. It was tested by Mr. Kirkaldy, and showed a crushing strain of 1,049·6 tons per square foot, or 16,321 lbs. per square inch, on three-inch cubes. Its capacity is 13·8 cubic feet per ton. According to the analysis of Mr. Pattinson it is made up, chemically, as follows :—

Silica	70·95
Alumina	17·64
Peroxide of Iron	1·36
Lime	0·76
Magnesia	0·11
Potash	4.36
Soda	3·79
Carbonic acid	none
Water	0·67
	99·64

The manager informed us that in blasting, triangular holes were always made $2\frac{1}{2}$-inch sides; that whenever possible the blast holes were let down on the joints, and when the lines of least resistance are uncertain a small preliminary blast of about 1 lb. of powder is used to find them.

The material is easily transported by means of the Tamar to Plymouth, and it has been used amongst other places in Saltash Bridge; James Street Station, Liverpool; in several docks; the Rossetti memorial, Chelsea; large fountain at Hampstead Heath Station, &c.

II.—ST. BREWARD DISTRICT.

The mineralogical composition of this mass is very similar to that of Dartmoor, being principally made of quartz, felspar, and two micas. It is frequently porphyritic, not particularly schorlaceous, though small crystals of schorl are sometimes found, chiefly towards the south. Near St. Clear all four minerals are present.

The *Cheesewring Quarries* comprise the Cheesewring quarries proper, and Kilmar and Bearah Tor. They are all worked by Messrs. J. Freeman & Sons, on the property of the Duchy of Cornwall, being situated about six miles north of Liskeard. The produce is sent direct to the shipping-port of Looe over the Liskeard and Caradon Railway, which is connected with the quarries.

An extensive view is obtained from the top of the hill on which the Cheesewring Quarry is situated, and a large tin mine is at the base on one side of it. The workings of the quarry have been carried almost to the edge of the famous Cheesewring, and as they are not permitted to go farther in that direction, the quarrymen have had to deepen the working at a large expense.

The stone is coarsely crystalline, each mineral being easily distinguished, and although the orthoclase felspar in places is rather large, the rock cannot be said to be very porphyritic. This mineral is quite white, and some of the more regular crystals exhibit twinning. The micas are black, white, and brown. Of these the first is most abundant. Quartz is clear and transparent.

The compact manner in which the minerals composing this stone are arranged, together with the fact that such large blocks can be obtained, renders it unquestionably one of the best granites for large engineering purposes.

Messrs. Freeman's manager for this district—Mr. Edward Jago—was kind enough to have an experiment carried out for us to test the facility of splitting up large blocks of the stone.

The diagram (Fig. 7) represents the different ways in which the stone is cut. *a*, is termed the cleaving-way; *b*, the tough-way; *c*, the quartering-way, which is the easiest direction in which the stone will split. The tough-way will take double as many holes to cleave as the quartering-way. In the experiment four men were placed on a block 5 feet 6 inches in length, 2 feet 6 inches in breadth, and 4 feet in height. They "jumped" (p. 117) fifteen holes three inches deep, in a line along the length of the stone, and with the usual wedges split it up in the quartering-way in fifteen minutes.

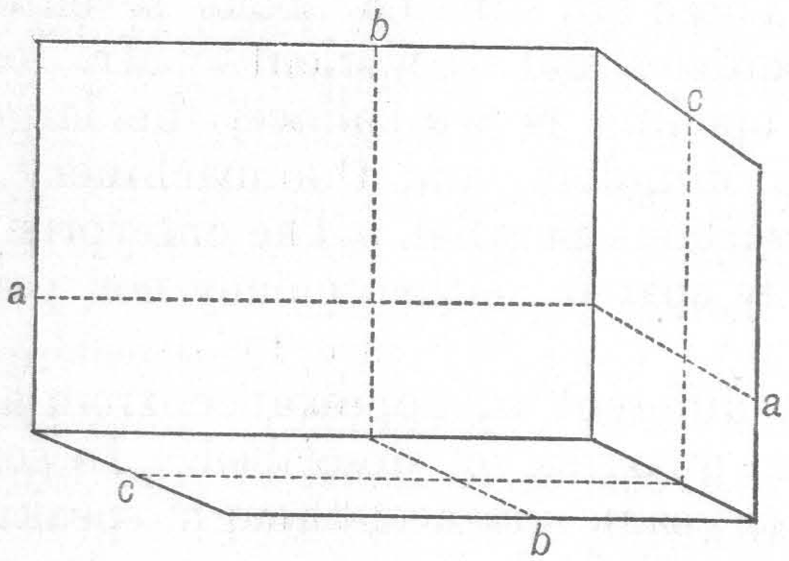

FIG. 7.—A BLOCK OF GRANITE LYING ON THE FLAT.

De Lank or Eddystone Quarries.—These are situated near Bodmin, and are worked by Messrs. H. Shearer & Co.

The constituents of the rock are two species of felspar, one orthoclase, the other a triclinic felspar, which exhibit in some cases a somewhat granulated structure. There are two species of mica—biotite (black), and muscovite (silvery white). A large proportion of quartz is present, and here and there a very few exceedingly minute crystals of apatite. The quartzose portions consist of small crystalline grains, and there appears to be little or no hornblende, no pyrites; and magnetite, if present, is only represented by a few exceedingly minute specks.

The following is the approximate mineral constitution of the De Lank granite, by Mr. Frank Rutley, F.G.S., of the Geological Survey, Jermyn Street, S.W., arrived at by an adaptation of Delesse's method:

Orthoclase felspar	30
Triclinic do.	6
Magnesian mica (biotite)	7
Potash mica (muscovite)	11
Quartz	46
	100

Its colour is of a uniform light grey, and there is little or no tendency of the stone to become porphyritic, as far as we can see.

Large blocks are obtained, and the joints are so regular that they require but little blasting to shift them out of their natural position. The resources of the quarries are practically unlimited, and the facility with which the stone can be supplied may be judged by the remarks of Sir James Douglass, Engineer-in-Chief to the Trinity House, in the discussion which took place on the "New Eddystone Lighthouse" (built of De Lank granite) at the Institute of Civil Engineers on the 27th November, 1883, when he pointed out that the granite contractors had completed their work six months within the specified time—three years.

This granite has also been used for the Smalls Rock Lighthouse, and in works at Portland, Devonport, Blackfriars Bridge, &c. It is shipped at Wadebridge, on the river Camel, within Padstow Harbour.

III.—LUXULLIAN DISTRICT.

The granite in this mass is far more variable in composition, and contains much more schorl than either of the other districts described. Sir H. de la Beche, however, says that the granite in the eastern part somewhat resembles that obtained from them, the mineral composition being about the same. Mica is scarce or altogether absent on the west side of the mass, being replaced by a steatitic or talcose mineral and schorl. Dr. Boase says that, although schorl is rare in parts, it is never quite absent, and veins of that mineral are abundant, especially in the western and central portions.

In some parts of the district immense boulders strew the surface of the ground, and rest upon one another in the most picturesque positions. The late Duke of Wellington's sarcophagus was made of one of these, the stone being called Luxullianite, and composed of schorl, flesh-coloured orthoclase, and quartz. It has never been met with *in situ*.

The Cornwall Minerals Railway, from Par Station to New Quay, runs through this district, and gives great facilities for the development of the quarries. The chief one of these is the—

Colcerrow Quarry, which is not far from St. Austell, and is worked by Messrs. John Freeman & Sons.

The principal characteristics of the stone are the enormous size of the masses in which it is found, and the regularity of the beds, which, contrary to the usual lie of the rock, are very nearly horizontal. The beds drop occasionally though, and now and then the quarrymen are troubled by the minor joints running "tight." The masses of stone are rarely less than 1,000 tons, and frequently 3,000 to 4,000 tons in their cubic quantity. We measured a solid block which was *in situ*—48 ft. by 36 ft. by 5 ft. 6 ins.

It is distinctly a coarse-grained granite, and the structure of the stone renders it singularly appropriate for polishing where monolith or moulded work is required. The felspar is of two colours, white and light green, the latter being far less abundant than the former. The white felspar is very irregular in appearance; large patches of it are seen here and there, but the peculiar manner in which it fills up little cracks, and envelopes and isolates the other crystals, especially the quartz, is very marked. The latter mineral occurs in rounded grains, and in some places has a tendency to become ovoid, several little grains being joined together, making rough lines of quartz running short distances. Both black and white micas are present, the former being the more abundant. Schorl is also found in minute quantities.

Cavities of some magnitude are occasionally found in this quarry, and they are seen to be lined with a large number of different kinds of crystals and minerals, a collection of which was kindly presented to us by the chief quarryman, Mr. F. Nicholls. These cavities often contain water which the men use for drinking purposes.

The rock is very easily blasted, as the following experiment will show: 30 lbs. of rough-grained rock powder was placed in a hole 16 ft. 4 ins. deep, all the joints being free, and the bed tolerably even but rising slightly, and the result was that over 2,000 tons were moved out one foot away from the perpendicular face of the parent rock. It must be noted that everything was favourable in this blast.

The following experiment shows the facility with which the Colcerrow granite may be split. Three men were put to work on a block 4 ft. by 4 ft. 6 ins. by 2 ft. deep. They made fifteen holes 3½ inches deep with jumpers, and split the block along the freest way with tearers and feathers in thirteen minutes.

This granite has been used in the construction of the Plymouth breakwater and lighthouse and in docks in the south of England and at Pembroke, &c.

Tregarden Quarry.—This is situated close to Colcerrow, being worked by the same large firm of granite merchants. The stone is grey, and there is nothing particularly noticeable about it, except that the white orthoclase felspar is very regularly crystallised, and we saw at least a dozen specimens in which skeletons (in black mica) of the felspar were traced in regular outline, one skeleton being inside another, so that the development of the crystal at various stages could easily be traced. Such examples afford fruitful ground in working out hypotheses in connection with crystallisation.

The weathering of granite into tors is well seen in this quarry, the summit of which looks quite like an old castle.

Cottage Quarry.—This is in the Luxullian valley, and is worked by Messrs. John Freeman & Sons. The stone is porphyritic and resembles the others in the immediate neighbourhood. We saw a block *in situ* measuring 18 ft. by 14 ft. by 18 ft.

The following diagram is inserted to show the way in which the stone splits, from which it will be observed that no rule can be laid down in a granite district in regard to the direction in which the stone can be most readily worked. Even when stones are somewhat similar in texture and structure they may differ in this respect in different quarries. *a* is the cleaving-way running parallel to the bedding joints (as in Fig. 7); *b*, the quartering-way, and *c* the tough way. The stone splits easiest in the cleaving-way, and large orthoclase crystals, which appear to run in a general direction parallel to the bedding joints, determine the cleavage.

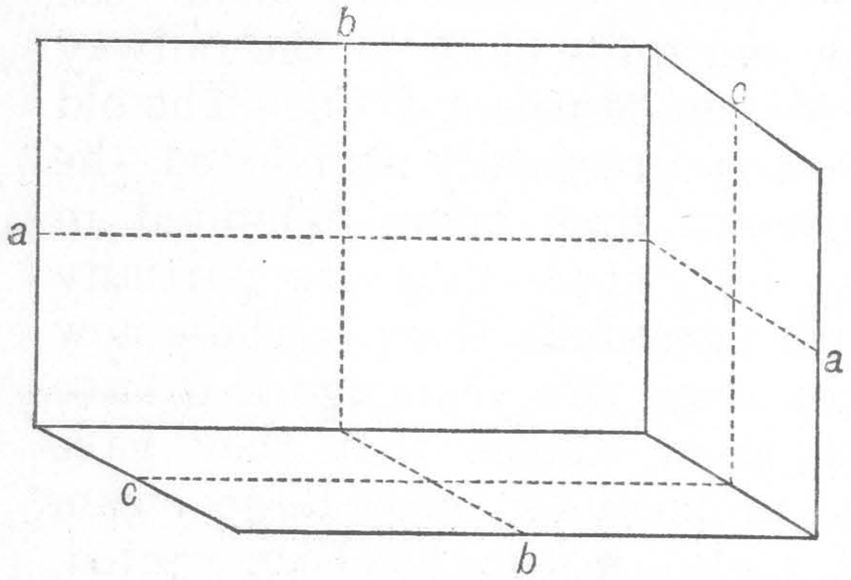

Fig. 8.

An experiment made for us to show the facility with which the material could be cut, gave the following result. Two men were placed on top of a block 5 ft. by 6 ft. by 2 ft. 6 ins. deep, and "jumped" fifteen holes, 3 inches in depth perpendicularly; whilst one man made five holes, 5 ins. deep horizontally in approximately the same plane, at the side. The block was then cut across the tough way by wedges, the whole operation taking half an hour.

Carn Grey Quarry.—This is near Luxullian and north of St. Austell, being worked by the same firm. The stone is rather fine-grained for Cornish granite, extremely hard, but of jointy structure and varying colour. It is used principally for pitching and kerb. A splendidly coloured red elvan runs through the quarry. It would make a magnificent stone polished. The granite on either side of it is disordered, and the stone is not extensively raised.

The granite in this district in the course of ages has undergone great decomposition, and the resulting silicate of alumina of the felspars has provided great thicknesses of kaolin or china-clay, which is one of the most valuable natural products in the county. It is largely raised round Carclaze, being used in the manufacture of china and porcelain. That the granite has decomposed *in situ* is certain, for the outlines of the felspars can be easily traced in the kaolinised material. Much of it, however, has been, removed by rain, &c., and has collected as pure clay at lower levels. It is noteworthy that the decomposition is constantly associated with parallel groups of quartzose or schorlaceous veins, which include also tin oxide; indeed many of the kaolin deposits continue in the direction of veins for as much as a mile in length, while their breadth may be but a few feet.*

IV.—PENRYN DISTRICT.

The granite of this district is more largely quarried than any other in Devon or Cornwall. The rock found here, in some places, is more like that of the Dartmoor and St. Breward districts, in mineralogical constitution, than that of the Luxullian, schorl not being abundant, whilst large felspar crystals render the stone porphyritic. These, however, are occasionally absent. Schorl sometimes occurs in veins, on the confines of the mass. There is a great uniformity in the grain of the granite in this district. With the exception of the Carnsew quarries and a few isolated and unimportant patches, it is a medium between coarse and fine grain. It is comparatively easily quarried, lies in large masses, though not so large as those in the Luxullian district, and the workings are carried on all the year round, as the climate is favourable. The

* Consult J. H. Collins, F.G.S., "On the Hensbarrow Granite District;" David Cock, "A Treatise, Technical and Practical, on the Nature, Production, and Uses of China Clay" (1881); and Brenton Symons, F.C.S., "Geology of Cornwall" (1884).

quarries lie from a mile and a half to five miles distant from the port of shipment, and are mostly worked at piece-work by gangs of men whose knowledge of the nature of the rock and skill in its manipulation are remarkable.

There are many quarries worked round Penryn which we do not think it necessary to speak of in detail. Messrs. John Freeman & Sons, whose headquarters are in Penryn, carry on an extensive trade in this district, and work a large majority of the quarries. In the vicinity the quarries of the West of England Granite Co., and Mr. Hosking, are also situated, and although Penryn cannot be called the "granite city," a large number of skilled masons and workers in granite find active employment as the hands of the three firms mentioned. The characteristic "ring" of the granite as it is struck by the chisels, and the "peal" of the jumpers of a gang of men at work on the refractory material, are the first sounds one hears on entering the place from the Falmouth road. Gantrees, cranes, engine-houses, and chimney-shafts soon come within sight. Vessels are being loaded with large blocks, for Cornish granite is principally used for engineering purposes, and now and then a traction-engine dragging its heavy burden from the quarry to the small shipping quays, may also be seen.

Carnsew Quarries.—These quarries, which are situated a little over a mile from the shipping quay at Penryn, have been very largely developed by Messrs. John Freeman & Sons.

The fineness of the grain, combined with the large size of the masses raised, are of great advantage to them; consequently the rock is employed for the more important parts of engineering works, and also largely for monumental purposes.

The colour of the stone is bluish-grey. It more closely resembles the De Lank granite, already described, than any other Cornish granite we have seen. It is even in texture, and is not porphyritic. The felspar is white, the crystalline boundaries not being at all well defined. Both black and white micas occur, the former being more abundant than the latter. Quartz is tolerably plentiful in small grains.

An experiment to test the facility with which holes can be bored in the stone will be found later on (p. 117).

To show the effect of a blast in these quarries, we may mention that a hole 8 ft. 6 ins. in depth, and 4 ins. diameter was bored, and twenty pounds of rock powder used to turn out a mass weighing 360 tons (not one block), which was lifted against the bed and cracked in several directions.

A very large portion of the arch-stones of Putney Bridge was supplied from these quarries.

Penryn Quarries.—The colour of the granite is grey, and differs from the Carnsew in being much coarser. The orthoclase felspar is white, some of it being irregular, but well-defined twinned crystals, about one inch in length, are seen close together, making the stone porphyritic. White and black micas are both present, the former being much more abundant than in the Carnsew; large silvery white flakes occur. The black mica is occasionally congregated together in small patches. Clear quartz is present in little grains, the average size being about 4 or 5 mm.

This stone is also used very extensively for engineering purposes.

Quarries have been opened in *Carnmath Hill*, near Redruth, and from the few samples of the stone we saw, it appears to be a good material. It is known as "Redruth" granite, and is much used locally.

V.—PENZANCE DISTRICT.

Generally speaking, the granite of this district has a considerable amount of schorl in addition to the three essential minerals. It is often porphyritic. The outskirts of the mass to the west of Penzance contain good examples of schorlaceous granite and schorl rock (schorl and quartz). Near Trevalgan, St. Ives, large felspar crystals are present with schorl and quartz, the mica being absent. At Tregender, near Ludgvan, the granite is composed of all four minerals, mica being especially abundant.

Lamorna Quarries.—These are situated on either side of

Lamorna Cove, about five miles from Penzance Harbour, those on the north-east being worked by Messrs. John Freeman & Sons. At present, however, the great difficulty in loading vessels with the stone prevents its more extensive use. Such is the nature of the coast round Lamorna Cove that ships have had to put out to sea two or three times whilst loading, or run the risk of being wrecked. This, of course, adds considerably to the expense of the material.

The general colour of the rock is light greenish-grey. Felspars are light green and white, those helping to form the base being scattered about irregularly. The dirty white felspars which cause the stone to become porphyritic are unusually large, some being 2½ inches to 3 inches in length. Both black and brown micas occur as very small flakes, and large black crystals of schorl are exceedingly plentiful. The transparent quartz is in little grains, being fairly distributed, but not too abundant.

The large crystals generally, in this quarry, do not occur with the longer axes approximately in one direction. Consequently it is often difficult to split the rock up. Although this renders the quarrying of the stone somewhat troublesome, it is an advantage rather than otherwise as far as the strength of the material is concerned. The crystals interlock with one another, and the stone has therefore no tendency to cleave along the planes which coincide with the clinopinakoids.* Black mica occurs in small quantities, whilst although the quartz is not over-abundant, here and there it is, for Cornish granite, in rather large crystals. Small pieces of black schorl are common.

The joints in these quarries frequently go "tight." It is not uncommon to find small pieces of schist caught up in the granite from the quarry on the southern side of the cove.

Sheffield Quarry.—This quarry takes its name from the village of Sheffield close by. It is about two miles and a half from the westernmost point of Penzance, being also worked by Messrs. Freeman.

* The planes of composition.

The boss of granite whereon this quarry is situated is rather peculiar. When it was first opened a point of granite was exposed above the surface, and working from that central point, the declination of the surface of the rock was about the same on all sides. The crust of ordinary earth varied in depth from two to eight feet, under which the granite appeared to be kaolinised for about a foot before the ordinary granite was reached.

The stone has a rather fine base composed of small crystals of light green felspar, which occurs in little granules; dirty white felspar exists in small pieces enclosing minute grains of quartz. Like Lamorna, the large white orthoclase felspars, which make the stone porphyritic, are very large, being frequently twinned on the Carlsbad type. Sometimes these large felspars are crystallised in a peculiar manner, presenting the appearance of a cross with boundaries well defined. The felspars lie parallel with the bedding joints, and unlike those at Lamorna, determine the cleaving-way of the stone.

We saw a blast in this quarry. The hole was 8 feet deep and 4 inches in diameter; the charge of nine pounds medium-grained rock powder threw 500 cubic feet of granite out from a tough joint up an inclined surface; 400 feet were removed 6 feet from the parent rock and 100 feet in four blocks were hurled 20 feet away.

The stone is principally used for dock-work, in blocks varying from one to ten tons, and also for dressed fronts of buildings, rough walling, pavings, and kerbings. It is carried by waggons for shipment to various ports, both at home and abroad. At present the material is being supplied for Her Majesty's dock at Malta.

New Mill or *Cranken Quarry.*—This quarry is situated about four miles north of Penzance, and is worked by Messrs. John Freeman & Sons.

About eight feet of earth crust and six inches of kaolinised granite were dug out before solid stone was reached. It is different in appearance from either Lamorna or Sheffield, the prevailing felspar being of a light yellow colour, and rarely light green. The porphyritic crystals are not so well defined, and the felspar and quartz are more equally divided. In places this granite contains little patches of dark matter, having a very fine microscopic base, in which black needle-like crystals are distinctly prominent, whilst the large orthoclase spars that occur in the base are usually much clearer and with more definite boundaries than in the other parts of the rock. Little schorl crystals are very abundant at the expense of the mica, which is black, or more rarely dark brown. The quartz occurs in small granules, making the rock look compact. Very large blocks have been raised.

The two quarries, Sheffield and New Mill, now represent nearly the whole working of granite near Penzance.

To give names of buildings, embankments, docks, &c., in which Cornish granite has been used, would be simply making a list of nearly all the great undertakings in this country carried out during the last thirty years in which large blocks of granite, consistent with economy, have been special requirements.

We may, however, mention the following: Keyham, Chatham, Portsmouth, Devonport (No. 3), and Bombay dockyards; Dover and Alderney breakwaters; Hanois, Ceylon, Wolf, and Bishop Rock lighthouses; Putney and Blackfriars bridges; fortifications at Plymouth, Portsmouth, Portland, Sheerness, Harwich, the Scutari and Wellington monuments.

CHAPTER V.

ENGLISH HORNBLENDIC GRANITE QUARRIES, SYENITE, &c.

A.—HORNBLENDIC GRANITES.

THE principal districts in which hornblendic granites occur in England are at Shap Fell, in Westmoreland, and in the igneous mass of Leicestershire.

The *Shap Quarries*, worked by Mr. Jas. Fenning, are situated at a considerable elevation above the works where the granite is polished, &c., and the two are connected by a railway, the gradients of which are about one in twenty-five.

In recent geologic times, glacial action has been at work in the district, and blocks of stone from this mass of rock have been carried away great distances from it. As might be expected, the adjacent moors are strewn with them, but chiefly to the east and south-east. Blocks of Shap granite have been found at irregular intervals, all the way between the quarries and the east coast, some sixty miles distant at the nearest point. In a south-easterly direction they have been carried farther still, and there is one, about 14 feet by 12 feet, half embedded in the ground at Seaham Station, two miles from Scarborough, —a distance of more than ninety miles from the quarries.

The stone itself may be described as a porphyritic hornblendic granite. It varies in colour from light grey, dark grey, golden grey, pink, full red, and deep purple, but for the purposes of commerce there are only two varieties, known as dark and light Shap. The base of the rock is fine, the dark kind having small granules of quartz, clear and transparent; the felspars are mostly deep red, but pink and almost white crystals are seen here and there.

Mica occurs in minute black flakes, whilst the comparatively speaking little hornblende present is just sufficient to cause the rock to be removed from the ordinary granites. Iron pyrites is also present in small quantities. The ground mass of the light kind is slightly coarser than that of the dark, yet it may still be called fine-grained, and it owes its light colour to the fact that the felspars, instead of being dark red, are a light yellowish green, sometimes almost white, and occasionally light pink. Otherwise the two rocks are very similar in appearance.

The large orthoclase felspars that cause the rock to become porphyritic are salmon-coloured, and, as compared with those in Cornish granites, are remarkably uniform in size, being usually from 1 to 1½ inch in length. They are twinned, and do not appear to lie in any particular position, except for short distances, so that the planes of the crystals, if produced, would intersect one another at various angles. The stone is capable of taking a high polish.

The face of the principal quarry is upwards of 130 feet in height, and detached blocks, weighing from 1,500 to 2,000 tons, have been blasted; but for practical purposes, blocks of more than 20 tons are seldom required.

Shap granite has been used in various parts of the country, and nearly all architects are well acquainted with its artistic appearance. The student will find good examples of the stone in the posts round St. Paul's Cathedral and the Temple Bar Memorial.

Attention will now be directed to the hornblendic granite of Leicestershire. There are many different kinds of stone quarried in this district, which bear but one name—granite—in the market.

The hornblendic granite of *Mountsorrel*, where there are large quarries (worked by the Mountsorrel Granite Co., Limited) is intrusive through a metamorphic schist; but its exact geologic age cannot be defined further than that it is of pre-carboniferous date. The neighbouring syenites of Groby and Markfield are shown by Mr. Hill and

Prof. Bonney to have been distinctly intrusive in Silurian slates, probably about the commencement of the Devonian period; whilst the greenstones of the Forest may belong to the period between the Carboniferous and the Trias.*

The stone obtained from the Mountsorrel quarries is of two colours, a pink and a greyish white, due to the difference in the tint of the felspar, this mineral occurring in very small crystals. The mica is black (biotite), and not too abundant, whilst, although the quartz is usually rather small, here and there it is in crystals of medium size, some being at least 14 mm. across. Hornblende occurs as minute almost black specks as well as thin elongated needle-shaped crystals. Microscopic sections show the presence of magnetite and apatite; and the brassy lustre of iron pyrites is apparent in places. Little round patches of exceedingly fine-grained mineral matter, of a hard nature, may also be occasionally seen in the rock, which, taken as a whole, might be described as a fine-grained, compact, hornblendic granite.

The decomposition of the surface stone by the ages it has been exposed to the weather extends down to more than twenty feet, the stone to that depth being quite friable.†

The working face of the Mountsorrel quarries is nearly half a mile in length, and forms a conspicuous object from the Midland main line between Sileby and Barrow stations. To obtain the stone, large chambers are excavated on the top of the hill, in which charges of gunpowder—sometimes as much as half a ton—are placed and fired. The blocks brought down on the floor of the quarry are then shotted, *i.e.*, split up by small charges of powder or dynamite. Masses of the rock are sometimes hurled by these agents to surprising distances; and instances are on record of small pieces having fallen in the village at the foot of the cliff. Great precautions are taken, however, to prevent accidents.

Large quantities are broken up for macadam, both by hand and machinery. In some parts of the quarries are still to be seen a few of the old-fashioned "ring-breakers,"

* *Quart. Jour. Geol. Soc.*, vol. xxxiv., p. 199 (1878).

† W. J. Harrison, F.G.S., "Geol. of Leicestershire, &c.," 1877, p. 10.

or men making macadam by hand. These breakers use a small short-handled hammer, and hold an iron ring in their left hand. With this ring they rake down the lumps of stone on to the block upon which they are broken, and also hold the pieces together to prevent their flying about. The stone is likewise used for kerbing, paving-setts, gravel for paths, concreting, &c.

A railway line has been constructed from the works to the Midland Railway, and there is canal carriage by the Soar.

The student will find further information concerning these quarries in the *Builder* of November 12th, and December 10th and 24th, 1870.

B.—SYENITES.

In concluding our remarks on the quarries of England in which granite is raised, we must not omit to say something concerning the workings in an equally crystalline rock, of very similar if not identical origin, namely syenite (see p. 7). Patches of syenite exist scattered over our islands, notably in the Malvern Hills, Mountsorrel district, and in four or five places in North Wales. They are quarried principally for road-metal, curbing, steps, &c.

Large syenite quarries have been opened in *Markfield Knoll*, near Leicester, by Messrs. Ellis & Everard.

The colour of the stone is dark green, freckled pink. It is composed of pink orthoclase felspar in minute crystals; hornblende, which is dark green, and very abundant; and a little quartz. The minerals are not very well defined, as they closely interlock each other, and the rock is so much altered, that the accessory minerals which might be present are now unrecognisable. It is very close-grained and compact, breaking with a splintery fracture. A vein of calcite of a pinkish-grey tint and a well developed rhomboidal structure, crosses the face of the workings. It is so pure that it has been proposed to use it for economic purposes.

Markfield stone is largely used for kerbs, paving-setts, and road-metal.

Groby Quarries.—These are situated near Glenfield, and about five miles north-west of Leicester. The "Patent Victoria Stone Co.," have quarries here.

The stone is very similar to that of Markfield, perhaps, if anything, of a little darker hue. It is composed of pink orthoclase felspar, hornblende, and a little quartz. There is also some opaque mineral, evidently in a greatly altered state, perhaps originally pyrites or magnetic oxide of iron. The felspar is in distinct crystals, but has often caught up much hornblende; the quartz fills up the spaces between the other minerals, or is curiously crystallised with the felspar, so as to form a microscopic "graphic granite" or "hebraic felspar"; and it is especially important to bear in mind that the quartz contains very many "fluid cavities," nearly filled with water, which indicate that the rock was consolidated under very great pressure. These fluid cavities also show the spontaneous movement of the bubbles contained in them very well indeed (Sorby).

The stone is used for paving-setts and road-metal. Crushed granite from quarries at Groby is used in making the Victoria stone.*

Stoney Stanton Quarries.—These are situated about nine miles south-west of Leicester, on a patch of igneous rock isolated from the main mass. They are worked by the Mountsorrel Granite Co., Limited. The stone is a syenite, composed of quartz, felspar, hornblende, and some magnetite; it is easily worked, and is used for kerbs, road-metal, &c.

There are quarries also at *Cliff Hill*, near Markfield.

Charnwood Quarries.—These are sometimes known as "Sheepshed Quarries," and are near Loughborough, being worked by the "Charnwood Granite Co." The stone is a syenite, as it contains felspar, hornblende, and a little quartz, but has undergone such an enormous amount of alteration, subsequent to its original formation, that it has a somewhat dull appearance.

When breathed upon, it emits the earthy smell characteristic of rocks containing a considerable amount of

* For a description of this, see *The Builder*, vol. l., p. 939.

silicate of alumina. The felspar is of two colours, one being light green, almost white; the other pink. The former frequently occurs in crystals 4 or 5 mm. across, the latter not being one-fourth of this size. The tinge of green seen in the felspar has been, most probably, produced by the decomposition of hornblende. The latter is dark green, and the high specific gravity of the rock is, no doubt, due to its abundance.

The rock has been called by some a "syenitic greenstone." The term "greenstone," however, includes so many rocks of different chemical and mineralogical constitution that it is somewhat ambiguous, and is thus likely to be misunderstood. If the rock were not so much altered and the felspar in it clearly capable of being referred to a triclinic species, we should have no hesitation in calling it a quartz-diorite, which it very much resembles.

It bears considerable mineralogical similarity and might be more strictly compared with the quartz-diorite of Quenast, in Belgium, than with any other rock used in the trade. The Quenast rock is quarried for paving-setts and macadam, being largely used in North-Western Europe, and is not unknown in the London market. The stone, however, is porphyritic, the crystals being small but prominent, and contains distinct accessory minerals. It has been the subject of a searching investigation by MM. De la Vallée Poussin and Renard.*

We have described the Charnwood rock at some length, because its high specific gravity and crushing weight have long been a puzzle to engineers and surveyors, it being known in the market as "Granite."

The quarries have been opened about twenty years, and are close to a branch of the L. &. N. W. Railway.

Syenite is also found in the *Malvern Hills*, Worcestershire, where it consists of reddish felspar, quartz, hornblende, and sometimes epidote.

C.—OTHER IGNEOUS ROCKS.

Bardon Hill Quarries.—These are situated about eleven

* See "Mém. cour. et des sav. étrang. de l'Acad. Roy. Belgique," xl. (1876), p. 265.

miles north-west of Leicester, on the highest ground in the county.

The stone, which is worked by Messrs. Ellis & Everard, is not a "granite," although known by that name in the market. Prof. Bonney says it has orthoclase and much quartz in it. He thinks that the Bardon Hill mass is the stump or plug of a cone, for there is a great deal of agglomerate on the side of the hill.

There can be no doubt that the rock belongs to the acidic series, and the term "felstone" in all probability is the one most applicable to it. It is less distinctly crystalline than the syenites of Groby or the hornblendic granite of Mountsorrel. The prevailing green colour is, no doubt, due to the decomposition of small quantities of hornblende, or other lime magnesia silicate, the resulting green hydrous silicate being more or less diffused throughout the whole rock.

The above description does not apply to the entire mass. Some varieties in the vicinity of quartzy veins present mineralogical features of much interest. The quarries are worked on two floors. The mass of the rock has a peculiar apple-green tint, and is very close in texture.*

It is much used as a road metal in the midland counties, for which purpose it is exclusively quarried. It does not break into cubes, as do the syenites, and is mostly broken by machinery.

Penmaenmawr Stone Quarries.—These are situated in North Wales, and are well known throughout the country for paving-setts and the like.

The stone is very easily split by cutting a fine line with an axe in the direction required, and then giving the stone a few smart taps with the hammer (Seddon).

Rowley Rag is a basalt found in Staffordshire and used for paving-setts.

* W. H. Hudleston, M.A., F.R.S., in "Proc. Geol. Assoc.," vol. iv.—Excursion to Charnwood Forest.

CHAPTER VI.

THE CHANNEL ISLANDS QUARRIES.

NEARLY all the quarries of Jersey and Guernsey are in hornblendic and syenitic rocks, but dykes and veins of other igneous rocks are not uncommon.

A.—JERSEY.

Most of the stone now raised in this island is used for local purposes, although until recently it was sent in large quantities to England. One is forcibly reminded of this in some of the quarries where gantrees and steam-engines are lying idle. It is not because the quality of the stone in these quarries is inferior that they have been so neglected of late; on the contrary, we can state with much confidence that the syenites and hornblendic granites of Jersey are generally of excellent quality. One has only to examine the old stone walls scattered throughout the island to be cognisant of the fact. We occasionally meet with books which inform us that the rocks of the Channel Islands are not more extensively used because the stone does not occur in blocks of sufficient size.

Now, however much this may be true of the other islands, it is certainly incorrect to apply the remark to Jersey. The quarries in the south-west part of this island have been worked a long way into the sides of the hills, and entire blocks may now be seen, both detached and *in situ,* which no machinery could conveniently shift. The upper parts of the quarries, as usual, contain but comparatively small blocks, and people are apt to run away with the idea that these represent the largest size obtainable when the workings are not on an extensive scale.

As a rule the blocks become larger as the rock is worked into.

We suspect that the reason why these large quarries have been almost abandoned is a purely commercial one. Although so near the sea, the nature of the coast forbids the approach of ships in which the stone could be loaded, except in the calmest of weather; and unless a harbour could be constructed close by—a very expensive operation —it is clear that the whole of it intended for shipment must be sent to St. Aubyn's or St. Helier's, a process which materially adds to its cost.

Notwithstanding the quantity of stone raised, we are informed that there are no polishing works in the island. We are quite prepared to believe this, as many of the polished slabs and columns in St. Helier's appear to be made of Peterhead granite and not of local stone. The absence of steam drills and other machinery of a like nature is very conspicuous, but the demand would have to be much greater than at present to enable such to be profitably used. We notice, too, that even some of the buildings at present being erected in that town are partly made of granite brought from France. This is a case somewhat analogous to taking coals to Newcastle.

We were rather surprised to find in some parts of the island that the granitic bosses had weathered so deeply, and this in close proximity to quarries containing good stone. It is usual to find some earth and decomposed rock in all districts where the stone is sheltered and contains very much felspar, but here the reddish earth, with loose quartz crystals sticking out from it, may sometimes be seen to a depth of from 30 feet to 35 feet, a little way inland; and if this is taken to indicate—as it is in some districts—that the rock is easily decomposable, a wrong impression would certainly be created. It seems a good indication that the island has not been raised out of the sea in recent times.

Splendid examples of the tremendous power of the waves may be seen in the abandoned breakwater at St. Helier's, and in the large wall at Greve de Lecq, both of which have been breached; and in the former case the huge blocks of pieces of granite concreted together have been hurled some distance and piled upon each other in an extraordinary manner.

Close to *Greve de Lecq* there is a quarry in hornblendic granite. The stone somewhat varies in texture from very fine to medium grain, and is of dark and light grey colours, slightly tinted pink in places. Quartz occurs in small crystals, but in the coarser varieties it is sometimes distributed in such a manner as to show prominently. The mica is black, the hornblende—present only in minute quantities—dark green, and the felspars are also very small, being either white or light pink, according to the tint of the rock. The junction between the fine and medium-grained granite is well seen in the quarry.

At *Grosnez*, the extreme north-west point of the island, the hornblendic granite is rather coarse-grained, this being principally occasioned by the large size of the orthoclase felspars, many of which are twinned. Some of these are pink—the general colour of the stone—whilst the smaller crystals are almost white, or light red. The very little mica present is black, the hornblende dark green, and the small quartz grains appear smoky.

Mont Mado Quarries.—These are in full working order, are situated in the north of the island, and worked under the management of Mr. Joseph Le Seelleur. A steam crane lifts the detached blocks from the bottom of one of the quarries to the level of the workmen's shops. The stone is a granulite. Mica is present, but not discernible until after a protracted search, and occurs in such minute quantities that it does not affect the main structure of the rock, so we prefer to describe it as an accessory mineral. The stone is of two colours, pink and dirty white, due, as usual, to the prevailing tint of the felspar. This mineral, although plentiful, occurs in small crystals. The quartz is in small rounded grains, and their shape gives the rock a peculiar granulated appearance. This is more particularly the case with the lighter-coloured stone. Hornblende, schorl, and magnetite are also present.

Large blocks are raised from the Mont Mado Quarries, and the very even grain can be well seen in them. The

rock is comparatively easily worked, and is largely used in Jersey for all kinds of building purposes, kerbs, &c.

La Perruque Quarries.—Although quite close to Mont Mado, the syenite from these quarries is coarse-grained, due principally to the orthoclase felspar being large and porphyritic. Mica is in very small quantities as an accessory mineral, hornblende being very abundant, and the quartz transparent and in little grains. It is now mostly used for local purposes.

La Moye Quarries.—These very extensive quarries, in the south-western part of the island, are not so much used now as formerly, but we hear that a company is about to carry them on, if it has not already commenced operations. When we were there in 1886 the remains of past industry were seen in the shape of enormous spaces of "opened up" rock, a gantree, and some steam-boilers and engines. The stone is a coarse-grained syenite, presenting all the appearances of ordinary granite, but the remark made respecting the mica in the Mont Mado stone applies equally to this. All the minerals are large, and the complicated manner in which they are interlocked causes the material to look very compact. The colours are of various tints of pink and grey. The felspar ranges from vermilion to smoky white, these different tints being often seen in one piece of stone. In those parts of the quarries where the general colour of the mineral is pink or yellow, hornblende occurs in minute quantities. In the lighter kinds it is very abundant, being dark green and frequently occurring in needle-shaped crystals; schorl also appears to be present, though not very distinctly.

A vein of fine-grained syenite of a dark green colour, and very much resembling the ordinary Guernsey road-metal, runs through part of these quarries, but is not sufficiently large to cause it to be worked more than is necessary for clearing up the face of the stone.

La Moye stone may be seen in buildings in all parts of the island, and it has been used in the construction of Chatham Dockyard and other large engineering works in England.

Portlet Bay Quarries.—These are on the south side of the island, close to Noirmont Point. This syenite is similar in appearance to that of La Moye, the crystals not being at all well defined, and are so much mixed up that the rock looks compact. Here and there the orthoclase is twinned on the Carlsbad type.

Southill Quarry is close to St. Helier's, and is principally worked for road-metal by the St. Helier's Harbour Committee, Mr. Thos. Blake, manager. The syenite is very fine grained and of a pink colour, due to the tint of the felspar. If mica were present, it would look exactly like the hornblendic granite of Mountsorrel. Hornblende is abundant. A vein of dark-coloured syenite, similar to the Guernsey stone before referred to, runs through the rocks on the shore up to this quarry, and if it could be easily got at, and were a little wider, the quarrying of it would form a profitable undertaking. A lava dyke (mica-trap) also occurs not far from the head of the present workings.

There are, in addition to those mentioned, quarries in the central and eastern parts of the island.

Much information on the different kinds of rock obtained, and many important details, will be found in "Géologie de Jersey," par Le P. Ch. Noury, S. J., recently published, with map.

B.—GUERNSEY.

The quarries here were first extensively worked about fifty years ago. Nearly all of them are situated in the northern half of the island. The stone obtained is described by some merchants as being all granite, and by others as all syenite. As a matter of fact, although syenite is quarried, yet by far the greater quantity of stone raised is hornblendic granite. It is, however, of quite different appearance from the ordinary hornblendic granites of Jersey or Leicestershire, being either a dark green or grey colour.

In examining a large collection of Guernsey stones, one is often met with the difficulty of discriminating the difference between the syenites and the hornblendic granites, owing to the variable occurrence of the mica. Sometimes it is a very distinctive feature in the rocks, and at others is so rare as to rank only as an accessory

mineral. From this it will be seen that the quality of the stone is also variable, a fact that should be borne in mind by those who habitually regard Guernsey "granite" as of one quality only. There can be no doubt that the road-metal and kerbstones obtained from this island are, generally speaking, first-rate; but uniform quality must not be expected, even from such a limited area as that now under consideration.

Then, again, the grain of the rock differs considerably, in some cases even in that obtained from the same quarry. The hornblende ranges in size from mere microscopic specks up to crystals half an inch or more in length, and often so predominates as to cause the stone to be made almost wholly of that mineral, which has a high specific gravity. We notice that several veins of hornblendic rock occur in the island, and in one large quarry, crystals of hornblende were distributed in the ground mass, in a very conspicuous manner. Quartz never occurs here in large crystals, and the mica is generally represented by very little flakes. The felspar appears to be mostly triclinic, of white or light green, and exceedingly minute; orthoclase is found in the rocks from the western side of the island. Iron pyrites is often seen in the coarser varieties, and in the veins just alluded to, it occurs in lumps an inch or two in diameter.

The finer-grained rocks all agree in being very tough and compact, especially when mica is rare or absent, and this is why they are so eminently suitable for road-metal. The "crushing-weight" of Guernsey granite is occasionally quoted on this side of the water as though all the stone were obtained from one quarry, of uniform structure, and capable of bearing exactly the same stress, neither more nor less. As the student will see, this is a great mistake, and the sooner it is acknowledged the better. The resistance to crushing, in rocks of such variable structure, must vary considerably, and many more experiments will have to be made before anything like satisfactory conclusions can be drawn in regard to their strength. Until that time arrives, those engineers and surveyors who have not made up their minds that the number of recorded experiments is wholly inadequate to express the practical utility of much of the stone, may safely do so. Probably, that time will never come, and, as regards the material obtained from quarries exclusively worked for road-metal, we do not think that such experiments are needed (see p. 131).

"Granite" is the chief export of the island, and its magnitude and importance may be seen on going to St. Sampson's Harbour, a place about two miles north of St. Peter Port. Here is a magnificent harbour, in which ships are being filled with granite, stupendous stacks of pitching and kerb-stones, and huge heaps of broken stuff being in readiness for shipment. We are informed, on good authority, that the total amount of stone annually exported from the island is not less than 220,000 tons. In the year 1885 it was as follows:—

	Tons.
From St. Sampson's Harbour	197,000
From St. Peter Port	17,782
	214,782

Of this, Guernsey vessels alone took 120,000 tons. It is sent principally to London and to towns in the south of England and Wales.

In describing granite areas, we have hitherto given the names of the quarries and the particular kinds of stone obtained therefrom, but if this were attempted to be done with Guernsey, we should merely present the student with a long list of French names, whilst considerable tautology would be inevitable in the description of the rocks. The quarries are principally worked by Messrs. John Hamley, Mowlem & Co., Gillingham, Le Maitre, and A. and F. Manuelle. To get an idea of the great number of quarries here, one has only to look round on all sides at the multitude of windmills so close together. These windmills as a rule mark the existence of quarries, for they are used to pump the water up from the bottom of the workings.

Large quarries, such as the Juas and Baubigny, both worked by Messrs. Mowlem and Co., have powerful steam cranes at work, which are used to lift carts from the road

at the top of the quarry to the floor of the workings, where they are filled and then lifted up again to places where horses are in waiting to take them away. This saves a considerable amount of labour. It is a curious sight to see the carts hitched on, swung round, and suspended in mid-air over a deep precipice, down which the men at work look like dwarfs. There is an incessant din created by the noise of the hammers, chisels, and crowbars of the workmen, reverberating against the solid walls of the wide gulf.

Both powder and dynamite are used in blasting the stone, but we saw no rock-drills at work, and were informed that they are not used in the island. Surely they might be advantageously employed.

C.—HERM AND SARK.

Hornblendic granite has been quarried in Herm for many years past, having been principally used for paving. The Rev. E. Hill, M.A., F.G.S., who has contributed very largely to our knowledge of the geology of the Channel Islands, says in a recent communication to the Geological Society,* that the granite of Herm is a highly crystalline rock, consisting of white felspar, both orthoclase and plagioclase, hornblende, quartz, and biotite, with a little apatite; that occasionally mica encloses a hornblende crystal; the felspar often shows plagioclase striping even to the naked eye. The hornblende is in well-formed crystals, often lathe-shaped. Mica is the least abundant essential constituent.

The rock of Jethou is much the same as that of Herm.

The granite of Sark is hornblendic also, but it would appear † that both the quartz and mica are variable in their occurrence. Much of the quartz present is secondary in origin. The structure and jointing are massive and irregular; there is no general appearance of bedding, nor any uniformity of divisional planes. It, however, possesses a rude cleavage or tendency to foliation in some parts of the island. Gneiss occurs at Creux Harbour.

* *Quart. Jour. Geol. Soc.*, vol. xliii. (1887), p. 333.

† *Id.* p. 328.

CHAPTER VII.

SCOTCH GRANITE QUARRIES.

THE granites of Scotland are chiefly quarried in Aberdeenshire, Kirkcudbrightshire, Argyleshire, and the islands of Arran and Mull. In a lesser degree it is also obtained from parts of Perthshire, Banffshire, Sutherland, and in the Hebrides.

A.—ABERDEENSHIRE GRANITES.

The granite quarries in this part of Scotland are unquestionably amongst the most important in the United Kingdom, and stone from some of them has been sent into the market for the last century.

Aberdeen granite is known, not only in Great Britain, but in many foreign countries, even as far as the antipodes. The quarries are principally situated on two distinct masses of granite, which differ from each other in a marked manner. Those on small and isolated patches we shall refer, as usual, to the nearest main mass with which they appear to be related. The two principal masses we shall designate (1) the Aberdeen district, and (2) the Peterhead district. Dr. Haughton thinks that the granite of the former district is, generally speaking, much more ancient than that of the latter.* Generally speaking, the Aberdeen granite is of a grey or light blue colour, and the Peterhead pink or red. There are exceptions, however, to these rules (see Cairngall, p. 83, and Corrennie, p. 76).

* Proceedings Royal Society, vol. xviii. (1870).

The rocks of the former district in some places show a rough tendency to foliate, and they may be looked upon in a great measure as the products of extreme pressure—metamorphism.

The mineral constitution of the granites of this county varies greatly. Speaking broadly, it consists of a mixture of quartz, felspar, and mica, frequently with the addition of some hornblende. This last mineral, however, is almost without exception in very minute quantities, and may thus be regarded as merely accessory; but true hornblendic granite is not unknown in the county. Occasionally the mica occurs in very small quantities; sometimes it is nearly or altogether absent, and many considerable masses of rock occur, known as granite, composed principally of quartz and felspar, with very little of anything else.

The difference in colour is owing primarily to the nature of the felspar, this mineral varying in tint from red to white. The redness is, no doubt, owing to the presence of peroxide of iron disseminated throughout the mineral.

Besides the Peterhead district, reddish granite is very common in many of the mountains in the interior of the county, more especially near Braemar. The celebrated mountain known as Lochnagar, not far from Her Majesty's Highland residence at Balmoral, is wholly composed of granite, much of which is of a reddish colour Ben-Muick-Dhui, Ben Avon, and Cairngorm, which are amongst the highest hills in Scotland, are likewise all formed of granite.

With such an abundance of material in the county, and much of it being near the sea, it is not wonderful that, after engineers and others gave an impetus to the quarrying of it, granite work became one of the most important industries, not only of the county, but of Scotland. We learn that even in 1817, the quantity of stone exported from Aberdeen to London was 22,167 tons; in 1821, the total export was 34,687 tons; and in 1868, about 50,000 tons. The amount fluctuated considerably in different years of the above periods. In 1860, for example, it only reached 24,666 tons. This, of course, represents nothing like the total amount raised from the quarries during the respective years, and it is calculated that over a million tons are now quarried in Aberdeenshire every year.

We are informed that years ago the trade with America was once much more considerable than it now is, which is largely owing to the import duty being so great and to the opening up of quarries in Rhode Island and elsewhere. Many of these latter are in the hands of well-known Scotch granite merchants. The following statistics have been supplied to us to show the value of granite sent from Aberdeen to America from the year 1880 to 1884 inclusive, which prove, however, that the trade is increasing:—

	£	s.	d.
1880	12,343	15	10
1881	14,344	3	8
1882	15,745	15	5
1883	18,807	7	11
1884	25,930	17	1

We will now describe the principal quarries that have come under our notice.

I.—ABERDEEN DISTRICT.

Rubislaw Quarries.—These are situated about two miles from the centre of Aberdeen, are six to seven acres in extent, and have been worked for a great number of years. Messrs. John Gibb & Son work one part of it, and Messrs. A. Macdonald Field & Co. another. The granite is of a greyish-blue colour, and very fine-grained. The three minerals are equally mixed, quartz being transparent white, felspar white and generally minute, but occasionally crystals up to 7 mm. in diameter are seen; the mica is black. A vein of giant granite runs through a part of the quarry.

The rock lies in irregular masses, with numerous seams in all directions, and the blocks are usually found standing on the flat. One portion of the quarries has been worked in benches of from 50 feet to 70 feet in depth, and the present section of rock shown will last a number of years,

even at the present rate of output, without compelling the owners to sink any deeper. Every time the quarry has been deepened the stone has assumed a slightly richer greyish-blue colour, which renders it valuable for monumental and polished work, for which purposes it is very largely used. It is one of the best granites in Great Britain. The blocks are roughly dressed and squared with hammers, and those intended to be polished are sent to the various granite works in Aberdeen, whence it is not only carried to various parts of the United Kingdom, but to America, Australia, and to the East generally.

Most of the paving-stones made, come into the London market, and the rest of the produce of the quarries is used for ordinary building purposes.

From 1795 to 1820-30 this stone was supplied in large blocks for dressed work, and used in the construction of Portsmouth and Sheerness Dockyards, Bell Rock Lighthouse, balustrade of Waterloo Bridge, London Bridge, &c.

Dancing Cairns Quarries.—These quarries have been worked for more than a hundred years, but the old workings have now been abandoned, and are full of water. The others are now quarried by Messrs. A. and F. Manuelle. It was in these old quarries that we found the piece of granite with schist, figured p. 22. They are about three miles from Aberdeen.

The stone is of a bright light blue or grey colour, and is composed of clear quartz, two felspars (orthoclase and oligoclase), and black mica. A thin vein of giant granite is found in the bottom of the quarry.

The "posts" of granite—the masses of granite that stand separate from each other by dries or natural divisions—as a rule, are irregular, and not very large, although occasionally, as the workings proceed, several large blocks are found together, when they are usually sent to Aberdeen to be polished. The quarries are largely worked for paving-setts, and many thousands of tons of rubble for building purposes are annually carted into Aberdeen. From the indiscriminate manner in which stones from different quarries are built into the walls of some of the buildings in that city, it is not easy to discover what buildings are wholly made of Dancing Cairns stone; but we might mention two good examples of it, one in the portico of the Music Hall Buildings, and the other, the monolith of the statue of the Duke of Gordon, which weighed over fourteen tons.

A "blondin" (see p. 74), fetches the rubble and smaller stones up from the bottom of the chief quarry, which is very deep.

Sclattie Quarry.—This is about a mile farther from Aberdeen than the last-mentioned quarries, being worked by Messrs. A. and F. Manuelle. The stone is fine-grained, not unlike the Rubislaw, except that it is a little lighter in colour, owing, perhaps, to mica not being quite so abundant. It has a decided and tolerably regular grain, being used largely by masons, though it is not very extensively polished. The beds of rock are heavier and more upright in this quarry than in Dancing Cairns. The workings are 130 feet deep. Two steam cranes are at work, fed by one boiler.

To use up the smaller stones and the cuttings from the larger ones, a number of "causeymen" and curb masons are employed. This quarry also supplies large quantities of building rubble, facings, &c.

Dyce Quarry.—This is situated about eight miles from Aberdeen and about two miles from Dyce Railway Station on the Great North of Scotland Railway. It is also worked by Messrs. Manuelle. It can be seen for many miles round, being situated on top of a high hill, and the tipped rubble is especially conspicuous. The rock is of a greyish-blue colour and fine-grained. In the quarry it is seen to be plainly foliated, and the lines of foliation run nearly vertical, being quite independent of the joints. The rock in one part of the quarry is so soft and full of joints as to be of no commercial value, and is known to the workmen as a "barr" (see p. 25). When polished on planes not coincident with the planes of foliation, the stone has a peculiar striped appearance, as might be imagined. This, of course, is of much assistance to the mason in chiselling it, and makes a useful

kind of ornamentation. We may remark that the folia are not so conspicuous as to make sharp lines; indeed, the minerals are quite as much interlocked with each other as in many of the other excellent fine-grained granites of the county, the only difference being that there is a general disposition of the three minerals to lie in definite planes, which is much more conspicuous on large polished surfaces than on small hand specimens. The mica is black and brown, the other two minerals being white with a slight tinge of blue. Iron pyrites is also present in very minute quantities.

The stone lies in "beds" sloping to the north-east, and large blocks are raised and polished, being especially adapted to monumental and architectural purposes, used both at home and abroad.

Kemnay Quarries.—These are situated about seventeen miles north-west of Aberdeen, and are worked by Mr. John Fyfe. The principal opening is, we believe, the largest granite quarry in the kingdom, and the machinery in connection with it is without parallel. The enterprising proprietor has evidently spared neither money nor pains to make it perfect.

The granite is quite different in appearance from any of that of the Aberdeen quarries yet described. In comparison with them it is coarse-grained, though, speaking of granites as a whole, it might be more properly termed medium-grained. Its general colour is a silvery grey, speckled light brown. The quartz is white and in a granulated condition, forming a great proportion of the stone. The felspar is also white, being minute in the ground mass, but in distinct and larger twinned crystals distributed throughout it. These crystals do not appear to lie in any definite direction, and this considerably adds to the strength of the rock. The mica forms the peculiar feature of the stone, both black and white varieties being present, but not very abundantly. The black mica is rather small, the crystals being some distance apart. The white, or silvery brown, mica occurs both as small and large crystals, and some of the latter are quite 7 mm. across, and correspondingly thick. Moreover, the lie of the crystals appears to be tolerably regular, and they are of much use in aiding the mason to determine the direction in which the stone will most easily split. This is somewhat curious, as they supply the want created by the felspar in this respect.

The largest quarry is 300 feet in depth, and a gigantic crane is at work over it (see Fig. 9). Other cranes are distributed on the floor about two-thirds up the quarry, where the principal work is done, and on the top. A machine called a "blondin" runs right across the chasm to this floor. The "blondin" is made of two wheels, one above the other, and a tray for carrying the granite is fastened to the lower one. The whole machine runs down an inclined steel wire-rope stretched across the quarry, and the enginemen can so regulate it as to cause it to stop at any part of its course, and then the lower wheel and tray are let down the quarry. When the tray is filled it is hauled up again and the machine is pulled up the wire-rope and its burden landed on top of the quarry. There is a very large steam granite-cutter for plane surfaces here, but we did not see it at work. This machine is almost unique, the only other one of the kind that we have seen being at Mr. Fyfe's works in Aberdeen.

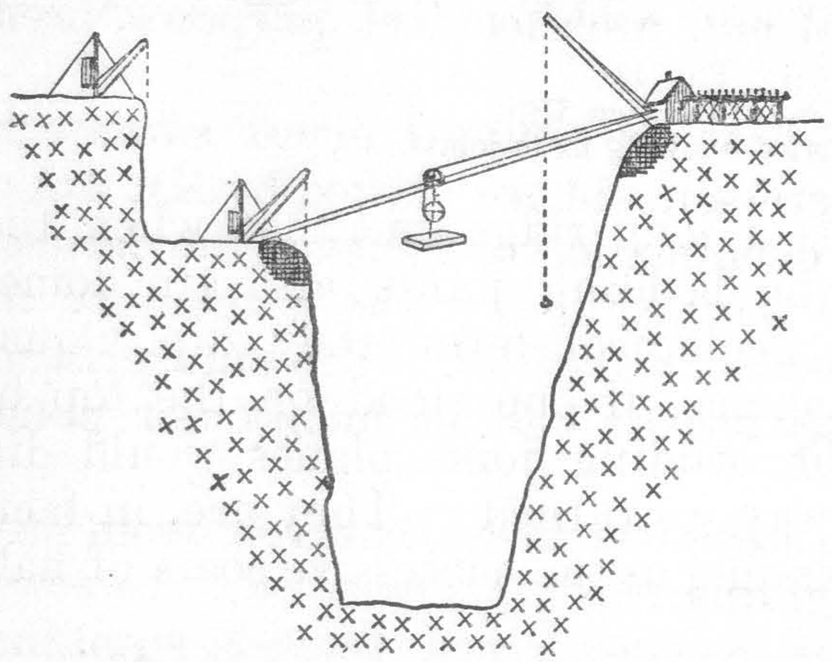

Fig. 9.

The quarries are connected with a branch of the Great North of Scotland Railway by a siding. Railway trucks are drawn up an inclined plane to the banks from the siding, by steel chains wound round a drum. The workings are in direct communication with Mr. Fyfe's office in Aberdeen by means of the telephone.

A noticeable feature in the chief quarry is a dyke of

igneous rock, which looks like basalt, running in an almost horizontal position in a great portion of the upper part of the workings. It throws out veins, as seen in the diagram (Fig. 10).

To give an idea of the magnitude of the dyke and veins, we may mention that the diagram was drawn several hundred yards away from it, across the gulf of the quarry. In specimens of it which we brought away, several angular pieces of the granite are seen to be caught up along the sides. We were informed that that part of the rock through which the veins run is comparatively soft, and no use for commercial purposes.

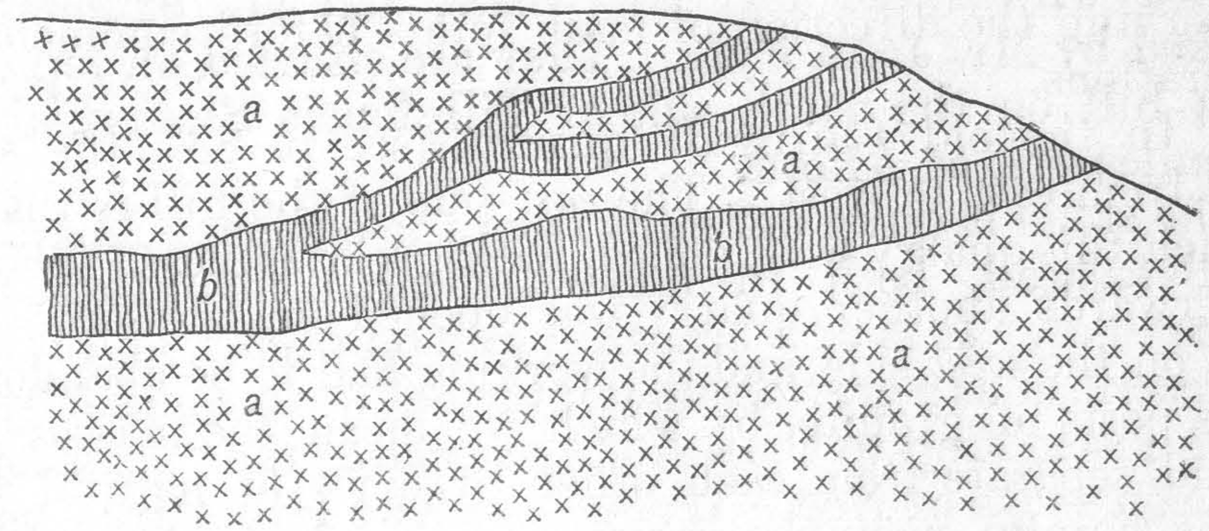

Fig. 10.

a, Grey granite. *b*, Dyke and veins penetrating *a*.

The granite is largely raised for building and engineering purposes, having been used in the construction of docks at Hull, Newcastle, Shields, Sunderland, and Leith, and is being utilised for the piers of the Forth Bridge.

Tom's Forest Quarries.—These are about half-way between Kintore and Kemnay, being also worked by Mr. John Fyfe. The stone is very similar in appearance to that from the latter place, except that it is a little darker in colour; the crystals are not quite so large. The mica is black and not very abundant. Here and there this mineral occurs as conspicuous black flakes, but it is more often seen bordering the other minerals, especially the felspar. The quartz is not so granulated, and is much more easily distinguished by its transparent glassy lustre, than that in the Kemnay stone.

The rock, as a whole, is compact, and is, no doubt, a serviceable material, capable of being comparatively easily worked.

Tyrebagger Quarry is well known, being near Aberdeen. The stone, which is of a grey colour, is composed of quartz, two felspars (orthoclase and oligoclase), and mica. Large quantities of kerb and paving-setts are annually raised.

Corrennie Quarries.—These quarries have only been opened within the last few years, but are extensively worked by Mr. John Fyfe. They are situated on top of a high hill on the south side of Tillyfourie Station, about six miles east of Alford.

The stone is quite different from the ordinary Aberdeen or Peterhead, both in mineralogical constitution and appearance. It is of a beautiful salmon colour, and might be described as a crystalline mixture of quartz and felspar, much resembling to the naked eye some of the "granitoid" archæan rocks of North Wales (*e.g.*, Twt Hill, Carnarvon). When a large polished block of the stone is looked at, little black specks are seen here and there. These are either black mica or hornblende, as the case may be. The quartz is mostly pure white, smoky crystals being the exception. Although at least half the stone is quartz, this mineral never occurs in very large crystals; several small and smashed-up pieces are often found close together, as though the rock had been crushed. These sometimes enclose one of the accessory minerals alluded to. The felspar is of a salmon-coloured tint. It is not porphyritic, though occasionally orthoclase crystals are seen, nearly an inch in diameter, especially where it joins the blue and bluish-red granite as explained, p. 24. The felspar is generally in small and jagged pieces, and closely follows the quartz, filling up little cracks and spaces. Magnetite appears to occur.

We have already alluded to the granite veins found in this quarry (see p. 24). The grey granite at the base of the hill contains much mica and hornblende, whilst the felspar, being light pink and white, gives the stone a very characteristic appearance. Iron pyrites is found, but being of the cubical variety does not detract much from the

value of the stone. Large blocks are found; we saw one 20 ft. by 10 ft. by 6 ft.

Steam rock-drills and boring machines are used in quarrying. There are four steam cranes. Perhaps the most noticeable feature about the machinery is the gearing for hauling trucks from the bottom to the top of the hill. There are two lines of rail, and whilst a loaded truck goes down an empty one is hauled up, both being worked by steel wire-ropes.

A large quantity of the Corrennie stone is being used in the erection of the new Glasgow municipal buildings and in the Tay Bridge. It is also extensively used for making millstones for paper and paint grinding.

Tillyfourie Quarries.—These quarries are about six miles south-east of Alford, and quite close to the railway station, being worked by Messrs. Mowlem & Co. The old workings near the line are now practically abandoned, the greatest energy at the present time being exhibited in those up the side of the hill, where they are partially hidden by the forest which surrounds them. These new workings were only opened about two years ago, but have been quarried to such a great extent that they have already assumed gigantic proportions, three large steam cranes being constantly at work. A fence has been erected, showing the intended size of the excavations, which, if carried out, will make this one of the largest quarries in Aberdeenshire.

A fact worth mentioning is the manner in which the surface of the ground has been searched in attempting to fathom the existence of dykes or veins—important items in opening up new ground. These are known locally as "barrs." As usual, a considerable amount of decomposed granite—an earthy substance—has been removed, and the blocks *in situ*, which resisted that action, have been carefully examined and turned over. The examination has apparently been satisfactory, and there are good indications that the stone will run in large blocks. There can be no doubt that, with plenty of capital, this is a good method of arriving at the value of the quarry. Steam rock-drills are not used. Steam is conveyed to the cranes in pipes, from boilers at a distance. Two lines of rails go down the precipitous sides of the hill from the quarry to the railway, steel ropes moving over rollers letting down trucks filled with the granite, and at the same time pulling up empty ones—precisely the same method as adopted at Corrennie.

The stone is of a bluish-grey colour, and the grain is strongly marked; that is to say, the minerals have a rough tendency to lie in lines. The felspar, like that in other granites in the vicinity, is variable in size and very irregularly crystallised. In addition to the white felspar, a pink variety occurs, as elongated crystals, up to an inch in length, and with their major axes lying in approximately parallel planes. This pinkish felspar is the chief characteristic of the stone. The quartz is white and clear, whilst the considerable proportion of mica present is quite black.

The rock is principally used for kerb and paving-setts, the greater part of which is sent to London.

Sylavethie Quarry.—This is worked by Messrs. J. Wright & Son. The stone obtained is a very dark grey, much deeper than the average Aberdeen granite tint. It is composed of irregular crystals of white felspar, from an almost microscopic size to 12 or 14 mm. across. The quartz is very minute, the large quantity of mica present being black. Schorl may occasionally, perhaps, also be detected, though, as far as we can see, it does not occur in large crystals.

It is no doubt a pretty polishing stone, and is worked into various monumental and ornamental purposes by the quarriers, who bring it up the Alford Branch of the Great North of Scotland Railway to Aberdeen.

Kintore Quarries.—These, which are worked by Messrs. Bower & Florence, are situated close to the village of the same name, and produce a bluish-grey stone, not unlike the granite nearer Aberdeen. When the stone is cut at right angles to the foliation, roughly exhibited, the minute black specks of mica cause it to look strong in the grain. The felspar is white, and some parts of the rock, when polished, present an appearance very much like that

of the granite obtained from Cairngall. The quartz is small and granular, and appears rather smoky.

Birsemore Quarries.—The stone found at these quarries—which are close to Aboyne, and are worked by Messrs. Burgess & Son—is a very peculiar one, and the only granite we can compare with it, as far as appearance is concerned, is that from Shap, in Westmoreland, for which, indeed, it is often mistaken. The principal difference between them is that the large porphyritic crystals of orthoclase felspar are not so well defined as in the latter stone. In other words, the large salmon-coloured spars are much more ragged in outline. These crystals occur up to an inch or more in length. There is a considerable proportion of the milky-white felspar in the base of the rock, which, when predominating more than usual, causes polished slabs to look rather cold. A similar appearance is presented by some of the light kinds of Peterhead rock. The quartz is in rather large pieces, transparent, but of a dark hue. Biotite mica is fairly abundant, hornblende being so rarely found that it ranks only as an accessory mineral.

This rock will no doubt become better known in the market. The darker kinds, when polished, are very handsome.

Persley Quarries.—These are close to the railway station at Buxburn, across the river. The general tint of the stone is a light grey. It differs from that of other quarries in the vicinity in containing white as well as black mica. The quartz is very minute, looking like transparent beads. White felspar forms a large part of the rock, which imparts to it a light tint.

The stone is quarried principally for dressed blocks, but we have also seen polished examples, which look well.

Cairncry Quarry is also extensively worked by steam machinery. The stone is of a dark grey tint, and similar to other rocks of that nature already described.

Kingswells, near Aberdeen.—Some authors state that granite is quarried here, but we are informed by the owner of the land that no such quarries exist. About thirty years ago the land was cleared of many large blocks of granite in order to bring it into a cultivated state, and some of these were worked up, being blasted on the spot. Specimens were also prepared and exhibited in London; this was the way in which the mistake probably arose.

The stone was originally selected for Prince Albert's mausoleum, for which purpose, however, it was not used, as the supply was found to be irregular.

II.—PETERHEAD DISTRICT.

The outcrop of granite in this area is not very large, but the extensive and systematic manner in which the stone is raised has rendered it famous in the market, where it is known as "Peterhead" granite. In the greater number of the quarries there is a considerable "bearing" over the rock, varying in depth from 3 feet to 20 feet. The first operation in removing the stone is to bore holes of varied depths, according to circumstances, up to 30 feet, having a diameter of 2 inches to 3 inches. These are charged with powder for the purpose of dislodgment. The blocks removed are cut with wedges, in a manner hereafter to be described (see p. 117).

The rock differs widely in chemical and mineral constitution, according to the part of the mass from which it is obtained. As the greater part of the stone is polished its durability is thereby rendered very much greater than if it was left in the rough. Rain does not have an opportunity of accumulating in little dents and holes, thus giving the acids no time to act; directly rain beats against the polished surface it glances off again. We see, therefore, that not only does polishing greatly add to the beauty of granite, but it assists in preserving it from decay. The quarries are worked by various firms, such as Messrs. A. Macdonald Field & Co., Great North of Scotland Granite Company, Bower & Florence, J. Wright & Sons, and D. H. and J. Newall.

Longhaven Quarries.—The granite quarries on the Longhaven estate are about five miles from Peterhead, and close to the sea. A range of granitic rocks faces the North Sea from Port Erroll to Boddam, a space of about four miles, and some of the most important quarries in Aberdeenshire are situated within these limits. The oldest quarry in the district is at Stirlinghill, which is on the Boddam estate. Eight quarries are generally in full operation on the Longhaven property, with an average of twenty men at work in each; sometimes this average is considerably raised, according to the state of trade. Some of the quarries have been worked for about forty years, but the majority have only been opened within the last twenty years. They are quarried principally (almost exclusively) for blocks suitable for polishing.

A brisk trade is, however, done by some of the quarries in providing principal stones for buildings in the neighbourhood, but a large amount of excellent building material is thrown into the sea, which affords a cheap and easy mode of disposing of superfluous stone. It is a pity this cannot be utilised in buildings in the cities of the south, where soft limestones and the like so soon decay. Surely it would pay for carriage.

The stone itself is of a red colour, and slightly differs in grain in some of the quarries. The quartz is very peculiar, and is a marked feature in the rock. It occurs as rounded crystals, some having a smoky appearance, others being white and transparent. Irregularly disposed dark patches are seen on the stone, which might easily be mistaken for some other mineral. A close examination, however, soon reveals the fact that they are quartz. The felspar is of a flesh-red colour and mostly orthoclase. In some of the coarser stone this mineral is in oval crystals of a milky white tint, and rarely yellowish green, not unlike the light green felspar in some of the Cornish granites. It is very evenly distributed, and forms a large percentage of the rock. It has no tendency to become porphyritic, and as no twinning is perceptible, is not regular, and the crystals are much interlocked; the stone cracks with a splintery fracture, the felspar looking much broken up. This mineral is very hard, and is so completely crystallised as to render the stone more durable than it would otherwise be even in spite of the presence of so much peroxide of iron.

The quantity of mica present is very variable. Large blocks from quarries in the southern part of Longhaven occur, in which not a particle of this mineral is seen, and the rock then usually contains much hornblende, being, in fact, a syenite; and there is every gradation, from a syenite through hornblendic granite to granite properly so called. The mica, when present, is black. Hornblende occurs in very minute crystals, congregated together so as to form dark green patches. It is a curious fact that when hornblende replaces mica in the Peterhead stone, the general appearance of the rock is not altered to an appreciable extent, so that, although the weathering of it must vary accordingly, the cause of the difference in durability would not, on a superficial examination, be suspected.

Notwithstanding the small area of granite on which these quarries are situated, the extent of unbroken ground suitable for quarrying in the district is still considerable. This is testified by the large and perfect blocks that come to light when a clearing is made.

The stone from Longhaven is used very extensively in London, whilst large quantities of it have been sent to America and other parts of the world.

Stirlinghill Quarries.—These quarries are on the Boddam estate, about four miles south of Peterhead, and close to the sea. They have been extensively worked for a long period, and produce stone very much like that from the Longhaven estate; so much so, that what has been said of the one will equally apply to the other. It is the usual Peterhead granite so common in the better class of London and provincial edifices.

When large slabs and columns of it are examined, spots and dark patches are rarely found, and the tint is tolerably uniform. This cannot be said of many granites, hornblendic or otherwise. It retains its polish for a long time. We saw a monument, which was erected in Aberdeen twenty years ago, and made of Peterhead granite. The weather had attacked the hornblende, and caused those parts of the stone containing a considerable proportion of

that mineral to look rather dull, but, speaking of the monument generally, the polish is still quite fresh.

Cairngall Quarries.—The granite quarries of Cairngall, worked by Mrs. Hutchison, are situated about five miles due west from Peterhead, in a rising piece of ground. They have been opened for a great number of years. The principal quarry was not worked systematically until 1808, in which year the foundations of the Bell Rock Lighthouse were laid, this stone being selected by Mr. Stevenson for use in that construction.

Although so near Peterhead, the colour of the stone is not red, but a bluish grey, and in this respect it resembles the granites near Aberdeen. It is readily distinguished from them, by reason of the white felspars—many of which are 7 mm. across—being distributed conspicuously in the exceedingly fine-grained ground mass. This gives the stone a somewhat porphyritic appearance, which would be much better defined if the crystals alluded to, had clearer outlines. As it is, they occur as white spots, the edges of which merge almost imperceptibly into the more minute felspars, forming, with the clear transparent quartz, the greater part of the base of the rock. The mica is black, and in very small flakes.

The joints in the quarries are, as a rule, perpendicular, and vary in thickness from 6 inches to 8 feet. These joints run from east to west, and are crossed by several slides from south to north at an angle of 45°. Blocks have been obtained above 20 feet square and 8 feet thick, an example being the sarcophagus in which the late Prince Consort is entombed, which is more than thirty tons in weight.

Other examples of the Cairngall granite may be seen at St. George's Hall, Liverpool, where eight pillars are erected, the shafts being 18 feet in height, and each made of one polished block; the lintel over the door of the Duke of York's Monument; round the fountains at Charing Cross; and the pedestal of the Duke of Wellington's statue at the Royal Exchange, Glasgow.

Other granites are found near *Ellon*, where the stone is exceedingly dark, and, in fact, the small workings opened are far too numerous to mention. We have confined our observations on Aberdeenshire granites to the quarries where steam machinery is used, or in which the rock presents features of general interest.

The student who visits the yards of the Aberdeen polished granite merchants will find in some of them stones of quite different characters from those we have described. That city is the principal emporium of the polished granites, and it is not surprising that we find there, stone from certain parts of Argyleshire and other parts of Scotland, which have been sent to be polished. Again, a rich green rock from Warberg, in Sweden, and a light grey fine-grained granite from near Breslau, in Silesia, may be found in some of the yards. The stone from the latter place is worked exclusively by manual labour, sent to and shipped at Stettin, and then carried to Aberdeen. After being made into monuments, &c., a great part of it is exported to America.

Many of the large firms in that city, however, polish Scotch granite exclusively, and will not permit foreign stone to enter their premises.

In concluding the observations on Aberdeenshire granites, we may draw attention to the fact that all granites, more or less, vary in tint even on the same stones. Those under consideration conform to this law, and we find that polished slabs and monuments of the ordinary grey and blue stones are not always uniform in colour and texture, the darker stones being frequently covered here and there with lighter streaks, and the lighter ones with dark spots. Of course, great care is taken to avoid these, as much as possible, and we could point to stones where the tint is quite uniform, but these may generally be regarded as of exceptional quality. As far as durability is concerned, these local differences in composition are not detrimental in most cases to their preservation, and unless such spots or veins contain more perishable minerals than does the normal rock, they do not detract from their value in this respect.

There are exceedingly few granites used in the polishing

trade which permanently retain their tints. A granite column, or slab, always looks better when it is just finished, and immediately turned out of the polisher's yard, than when it has been made a year or two. This means that the quarry water, or moisture introduced during manipulation, has dried out, and in some cases, that the stone has commenced to decay. If it has been caused by the former action, it is astonishing to find that after its original colour has been toned down it will often remain permanent for many years, unless time discovers that magnetite or some other discolouration mineral is present, when unsightly brown marks are caused—too well-known to the architect to need much description. The best method of detecting these minerals is by the aid of the microscope in the manner previously described. They are rarely seen on a fresh surface of stone, by the naked eye. If the student elects to examine granite from examples seen in buildings that have been erected for a few years, we must caution him to be very careful in identifying each of the stones. Even the experienced eye cannot always be sure of the quarry from which certain stones have been obtained, as many of the grey and blue granites are almost exactly alike in general appearance, though the differences existing, as far as quality is concerned, are often very considerable. The rocks are no sooner investigated closely, from a scientific point of view, than these diversities become at once apparent.

B.—KINCARDINE GRANITES.

The granite quarries in this county are all situated in the northern parts of it.

When the enterprising merchants who caused the loose stones to be worked on the surface of the high ground of Torry, on the southern side of the river Dee, began sending the fruits of their labour to the London market, they little thought that their energies would be the precursor of a gigantic trade, the seat of which was to be transferred across the river to Aberdeen.

A preliminary survey of the district, of the respective merits of the granites of the two areas, and the facilities of carriage, soon convince us, however, of the *raison d'être*. The rock at Torry is not worked to an appreciable extent at the present day, and no quarries have been opened there, to our knowledge. The student who starts from Aberdeen, crosses the river into Kincardine, and makes his way to the quarries at Cove, will do well, however, to direct his attention to the exposures of the rocks on the beach at Torry *en route*, as we have before remarked (p. 18). It will give an idea of the kind of stone that was formerly sent to the market, whilst the observant student will learn a great deal about the relation of the granite to surrounding rocks, and the manner in which the atmosphere and water have attacked the granite, which information might be directly applied to his studies with regard to the granites of a similar nature which are now being used in the neighbourhood or elsewhere.

Cove Quarries.—These are situated about four miles south of Torry, close to the sea, being worked by Mr. John Fyfe. The stone is very hard, and, owing to the presence of a great quantity of black mica, which occurs in minute flakes, the stone is of a dark hue, much more so than the ordinary granites of the district. It is medium-grained, and foliation is roughly marked. The white felspar is in very small crystals, is most probably orthoclase, and forms a comparatively small portion of the rock. The clear white quartz, on the contrary, occurs in rather larger crystals, not well defined, but tolerably abundant.

The rock is used principally for kerb, paving, &c. The few polished examples we have seen show that it is capable of taking a fine polished surface.

Nigg is a village about two miles to the north of Cove. The granite obtained is fine-grained and of a dark colour. The three minerals are about equally abundant, and so much interlocked with each other that the rock is very compact; in fact, they are so intimately mixed that it is quite impossible to make out the boundaries of the crystals with the naked eye. The milky-white felspar is barely distinguishable from the quartz, and black biotite, which

on weathered surfaces is copper-coloured, occurs in such minute flakes that, although it appreciably alters the tint of the stone, it cannot be distinctly seen without the aid of the microscope. This mica is also found in every intermediate size up to two or three mm. in breadth.

The stone is not extensively employed, the loose blocks being principally used for making dykes, and for other agricultural purposes.

Hill of Fare Quarries.—These are situated a little to the north of Banchory, a considerable distance inland. The stone is of a dark red colour, fine-grained, and is chiefly composed of quartz and felspar, both mica and hornblende being, however, present. The former is scarce, and might be said to be only accessory, whilst the greater abundance of the latter entitles the rock to be called a syenite rather than a granite. The quartz is the most striking feature in it. This mineral is found as little distinct crystals, many of which show in section the six sides, due to the fact that it crystallises in the hexagonal system. Although the boundaries of each of these crystals are so clearly defined, they are, as usual, not all regular. Twenty or thirty of them appear to have congregated together, squeezing up one another in their efforts to crystallise out, and some appear to have been much more successful in arriving at their proper form than others. The quartz causes the stone to have a dark speckled appearance, though, when closely examined, it is seen to be quite transparent.

Both orthoclase and triclinic felspars are present. The triclinic felspars are readily distinguished in microscopic sections by the parallel lamellæ which they exhibit. The stone is not porphyritic, notwithstanding that perfect crystals are often twinned, and of common occurrence in the rock. In other words, as these small red felspars help to form such a great proportion of the mass of the rock, and as there is no distinct ground mass, the perfect crystals alluded to are not conspicuous, and are thus absorbed in the general appearance of the whole. The little hornblende is dark green, and the mica, when present, is black.

The stone is used in a great measure for tombs, monuments, and high-class polished ornaments. It may be found in most of the granite-workers' yards in Aberdeen, and, when finished, looks very handsome.

This red Kincardine rock is often spoken of (by quarriers) as though it had some connection with the Birsemore, Corrennie, and Peterhead rocks. It appears to agree with them, in being of a red tint, but we cannot admit more; they are dissimilar from, and bear no relation whatever to, each other. It is finer-grained than any of them, and the only one it at all agrees with, in general structure, is the Peterhead stone. The latter rock, however, so frequently has hornblende, in little minute specks congregated together, with the felspar of a lighter tint, that it is impossible to make a mistake in their identification.

It has sometimes been suggested to us that a bank of red rock runs from Banchory to Peterhead, via Corrennie, and that, at a little depth from the surface, red rock is found in the intermediate spaces. From this, the opening of the ground to obtain the red stone between these places has been advocated. We think, however, that before doing so the ground should be thoroughly examined, because we are quite certain that this red rock is not persistent—at least, not the whole of the way. For instance, if it is persistent a short way from the Kincardine quarries, it falls short of the Corrennie. The fundamental rock at the latter place, and, indeed, in the whole district, as far as we can make out, is a grey stone. The red stone at Corrennie occurs at the top of the hill, but is apparently cut off on the north by the grey stone, which rises to a great height at Tillyfourie.

Besides, we do not think that the Corrennie stone is a northward extension of that of Kincardine, the structure of the two rocks being so dissimilar, and having most likely originated under different conditions. The red rock, which is said to occur a little to the north of Tillyfourie, can also be shown to have no connection with that of Peterhead,—at least, not within quarrying bounds, as a considerable breadth of metamorphic rocks is found to intervene. The best method of speculating on the nature of the rock underneath the surface of a granite area is, no doubt, to examine the blocks above ground, or in the decomposed rubbish, as is generally done, and quarriers who have not gained considerable knowledge in geology must not depart from this rule, unless, indeed, they have plenty of money to play with. They must always keep before them the fact that igneous, unlike many aqueous, rocks are not at all persistent in their occurrence. It is true that the outcrop of a large granite area can be comparatively easily traced, but it is exceedingly difficult to be sure that rock of a certain colour or texture is persistent in that area, as is suggested by the remarks we have alluded to. If the rock under consideration was a sandstone there might be some foundation for the suggestion, because rocks laid down in water, as we have previously observed, generally speaking, are tolerably persistent for short distances. But an igneous rock might burst up anywhere, and in a very irregular manner; therefore, its persistence is just as uncertain, and nothing short of a close study of the geology of a granite area can enable the quarrier to gain even a rough idea of the extent of outcrop of any particular kind of rock within that area.

Those who, by experience, have acquired considerable knowledge in opening up new granite areas will not find any difficulty in understanding the foregoing remarks. They know that the boulders and blocks of rock at the surface are the most practical guides in assisting them. The less-advanced student must learn that, without careful observation, even these blocks might lead him astray.

In a very recent period of geological history the part of Scotland of which we are writing, together with almost the whole of the British Islands, was under the surface of the sea. Icebergs—the broken-off ends of glaciers which had reached the sea—floated over it, laden with boulders and pieces of rock. These icebergs, with their freight, came from Norway and other parts, and when they melted up, dropped the boulders, &c. Subsequently this sea-bottom was raised into dry land, and the boulders and blocks of rock came with it. The quarry-owner who may be opening up new ground, will thus occasionally meet with blocks of foreign stone, or stone not *in situ*, together with the normal rock of the district, the boulders of the latter stone being kernels of the underlying rock which have resisted the decomposition that has taken place all around them; he must, therefore, be guided by those blocks that are most prevalent, and few, if any, mistakes can then arise.

The Cornish quarriers consider that when the overburden is brownish and loamy, or clay, it is a good sign that fine rock is underneath. When it is sandy it is a bad sign.

C.—KIRKCUDBRIGHTSHIRE GRANITES.

There is plenty of granite in this county. The three principal districts where it is found are, that in the north-west, extending from Loch Dee to Loch Doon; the second, stretching from Loch Ken to Palnure Water; and the third, from Criffel to Craignair.

These granites occur in the lower Silurian tracts. The strata in some cases do not dip away from them on all sides, but, with trifling exceptions, maintain their normal north-east and south-west strike up to the granite on one side, and resume it again on the other. The granite, indeed, has not merely pushed aside the strata so as to make its way past, but actually occupies the place of so much Silurian rock, which has disappeared as if it had been blown out or melted up into the granite. There is usually a metamorphosed belt of about a mile in width, in which, as they approach the granite, the stratified rocks assume a schistose or gneissoid character. Numerous small, dark, often angular patches or fragments of mica-schist may be observed in the marginal parts of the granite. Occasionally granite veins protrude from the main masses, but in the metamorphosed zone which surrounds the Criffel granite area in Kirkcudbright, hundreds of dykes and veins of various igneous rocks occur.*

* Dr. A. Geikie, "Text Book of Geology" (1882), p. 543.

It is a noteworthy fact that, although its existence was known a long time ago, the principal houses and gentlemen's residences were, in the early part of the present century, almost exclusively built of Old Red Sandstone from Dumfriesshire. And Mr. David Bremner, in his "Industries of Scotland," informs us that when the bridge over the Dee at Tongland was built, in the years 1804-5-6, after a plan by Mr. Telford, the celebrated engineer, at a cost of nearly £7,000, it appears never to have entered the mind of any one concerned in the matter, to utilise the granite boulders close by, so that the stones used in the structure were transported, at great expense, from the island of Arran, and they were subject to heavy duty, which greatly added to the cost.

Granite was, however, used at Dalbeattie for some years previously, but it was not until 1825 that anything like extensive operations in the working of granite were commenced in the district. In that year, the Liverpool Dock Trustees leased a portion of Craignair Hill, near Dalbeattie, for the purpose of obtaining material for the construction of the docks. This was attended with great success; so much so, that other enterprising spirits took the matter up after the dock authorities had finished their work. Several quarries were opened in addition, and a brisk trade was carried on for a long time, not only with the United Kingdom, but with Russia, several Mediterranean ports, and South America.

We may mention that in some of the quarries in the parish of Kirkmabreck the stone was worked without blasting.

Several of the quarries opened have, for various reasons, been closed, but the excellent material which is found near Dalbeattie is still worked and polished on an extensive scale in that town by Messrs. D. H. & J. Newall. All the granite, so far as we are aware, is of a grey colour.

Dalbeattie Quarries.—The light grey stone obtained from these quarries is fine-grained, some kinds approaching medium. The quartz is white, clear, and transparent. The felspar is mostly white also, but here and there assumes a light brown tint. None of the crystals are well defined, and they are much interlocked with the quartz. There is a fair proportion of black mica present, and another black mineral, which occurs in long needle-like crystals, denotes the presence, perhaps, of schorl. This last mineral is not abundant.

The stone appears to be very hard, compact, and takes a beautiful polish, being highly suitable for ornamental decorations and the like. Besides being used in Liverpool, it may be found in the Newport, Birkenhead, and Swansea docks, and several public buildings in Manchester and other large towns in the north-west of England.

Creetown Quarries.—These are near Newton Stewart, and are sometimes known as the "Globe" quarries. The stone is very similar to that lastly described, and bears a great resemblance to certain kinds of Newry granite. It does not, however, contain much of the light brown felspar.

It was extensively used in the Liverpool docks, but is not much worked at the present time.

The stone obtained from the *Rockcliffe Quarry* is much darker than either of the other Kirkcudbright granites described. This is principally owing to the greater abundance of the black mica. It is fine-grained, and the white felspar and quartz are with difficulty separated from each other.

D.—ARGYLESHIRE GRANITES.

The granite industry in this county is largely—almost exclusively—confined to quarrying only, the stone being sent elsewhere to be polished or elaborately worked into monuments, &c. Quarries are scattered about in various places, such as at Inveraray, Oban, Strontian, Loch Awe, and the Ross of Mull. We first deal with the—

Ross of Mull Quarries.—The Isle of Mull contains a considerable quantity of granite. Some of it is found in the centre of the island, where it is cut up by great masses of an equally crystalline rock—gabbro, which has formed subsequently to the granite. It would appear from the researches, principally of Professor Judd, F.R.S.,

that these highly crystalline rocks are the stump of an ancient volcano, and the greater part of the island is described as the basal wreck of a volcano. The lavas, which surround these central masses, bear a close relationship to the granites and gabbros alluded to, and, like them, they can be shown to have formed in at least two different periods. This volcano was in eruption in very early Tertiary times, as has recently been shown by Mr. J. Starkie Gardner, F.G.S., from a critical study of the fossil plants found imbedded in rocks between the sheets of basalt, the most recent lava erupted.*

It appears that the granites, &c., in the interior of the island are not used to any extent for commercial purposes, but that quarrying operations are chiefly confined to the extremity of the south-western part of it, known as the Ross of Mull.

The granite at this place has no connection with the central masses; neither has it anything to do with the volcano. It is simply a part of the groundwork upon which the volcano was built, and is thus of much more ancient formation.

The rock has been extensively quarried from time to time, by some of our greatest granite merchants; but it does not seem to have been worked in a steady systematic manner for any long consecutive periods, such as have the majority of the other rocks described. The principal works there now are conducted by Mr. Vass. People seem to have procured the stone only when large contracts required it. Why this should be the case is difficult to understand, for the rock, when polished, is exceedingly handsome, much more so than many of those that find their way in large quantities into the market. The opinion we thus express regarding the Ross of Mull granite is shared by all architects who know the stone, by whom it is much sought after. One would imagine that the supply had fallen short of the demand, if it could not be easily shown that this is not the case. Very large blocks are obtainable, and the supply is almost inexhausti-

* See *Quart. Jour. Geol. Soc.*, vol. xliii. (1887), p. 270, *et seq.*

ble. We are informed by one of the quarriers that the principal cause of the trade being so disproportionate to the beauty of the stone is a lack of the "sinews of war," and quite recently he has had to decline some large orders solely on this account. The fact that Mull is a rather out-of-the-way place has, however, no doubt a great deal to do with it.

On the contrary, a good trade is done, we are informed, by the chief of the Shap quarries, Westmoreland, in bringing the Mull granite by sea and rail to that place to be worked and polished; and, as we have previously pointed out, the tremendous columns at Blackfriars Bridge were turned by a lathe which is now at Shap. But we should like to see the Mull quarries more fully developed, and more machinery would then be erected for treating the material economically on the spot than is now the case.

Speaking of the stone itself, it is of a warm red colour, brought about principally by the presence of a large proportion of red orthoclase felspar, which, although occurring as masses of crystals congregated together, have no definite outline, their edges presenting a ragged appearance and dovetailing into the other minerals in such a manner as to cause the stone to have no marked grain, other than that always more or less exhibited in this class of rock, and found out only by the manipulators. White felspar is also exhibited. The quartz is clear and transparent, and occurs in tolerably regular crystals, whilst the black biotite mica is not very abundant. Two or three accessory minerals are present, but do not affect the general structure of the stone, which is coarse-grained.

Examples of the Ross of Mull granite may be seen at Westminster and Blackfriars bridges, Holborn Viaduct, &c., in London; in the docks at Liverpool; several public buildings in Manchester, where the polished work is now being used; and in some docks and lighthouses in the north-west of England and south of Scotland.

Loch Awe Quarries.—These quarries are situated at the head of Loch Awe, in the base of Ben Cruachan, and about three miles from Loch Awe station, being connected with the Callander and Oban Railway by a branch line belonging to the Ben Cruachan Granite Company, Limited (Mr. John Petrie, manager), who are the quarry-owners. At present there are two workings opened, one being 300 feet above the other. The branch line comes into the lower quarry, being about a mile and three-quarters in length, with a gradient of from one in fifteen to one in thirty. The upper quarry is connected with this by a drum tramway.

There are two different kinds of stone, one being grey and the other a dark grey, speckled black. The former is found in the lower quarry, and when it is properly opened up a great quantity of large stones for monumental and other purposes will be raised. The dark stone is obtained from the upper quarry, where there is a very large face of granite, capable of being opened up to the extent of about 300 yards. It is suitable for either monumental or dock work; at the present time some large blocks are being cut up for the former purposes, and the polished stone is becoming a marked feature in the yards of the Aberdeen granite-workers, where it is finished.

Mineralogically, the stone is composed of quartz, felspar, mica, and a little hornblende. All the minerals are thoroughly interlocked with one another, and none of them have had space enough to crystallise regularly. This shows that they crystallised out almost simultaneously, and gives a very characteristic appearance to the stone. The quartz is white and crystalline, being much broken up; the felspars are of three tints, milky white, light green, and light pink. The other minerals are black. It is fine-grained.

Arran granite does not appear to be worked on a very extensive scale. There are many large boulders, from half a ton to a ton in weight, in the vicinity of Sannox, which are split and used in mills. Goat Fell, with an elevation of 2,875 feet, is composed principally of granite of two varieties, the coarse-grained and the fine-grained, formed probably at successive periods. In composition, however, they are similar, being formed of white orthoclase, a triclinic felspar, probably oligoclase, quartz, and a little black mica; the quartz is very abundant.*

Strontian granite is medium-grained, of a grey tint, consisting of quartz, oligoclase white felspar, and black mica in abundance.†

Scotch granites are also obtained, though in a lesser degree, from parts of Perthshire, Banffshire, Sutherland, and the Hebrides.

* Hull's "Building and Ornamental Stones," p. 34.
† British Association Report, 1863, p. 62.

CHAPTER VIII.

IRISH GRANITE QUARRIES.

GRANITE is chiefly obtained in Ireland from the following districts: Donegal, Galway, Wicklow, Wexford, Dublin; in the mountain ranges of Mourne; at Newry, Slieve Croob, Carlingford Mountain, Belleek, co. Fermanagh; and in a few islands.

Although there are large quarries dotted here and there over some of these tracts, yet it appears to us that the beautiful material is by no means so extensively raised as it should be. If the granites of Ireland were proportionately worked according to their respective merits, and as compared with rocks of a similar nature in England or Scotland, there can be no doubt that a gigantic industry would be developed, which would go a long way to alleviate the sufferings and distress of the people in certain districts. It might also have a tendency to keep out the foreign stone which is gradually creeping and finding its way into our markets. If the authorities in the island employed more local stone in the construction of their buildings, and for kerbs, paving, &c., a greater stimulus would be created in opening up new ground. Most of the granite tracts alluded to are not far from the sea, whilst some of them actually form sea-cliffs, and every facility, as far as nature can provide, is afforded for the cheap raising of the stone.

The first large tracts to which we will direct the student's attention are those in the north-east of Ireland. Granite is found here in three distinct areas forming the mountain ranges of Mourne, Carlingford, and Slieve Croob.

According to Professor Hull, the granite of Mourne has hitherto been used only to a very limited extent for building; and, owing to the numerous cavities it contains, and its distinctly crystalline structure, it is probably not so well adapted to architectural purposes as the granite from the Newry district adjoining.

The granite of Mourne is of great interest, however. It is an example of granite that has forced its way *en masse* into overlying rocks.* Prof. Hull, in speaking of it, says it is, in that sense, truly irruptive, and seems to have been intruded amongst the stratified rocks in a state bordering on solidity, and with a temperature only sufficient to indurate, but not to completely metamorphose the Silurian rocks by which it is surrounded, and, in some places, surmounted.† Nevertheless, it would appear that along the outer margin and in extruded veins it passes into a quartz porphyry,‡ a rock made fundamentally of a very fine-grained ground mass, composed mainly of orthoclase felspar and quartz, through which some of the minerals are crystallised in conspicuous forms.

The granite of Carlingford Mountain, which in some parts is syenitic, is thought to be newer in age than the Carboniferous period, as it is seen penetrating Carboniferous limestone.

The granite of Newry and Slieve Croob is altogether different in texture and composition from that of Mourne. It is of metamorphic origin, and is much older than that of Mourne and Carlingford. It is a potash granite, consisting of quartz, orthoclase, and black mica. The analysis of this granite from Goragh Wood Station shows an unusually low percentage of silica.¶

Bessbrook Quarries.—These are situated near the town of that name, not far from Newry, and are principally worked by a limited liability company, under the management of Mr. T. M. H. Flynn. There are three large quarries, the stone in the first being of medium grain,

* A similar phenomenon is described as occurring in the Island of Sark, by the Rev. E. Hill, M.A., F.G.S., *Quart. Jour. Geol. Soc.*, vol. xliii. (1887), p. 330, Fig. 5.

† "Building and Ornamental Stones" (1872), p. 44.

‡ See Horizontal Section, No. 22, "Geol. Surv. Ireland."

¶ Zirkel, Petrog., vol. i. p. 486.

and not unlike that from Dalbeattie; that of the second is much lighter and fine-grained; whilst the granite from the third is of a light blue colour. It is the last-mentioned quarry that produces the stone commonly known as "Bessbrook granite," which is very similar in appearance to the Cairngall stone, near Peterhead.

The principal quarry lies at the base of Camlough, a mountain in the Newry chain. It is a vast excavation, some 700 feet or 800 feet long, about 100 feet broad, and from 80 feet to 100 feet deep. The blocks of stone are lifted from the floor of the quarry to the top by a "gantree," which travels over the quarry either across or longitudinally, on a line, the rails of which are laid on blocks of timber some 80 feet or 90 feet apart. Much of the granite is polished, and the works where this branch of the trade is carried on are located apart from the quarries. Splendid specimens of the stone may be seen at the Manchester New Town Hall, where they are up to 21 feet in length, polished. It has also been extensively employed in buildings, and for kerbs, paving-setts, &c., in London, Manchester, Liverpool, Bristol, Edinburgh, Glasgow, and other large cities. An example of a dock built with it is to be found at Greenock, whilst Newry granite also forms the quays of Bucharest.

Other quarries in this part of Ireland are at Castlewellan, Mullaghglass, and Rathfriland, near Banbridge.

The *Belleek* quarries, county Fermanagh, produce stone of a reddish tint, the greater portion of which is used in making porcelain. The rock has a high percentage of orthoclase felspar. Generally speaking, porcelain is made from decomposed granite, but in this case Prof. Hull says that the red felspar retains its crystalline form in its original perfection, and on being calcined loses colour and becomes white. The metallic iron which separates itself from the rock during the process of calcination is afterwards extracted by simply immersing magnets into the powdered china clay when mixed with water; the particles of iron then adhere to the magnets and are lifted out.

The most extensive granite district in the British Islands stretches south from Dublin through the counties of Wicklow and Carlow into Kilkenny and Wexford, and occupies an area about 70 miles in length and from 7 to 17 miles in width. This mass supplies an admirable illustration of the relation between granite and the surrounding rocks.* The lower Silurian strata in which it is found was apparently contorted before the granite made its appearance. Patches of lower Silurian beds that lie on it, at distances from the main mass, occur in such a manner as to bear no apparent relation to the movements which it could have produced. For a mile or more, the aqueous rocks which surrounded the mass have been made into mica-schist (a metamorphic rock), whilst veins from the central mass pierce it in several directions. The granite is mostly composed of quartz, orthoclase felspar, and silvery grey mica, but frequently biotite appears, together with the usual accessory minerals. The stone runs in large blocks, and the *Killiney Hill* quarries (Carnsore Point) have supplied a great quantity of granite for the construction of the harbour and pier at Kingstown, the Thames Embankment, and many large buildings in Dublin. Most of the stone is of a grey colour and of good quality, but some care should be exercised in its selection. It is interesting to note that the Killiney granite is in some places distinctly foliated, presenting that metamorphic appearance we have described as occurring in some of the grey and bluish granites of Aberdeen. A representation of this foliated Irish granite is given in the "Explanation" of sheets 102 and 112 of the "Irish Geological Survey," p. 33.

The *Blessington* quarries are noted for a bluish grey stone, which works very well, an example of which may be seen in the campanile in the central quadrangle of the Dublin University. The greater part of the large buildings in Dublin are made of granite which comes from *Glencullen* and *Kilgobbin*, in the vicinity, and *Ballyknocken*. co. Wicklow. The stone from the first-mentioned places is of a brownish grey colour, and is, no doubt, a good serviceable material. The stone from Ballyknocken is greyish white. All three are said by Professor Hull to be

* See Jukes' "Manual of Geology," 3rd. ed., p. 243.

less siliceous and more uniform in texture than that of Killiney. The granite from the *Dalkey* quarries, co. Dublin, is of a grey colour. It is used largely for buildings, kerbs, and paving setts, and is hard to work. Examples may be seen in St. Paul's and St. Werburgh's churches, in the Irish metropolis. Other quarries in this district are at *Bagnalstown,* near Carlow, where the stone is of a dark bluish grey colour; *Glencore,* near Enniskerry; *Lough,* of a whitish yellow colour, being fine-grained. A good example of the last-mentioned stone may be seen in the new church at Carlow.

The Donegal mass of granite is principally composed of red orthoclase felspar, oligoclase, quartz, black—and occasionally white—mica, and hornblende. Like the Killiney granite, much of it is roughly foliated, whilst it has also been observed to branch off in veins, on the confines of the mass, which traverse the surrounding metamorphic schist, &c. The Donegal granite does not appear to have been very extensively used. The principal quarries are at *Garvary Wood,* and the stone is very handsome, being composed of large pink felspars—most likely orthoclase, but oligoclase is present—clear and transparent quartz, and black mica. The rock found at *Dungloe* is of a reddish colour, but is only used locally.

Mr. R. H. Scott, Sir R. Griffith, and the Rev. Dr. Haughton presented an admirable report to the British Association, which was duly printed in 1863, "On the Constitution of the Granites of Donegal;" and the last-mentioned gentleman has written on the same subject in the *Jour. Geol. Soc. Lond.*, vol. xviii, p. 402, *et seq.* We must refer the student to these works for further information.

The granitic rocks of Galway are spread over a large wild tract of country stretching from the town of that name to Roundstone Bay. They are associated with strata probably of lower Silurian age.

Two principal kinds of rock are found, and, according to the observations of the officers of the geological survey, one of these is of metamorphic origin,* and the other intrusive.

* See, however, paper by Dr. Callaway, *Quart. Jour. Geol. Soc.*, vol xliii. (1887), p. 517, *et seq.*

The largest quarry in the former kind of stone is at *Furbogh*, about eight miles from Galway. It is composed of large red crystals of orthoclase felspar porphyritically developed in a ground mass of orthoclase, light green oligoclase, quartz, and minute flakes of mica. The latter kind of rock is obtained chiefly from *Oughterard* quarry, and is of a light bluish tint, being composed of quartz, orthoclase felspar, and white and black mica. Iron pyrites is also present, but ranks only as an accessory.

Speaking of the Galway granites, Prof. Hull remarks* that "little has been done in the way of utilising these rocks, though there can be no doubt that the porphyritic granite is capable of yielding a stone of great beauty, and is well adapted for architectural purposes. A polished pillar of a porphyritic variety of granite may be seen in the Museum of the Royal College of Science, Dublin."

We are glad to hear that the granite of this district is about to be extensively quarried by a Liverpool firm.

Before concluding our observations on Irish granite, it may be well to mention that a most valuable series of experiments on the crushing weight and other qualities of various Irish granites has been published by Mr. G. Wilkinson, M.R.I.A., in his work on the "Ancient Architecture and Practical Geology of Ireland," 1845.

* "Build. and Ornam. Stones" (1872), p. 42.

CHAPTER IX.

JOINTS.

In entering a granite quarry, one of the first things which strikes the observer is the joints or cracks which are seen universally to split the massive rock up into blocks of various sizes. They generally run in a more or less irregular manner in the Aberdeen quarries, but the experience of a lifetime has taught the quarriers where they may, or may not, find a joint, the existence or otherwise of which it would be impossible for an outsider to prove. Of course, in these, as in all quarries, there are main joints, the principal of which occupy a more or less horizontal position.

The joints in the granites of Cornwall, on the contrary, run in a very regular manner, in consequence of which the material is very much more easily quarried.

In the course of our study we visited over thirty large quarries in this county and made observations in most of them as to the direction and dip of the principal joints. There appears to be three general directions. 1. The "master" or "quartering" joints; 2. The oblique or "tough way" joints, and 3, the "bedding" joints. Of these, the most constant are the first and third. The master joints run nearly perpendicular, irrespective of the bedding, and their general direction is north and south. In the Penzance, Penryn, and Luxullian districts (see p. 35), they vary from 10° to 20° west of north, whilst at Cheesewring they run almost due north and south. The oblique joints are the most inconstant, especially in regard to their dip. Their general direction is east and west, but they may vary a few degrees on either side. In the Penryn district, where they are tolerably regular, they appear to take a slightly southerly direction. They usually incline at an angle of 50° to 60° with the horizon. It would appear that there is a connection between the directions of these joints and those of the mineral veins of the county.

Perhaps the most striking system of joints is the "bedding" joints. Of course the reader, by this time, will understand that the term "bedding" does not apply in the same way in regard to granites as to sandstones and the like. Every Cornish quarryman, however, calls the more or less horizontal joints "bedding" joints; and although we may, perhaps, take exception to the term as being somewhat ambiguous, yet from the fact that it has

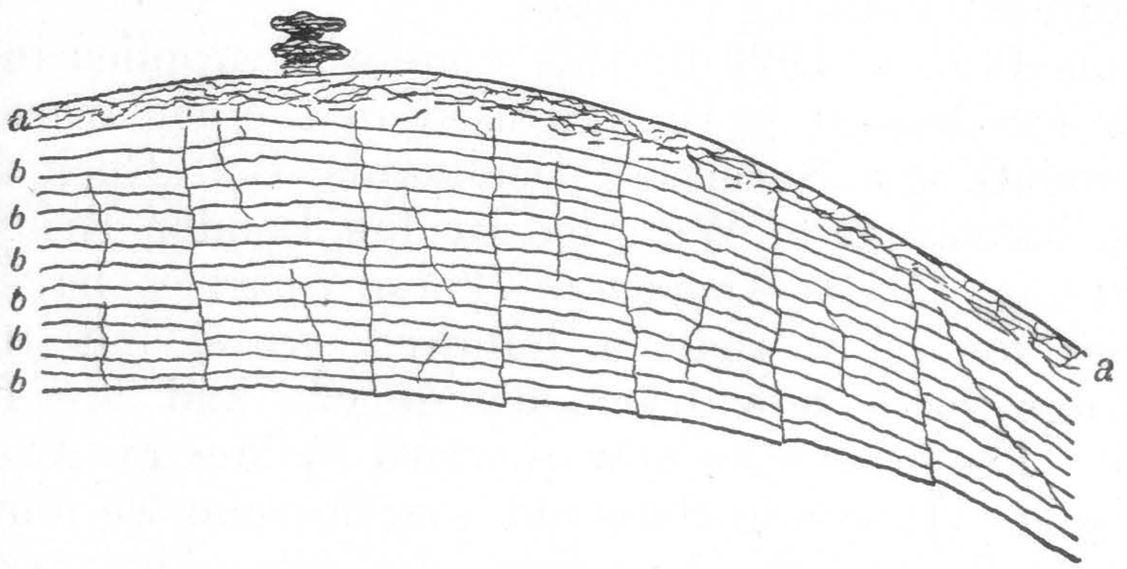

Fig. 11.

received the sanction of universal adoption amongst them, we may conveniently retain it.

Now, although we found that the north and south, and east and west joints, were tolerably constant in direction, especially the former, the rule we are now about to lay down in regard to "bedding" joints is always constant. In every quarry visited, we found that the direction of the "beds" approximately corresponded with the outline of the hill on which it was situated. In the case of a small hill, or when the quarry was situated at the summit of a large hill, the bedding joints, without exception, were seen to follow approximately the same curve. To illustrate our meaning the diagram of the Cheesewring quarry (Fig. 11), may be useful.

a is the outline of the hill, with the Cheesewring at the top; *b* the bedding joints, following the outline of the hill.

In cases where the quarries are not situated at the top of the hill, or where several are situated on different parts of it all round, observation has shown us that the planes of these bedding joints do not run in the form of an anti-

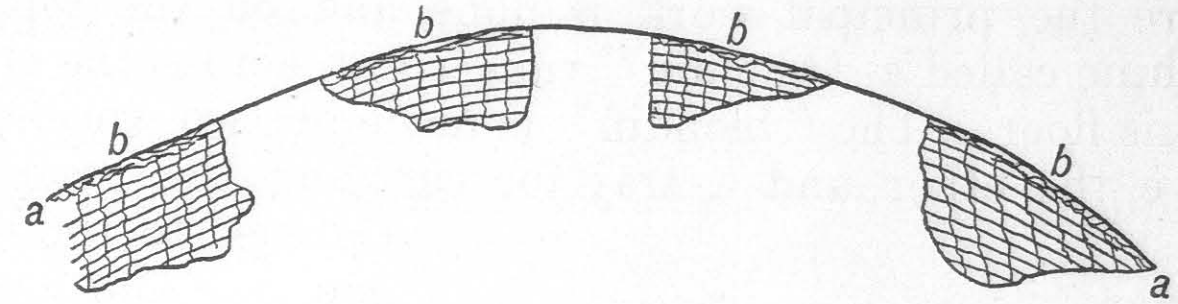

Fig. 12.
a, Outline of Carnsew Hill.
b, Quarries, showing main joints.

cline, unless the hill is a long ridge, but that when the hill is dome-shaped, the bedding joints also are dome-shaped, or, to use a geological term, they dip "quaquaversally." For instance, if one stood on the top of a dome-shaped hill, the bedding joint planes would dip all round, whichever way we turned. They are, in fact, disposed in the same manner as the successive coats of half

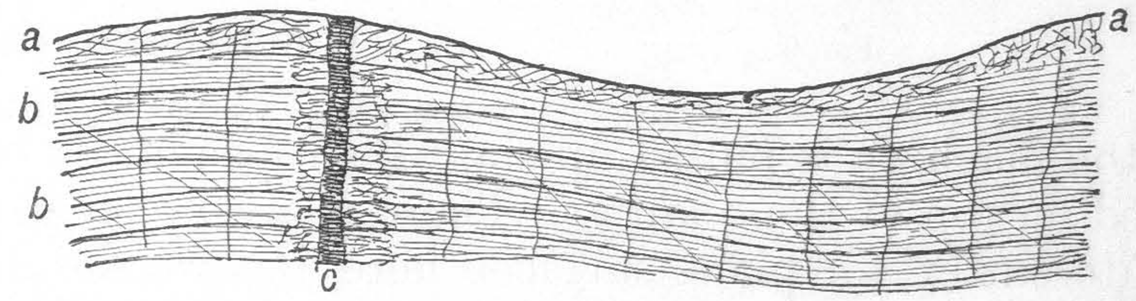

Fig. 13.—Carn Grey Quarry.
a, Outline of the hill.
b, Bedding joints following outline of the hill.
c, Elvan running through the granite, showing alteration on its sides.

an onion are. We will illustrate this point by a reference to the quarries on Carnsew Hill (see Fig. 12), where our attention was called to the subject by Messrs. J. A. and B. A. Freeman.

When the outline of the hill is undulating, the bedding joints still follow it, as is shown by the Carn Grey Quarry (see Fig. 13).

It is not our purpose to inquire at any great length into the phenomena which have brought about these results. We know that when solid bodies become heated they expand, and we have seen (p. 27) that granite has once been in a highly heated condition. Now we may learn that on cooling, the granite would shrink or contract, and it is believed that joints are to a large extent produced by this shrinkage. By reason of unequal contraction we occasionally find that the beds are slightly dislocated, producing (*e.g.* Sheffield and Cheesewring quarries) step-like levels. Or, the same thing may have been occasioned by subsequent faulting due to elevation or depression of the and (see p. 28), earthquakes, or strains.

We do not for a moment suppose that the contours of the hills had any influence in causing the bedding joints to follow them; but we believe the reverse to have been the case, namely that the contours of the hills have been governed, in being carved out by denudation (p. 28), by the directions and positions of the bedding joints. They would form lines of weakness, as it were, along which denudation would be guided. No doubt such an elementary solution as this has occurred to most geologists who have worked in Cornwall. In the case where the top of a granite dome has been denuded, it would be possible to restore the outline of the hill from observations of bedding-joints.

Occasionally minor joints are seen to come to an end, or "run tight," as the quarrymen say.

A consideration of the position of joints is of the first importance in selecting a site on the side of a hill in which to open a quarry, and in judging of the direction in which the opening should be made. A great deal of money would be saved by quarry owners if such points as these were carefully considered before opening the ground, instead of going to work in a haphazard sort of way. It frequently happens that quarries are opened on the steep sides of a hill. Now, where the direction of the joints are well known to be uncertain, other things being equal, we have no objection to this. But if, as we have shown is often the case, the bedding-joint planes

approximately correspond with the outline of the hill, it follows that the bedding-joints in such a case as is now before us would dip considerably. It is perfectly well-known that such a qualification as this is very undesirable, for the stone becomes exceedingly difficult to quarry, and there is considerable danger from blocks which would have a tendency to slip down the steep planes. Perfection can only be obtained by opening a quarry where the bedding-joint planes are either quite horizontal or dip very slightly from the face of the rock and towards the direction in which it is to be blasted. This perfection in the case of Cornish quarries would be more generally met with on the summit of a large dome-shaped hill. Very often the quarry has been opened in such a position that the rock has to be "lifted against the bed." The amount of powder used in such cases is generally excessive, as it has so much extra work to do, but a great deal would depend on the skill of the quarry-master in foreseeing such an event. Quarrying becomes an expensive matter under such circumstances.

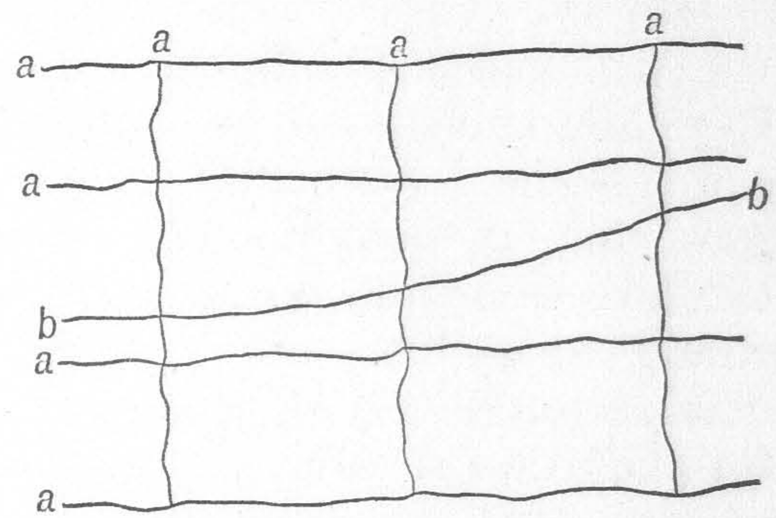

FIG. 14 (Section).—PECULIAR JOINTING KNOWN AS PEDNIAMEAN.
a, Normal joints in the granite. *b*, Abnormal joint.

Occasionally a minor or false joint will occur in Cornish quarries, running in a slightly different direction from the main bedding-joints, and which is known in the Penzance and Penryn districts as *pedniamean*. It may be illustrated by the above section (Fig. 14).

Quarry-masters have always some difficulty in blasting with a joint like this.

In cases where it is absolutely necessary to open a Cornish quarry on the steep sides of a hill, the opening should never be made straight into it, but should be driven sideways, for reasons which are sufficiently obvious.

In those districts where the positions of the main joints are uncertain, it is practically impossible to make any rule, but a considerable amount of information on this heading may often be obtained by observing the joint-planes in crags and pinnacles of the granite which sometimes project from the sides of the hill. It would seem desirable in most instances to open the rock near the top of the hill.

The following example, quoted from a well-known authority, may sufficiently demonstrate the importance of observing the direction of main joints before commencing operations.

"In the old Cairngall quarry (see p. 83), the stone lies from east to west. The *east* side of the hill is that on which this quarry was opened, with great success. Shortly afterwards another quarry was opened on the same hill, but on the *west* side, and the working had to be abandoned. The posts of granite, by which we mean the masses that stand separate from each other by dries or natural divisions (joints), were the quarry to be worked on the side to which they incline, would fall upon the workmen engaged beneath them."*

We have before alluded to the advantage of examining the blocks, or "heathens," which strew the surface in most granite districts, as showing the quality of the material underneath (see p. 77). The elvans, lodes, dykes or traps may in this way be traced, where they exist; and we presume it is hardly necessary to say that, inasmuch as the granite for some distance on either side is almost invariably much discoloured and full of joints and cracks, unless it is absolutely necessary, no quarry should be opened near any of them. The same remark applies to those places where the granite may join a schist or other metamorphic rock. In Cornish granite it would appear that schorl is more abundant † near such a junction than elsewhere.

Even when a quarry is to be started in the centre of a main mass of granite, it by no means follows that the schist may not indirectly be present. In the case of

* See paper by G. W. Muir, "On Granite Working," *Journal of the Society of Arts*, vol. xiv. (1866), p. 471.

† Rutley, "Study of Rocks," p. 139, and other authorities.

Cornwall, for example, we know that the fundamental rock of the county is granite, and although we meet with large areas of "killas," or clay slate, &c., yet it is proved that these are simply lying as patches on the granite underneath. This can be shown, not only by the elvans which run from one exposure of the granite to another,* but by the numerous mines which pass through the "killas" and enter the granite. We have reason to believe, therefore, that "killas" once overlaid all the granite exposures or masses in that county, but have been removed by denudation (p. 28); and it may so happen that in the centre of some of these granite masses, the killas has only just been removed; or in other words, if we, in imagination, restore the killas, we should find that it would come just above the present surface of the ground. The proximity, or otherwise, of such pre-existing killas would, we believe, be easily ascertained by the appearance of schorl in the granite. Thus we believe that schorl is to a great extent a product of metamorphism. We would not advise opening a quarry where schorl is particularly abundant, unless it is to be used for very rough engineering purposes, because large patches of the black mineral do not add to the beauty of the stone, and cavities are apt to weather out.

As a matter of observation, we find that joints are closer together in the finer-grained granites than in the coarser-grained varieties; and from this it will be seen that whenever large blocks are required in any number for engineering, &c., the coarse-grained granites are more likely to fulfil the requirements than the fine-grained. We have heard it stated that the reason why rocks containing oligoclase (p. 14) felspar have irregular or rhomboidal joints is because the cleavage of that mineral is oblique, and the scenery, in a district where it is a principal constituent of granite, would present sharp crags and pinnacles; but that, on the contrary, when orthoclase (pp. 14, 15) felspar predominates in the granite, such as in Devon and Cornwall, the scenery would present

* Brenton Symons, "Geol. of Cornwall" (1884), p. 47, and Sir H. De la Beche, "Report, &c., on Cornwall."

castellated "tors," and approximately right-angular joints, from the fact that orthoclase has a right-angular cleavage. We regret that we are unable to give reference to these interesting points.

We have seen that, although in most cases the main direction of orthoclase felspars determine the direction of the bedding-joints, and the way the rock will most readily cleave, yet there are exceptions to this rule (see p. 50).

CHAPTER X.

BLASTING.

In quarrying granite, it is nearly always necessary to dislodge the blocks from their position by blasting. The explosive varies according to the circumstances of the case. For instance, suppose the material is to be used as road-metal, as in Guernsey, &c., or a quantity of bad rock is required to be quickly removed, dynamite is the explosive generally used. But, if the blocks are for building or engineering, the blasting is invariably effected by powder. All quarrymen agree in stating that the explosion of dynamite is such, that the rock is shattered too much for ashlar purposes; whilst gunpowder "heaves" the rock out more easily, and in more solid blocks.

In Cornwall, where blasting as a rule is tolerably easy, the following is the method commonly employed. The first thing to be done is to bore a hole in which the charge is to be placed. This is accomplished by three men, one holding a steel bar with a cutting-edge, which, as the hole is bored, is moved round, and the other two striking the bar with hammers. The diameter of the hole varies from three to five inches, and the rate at which it is bored depends on the hardness of the rock and the experience of the workmen. Four feet in nine hours is reckoned good work. The hole bored may be either triangular or circular. In the latter case a circle of steel is placed at the bottom of the bar. In making a triangular hole, which most of the men prefer, so great has been the experience of some that, in spite of the twisting of the triangle, they are said to be able to judge of the position in which any face of the triangle may be, at the bottom of a hole. Water is used in boring, and the mud at the bottom of the hole is in many quarries drawn up by means of a hollow cylinder with a valve at the bottom, and which is attached to the end of a rod. When the rod and cylinder are pushed down the hole, the valve opens and admits the mud, whilst, as it is drawn up, the valve closes.

After the hole is bored it is cleaned out, and finely-powdered dust is shaken in it to dry the sides and bottom. The gunpowder is then brought from the magazine to the spot in tin canisters, and about half the charge is poured down the hole. Two lengths of patent fuse, made with hemp twisted so as to form a sort of pipe filled with powder, are tied together at the bottom and gently let down the hole. The remainder of the charge is then poured in, and the outside ends of the fuse secured by a stone from slipping down the hole. A man now comes forward with a pail full of rotten granite and quarry dust, slightly moistened, whilst another pounds it up, and after ramming a little hay down on top of the powder,* he pours a quantity of this rotten granite, or "tamping" as it is called, into the hole, and carefully rams it down on top of the hay. The ram or "tamping-bar" is a rod of iron or wood, with a knob of Muntz metal or copper at the end, to keep the quartz from "striking fire." This is the most dangerous part of the operation. After a foot or so has been carefully rammed down, they are not quite so particular, and the remainder of the tamping, all of rotten granite, is soon filled in. Meanwhile, in those quarries where necessary, a man is sent round warning people not to come near, and sending all horses and carts out. All the quarrymen then either leave the quarries or shield themselves behind masses of the rock. A man then lights the two ends of the fuse, and we, who have watched the operation, run as fast as possible out of the way, hear a rumbling noise and a loud report, see hundreds of small pieces of granite fly up into the air, a crash, dense smoke, and then, cautiously approaching the scene of the explosion, where the smell of powder is sometimes almost unbearable, observe the effect of the blast.

In cases where it seems advisable, no hole is bored, but

* All quarrymen do not use the hay.

the powder is poured down a crack, the fuse being armed at the end with a lump of moistened powder, or "spit devil," tied on, with a piece of paper round it, by string. No tamping is then used, but ashes are poured on top of the powder.

There are many ways in which these methods of blasting may be improved. We will first deal with the boring of the hole which is to contain the charge. When a large one is made, no matter in what position, it is called, in Cornwall, a "muckle" hole; but a small one made horizontally is termed a "capping" hole. We have shown that the hole may be either triangular or circular. On inquiring why the former kind was more often used, we were informed that the sides of the triangle frequently gave a direction for the cracks made by the powder, and as operators could end the hole with any face of the triangle in a particularly desired direction, that the quarrymen were thus enabled to guide the cracks and the effects of the blast. Now this is all very well, providing they know the position of the lines of least resistance; but we found in many cases the blocks were so placed that they were unable to ascertain this. Nevertheless, triangular holes were used, and so we see that frequently the powder was urged to force its way along certain directions, which, for aught they knew to the contrary, might be in a totally different position to that required to do the work effectually. In all cases where there is any doubt as to the direction of the lines of least resistance, we would advocate the use of round holes only, which would allow the charge to find its own way. Unless very skilled borers are employed, we would not advise triangular holes on any account.

Again, the tamping might be considerably improved. It is not our purpose to go into all the details to substantiate this fact. We would refer the reader to Major-General Sir John Burgoyne's excellent little work* for information on this head for cases where the charge is to be fired with the patent fuse. His work, although written some time since, embodies all the important points, and they have not been much modified, except in regard to firing by electricity.

* "On Blasting and Quarrying Stone" (Weale's Series), 1849.

In recording the results of experiments in blasting with different tampings, he concludes that the following rules may be generally laid down.*

1. "That clay dried to a certain extent is, all things considered, the best material that can be used for tamping.

2. "That broken brick, tempered with a little moisture during the operation, is the next best material.

3. "That some kinds of rotten stone are as good as either, but that it is not so easy to be sure of always having the proper kind, and the use of it is very likely to lead to an occasional substitution or mixture of stone of other quality, such as is decidedly objectionable.

4. "That sand, or any other matter poured in loose, is entirely inefficient.

5. "That the stone-dust and chippings of the excavation itself (excepting the rotten kind above mentioned) afford less resistance than clay, and being always more or less attended with risk of accidents by untimely explosion, should never be employed.

6. "That of the mechanical contrivances by means of plugs or wedges, the most effective of those referred to, are the cone with arrows and the barrel-shaped plug, both of which, particularly the former, give a great increase of resistance; but that all such contrivances, leading to increased expense, requiring extra arrangements and some attention to a proper application such as cannot always be depended upon, are none of them applicable to ordinary purposes, but might be very useful under circumstances where every blast is under great difficulties or attended with much expense; for instance, under water, or in carrying on shafts, galleries, &c., through very hard rocks. In such cases the additional cost and labour of employing these means would perhaps be well repaid by the improved effect of each explosion."

We believe that a medium-grained powder of good quality would be more effectual in quarrying granite than the very coarse powder now so much used. It would concentrate all the force near the bottom of the hole, which, as all quarrymen admit, is what they want. In

* *Op. cit.*, p. 59.

all cases where there is a miss-fire, water should be poured down the fuse-hole and the charge thoroughly wetted before the tamping is bored out.

We wonder that electricity is not more used in firing the holes in Cornwall. There can be no doubt that it is a very safe and expeditious method. In using the patent fuse, which, however, is very effectual, a great deal of the force of the blast is expended up the holes in which the powder has burnt, and is thus lost. When electricity is used there is no such escape for the explosion; two insulated copper wires, connected at the bottom with a thin platinum thread surrounded by fine powder, form the fuse.

In the Aberdeen district, all the explosions we saw were fired by electricity, the whole charge of powder, with the fuse, being placed in elongated water-tight bags and dropped *en masse* down the hole. After tamping, a horn was blown, when all the men left the quarries, and the explosion soon followed.

In reading works on the subject one frequently sees a great deal about rules for determining the quantity of powder to be used in blasting, direction of the holes, &c. Theoretically these are all very well, but in practice most of them will not work. They nearly all assume that the rock to be blasted is a firm solid body without any cracks, &c., whilst the peculiar directions in which holes would have to be bored to follow out the rules would waste too much time and cost too much money to be of real advantage. As a matter of fact, before a hole is bored for the blast, a good quarry-master looks at the block to be removed and endeavours to find all cracks and joints. He then sees whether the mass has to be blown up the bed or against it, and observes the manner in which it may be wedged in by other blocks. After mature consideration he instructs the men under him to bore the hole, and estimates the quantity of powder to be used, not by the depth of the hole, but by judging the amount of force required to move the block. Experience has taught him how to do this.

A peculiar method is adopted by some quarry-masters to find the lines of least resistance (see p. 41).

CHAPTER XI.

THE MANIPULATION OF GRANITE.

A.—CUTTING AND DRESSING.

AFTER the stone has been blasted from the parent rock, or sometimes when *in situ*, it is cut up into the required shape. This is commonly done by making a series of holes three to four inches apart, and about three inches deep, along the lines where it is desired to be split. In the case where a cube block has to be cut, and the quarrymen are not particular where it will split to a few inches, only one row of holes on the top of the block would be made; but, if they were cutting against the grain, or the tough way of the rock, they would also place rows of holes down the sides leading from those on the top. The former kind of holes are generally slightly wider apart than the latter. In other cases a groove from two to three inches in depth would be cut on the top of the block in the direction in which it is intended to be split, and then the small holes would be made as usual along the bottom of the groove. When extra care is necessary, by reason of the refractory nature of the granite, or when it is particularly desired to be sure of splitting a block exact, we have seen holes 2 inches in diameter, 3 feet 4 inches deep, and 4½ inches apart, let down into a block, and even small holes placed between them and down the sides. This is very exceptional, though.

The three-inch deep holes in some districts are cut with the hammer and chisel, and for very hard rocks this is perhaps as expeditious as any other way would be. In Cornwall these small holes are made by means of a

"jumper." * This is a curious instrument, as will be seen on reference to the annexed figure (Fig. 15).

The operator catches hold of the "jumper," placing one hand under the iron knob in the centre, and the other about halfway between the knob and the upper part of the tool. He stands upright on the block, and lifting the tool, keeps plunging it down on the spot where the hole is to be made. When the hole is sufficiently deep he moves on to the next one, and so on. In an experiment carried out in the Carnsew quarries (p. 48), we found that 112 blows of the hand-jumper made a hole 2½ inches deep against the grain of the rock.

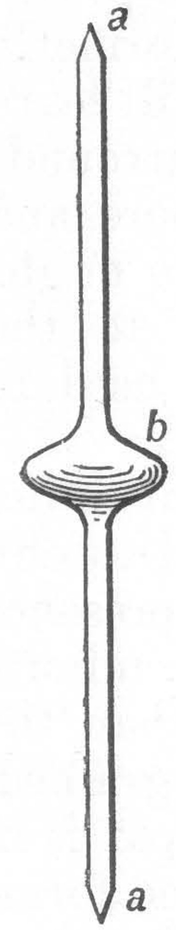

FIG. 15.
a, Cutting edges of the jumper.
b, Iron ball welded to the rod. Length of rod, 4 ft. 6 ins. to 5 ft. 6 ins.

The monotony of the quarry is often considerably relieved by four or five workmen standing on a large block using "jumpers" of different tones, and, keeping time, ringing a merry peal in making the holes. The men themselves are very fond of this, and they consequently work much better.

The deep holes, two inches in diameter, before alluded to, are made by a patent steam drill, which is capable of boring in the aggregate from 40 to 50 feet in seven hours. We were informed that this rate is very often exceeded, especially when the holes are bored with the grain and not against it.

On the 8th March, 1887, the Carnsew patent drill of Messrs. John Freeman & Sons bored 50 feet of granite, the bore-hole being 1½-inch in diameter, in 5¼ hours. This is not continuous working, but allows for shifts, &c. Whilst at work it is said to bore seven inches a minute.

When the holes are made, the block is split by means of "plug and feather" wedges. The "feathers" are small thin pieces of wrought iron, rounded off on one side. Two of these are placed in each hole, and the "plug," which is made either of iron or cast steel, is

* In some, if not all, the Irish and Scotch granite quarries, the term "jumper" is applied also to the cutting tool for making the blast-holes.

inserted between them and driven tight. The quarryman then gives each "plug" a few knocks in succession with a hammer until the rock splits. When the granite is sound and firm, a sharp whip-like crack is heard on splitting.

Granite blocks are dressed in a variety of ways. The chisels used require a particular temper, which must neither be very hard nor very soft, else they would either lose their edges by chipping, or fail to cut the stone. They frequently require sharpening. The chisel is held by the workman at a much less oblique angle to the surface of the block than when working freestone, and he separates only small particles at a time.

Unless the "natural" face of the stone is left it is either "punch" dressed, which is considerably lighter than the "natural" face; "picked," which is lighter than "punched;" or "axed," which is a superior finish.

Previous to the year 1818, all dressed granite work was done with small picks. The manner in which "patent axes" were first introduced in working Aberdeen granite, and, in fact, of their being introduced into the kingdom, is worthy of notice. The late Provost Hadden of Persley, Aberdeenshire, being at New York, saw one of them for the first time and brought it home. He gave it to a Mr. Milne, who was contractor for some public buildings then in course of erection, and after being tried by that gentleman, it was pronounced a failure and laid aside as useless. Some time afterwards, the axe fell into the hands of Mr. Macdonald, the well-known Aberdeen granite worker, who had two axes made on the same pattern, when they were found to be so successful that they have ever since been universally used. It is an instrument composed of a number of thin slips of steel tightly bound together and fastened to a handle, their edges being on the same plane. The surface of the granite to be "fine axed" is then smoothed by a series of taps, given at right angles to the surface previously operated upon.

The surface of some of the granites used by the ancients, and handed down to us, has been observed to peel off, but it is noteworthy that the granites in buildings erected in more modern times do not exhibit this peculiarity. Professor

Tennant believed* that this scaling was produced in the process of dressing, by which the tool fractured or "starred" the surface, so that eventually the fractured part would weather loose or fall off the stone. Whether this is so or not, there cannot be much doubt that fracturing of the surface has become very much minimised, if it has not altogether disappeared from the better kinds of granite, by reason of the introduction of less cumbersome tools, and especially by the application of the patent axe referred to.

B.—POLISHING.

Although the introduction of the present system of polished granite into architectural ornamentation, monumental sculpture, &c., is of comparatively recent date, granite polishing was known more than one hundred years ago among the jewellers of Aberdeen, as the following extract from the *Aberdeen Journal* of the 3rd December, 1770, shows:—

"Collin Allan, jeweller and goldsmith in Aberdeen, begs to acquaint the public in general that he has established a manufactory for sawing and polishing granite slabs, tables, and chimney pieces, &c."

In modern times the fabrication of slabs, pedestals, and vases in hard porphyries, and in granites, has been carried to great perfection in Sweden. The quarries of Blyberg, at Elfdalen, for many years have furnished materials for the exhibition of this Swedish ingenuity and artistic skill. They add greatly to the splendour of the homes of the Swedish capital, and are known and admired all over Europe.

Granites are polished in the vicinity of most of the granite-quarrying centres, principally at Penryn, Plymouth, Shap, Aberdeen, Dalbeattie, and Newry, as well as in London and a few of our largest cities. The machinery used in all these polishing works is practically of the same kind, varying only according to the magnitude of the respective establishments. The polishing works at Aberdeen are un-

* *Jour. Soc. of Arts*, vol. xiv. (1866), p. 471.

questionably the most important in the kingdom, and we have visited many. Some of the polishing firms also quarry the material, whilst others purchase the stone as they want it from the quarry-owners.

The cut blocks for architectural and monumental purposes are conveyed to the polishing works, where they are first masoned, and the smoothest possible face put on before being placed in the polishing-mills.

The granite turning-lathe, otherwise known as the "steam-mason," is capable, in some works, of doing the work of fifteen men, and dealing with columns up to 16 ft. or 18 ft. in length and 2 ft. 8 in. in diameter. The corners are roughly scabbled off a squarely cut piece of granite before being put into the lathe. The cutters of the lathe consist of two circular cast-steel discs, which are on opposite sides, one acting as a counterpoise to the other, as well as doubling the amount of out-turn. These cutters have a tapered hole bored in the centre, through which is passed a spindle with boss. This in turn is placed in the rest, when the boss on the spindle is tightly screwed up against the face (or rather, in the tapered hole) of the cutter. The cutter and spindle revolve, the rotary motion being given by the column or block of granite, which is turned by steam-power. The Ross of Mull granite columns at Blackfriars Bridge, which are eight feet in diameter, are productions of these lathes.

In the largest works there are usually smaller lathes also, for turning vases, balusters, urns, &c.

Let us now consider the polishing process. When a column comes from the turning-lathe it is placed in an ordinary lathe, and is so fixed as to revolve. Cast-metal planes are then placed upon it, and sand and water applied, which puts on a fairly smooth surface, then emery and water, which imparts a still finer surface. At this stage the plane is covered with thick felt, and the polish is brought out by the application of putty-powder. This process applies to the polishing throughout.

That employed in polishing plane surfaces of granite is, briefly, as follows:—

The stone to be polished is fixed in a machine called a

"wagon" after being fine-axed. The surface to receive the polish is placed in a horizontal position, uppermost. The "wagon" travels very slowly to and fro on rails, like the bed of a planing machine, and the polishing is effected by two or more vertical spindles, to which are attached flat cast-iron rings of various sizes connected one within the other in the same plane, so arranged that the largest ring is farthest away from the spindle, the sizes decreasing as the spindle is approached. The undersides of the rings lying on the stone to be polished are lined with felt or other similar material. It will thus be seen that when the spindles revolve, the rings have a circular horizontal motion on the flat surface of the stone, whilst the latter travels backwards and forwards underneath it in the wagon, which thus passes the different parts of the stone under the rings to be polished.

In Aberdeen, at Messrs. Alexander Macdonald & Co.'s works, we have also seen an instance in which the stones to be polished are stationary, and the frame with the revolving spindles and rings passes over them, polishing in the usual way. We presume that this method is more convenient when dealing with heavy blocks.

Other machines for polishing granite are called "verticals," but the amount of work done is nothing like so much as with the methods just mentioned. In these the granite is stationary. The rings revolve as in the other machines, but a piston-like motion, combined with a swivel-joint, enable the workmen to direct the polishers over any part of the surface.

The machines by which mouldings are polished are known as "sliders." In the first place the mould is cut to drawing, by a mason, then plaster of Paris is run on the mould, and an accurate impression thus obtained. From this pattern a metal casting is made. The granite is then laid on a frame, or on the ground, the casting is attached to a long wrought-iron arm fixed to a pin on a large face-plate, and the machinery set in motion. The arm travels to and fro, and, to prevent loss of emery, &c., the moulds are roughly encased in a wooden frame and the joints stopped with plaster of Paris.

Circular door and window heads, can be polished in these machines as well as straight mouldings. Where anything very elaborate has to be executed, it is done by hand, and thus the price of the material is considerably augmented.

In sawing granite into slabs, the material is placed in a frame, the saw-frame being suspended from above. A sawing motion is imparted to the frame by a crank attached to proper steam machinery. Water and chilled iron shot are used to assist the saws.

Sawing and polishing granite is a slow operation even with the best machinery.

CHAPTER XII.

THE SELECTION OF GRANITE FOR VARIOUS PURPOSES.

EXPERIMENTS of many different kinds have been carried out to try and test the durability of stones. We will now examine the results of a few of the more important of them which relate to granites.

We know that the acids contained in rain are powerful agents in denuding rocks, and it therefore seems that our first consideration in selecting a granite should be to find its chemical composition, and to see whether it contains any matter which is especially liable to be attacked by these acids.

But we should by no means allow the results thus arrived at to guide us in selecting solely, for a very great deal of the weathering of the stone depends on the state of crystallisation of the component minerals. In the finer-grained granites, for instance, it is important to notice the disposition of the quartz. This mineral, which is exceedingly durable, is sometimes seen partially enveloping other less durable minerals in such a manner as more or less to protect them from deleterious agencies. Most granites are very durable, but there are notable exceptions to this rule even in the midst of the best quality districts (see p. 14). The majority of granites which come to the market in the polished state are not so much affected by the weather as those in the rough, or even the "axed" state, because the rain on falling on the polished work, as a rule, glances off or easily runs away, whilst the uneven surfaces of the rough kinds afford ledges, which, however small they may be, assist in retaining the rain-water, which thus has greater opportunities of attacking and soaking into the stone.

In selecting granites from a chemical point of view the principal things to attend to are the condition of the felspar, the nature of the blotches that so frequently occur, and the easily decomposable accessory and secondary minerals, especially iron oxides. Granites which contain an excess of lime, iron, or soda, are the most liable to decay (see p. 14). Compact medium-grained varieties are generally good stones.

Those containing large crystals of mica are unfit for architectural purposes, and the same may be said of varieties in which soda-felspar and very deep red (iron) felspar predominate.*

The quantity of water a stone is capable of absorbing has material influence in determining its comparative durability. All stones contain interstitial or "quarry" water. It is not in chemical combination with the various minerals which constitute the rock, but is merely retained in their pores. A great deal of this water evaporates when the stone has been subjected to the influence of the atmosphere, and the material becomes more difficult to work in consequence.

We find by experiment, exactly as might be inferred, that the more water a stone absorbs the less durable it is; this must, therefore, be borne in mind when dealing with other matters respecting its durability.

A simple method of finding how much water stones absorb is to dry them thoroughly, and then carefully weigh them with a spring balance. Then immerse the specimens in water for a day, after which they should be taken out and re-weighed. The additional weight shows the amount absorbed. This amount may be increased by exhausting the air from the specimens before immersion.† When water freezes it expands, and in expanding produces a tremendous pressure on the material which contains it. To give examples of this: bomb-shells and cannon filled with water, and hermetically sealed, have been burst in strong frosts, by the expansion of the freezing water within them. In winter weather, as plumbers are well aware of, water-pipes are frequently burst in a similar manner.

* See Page's "Economic Geology," p. 60.

† See further on this subject, Delesse, "Bull. Soc. Géol. France," 2me sér., xix. (1861-62), p. 65.

When a stone, therefore, contains much water, the water in freezing forces the particles composing it asunder. Consequently, when a thaw comes, the particles having lost their original cohesion are easily removed from the stone, which thus rapidly decays. Experiments have shown that the more a rock becomes weathered the more water it absorbs. So that when a stone has commenced to decay it will increase in a greater proportion as the decay proceeds.

Many experiments have been made to imitate the action of frost on stone, but with doubtful success. Consult "Guide to the Museum of Practical Geology" (1877), p. 40; Ansted, "Physical Geography and Geology" (Orr's Circ. of the Sc.), 1855, pp. 205–6; *id.* "Lectures on Practical Geology," p. 170; Dobson, "Rudiments of Masonry and Stonecutting," 1873; Appendix, p. 131, and the "Commissioners' Report," &c.

Stones having a somewhat similar appearance to each other are often found on examination to be of different strength, so that considerable attention has been paid to the results of experiments dealing with their comparative resistance to thrusting stress.

The weight necessary to crush a stone varies with the state of cohesion and hardness of the particles composing it. It follows, therefore, as the amount of water a stone absorbs is proportionate to the state of aggregation of the particles composing it, that the crushing weight will be proportionate to the amount of absorbed water. Or, to put it in another way, suppose we know the average amount of water absorbed by stones of similar natures, we can get a rough idea of their relative strength. A careful comparison of several published accounts of crushing weight and absorption of water by stone, would show that this rule is almost invariably borne out. The exceptions that exist are due in a great measure to the insufficient manner in which the stones have been described, causing the comparison to be made between stones widely different from each other, but which, unfortunately, bear the same name.

Stones of aqueous origin made up of large shells are difficult to deal with in selecting pieces for crushing; it is not easy to obtain average pieces. It is simply ridiculous to find the strength of one-inch cubes of such stones (as has often been done); large pieces should always be experimented upon, certainly not smaller than six-inch cubes. It can be shown that in many cases no very great difference exists between the relative crushing weights of one-inch and six-inch cubes of stones of a homogeneous character; but when rocks contain large crystals, such as many of the granites and porphyries, or large shells, such as are found in many limestones, the crushing weight must vary considerably according to the general position of the cleavage planes of the crystals, or the predominant direction of the exterior faces of the shells.

A small cube of granite might fail to prove the existence of cracks and flaws invisible to the naked eye, in large blocks of the same stone. The comparative strength of the large blocks would thus be lower than the examination of the small cube would seem to warrant, for it must be remembered that the strength of a stone is only the strength of its weakest part. In testing the crushing weight of granites and other stones it is desirable for comparison's sake that they should be of the same size and shape. This is not always attended to.

Experiments as to the strength of stone also vary according to the machinery used, as well as the skill and care with which the experiments are made and recorded.*

A very important point to ascertain in comparing results of experiments of different kinds of granite is whether all the materials under experiment are actually granites. It is not near enough, even for practical purposes, to admit other kinds of stones, simply because they may be known in the market as "granites," into the comparison.

* A striking example of this will be found in the *Builder*, vol. xxx. (1872), p. 418.

The results of resistance to thrusting stress are of no real value unless stones of approximately similar mineralogical composition are tested. For instance, granite should be compared with granite, syenite with syenite, greenstone with greenstone, and so on.

Further than this. In the case of granite, we have a peculiar substance to deal with. If we place a piece of coarse porphyritic granite,—say, from near Penzance,—side by side with a piece of very fine blue granite, such as that from Rubislaw quarries, Aberdeen, the difference in structure is very striking, so much so, that at first sight they do not appear like the same class of stone. We have before stated (p. 126) that experiments as to crushing on small cubes of stone containing large crystals are not of much value. Applying this remark to the two granites under consideration, we see that the results on a 6-inch cube of the porphyritic Penzance stone would be of no use. If machinery permitted it, and a very large block of each were tested, it would be quite another matter.

This leads us to the conclusion that, in respect to granites, the crushing weights on 6-inch cubes are useful only for comparison of the finer-grained varieties; and any one who is selecting stone should therefore know the grain of the rocks, the results of compression of which he is comparing.

It is often found useful to know the weight of stones, because to a certain extent it is an index to their durability. Many published results show the average weight per cubic foot, whilst others give the specific gravity. The trouble of preparing several samples of hard stones, making them of the required size and shape, in order to find their average weight, is a drawback to the former method. The latter method is, perhaps, the preferable one, for not only can the stones be of irregular shape, but when an average piece is carefully selected more accurate results are obtained.

The specific gravity of a substance is its weight compared with that of an equivalent bulk of pure water, at a definite temperature and pressure. The density of a rock or mineral depends, to a great extent, on chemical composition and minute structure.

The stone to be weighed must be an average-looking specimen, because two fragments of the same rock may contain different proportions of its constituent minerals.

The most convenient way of finding specific gravity is by weighing the same specimen first in air, then immersed in water, and dividing the former weight by its excess above the latter.

A special instrument is required for this purpose. A good one is that called "Walker's Specific Gravity Balance," invented by Mr. W. N. Walker, F.G.S., and sold by Mr. G. Lowden, Optician, Dundee.*

A knowledge of specific gravity is perhaps more useful in selecting granite for marine works than anything else with which we have to deal. For sea-walls and pier harbours, exposed both to heavy breakers and shingles, hardness and durability, with great specific gravity combined, should be sought for.

The greater the weight of a given sized sea-wall or pier, all other things being equal, the better will it stand the force of the breakers.†

Some years ago Mr. Thomas Stevenson conducted a series of experiments on the force of the breakers on the Atlantic and North Sea coasts of Britain. The average force in summer was found in the Atlantic to be 611 lbs. per square foot, while in winter it was 2,086 lbs. But on several occasions both in the Atlantic and North Sea the winter breakers were found to exert a pressure of 3 tons per square foot, and at Dunbar as much as 3½ tons.‡

Besides the continual bombardment of breakwaters and other marine works, caused by waves throwing huge blocks of stone against them, we have to take into consideration, even where this action is less violent, another powerful agent which also does a great deal of damage.

* Several kinds are treated of by Professor Judd, F.R.S., in "Proc. Geol. Assn.," vol. viii., pp. 278—287.

† "Rep. on Geol. of Corn., Dev., and W. Somt.," by Sir H. T. De la Beche, F.R.S.

‡ "Trans. Roy. Soc., Edin.," xvi., p. 25.

It is the alternate expansion and compression of air in crevices made in the masonry, which dislocate large masses of the stone even above the direct reach of the waves.

Engineers know that, even from a vertical and apparently perfectly solid wall of well-built masonry exposed to heavy seas, stones will sometimes be started out of their places, and that when this happens a rapid enlargement of the cavity may be effected.

At the Eddystone Lighthouse, during a storm in 1840, a door, which had been securely fastened against the force of the surf from without, was actually driven outward by a pressure acting from within the tower, in spite of the strong bolts and hinges, which were broken. We may infer that by the sudden sinking of a mass of water hurled against the building, a partial vacuum was formed, and that the air inside, forced out the door in its efforts to restore the equilibrium.*

Dr. A. Geikie says† that this explanation may partly account for the way in which the stones are started from their places in a solidly built sea-wall. But, besides this cause, we must also consider a perhaps still more effective one, in the condensation of the air driven before the wave between the joints and crevices of the stones and its subsequent instantaneous expansion when the wave drops.

We quote these examples to show the influences to which granites selected for lighthouses, sea-walls, &c., are in some instances subjected. There can be no doubt whatever that stones having a high specific gravity, which include some of the compact, medium-grained, heavy varieties of granite, are amongst the best materials for these purposes. Exceedingly heavy and compact limestones have been used for large marine works; but the action of molluscs, which bore into the stone, is a serious drawback to them in many instances.

Bearing in mind what we have said as to a stone weighing less in water than in air, the student will readily understand that in dealing with submarine structures, the relative weight of the stones used is greatly reduced.

* Walker, "Proc. Inst. Civ. Engin.," i., p. 15.

† "Text Book of Geology" (1882), p. 429.

The following examples, taken from Mr. T. Stevenson's "Harbours," p. 107, will further illustrate this fact:—

—	Specific Gravity.	No. of cubic feet to a ton in air.	No. of feet to a ton in sea-water of specific gravity 1·028.
Basalt . . .	2·99	11·9	18·26
Red Granite .	2·71	13·2	21·30
Sandstone . .	2·41	14.8	26·00

Although the care in the selection of stone by specific gravity for rather deep submarine work should by no means be neglected, it is not so important, perhaps, as for that portion of the structure near and just above the surface of the water; for this reason—waves, which are the principal source of the destruction of the works, only exist at the surface of the water. Underneath, everything is comparatively quiet, and very little or no damage is caused from the motion of the water.

Delesse says that engineering operations have shown that submarine constructions are scarcely disturbed at a greater depth than 5 mètres (16·4 feet) in the Mediterranean, and 8 mètres (26·24 feet) in the Atlantic.*

As might be expected, there is an intimate connection between the specific gravity and crushing weight of stones. Information bearing on this point may be found in Barlow's "Treatise on the Strength of Materials" (ed. 1867), p. 110; and the *Builder*, vol. xlviii. (1885), pp. 192-3.

In regard to aqueous rocks, the specific gravity is in some measure an index to their durability; but when we apply it to granites and stones of a like nature, it begins to lose its value in this respect. Its principal use so far as igneous rocks are concerned is in assisting to calculate the weight of a certain sized mass, so that it may be used by the engineer in estimating the strain on certain portions of large structures. It is very convenient also to know the specific gravity of granites intended for marine works, as—other

* "Lithologie des Mers de France" (1872), p. 110.

things being approximately equal—the higher specific gravity granites are the best for these purposes, as previously mentioned.

The specific gravity of igneous rocks is frequently quoted in matters connected with road-metalling; but though this occasionally enables us to form some idea of the "resistance to crushing" under ordinary circumstances, for road-materials a knowledge of the specific gravity is practically useless, whilst whatever value it might have in assisting us to discover what pressure these materials are capable of resisting, is certainly lost. The results might be useful where the stone is to be built in a wall, and where the pressure is tolerably equal all the year round, but road-metal is not subjected to such steady pressure. The pieces that form it are suddenly called upon to bear enormous weights, which are withdrawn as suddenly as they came, so that if the stones used for these purposes are not *tough* they soon snap. Care must be taken to distinguish the difference between the hardness of a stone and its toughness. Some people seem to think that hard stones are necessarily tough, but such is not the case. Many of the hardest stones in existence are very brittle. Toughness in granites, syenites, and the like is occasioned by the disposition and size of the crystals forming them, these crystals being more interlocked in the tougher varieties of these stones than in the others.

The student might well ask, then, why the "crushing weight" is not an index to toughness, seeing that the two things are both dependent on structure. In answer to this, we must urge that the steady pressure of machinery on a plane surface must not be compared with that uncertain, uneven, grinding action to which road-metal is subjected.

In addition to being tough, however, road-metal must be made of *durable* minerals; for it is often subjected to very severe chemical tests. On some country roads, for example, the stones, after a rain, might be described as being literally in a chemical solution, which is trying its best to disintegrate them.

Although we have defined syenite as being made of quartz, felspar, and hornblende (excluding the few accessory minerals, for simplicity), we have not stated in what particular quantities these may exist, and this is an important factor in the inquiry. It will be found that the proportions vary considerably, and on this the differences in durability and specific gravity are largely dependent. There cannot be much doubt that in the syenites commonly used as road metal, the rate of decomposition of the felspar is the principal source of the superiority of one kind over another.

The most durable syenite, then, is that which has the least felspar, and, we may add, the least iron in that mineral. Syenites which contain an excess of felspar, generally have a low specific gravity, unless the hornblende is superabundant.

Those hornblendic granites, in which the felspar has a tendency to occur in rather large crystals here and there, cannot be expected to make such good road metal as those kinds of syenite which do not exhibit this feature, are fine-grained, have comparatively little felspar, but much hornblende.

This enables us to see why it is so very essential to distinguish between rocks of different structure and mineralogical constitution, but which bear the same name in the market.

Another cause of the disintegration of granite and other rocks is by considerable variations in the daily temperature. Its effects on granites used in Great Britain are no doubt very slight, but in countries where there is a great daily difference of temperature, much difficulty is experienced in selecting building materials from this cause. Many cases are extant in which fine-grained and very durable granites (as far as this country is concerned) have not only lost a great deal of the beauty of their polishing by discolouring, but by actual disintegration, when sent abroad, especially to the tropics.

Rocks are expanded by heat and contracted by cooling. Variation in temperature thus causes some building stones to alternately expand and contract, and this prevents the joints of masonry from remaining close and tight. In the United States, with an annual thermometric range of more

than 90° Fahr., this difficulty led to some experiments on the amount of expansion and contraction in different kinds of building stones. It was found that in fine-grained *granite* the rate of expansion was ·000004825 for every degree Fahr. of increment of heat; in white *crystalline marble* it was ·000005668; and in *red sandstone* ·000009532 or about twice as much as in granite.*

Granite is very susceptible of injury by fire, much more so than compact sandstone with a siliceous matrix. This latter is, no doubt, the best natural stone for withstanding fire. Formerly it was exceedingly hard to work with the chisel, and although this difficulty has been much lessened, yet the tendency of siliceous sandstones to have a splintery fracture will always be a great drawback to their general use.

Although a great deal of granite is used for road-metal, yet by far the greatest quantity is quarried for dock-work, embankments, kerbstones, and things of a like nature. Mouldings and ornamental work made of granite are much more common in the better class of buildings than they were a few years ago, whilst for monuments, drinking-fountains, &c., it is very popular. We notice that the foundations of several large buildings in London have recently been constructed of granite, and this is decidedly a step in the right direction. When we look at the rotten stone with which many large edifices in our metropolis are built, we wonder why granite is not oftener used for foundations and exposed situations. We will not go so far as to say that the buildings should be entirely made of granite; but if more care were exercised in selecting the freestones and sandstones used in the less exposed situations, and—consistent with artistic appearance—good granites were placed in places where those stones would suffer most injury, the greater cost of the first production would be amply repaid eventually. We are informed on good authority that cheap granite ashlar, but little exceeding the price of freestones, could be introduced into the London market, being the waste of large blocks. These blocks are not of bad quality, but lying as they do in the

* Totten, "Amer. Jour. Sci.," xxii., p.136.

way of quarrying operations, and costing so much to shift about the quarries, quarry-owners, in general, would be glad to get rid of them. The "waste" might especially be employed in constructing warehouses, wharves, &c. We should then find in the metropolis what appears to be a great rarity at present, viz., buildings made of a durable and beautiful material.

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