Modiolaria Petagnæ, *Limopsis aurita*, and *pygmæa*, *Chama gryphæoides*, *Astarte incrassata*, *Isocardia cor.* *Cytherea* or *Venus chione*, *Lucinopsis Lajonkairii*, *Tapes texturata*, and *Mactra glauca*, have a much more southern aspect than does the upper horizon, the characteristic bivalves of which are *Cardium Grœnlandicum*, *Leda* (*Yoldia*) *hyperborea* and *L. Myalii*, and *Acila Lyallii*.

The difference is perhaps more particularly apparent in the univalves, thus *Cancellaria* and *Pyrula*, *Nassa prismatica*, and *N. elegans*, *Desmoulea conglobata*, *Defrancia histrix*, *Pleurotoma Bertrandi*, *P. lævigata* and *P. carinata*, *Mitra ebenus*, *Ovula spelta*, *Odostomia suturalis*, *Vermetus triquetra*, *V. glomeratus*, and *Dentalium rectum*, are decidedly Mediterranean forms; whilst *Fusus Largillierti*, *F. Turtoni*, *Pleurotoma bicarinata*, *Columbella arara*, *Amaura candida*, *Natica borealis*, and the large variety of *N. affinis*, *N. occlusa*, are equally northern.

Having noticed the Mollusca, a few words in reference to the Echinoderms and Corals will not be out of place before bringing our paper to a close. Of the twelve species of Radiata known by us in both divisions of the Red Crag, *two only* can be recognized as common to each, a *Spatangus*, and *Echinocyamus*. Out of the five Corals two are common to the Lower and Upper Red Crag, these are *Balanophyllia calyculus*, and a *Sphenotrochus*.

The areas which we have considered as indicating the deeper seas are those in which this Cœlenterate fauna abounds, *Balanophyllia* attaining to exceedingly large dimensions. *Flabellum Woodii* also obtains here, but in all our specimens we notice that the Coral is much smaller and stonier in composition than in those from the Lower Crag; they are also free at the base, but this and the separation of the laminae forming the septa appear to be the result of age. At present Dr. Duncan considers them to be the same species. Perhaps the most interesting Coral in our list is *Solenastræa Prestwichii*, Dunc., a new species (essentially a reef-building one).

In a further paper we hope to amplify our remarks, and as the lists of Fossils will shortly be published by the Geologists' Association, we meanwhile beg criticism upon them, and information that may bear on the subject of the English Crag.

V.—METAMORPHIC ROCKS OF SCOTLAND AND GALWAY.

By G. H. KINAHAN, M.R.I.A., F.R.G.S.I.

(With a Page-Plate VII.)

IT appears evident from the history of the metamorphic, granitoid, and granitic rocks of Scotland, written exactly half a century ago by MacCulloch,¹ that those rocks are very similar to rocks of the same classes in West Galway, Ireland. This acute observer evidently examined the Scotch rocks most minutely, as the groups, sub-groups, and varieties of his "primary rocks" are carefully classed and de-

¹ A Geological Classification of Rocks, etc., by John MacCulloch, M.D., F.R.S., etc. A.D. 1821.

scribed. Still, however, his arrangement seems to require modification, as many of the rocks he has put among his granites seem not to be true granites, but rather granitoid rocks, due to the metamorphism of igneous rocks.

In the Memoirs of the Irish branch of the Geological Survey of the United Kingdom (Exs. sheets 95, 105, etc.) it has been pointed out that while some granites are undoubtedly intrusive, others seem to have been formed in the position they now occupy by the extreme metamorphism of both igneous and derivate rocks. In that country the metamorphosed sedimentary rocks form three well marked groups, namely, the *Schist series*, the *Gneiss series*, and the *Oligoclastic granite* (Galway-type granite). As, however, some rocks are more susceptible of change than others, on account of their mineral constituents, subordinate beds of gneiss will occur in the *Schist series*, while beds of schist will be found in the *Gneiss series*, or even on some occasions in the *Oligoclastic granite*. As mentioned by MacCulloch, so also in this country, the unaltered rock graduates into schist, the schist into gneiss, and the latter into granite. (See Plate VII. and explanation of same.)

The argillaceous rocks at the first become glazed or micaceous on the surfaces of the most conspicuous structure of the original rock, changing them into argillite or argillaceous schist, while pyrite and such minerals as chistolite and phyllite are developed, usually on the surface planes of the stratification, lamination, or cleavage, but often promiscuously through the mass. Moreover, the joint lines are often sealed, or a thin film of rock alongside them hardened. Subsequently the rocks change into mica-schist and the like, and thence through gneiss into granite. Some arenaceous rocks at the first become schist (mica-schist or quartzite), while others, on account of their constituents, are gneissic from the first. The latter, although containing the essential constituents, are not typical gneiss, that is, the quartz, mica, and felspar are not arranged in leaves or plates; nevertheless, in general there is more or less of an incipient foliation. (Plate VII., Fig. 6.)

Seemingly, as first pointed out by Sorby, in all schists the foliation is induced by and follows the most conspicuous or marked structure in the original rocks; let it be cleavage or lamination, whether the latter be parallel, oblique, spheroidal, curled, folded, nodular, concretionary or conglomeritic; except perhaps in some argillites and mica-schist which have a sharply folded or frilled foliation, while a similar lamination is rare in argillaceous rocks. This, however, is not necessarily the case in gneiss, for the *Gneiss series* consists of two sub-divisions. First, ordinary gneiss, having the foliation following similar laws to those just mentioned, and among which subordinate beds of schist are not uncommon. Second, granitoid gneiss, in which the foliation, with rare exceptions, is in parallel lines, and dips at a high angle, if it is not perpendicular. The strike of the foliation of the latter and of the original stratification of the rocks, appears generally if not alway to coincide, but in no other way does the original structure seem to affect it, as all the other structural pecu-

To Illustrate Mr. G. H. Kinahan's Paper on the Metamorphic Rocks of Scotland and Galway.

liarities are obliterated, save and except when the original rock was conglomeritic, some blocks in which may have resisted the action which tends to make the foliation regular and nearly perpendicular;¹ consequently in some granitoid gneiss, blocks or nodules may occur differing in appearance, structure and composition from the rest of the mass; moreover they nearly always, more or less, deflect the strike of the foliation in their vicinity; but they are generally more or less elongated in the direction of the strike. Furthermore the structure of the constituents of the granitoid gneiss seems to have undergone an entire change. In ordinary gneiss many of the particles, as to form and composition, seem in a measure to partake of their original nature, while in the granitoid gneiss all seem to be crystalline, while the felsitic portions are developed into feldspar and quartz. Perhaps hereafter Microscopists will point out that such rocks should be classed as *Foliated granite*, and removed from the *Gneiss series*. Nevertheless the granitoid-gneiss or foliated-granite will always be the passage-rock between gneiss and typical granite.

The granite due to extreme metamorphism of derivate or sedimentary rocks, as pointed out by Haughton and others, is very varied in composition on account of the diversity of the rocks from which it is formed; and nearly all the changes just enumerated have been previously pointed out by MacCulloch, except that he has not mentioned the peculiarities of the foliation of the granitoid gneiss.

The historian of the Scotch rocks has grouped among his Granites certain intrusive rocks, on account of their aspect, make, and position. This grouping to a certain extent is not unnatural, as the rocks have a granitoid aspect and occur as intrusive masses; nevertheless many, if not all of them, in favourable localities, will be found to be metamorphosed igneous rocks.

In the portion of Galway before referred to, it has been found that some of the high silicious felstones (*Petrosilex*), many of the basic-felstones (*Eurytes* of Daubuisson, included in the *Hybrid rocks* of Durocher), also some of the Whinstones or basic igneous rock (*Dolerite*, *Melaphyre*, *Diabase*, etc.), more especially if affected by a scaly, platy or cleaved structure, will become first, schistose; second, gneissic; and lastly, granitic. The homogeneous or compact varieties however, generally change by gradually becoming more and more highly crystalline and granitoid in aspect, till eventually they are

¹ In the description of the Geology of Abyssinia (Geology and Zoology of Abyssinia, by W. T. Blanford, p. 169), the learned author calls particular attention to the regular and nearly perpendicular foliation of the gneissic rocks of both that country and also the southern part of the Indian peninsula. This is evidently similar to the foliation in the granitoid-gneiss of West Galway, and probably is due to the same cause. In the countries to which he refers, Blanford suggests that cleavage induced the foliation; this, however, could not be the case in West Galway, as evidently cleavage was not developed in the associated metamorphosed sedimentary rocks. Therefore, it is impossible it could have existed in the portions now changed into granitoid-gneiss, more especially as some are small and isolated, and may surround a centre that has been changed into typical granite. To me, therefore, it seems that this linear-parallel, nearly perpendicular, foliation of granitoid-gneiss must be due to a high state of metamorphism, and not to an original rock-structure; and if this has been the cause in West Galway, it was also probably the cause in Abyssinia and India.

altered into granite. Granites formed by metamorphism from *Petrosilex* or any other highly silicious felstone will be more or less highly silicious, while those due to Euryte or Whinstone will be more or less basic, containing as essentials oligoclase, amphibole, titanite, ripidolite, and such like minerals.

From this it would appear that the rocks included in MacCulloch's Granite of the first division under A and B,¹ are highly silicious felstone (*Petrosilex*) in the schistose stage, while the rocks classed under D are partly metamorphosed whinstone.² As among the original rocks of Galway, so also among the original Scottish rocks, there were bedded masses of whinstone and euryte graduating into tuff and agglomerate, and these, when metamorphosed, became hornblende-rock (more or less basic according to the nature of the original rock), hornblende-schist, and conglomeritic schists. This, however, does not seem to have impressed itself on MacCulloch, who gets over the difficulty by classing some of the hornblende-rocks among the granite, and the rest among the hornblende-schist, although he allows that the rocks are identical; this will be also seen from his descriptions. Furthermore, while writing of the varieties (*b* and *c*) of this rock, he points out their similarity to Plutonic-rocks, which only goes further to prove their metamorphic origin, as such varieties in West Galway only occur among partially metamorphosed sedimentary rocks.

In his "second division" of the Granite, MacCulloch is rather obscure, as his group A³ would include both the highly silicious granite and the metamorphosed or granitic-felstones of West Galway. In that country the amorphous felstones at the first become a felsitic mass mixed with mica; second, a felsitic mass in which there is more or less mica, felspar, and quartz developed; till eventually all the minerals are developed, changing it into a true granite. Although MacCulloch's classification is adopted by most geologists and petrologists of the present day, nevertheless, I believe, it is incorrect, as the metamorphosed felstones generally can be found graduating from a felstone through a gneissic-rock into a granite; moreover, when studied and consequently known, their make, form and character are peculiar, and readily distinguishable from those of the highly silicious granite. The typical highly silicious granite weathers with the rough rugged aspect so characteristic of all typical granites, while the granitic-felstone has a weathering not smooth, like the weathering of felstone, or yet rough, like that of granite, but rather partaking of the nature of both; it moreover is inclined to form a whitish crust like a felstone. In typical highly silicious granite the rock may graduate from coarse to fine; but in the granitic-felstone the rock is often thin, very fine or coarse bands striping the rock, like ribbon, differing not only in texture, but usually in colour and composition. These bands apparently follow a structure in the original rock, probably the lines of viscid fusion. Moreover, the outside of large veins and masses may be quite granitic, while the inside portions are very little altered. Furthermore, these rocks

¹ MacCulloch, p. 234.² MacCulloch, p. 235.³ MacCulloch, p. 236.

occur in more or less regular protrusions and dykes, and not in the irregular and tortuous intrusions and veins so common to some granite.

MacCulloch's remarks on this class prove that some at least of them are not typical granites, as he distinctly mentions that all the constituents are not crystallized out.

The rocks of MacCulloch's class B, second division of the granite,¹ would answer the description for some of the varieties of the hornblende-rock. These rocks in the first stage are a highly crystalline compact mass, that might perhaps be called Hornblende-aphanite, or it may be for the most part a crystalline aggregate of amphibole + felspar, not orthoclase (*Diorite*), or amphibole + orthoclase (*Syenite*), or ripidolite, talc or mica may replace more or less the amphibole. In these rocks quartz may be present as an accessory, but eventually it appears as an essential, and they merge into granite.

In the third division,² class A is the typical metamorphic granite of the "Galway type," while C, D, and E, are varieties, and class F appears not to be a normal rock. Class B is evidently one of the metamorphosed felstones previously described, in which part of the felsite is not developed into quartz and felspar, a not uncommon rock in parts of West Galway. Of these rocks MacCulloch makes a similar remark to that in reference to those in his second division, class A, pointing out that all of the constituents may not be crystallized out, and a similar remark is applicable to these rocks in West Galway. As a supplement to the granite,³ there is a rock described called *Whitestone*, a compound of "mica and compact felspar" (*felsite*). Under this head apparently are classed two distinct rocks, one being a felstone in the schistose stage of metamorphism, and the other being a felsite-schist, a metamorphosed sedimentary rock; both kinds occur in West Galway.

In conclusion, it may be pointed out that this author, as he himself allows, did not fully understand the nature of serpentine; consequently he has mixed up together rocks of quite different origins. These rocks, however, and their origin, will be described in forthcoming Memoirs of the Irish branch of the Geological Survey.

EXPLANATION OF PLATE VII.

Fig. 1. Diagrammatic sketch, showing flows of Hornblende-rock, interstratified with schist.

Fig. 2. A junction of Hornblende-rock with schist.

Fig. 3. Nodular Hornblende-rock graduating upwards into Conglomeritic-schist.

Fig. 4. Nodular Hornblende-rock graduating at the margin of a flow into Conglomeritic-schist.

Fig. 5. Conglomeritic-schist; showing irregular foliation in the matrix, while in the enclosed blocks (most of them being some one or other variety of Hornblende-rock) there is a faint foliation developed, which is evidently induced by the grain or structure of the original rocks.

Fig. 6. Conglomeritic-gneiss changing into Granitoid-gneiss, a linear foliation having been developed both in the enclosed blocks and the matrix, the texture of the former being coarse and of the latter fine.

Fig. 7. Granitoid-gneiss or Gneissoid-granite, with schistose layers or seams.

¹ MacCulloch, p. 237.

² MacCulloch, p. 238.

³ MacCulloch, p. 241.