X.

THE INTRUSIVE GNEISS OF TIRERRILL AND DRUMAHAIR.

By GRENVILLE A. J. COLE, M.R.I.A., F.G.S., Professor of Geology in the Royal College of Science for Ireland.

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THE beautifully contrasted scenery between Ballysadare and Manorhamilton, in the counties of Sligo and Leitrim respectively, is due to the ridge of ancient gneiss, with its irregular and rounded summits, which here appears through Lower Carboniferous strata. On the south-east rises a broad upland, that culminates in the coal-field of Lough Allen; on the north-west, the Carboniferous Limestone weathers out in huge scars and terraces, from the cliffs of Glenade and Benbulben, to the massive outlier of Knocknarea.[1] The conspicuous gneissic axis, running north-east and south-west, in continuation of the line of the Ox Mountains, has been the subject of various investigations.

By its general character and trend it is to be classed with the Caledonian folds of M. Bertrand, as a mass which was brought into its present position by earth-movements in earliest Devonian times. In this it agrees with the main axes of folding throughout the county of Donegal; but it is well recognised that the rocks thus brought into prominence and re-arranged may be much older than the Caledonian epoch of earth-movement. Prof. Hull[2] included the gneiss now under consideration "provisionally" in his Laurentian group; and I cannot bring forward any conclusive proofs that it is of later age than the close of the Archæan era. The Hercynian movements sent earth-waves against it, which uptilted the Carboniferous strata on its flanks, while preserving its north-east and south-west trend. As

[1] Compare A. B. Wynne, "On the Geology of Parts of Sligo, &c." *Journ. Geol. Soc., Dublin*, vol. x. (1863), p. 34.

[2] "On the Laurentian Rocks of Donegal and of other parts of Ireland." Trans. R. Dublin Soc., vol. i. (1882), p. 252.

the Geological Survey Maps, sheets 43 and 55, so excellently show, faults were at the same time produced, which enabled the ancient crystalline mass to assert itself above the denuded Carboniferous Limestone as a "horst."

Those who have hitherto examined the gneiss of the ridge do not seem to have greatly concerned themselves with its mode of origin. Mr. G. H. Kinahan[1] classes the gneiss of the Ox Mountains, with other western gneisses, as a highly altered sedimentary series. In dealing with such rocks in Galway, he speaks[2] of schists that graduate into "metamorphic granite and granitoid gneiss"; even when he states that "rocks of the older groups are absorbed into the granite and gneiss," it appears that we must not read into these words the modern view that the granite is intrusive and is responsible for much of the metamorphism. The words "changed into gneiss or granite" occur later, and indicate the prevalent attitude of the Irish surveyors twenty years ago. Mr. E. T. Hardman's[3] paper, in the same volume, is a solid contribution to the geology of the Ox Mountains, and deals specially with the north-east portion of the range. The gneiss is clearly regarded as of sedimentary origin, and attention is called for the first time (p. 358) to "a curious band of conglomerate," near Ballydawley Lake, consisting of "a coarse granitoid gneiss, containing lenticular blocks and rounded pebbles of diorite or hornblendic rock weathering out on the surface." The importance of these inclusions as indicating some earlier mass of hornblendic rocks is duly noticed.

The mineral notes in Mr. Hardman's paper are somewhat incomplete, and are subordinate to a very detailed description, by the author and Prof. Hull, of the dyke of serpentine in the valley of Correagh. I venture to question if olivine is disseminated in the gneiss at any point, as is implied on p. 361; the granules observed were probably a green pyroxene, like that derived from eclogite in Glennagoolagh. Very scant justice, on the other hand, is done to garnet, which simply abounds throughout the range.

The Memoir to Sheet 55 of the Geological Survey of Ireland was written by Mr. J. R. Kilroe, and was published in 1885. Simultaneously Mr. A. B. Wynne's Memoir to Sheets 42 and 43 appeared, which includes the gneissic areas of the Rosses and Manorhamilton.

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[1] "Palæozoic rocks of Galway and elsewhere in Ireland, said to be Laurentians," Sci. Proc. R. Dublin Soc., vol. iii. (1882), p. 348.

[2] *Ibid.*, p. 353.

[3] "On the Metamorphic Rocks of Counties Sligo and Leitrim, and the enclosed minerals," *ibid.*, p. 357.

Both authors speak of the "bedding" of the gneiss; and the general variations in its structure are well described. Mr. Kilroe[1] notes its tendency to pass into quartzite, by the disappearance of felspar and mica; and these quartzose areas are shown upon the map. The same author lays proper stress on the hornblendic inclusions observed by Mr. Hardman, and gives excellent figures of them. He declines, however, to regard the rock as a conglomerate, and makes the important observation that "thin streaks of hornblendic schist and gneiss also occur in the same place which bifurcate, and thus become lost in the containing rock." Sir A. Geikie is quoted in a foot-note as considering the basic masses as "geodes—segregations of hornblende rock in the gneiss." At that date this was the common way out of all such difficulties, and Professor Sollas[2] was probably one of the first British geologists to enter a protest against the assumption of local segregation as opposed to igneous absorption and inclusion.

From experience gained in southern and central Donegal,[3] I was led to conclude that these interesting rounded masses of amphibolite, and the conspicuous banding of the gneiss throughout the ridge, were phenomena of igneous intrusion, *i.e.*, that a granite magma had penetrated an earlier series of rocks along the axis of the Ox Mountains. Nothing could be better, from this point of view, than Mr. Kilroe's descriptions and figures of the phenomena near Ballydawley Lough; and it is noteworthy that this author refrained from drawing any conclusion on his own account. I am fortunately able to add details of similar features from other portions of the baronies of Tirerrill and Drumahair, which will, I think, materially assist in a correct appreciation of the ground.

Taken as a whole, the gneiss of the area may be regarded as a granitoid rock, consisting of quartz and potash-felspar, fairly free from mica, but occasionally containing biotite. The micaceous portions are arranged in strings and bands, and sometimes impart a superbly gnarled and striped character to the mass. In the townlands of Dromore, Crossboy, and Killery, east of the Correagh or Slishwood valley, white quartz-veins have penetrated the rock along

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[1] Memoir to sheet 55, p. 15.

[2] "Relation of granite to gabbro of Barnavave," Trans. R. I. Acad., vol. xxx. (1894), p. 502.

[3] "On metamorphic rocks in Eastern Tyrone and Southern Donegal," Trans. R. I. Acad., vol. xxxi. (1900), pp. 453 and 464.

"On composite gneisses in Boylagh," Proc. R. I. Acad., vol. xxiv., section B (1902), p. 203.

the foliation-layers, and still further emphasise its handsome structure. In Castleore, on the other hand, just above the Correagh hamlet, the quartzose type prevails, and may easily be taken for a true quartzite in the field. In sections under the microscope, however, the rock is seen to be still felspathic, and a good type of that fluidal aplite, affected locally by pressure, which forms the basis of the gneiss of north-west Ireland.

In Castleore, the rocky bosses of brown gneiss show a delicate banding, which is mainly due to abundant strings of garnets carried out along the general lines of flow (fig. 1). Where blocks of amphi-

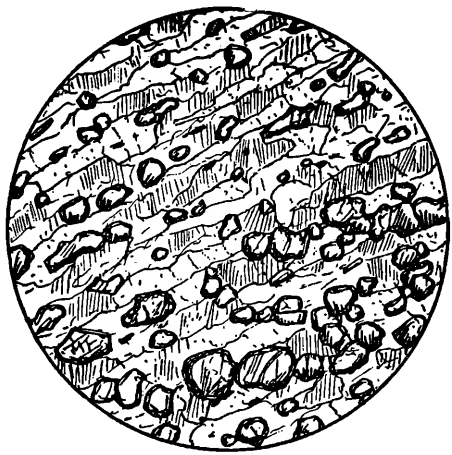

Fig. 1.

Microscopic section of fine-grained gneiss (fluidal aplite) with abundant garnet. Castleore. × 18. The garnet is derived from the included eclogites and amphibolites.

bolite occur in the gneiss, the banding becomes emphasised, and the flow-surfaces fold round them. At its junction with one large mass, the gneiss sends off dykes into the amphibolite, and cuts into it along a zig-zag surface, the flow-lines following the serrated margin (fig. 2). The appearance of sharp folds thus produced in the gneiss is due to its having worked its way into the amphibolite along joints or planes of weakness. In one place a dyke arose; in another the amphibolite became deeply notched; and the crest of the "infold" of gneiss occupying the notch sometimes runs on as a thin sheet into

the crack which determined its position. The case is conclusive against the production of the foliation in the gneiss by subsequent pressure. The banding is due to primary flow; the metamorphic effect of the hot magma on the amphibolite can be clearly traced; and the accumulation of garnets locally in the gneiss, at the expense of the amphibolite, is easily observable in the field.

The absence of marked alteration in the colour of the aplitic gneiss indicates, however, that little absorption of basic amphibolite has here gone on. I have elsewhere[1] given reasons for regarding streaks and layers of garnet in this type of gneiss in north-west Ireland as distinctly derivative; but we may conceive that the foreign material absorbed in Castleore was a series of quartzites, schists, and limestones, containing only a few basic igneous rocks. In this and similar cases, we may picture the garnets as arising during the early stages

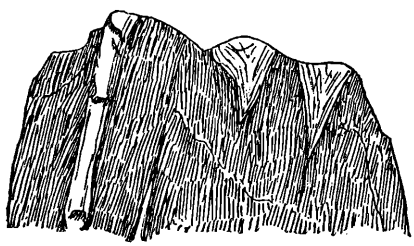

Fig. 2.

Dykes and trough-like intrusions of gneiss (fluidal aplite) in amphibolite, Castleore. From a photograph by the author. Width of the block shown, 80 cm.

of metamorphism of the invaded masses, and then being carried off, and frequently dissolved, in the dominant intrusive rock, which in the first instance promoted their growth along the contact-zone. In other cases they may have formed a constituent of an already metamorphosed and schistose series, into which a granitic magma penetrated, inducing the formation of sillimanite, altering amphibole to biotite, but without effecting much else in the way of crystallisation.

In confirmation of the above observations, it should be stated that in a section in the Geological Survey collection, cut from a granulitic gneiss near Slishwood, the garnets are associated with patches of biotite,

[1] *Op. cit.*, Trans. R. I. Acad., vol. xxxi., p. 457; also p. 456.

which is probably a relic of amphibole, absorbed into the aplitic intruder. Again, on the rocky crest about one mile from Drumahair, beside the mountain-road to Lurganboy, the various stages of absorption can be traced with the unaided eye. Lumps of amphibolite seem to swim in the gneiss, and to fade off into it, as if melting before our eyes. The gneiss becomes enriched with streaks of basic matter, in which biotite begins to predominate over amphibole. Over a wide area it passes into a banded biotite gneiss, in which the lens easily reveals the pale brown garnets, derived from the amphibolite, still surrounded in most cases by a retinue of biotite-flakes. A mile westward, in Stonepark, down against the road to Lough Gill, the evidence of the intrusive character of the Leitrim gneiss is still more marked. The blocks of dark included rock here consist of eclogite, containing a deep green pyroxene, abundant garnet, magnetite, quartz, granular triclinic felspar, and a variable but subordinate amount of hornblende and brown mica. On the margins, in contact with the gneiss, biotite has freely developed, so that some lumps, before they are broken across, resemble mica-schist. Biotite similarly appears along the margins of the aplitic veins sent off into the larger masses of eclogite from the gneiss.

The gneiss of Stonepark is in consequence beautifully flecked with dark absorption-products, grouped along the lines and surfaces of flow. Under the microscope these black flecks prove to consist largely of biotite and garnet (fig. 3), as in the slide prepared by the Geological Survey from the Slishwood mass. Muscovite, however, is also present, and here and there a prism of pale pyroxene remains. Isolated garnets lie in the gneiss, which is also speckled by a number of crystals of a spinelloid. This black mineral, by its red alteration-products, seems to be ordinary magnetite, which is an abundant constituent of the amphibolites.

I have similarly no hesitation in assigning a composite origin to a rock styled "hornblende-omphacite-gneiss," No. 1966 of the Survey collection, from the east end of the metamorphic area of the Rosses. Another slide in the same collection, from the south of Lough Cooney, and about one and a half miles south-west of Ballysadare, shows clearly the derivation of garnetiferous material from the amphibolite. The label, "amphibolite penetrated by granite," indicates that a revision of the area by the officers of the Survey would probably have led to the conclusions expressed in the present paper. No suggestion, however, as to the relations of the granites to the amphibolites is given in the "Guide to the Collections of Rocks and Fossils," published in

1895 (p. 52), though important remarks on the structure of the Ox Mountains appear on p. 42 of that valuable work. Here it is stated, however, that the amphibolites penetrate the gneiss in the region to the west. This is contrary to my experience elsewhere. It is of interest also to observe that the geological map of Sir R. Griffith, edition of 1855, shows a patch of "gneiss passing into granite" on Benbo, near Manorhamilton. This gives us no clue, however, as to whether the granite was regarded as intrusive; we may almost safely presume that the metamorphic view was then adopted.

Fig. 3.

Microscopic section of gneiss, with inclusions of light and dark mica, garnet, and pyroxene, derived from the adjacent eclogites. Stonepark, near Drumahair. × 18.

A variation on the prevalent type of composite gneiss is seen in the strongly banded masses east of Castleore. A granulite with pale pyroxene and biotite has here arisen, with obvious residual inclusion-flecks containing both these minerals. I have not been able to trace the original pyroxenic rock in this instance; but colourless pyroxene occurs in many of the amphibolites and eclogites of southern Donegal. Such basic crystalline rocks arise as products of metamorphism from very different materials, when these become invaded by and immersed in a granite magma; and the variety of mineral constitution in the

Leitrim gneiss points to a corresponding variety in the rocks forming the more ancient series traversed by it.

The characteristic blocks of hornblendic rock in the gneiss are well seen again at the north-east termination of the chain, in the townland of Pollboy, 1½ miles west of Manorhamilton (fig 4). The basic inclusions, which do not seem to have attracted attention in this area, are as striking as those of Glennagoolagh, near Ballydawley Lough. They similarly weather away more rapidly than the surrounding gneiss, leaving in places mere lenticular cavities. In section they resemble dull and altered diorites, rich in hornblende.

Fig. 4.

Glaciated surface of banded gneiss, showing included blocks of amphibolite (aphanite and diorite), which are often drawn out parallel to the general flow. A dyke of later granite cuts the whole. Pollboy, near Manorhamilton. From a photograph by the author.

The gneiss has here become much darkened by biotite, and is traversed by later veins of coarse white granite, corresponding with those so frequently seen in Donegal.

Returning now to the instances of amphibolite originally observed by Mr. Hardman, we have no difficulty in recognising them as inclusions in the gneiss.

The typical gneiss in Glennagoolagh is banded and rich in biotite; and garnet and green pyroxene occur in the micaceous bands. The rock is obviously darkened in the neighbourhood of the inclusions,

which consist of amphibolite, rather poor in garnet. Neither in the Survey collection nor my own have I found an eclogite from this area; yet the handsome occurrences of eclogite in Stonepark make it probable that some such rock has furnished the green pyroxene to the gneiss of Glennagoolagh. The marked banding of the gneiss is again clearly associated with an abundance of inclusions; and we have now sufficient evidence from various parts of Tirerrill and Drumahair to show that this is a normal characteristic.

The gneiss, then, of the ridge on the south side of Lough Gill repeats the features of the granite floor of Donegal, and was probably formed during the same epoch of intrusion. It has certainly absorbed a Dalradian series on its margins; and one is tempted to regard it as of the same age as the Caledonian earth-movements. Yet we must remember that the Gotlandian (Upper Silurian) conglomerates of Lough Nafooey, in County Galway, contain pebbles of granite, associated with quartzite, and prove that an earlier intrusion of granite had taken place in these western highlands. It is always possible that the composite rocks formed in Archæan times may have been brought to the surface at a far later epoch, and that they then underwent a certain amount of mechanical deformation. While I do not think that such deformation is a prominent feature in Tirerrill and Drumahair, it has been sufficient in other cases to lead to a misapprehension as to the origin of the banding and flow-structure throughout the gneissic mass.[1]

In conclusion, now that the composite origin of banded gneiss is becoming a matter of general acceptance by geologists, it is well to refer back to the views of M. Michel Lévy, summarised by him in 1887.[2] Sixteen years ago M. Lévy emphasised the similarity between more recent ribboned gneisses, formed by parallel intrusions of granite into metamorphosed sediments, and the ancient yet complex masses, which were commonly regarded as the primitive crust. Sederholm in Finland, working on the earlier masses, and Duparc and Mrazec, dealing with far more modern intrusions on Mont Blanc, may be cited among those who have verified the master's generalisations. Similar views have even found their way into the text-books; and now that Mr. A. Harker[3] has given us a convincing study of a

[1] Compare *op. cit.*, Proc. R.I. Acad., vol. xxiv, sect. B., pp. 220 and 221.

[2] "Sur l'origine des terrains cristallins primitifs," Bull. Soc. géol. de France, 3me. sér., t. xvi. (1887–8), pp. 102–113.

[3] "The Overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses," Quart. Journ. Geol. Soc. London, vol. lix. (1903), pp. 207–215.

Cainozoic example in the Isle of Rum, we may be sure that the theory of the formation of banded gneisses by admixture will receive adequate recognition throughout the British Isles.

As will have been seen, I am much indebted to the officers of the Geological Survey for permission to examine the specimens and rock-slices in their collection. Mr. A. M'Henry has been especially generous in discussing material gathered by himself from the Ox Mountains, which will form the basis of a report to be presented by him shortly to the Academy; and I am glad to think that our views are likely to be in complete harmony as to the intrusive nature of the gneiss.