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The Rev. William Liston, Bushbury Vicarage, Wolverhampton ;
the Rev. Alfred Deck, A.M., Royal Military College, Sandhurst ;
and Charles Rooke, Esq., Bellevue Cottage, Scarborough, were elected
Fellows.

The following communications were read :—

1. *On the STRUCTURE of the SOUTH-WEST HIGHLANDS of SCOTLAND.*
By T. F. JAMIESON, Esq.
(Communicated by Sir R. I. Murchison, V.P.G.S. &c.)

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1. Introduction : general arrangement of the rocks of the district.
2. The anticlinal axis, and character of the strata composing it.
3. Succession of the older rocks in Bute.
4. The geology of Knapdale.
5. The relations of the rocks of Jura, &c., to those described.
6. The greenstones of Knapdale ; metamorphic action ; metallic veins.
7. Probable age of the rocks described.

§ 1. THE following paper is an attempt to throw some light upon
the relations of those rocks which figure in our geological maps as
the mica-schist, clay-slate, the chlorite-series, and quartz-rock of
the South-western Highlands, and the prolongations of which, rang-
ing N.E. through the middle of Scotland, form so conspicuous a fea-
ture in the geology of that country.

An examination of these rocks, as displayed in Bute and Argyle-
shire, has led me to believe that from the quartz-rock of Jura to
the border of the Old Red Sandstone we have a conformable series

of strata which, although closely linked together, may be classed into three distinct groups, namely:—

1. A set of lower grits, of immense thickness.
2. A great mass of thin-bedded slates.
3. A set of upper grits, with intercalated seams of slate.

Beds of limestone* occur here and there sparingly in all the three divisions, the thickest I have met with being situated deep down in the lower grits. These limestones appear to attain their greatest development in the western extension of the strata, thinning out to the eastward. The siliceous grits also seem to become purer and more devoid of green sediment as we trace them to the west. All the members of the series, namely the upper grits, slates, and lower grits, have a persistent strike from S.W. to N.E. (sometimes in Bute approaching to due N. and S.), following one another in conformable order; and the three groups graduate into each other where they meet, in such a way as to show that they belong to one continuous succession of deposits; and not only so, but the materials of which they are composed seem to have been derived from very similar sources: beds of the lower grit are often undistinguishable in hand-specimens, or even in mass, from those of the upper, being made up chiefly of water-worn grains of quartz, many of which are of a peculiar semitransparent bluish tint.

I selected the region lying between Rothesay and the Sound of Jura as likely to afford the best insight into the disposition of these rocks, and devoted my attention to the districts of Bute, Cowal, Knapdale, and the line of the Crinan Canal†. In order to render the following pages more intelligible, it is necessary, before going further, to mention that the outlines of the chlorite-series, as laid down in the map of Macculloch, and also in the smaller one of Nicol, are incorrect in some places to a considerable degree. For instance, almost all South Knapdale is brought into the chlorite-series, whereas the coast-section across the strike of the beds from Barmore to Inverneil, being a distance of about six miles, shows no chlorite-slate, but is almost all a highly siliceous grit, often forming indeed a true quartz-rock. On both sides of Loch Fyne also, in the neighbourhood of Otter Ferry, and apparently for some distance up and down the

* I ought to mention that I did not myself observe any mass of limestone in the middle division, or great body of slates, although it occurs closely associated with slate amongst the upper grits. See, however, Macculloch, 'Western Isles,' vol. ii. p. 458, where he says that the limestone "peculiarly accompanies" the clay-slate. And Col. Imrie, in the *Edinburgh Philosophical Transactions*, vol. vi., describing the section along the N. Esk in Kincardineshire, mentions a bed of limestone, 6 feet thick, amongst the slate, and another, 12 feet thick, between two thin layers of black shale. See also an interesting short notice by Prof. James D. Forbes on the geology of the parish of Fordoun, in the 'Statistical Account of Kincardineshire,' where he mentions a bed of limestone occurring in the midst of the slate, and quarried at a place called Clattering-brigs. Daniel Sharpe seems to have found no limestone in the slate at Brig o' Cally, Birnam, Stratherne, and Aberfoyle, nor in the Loch Lomond section, these being the points where he examined it: see his paper in the *Quart. Journ. Geol. Soc.*, vol. viii. p. 126.

† A geological sketch-map of the district has been deposited by the author in the Society's Library.

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Diagram-section illustrating the supposed disposition of the Rocks from Jura to Rothesay.

d. Slates [represented as too thin in Bute].
a. Lower grits.

d. Old Red Sandstone (and trap-rock at Rothesay).
c. Upper grits (and greenstones in Knapdale).

loch, the strata are also very quartzose with no chlorite-schist; and the thickest and most persistent bed of limestone, lying at the base of this immense quartz-deposit, and ranging from Otter by Barmore to Western Loch Tarbert, is omitted; while the whole district of Knapdale and Crinan is traversed by great ranges of greenstone, of which no indication is given. The reason, however, why Macculloch omitted these greenstones will be afterwards more particularly referred to.

§ 2. The rocks of the district under consideration seem to have been thrown into a great undulation, whose anticlinal axis extends from the north of Cantyre, through Cowal, by the head of Loch Ridun, on to Loch Eek, while the axis of the synclinal trough seems to lie nearly on the line of Loch Swen. (See the woodcut.)

Macculloch, in his work on the Western Isles (vol. ii. p. 288), had remarked that in Cantyre the mica-schist on the eastern shore dips to the E., and on the other side to the W.; and Sir Roderick Murchison (Quart. Journ. Geol. Soc. vol. vii. p. 169) had noticed a fine anticlinal fold at Loch Eek. These observations led me to expect that I should find a similar phenomenon somewhere near the north end of Bute; and accordingly I went in search of it, and found it, not in Bute itself, but a little to the north of that island, in a high ridge near the Tighnabruich steam-

boat-quay, in the Kyles of Bute. There in the brow of a large hill called Ben Y-Happel, whose height is probably somewhere about 1500 feet, the folding over of the strata is distinctly seen; and from its summit I could trace the same anticlinal axis ranging away for a long distance in a direction about N. 33° E. The lowermost strata brought up in this anticlinal fold, as displayed here and at the north end of Cantyre, where also I examined them, consist of hard rugged masses, much wrinkled and contorted, composed chiefly of quartz and mica—although felspar is also to be found, but forming in most places only a small proportion of the rock. Portions would be correctly termed gneiss, even in the strict definition of that term; other portions are more of the nature of mica-schist, and some of quartz-rock; while a greenish substance, probably chlorite, is often added to the whole, giving its hue to the rock. The colour, however, varies from pale greenish-grey to reddish-brown; and I observed small glancing octahedral crystals of iron-ore in various places, both near the Kyles of Bute and in Cantyre. Notwithstanding the metamorphic aspect of these lower rocks, their original arenaceous character is in many parts still apparent,—thick beds, finely laminated, containing the same water-worn particles of blue and grey quartz as are found throughout the whole series of both upper and lower grits, being met with in various places, enclosed amongst others in which the lines of deposition are confused and obliterated. But the pervading feature of the rocks all about this anticlinal axis is their highly corrugated and contorted aspect, with numerous segregations of quartz. This axis, I am inclined to think, will be found to run through the country for a very long distance, passing probably by the head of Loch Lomond on to the valley of the Tay, where I observed it on the same line of strike, at Aberfeldy, in 1859. Similar masses of hard rugged gneiss and mica-schist rise up there in a gentle dome-shaped curve, and are seen on both sides of the river, more especially in the rocky face of Weem Craig, throwing off heavy micaceous strata to S.E. and N.W.

From this ridge of Ben Y-Happel, if we proceed (south-eastward) across the Kyles through Bute, we pass over a continuous series of rocks, following each other in quite conformable succession, and all dipping steadily to S.E., until we come to the Old Red Sandstone in the neighbourhood of Rothesay. In no part of Bute, neither on the east side nor on the west, where I followed the whole line of coast to the north of Scalpsie Bay, nor in the interior, did I meet with a reversed or N.W. dip. If again we turn our faces in the opposite direction (to the N.W.), towards Loch Fyne, we pass over a similar series, all conformable and dipping in like manner to the N.W.

§ 3. Taking the Bute or south-eastern section first (which is a very satisfactory one, as the rocks are disposed with great regularity, without any quantity of disturbing masses of an eruptive nature), it will be found that after leaving the neighbourhood of the anticlinal axis the strata become gradually less and less contorted, falling into regular parallel beds as we proceed across them; the quantity of

mica also becomes less; and the great body of the rocks along the very clear section of the west shore from Kilmichael to Kildavannan Point, where the slates commence (a distance of about three miles), is found to be highly siliceous, often almost wholly of quartz; they are in fact altered sandstones, varying in quality from fine grit to coarse indurated sand with grains of the size of peas or beans, in which the water-worn character still remains quite distinct; nothing, however, so coarse as to be termed a conglomerate occurred. These siliceous beds vary in colour, but are for the most part of a pale greenish-grey. Although no decided beds of slate are met with along this part of the section, yet there are some nests and patches of fine sediment, and even a few thin seams here and there, precisely similar in quality to the material of the thick beds of slate that follow. These slates commence, as I have said, at Kildavannan Point on the west, and at Ardmaleish Point on the east shore of Bute, there being frequent alternations of grit and slate where they first make their appearance. Near the base of these slates at Kildavannan Point I found some arenaceous beds composed of exceedingly fine yellowish-green sand, often parted by seams of white sand, all laminated in the most delicate manner, and even showing indications of false-bedding; they also alternate with coarser-grained layers similar in quality to the underlying grits.

The great mass of slates that follow consists of finely laminated sediments, generally of a greenish colour, but containing also many seams of dark-blue roofing-slate: these blue slates are not exclusively confined to any one part of the series, being found in every portion of this division; but they are perhaps most frequent near the base and top. Many alternations of dark-blue and green slate are seen. I am led to notice this the more as the late Daniel Sharpe, in his paper on the Southern Border of the Highlands (*Quart. Journ. Geol. Soc.* vol. viii. p. 127), had distinguished them into two separate formations, which he termed the dark-blue and the chloritic or green slates,—a distinction perhaps correctly descriptive of some localities, but evidently not of general application. These thin-bedded sediments form a zone across Bute, extending on the west side from Kildavannan Point to a place called Mecknoch, a short distance to the north of Ardscaipsie Point, and on the east side from Ardmaleish Point to Rothesay Bay. They vary in quality from the finest clay-slate to slaty flag and thin-bedded grit; and there are even a few seams of coarse-grained grit, with grains of the size of peas or beans. Intercalated seams of mica-slate are also met with. The colour is various, from dark purplish-blue to pale green, silvery-grey, and brown; but the prevailing hue is greenish, and the rock is thinly laminated. They had been the finely comminuted sediment, the silty mud and clay, of the old sea-bottom, the grits being the sand and gravel. So far as I noticed, the lines of deposition are almost always quite distinct, being seldom obscured by cleavage.

Covering these thin-bedded slates I found a thick mass of grit, forming a rugged hilly ridge stretching from Ardscaipsie Point to Barone Park near Rothesay, and of which Barone Hill attains a height

of 538 feet. These grits cover a space at least a mile broad in the middle of the island; and as they dip at high angles to the S.E., they must evidently be of considerable thickness. They are the uppermost of the old rocks as displayed in Bute, being bordered by the Old Red Sandstone to the south along the hollow of Loch Fadd and Loch Quien to Scalpsie Bay. The actual meeting of the two formations, however, is not seen, except for an insignificant space at Ardscaipsie Point; and a good deal of trap appears to occur along the boundary. These grits are not, I believe, the lower grits brought up by a fault; for they follow the slates quite conformably, without, so far as I observed, any trap coming up between them. They contain at least one band of dark-blue slate, near their base, and also differ somewhat from the lower grits in containing a greater prevalence of coarse-grained gravelly layers. There may be some fault at the N.E. base of Barone Hill, where the ridge suddenly terminates; for a great trap-dyke crosses the island there in a N.W. direction, and, traversing the slates, runs out to the shore a little to the south of Ettrick Bay; but whether there actually is a fault I could not determine, owing to the nature of the ground.

This Bute section, then, shows at its base a set of contorted micaceous grits, followed by a great thickness of siliceous grit, above which comes an extensive development of thin-bedded sediments or slates, these slates being covered by a mass of grit containing at least one seam of slate, and having more frequent beds of coarse gravelly texture than are met with in the lower grits. I observed no decided bed of limestone in these old rocks of Bute, but found, deep down in the lower grit, some beds which contained calcareous matter, effervescing readily with nitric acid.

§ 4. In descending from the anticlinal axis of Ben Y-Happel towards Loch Fyne, I found ridge after ridge unfolding precisely the same series of micaceous grits, indurated sand, and gravel that I had examined in Bute, in a similar state of metamorphism, all following each other conformably, and dipping steadily to the N.W.; and these grits continue all the way across to Otter, where there is a thick bed of bluish limestone, forming a small wooded hill, and quarried beside the Otter Inn. This limestone is covered by quartz-rock, and rests upon micaceous grit, and may be traced for some distance along its N.E. strike. I believe it is also found near Kilfinnan; and I heard of some other seams or bands of limestone in Cowal—one somewhere near Ardlamont Point, which would be on the strike of the calcareous grit that I observed in Bute.

Again, in following the west shore of Loch Fyne from the neighbourhood of the anticlinal axis in Cantyre north to Loch-Gilphead, the strata all have a general dip to the N.W. I found, first the crumpled coarse gneiss and mica-schist to the south of East Loch Tarbert, gradually falling into more regular stratification towards Barmore, near which a strong band of bluish limestone, quarried at Ashins, and apparently the same as that of Otter, runs across to West Loch Tarbert. After passing Barmore the rock is very siliceous, and continues so all along the base of the lofty ridge of Slia bh Gail on to

Meal Dhu Point, the general character being a sort of granular quartz-rock with little mica. Several large masses of greenstone come out between the beds, and have crumpled them up, and in some cases much altered their mineral texture, but do not seem to derange the succession of the main body of the strata. At Meal Dhu Point, or Strondoir, the rock assumes more mica, and continues to be mostly micaceous with occasional beds of a more quartzzy nature on to Inverneil, where seams of green slate begin to show themselves and become more and more numerous until they finally give the character to the whole; and from Ardrishaig to Loch-Gilphead the rock all consists of the thin-bedded green slates, much traversed by greenstone, but dipping constantly to N.W. at low angles. Notwithstanding the prevalence of these greenstones all along the shore here, the passage of the lower grits into the base of the slate-series is clearly indicated; and some of the finely laminated green arenaceous layers noticed near Kildavannan Point occur also in the corresponding part of the section.

Finding, however, no sections along the Crinan Canal to show the upper part of the slates, I betook myself to the ridge of Cruach Lussa (the highest hill in North Knapdale—according to the Admiralty Chart 1530 feet), lying between Loch Fyne and Loch Swen, where I found the passage of the slates into the upper grits well manifested in the south-eastern flank of that mountain.

The base of the hill is here formed of a great thickness of these finely laminated greenish slates, dipping N.W., at a high angle, into the interior of the ridge; and as I ascended I found them pass up into greenish grits, with several thick masses of bedded greenstone. These appear to form all the upper part of the hill; but subordinate slaty seams occur here and there, and one such finely laminated bed passes over the very summit, enclosed between beds of grit and greenstone. The N.W. brow of the hill shows thick strata of coarse gravelly grit, perfectly identical with those in the upper grits of Bute, and showing the same water-worn grains of bluish-hyaline and grey quartz, of the size of peas or beans,—these beds all dipping to N.W. at a very steep angle, accompanied by enormous masses of bedded greenstone, which range from S.W. to N.E. for miles, quite conformably to the strata.

Between Cruach Lussa and the Crinan Canal there is a barren upland tract studded with tarns or little mountain-lochs, several of which have been converted into reservoirs for the service of the canal. This region is highly interesting in a geological point of view, much of the rock being exposed, and showing great parallel ridges of greenstone running along between thick beds of grit, with some intercalated seams of slate and bluish limestone. At least two beds of limestone occur in these upper grits here, but neither of them so thick as that at Otter. They contain a good deal of sand, and seem well adapted for the preservation of fossils; and, although I failed to find in them the slightest trace of organic life, I cannot but think such will yet be found. There are also several finely laminated schistose or slaty beds; but these are seen to be clearly

subordinate to the grits, which, with the greenstones, form the predominating features in the geology of this tract. From this to the head of Loch Swen, the dip of the strata becomes nearer and nearer to vertical; and in the neighbourhood of that loch the general position of the strata is almost upright, leaning occasionally to S.E., and occasionally to N.W., but always striking from S.W. to N.E.; and to the west of Loch Swen the character seems to be a mere repetition of those I have been describing. We find the same thick beds of grit and greenstone, accompanied by subordinate seams of slate and indications of limestone, still dipping at high angles; but the inclination is now found to set in to S.E. I therefore think that here we have a synclinal trough whose axis lies in the direction of Loch Swen; and, from the great apparent thickness of the strata, even allowing for many repetitions, I conceive that we have in this district a quantity of beds belonging to the upper grits beyond what is found in Bute, where they terminate abruptly at the border of the Old Red Sandstone.

§ 5. From the descriptions and maps of Macculloch, in his capital work on the geology of the Western Isles, it appears that the easterly dip is maintained all through the islands of Shuna, Luing, and Scarba, on to Jura, subsiding gradually to lower angles, and exhibiting a descending series of grits and greenstones, followed by clay-slate, mica-slate, and quartz-rock, in the very same order as I have described them in Knapdale; and, although I had not time to visit those islands, I have little doubt that in the quartz-rock of Jura we have the western extension of those great siliceous masses that form the lofty ridges of Sliabh Goil and Meal Dhu, between Loch Tarbert and Loch Killisport. The clay-slate forming the eastern border of Jura, and ranging north-east through Scarba, Lunga, and Luing, on to Eisdale, I have as little hesitation in saying, represents the slaty beds of Bute, which, rolling over the anticlinal fold, plunge under the upper grits of Cruach Lussa, and reappear again to the westward in the reversed curve, troughing, as it were, these upper grits; and if the limestone of Islay, Garveloch, and Lismore lies at the base of the Jura quartz-rock, we have that also paralleled by the calcareous masses of Otter, Barmore, and West Loch Tarbert, which lie beneath the quartz-rock of these localities.

With regard to the thickness of these old rocks, taking either side of the anticlinal axis, their enormous dimensions are equally apparent. The mass of lower grits, judging from the Bute section, must be many thousand feet thick; and the group of thin-bedded slates in that island has an apparent thickness of 2000 or 3000 feet; while the upper grits, although far short of the dimensions they seem to attain in Knapdale, form also a considerable body of strata.

§ 6. The greenstones, which I have so often mentioned, form a most remarkable feature in the geology of Knapdale. They attain their greatest development among the upper grits of the synclinal trough, but are not confined to them, and alternate with the strata

in huge parallel masses running from S.W. to N.E. ; and to such an extent are they developed in many places, as quite to overwhelm the associated strata. From the fact of their being thus interstratified with the slates and grits, Macculloch seems to have regarded them all as aqueous sedimentary masses ; for he has inserted no trap or igneous rock in his map where they occur, and has described them as a mere variety of chlorite-schist (see ' Western Isles,' vol. ii. p. 290). They are the typical beds of his " chlorite-series," forming, as he says, nearly three-fourths of it ; and it is from them that he has bestowed the name on the group,—quartz-rock being ranked next in quantity.

I was unable, however, to perceive any character whereby they could be distinguished from other greenstones: for they seem to be, for the most part, composed of felspar and hornblende, and have a massive form and crystalline structure like syenite or granite ; they may also be occasionally observed resting on the upturned edges of the sedimentary strata ; and finally, what seemed to me a conclusive character, they have in many places exerted a powerful metamorphic action on the adjoining strata. On the other hand, it is difficult to conceive how they could be of an eruptive nature, or be injected among the stratified beds posterior to their formation without deranging the disposition of these to a far greater degree than they have done : and, what is even still more singular, there are many huge masses which seem to have exerted no metamorphic effect whatever on the adjoining beds of grit, which display the water-worn grains of quartz in a perfectly similar condition to those of Bute, where no such greenstone is near them.

I have already mentioned that great quantities of greenstone come out between the strata along the west shore of Loch Fyne, between Barmore and Loch Gilp. One of these, near a place marked Milmore on the Admiralty Chart, is about sixty yards broad, and has affected the quartz-strata on both sides, crumpling them up into strongly wrinkled and corrugated masses, whose original greyish-white colour has been changed into various hues of purple, red, and yellow ; and there are many segregations of vein-quartz, together with streaks of a red colour strongly impregnated with iron-ore. Their granular texture is also effaced, and they have become compact and close-grained, like hornstone. The lamination and stratification are in some places obliterated, and the rock traversed by numerous fissures. At another spot, near Erins, I observed some wedge-shaped masses of greenstone proceeding from the main body and intruding amongst the quartz, where they thinned out into tendril-like streaks. Near Meal Dhu Point another bed of greenstone, 30 or 40 yards thick, is seen coming out between the quartz-strata, and powerfully affecting them on both sides to a distance of about 20 yards. The stratified rock is crumpled up, loses its ordinary pale greenish-grey hue, and assumes a variegated colour of red, ochrey-yellow, green, and brown, irregularly mingled ; while the lamination is in many places quite obliterated, and ravelled veins of quartz ramify through it. Masses of the rock are con-

verted from a quartz-grit into compact jasper-like or hornstone-quartz. The greenstone itself is likewise affected, and traversed by some very odd veins of quartz, which seem to proceed out of the sedimentary rock. Various thinner beds of greenstone are seen near these, interstratified with the quartz-rock and following its undulations. Between Inverneil and Loch-Gilphead I noticed instances where layers of mica-slate, followed along their strike, may be seen gradually to assume a greenstone aspect; these micaceous strata are also often much contorted in the neighbourhood of the greenstone, which is itself occasionally altered and traversed by cream-coloured veins. The action of the greenstone upon the thin-bedded slates may be noticed in the low masses along the shore near Ardrishaig Hotel. Sometimes it has caused a segregation of the mineral ingredients, the quartz forming numerous white streaks parallel to the bedding, together with some larger veins ramifying in a more irregular manner; carbonate of lime has also in some cases segregated along with the quartz; while the chlorite has also in a great measure been purged of its impurities, forming a tough mass which has quite lost its laminated fissile character, and in some cases it appears to pass insensibly into the greenstone. Although neither here nor elsewhere did I notice veins ramifying from the greenstone, yet it has in some cases burst through the strata transverse to the bedding, in good-sized masses. An instance of this may be seen on the shore about halfway between Ardrishaig and Loch-Gilphead, near a place marked Glenburn in the Admiralty Chart, where some greenstone has protruded across the green slaty strata, which become much crumpled as they approach it, and assume an irregular sort of cleavage, or cross-planes of division; they also become more micaceous; and at some points the prolongation of these micaceous slates passes insensibly into the greenstone without any clear line of separation; there is, in short, a gradual conversion of the slate into a massive greenstone; but in other parts the line of meeting is easily seen.

On the shore of Loch Fyne, to the north of Otter Ferry, near a place marked Gortans in the Admiralty Chart, where greenstone has invaded the quartz-strata and caused much alteration and contortion in them, I observed a curious change in the greenstone itself near its contact with the quartz, whereby it assumed a foliated structure, and became highly micaceous—in short, took on the aspect of a greenish mica-schist to the thickness of one or two feet.

I observed likewise instances, both in Bute and Knapdale, where dark fissile clay-slate is changed, near its contact with greenstone, into a substance like basalt. On the line of the Crinan Canal, between Dunartry and Ballenoch, a mass of greenstone is conspicuously seen, the weathered surface of which is full of circular concretions like those often noticed in decomposing trap.

The chlorite-series has been laid down in the map of Macculloch only in Argyshire; this geologist therefore seems to have regarded it as distinct from any of the other Scottish formations. Under

this view we should have the singular fact of an immense succession of sedimentary strata developed here and nowhere else. This I believe to have arisen from his having mistaken a trap-rock for an aqueous sediment.

Another feature of the case even still more singular, if we should, with Macculloch, hold these greenstones to be merely highly metamorphosed aqueous sediments, would be the fact of immense felspathic and hornblendic beds alternating with others remarkable for the absence of both these ingredients, and all deposited from the same sea. It is easily understood how beds of grit should alternate with slate and schist; for the one is the sand, the other the mud of the old sea-bottom, separated by the action of gravity; but it would be difficult to comprehend how the action of sea-water could have sifted so finely grains of felspar from those of quartz, their specific gravity being alike. In the Silurian rocks of Wales and elsewhere, beds supposed to consist of contemporaneous trap or volcanic ash are interstratified with ordinary aqueous sediment; and it is quite intelligible that felspathic matter from an igneous source might be ejected at intervals, so as to be thus interstratified with quartz-sand derived from the erosion of different materials; but in such cases the beds of igneous matter have been distinguished from the ordinary aqueous deposits with which they are associated, by a name marking their proper origin. Whether, therefore, these greenstone-rocks of Knapdale are of contemporaneous formation with the strata beside them, or whether they have been subsequently injected amongst them, they ought in my opinion to be clearly distinguished from the grits and clay-slates, and not classed under the head of a mere variety of these, as they have been by Macculloch. I prefer, then, using the term *bedded greenstone*, as marking this distinction and, at the same time, indicating the fact of their alternation with the stratified layers, as well as conveying a more just idea of their mineralogical features.

I was unable to devote sufficient time for a thorough examination of the district where these bedded greenstones occur, and would recommend the locality to the attention of any geologist who may have the opportunity, as likely to be well worth the labour of an examination; for it is very probable that here there may be greenstones of different ages and various origin. I myself noticed some vertical dykes of trap, of a blacker hue, which were evidently of a later date, running in a N.W. direction, and cutting across both the greenstone and grit, and causing alteration at the line of contact. Two such may be seen in following up the course of the stream that joins the Crinan Canal at Cairnbaan, and down which the torrent descended when the reservoirs burst.

The fact of veins of lead-, copper-, and iron-ores being met with in several parts of this greenstone-traversed district, is a circumstance characteristic of igneous action. In the micaceous strata to the south-west of Inverneil I saw a lode or vein of white quartz, a foot or more thick, which in many places is very rich in galena, frequently accompanied by sulphuret of iron and copper. This vein

of quartz is also encrusted in some places with beautiful little crystals of carbonate of iron or sparry iron-ore. Its course is nearly vertical, with a strike about N. 25° W. It had been wrought in former times as a mine, and is now opened anew. Other veins of a similar nature, with some ironstone, are known to occur in the lower grits between Inverneil and Barmore; and I heard that a vein of lead had once been opened, at the rocky point between Loch Gilp and Loch Fyne, and also near Dunartry, in the upper grits.

§ 7. I examined the limestones that came under my notice for fossils, more particularly the thick calcareous grit of Otter, which seemed a likely rock for containing them; but in none did I perceive anything of the kind. In the weathered surface of some of the quartz-grits in Knapdale, both above and below the slates, I noticed numerous circular cavities, and also some curious elongated stripes of coarser sand, which suggested the idea of Annelide-burrows; I could not, however, satisfy myself as to whether such was actually their origin, and must leave it to the decision of those who know more about these matters.

The period at which these old beds of sand and mud had been thrown into undulations and changed into quartz-rock, mica-schist, and slate is evidently very remote; for the Old Red Sandstone conglomerate in the shore beside Rothesay is seen to be made up of the débris of these strata; and it is important to remark that its water-rolled pebbles of siliceous grit, mica-schist, and slate have quite as metamorphic an appearance as the parent rocks from whence they were derived have at the present day. Many of these imbedded fragments show the same contorted, wrinkled, foliated structure, and are traversed by the same ramifying veins of quartz (which had solidified before the water-rolling of the fragments), and, in short, are altogether identical in their mineral complexion with the present features of the rocks I have been describing. Their metamorphism must therefore have been completed before the Old Red conglomerate began to accumulate; and this leads to the conclusion that a great chasm intervenes between the era when these old rocks were formed and that of the Old Red Sandstone, and brings us to assign to them a date anterior to that of the upper Silurian beds. They do not appear to resemble, in mineral features at least, either the "Cambrian sandstone," or the "fundamental gneiss" of Sir Roderick Murchison, described by him as occurring in the North-west Highlands; while they seem to bear a striking resemblance to the quartz-rocks, limestones, and mica-schists of Sutherlandshire, &c., shown by the same geologist to be of Lower Silurian age,—the chief difference being the presence of the bedded greenstone, which, however, is, as I have shown, a local phenomenon, being absent in Bute. So far, therefore, as lithological appearances are entitled to weight, there is reason to believe them to be of similar date to those rocks of the North-west Highlands. However, as mere mineral features alone form a very unsafe criterion in such cases, we must look either for evidence proving the physical synchronism of these beds of Argyleshire with the North-western types of Murchison, or, still

better, for some clear fossil-evidence, before we can arrive at a positive determination.

Perhaps the most interesting feature of the district described is the immense development of these bedded greenstones, which may serve as a parallel to the similar phenomenon in Wales; and to this I would beg to draw the further attention of those interested in the study of trap-rocks.

2. *On the POSITION of the BEDS of the OLD RED SANDSTONE developed in the COUNTIES of FORFAR and KINCARDINE, SCOTLAND.* By the Rev. HUGH MITCHELL.

[Communicated by the Secretary.]

§ 1. THE time has now come for us safely to pronounce, from palæontological evidence, upon the place of those fossiliferous flagstones, with their associated sandstones and conglomerates, which are spread over a large territory in the counties of Forfar and Kincardine, and which are referred to in a paper* read by Prof. Harkness before the Geological Society on the 18th January of this present year †.

The superficial area of country referred to in this paper is almost the same as that in the paper of Prof. Harkness, namely a district, comprehending all the lowland parts of the two counties, bounded on the north by the Grampian Mountains, impinging on the west on the County of Perth, and bounded on the south and east by the German Ocean. The objects of the papers are, however, very different. Prof. Harkness illustrated the stratigraphical arrangement of the rocks by numerous sections along the northern boundary-line, where they lean against the crystalline schists of the Grampians; our attention is now directed more to the beds as spread out and exhibited in the beautiful tract of country to the south-east of the mountains, and which have of late years begun to yield not a few characteristic and important fossils. It is now wished to state the palæontological data, collected by the writer in the course of several years, which lead to certain conclusions, in his opinion, sufficiently determining the position and the importance of these rocks in the geological scheme‡.

* Entitled "On the Association of the Lower Members of the Old Red Sandstone and the Metamorphic Rocks on the Southern Margin of the Grampians," *Quart. Journ. Geol. Soc.*, vol. xvi. p. 312.

† See also a paper by the author "On the Flagstones of Forfarshire," *Geologist*, 1859, vol. ii. p. 147; his "Notice of New Fossils from the Lower Old Red Sandstone of Scotland," *Geologist*, 1860, vol. iii. p. 273; and Mr. W. Powrie's paper "On the Old Red Sandstone and its Fossil Fish in Forfarshire," *ibid.* p. 336.

‡ The reader is referred to the 11th chapter of 'Siluria,' 2nd edit., 1859, for the latest and most complete review of the history of the Old Red Sandstone, and for the corrections made by Sir R. I. Murchison in the correlation of the several members of this group. The Table at pp. 432 & 433 of 'Siluria' gives a general view of the classification adopted by Sir Roderick,—the Upper, Middle, and Lower divisions of the Old Red Sandstone of Scotland being respectively synchronized with different zones of the Old Red and Devonian rocks of England and Europe.—EDR.