papers on the science as, in justice alike to the author and the cause of science, can only properly be received and published by a great national society like the Geological Society of London. Its ambition should be to be distinguished by the amount of useful work which it can do, being well assured that no such work, no matter how local in its first aspect, can be honestly done without adding something to the stock of knowledge, and thereby advancing the cause of science.

Thursday, 17*th December* 1868.

ARCHIBALD GEIKIE, Esq., F.R.S., President, in the Chair.

The following Gentlemen were elected Ordinary Fellows of the Society:—

WILLIAM DRUMMOND, S.S.C., Edinburgh.
JAMES LANDALE, M.E., Edinburgh.
JAMES LINN, Teacher, Whitburn.

The following Communications were read:—

I. *Notes on some Fossils from the Oolite of Yorkshire.* By JAMES GOWANS.

II. *Remarks on the Family Orthoceratidæ.* By GEORGE LYON.

III. *On Columnar Structure developed in Mica Schist from a Vitrified Fort in the Kyles of Bute.* By JAMES HASWELL, M.A., Corresp. Mem. California Acad. of Sciences.

While staying at Tighnabruigh, in the Kyles of Bute, in the beginning of July 1867, I visited the vitrified fort on Island Buie, one of "the Burnt Isles," which lie at the head of the East Kyle between Argyleshire and the north-east end of the Island of Bute. The "Island Buie" means "the yellow island," and the name "Burnt Isles" seems derived from the burnt or vitrified appearance of the stones of which the fort is built. The size of the island is about 200 yards long by 100 yards broad, and is about 100 yards distant from the mainland of Argyleshire. It commands the whole East Kyle from Kamesburgh to Loch Riddan, and was therefore admirably fitted for the purposes of a fort.

The fort itself is of a circular form, and, so far as I could make out, it measures 21 by 22 yards in diameter from centre to centre of wall. The wall measures from 5 to 6 feet wide at the base as it stands at present, but from the circumstance that the upper portion of the wall has fallen down outside, it is perhaps broader now than when first formed, which may have led the author of the "Guide to Rothesay" to believe that there was a double wall, of which, however, I could see no trace. The maximum height of the wall as it stands is from 3 to 4 feet.

The stones composing the fort seemed to be all fragments of *mica schist*, which is the predominating rock of the neighbourhood. They were of various sizes, but most of them were from 6 to 10 inches long, and 5 or 6 inches thick. They exhibited the same vitrified appearance as is to be seen in most of these old forts, and were firmly cemented together, evidently by the action of intense heat, the outer portions of the stones being quite burnt, like the refuse from a glass-work. In one part of the wall, however, I came upon some fragments which exhibited a different appearance, and were of a true columnar structure. A specimen showing this kind of structure had previously been obtained here by the Rev. H. W. Crosskey of Glasgow, who exhibited it to the Philosophical Society of Glasgow, along with a piece of "burnt coal" from the neighbourhood of a trap dyke, and sandstone from an ironstone furnace, both showing the same columnar form.* These miniature "Samson's Ribs," as they may be termed, are now exhibited to the Society, and are very interesting and instructive in connection with the great subject of *metamorphism*. The mica schist, itself a metamorphosed rock, has been again metamorphosed, and if we can solve the questions suggested by this *second* metamorphism, it may help to clear up others of a kindred nature.

It may be asked at the outset, Why should the schist not have assumed the columnar form in other fragments and at other parts of the wall, instead of being confined, as it appeared, to one particular portion of the wall? Were the conditions not favourable throughout? Or, was there a longer time given to cooling, the fire having been perhaps slower and longer in dying out at this part of the wall?

In order to be able to answer this query, and to explain the appearance presented by these specimens, we must first of all be able to answer another question which suggests itself, and that is, How was the fort formed, and what was the means employed to vitrify the stones?

The oldest idea of the origin of vitrified forts, and it is the crudest, is that the burnt and melted appearance of the stones was the result of *volcanic action*. In the year 1777 several learned members of the Royal Society pronounced some specimens of vitrified stones from Creck Faterick, now generally called Craig Phadric, to be lava from an extinct volcano; and those who gave this decision were said to have been well ac-

* Proceedings of Phil. Soc. Glas., 27th January 1864, vol. v. p. 335.

quainted with volcanic productions.* I visited this fort in 1865, and although it was then mostly covered over with grass, I succeeded in getting a good example of the vitrified rock, which I now exhibit for the sake of comparison. Had Mr West, who described this hill as an extinct volcano, looked a little below what appears to have been a second or outside wall, he would have found the outcrop of the conglomerate of which the hill is principally composed; and besides, the regular form of the fort, which is a parallelogram 80 yards long by 30 yards broad, measuring from the inside of the wall, might have led him to conjecture its artificial origin. Nevertheless, the volcanic theory found additional supporters, among whom may be mentioned the Bishop of Derry, who visited Craig Phadric, and who declares that the mound on the top of this hill is *not* of artificial origin, but the remains of an old volcano. Cordiner also adheres to the same view.†

Williams‡ was the first to point out that these mounds on the tops of hills, like Craig Phadric, are of *artificial* origin,—hill forts built by a people unacquainted with the use of lime or cement, probably referable to the times of Fingal,—and that the vitrification was produced in order to strengthen the walls for the purposes of defence. His idea is that the ancient tribes who formed these forts, having been led to observe, either while making their iron utensils or when engaged in offering burnt sacrifices, that a strong fire would melt stones, they were induced to apply it somewhat in this way. They first of all raised two parallel walls of earth or turf in the direction of the proposed wall, leaving a hollow space which they filled up with alternate layers of fuel and the fragments of stone they intended to vitrify. They then set fire to the whole, and kept heaping up fuel and stones, and at the same time adding more earth or turfs to the outside framework, till they succeeded in bringing the whole wall to the height they wished; and after the fire burnt out they removed the outside earthen walls, and the fort was complete. Dr Anderson of Monkshill § and Cardonnel,‖ subsequent writers on this subject, also lend support to this view. And, in the absence of all authentic information, it seems not an unnatural view to take, for although it must be admitted that it is a matter

* See "Account of Creck Faterick, a volcanic hill near Inverness," by Thomas West, in Phil. Trans. of Royal Soc. of London, 1777. Pennant had held a similar view. See his "Tour in Scotland," vol. ii. 165.

† Antiquities and Scenery of the North of Scotland, p. 11. London 1780.

‡ See his Letters on Vitrified Forts, 1777.

§ "An Account of Ancient Monuments and Fortifications in the Highlands of Scotland," in a Letter dated 27th November 1777, read to the Antiq. Soc. of London, Archæologia, 1779, vol. v. p. 241; and "A Further Description of Ancient Fortifications in the North of Scotland," in a Letter read January 13th and 20th, 1780.—Archæologia, vol. vi. 87.

‖ "Picturesque Antiquities of Scotland," part ii. introd. p. 4.

of extreme difficulty to bring stones, no matter what the material of which they are composed may be, into a state of fusion, and that it is almost incredible that these old tribes could keep up such an intense heat as was required to produce the appearance they now present, yet it seems almost the only way in which we can account for them, and few will now be inclined to doubt that they are artificial in their origin, and must have been produced by the application of intense heat.* And it is certainly a more plausible mode of accounting for them than the theory of Mr A. Fraser Tytler,† which is the only one remaining to be noticed. This author agrees with Williams in thinking these forts are artificial, but he denies that the vitrification was produced in the construction of the wall, or was intended to strengthen it. He maintains, on the contrary, that it is purely accidental in its origin, and was caused by an enemy besieging the fort and setting fire to the double row of pallisadoes or strong stakes intertwined with boughs of trees within which the stones now composing the walls were thrown. His main reason for maintaining this view is that many forts do not exhibit any traces of vitrification, and that in those which do exhibit it there are portions of the wall which are not vitrified at all, as in the case of Craig Phadric, a portion of the outer wall of which bears no trace of fire; but a sufficient answer to this is, that the hill being naturally steep and therefore well protected on that side, the fort did not require the additional protection of a vitrified wall, the dry stones and turf being a sufficient defence. Sir George Mackenzie of Coul started still another theory, that the vitrification of these forts was the result of beacon fires.‡ The fact, however, that the fort in the Kyles of Bute is situated on a small island, on which a beacon fire would have been useless, shows that this theory is not universally applicable.

It being therefore now generally admitted that intense heat was necessary, and was no doubt employed, to melt the stones in these forts, we can easily understand how the ash of the fuel, aided perhaps by a piece of felspar from a fragment of gneiss which may have got in amongst the mica schist, would act as a flux, and vitrify the fragments of mica schist in the present case, § and how the subsequent contraction of the mass, induced pro-

* Dr M'Culloch also adopts Williams' view. See his paper on Vitrified Forts, in Trans. Geol. Soc. vol. ii.

† "Account of some extraordinary structures on tops of hills in the Highlands." Trans. Roy. Soc. Edin. vol ii.

‡ See his article on Vitrified Forts in Dr Brewster's Edin. Cyclopædia, vol. ix.

§ We may also account, in part at least, for the vitrified appearance, by supposing, as my friend Mr David Forbes, F.R.S., has suggested to me, that those who constructed such forts used fires of *seaweed*, which would with great ease account for the vitrification of the external surface, as the ash contains so much alkali (salt, &c.) that it would glaze the stones, just as ordinary bricks or stoneware are glazed, without any great heat being requisite.

bably by the dying out of the fire at this part of the wall, would give rise to the columnar structure which these specimens assume.

But let us now examine the specimens themselves in detail, and see what can be gathered from a minute inspection.

No. 1 presents a surface of six well-defined columns about three inches long, having a tendency to converge towards a point at the one end, which has been fractured across. We might have said that the columns seem to have radiated from this point, were it not for the slaggy appearance of the rock and the absence of a columnar structure at this end. The columns on this specimen are four-sided, which is the prevailing form in all the specimens. The two centre columns unite towards the one end and form a single column. The reverse side of this fragment exhibits the vitrified, slaggy appearance which the mass of the stones in the fort present. It also shows the vesicular appearance which is common to them all, and which is due, no doubt, to the presence of air bubbles in the burning mass. When we come to examine the texture of the rock itself, we find we can hardly recognise the mica schist in its altered form. The glistening scales of the mica are now absent, and the quartz assumes a more granular aspect, and, in fact, at the fractured end of two of the columns is hardly distinguishable from a secondary granite of a fine grained texture. On examining it with a glass we can detect a small crystal of quartz here and there, and even one of felspar. The most striking feature, however, next to the columnar structure, is the presence of a black glistening substance, which fills up the smaller cavities. It has a glassy appearance, and, when viewed under a powerful lens, has a close resemblance to *obsidian*, which resemblance is rendered the more striking when we examine the fracture, which is *conchoidal*. Obsidian is composed in great part of silica (analyses giving 70 to 80 per cent.), along with some alumina (6 to 12 per cent.), soda (3 to 10 per cent.), and lime, magnesia, and peroxide of iron in small quantities. Now, although the quartz of the mica schist contains a large proportion of silica (say 70 per cent., with 29 oxygen, and small quantities of lime, alumina, and oxide of iron, &c.), yet I am not aware that quartz has ever been converted into obsidian. Obsidian, as it occurs in nature, is supposed to be a melted trachyte or basalt rapidly cooled, and is classed with the felspar family, and not with the quartz. Nor am I aware of mica—the other constituent of the mica schist—ever having been converted into obsidian. The chemical composition of mica is variable. Potash-mica is composed of silica (40 to 48), alumina (32 to 37), potash (5 to 10), peroxide of iron (3 to 9), peroxide of manganese (1 to 2), with traces of the protoxide of iron, lime, magnesia, and soda. Magnesia-mica has more magnesia (10 to 25) than alumina (13 to 16), and Lithia-mica, the third kind, has lithia (2 to 6) instead of magnesia. The mica in mica schist is generally of the first of these kinds, viz., potash-mica, which contains little magnesia.* Bischof, whose work on "Chemical and Physical Geology" is full of instruction on metamorphic points, has endeavoured to show† how mica schist has been altered from *clay slate*, which contains a felspathic matrix, and that, therefore, mica schist has originated from felspar by alteration, "a portion of the alkaline silicates having been eliminated, another portion decomposed by carbonic acid, the bases removed, and the silica left in the state of quartz."‡ He has also shown, both from examples occurring in nature and from experiments in the laboratory, that mica is capable of being formed from felspar.§ Yet mica itself is very infusible, and Bischof conducted a great many experiments to show that even the mica which is sometimes thrown out of volcanoes was not formed by fusion, and that, although it occurs in such solid masses as basalt, yet it was probably not formed during their solidification, but had a prior origin.‖ He melted a piece of basalt from the Lake of Laach containing mica, but the result showed that the mica was less altered than the basalt, for it only changed its colour to a gold colour with brown spots, while the plates were neither bent nor cracked, and the laminæ could be separated with a knife. He comes to the conclusion, therefore, that the mica which occurs in these basaltic rocks (a rare occurrence, no doubt), is a "product of alteration." He also gives several analyses¶ to show that it is always magnesian mica which is thus formed. These analyses show a strong similarity to that of basalt, and "the conversion of the one into the other would appear to consist merely in substitution of magnesia and of potash for the lime in the basalt."** The tendency, moreover, of these analyses and experiments is to show that the mica associated with mica schist cannot have been formed by fusion, and that, therefore, the alteration of sedimentary slate and limestone rocks into micaceous schist was not produced by the influence of heat, for if this had been the case "the potash of the mica would have been displaced by lime, and removed by water subsequently penetrating the mass."††

Another mineral which the glassy substance in these specimens resembles is *tourmaline*, which, as well as obsidian, is vitreous and has a conchoidal fracture. Its chemical composition is very variable, being 36 to 41 silica, 5 to 10 boracic acid, 1·3 to 2·7 fluorine, 30 to 45 alumina, 0 to 13 iron peroxide, 0 to 5 manganese peroxide, 0 to 10 iron protoxide, 0·5 to 15 magnesia, with some lime, soda, potash, and lithia. There are instances on record of the conversion of black tourmaline into mica, which

* Bischof, ii. 394. † *Loc. cit.* ‡ Ibid.
§ Ibid. and p. 172, and whole of chap. xxxviii. ‖ Vol. ii. pp. 382–385.
¶ P. 387. ** P. 388. †† Ibid. p. 390.

"involves displacement of soda by potash, by means of the reaction between silicate of soda and carbonate of potash."* But I have not been able to find an instance of the conversion of mica into black tourmaline. There are examples of mica being converted into steatite, into talc, into serpentine, and there is one instance given by Bischof of the displacement of mica by hornstone, but as to this last additional evidence is wanted.†

Looking, however, at the specimen (No. 1) before us, it may well be asked, if this black, glassy, amorphous substance is not *altered mica*, what has become of the mica which formerly existed in the schist? In the experiments conducted by Bischof, and alluded to above, no change was produced by intense heat on the mica, with the exception of a slight change of colour. If mica, therefore, be infusible, we ought to have been able to detect its presence in this specimen. But as it is absent, it seems not unwarrantable to conclude, that although the amount of heat employed by Bischof was not sufficient to melt the specimens of mica experimented on by him, yet the peculiar conditions at work in the formation of this vitrified fort, and the keeping up of a strong fire for days, and probably weeks in succession,—a fire in fact so strong that it has vitrified most of the stones, and cemented them together,—were quite enough to alter the mica in the present case, and to produce the black, glassy substance now observable in these specimens. What that substance is to be called, a chemical analysis ‡ will perhaps enable us to determine.

No. 2 specimen shows a column with three sides exposed. It is not seen until we break the specimen, when we have also a cast of the column. The glassy mineral is here not so distinct, as it has been more thoroughly mixed with the mass.

No. 3 is a very interesting fragment. About a dozen columns are clustered together, and on one side are cut off abruptly by a piece of the schist which shows the quartz distinctly, and has become more crystalline in its aspect, though still preserving its *stratified* appearance. There is very little of the slaggy appearance on this fragment, and it is only seen at the end of the columns.

No. 4 is conspicuous for the quantity of the black obsidian-like substance which, on the reverse side from that showing the columns, has been so thoroughly mingled with the rest of the rock as to give it a black colour throughout. We have also here a little of the semi-granitic appearance at the end of two columns.

In No. 5 we have several neat little columns about two inches long, in which the presence of the black substance is conspicuous.

No. 6 has evidently not been subjected to much heat, and is attempting to assume a columnar form. The two kinds of altera-

* Bischof, vol. ii. p. 399. † Ibid. pp. 406 and 485.

‡ See Note at the end of this paper.

tion of the schist are here displayed in a specimen two inches long. The light coloured part has none of the black substance, and still preserves marks of stratification. The other is discoloured with this substance.

Nos. 7 to 11 are good examples of detached columns of four sides, and all showing the black substance referred to.

With regard to the *columnar form* which the mica schist in these fragments has assumed, we have here additional evidence of the fact that masses of stone, if of a nearly homogeneous structure, become altered under the influence of heat and assume a columnar form, sometimes even when exposed to a low temperature, provided it be continued for some time. In brick clamps, for instance, it is very common to find masses of the burnt bricks showing a most perfect columnar structure. Wet clay when dried sometimes shows the same phenomenon, which seems to be due to contraction of the mass. The blocks of sandstone used in the construction of iron blast furnaces (the bottom stones) assume the columnar form, after they have been some time exposed to the heat of the furnace. A moderate heat would not be sufficient to cause this change, for the amount of water in the sandstone, which would certainly be expelled by a low heat, is too small to cause the sandstone to contract after it was expelled. Starch, when it contracts on drying, furnishes another example of the mechanical effect thus produced by the shrinking of a homogeneous mass.

Similar examples occur in nature. The coals and shales of the carboniferous formation, when found in contact with igneous rocks, have a burnt appearance, and very often assume a columnar form. In the Edinburgh Museum of Science and Art there are some specimens of these burnt coals and shales, found below greenstone in Chalmerston Glen, Dalmellington, Ayrshire, by the Geological Survey. In Staffordshire burnt coal of this kind was found in contact with the Rowley Rag basalt,* and the ironstone beds at Powkhill also present a beautiful columnar jointing at those parts where they are overlaid by a similar rock. While working the Brown Coal beds in the Vogelsgebirge, Westerwald, and Meissner, many examples of columnar coal were got, wherever it was found in contact with the basalt;† and even a layer of plastic clay, from six inches to five feet thick, which occurred at Meissner between the brown coal and the basalt, presented a columnar structure, which at some points even extended into the brown coal beneath. The columns of clay were at right angles to the basalt (which is the case also with the burnt coal from Ayrshire mentioned above), and were reddish brown at the point

* See paper "On the Igneous Rocks of South Staffordshire," by David Forbes, F.R.S., in Brit. Assoc. Report for 1865, sections, p. 53.

† Bischof's Chem. and Phys. Geol. vol. iii. p. 75.

of contact, and at the distance of several inches became pale red or grey.* Near St Saturnin in the Puy de Dome, a layer of plastic clay was found hardened and assuming a columnar form in consequence of an overlying mass of basalt, which moreover had carbonised the vegetable remains in the clay.† At the Habichtswald columnar brown coal is found in contact with basaltic dykes 10 or 12 feet thick, but it preserves its original structure where the dykes are only 4 to 6 feet thick.‡ The brown coal found at the Giant's Causeway is also little altered, although it is there in contact with basalt.

Again, take *sandstone.* At Wildenstein, near Büdingen, a variegated sandstone, underlying basalt, has assumed a columnar structure; and Bischof, who cites this example, mentions that "Leonhard saw some columns that were upwards of 7 feet long, and 1 inch diameter. The columns have a greyish white fracture, sometimes with black spots."§ There are numerous specimens of these Wildenstein columns preserved in the Museum at Bonn.

All these examples serve to show how the structure of rocks may be materially altered by the application of heat, and how the shrinking of a homogeneous mass, thus altered, may often produce the mechanical effect of which these specimens of columnar mica schist have furnished us with so good an instance.

Note.—Since the above paper was read I have seen a very exhaustive paper by Dr S. Hibbert, entitled "Observations on Theories which have been proposed to explain the Vitrified Forts of Scotland," which was read 28th March 1825, and will be found in "Archæologica Scotica," iv. 160. He reviews the whole subject, and in an appendix gives a list of localities where vitrified forts occur. In a note to p. 178 he mentions, curiously enough, that he had found among the vitrified ramparts of the Burnt Island in the Kyles of Bute "the most beautiful and perfect specimens of prismatic gneiss." "They were small, being about four inches in length, and about half an inch in diameter, being formed at nearly right angles to the laminar planes of the rock." He also mentions that he had observed "in the cabinet of M. von Leonhard, the celebrated Professor of Mineralogy in the University of Heidelberg, several specimens from the vitrified sites of Scotland, which he had collected for the geological information that they conveyed to him of the effects of heat upon certain rocks." M. Leonhard, moreover, wrote an essay on "the Vitrified Forts of Scotland," which will be found in the first number of the "Jahrbuch für Mineralogie, Geognosie, &c.," publishedat Heidelberg, and conducted by him and M. Bronn.

My attention has also been since directed to a notice of the fort in the Kyles of Bute, by the late James Smith, Esq. of Jordanhill, read 17th March 1823, which will be found at p. 79 of vol. x. of Trans. Roy. Soc. Edin.

With reference to the chemical analysis mentioned at p. 235, I find that two analyses, at least, would be required, and these of the most difficult and laborious character, which, even if made, would perhaps not be of much service. I have, however, submitted the specimens to Mr David Forbes, F.R.S., whose name I have already had occasion to mention, and whose papers on metamorphic questions are known to all geologists, and his opinion of the altered minerals in these specimens is shortly this—that the white substance is mainly quartz, with probably a little felspar, while the black substance is a basic silicate, analogous

* Bischof's Chem. and Phys. Geol. vol. iii. p. 75. † Ibid. p. 76.
‡ Ibid. p. 77. § Ibid p. 78.

to hornblende or augite, the oxide of iron producing the colour. He has also sent me several pieces of mica schist, on which he experimented some years ago by exposing them to a moderate heat and slight pressure. The result of this treatment was the production of an artificial rock almost identical with the vitrified specimens under consideration.

Mr ALEXANDER SOMERVAIL exhibited a very beautiful and well-preserved specimen of *Nautilus marginatus*, Flem., from the "Silver Mine" Quarry, Bathgate. This cephalopod is somewhat rare, and was not met with by the Geological Survey when they visited Bathgate, nor has its occurrence been noted in the Carboniferous Limestones east of the Pentland Hills.

Thursday, 21st January 1869.

ARCHIBALD GEIKIE, Esq., F.R.S., President, in the Chair.

The following Gentlemen were elected Ordinary Fellows of the Society:—

JOHN R. WILLIAMSON, M.E., Edinburgh.
JAMES CROLL, Geological Survey, Edinburgh.
CHARLES MACDONALD, Writer, Thurso.
WILLIAM LIVESAY, University, Edinburgh.

The following Communications were read:—

I. *Obituary Notice of James David Forbes, D.C.L., LL.D., F.R.S., Principal of the United College of St Salvator and St Leonard in the University of St Andrews, and late Honorary Fellow of the Society.* By ARCHIBALD GEIKIE, F.R.S.

Since the last meeting of the Society we have lost one of the most distinguished of our Honorary Fellows. Principal Forbes died on the 31st of last month. The removal of such a man ought not to be allowed to pass without some tribute to his memory, or some outline, however imperfect, of what he accomplished. It is customary to reserve the notices of deceased Fellows until the beginning of the succeeding session. But on the present occasion we are justified, I believe, in departing from the usual rule. Before proceeding to the ordinary business of the evening, the Society will, I am sure, agree with me in thinking it at once a duty and a privilege to linger for a little over the life and work of our departed associate.

James David Forbes, born at 86 George Street, Edinburgh, on the 20th of April 1809, was the son of Sir William Forbes of Pitsligo and Williamina, only child of Sir John Steuart of Fettercairn. His mother, who at the time of his birth was suffering from an advanced state of consumption, was removed, along with her son, in the autumn of the same year, to the south of England,