I.

## ON VITRIFIED FORTS, WITH RESULTS OF EXPERIMENTS AS TO THE PROBABLE MANNER IN WHICH THEIR VITRIFICATION MAY HAVE BEEN PRODUCED.

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In asking the attention of the Society to some observations on the subject of vitrified forts, it is not necessary for me to rehearse what has already been written about them. The mystery of their origin has never been cleared up in a satisfactory manner, although they have attracted the attention of many antiquaries.

The first printed notice of vitrified forts seems to be that found in Pennant's *Tour in Scotland*, published in 1774, where he says he saw on the top of a hill near Fort Augustus, in a small oval area, a quantity of stones cemented with almost vitrified material, and he could not make out if they came from a volcano or a forge.

Shortly after this we have Williams' letters, in which he described the forts of Knock Farrell, Craig Phadric, and others; his theory being that a fire had been made along each side of the wall, and the stones thereby vitrified; but he puts the suggestion forward with hesitation.

At that time it was believed that vitrified forts were to be found only within a very small area in Scotland, but since then (1777) vitrification has been observed in the remains of old fortifications in many different parts of Scotland, in Ireland, Germany, Austria, and several regions of France. Indeed, it is probable that this list of the distribution of so-called vitrified forts is still far from being complete.

It is therefore clear that vitrification was well known among various races, of whom it may be said, without defining in any way the exact epoch when the work was done, that they must have been in a primitive state of civilisation.

The scheme on which the forts in Scotland have been disposed has led me to consider the time of the Vikings a probable date for some of them.

What is termed a vitrified fort of a normal character may be described as a mound or parapet, roughly circular in plan, or traced as an irregular polygon following more or less closely the edge of the flat top of a hill or ridge.

If we examine the section of the parapet, we find on the soil a mound of loose stones, varying in size, say 2½ feet deep; and overlying the loose stones, a layer, say 2 to 3 feet thick, of similar stone held together by a lava-like substance obtained by the complete or partial fusion of some of the stones in the heap.

This may suffice for giving a general idea of the section of the parapet, but more investigation is necessary, by careful excavation on the ground, before the exact section of the parapet of a vitrified fort is known, and probably considerable variety will be found.

The vitrified material is in most cases now found covered on the top with a little soil and vegetation. The vitrified layer is not found, I believe, perfectly continuous in every part of the parapet, and often appears only at certain points, notably at Tap o' Noth.

The size of the forts varies greatly, from the large fort just mentioned to a heap of stone with no indication of an enclosure which could be called a fort.

In position, the vitrified forts I have seen (seventeen) in Scotland are situated either near the coast where it is deeply indented by the sea, or at inland points which open up a large valley, or a group of valleys radiating from a common centre.

The rocks which seem to melt to form the slag are chiefly mica-schists, felspathic rock, diorite, and moine schist, while the granite has not been affected in the same way by the process. Through the kindness of the late Mr Ivison Macadam, I am able to give a chemical analysis of the slag from the following places :—

| | Fintraven. Felspathic Sandstone. | | Tap o' Noth. Diorite. | |
|---|---|---|---|---|
| 1. *Soluble in Acids*— | | | | |
| Ferrous oxide | 0·41 | | 0·75 | |
| Ferric oxide | 0·12 | | 3·64 | |
| Aluminic oxide | 1·79 | | 11·18 | |
| Calcic oxide | 1·16 | | 1·26 | |
| Magnesic oxide | 1·76 | | 1·52 | |
| Potassic oxide | 0·04 | | 0·12 | |
| Sodic oxide | 0·02 | | 0·06 | |
| Phosphoric anhydride | 0·72 | | 1·22 | |
| Sulphuric anhydride | 0·12 | | 0·15 | |
| Carbonic anhydride | 0·06 | | 0·04 | |
| Soluble silica | 3·76 | | 11·04 | |
| | —— | 9·96 | —— | 30·24 |
| 2. *Insoluble in Acids*— | | | | |
| Ferric oxide | 2·22 | | 5·22 | |
| Albuminic oxide | 6·58 | | 10·82 | |
| Calcic oxide | 0·96 | | 1·24 | |
| Magnesic oxide | 3·12 | | 2·03 | |
| Potassic oxide | 4·14 | | 4 03 | |
| Sodic oxide | 0 92 | | 1 47 | |
| Titanic oxide | 1·76 | | 1·42 | |
| | —— | 19·70 | —— | 26·23 |
| 3. Insoluble silica | 70·11 | | 43·34 | |
| Loss and undetermined | 0·23 | | 0·19 | |
| | —— | 70·34 | —— | 43·53 |
| | | 100·00 | | 100·00 |

| | Eilean-nan-Gobhar. Moine Schist. | |
|---|---|---|
| 1. *Soluble in Acids*— | | |
| Ferrous oxide | 0·999 | |
| Ferric oxide | 0·216 | |
| Albuminic oxide | 0·642 | |
| Calcic oxide | 0·082 | |
| Magnesic oxide | 0·453 | |
| Potassic oxide | 0·143 | |
| Sodic oxide | 0·068 | |
| Phosphoric anhydride | 0·026 | |
| Sulphuric anhydride | 0·666 | |
| Carbonic anhydride | 0·053 | |
| Soluble silica | 4·212 | |
| | —— | 7·560 |

| | | | |
|---|---|---|---|
| 2. | *Insoluble in Acids*— | | |
| | Ferric oxide | 2·952 | |
| | Aluminic oxide | 13·446 | |
| | Calcic oxide | 0·248 | |
| | Magnesic oxide | 0·693 | |
| | Potassic oxide | 5·216 | |
| | Sodic oxide | 1·431 | |
| | Titanic oxide | 5·602 | |
| | | | 29·588 |
| 3. | Insoluble silica | 62·531 | |
| | Loss and undetermined | 0·321 | |
| | | | 62·852 |
| | | | 100·000 |

We now pass on to consider how it is that the vitrification of these forts has come about. Various opinions have been expressed:

(*a*) Some that it was done incidentally as the result of beacon-fires, or great fires for religious or other purposes.

(*b*) Other authorities see in these forts the intended result of structural operations, believing that the intention was to strengthen the parapet by fusing together the small stones of which it was composed.

The interdependence which can be observed in some of the groups of vitrified forts lends support to the view that they were used for signalling purposes, and I think that that may be assumed as certain, although there seems no reason to suppose that they only were used for that purpose any more than other forts in similar situations, which, being composed of different and more refractory materials, have not left the result of the fires so distinctly marked by the slag.

(*a*) I shall refer to the possibility of producing vitrification by beacon-fires later on.

(*b*) Turning at present to the view that the vitrification was inten-

tionally done to strengthen the parapet, we are met by some difficulties.

In the first place, it is almost certain that vitrification of the larger masses often met with, if intended as a structural method, must have been a troublesome business, and a process to which recourse would have been had only when ordinary building was impossible. But we find in various forts, notably at Tor Duin, near Fort Augustus, and at other places, that the loose stones below the vitrification are supported by ordinary masonry, which apparently might have been carried up the whole way had the builders so desired.

Another difficulty which presents itself is that the vitrification is not as a rule continuous all round the parapet, although for structural purposes, if that were the object, it would seem to be equally required at every point.

But not only is this the case, but we find that the greatest amount of the slaggy mass occurs often—I think I may say generally—where a strong parapet is least needed. At the top of an inaccessible cliff is often found the bulk of the vitrification. This is well seen at Shielfoot, Dunagoil and Ard Ghaunsgail (Arisaig). The last-named fort, which stands on a peninsula, has on the land side a defended entrance which would appear to be the weakest point; but the parapet is there devoid of vitrification, or nearly so.

It will also be admitted that, if the builders were determined to have solid walls, they were not very wise in setting them up on a foundation of loose stone, for they might have anticipated that the vitrified blocks would slip down the hill, as we find a great many of them have done, by the foundation sinking.

Lastly, I think it may be fairly assumed that, if the builders had designed a wall built with a mortar of semi-melted stone, they would have restricted its width to much less than a thickness of say 4 to 6 feet. In this connection, what are we to say to the mass of vitrified matter (described by Fraser-Tytler more than a hundred years ago)

extending along the east end of Craig Phadric, 40 feet wide and 70 feet long?

For these among other reasons, it seems unlikely that vitrification was undertaken as a structural method.

As the air of mystery still hangs over vitrified forts, it occurred to me that it could be to some extent dispelled if we could reconstruct a vitrified parapet; and my purpose to-night is to explain the experiments made with this object during the last five or six years, at long intervals and with insufficient leisure. The positive results have been poor, but a good many negative results have been obtained.

Beacon-fires seemed, at first sight, the most likely source of the necessary heat; so their results were first examined. Undoubtedly a large amount of slag can be obtained from burning grass or straw. This can be easily seen by inspecting the site of any large stack fire. I was fortunate enough (if I may use the expression) to see the results of a large stack-yard fire which occurred at Hay Mount Farm, near Kelso. There fifty-seven stacks of grain and eight of hay were consumed. It was found, where the stacks had been recently erected and the straw was strong, producing an open texture in the heap, so as readily to admit the air, as is the case with a rick of wheat, that there was no slag at the bottom. The silica had gone off in vapour, which had partially condensed on the lee side of the rick in the form of small pellets about the size of a pea. These could be found in considerable number on the ground. Where the material was closer in texture, as in the older oat ricks, some slag was seen at the bottom among the débris; but most of the slag was found at the bottom of the closely packed haystacks, where it lay in a nearly continuous crust, in places about 2 inches in depth.

I should have said that the wind was very high when the fire occurred, and that the combustion of the oldest stacks alone was at all slow.

The chemical analysis, by Professor Macadam, of the slag from this fire is given below, as it may be useful in further investigations:—

| | | | |
|---|---|---|---|
| 1. *Soluble in Acids*— | | | |
| Ferrous oxide | | 0·77 | |
| Ferric oxide | | 0·18 | |
| Aluminic oxide | | 4·68 | |
| Calcic oxide | | 9·73 | |
| Magnesic oxide | | 2·03 | |
| Potassic oxide | | 8·96 | |
| Sodic oxide | | 0·57 | |
| Phosphoric anhydride | | 7·13 | |
| Sulphuric anhydride | | 0·21 | |
| Carbonic anhydride | | 0·16 | |
| Soluble silica | | 35·62 | |
| | | | 70·04 |
| 2. *Insoluble in Acids*— | | | |
| Ferric oxide | | 0·11 | |
| Aluminic oxide | | 4·43 | |
| Calcic oxide | | 0·21 | |
| Magnesic oxide | | 0·38 | |
| Potassic oxide | | 2·59 | |
| Sodic oxide | | 0·32 | |
| | | | 8·04 |
| 3. Insoluble silica | | 21·76 | |
| Loss and undetermined | | 0·16 | |
| | | | 21·92 |
| | | | 100·00 |

As the stack fires, when nearly burned out, had been extinguished with water and otherwise, and as the stone bottoming might have thus escaped fire action, the following experiments, among others, were carried out to ascertain the action of open fires having a base of selected stones. The first experiments were made on the high moorland near Riccarton. To begin with, on a base of stones constructed like a saucer, having a diameter of 5 feet, 100 stones of old moorland hay were burned. The process took about eight hours. The result on the stones was nil, but some very small streams of slag were found outside

the lip of the saucer on the lee side of the fire. The stones in the bottom were covered with ash. They were chiefly whinstone.

The next fire was arranged with the stone heap raised in the centre and having a diameter of 10 feet. On this, some hay and an unlimited amount of bracken were burned for six hours. The heat was so great that with difficulty could the men pile on the fuel. The result on the stones in the heap at the bottom was that many of them were fractured and burned, but there was no vitrification.

The third experiment was carried out on the sea-shore at Arisaig—that district being selected because it is the site of a group of vitrified forts. On the stone heap in this case a mixture of four loads peats, four boat-loads brushwood, twelve cart-loads of sea-weed, and a boat-load of grass was burned, and the blaze was kept up for thirty-nine hours. The result on the stones below—they were principally moine schist—was, as before, fracture and roasting, but no melting or approach to fusion.

With this experience I had become satisfied that a beacon-fire—understood in the sense of an open blazing mass—had not produced vitrification of stones lying in a heap below it. Another solution had therefore to be found.

In a good many papers on the subject of vitrification, it is explained how easily it can be produced; but it does not seem such an easy matter in the field, when you tie yourself down to use only the materials found on the ground. It may be convenient here to refer to a remark made by Mr Ramsay of the Geological Survey, writing in 1859, and repeated later by others.

The observation was to the effect that he thought the vitrification at Knock Farrell had been produced by burning with wood, and explained how the rocks near Barnsley were more or less vitrified by being burned in heaps with coal and brushwood. The stones were described as sandstones. I thought this so interesting that I communicated with the Borough Surveyor, Barnsley, Mr J. H. Taylor, who informed me that

never had any *stone* been burned, but that some clay shale used to be burned in clamps about sixty years ago, so as to harden it for use on roads with light traffic, or for blinding—as we now see the same thing done on railways for ballast. That is a very different thing from fusing pieces of mica schist such as are found in vitrified forts, and I think some mistake seems to have been made by Mr Ramsay as to the sufficiency of the explanation.

To return to the experiments at Arisaig: What had already been done and observed led to the conclusion that the burning was too rapid, and that the supply of air had to be reduced.

A rough stone square enclosure was therefore set up, the walls being about 3 feet high and the sides about 4 feet long. A layer of loose stones was put in the bottom of the enclosure, and over them peat and brushwood were filled in up to the top of the wall, and a fire set agoing. When the fuel was about half burned, more wood was added, and a layer of stone about 1 foot thick was placed on the top and covered over with peat. As this sank down, hay was added to check the draught.

The result of this was that incipient fusion, producing a sort of glaze, was noted on some of the stones which had been placed on the top and had sunk down into a part of the fire where there was little or no draught. The remainder were only burned. The burning lasted six hours, but the enclosure remained hot for twenty hours.

Another experiment was made under similar conditions, except that the walls were less open and damp moss was placed on the top; but no vitrification resulted.

A third trial was made in the same built enclosure, with $2\frac{1}{2}$ feet of small branches below, with some peat and then 1 foot of stone above, and the top was kept covered with rough hay. The stones which had most heat were burned; where they were out of the draught they showed signs of commencing fusion on the surface. This took about nine hours.

Some other similar experiments were made.

It will be seen that the attempt to vitrify by heat above the stone

was being abandoned, and the fuel was now being put below the stones. To this I had been led by a more close examination of specimens from vitrified forts, on many of which can be seen the imprint of woody fibre (as in fig. 1), showing that branches had been used for fuel, to some extent at least; and from the direction of the drops at the ends of the semi-fluid slag it was clear that the branches had been under the melting stone in many cases. These prints of the branches in the slag from

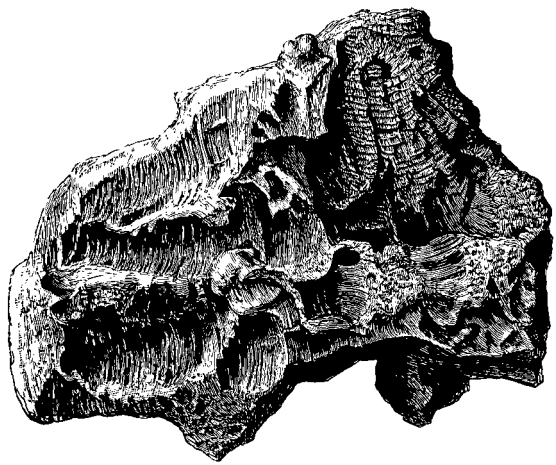

Fig. 1. Portion of a Vitrified Mass from Eilean nan Gobhar, showing impressions of woody fibre. ($\frac{1}{2}$.)

vitrified forts are very interesting. They are referred to by Daubrées in his "Comptes Rendus" (1882), *Revue Archéologique*.

The last experiment I made was on different lines.

A small fire of brushwood was lighted on the shingle on the shore. After the fuel was alight, it was covered with a thin layer of stone. When it was thought that the fuel below was nearly exhausted, then a few more pieces of wood were put on, and these again were covered with stone, and so on. The object was to check the consumption of the fuel as much as possible, without altogether extinguishing the fire.

After about eighteen hours the pile had risen to about 4 feet high and the base was 6 feet in diameter, and a great heat was emitted. It was noted that the top surface of the pile, as the experiment was going on, was so hot and flat that it would have sufficed for cooking purposes. When the heap was examined, a vitrified portion was found in the centre, weighing about 8 lbs. and situated about 18 inches from the top.

Up to the present time I have had no opportunity for continuing these experiments, but, as they have already been spread over some years, it seemed to me desirable that they should be recorded for the use of any others who may care to continue the investigations. I have come to believe that vitrification in these ancient forts was brought about somewhat after the manner of the last experiment, but the rate of combustion requires still to be largely reduced, and the heat which escapes from the mass conserved. It is in this direction that I hope to make further trials when opportunity occurs.

With the small results already obtained, I think it is fair to assume that vitrification was produced by a very slow process: not by a great fire in the open, but by a slow heat with a very limited supply of oxygen. The delicate impressions of the fibre of the wood (as shown in figs. 1 and 2) could not have been taken except in an undisturbed environment, and with a liberal supply of time, with a moderate temperature. This is in keeping with the investigations of Professor Joly, who has pointed out that rock solids can be fused at a comparatively low temperature if it is kept up for a long period. These schists would probably require from 1000° to 1200° F. Further, it is difficult to believe that the inhabitants of these forts had a large command of fuel —certainly not in some districts such as Arisaig, or on the barren islands along its shores.

Looking at the subject generally, I think it is clear that the occupiers of the vitrified forts in Scotland did not possess the command of the sea, and that the so-called forts were in many cases simply signalling stations, which necessarily, with such a purpose, would be occupied for considerable

periods at one time—probably during the summer half-year at least. The interior line of forts in the series would contain a certain number of men, who would defend the position or retire as they estimated the strength of the attack. I suggest that a smouldering fire would be required in such forts, which could be stirred up at any moment as a signal; and at the same time it might be used for cooking, as I believe

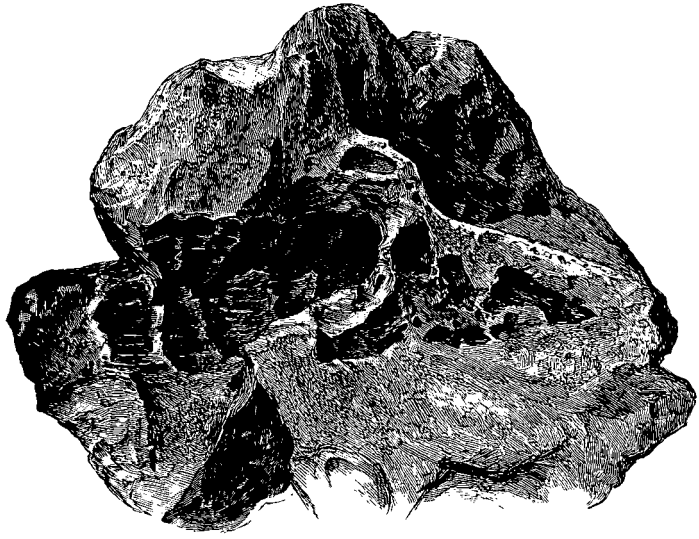

Fig. 2. Portion of Vitrified Mass from Tor Duin, showing impressions of woody fibre. ($\frac{1}{2}$.)

is now done in some of the Pacific islands. Such a fire would in time produce a large amount of slag in a region where the stone was easily made viscous, while in other places there might be no trace of vitrification.

The group of forts near the Sound of Arisaig, just north of the peninsula of Ardnamurchan, may be taken as an illustration.

From the broad arm of the sea called the Sound of Arisaig there run to the eastward into the land two lochs, marking the bottom lines of two

extensive valleys. On the north end of the east side of the sound is Loch nan Uamh, and at the south end Loch Ailort.

At the mouth of Loch nan Uamh, on the north side, stands the vitrified fort of Ard Ghaunsgail, on a small headland from which the valley at the head of the loch is open.

At the mouth of Loch Ailort, on a small island, stands the double fort of Eilean nan Gobhar. This island is close to the shore on the south. These two forts are in view of each other; but, if they were to some extent to be used for sentinels, it is evident that they could give little notice of a fleet from the north, as the north side of the sound is covered by the projecting headland which ends in Rhu Arisaig. But, on making close inquiry, I found that there were vitrified remains on an island near the north-west angle of the sound called Eilean na Ghoil. There is on this island a fine example of the raised beaches so common on the west coast. On the top are remains of a fort with sporadic vitrification, and on the low beach other traces of vitrification. The places in both cases are more or less triangular. From this point the forts at Ard Ghaunsgail and Eilean nan Gobhar are visible, but there is a very limited sea-view to the north. Further inquiry was made, and an islet called Eilean Port na Muirach was ultimately found with vitrification on the top, whence a fine open view was got of the sea from Ardnamurchan to the Sound of Sleat. Thus, then, there could have been telegraphic communication by smoke or fire to the valleys at the mouths of the Lochs nan Uamh and Ailort of a ship rounding Ardnamurchan Head from the south, or coming down the Sound of Sleat from the north. Now, while on no system of defence would it have been reasonable to isolate a small garrison on Eilean na Ghoil, and while in the case of Eilean Port na Muirach there was no space for a fort or garrison, these islands provided a perfect system for warning the inhabitants of the valleys round the Sound of Arisaig and its eastern lochs of the approach of an enemy, and this, I suggest, was their purpose.

The group of forts just described is a very small one, and I think

that progress in the investigation of the questions connected with vitrified forts would be much facilitated if the interdependence and correlation of the forts were more fully studied. For instance, a good deal has been somewhat loosely written about the extent to which the known vitrified forts along the great line of lochs between Inverness and Fort William are visible one from the other.

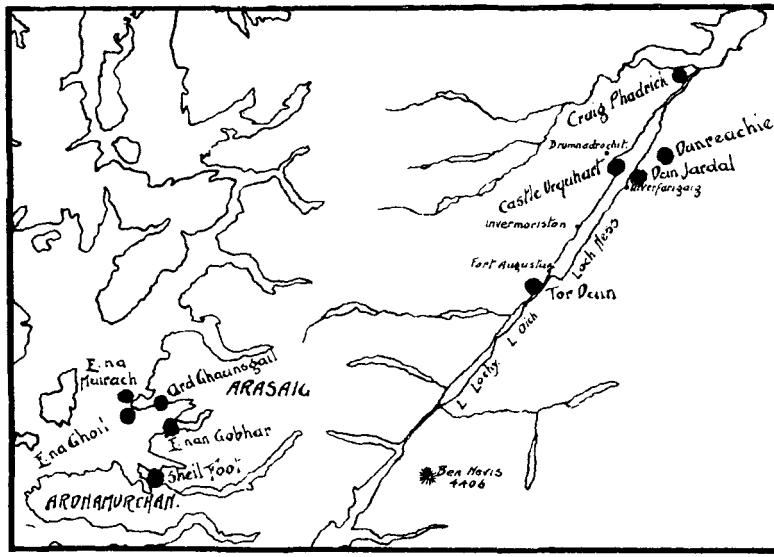


Fig. 3. Map showing Vitrified Forts in Arisaig and along the Caledonian Valley.

In trying to find out what the line of communication was—if, as is probable, there was one—I was driven to examine the promontory on which Castle Urquhart now stands. That point seemed to me the necessary site of a vitrified fort, if the assumptions on which I was proceeding were correct. It was gratifying, therefore, on a pretty close search being made, to find among the débris on the shore several water-worn pieces of vitrification which had formed part of a fort which must have been removed when the now ruined castle was built.

This discovery permits of the following suggestion being made as to the line of military signalling and communication from the north-east along the line of the lochs.

Starting from Craig Phadric, which commands a far view of the Moray Firth, communication could be carried to Dunreachie Fort on Ashie Moor. The stones of which Dunreachie is formed are of a very refractory nature, as the district belongs to the Old Red Sandstone, and no vitrification appears there.

From Dunreachie the fort at Castle Urquhart was visible, and would be now, were it not for the tall trees in Erchite Wood.

From Castle Urquhart, Dunjardel is well in view, and there is a clear though long line to Tor Duin, near Fort Augustus. It may be that there was another fort somewhere near Glen Moriston. But the discovery of that and of the communication south-west from Tor Duin remain for further investigation.