

9. *The BALA BEDS and ASSOCIATED IGNEOUS ROCKS of LAMBAY ISLAND, Co. DUBLIN.* By C. I. GARDINER, Esq., M.A., F.G.S., and S. H. REYNOLDS, Esq., M.A., F.G.S. (Read December 1st, 1897.)

[PLATE IX—Map.]

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I. INTRODUCTION.

LAMBAY ISLAND lies off the East Coast of Ireland, some 10 miles north of Dublin, the nearest point on the mainland being in the district of Portraine, where there occurs an inlier of Bala rocks which we have already described.¹

The name of Lambay is probably familiar to geologists from the occurrence there of the 'Lambay porphyry,' a very handsome and striking rock, described in detail by Von Lasaulx² and mentioned in many geological and petrological works.³

It was with the intention of investigating the occurrence of this rock in the field, and at the same time of seeing whether the other rocks exposed on the island were of a similar nature to those at Portraine, that we visited the island.

The only detailed account of the geology of Lambay appears to be in the explanatory memoir to Sheet 102 of the Geological Map of Ireland, published in 1861. Homogeneous and porphyritic trap-rocks are mentioned, catching up in places masses of slates and grits which they have baked and hardened. Ashes were also found, while limestone and graptolitic shales gave evidence that some of the rocks of the island were of Bala age.

On looking at the map of the island it will be seen that a large part of it is drift-covered, but from the exposures which occur it is obvious that the greater part of Lambay is formed of igneous rocks, the sedimentaries occurring in detached masses of no very great extent, and, except in the case of the limestone, they yield little fossil evidence from which their age can be determined. It will be most convenient to describe first the sedimentary and then the igneous rocks.

¹ Quart. Journ. Geol. Soc. vol. liii (1897) p. 520.

² Tscherm. Min. u. Petrogr. Mitth. vol. i (1878) p. 419.

³ See, among others, Teall's 'Brit. Petrogr.' 1888, p. 243; Harker's 'Petrolog. for Students,' 1895, p. 106.

II. THE SEDIMENTARY ROCKS.

At the north-western corner of the island, in Saltpan Bay, is an exposure of brown fissile slates, faulted, along its western edge, against an andesite, but apparently overlain conformably to the east by igneous rocks; for though at this junction, which can be seen at sea-level, near Calico Hole, the slates appear somewhat crushed, the line cannot be taken as a fault.

Exactly similar slates are to be seen in the road north of the Castle, about $\frac{1}{4}$ mile south-west of Saltpan Bay, and, though the intervening country is drift-covered, it is probable that the two sets of exposures are in the same bed of slate, as is suggested in the Survey Memoir (p. 49).

Similar slates are exposed in Broad Bay, the next bay to the west of Saltpan Bay, and they run across the inner end of Scotch Point, being seen on its western side. The ashes forming Scotch Point underlie these slates conformably.

No other sedimentary rocks are to be seen on the western coast of the island, but on the south-western side, in Talbot's Bay, patches of green and red slates occur, several yards in length and breadth, entirely surrounded by the dark green andesite which here forms the coast. In places these slates are baked by the igneous rock, and at one spot they contained *Orthis biforata*. Bands of grit and tuff occur with the slates, the tuff-bands containing fragments of grit, slate, and ash.

The middle of Talbot's Bay is cut out in black and green slates showing much contortion and containing bands of purplish grit. These beds are so utterly unlike the brown slates exposed in Saltpan Bay and near the Castle that we cannot fall in with the suggestion in the Survey Memoir that they are 'evidently a portion of the same Silurian slates.'

The Talbot's Bay slates are, however, extremely like those exposed in Carnoon Bay to the south-east, the coast between the two bays being formed of a coarse tuff or agglomerate. The Carnoon Bay slates are black and purple in colour, and contain a tuff-band somewhat similar to that which occurs in Talbot's Bay.

To the south many small patches of red and green slates and fine ashes are exposed, caught up in the andesite, which here forms the coast-line, the smaller inclusions being baked and porcelainized, the larger ones showing no signs of alteration.

The largest and most important mass of sedimentary rocks that occurs in the island forms the summit of Heath Hill, and occupies the shore-line from Kiln Point to Seal Hole.

To the north-east these rocks are bounded by a fault, which can be seen at the top of the cliff on the northern side of Seal Hole. At Kiln Point, to the south, the junction is seen to be an unfaulted one, the limestone overlying the igneous rock, and here the former rock shows evidence of alteration by the andesite. This alteration is visible both in a hand-specimen and under the microscope, the limestone becoming thoroughly crystalline and the shaly partings

porcelainized, while the igneous rock becomes much more finely granular.

The corals, chiefly *Favosites* sp., which are found in the limestone are not obliterated by the alteration in it, but are to be seen to within an inch or two of the igneous rock. From this limestone we also obtained *Halysites catenularia*, Linn.

The limestone is covered by a conglomerate formed of large and small blocks, the larger of which sometimes reach 6 feet in diameter and are usually rounded, while the smaller blocks are frequently angular.

The matrix is sometimes calcareous and contains small, perfectly - preserved corals, but is more usually a black shale in which small angular fragments of rocks are irregularly scattered, so that it resembles an ash in appearance. The included blocks are usually of limestone, very often fossiliferous (*Favosites* sp., *Halysites catenularia*, Linn., *Heliolites megastoma*, McCoy ?, and *Rafinesquina expansa*, Sow., small var., having been obtained), and of andesite; but blocks of black earthy shale, green slate, grit, conglomerate, calcareous ash, and coarse porphyrite also occur.

A section of this rock showed fragments of various andesites, one a rock formed of parallel acicular felspars in a much altered matrix, another a fresh mica-andesite, a third a vesicular andesite, all embedded in a matrix formed of fragments of crystals, quartz, and iron-ores.

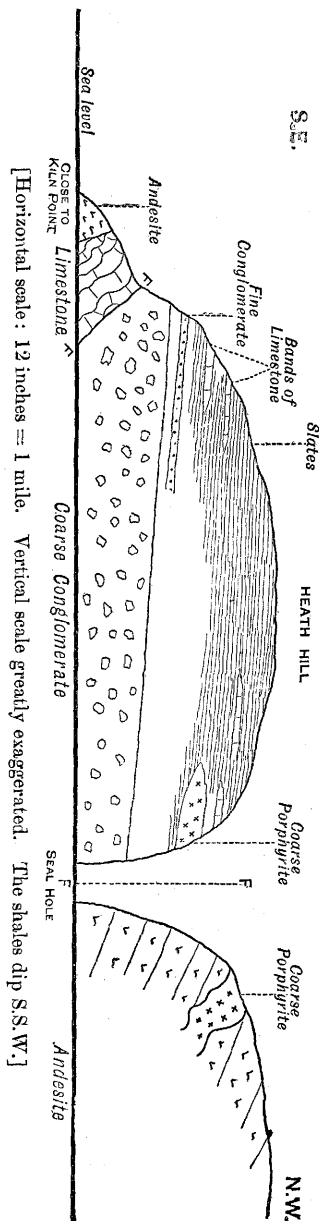
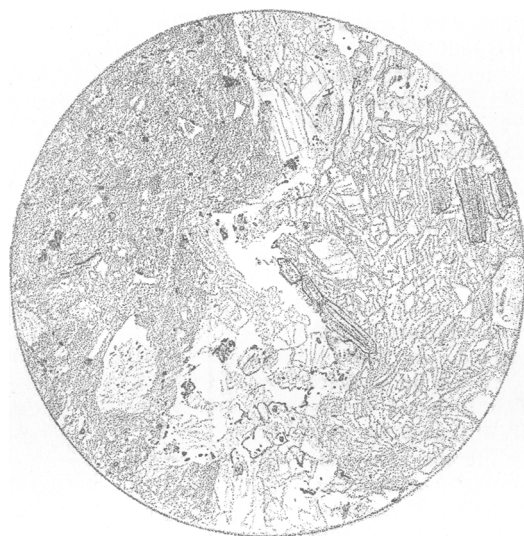


Fig. 1.—Section of Heath Hill, from near Kiln Point through Seal Hole.

The conglomerate shows signs of faulting and is covered by slates and impure limestones, which, as will be seen from the map (Pl. IX), form the whole of Heath Hill. The dip of these beds is about 60° – 50° S.S.W. at various points of the hill. From them we obtained *Calymene* sp.; *Illænus* sp.?¹; *Remopleurides* sp.; *Trinucleus* sp.; *Tresias* sp.¹

Just above Seal Hole, on the north side of the hill, a small plug of coarse porphyrite is seen cutting into the slates, which do not appear much altered by its intrusion. The occurrence of this rock here is noted in the Survey Memoir (pp. 48, 49), where it is represented

Fig. 2.—Conglomerate from Kiln Point.



× 18.

[The section shows a fragment of a mica-andesite on the right, and on the left the matrix of the conglomerate, in which small quartz-fragments and pieces of felspar and felspathic rocks are found.]

in the section given as a mass resting on slates and covered by no deposit, and it is supposed to be a remnant of a mass which 'entirely embedded the conglomerate and shales.' As, however, the mass of igneous rock is entirely covered and surrounded by slates, it appears to us to be of the nature of an intrusion.

At Raven's Well, on the north side of the little valley leading down to Seal Hole, brown and grey slates, sometimes of a very ashy nature, are seen dipping at 60° S.S.W., and the faulted junction of

¹ These, and the other fossils which we obtained from the island, have been identified for us by Mr. F. R. Cowper Reed, M.A., F.G.S. A list of fossils found on Lambay Island is given in the Survey Memoir, pp. 11 & 12.

these beds with the andesites is seen, as mentioned above, in the cliff on the north side of Seal Hole.

The coarse conglomerate is visible at sea-level, a little way to the north-east of this fault-line, and also at the top of the cliff along the coast due east of the Bell Rock.¹

With the occurrence of a thrust-conglomerate on the mainland immediately opposite at Portraine, the question of the origin of the Lambay Conglomerate is one which naturally arises. That earth-movements have affected the conglomerate and the limestone-bands at Kiln Point is obvious from the faults in the former and the curvature of the latter which are to be seen there; but the junction of the conglomerate and the igneous rocks never has the appearance of a thrust-plane. The limestone, which is altered by its contact with the igneous rock, is bent, and the conglomerate is faulted against it; there is no resemblance, however, between the crushed material along the fault-line and the gradual formation of the conglomerate at Portraine.

The beds immediately above the conglomerate are not seen, but a very short distance up the hill-side occurs a fine conglomerate of well-rounded pebbles of limestone and andesite sometimes an inch long, in a calcareous matrix, and this is covered by the slates of Heath Hill. None of these show any such crumpling as might be expected if the mass had been thrust over the underlying igneous rocks, and the limestone at its base had been crushed and broken up into the conglomerate. At Portraine the tough grits which have been thrust over the underlying limestones are very obviously curved, and similar, if not more pronounced, curvature might be expected in the Heath Hill slates had they been acted on by similar forces, as they would have been more readily affected. The occurrence of the fine conglomeratic bands above the coarse bed also points to the latter being an ordinary conglomerate, for if it had been laid down close to the shore (as appears probable from the size and angularity of its blocks) when the shore-line had increased its distance from this spot, we should expect the materials brought thither to be smaller and better rounded.

The constituents of the coarse conglomerate have been mentioned already, and among them, it will be seen, are lumps of black earthy shale. These contain obscure traces of graptolites, and are absolutely uncrushed; but if the conglomerate were formed by earth-movements, which had broken up hard limestone-bands and mixed their fragments up with pieces of igneous and other rocks, it would be imagined that blocks of such a soft nature as these black shales would have shown some signs of the stresses to which they must have been subjected.

The matrix of the conglomerate shows no signs of crushing either in the field or under the microscope, but appears to be of a somewhat

¹ On the very top of Heath Hill occur a large number of well-rounded blocks of various rocks, gneiss, quartzite, feldstone, andesite, fossiliferous limestone, grit, etc.; but this deposit does not in any way resemble the Kiln Point Conglomerate, and is very probably a Glacial drift.

ashy type. Small detached corals occur here and there throughout the rock.

It appears, therefore, that this conglomerate is not a thrust-conglomerate, but resembles rather the ashy conglomerate of the northern end of the Portrairie section. They both have an ashy matrix, and both contain blocks of much the same nature. The limestone-blocks on Lambay Island are more fossiliferous than those at Portrairie, and are shown to be of the same age as the Bala Limestone of the mainland.

The bed is a fairly coarse deposit, and, though many of the blocks are well rounded, one occasionally meets with corals (not attached to any piece of rock) in a comparatively fresh condition, and with angular blocks. This points to the derivation of some of the material from close at hand, but some of the blocks may have been rounded on land and then not moved far from the shore before being finally entombed.

Summary of the Sedimentary Rocks.

The sedimentary rocks of Lambay Island are therefore seen to be chiefly of the nature of slates and limestones, and to be contemporaneous with some of the igneous rocks of the island. On the north-west the slates have yielded no palæontological evidence of their age, while but little is forthcoming from those on the south-western side. All these slates occur in the neighbourhood of deposits of ashes or tuffs, and may have been laid down during intervals of comparative quiescence, when the neighbouring volcano was inactive or pouring out its lava in other directions, while the ordinary agents of denudation were cutting down its cone and distributing the fragments thereof to a distance. That advancing streams of lava occasionally caught up some of the mud from the sea-floor and baked it appears from the red shales of Carnoon Bay, while the intrusion of coarse porphyry on Heath Hill into the slates shows that igneous activity had not ceased after the deposition of those beds, the baking of the limestone at Kiln Point leading the observer to the same conclusion.

III. THE IGNEOUS ROCKS.

These may be divided for purposes of description into (a) the fragmental rocks, (b) the andesitic rocks, and (c) the coarse porphyrite.

(a) The Fragmental Rocks.

These consist of rocks of every degree of coarseness, from fine ashes to coarse tuffs. There are two localities where they occur over areas of large extent, namely at Scotch Point and along the coast between Talbot's Bay and Carnoon Bay. Between the Castle and Broad Bay there occur several exposures in a tuff-band which runs roughly north and south, while small exposures of ashes associated with the igneous rocks occur here and there throughout the island. Such are the bed between Knockbane and Calico Hole, and the patch

between Trinity Well and Raven's Rock, these beds appearing to have been due to small outbursts which scattered fragments of pumiceous and compact andesitic rocks over the top of the lava-flows at various points.

The Scotch Point ashes are of medium grain, and in a hand-specimen show rounded and subangular fragments of andesitic rocks, dark- and light-green in colour. A microscope-section shows angular and rounded fragments of felspathic rocks in which all the felspars are replaced by calcite, and many of the fragments are exceedingly vesicular. In many places blocks of coarse porphyrite are to be seen, often very amygdaloidal and probably of the nature of volcanic bombs, while dykes of a similar coarse rock are seen cutting the ashes here and there.

The other large patch of ground in this corner of the island occupied by pyroclastic rocks is between the Castle and Broad Bay. It is separated from the Scotch Point ashes by a mass of coarse porphyrite, a drift-covered region, and the outcrop of slates mentioned above (p. 136). Here the ash-bed rests on what is apparently an andesite containing large rounded blocks of amygdaloidal coarse porphyrite; this, in its turn, is underlain by a band of coarse porphyrite, which can be traced for some 300 yards in a north-and-south direction. But the microscope shows that the supposed andesite is really andesitic ash, and at the northern end of the exposure occur well-marked bands of fine ash, striking roughly south-west and dipping at about 80° S.E.

The occurrence in these ash-beds of bomb-like portions of coarse porphyrite points to the near presence during their formation of the coarse rock in the liquid state, and we may well imagine a series of explosions drilling a hole through the andesitic flows and forming a passage for the uprise of the porphyrite: the ash-beds being chiefly formed of fragments of the shattered andesites, but including portions of the uprising rock which were blown out from it at intervals.

On the south-western coast of the island, between Talbot's Bay and Carnoon Bay, is exposed a fairly coarse tuff or agglomerate, numerous exposures of the same rock being found for some distance inland. It ends off against much-crumpled slates in Talbot's Bay, the actual junction being a faulted one, while in Carnoon Bay a few finer tuffs and slates, dipping east at a high angle, intervene between the coarse tuff and the crumpled slates. The coarse bed is largely composed of rounded and angular blocks of slate and fine andesite, but blocks of coarse porphyrite also occur, generally rounded and very amygdaloidal. This mass of agglomerate may very possibly mark the spot where a volcanic neck was drilled through the sea-floor which was formed of the slates of Talbot's Bay and Carnoon Bay.

Owing to insufficient exposures, it is difficult to say decidedly whether these three masses of ash and tuff are to be regarded as marking the positions of old vents, or as being merely beds of ashes formed by the scattering over the sea-floor of fragments which were shot out from some vent in the vicinity.

(b) The Andesitic Rocks.

As will be seen by reference to the map (Pl. IX), much the greater part of the island is formed of rocks of an andesitic nature. In a hand-specimen some of them show small porphyritic feldspars, and some are difficult to class, as they appear to be intermediate between the andesites and the coarse porphyrite.

At certain spots the andesites include angular blocks of igneous rock, sometimes in large numbers, as on Lambay Head and in the cliffs at the mouth of Thornchase Valley; while at other spots fine and coarse breccias occur among them, as above Freshwater Bay near Gillap. The inclusions in the rock at the mouth of Thornchase Valley are noted in the Survey Memoir.

The andesites as a rule show no augites, but examples of augite-andesite occur. The rock at Kiln Point is a hypersthene-andesite, the hypersthene being now replaced by bastite. One of the inclusions in the andesite at Carrickdorish shows numerous porphyritic crystals; these cannot be determined with certainty, owing to the alteration which has gone on, but they are very probably altered olivines. Some of the inclusions at the mouth of Thornchase Valley show augites, though the enclosing rock does not appear to have any.

As shown in the map, the chief exposures of augite-andesite are close to the top of Knockbane, close to Raven's Rock, west of Flint Rock, and on Lambay Head.

The Lambay Head augite-andesite is a very well-marked rock running along the crest of the Head towards Pilot's Hill, its large augites being readily seen on its weathered surfaces. In a hand-specimen this rock shows a dark green, somewhat horny-looking groundmass, in which small feldspars are sparingly scattered and large porphyritic augites occur, the largest one seen measuring 9 mm. in length. A microscope-section of this rock shows a fairly prominent, highly altered groundmass, in which are many short, broad feldspars, now entirely replaced. The porphyritic feldspars are also entirely converted into a quartz-mosaic, but the porphyritic augites are very fresh, and occur in granular aggregations; magnetite is present, while chlorite and epidote have come in as secondary minerals.

The augite-andesite which occurs close to the top of Knockbane has a fine, compact, somewhat horny groundmass, purple in colour, containing numerous ill-defined patches of a green colour (generally rounded in outline), and small black patches are also to be seen. The microscope shows the groundmass to be now formed of secondary minerals, quartz, iron-ores, and calcite, while the porphyritic feldspars which it contains are also entirely altered. Augites are represented by a brown decomposition-product, which here and there encloses cores of the original undecomposed mineral.

Running east-south-east from the steep cliff known as Raven's Rock, and traceable for some 350 yards, is a third well-marked

band of augite-andesite. The rock, when fresh, is of a dark-green colour; small green feldspars are with difficulty to be made out, the most obvious constituents of the rock being large black augites, measuring as much as 6 mm. in length, and showing well-marked cleavage; the groundmass of the rock is fine-grained. The microscope shows a groundmass of feldspar-microlites, augite-granules, magnetite, hæmatite, and chlorite; in it are small porphyritic feldspars, now entirely replaced, and large augites.

Going east-south-east from Raven's Rock, the last exposure of this augite-andesite is close by a wall running north and south, after which no exposures are to be seen for some distance. Almost due east of the last exposure, however, near the wall, occurs a small area of exposures, most of which are in a rock with a fine purple groundmass containing bright yellow-green, rather small, porphyritic feldspars and large black augites, sometimes 9 mm. long. Other exposures are in a green-and-purple rock with a fine-grained groundmass, containing a few small porphyritic feldspars and numerous vesicles.

About 450 yards due west of the summit of Flint Rock occurs a small exposure of a greenish rock with a fine groundmass, no distinctly porphyritic feldspars, but with large black augites, sometimes 7 mm. long. This rock resembles markedly the augite-andesites of Lambay Head and Raven's Rock; but, as the ground between Flint Rock and Knockbane is much covered with drift, it is impossible to tell whether there is any extensive occurrence of the rock between the two hills.

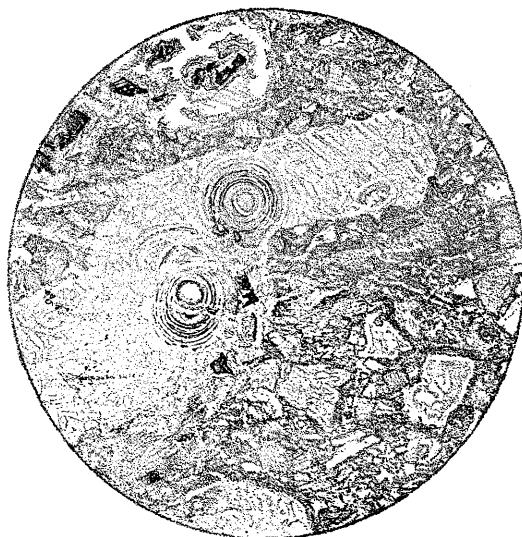
Though augites occur in some of the other andesites, they are found very seldom, and the above-mentioned type of rock, containing abundant augites, was found nowhere else on the island.

The remaining andesites call for very little remark. They are generally of a very normal type of fine-grained andesite; porphyritic constituents are rarely visible in a hand-specimen, but under the microscope they are all seen to contain porphyritic plagioclase-feldspars, now much replaced, and frequently the twinning is wholly obliterated. Flow-structure is to be seen at times in the groundmass, which is composed of small feldspar-microlites and decomposition-products, such as quartz, calcite, chlorite, and epidote, while either magnetite, hæmatite, or ilmenite is generally present. A far from uncommon porphyritic constituent of these rocks is apatite, which occurs in the usual needles, giving straight extinction, while bastite-pseudomorphs after hypersthene occur in the Kiln Point andesite.

The alteration that has gone on in these rocks is very great, and the resulting formation of secondary minerals most marked. In some cases the production of epidote and quartz has been the result following on the destruction of the porphyritic feldspars; in other cases calcite has come in, and more or less spherical masses of calcite occur (see fig. 3, p. 144), the concentric shells of calcite being separated by shells of hæmatite, while in other cases chlorite occurs abundantly.

There are a few instances, however, where the groundmass shows the structure known as 'micropoikilitic.' Mr. Alfred Harker, in his paper on 'The Gabbro of Carrock Fell,'¹ and Mr. F. R. Cowper Reed, in his notes on 'The Geology of the Country around Fishguard,'² notice this structure, the former in lavas metamorphosed by the gabbro, the latter in felsites which he considers metamorphosed. In the last-named paper a very full account of previous notices of this structure, which seems generally to have been seen in felsitic rocks, is given. On Lambay Island, however, it occurs in andesitic rocks and in the coarse porphyrite. It is to be seen in five of the slides which we have had cut; three of these

Fig. 3.—*Vesicular andesite from Freshwater Bay.*



× 18.

[The rock is very much altered, calcite and other minerals having come in with the alteration. In the vesicles the calcite often assumes a spherical arrangement, as shown in the figure, the spheres of calcite being separated by spherical shells of hæmatite.]

are from andesites, and two from the coarse porphyrite. Two of the slides from the andesites are cut from rocks close to the junction with the limestone at Kiln Point. This rock in a hand-specimen is seen to have an appearance somewhat different from that of the usual fine andesite of the island, being more compact and horny, and the sections show the alteration of the rhombic pyroxene which they contain and of the groundmass, the small felspars in which have to a large extent disappeared, ragged-edged plates of quartz having been formed, giving rise to the micropoikilitic structure.

¹ Quart. Journ. Geol. Soc. vol. 1 (1894) p. 311.

² *Ibid.* vol. li (1895) p. 149.

The other example of this structure in a fine andesite is in a rock some 200 yards south-west of Kiln Point.

In these three slides, though the alteration of the groundmass has gone on to so great an extent, the porphyritic feldspars are remarkable on account of their freshness.

Here and there the andesites are amygdaloidal, and occasionally as much as half the rock consists of amygdules; this is especially well seen in a rock obtained from a spot about halfway between Heath Hill and Bishop's Bay.

The inclusions noted as occurring at the mouth of Thornechase Valley and on Lambay Head are also to be seen along the cliffs between Bishop's Bay and Sunk Island Bay, and on Sunk Island itself, while the island of Carrickdorrish also shows them all over its surface. They were very possibly blown on to the surface of the andesites, and gradually incorporated in them, or they may have been portions of the rocks which formed the vents through which the andesites rose to the surface.

(c) The Coarse Porphyrite.

The last type of rock remaining for description is the coarsely porphyritic rock, well known as the 'Lambay porphyry,' and described by Von Lasaulx both macro- and microscopically.¹ This writer mentions that it has been described as an amphibolite-greenstone, as a quartzless orthoclase-porphyry, and as a diabase-porphyry, and pronounces in favour of the last name.

From the map (Pl. IX) it will be seen that the coarse rock occurs in very many places on the island, but in only a few does it extend over a large area, the rock being more usually found in small unconnected patches.

The coarsest variety was found in a small exposure on the seaward face of the point forming the south-western edge of Sunk Island Bay. Here the groundmass is green in colour and very compact, while large green platy feldspars, sometimes as much as 23 mm. broad, are present in great abundance, showing repeated twinning. Calcite occurs in little rounded masses, possibly filling vesicles or replacing augites. More usually, however, the porphyritic feldspars are smaller; thus in the exposure between the Coastguard Station and Scotch Point the groundmass is also green and compact, but the feldspars are not more than 11 mm. broad; here augite is a fairly abundant porphyritic mineral, crystals of this mineral measuring as much as 6 mm. in length. In the mass occurring round Trinity Well the porphyrite has a compact purple groundmass; the porphyritic feldspars are numerous, and run up to 12 mm. in length, being green and platy like those described above. Amygdules are fairly common in this rock, being formed of calcite or of calcite and chlorite.

The long strip of coarse rock exposed along the base of the hills

¹ Tschern, Min. u. Petrogr. Mitth. 1878.

east of the Castle is of the same type as the mass near Trinity Well, and seems to be intruded along the junction of the andesites and slates.

The two exposures of the porphyrite, one of which forms the conical hill at the south-western end of Pilot's Hill, and the other Flint Rock and part of Bell Rock, resemble one another exactly. The groundmass is more prominent than in most of the coarse rocks, and of a grey-green colour, while the feldspars are thinner than the usual porphyritic feldspars; they are about 7 mm. long, and show a markedly parallel arrangement. On the northern slopes of the conical hill, mentioned above as forming the south-western end of Pilot's Hill, the coarse rock is extremely amygdaloidal. The amygdules, formed of calcite, weather out into round masses, sometimes 17 mm. long, and occasionally form by far the largest portion of the rock. This very amygdaloidal porphyrite is also seen on the northern slopes of Flint Rock.

Another peculiarity of the coarse rock of these two exposures is the presence of a large number of included fragments. These are of very irregular shapes, angular in outline, and generally blue or purple in colour; they are consequently very obvious in the faces of rock exposed. They vary much in size, the largest one seen being about 12 inches long; they all have a somewhat striped appearance, break with a fairly perfect conchoidal fracture, and appear somewhat porcelainized. In fact, they look like baked ashes, and under the microscope they are seen to be fine ashes which have undergone considerable alteration.

The base of the mass which forms part of Pilot's Hill was seen in the cliff just above sea-level; it was slightly amygdaloidal, enclosed blocks of andesite, and rested on an andesitic breccia, beneath which came a red amygdaloidal andesite.

It appears, therefore, from these two exposures of the coarse rock that we have evidence of the actual outflow of the porphyrite, for we can see the brecciated surface of the underlying andesite in the sea-cliffs, the slightly amygdaloidal base of the porphyrite (which caught up and enclosed portions of the rock beneath it), and its extremely amygdaloidal nature along the northern slopes of the two exposures, while the closer grain and appearance of the rock also mark it out from the other coarse porphyrites of the island.

The other exposures of the rock are small in extent, though numerous, and show the porphyrite penetrating the finer andesite in dykes of various lengths. Here and there they accompany exposures of breccia, which seems to point to explosive action having caused, or having assisted in causing, the opening in the andesites, which was afterwards filled with the coarser rock.

Two sections from the coarse porphyrite show a micropoikilitic structure in the groundmass. One of these is from the edge of the Trinity Well mass, and the other from a small exposure of the rock south-west of Heath Hill. In one of these the freshness of the porphyritic feldspars, as was the case with the andesites showing micropoikilitic structure, is remarkable.

The coarse porphyrite, therefore, usually occurs in dykes or sills, but it is also found as an extruded mass on Flint Hill and Pilot's Hill.

With regard to its mineralogical constitution, we have nothing to add to Von Lasaulx's account. We have recognized porphyritic feldspars allied to labradorite, much decomposed, in a groundmass of lath-shaped feldspars and augite-granules. Calcite, epidote, magnetite, pyrites, and sphene also occur.

IV. CONCLUSIONS.

From the observations recorded herein, it seems plain that in Bala times Lambay Island was close to a centre of vulcanicity. A vent could not have been very far distant, and its flanks must have extended close to the districts of Lambay and Portraine.

The main extrusions of lava were of a very normal type of andesite, augite- and hypersthene-andesites being, however, represented to a small extent on the island, while the coarse Lambay porphyrite was injected into these andesites, and must occasionally have reached the surface. That some of the lavas flowed beneath the sea seems probable from the occurrence among them of beds of slate, while that the period of igneous activity had not ceased when the sedimentary rocks of Heath Hill had accumulated is shown by the intrusion of the coarse porphyrite into the slates of that hill, and the baking of the limestone at its eastern edge.

The palaeontological evidence is scanty, but, such as it is, it points to the sedimentary rocks being of the same age as the Portraine beds, namely, Upper or Middle Bala.

Hence, in Bala times, there was an immense outpouring of andesitic rocks in this district, while explosions shot out fragments which formed ash-beds at various places, and cracks in the andesites were filled with a coarsely porphyritic rock, which also here and there welled up to the surface. Meanwhile limestones and shales were being deposited round the volcano, and were in part subjected to the ordinary agents of denudation. Fragments of the igneous rocks and of these upraised sedimentaries were rolled down to the shore and piled up to form a massive conglomerate, which, as it sank beneath the waves of the Bala sea, was covered by calcareous mud; and therewith the history of Lambay Island in Bala times is brought to a close.

In conclusion we would offer our best thanks to Mr. W. W. Watts, for the assistance which he has so kindly given us; to Mr. F. R. Cowper Reed, for naming our fossils; and to the authorities of the Geological Museum in Dublin, for the generosity with which they have afforded us every facility for examining the collections of rocks and fossils in their possession.

PLATE IX.

Geological Map of Lambay Island, on the scale of 4 miles to the inch.

DISCUSSION.

Mr. W. W. WATTS congratulated the Authors on the excellent work that they had done. He was not quite convinced by the arguments which he had heard as to the outpouring of parts of the Lambay porphyry in the form of lava.

Mr. G. W. LAMPLUGH asked whether the Authors had found any pebbles of the porphyrite in the Old Red Sandstone, as he believed that Mr. McHenry thought the point of importance.

Mr. GARDINER, in reply to the last-named speaker, stated that no pebbles of the coarse porphyrite had been noticed by the Authors in the Old Red Conglomerate which occurred on the island.

