XVI.—*Descriptions of some New Volcanic Vents in East Fife.*

By DAVID BALSILLIE, B.Sc., F.R.S.E., F.G.S.

(Read 21st November, 1917.)

In the present brief communication I propose to add a small number to the already long list of "ancient volcanoes" that have been described from East Fife. The first occurs on the shore at Kinkell Cave, one mile to the east of St Andrews. The second was discovered by a boring sunk in search of water to the south of that city, while the third is situated at Walton Hill, a little over two miles, to the south-west of Cupar. The remaining vents to receive mention have been laid bare by the sea to the west of the village of Pittenweem.

Vent at Kinkell Cave.

—A mile to the east of St Andrews, and immediately in front of Kinkell Cave, the materials of a neck have been cut in section by the waves. Fig. 1

will serve to illustrate the structure of the foreshore at this part, as also the outline of the visible part of the rock that fills the opening.

As will be seen the strata are here swinging round the nose of an anticlinal fold that pitches towards the north. To an observer on the cliff top the curvilinear disposition of the beds is beautifully clear and, at low water, is sufficiently striking to arouse the interest of the non-geological observer. It is on the north-east flank of the fold that the vent has been drilled.

The material filling the neck consists in the eastern portion of a dark coaly, or sometimes purple, fragmental rock that includes larger masses of various disrupted sediments. Among the latter occurs a grey compact limestone with large crinoid ossicles, which certainly cannot have been derived from any of

Fig. 1. Ground plan of neck on beach below Kinkell Cave, near St Andrews. A = agglomerate; B = white trap with included fragments of sedimentary rocks.

the rocks underlying this portion of the coast line (although the vent is known to have here penetrated the Encrinite-bed) and must have come from some higher stratigraphical horizon. A similar phenomenon was demonstrated by the writer several years ago (*Geol. Mag.*, 1911) at the well-known vent of the "Rock and Spindle," where blocks of a limestone with *Lithostrotion* and other common Carboniferous Limestone fossils occur in an opening that is surrounded by rocks of Calciferous Sandstone age.

Included also in the coaly agglomerate are the broken up remains of some fragmental aggregate that likewise is dark in colour and contains a considerable quantity of carbonaceous matter. There appears, therefore, in this neck to be evidence of more than one period of eruptive activity. Enclosed in both the older and the newer ash are numerous pieces of vesicular white trap.

In the western portion of the opening the material is quite different. There it weathers with a ferruginous crust and was for long taken to be a fine-grained sandy ash. It is crowded with sedimentary fragments, which in all cases have undergone the most extreme alteration. Subsequent investigation has convinced me that the whole mass is white trap and that the extraneous xenolithic materials owe their change to thorough immersion in a medium which must formerly have been at a very high temperature.

The strata around the vent, which are mainly thin-bedded and massive sandstones, do not appear to have suffered any remarkable change. In size the visible part of the neck measures about 60 yards from east to west by 30 from north to south.

New Grange.—The Town Council of St Andrews, endeavouring to augment the burgh water supply about twelve years ago, sank a number of boreholes to the south of the city on sites previously determined by a water diviner.

With but one exception the rocks beneath the surface were found to belong to the ordinary Lower Carboniferous type, viz. sandstones, shales, fireclays, ironstones, etc. One of the series, however—No. 9—proved to be of more than ordinary interest as indicating the site of an old volcanic chimney. The position of this borehole is at a distance of 440 yards from the farm steading of New Grange, measured in a direction 25 degrees to the north of west. After passing down through boulder-clay the boring rod entered a grey-looking rock, which could not be penetrated but persisted throughout the whole depth to which operations were carried, amounting altogether to 350 feet.

While boring was in progress the writer had the privilege of visiting the workers every day and of examining the material

brought to the surface. This was uniformly a dark grey and greenish ash that enclosed numerous finely-vesicular basic lava fragments, as well as frequent rounded and sub-angular grains of quartz. Being requested by Sir Archibald Geikie to forward him the bore journals he replied, "They are interesting in their revelations of the strata to the south of the city, No. 9 being especially so as showing the position of a volcanic vent."

Walton Hill.—A little over two miles to the south-west of Cupar and on the north-west slope of Walton Hill, a commanding eminence that overlooks the "Howe of Fife," occurs an area of ash which does not appear to be recorded on the published maps of the Geological Survey, and which is not referred to in the *Memoir on the Geology of Eastern Fife*. The volcanic material here displayed, which is well seen in an old quarry on the north-west slope of the hill, is a greyish-green or almost black, exceedingly fine-grained sandy tuff that weathers into large spheroids with exfoliating crusts. It contains abundant, much-altered, finely-pumiceous basic lava fragments along with numerous rounded quartz grains that are frequently of the blue and opaline variety familiar to workers among the Highland rocks.

The vent is of special interest as rising near the boundary between the Carboniferous and Old Red Sandstone systems. The thickness of strata belonging to the Carboniferous cannot here be great, and it was hoped that it might be possible to detect in the ash some fragments brought up from the volcanic series of the Lower Old Red Sandstone. This expectation, however, was not realised, and, apart from the sandy nature of the ash, which may be due to proximity to the Upper Old Red Sandstone, there was not recognised in the materials of the vent any rock that could with certainty be assigned to a time earlier than the Carboniferous.

Of the exact size and relations of this neck there is unfortunately no evidence. It has risen at the edge of the great dolerite sill that stretches east from this point towards Craigrothie. No disrupted pieces of this mass, however, were detected in the vent.

The visible part of the neck in the quarry measures about 40 yards in a north-east and south-west direction, though evidences of a greater extension than this towards the north-east can easily be found. Judging from the size and girth of the trees that are now growing in it the quarry was probably worked not less than sixty years ago. It was a common custom in older days to utilise this "rotten whin" as a macadam for farm roads.

Vents at Pittenweem.—On the beach immediately to the west of the fishing village of Pittenweem four vents have been laid bare by the sea, which do not appear to have found representa-

tion on geological map or mention in geological literature. The arrangement of the strata at this part of the coast and the position of three of the necks will be readily inferred from the accompanying figure.

As indicated, the sedimentary rocks are here dipping to the north-west at high angles. They consist of sandstones, shales, fireclays and ironstones, and include one thin band of impure limestone that contains beautifully preserved entomostraca, spirorbis and a small gasteropod. This stratum appears to be No. 301 of Mr Kirkby's well-known vertical section of the

Fig. 2. Ground plan of foreshore at west end of Pittenweem. Closely-dotted areas = Volcanic rocks; *a* = Entomostracan limestone.

Calciferous Sandstone Series of East Fife, as developed in the Anstruther area (vide *Mems. Geol. Surv.*, "Geology of East Fife"), which will perhaps sufficiently define the stratigraphical horizon of the beds that have been disrupted by the volcanic forces.

The rocks here are not altogether undisturbed but have been affected by a series of faults that sometimes run sinuously along the strike. One of these is shown in the figure. Whether they belong to the pressure period of the folding or are due to simple sagging was not determined.

Vents Nos. 1 and 2.—These are only a few square yards in extent and may conveniently be described together. Some-

what dyke-like in their manner of occurrence their enclosed material consists of an agglomerate or breccia of disrupted sediments which is generally dark grey in colour, sandy, and includes, as by far its most abundant constituent, innumerable fragments of clay ironstone that weather with a deep red crust. Along with these occur frequent pieces of sandstone, sandy shale and coal. Many of the sandstone fragments appear to have suffered some slight hardening, but there is here no evidence whatever of any prolonged manifestation of volcanic action.

In kind these openings recall the first vent on the beach immediately to the east of the Rock and Spindle, near St Andrews, which likewise is filled with non-volcanic detritus. This example has been described by Sir A. Geikie as an "explosion-fissure" or "blow-hole."

The larger of the two above-mentioned necks measures about 20 yards by 12, the smaller 5 by 2.

Vent No. 3.—A few yards to the north of the small volcanic openings, Nos. 1 and 2, the materials of another and much larger vent can be seen at the upper part of the beach.

The visible portion of the opening, as will be apparent from the figure, is somewhat triangular in outline, the southern margin only being available for examination. This can be seen cutting sharply across the highly-inclined strata which preserve their normal characters up to the edge of the neck.

The enclosed material is a dark grey sandy mass, having numerous fragments of sediment distributed through it. These include sandstone, in size up to masses that must contain 60 cubic feet, coaly shale, ironstone, etc., along with which are pieces of a white or whitish-green finely vesicular white trap. A continuous string of the latter material is visible among some shales at the south-east corner of the opening. The whole mass strongly resembles the aggregates that are found in some of the St Monans-Elie necks, as also in the curious linear occurrences at the west end of Kinkell Cliffs, St Andrews.

Vent No. 4.—Sixty yards from Vent No. 3—along the strike of the entomostracan band, which is by no means so regular in character as shown in the figure—occurs about 30 square yards of a very coarse sandy breccia that appears to mark still another site of volcanic action. This is an irregular assemblage of sedimentary fragments, the majority of which are sandstone, but again containing as its volcanic ingredient abundant pieces of white trap. The mass is peculiar as lying just to the south of a transverse fault, of small displacement, whose plane is dipping seawards at an angle of forty degrees to the horizontal.

The cost of illustrating this paper has been defrayed by a grant from the Carnegie Trust for the Universities of Scotland.