shingle, which latter indeed is not covered by the sand at the northern end. Narrow here, this shingle widens at Deal and then reaches southward for 4 miles further, to Hope Point. Deal itself is partly on the shingle, partly on Alluvium, and partly on low-lying loam.

At Walmer the Chalk again comes to the coast and forms a line of cliffs nearly to Folkestone, these cliffs on the whole gradually increasing in height south-westward and being breached midway by the valley of the Dour.

We now pass to lower and lower beds. The Gault (clay) rises to the surface just north of Folkestone and forms a cliff for a short way. Then the sand of the topmost division of the Lower Greensand rises up at the harbour and forms the base of the cliffs, thence westward to Shorncliffe, beyond which there is no cliff for many miles.

The peculiar district now reached, that of Romney Marsh, etc., consists of a broad tract of alluvial beds, largely below high water mark and generally bordered by beach. The only parts rising above the ordinary level are formed of shingle, which here reaches far inland in places, Dunge Beach being, I believe, the largest area of shingle in the kingdom.

By reason of this great spread of Recent beds the formation that next underlies the Lower Greensand, namely, the thick mass of the Weald Clay, never shows at the coast here, being wholly hidden, and we have, therefore, no cliff-section to show us the details of its structure.

It is not till we get westward, nearly to Fairlight, that higher land is found. There we have the lowest beds of the Wealden Series (the Ashdown Sand) and the Fairlight Clays beneath, classed with the Purbeck Beds. These, with some overlying Wadhurst Clay, form the fine cliffs on to Hastings, and the like is the case with the cliffs of the Bexhill district, separated only by the Alluvium of the Catsfield stream.

Next comes the broad alluvial tract of Pevensey Levels, with its border of beach, the latter swelling out to a breadth of seven-eighths of a mile at Langney Point and then again decreasing in breadth to Eastbourne, where the Upper Cretaceous beds rise up, the Weald Clay being here again cut off from the coast and mostly hidden under the Alluvium, as also is the Lower Greensand, which, however, is here much thinner than on the Kentish coast.

(To be concluded in our next Number.)

II.—THE HILL OF BEATH, A VOLCANIC NECK IN FIFE.

By J. S. GRANT WILSON¹ & H. BRANTWOOD MUFF.

THE Hill of Beath, which lies 3 miles to the north-east of Dunfermline, Fife, is an isolated hill with steep, but rounded, contours, and rises fully 250 feet above the surrounding plateau. Whilst the hill itself consists of dark grey tuff, the rocks forming the

¹ On January 2, 1909, the Editor received the sad intelligence of the sudden death of Mr. J. S. Grant Wilson, who had only a few days previously communicated his MS. for publication in the *GEOLOGICAL MAGAZINE* (see his Obituary, p. 91).

plateau belong to the Coal-measures of the Carboniferous Limestone series. The latter are thrown into gentle anticlines and synclines, the dip on the limbs of the folds usually lying between 10 and 15 degrees. The outcrop of the tuff has the form of an ellipse, the long axis of which trends east and west and measures nearly 1,000 yards, whilst the breadth of the ellipse is rather more than 500 yards. The distribution of the outcrops of the Carboniferous rocks around the hill and the evidence from the coal workings show that the tuff is not interbedded with the sediments, but that it breaks through them somewhat like an intrusive rock. Sir Archibald Geikie¹ recognized that the Hill of Beath was a volcanic neck, and this view has been confirmed by recent mining operations in a conclusive manner.

The Dunfermline Splint and Five Foot coals on the east side of the hill are worked in the Hill of Beath Colliery belonging to the Fife Coal Company. In order to reach the same seams on the north-west side of the hill a 'stone-mine' was driven in a westerly direction beneath the summit of the hill and almost along its greatest diameter. The stone-mine commenced at the foot of a roadway, which is partly cross-cut and partly 'dook' in the Dunfermline Splint coal, as shown

Section across the Hill of Beath near Dunfermline, Fife.

in the section, at a depth of 500 feet beneath the pit-mouth, or a little above Ordnance Datum. After driving a short distance the tuff was entered, and on plotting the underground position of the junction on to the 6 inch map it was found to be more than 550 feet vertically below the junction at the surface. The stone-mine was driven through compact tuff quite similar to that at the surface for about half a mile, and finally emerged into sedimentary rocks, the junction being vertical and almost perpendicularly beneath the margin of the neck as seen at the surface. The mine passed beneath the summit of the hill and at a depth of 700 feet beneath it, so that these mining operations have proved a vertical column of tuff piercing the Lower Carboniferous rocks and at least 700 feet high.

The eastern margin of the tuff against the sedimentary rocks is a typical neck junction, i.e. the beds as they approach the contact bend down sharply towards it. Whilst the general dip of the beds in the mine is about 10°, near the junction of the roadway with the stone-mine through the tuff the dip is 22° towards the neck. Eighteen yards further on it has increased to 50°, and 14 yards further it is 65°, and close to the contact with the tuff a dip of 74° was measured. This great increase in the angles of

¹ *Ancient Volcanoes of Great Britain*, vol. i, p. 425, footnote.

dip close to the tuff was also proved in the 'levels' in the Five Foot coal on both sides of the roadway. At the actual contact the shales are much crushed, dragged out, and slickensided, and the sandstones are shattered, but there is no sign of contact alteration, which sometimes occurs at the edge of other necks. On the western side the stone-mine has penetrated a massive white sandstone, which shows no signs of bedding, so that it is not yet possible to say whether the usual downward flexure of the beds takes place here also.

Further evidence of the behaviour of the tuff is afforded by the now closed down Halbeath Colliery, in which the coals were worked close up to the south wall of the neck, until they began to dip down towards it at an angle of 24° . At the south-east corner of the hill the coals were worked for a short distance vertically beneath the surface crop of the tuff, thus showing that the wall of the neck was here not vertical but inclined inwards. The angle of inclination, however, is not large. Thus the neck has not only been pierced from side to side and found to consist of volcanic tuff, but it is known to possess approximately vertical walls around more than half its periphery.

The cause of the characteristic downward flexure of the strata surrounding necks is not perfectly clear. The deformation must often have taken place very slowly, for massive beds of sandstone, etc., are in many cases bent without being broken, though in other instances the beds are fractured and displaced. Slickensides are frequently found on the walls of necks, and the clearest exposures closely resemble sections of a fault in which the strata on the upthrow side have been dragged downwards and the weaker beds crushed and drawn out. In the case of a neck the fault must be a circular one, the whole mass of material filling the neck having subsided bodily. If the subsidence were due merely to the consolidation and consequent contraction of the infilling volcanic rock, the amount of the flexure should decrease with the depth. This is not corroborated by the examination of neck-junctions underground. Sir Archibald Geikie points out that "after copious eruptions, large cavernous spaces may conceivably be left at the roots of volcanoes, and the materials that have filled the vents, losing support underneath, will tend to gravitate downwards, and if firmly welded to their surrounding walls may drag these irregularly down with them".¹ The phenomena at the margin of the Hill of Beath neck are very much what might be expected if such a subsidence had taken place. Though the surrounding sediments are dragged downwards, the tuff shows no signs of disturbance except near the margin, where it is cracked and the fissures occupied by calcite.

The material filling the neck is a palagonite tuff quite uniform in character throughout. It is composed of greenish vesicular lapilli scattered through a dull bluish-grey matrix, in which sand-grains can be made out. The lapilli vary in size from particles only just visible to the naked eye to fragments an inch or more across. The tuff is not stratified, strictly speaking, but it exhibits in the mine a broad striping due to bands containing large lapilli alternating with others made up only of smaller ones.

¹ Loc. cit., vol. i, p. 73.

A thin slice of a specimen from the mine shows under the microscope that the lapilli are irregularly rounded masses of greenish-brown palagonite, charged with cumulites and longulites, and without action on polarized light. Pseudomorphs in calcite after olivine are enclosed in some of the lapilli. The abundant, minute vesicles, which have oval shapes and are not often cut by the margins of the lapilli, are filled by zeolites or sometimes by chlorite. In some parts, however, the brown palagonitic substance shows faint aggregate polarization under crossed nicols, whilst the walls of the vesicles and of cracks show a fibrous structure, the very short fibres being arranged perpendicular to the walls.¹ This alteration is probably a secondary devitrification, and the vesicles in these altered parts are frequently occupied by calcite. In the dark matrix chips of quartz and felspar and minute particles of palagonite may be discerned, but the structure is in most parts quite obscure.

The numerous sand-grains in the tuff consist of angular and rounded particles of quartz, with some of microcline and plagioclase. These minerals are the chief constituents of the surrounding Carboniferous sandstones, and the grains in the tuff may have been derived from them, the concave curves bounding many of the angular quartz-grains being readily explained as the trace of fresh conchoidal fractures produced during the volcanic explosions which blew out the strata. But if the grains were really derived from the disruption of the Carboniferous sandstones, the absence of blocks of sandstone and shale is remarkable, unless it may be assumed that the rocks were not thoroughly consolidated at the period of vulcanicity. We refer later to the probability that the neck belongs to the age of the Upper Limestones, and supposing the volcano to have been a subaqueous one, the sand-grains may have been derived from the same source as the other Carboniferous sediments and deposited in the neck along with the truly volcanic material.

The lenticular mass of basic rock, which crops out on the eastern side of the neck, was not met with in the mine. The rock is decomposed at the outcrop, and its junction with the tuff is not well exposed, but probably it is intrusive into the tuff. It is a very fine-grained black rock, showing to the eye small, scattered phenocrysts of idiomorphic olivine altered to serpentine. Under the microscope an abundant second generation of idiomorphic olivine phenocrysts replaced by serpentine, reddish-brown strongly pleochroic biotite hexagonal in cross-section, and two or three small phenocrysts of pale green augite lie in a groundmass, which is charged almost to opacity by dusty magnetite, and is further obscured by spots of secondary calcite. In the thinner parts of the slide, however, one can see that the groundmass consists of minute prisms of augite, apparently pale green in colour, embedded in a clear, colourless, isotropic substance, which has a very low refractive index and is probably analcime. Recognizable analcime occurs in certain clear areas to be referred to below, and from these areas it appears to be

¹ Zirkel noted a somewhat similar alteration in palagonite tuff from Nevada. *Micro. Petro. Fortieth Parallel*, 1876, p. 274.

continuous with the base of the rock. There is no felspar. The rock has some affinities with the biotite-bearing limburgite of Carboniferous age from Whitelaw Hill, East Lothian, described by Dr. F. H. Hatch,¹ but it resembles more closely certain monchiquites of the same age from East Lothian to be described by Mr. E. B. Bailey in the forthcoming memoir on that district, and probably it is best termed an augite-monchiquite. Though evidently very basic in composition, it is too decomposed for the determination of the specific gravity to have any value, and further it contains numerous small, irregular vesicles filled with zeolites or calcite. There are also small but less well-defined spots free from magnetite. They are occupied by minute prisms of pale green augite embedded in analcime or calcite. Often the augite prisms form a distinct border on the periphery of the spot, the centre of which is occupied by calcite or analcime or both these minerals, whilst the biotite scales are sometimes very abundant in a narrow rim immediately outside the augite border. Though somewhat resembling the reaction-rims of augite, which surround xenocrysts of quartz in some basic rocks, these spots cannot be explained in that manner. Neither is there any sign of the regular crystallization of the augite in spherulitic fashion from a centre, or from points on the wall of the cavity. It is difficult to discriminate between two possible explanations. The spots might be due to an attempt on the part of the analcime to form definite crystals, which have succeeded in pushing away the magnetite and biotite, but the augite has only been collected on the borders. It is possible, however, that they are early-formed steam cavities, into which still unconsolidated parts of the magma have soaked and there crystallized out. There would be nothing surprising in the early formation of steam cavities in a rock containing a considerable quantity of analcime.

The age of the neck cannot be determined with absolute certainty. It must be younger than the rocks which it pierces, viz. the lower part of the Coal-measures of the Carboniferous Limestone series, but the higher limit of its age is indefinite. There are no bedded volcanic rocks in the neighbourhood with which it can be connected, but in the Saline Hills some 6 miles away in a west-north-westerly direction, similar tuff-necks are associated with bedded tuffs lying on the position of the Upper Limestones above the coal-bearing group, and Sir Archibald Geikie has classed the Hill of Beath neck with this group of Carboniferous puy.² The petrological evidence given above is in conformity with this correlation, for the monchiquite clearly belongs to the Carboniferous and not to the Tertiary igneous magma.

Amongst the many volcanic necks, between two and three hundred in number, which pierce the Old Red Sandstone and Carboniferous formations in the south of Scotland, several have had their subterranean extension proved by mining operations. Perhaps the best known cases are those in the Ayrshire Coalfield.³ An instance in which a mine was driven from side to side of a neck, situated about 2 miles south-west of Muirkirk in Lanarkshire, is given in the "Explanation of

¹ Trans. Roy. Soc. Edin., 1892, vol. xxxvii, p. 116.

² Loc. cit.

³ Memoirs of Geol. Surv. Scotland, Explanation of Sheet 22, p. 25, and Explanation of Sheet 14, p. 22.

Sheet 23 (Scotland)", p. 39. Dr. Peach mapped a neck near East Grange, $5\frac{1}{2}$ miles west of Dunfermline, the cross-section of which was ascertained in underground workings.¹ A somewhat similar case is that of Knock Hill in the Saline Hills.² The vertical extension of necks piercing the Calciferous Sandstone series has also been proved in the shale mines in the oil-shale field west of Edinburgh. Mr. H. M. Cadell³ has described a remarkably good instance from the Broxburn oil-shale workings near Philipstoun (West Lothian). At a depth of 120 feet below the surface a mine was driven from a level in the Broxburn Oil-shale through the tuff of the neck into the oil-shale on the other side. The neck was 360 feet broad on this line of section, and the oil-shale on approaching the tuff dipped steeply towards it on each side. The walls of the neck were quite perpendicular and somewhat slickensided, like the face of a fault.

For information, and for giving us all facilities to examine the stone-mine through the neck, we are indebted to Mr. Henry Rowan, general manager of the Fife Coal Company.

III.—NEW SPECIES OF CRETACEOUS BRYOZOA.

By Professor J. W. GREGORY, D.Sc., F.R.S., F.G.S., University of Glasgow.

THE second volume of the Catalogue of Cretaceous Bryozoa in the British Museum, of which the manuscript has been completed, contains the description of various new Cretaceous species. Such a catalogue inevitably takes some months in passing through the press, during which it might happen that the species were anticipated by description elsewhere. To avoid the risk of reduplication of the names it is most convenient to publish the diagnoses. Fuller accounts of the species, with illustrations, will be given in the Catalogue.

MULTITUBIGERA, d'Orbigny, 1853.

Multitubigera sulcata,⁴ n.sp.

Diagnosis.—Zoarium massive and thick. Radial ridges of each zoecial sub-colony short, thick, and wedge-shaped. Apertures triserial to multiserial at the ends of the radii. The zoecial colonies are elliptical, and usually separated by valleys or depressed porous areas, and not by definite regular laminae.

Distribution.—Senonian—Maastrichtian: Maastricht.

DISCOFASCIGERA, d'Orbigny, 1853.

Discofascigera vinei, n.sp.

Diagnosis.—Zoarium small, with a short, pointed base, covered by epizoarium. The upper surface is flat, with small raised marginal projections. In young zoaria the apertures are sparse and widely scattered.

Distribution.—Cambridge Greensand: Cambridge.

FASCICULIPORA, d'Orbigny, 1846.

Fasciculipora spicata, n.sp.

Diagnosis.—Zoarium with a narrow stem, widening into a thick horizontal expansion, from which rise numerous short, blunt fasciculi. The zoarium seen from

¹ *Ancient Volcanoes*, vol. i, p. 426.

² Loc. cit., p. 435.

³ "On an Ash Neck in the Broxburn Shale Workings at Philipstoun": *Trans. Edinburgh Geol. Soc.*, 1899, vol. vii, p. 477.

⁴ So named on account of its furrows between the sub-colonies.