Elephas antiquus, *Rhinoceros hemitæchus*, *Rhinoceros tichorhinus*, *Hipopotamus major*, *Bos* sp., *Cervus* sp., and others, and states that Dr. Falconer and Professor (now Sir Andrew) Ramsay together discovered fragments of Cockles and other marine shells in the clay, and amongst gravel and stones, with which the cave is filled.¹ Sir Andrew Ramsay himself refers² to this discovery, and states that the Cefn caves “were below the sea during part of the Glacial Epoch, for the Boulder-clay beds reach a higher level, and with Dr. Falconer I found fragments of marine shells in the cave overlying the detritus that held the bones of elephants and other mammalia.”

No reference is made by Dr. Buckland, in the “*Reliquiæ Diluvianæ*,” to the Cefn Cave, but he quotes Pennant as to the discovery of two molar teeth and tusk of Mammoth at Halkin Mine at the mouth of the Vale of Clwyd, which was probably the Talargoch Mine, of which Dr. Buckland gives the following section:—

	Yds.	Ft.
Vegetable mould	0	2
Clay	26	0
Sand and Gravel	68	0

He states that pebbles of lead and some pebbles of copper occurred in the gravel, and that horns, teeth, and bones of Mammals occurred at from 40 to 70 yards from the surface, and also in the bottom bed resting on the subjacent rock.

Mr. Mackintosh³ found the “sand with minute fragments of sea shells, still adhering to one side, of a rising branch” of the cavern “ascended by steps.” On the 22nd of May last Mr. Bouverie Luxmoore, F.G.S., and the writer, found this bed still visible, fragments of *Tellina Balthica* being determinable.

From these observations it is obvious that the bones discovered belonged to Mammals, who lived before the filling up of the Vale of Clwyd, and the sealing of its cavern by Glacial Drift.

V.—NOTES ON THE IGNEOUS ROCKS OF THE LLEYN PROMONTORY.

By J. VINCENT ELSDEN, B.Sc. (Lond.), F.C.S.

MANY of the rocks of this district have been already described by the late Mr. E. B. Tawney, in a series of papers entitled “Woodwardian Laboratory Notes,” contributed to the *GEOLOGICAL MAGAZINE* a few years ago. The following additional remarks are to a certain extent supplemental to the above-mentioned papers, and are founded on a microscopical examination of a large series of rocks, collected some few years ago during a brief visit to the Lleyn district.

Commencing at the extreme end of the promontory, we find around Aberdaron three or four masses of intrusive rock, which are described in Mr. Tawney's paper as diabase, containing plagioclase often full of greenish microlites, augites in small quantity, of corroded outline and much altered into viridite, and a large quantity of black iron-

¹ Dr. Murchison states Dr. Falconer's visit was in August, 1859.

² Physical Geology and Geography of Great Britain, p. 462, 5th edition.

³ Q.J.G.S., 1876.

oxide, both magnetite and ilmenite.¹ His specimens were selected from Pen-y-cil, Aberdaron quarry and Tynrhedyn, S. of Llanfaelrhys, and to his description of these rocks I find nothing to add, with the exception that one of my rocks taken from Pen-y-dre, close to Aberdaron, contains a much larger quantity of augite, in well-defined crystals.

The small isolated patches, lying to the North of Aberdaron, and coloured as serpentine on the Survey map, are not described in Mr. Tawney's paper. I obtained specimens of these so-called serpentines from Hendrefor, Ty-hen and Methlan. The rock from the last-mentioned locality appears under the microscope to consist of a network of plagioclase crystals, sometimes polarising brilliantly, but generally clouded with minute enclosures and decomposition products. The feldspars are seen penetrating plates of augite, with brilliant polarisation colours. The whole rock is traversed by veins of serpentinous substance, and there are many patches of viridite. Biotite is sparingly represented and probably of secondary origin. Titaniferous iron, mostly decomposed into leucoxene, is present, and some bronze crystals of pyrite are seen by reflected light. Although there is far more serpentinous and viriditic matter than in the rocks of Aberdaron, iron separation has been less extensive.

The specimen from Ty-hen is finer-grained, and the feldspars much more decomposed. The interspaces are chiefly filled with green fibrous viridite, with aggregate polarisation. There is but little fresh augite, and a good deal of titaniferous iron generally altered into grey opaque leucoxene. Some threads of serpentinous substance also occur, and a little secondary biotite. Two specimens taken from the extreme margins of these small bosses are interesting examples of contact metamorphism. The feldspar crystals become very minute, probably owing to more rapid consolidation, and portions of the surrounding sedimentary rock appear entangled in a confused way with the igneous matter.

Macroscopically these rocks are greenish-looking and sufficiently soft and serpentinous to account for the Survey colouring. They do not differ much, however, from the diabases around Aberdaron, except in their more pronounced viriditic decomposition.

We come now to the large mass of igneous rock extending from Mynydd Penarfynydd on the south to Mellteyrn on the north. The rocks of this area are especially interesting on account of their variety. Thus the western slopes of the Penarfynydd ridge, as shown by Mr. Tawney, are of olivine diabase, which he considered to be a dyke intrusive in the hornblende diabase of which the rest of the ridge is composed. It must be mentioned also that Mr. Tawney was unsuccessful in his attempt to discover the locality from which Sedgwick procured his specimen of hornblende picrite in this vicinity. The specimens of hornblende diabase described in "Woodwardian Laboratory Notes" were taken one from Careg Llefain, and the other from near Plas Rhiw.

My first specimen, in connexion with this area, was taken from

¹ GEOLOGICAL MAGAZINE, 1880, Decade II. Vol. VII. p. 214.

the northern flank of Mynydd-y-Graig, about midway between these last-named localities. In this rock plagioclase is abundant, but rather decomposed. The extinction angle is rather large, corresponding to anorthite. Some crystals look like orthoclase twinned on the Carlsbad type, but are shown by their symmetrical extinction of about 33° to the trace of the twinning plane to be plagioclase. The augite is sometimes tolerably fresh, extinguishing perfectly, but other crystals show aggregate polarisation. It is often interpenetrated by feldspar, and the margins are developed into strongly dichroic brown hornblende. A brownish granular substance is often arranged in bands across the cleavage directions, and sometimes there are inclusions of hornblende. There is also a good deal of fibrous yellowish green viriditic substance, resulting probably from the decomposition of augite and hornblende. In one case lines of opaque granular decomposition product intersect at the characteristic prism angle of augite.

At Treheli the same general characteristics are noticed. Under the microscope the plagioclase is seen to be abundant, but rather decomposed. Where polarisation colours are still given, the extinctions are apparently not so high as in the last-mentioned specimen. The augite is also not so fresh: it occurs in irregular masses, often developed into hornblende. Some crystals have a central patch of decomposition product, giving aggregate polarisation, the margins extinguishing perfectly. In other cases the margins are decomposed and the centre fresh. Large masses of a clear pale yellow substance, with granular patches here and there, show between crossed Nicols a central dark patch, changing but little on rotation, surrounded by densely interlacing fibrous crystals, with brilliant aggregate polarisation and feebly pleochroic. These fibrous, tufted crystals occur chiefly at the junction of hornblende and augite. The hornblende is much less altered than the augite, many of the viridite patches being fringed by perfectly fresh-looking hornblende. Original magnetite seems scarce, but lines of secondary oxide of iron often mark the boundaries of augite crystals, the interior being occupied by viridite.

North of the road near Tyganol-bwlch-y-rhiw, we begin to approach the so-called Rhos Hirwaun syenite, and here the rock undergoes considerable change in character. The feldspar is here very opaque, and often encloses green microliths. The augite seems to be nearly all converted into viridite, which is interpenetrated by the feldspars. Even the apparently unaltered fragments give aggregate polarisation. Quartz is fairly abundant in crystals and irregular grains, and generally contains enclosures of apatite needles, as well as cloudy patches of fluid and gas cavities. No hornblende can be detected; but there are a few ill-defined flakes of brown mica. There is a fair quantity of magnetite, and some ilmenite, partly converted into leucoxene. This rock appears to be a quartz-diabase, but a comparison would be interesting with the diabase of Castell Carron, about two miles north of this point, in which Tawney recognized quartz of secondary origin.

Immediately around Meyllteyrn we find the whole rock consisting of a network of felspar prisms, generally rather turbid, the interspaces being filled with augite in every stage of decomposition into viridite. In one specimen not a fragment of unaltered augite remains, while in others some crystals are still very fresh, polarising brilliantly and extinguishing perfectly. One large patch of viridite has at its two extreme ends two small portions of still unaltered augite, which extinguish simultaneously, as if originally portions of one and the same crystal. Magnetite is not very abundant, and generally of secondary origin, forming imperfect skeletons of augite crystals. There is a fair quantity of ilmenite, but much decomposed into leucoxene, and pyrites is sparingly present.

It now remains, before leaving this tract of igneous rock, to mention the so-called Rhos Hirwaun syenite, which is mapped by the Survey as occurring in two isolated patches. It has been shown by Mr. Tawney that the boundaries of these patches are incorrectly mapped, for he describes specimens from Pen-y-gopa and Penllech (within the greenstone area) which should belong to the so-called syenite, while the rock of Clip-y-Cilfinhir is in reality a diabase.¹ The rock of Pen-y-gopa differs from that of Ty-mawr, described by Prof. Bonney,² in containing hornblende and but little mica, and is described as hornblendic gneiss. The specimen about to be described is taken from quite the other side of the main mass of this rock, from near Pen-y-bont, close to Llangwnadl. In the hand specimen this rock is an exceedingly tough fine-grained dark green hornblendic rock, traversed by fine veins of lighter green and speckled with small grains of quartz and felspar. Under the microscope the rock is seen to consist chiefly of dark greenish-brown hornblende, with characteristic cleavage and strongly dichroic where fresh, but the dichroism decreases rapidly with alteration, and it ultimately passes into a chloritic pseudomorph. The felspar is generally turbid, but here and there shows the characteristic twinning of plagioclase. Some orthoclase is also recognizable. The quartz is almost indistinguishable from the felspar except in polarised light, and is generally turbid with a multitude of minute cavities. A few crystals of magnetite and some pyrites are present.

On the whole this rock bears a much closer resemblance to the Pen-y-gopa specimen than to that of Ty-mawr, but there seems to be scarcely sufficient trace of foliation to entitle it to be classed as hornblendic gneiss.

Between Llanengan and Llangian are two small greenstone areas not touched in Mr. Tawney's paper. At Pen-y-gaer quite half this rock appears to consist of felspar, but much decomposed. The felspars form a network, filled up by augite, which it also penetrates deeply. The augite is brownish, with much iron separation along the cleavage cracks, and sometimes the whole crystal is rendered opaque from this cause. Scarcely any of the augite extinguishes

¹ GEOLOGICAL MAGAZINE, Vol. X. p. 68.

² Q.J.G.S. vol. xxxv. p. 306.

completely between crossed Nicols. There is a good deal of strongly dichroic hornblende, sometimes intergrown with the augite, at other times in detached crystals. It generally polarises more brilliantly and extinguishes more thoroughly than the augite. Viridite patches are abundant, and a little secondary quartz occurs. Most of the iron oxide shows the grey decomposition product of ilmenite, but some pyrites is to be noticed. The same rock near Llangian is much more decomposed, the feldspars being quite opaque and much viridite and opaque ferric matter present. Some of the viridite tracks appear to have outlines of augite crystals; one looking like an orthodiagonal section gave an angle of 135° , which nearly corresponds to the angle between ∞P and $\infty P^c \infty$ (clinopinacoid) in augite. Small quartz fissures traverse the rock.

We now pass to the large patch coloured as porphyry on the Survey Map, lying between Llanbedrog and Capel Ceidio. The southern portion of this area consists chiefly of quartz-felsite, and at Pig Street, Mr. Tawney described a volcanic ash. I find a coarse tuff on the south side of Mynydd Mynytho, and a similar kind of rock to the north of Madryn, at Y Gledrydd. My other specimens from this area do not differ essentially from those already described in Woodwardian Laboratory Notes.¹

The Boduan mass of porphyrite is described from several localities in Mr. Tawney's paper. I will only add one more description of a rock taken from the extreme south side, near the village of Boduan. The rock here is much decomposed; the ground-mass is micro-crystalline, consisting of small feldspar prisms, which from the small extinction angle is possibly oligoclase. Precise determination of the larger feldspars, which occur porphyritically, is difficult owing to decomposition, but no orthoclase can be recognized with certainty. There is some glassy base between the crystals. A few magnetite grains and a good deal of opaque ferric matter occur throughout. No trace of hornblende remains, although a few feebly dichroic chloritic pseudomorphs are to be seen. This rock differs, therefore, from that of Carn Boduan.

Approaching Nevin the character of the rock changes considerably. I give a description of the rock near Nevin, which much resembles that described by Mr. Tawney as probably coming from Moel Gwyn, and which he classes as epidiorite. The large feldspars are much decomposed, but are apparently triclinic: they are generally filled with a fine granular substance, and sometimes crowds of colourless microliths are visible with crossed Nicols. The ground-mass consists chiefly of quadrangular sections, with nearly parallel extinction, corresponding to oligoclase. Hornblende is present in detached crystals, which gradually lose their fibrous structure and dichroism and pass into chloritic pseudomorphs. A few remnants of augite are visible. Magnetite is abundantly associated with the decomposing hornblende, and there are some opaque rhombohedral crystal of ilmenite.

¹ GEOLOGICAL MAGAZINE, Vol. X. p. 70.

We now come to the so-called serpentine of Porth Dinlleyn, described by Prof. Bonney in Q.J.G.S. vol. xxxvii. p. 48, and identified as altered diabase-tuffs, decomposed diabases and basalts. His specimens were selected exclusively from the eastern side of the peninsula. I therefore proceed to the west side of the promontory. Near the "Ancient Fortress" the rock appears to be a true diabase, and shows under the microscope a network of feldspar, too clouded for determination of extinction angles. Strings of serpentinous matter and a good many viridite patches are scattered through the slide. Pale brownish augite occurs in small crystalline grains still polarising brilliantly. The opaque bodies are not abundant, and seem to consist entirely of magnetite and some pyrites. A little further south the rock is very similar to the above. About half the slide consists of prisms of feldspar, sometimes polarising brilliantly, but generally decomposed. The extinctions are at a somewhat high angle to the trace of the twinning plane. Some of the feldspars are porphyritic, with broken outlines. Augite is sparingly represented in detached grains and crystals, rather deeply coloured, and showing marked pleochroism. A good deal of greenish decomposition product occurs between the feldspar crystals, and magnetite, ilmenite and some pyrites are scattered throughout. Apatite needles and a little biotite also occur here. Some of the feldspars show a tendency to saussuritic decomposition, giving aggregate polarisation, and greenish alteration products with some epidote.

Still further south the rock becomes more serpentinous in appearance, and under the microscope more than half the slide is seen to consist of bright green serpentine, the remainder being an opaque, greyish substance, interpenetrated everywhere by serpentinous matter. Patches of calcite abound, and threads of the same mineral traverse the serpentine. Innumerable bands of dark granular matter, in more or less wavy parallel lines, occur throughout. These under higher powers transmit feeble brownish colours, and have the appearance of picotite. This is so far as I know the only instance of the occurrence of a rock approaching the character of true serpentine in Lleyn. The arrangement of the opaque bands is not such as to recall the "maschen structur" of peridotite serpentines, but possibly as my specimen was taken from the junction of the rock, we may have here the results of contact metamorphism of the surrounding schists.

The greenstone dykes of Porth-wen appear to be chiefly dolerite, Under the microscope the rock appears to be crowded with lath-shaped crystals of feldspar, no longer polarising in very bright colours. A good deal of viridite and some biotite are present. Olivine crystals are almost entirely altered, but are still recognizable. Augite also remains, but generally very opaque, from iron separation. A good deal of secondary calcite is seen, as well as magnetite and pyrites.