of cavilling at Mr. Edwards, for whom I entertain great respect, but purely to arrive at the truth.*

A discussion followed the reading of the papers in which Professor Tennant, the President, Mr. Mackie, Mr. Wetherell, and Mr. Cuming took part.

Ordinary Meeting, Monday, April 8th, 1861.

The Rev. Thomas Wiltshire, M.A., F.G.S., President, in the Chair.

The following gentlemen were elected members of the Association :—
Rev. T. Cornthwaite, M.A.; T. Dexter, Esq.

The following donations were announced :—

The “Geologist” Magazine. By the Editor.

“Abstracts of the Proceedings of the Geological Society.” By the Geological Society.

The following papers were read :—

1.—“On the Geology of the Isle of Portland.” By W. Gray, Esq.

The Isle of Portland, bare, barren, and uninteresting as it may appear to a casual observer, is not, after all, without interest, and to none does it offer more attraction than to the Geologist. He looks upon it as a silent witness of mighty changes in the world’s past history; he sees that its foundations, once deep below the action of the waves, entombed myriads of creatures that sported over its muddy surface; that next its rocks, rising through the influence of vast forces, emerged from the deep, becoming the home of mighty reptiles, and the nursery of a tangled forest; and that, finally, though in ancient days again subsiding, its soil received new deposits from rivers gently flowing over its land, and that at last it became in a subsequent period fitted for the habitation and use of man.

In position, it is situated in the county of Dorsetshire, nearly opposite

* Since writing the above I have had an opportunity, through the kindness of Mr. Jones, Mr. Bott, and other Members of the Association, of examining several specimens of the shell under consideration, together with the opercula found associated with it, one of which is unquestionably that of one of the species of *Paludina* found in the same deposit; the other, being oval and pointed, does not correspond with the aperture of the other species, and therefore it is highly probable to be the operculum of *Pitharella lickmani*; should that prove to be the fact, on further investigation, “*Pitharella*” will become a member of the family “*Paludinidæ*.”

Weymouth, and is connected with the main land by a remarkable bank of shingle, which extends for some miles, as far as Abbotsbury.

In configuration it is wedge-shaped, with the axis, or centre line of the wedge running north-east, and is composed of a series of strata, marine and freshwater, slightly inclined. The series of strata, though not everywhere exhibited together, yet when grouped as a whole afford a vertical section of about 525 feet; hard rocks of a light colour giving about 145 feet; dark brown sandy deposits about 45; and the Kimmeridge clay formation the remaining 335. The sides, which to the east and west present bold fronts to the sea, have been much affected by landslips.

At Black Nore Point, on the west side, a large mass of rock, composed of several layers *in situ*, has fallen down through a height of 40 feet, and continues compact. On the eastern side, south of Pennsylvania Castle, the beds of stone have been overturned in many places; to the north of the Castle, and between it and the prison the whole space is covered with masses of stone detached from the strata above. To the north of the prison, and along the north-east of the island, vegetation covers the irregular surface, and to the north and north-west, the atmospheric action of ages has softened down the rough surface, and formed the undulating slopes in that locality, which are crowned by the perpendicular cliff or escarpment of Portland Stone, below the crest of the hill upon which the barracks stand. At the north-west, the slope formed by the debris of the overturned rocks has taken its permanent angle of rest, and prevents any further slips above the villages of Fortune's Well and Chiseltown, both of which are built upon the subsidence of ancient landslips.

That the general aspect of the north and north-west slopes has not changed for hundreds of years, may be gathered from the fact, that remains of Roman and ancient British earthworks are still to be seen in various directions.

The slips have been promoted by the existence of fissures, which traverse the island from north-east to south-west, and extend from within a few feet of the surface down to the clay. It would seem, also, from the fact of the fissures being independent of any particular bed, that they were produced subsequent to the deposition of the most recent formation developed on the island. The direction of the fissures is so constant, that the quarrymen profess to *ascertain, very nearly, the hour of the day by the extent of shadow cast in the opening.*

In these cracks or fissures, which do not converge to any one point, and which for the most part are widest at the bottom, and gradually diminish in size as they approach the surface, have been discovered human remains, associated with the bones of the elephant, elk, wild boar, and other animals. The Portland fissures can neither be compared with the ossiferous caverns of Oreston, Kirkdale, Banwell, and other places, nor can they be properly called caves, for they are simply narrow openings, as was stated just now, not wide enough for any animal larger than an ordinary sized dog to enter. They also afford no assistance to the theory which supposes that the bones thus discovered are the remains of animals that were washed into those openings by the action of water; for the remains are not water-worn or otherwise injured, which should be the case if they had been washed in through those very narrow openings, or driven with any violence against the jagged and broken sides of the fissures. It seems, therefore, that the bones fell in from above, and this supposition is confirmed by the fact, that it is generally on projecting ledges that they are found.

Graves are frequently met with on various parts of the island, and from the discovery of vases, coins, and other articles in them, are acknowledged to be of Roman origin. These graves are generally sunk down into the calcareous slate of the Purbeck beds, and the body was deposited within a case, rudely formed of unhewn stones or slates—without the intervention of a coffin—the earth being filled in upon a covering of similar material.

It would appear that the human remains are only found in fissures *beneath the calcareous slate*, so that it is highly probable that the weight of the earth, in the above instances, caused the heretofore undisturbed layer of slate, between the graves and open fissures to give way, and launch its contents into the space below. Captain Manning, Her Majesty's Lieutenant of Portland, and resident magistrate, has in his cabinet at Portland Castle, a good collection of fissure bones, *skulls, and other human remains*, as well as the bones of the deer, boar, and other animals, found in fissures in the central quarries, and therefore *below* the calcareous slate. In a cabinet, in the office of the Commanding Royal Engineer, Vern Fort, there are also several specimens of bones, the latter having been found on the Vern Hill, where the calcareous slate is not developed. These bones *were not accompanied by human remains*. The fissure-bones of Portland are generally found in good preservation, usually separate, but often cemented together by car-

bonate of lime, the shells of land snails being rarely associated with them. In some of the fissures, passed through by the Vern Ditch excavation (described in the sequel), there were discovered numbers of shells, very delicate, yet well preserved, and similar to those described as common in the Loess of the Valley of the Rhine, viz., *Helix plebium*, *Helix nemoralis*, and *Cyclostoma elegans*. Numbers of them were detached, but they were principally cemented together with broken pieces of stone, and cherty fragments, into a concretionary mass, by a filtration of carbonate of lime crystallised, and encrusting each. The specimens obtained were 30 feet from the surface.

The several beds, as developed in this island, are shown in the annexed wood-cut, and may be enumerated as follow :—

Belonging to the Purbeck series.	{	Sand and gravel of the Raised Beach.
		Calcareous slate ; 8 to 30 feet thick.
		Clay band.
		Bacon-tier ; 1 to $1\frac{1}{2}$ ft.
		Clay band ; 8 ft.
		Aish ; 3 ft.
		Soft burr ; 1 ft. to 14 in.
		Dirt-bed ; 1 ft. to 16 in.
		Top-rising ; 2 ft.
		Cap ; 4 to 7 ft.
		Seam of black earth.
		Skull-cap ; 20 in. to 3 ft.
Portland stone.	{	Roach ; 3 ft.
		Whit-bed ; 9 feet. (The really best bed of stone.)
		Curf and waste, with chert-beds ; 6 ft.
		Roach ; $1\frac{1}{2}$ to 2 ft.
		Base-bed or lower tier, 5 ft. (Called also the “ Best-bed.”)
		Limestone and chert ; 75 ft.
		Blue clay ; 8 to 10 feet.
		Portland sand ; 45 feet.
		Kimmeridge clay, with septaria ; 335 ft. seen.

These beds, beginning with the oldest and ascending upwards, may be thus described :—

The Kimmeridge clay forms the basis of the whole Portland series, yet it

SECTION OF THE STRATA IN THE ISLE OF PORTLAND.

is not well exposed in any part of the island. The slopes to the north, north-east, and north-west would afford the best points of examination had they not been overgrown by vegetation in that locality. It is laid bare by the waves along the coast, and large quantities of iron-pyrites are washed from it, and also septaria: sometimes, but rarely, small ammonites, and occasionally the bones of the pliosaurus, the specimens being charged with the pyrites, which give them a metallic appearance.

It would appear from certain indications on the north-east slopes, that the clay is made up of hard laminated beds, interstratified with bituminous shale, which, when exposed to atmospheric influence, soon becomes disintegrated, and is converted by moisture into a stiff plastic clay. It assumes this latter character along the margin of the sea, particularly under the west cliff, where it has been forced up by a recent landslip.

One of a number of graves dug up in the Roman earthworks, that existed on the site of the present fortification, was formed of the bituminous shale of the Kimmeridge clay.

The clay towards the top, and immediately under the Portland sand, is very hard in its native bed, and is sub-divided by layers of spheroidal nodules, some of which contain crystals in the centre. They are of different sizes, from three to ten inches in diameter, very solid and hard, with an external crust of concentric coats; they are disposed so regularly, that they appear in a section of the cliff as if artificially arranged in courses. The junction of the clay with the sand is ill-defined, as the upper portion of the clay and the bottom of the sand assimilate in their general character. The thickness of the clay, as developed in Portland, is about 335 feet.

The Portland sand, next above the Kimmeridge clay, and into which it gradually merges, is made up of layers of an olive-green-coloured limestone, divided horizontally by sandy beds, the mass being shattered and broken. So unshapely are the blocks of which the layers are composed, that if it could be conveniently quarried, it would be unsuitable for building-purposes. Some of the beds are soon destroyed by exposure to the weather; but others are comparatively unaffected, and the exposed surface becomes covered with lichens, as may be seen on several of the overturned blocks on the north-west slope. The thickness of the Portland sand is about 45 feet.

Occupying an intermediate space between the Portland stone proper and

the Kimmeridge clay, the Portland sand may be considered the transition series, but notwithstanding this graduated development of the solid Portland beds, it is not easy to comprehend how it comes to pass that they overlie a formation very little altered at present from what we should suppose the Portland stone beds were when first deposited. What consolidated the Portland beds? If pressure produced the effect, why should the clay below remain unchanged? In the Portland sand, like in the overlying strata, are found fossil casts of ammonites, trigoniæ, &c.; it might have happened that the shells decomposed as they lay in the original silt or sand, and that the carbonate of lime thus supplied was taken up by water, and distributed throughout the strata, and, again crystallizing, consolidated the mass interposed between the beds of clay, the latter, by its impervious character, preventing the filtration of the water.

Above the Portland sand, and between it and the Portland stone, there is a stratum of blue clay, about eight or ten feet thick. This receives the surface drainage, after percolating through the several layers of the Portland stone, and therefore it becomes the source from which the fresh-water-supply for the island is procured. As the dip of the strata is rather to the south-west, in that direction—wherever this clay crops out, or shows itself in section on the cliffs—there will be seen small streams issuing between the clay and the overlying beds. In the caves and fissures the surface-water may be found making its way downwards to the clay, and it is this that in its passage takes up lime in the upper beds, and deposits it again in the form of stalagmites and stalactites in the fissures and the open spaces below. A beautiful example of a stalactite cavern was met with last year in a quarry belonging to Messrs. Freeman, near the Church: this cave was about thirty feet long and twelve feet wide, and hundreds of stalactitic columns, of various forms and proportions, connected the ceiling with the floor. The ceiling was rather flat, but the floor was very irregular and broken, a circumstance which added much to the beauty of the whole, for every portion of it was incrustated with a transparent coating of carbonate of lime, and the course of every dropping was well defined by this beautiful deposit. Some of the columns were grouped in clusters like organ-pipes; others, fragile and delicate, not stouter than a goose-quill, hung by hundreds from the ceiling to the floor.

The surface-water, when it reaches the clay, flows along its surface until it finds an outfall in the cliffs as it crops out on the slopes, or

"Royals," as they are locally termed, below the Vern Hill. The inhabitants in that locality are well supplied with water, a fact which gives the name of Fortune's Well to the principal village.

So bountiful is the supply, that some persons on the island believe that it does not depend upon the rainfall, but that the main spring is *beyond* the island, and that the water rises up through some open gullies; or that it is derived from the surrounding sea, and, rising by capillary attraction, is purified and freshened by the process. Such ideas are entertained under the conviction that there is more water used by the inhabitants than falls from the clouds.

Now, it so happens, that the physical conformation of the district above noticed, is most favourable for retaining the rainfall, and directing it to one point, *i.e.* Fortune's Well. Taking the surface thus drained to embrace the space bounded on the west by a line drawn from the Church below the Hill, to the Rectory, on the north and south, by two parallel lines drawn respectively from the above points to the eastern cliff, which latter forms the eastern boundary, we have an area of at least 120 acres; then, taking the rain-fall at two feet for the year (the actual rain-fall for the last five years being—

For 1856	-	-	-	28·690 in.
1857	-	-	-	23·480
1858	-	-	-	19·955
1859	-	-	-	25·560
1860	-	-	-	30·770
	.			
Total	-	-	-	128·455

or an average of 25·69 inches), if we take 24 inches as the depth of rain-fall, and 120 acres as the area drained, we obtain about 65,251,800 gallons per annum, or 178,700 per day. Then, considering the population of the villages supplied from this source at 2,000 (which is nearly correct), and allowing 20 gallons per day for each individual, there will be left for evaporation, absorption, and overflow 138,700 gallons per day, or a constant flow of 5,780 per hour throughout the year, which is certainly not less than the actual waste.

The other villages on the island are very badly supplied with water, for being situated *above* the hill, well-shafts must be sunk through the entire

Portland series of beds, an operation found so expensive, that there are only a few wells sunk for the accommodation of several villages.

Leaving this stratum of clay (the blue clay), we next, in an ascending order, meet with a series of solid beds of stone interstratified by layers of chert, making up a total thickness of 75 feet; the thickness of the several layers varies considerably, yet the general characteristics of each are very similar; they are all fossiliferous, they are all broken and shattered, and there is not a bed in the series of any marketable value.

It is through this series that the Vern Ditch (in connection with Portland defences) is cut, where a most favourable opportunity is afforded for its examination and study. This cutting, when finished, will, in the aggregate, make up a length of 1,100 yards, by in width 100 feet, and in depth from 30 to 75 feet. From this, the enormous quantity of 1,073,000 tons must be removed. The excavated material is used in constructing the Breakwater now in progress, under the Admiralty, in Portland Roads.

The first thing that strikes the visitor in this excavation is the extraordinary regularity of the strata; a narrow bed of stone between layers of chert can be traced for a long distance, and many of the beds as developed here can be recognized again on the cliffs on the eastern and western sides of the island; some beds are subdivided and again united within a short distance, one bed in particular, showing a thickness of 14 feet at the eastern entrance to the ditch, is subdivided within a short distance on that face into several beds.

The general thickness of the beds of stone is from two to five feet, and the cherty beds vary from six inches to three feet. Sometimes the chert runs from one layer into another, and very often the rents in the bed of stone between two layers of chert are filled up with chert also, so that it looks on some sections like vertical, or *almost* vertical, markings made with a tar-brush. The horizontal beds of chert, where a fresh section is opened, appear almost black, and contrast strongly with the light colour of the intermediate beds of stone. This difference of colour is soon mellowed down by the growth of lichens and other vegetation. Some of the cherty layers are made up of shells, and in the upper beds of this series cherty nodules are not uncommon, which, when broken, show a shell in the centre. These nodules vary from the size of an egg to the size of a heavy cannon-shot. In the lowest beds the chert is in irregular patches, as if collected

round a branched nucleus, and a section shows a number of parallel lines from the centre to the surface of the mass, disposed in concentric rings.

The beds, so remarkably regular, and almost horizontal in the cross section, suddenly dip at a considerable angle (30 degrees) on the east and west faces. This seems to have been caused by slips parting in the direction of fissures, and becoming thus tilted over in the direction of the slopes already described. The ditch in one direction, on the west face, is cut through a slip of this kind; and on the east face the tilted nature of the strata causes a difficulty in forming the contemplated perpendicular escarpment. This phenomenon, manifested also in other portions of the island, was evidently caused by the wearing away of the underlying clay and sand, the destructive effect of which was promoted by the existence of the fissures.

These beds, though highly fossiliferous, do not easily afford perfect specimens in the quarries, the shells being incorporated with the stone; but where the stone is exposed for many years to atmospheric action (as on the faces of the cliffs), shells, being less acted upon by the weather than is the mass in which they are enclosed, then stand out in bold relief. Crystallized casts of shells abound in some of the lower beds. The principal fossils of the series are as follow :—

Ammonites giganteus.

„ *biplex.*

Cardium dissimile.

Trigonia gibbosa.

„ *incurva.*

Ostrea expansa.

Pleurotomaria rugata.

Vertebrae and other bones of the *Plesiosaurus* (?)

Isastræa oblonga.

Serpulæ.

The fossils are not confined to the calcareous beds, for they are also plentifully distributed through the cherty layers; even the great ammonites are sometimes enclosed in the chert.

The ammonites are found in every bed, and in some, in great numbers. In one of the Admiralty quarries, on the east side, between the Prison and the Vern Fort, a bed of this series is stripped for a considerable space, and the ammonites (the “ congers ” of the quarrymen,) are scattered about in all

directions. They lie flat on the bed, half imbedded in the stone, and half above its surface. In the lowest beds of this series, numbers of vertebræ have been found, sometimes as many as 12 in natural order ; but, whenever a discovery of this kind is made, the men of the discoverer's gang all scramble for "speses" of the bone, so that what an *individual* may secure is of very little value. Saurian teeth, and the dorsal fin of a shark, have been also found in these beds.

Upon a close examination of the beds as developed in the Vern Ditch, the observer will discover tracings of what appear to be ancient river-courses. An example of this may be seen at the bottom of the Ditch, near its eastern end. A space of about three feet by two has been carved out of the stone for a considerable length, and is now filled in with sand and clay. This is first seen on the face of the eastern cliff. It appears again on the counterscarp of the ditch, and continues at the other side, running under the Fort. The clay and sand now filling up the courses are deposited in alternate layers, and represent, in miniature, the original state of the whole Portland series; it is, in fact, a register of the differences in quantity and velocity of the water that once flowed through those courses, changes wrought by the variations of the weather in the locality from whence the current had its rise. The pebbles contained in the deposit are angular, yet worn by attrition, and they are all covered by a black substance which, when rubbed between the hand, gives them a polish, as if with black lead.

In excavating for the foundation of the casemates on the south-west flank, a large quantity of clay was met with, through which was interspersed fragments of bone, pieces of fossil wood from the "Dirt-bed," flints, and broken pieces of stone, all blackened on the outside, similar to the pebbles of the water-courses described above, and they appeared besides to have been subjected to the action of fire. Some of the pieces of stone had an incrustation of an enamel-like substance on the outside, about the thickness of cardboard, but all the inside was soft as chalk ; sometimes the centre retained the colour and hardness of flint. The pieces of tree were also blackened on the outside, and when broken, they presented a calcined appearance. But the most singular circumstance connected with this local deposit, was the quantity of broken stone that it contained, belonging to the fresh-water strata of the Middle Purbeck series, a bed not developed in any part of the island. The fragments

distributed through the above clay deposit contained species of *cypris*, *paludina*, *cyrena*, *planorbis*, and *cyclas*, with seeds of *chara*. This will seem the more remarkable when we remember that the clay in which the above specimens are found is deposited in the cherty beds above described, which are the *lowest* of the Portland series; but in the locality now under consideration they crop out at the surface.

Leaving the cherty beds, we next come upon the "lower tier" of the Portland stone proper, or "Base-bed," commonly called the "Best-bed." It is the oldest bed reached by the quarrying operations of the island for trade purposes.

On the Vern Hill—which is a comparatively level space of about 50 acres, at the northern end of the island, bounded by the slopes described in the beginning of this paper—the Base-bed has been quarried to a limited extent; but, as might be expected from its geological position, the quantity was scanty and of inferior quality; for in Portland the beds, whether they merely crop out by running with a quicker dip than the fall of the surface, or run parallel with the surface, in either case, are very much broken and shattered for about eight or twelve feet from the surface. The Base-bed, in this shattered condition, extends over the greater part of the Vern Hill. It runs out to the south as it approaches the Ditch, and from about 200 feet at the other side of the Ditch, where it again crops out, it continues all over the island.

The local term "Best-bed," as applied to the stratum now under consideration, has caused no little confusion and disappointment; for, though it possesses the finest texture and the most uniform colour of any bed on the island, it is not really the best for many of the purposes to which it is at present applied; it is liable to rapid decay when exposed to the weather; but, being soft, it is easily and economically sawn into any size, and therefore meets with demand in the market. There can be no objection to its use for *inside* work, where it answers admirably, and the wonder is, that it is not oftener so employed; but, for *outside work* it is ruinous. The misapplication of the term "Best-bed," and the injudicious employment of it for works exposed to atmospheric influences, had created a considerable prejudice against it, and many thousand tons that should have been quarried in Portland are left behind, and covered up in the *débris* quarried from the other beds. The term "Best-bed" may be a corruption of the term Base-bed, the latter being most correct when applied

to what is commonly called the Best-bed, for it is the *base*, or lowest bed quarried in the Isle of Portland. It is very uniform in its texture and colour, free from fossils, and may be had in any reasonable sized blocks, not more than five feet in one direction, this being the average thickness of the bed.

Overlying the Base-bed, and closely associated with it, there is a bed of "roach," from eighteen inches to two feet thick; this bed abounds in fossils, casts of *Trigonia incurva*, *Trigonia gibbosa*, &c., &c.; and, the calcareous matter of which they are composed being of a firm texture, the casts are generally clearer and sharper than the same kind of fossils in the upper and coarser beds.

Between the roach of the base-bed, and the Whit-bed, or really *Best* bed, there intervenes a bed, or beds, called by the quarrymen "curf," and "waste;" this is divided from the underlying, as well as from the overlying beds, by layers of chert, and is often subdivided by similar layers; the quality of the stone, too, varies considerably, and is *never* fit for *particular* work. In some of the quarries, as on the eastern side, the curf is very much like the Base-bed, and contains very little flint or chert; towards the centre of the island it is more like the roach of the Base-bed, and contains similar fossils, but in the western quarries the curf is worthless, and is all thrown aside with the waste; its general thickness is about six feet, it is sometimes much more, and often considerably less; indeed, it is absent in one or two places, or only represented by a layer of oyster shells. The curf contains similar fossils to the roach of the Base-bed, but in less quantity.

Next above the curf is the Whit-bed, or the true Best-bed of Portland stone. The local term Whit-bed is a misnomer, and like the term Best-bed, as applied to the lowest bed, leads to confusion; for Whit-bed, in contradistinction to Best-bed, implies that the former is whiter and second in quality to the latter, whereas, in reality, the Whit-bed is the *darkest* and *best*, and (what is called) the Best-bed is the *lightest* and *worst*.

Architects should carefully note those distinctions. The texture of the Base-bed differs from that of the Whit-bed, in that the former is comparatively free from fossils, whereas the latter contains a great quantity of comminuted shells, the fragments being just small enough to impart a light brown tint to the stone, without giving it a speckled appearance.

The durability of this stone, as compared with the Base-bed, may be occasioned by the quantity of crystallized carbonate of lime by which it is impregnated, derived from the contained shells. The centre of the Whit-bed proves the best for exposure to weather, inasmuch as the top, and more particularly the bottom, of the bed is much softer. A knowledge of this fact is necessary to the proper disposal of this stone in architectural works, and to counteract the injurious effect of the workmen's practice in dressing the top or bottom of the bed for the fine or exposed surface. The Whit-bed is generally about nine feet high, and is necessarily split up into smaller blocks before it leaves the quarry. When a block, the full height of the bed, is parted in the centre, two stones are produced, each of which has a hard and soft face, the hardest being that part nearest the parting joint, and the softer, the parts next the top and bottom of the bed respectively.

When a mason is given one of these stones to work, he selects the softest part for the face, taking the least amount of labour to produce the more particular surface required; the result must therefore be to the disadvantage of the stone. Whereas, had the centre portion of the original block been selected for the face-work, the result would be more durability, as well as uniformity of colour. The foregoing observations apply more particularly when the stone is laid *square* with the direction of its bed, and not "*on its natural or quarry bed*," as is generally specified, and, indeed, most necessarily so, when the stone is of a laminated or fissile structure; but with Portland stone, for the reasons stated, it is questionable whether any advantage would be derived from insisting on laying the blocks on the quarry-bed; it would require constant, untiring supervision to secure the fulfilment of such a condition, and very few, except the practical workman, can detect in some blocks of Portland stone which way the bed runs, unless by the difference in quality between the centre of the layer and its top and bottom; and when this difference is apparent, it would be, indeed, unwise to enforce the above rule, viz., "*that every stone should be laid on its natural or quarry-bed.*"

The quality of the Whit-bed—*like all the other beds in Portland*—varies considerably; for example, in one part of the Admiralty quarries it is exceedingly rough and frothy, containing numerous shells and white spots of a calcareous substance; the latter crystallized in concentric rings; whereas, *in the same quarry, nay, even at the other side of a joint or*

parting, the stone assumes its usual fine and uniform texture. It would be useless attempting to account for this phenomenon, but such is the fact.

Generally speaking, the beds produce the best quality of stone northwards. At the north-west, both Whit-bed, and Base-bed, are of excellent quality; farther south, the Whit-bed reaches its highest degree of perfection, but the Base-bed fails in quality; at the south-west both are inferior. On the east side of the island the Base-bed is very good, and the Whit-bed is coarse and shelly; both beds are again deteriorated in quality southwards. The same difference in quality may be noticed in the curf and roach. The former may sometimes be found *almost* equal to the latter, but, as a rule, the distinction between curf and roach should always be observed, and the former *never* put where roach is intended, particularly in exposed situations, as sea-walls, or docks. What has been said relative to the curf equally applies to the roach of the Base-bed, already noticed.

Overlying and closely associated with the Whit-bed is the celebrated Roach a local term applied to a layer of about three feet thick, made up almost entirely by casts of various shells, such as a *Cerithium Portlandicum*, *Trigonia incurva*, *Trigonia gibbosa*, *Neritoma sinuosa*, *Pleurotomaria rugata*, *Lucina Portlandica*, &c. This is the only bed in which "the screw," or *Cerithium Portlandicum*, is found, and here it is in the greatest abundance; not a fragment of Roach can be picked up without some portion of this shell; so thickly are those casts crowded together, that they frequently run one into the other; it is not uncommon to get a *Cerithium* in the cast of a *Trigonia*, or the cast of a small *Cerithium* in another. All the fossils of the roach, except the *Ostrea expansa*, are merely casts, not a vestige of the original shell is left, nor is the space it once occupied filled up by any calcareous matter; a clear space is left round the cast; it is this circumstance that gives the stone its spongy or aerated appearance

For durability the Roach cannot be surpassed, yet, notwithstanding this latter quality, it has not heretofore met with much favour in the market; hence thousands of tons quarried and squared up, have for many years been left lying about in all directions in the quarry-heaps, and hundreds of tons more have been covered up in the quarry *débris* or "tipped" over the western cliffs; latterly, however, it has received more attention, and it is now beginning to be extensively employed on large works of all kinds

where its roughness is not an objection ; for docks, sea-walls, heavy abutments, or bridges, it answers admirably.

In selecting even this bed for building-purposes, care must be taken that no portion of the Curf-bed, or even the Roach of the Base-bed is substituted ; for, unlike the Roach proper, neither of the latter will stand the weather, nor are they by any means as strong as the best Roach. Though very much alike in appearance, the good Roach is easily distinguished from the others by its darker colour ; it is more siliceous ; and the cast of the *Cerithium Portlandicum* is *peculiar* to it.

The Roach-bed is, on an average, about three feet thick, and blocks of almost any lateral dimensions can be procured from the quarries ; blocks are sometimes raised containing so many as twenty tons. The bed is made up of three layers ; the lowest is rather compact and close-grained, resembling the underlying Whit-bed. In the west quarries this lowest division of the Roach contains the peculiar white, cylindrical crystallizations noticed in the rough Whit-bed of the Admiralty quarries. The centre division is that which gives the Roach its peculiarity, being made up (as described above) of numberless casts of shells ; the upper and smallest division of the Roach is rather laminated, and resembles in a faint degree the calcareous state of the overlying beds ; these three divisions are not easily divided, they are all closely combined in one mass. It is remarkable that the Roach-stone will not cleave readily in the direction of a plane parallel with the bed, or line of deposition. The quarrymen invariably cleave it in a direction square with the bed, and the fracture thus produced is uniform and regular, whereas, if the stone were split *with* the bed, the fracture would be irregular and wasteful.

The Roach is the most recent formation of the Portland series ; immediately above it comes the first bed of the Purbeck ; but between those beds, and more particularly attached to the Roach, there are irregular patches of flints, full of shells ; in the upper surface of the flints the shells are especially well preserved. The variety of shells here discovered is very great, from the large oyster and pecten to the smallest cyrena, but it is difficult to detach perfect specimens, owing to the refractory character of the flint ; polished specimens, and pebbles from the beach composed of it, give very good sections of the shells which it contains.

The next bed above the Roach is the "Skull-cap," so called from its position with regard to the Roach : though thus closely associated, they are

essentially different, the Roach being of marine origin and belonging to the Portland series, and the cap of freshwater origin and belonging to the Purbeck series. The skull-cap, which is one division of the overlying cap, is, like the latter, most irregular, and as to shape and texture, has no constant thickness ; for example, the skull-cap, in one part of a quarry may be only twenty inches, and within a short space it may swell out to a thickness of three feet or more ; the overlying cap, taken together with the skull-cap makes up a deposit having a total thickness of from nine to twelve feet ; the irregularities of the upper surface of the skull-cap corresponding with the uneven bed of the cap, the ridges of the one fitting into the hollows of the other : but they are divided by a layer of black earth, resembling the Dirt-bed, and which occasionally, like the latter, contains cycadeæ. In the cap there are circular perforations of about four inches in diameter ; they resemble very much the holes drilled for blasting, were it not that the stone for about ten inches all round the hole, differs materially in its texture from the main block, being vesicular and porous, and seems as if some crystallization had taken place around some substance once occupying the now vacant space ; this appearance is the more remarkable in the cap, otherwise compact and close-grained, not even presenting the oolitic structure. The upper portion of the cap is more laminated than the lower, and about two feet of it is easily separated from the top ; this thickness is called the "top-rising."

We now come upon the most peculiar of all the beds in the island of Portland, that of the "Great Dirt-bed." This is a layer of black mould from twelve to sixteen inches thick, containing silicified stumps of trees and remains of cycadeæ, with rounded stones about the size of an egg. If it is difficult to account for the *solidity* of the Portland beds superimposed upon *clay*, it is a matter of no less surprise and difficulty that the fossil remains of plants should be converted into a hard siliceous stone, while the soil upon which they grew preserves its character unaltered. Of the abundance of vegetable life once flourishing upon what is now the Isle of Portland, we may have ocular demonstration wherever the Dirt-bed is exposed, either on the flat surface, or in section on the cliffs or quarry-face ; there we see the prostrate giants of the forest, as if felled by the swoop of some terrible tornado.

The stumps, for from two to four feet high, continue erect as they grew, but they lean in the direction of the fallen trunk ; their average size is

about twelve inches in diameter, some few are over two feet in diameter some of the prostrate trunks are from twenty to thirty feet long, but never in one continuous length, being always broken into short pieces about twenty inches long ; a length of three or four feet *in one piece* is rarely obtained, and, this being the case, it is difficult to identify the branches, the dividing stems being broken off short at the fork, nor can the roots be distinguished from the tree itself, as they extend in the same horizontal direction. If the mould be carefully removed from about the upright trunks, the roots will be seen running in all directions, but broken into short pieces similar to the main trunk ; there is no leading root running down far into the soil, for roots and branches are contained in this twelve-inch layer of black earth, and neither penetrates the underlying bed, so that if the original tree had no better hold in the soil than what the lateral roots could give, it is no wonder that they were blown or washed down easily ; but this was not the case, for the portions still retaining their upright position show that the force required to break them short off, within a foot or two of the ground (or roots), must have been very great indeed, while the shattered fracture of the broken tree proves that the timber did not yield without considerable resistance.

In examining the Dirt-bed there is no difficulty in identifying the fossil wood ; it looks exactly like ordinary weather-worn timber, stripped of the bark, particularly those coarse-grained sorts, as elm and oak. The bark is not preserved in a petrified state, but is sometimes found like lignite, attached to the outer surface of the siliceous fossil, not even compact enough for removal.

The cycadeæ found are of two species—*Cycadites megalophyllus* and *Cycadites microphyllus*. The trunks are found tolerably perfect, and vary in size ; sometimes they are twelve or fourteen inches high, and the same in diameter, but more generally they are about ten inches in diameter, and from four to six inches thick ; in the latter case they are called “ Birds’ nests ” by the quarrymen. Besides the fossil wood and cycadeæ there are no other organic remains found in the Dirt-bed.

Immediately above it there is a bed about twelve or fourteen inches thick, called the “ soft burr.” It is used in the island for building dwelling-houses, which its soft porous nature causes to be exceedingly damp. The upright stumps of trees from the Dirt-bed penetrate the burr, so that when the latter is cleared for any considerable space, the trees appear

above its surface, as from the surface of the natural soil, and the burr is formed into a ring or conical heap round the tree, resembling the mound sometimes formed for protection at the base of tender trees in parks and plantations.* Associated with the burr is the "aish," which is more fissile than the burr, and about three feet thick. Above the aish there is a band of clay, about eight feet thick; then the "bacon-tier," a foot or eighteen inches thick; above this, another clay band; and then comes the calcareous slate, the uppermost layer of the island. Up to this deposit all the beds or seams from the Dirt-bed are very much contorted, owing in a great measure to the erect trunks of the fossil forests. In some places, too, the calcareous slate is disturbed, and very often yields in the direction of fissures below it, showing, on section, as if the slate was forced into those openings by rushing waters. Towards the north of the island the calcareous slate is about eight or ten feet thick, and is very much broken up; but, at the southern part, it is increased to twenty or thirty feet, made up of several solid though fissile beds, interstratified by clay bands of from an inch to twelve inches thick.

There are no fossils found in the beds between the Dirt-bed and the calcareous slate; nor will the quarrymen admit that any can be had from the slate; nevertheless, there are numerous scales and minute bones of fishes, as well as palatal teeth, &c.

From one of the western quarries I have secured two very perfect specimens of fish—one *Lepidotus minor*, the other, of the genus *Microdon*(?). Captain Manning, of Portland Castle, has some good specimens of fish from the calcareous slate in Portland.

Having passed through the several beds, as they are developed in Portland, it is only necessary to notice the ancient raised sea-beach of the "Bill," to complete our survey of the geology of the isle.

To the south of the island, on the west side, and close to the Bill (or the most southern point of the island), there is an extensive deposit of gravel and sand resting on the cap, being the accumulation of an ancient sea-beach. It is now raised about twenty-five feet above the water, and is deposited in alternate layers of coarse and fine gravel and sand. Here and there rents or fissures occur, which are filled up with

* Some fine large specimens of the "burr" of the silicified trees, and of the "roach," are preserved in the gardens of the Royal Botanic Society, Regent's Park.—EDIT.

clay, a circumstance worthy of observation ; for, if it can be discovered that those rents are but continuations of the fissures in the underlying stone, it will go a great way to prove that the latter were produced subsequent to the deposit and elevation of the beach. Some of the gravel has been consolidated into a concretionary mass, by the infiltration of a calcareous matter, so as to form a conglomerate, or pudding-stone.

It is from this that the sand used for building-purposes on the island is obtained, thousands of tons being used on the extensive works in progress on the Vern Hill. There are no remains of shells, or other organic body, found in those sand and gravel-pits, but on the east side, and north of both lighthouses, to the edge of the cliff, there is another deposit of a finer description, which is full of shells and roots of plants ; one layer, of about seven inches thick, is composed entirely of shells in a perfect condition, and where they are exposed in section they are conglomerated together like the pebbles of the pudding-stone. Thousands of those shells can be gathered in a few minutes. The deposit is about forty feet above the level of the sea.

From the above remarks it will be seen that a visit to the Isle of Portland will well repay the inquiring geologist, who will find a full week's enjoyment rambling over its cliffs, numerous quarries, and rocky sea-board, and who cannot fail securing, by the exercise of his eyes, hands, and hammer, very many specimens. The immediate neighbourhood, also, is no less interesting and instructive, and possesses an excellent guide in Mr. Damon's two small and inexpensive volumes.*

2.—“ On Some Anomalous Fossils from the Upper Greensand of Cambridge.” By Harry Seeley, Esq.

ABSTRACT.

The bodies in question consist of carbonate of lime, with a very slight animal basis. The larger and more common type is in form an elongated sphere, with a single longitudinal wedge-shaped slit, the margins of which are tuberculated ; it is granulated, but has one end smooth and flattened. These characters indicate the structures to be Echinodermatous.

* “ Handbook of the Geology of Weymouth and the Isle of Portland,” and “ Supplement,” by R. Damon. (London : Stanford. 1860.) In these works, the chief fossils of Portland, and the neighbouring districts, are carefully figured, and a great deal of detailed information about the strata is given ; and also a list of the many geological books, papers, and maps, relating to the locality.—*EDIT.*

The specimens might possibly be, therefore, portions of sea-urchins, urchin-spines, joints of the arms of a crinoid, ocular plates of a star-fish, or parasites on Echinoderms. Against all these suppositions, however, there are fatal objections; so that exhausting them one by one, it may be demonstrated that the fossils are not related to *Pedicellariæ*, and that they form no part of any member of the known orders of *Echinodermata*; it therefore follows that they are echinoderms of a new type. On anatomical grounds it is seen that each specimen was not an entire creature. All arguments from anatomy and analogy are opposed to the possibility of a bilateral animal formed of two of the fossils united; whilst there is every reason for believing that several of them (5) must have been grouped round a centre. It may be shown that this was not of a creature of the crinoid kind, and therefore it must have been of one that was free, *i.e.* of a form of starfish. There are several plausible reasons to account for the disc not having been found.

It is believed that ambulatory suckers were protruded through a membrane covering the groove already alluded to. The relative smallness of the groove to the side of the disc is regarded as indicating a concentration of the viscera, as in Brittle-stars.

There are good reasons for excluding them from both the *Ophiuroidea* and *Asteroidea*; while the concentration of viscera will show their near relation to the former order, and the development of feet throughout the length of the groove their close connection with the latter. They would appear to constitute a sub-order of equal value with these two, the whole forming one great order of corresponding importance with the sea-urchins.

A discussion followed the reading of the paper, in which Professor Tennant, Mr. Smith, Mr. Busby, Mr. Bott, and other members took part.