CHAPTER X.
**THE CHALK CLIFFS OF KENT AND SUSSEX,
 AND THE TERTIARY BEDS OF
 HERNE BAY.**

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THE Weald of Kent, Surrey, and Sussex is encircled by an imposing range of chalk hills known as the North and South Downs. This great rampart is the escarpment of the Chalk formation, and it doubtless formerly extended across the area now occupied by the English Channel and joined the extreme eastern fragment which still exists to the north and south of Boulogne. The cliffs produced by the breaching of this rampart afford the geologist a convenient means of examining two complete sections of the Chalk formation as developed in the south-east of England. The Geologists' Association has made many excursions to these places, and references to all of them can be found scattered through the volumes of its *PROCEEDINGS*. Not only is this so, but the district about to be described forms the subject of the first of the splendid series of papers by Dr. A. W. Rowe on "The Zones of the White Chalk of the English Coast" which have appeared at intervals in the *PROCEEDINGS* during the last ten years. This account is so complete in every detail, so graphic in its language, and so lucid in its descriptions, that there would have been no necessity for a special chapter on this region in this volume were it not for the fact that the paper in question is out of print. The present account, therefore, is largely based on that paper, supplemented by my own observation and collecting.

As a convenient introduction, a short account will be given of the Tertiary coast-section in East Kent, which, together with the Chalk of Thanet, will be described in descending order, but the two main Chalk sections, which dip away on opposite sides from the antichinal axis of the Weald, will both be described in ascending order so that the differences and resemblances may be the more easily contrasted.

HERNE BAY AND THE ISLE OF THANET.

Between the chalk of the North Downs and the Thames the Tertiary beds occupy a strip of undulating and mostly low-lying ground, the lower parts of which are overspread by the wide

sheets of alluvium of the Medway, the Swale, and the Stour. The main road from Chatham to Sandwich roughly marks the junction of the two formations, and as far as Canterbury this is the line of the ancient Watling Street. The well-known coast section between Herne Bay and Reculvers has often been described, and several times visited by the Association. Owing to the gentle westerly dip the beds can be successively examined with great ease.*

At the end of the parade at Herne Bay the ground rises into cliffs composed of *London Clay*. Slipping is continually taking place, and great hollows of broken ground are formed. The clay contains many septarian nodules of varying sizes and much pyritized wood, quantities of which have been washed out of the cliffs and are mingled with the shingle on the beach. Many of the septaria show fucoid markings on the exterior. Occasionally the slipped masses of the clay show large patches with a well-marked slickensided surface, which, on drying, contracts with the well-known "starch structure" fractures, both features frequently being seen on the same slab.

The London Clay is succeeded by the *Oldhaven Beds*, so named by Mr. Whitaker, in 1866, after Oldhaven Gap (also called Bishopstone Ravine), the small chine which breaches the cliffs a little to the east of this point. They consist of compact fine drab-coloured sand, with frequent pockets and impersistent layers of fragile marine shells, mostly in fragments. In the cliff the junction with the London Clay is even and sharply defined, and can be easily followed by the contrast in colour of the beds, but where it rises from the beach the relationship is obscured by the slipping of the clay above. The junction with the Woolwich and Reading Beds, which underlie the Oldhaven Beds, is equally well defined by a remarkable bed of flint pebbles. This varies from 3 inches to 1 foot in thickness, and can be traced for a considerable distance as it gradually rises from the bottom to the top of the cliff. The pebbles composing it are well-rounded, and range up to 6 inches in length, and are remarkably black in colour, without any vestige of cortex. The latter feature is confirmative of Mr. Whitaker's suggestion† that this bed was accumulated at some distance from land, and therefore entirely submarine, as the pebbles in an ordinary tide-mark shingle beach usually show signs of atmospheric bleaching. Sharks' teeth are not uncommon in this pebble bed.

The *Woolwich and Reading Beds* also consist of compact sand, rather darker and greener in colour than the overlying beds, and contain numerous marine shells. They form the

* For reports of Excursions, see *Proc. Geol. Assoc.*, vol. i, p. 339; vol. iv, p. 254; vol. ix, p. 168; vol. xix, p. 149. See also *ante* chapter ix, p. 241.

† "Geology of the London Basin." *Mem. Geol. Surv.*, vol. iv, 1872, p. 240.

principal part of the cliff at Oldhaven Gap. The banks of this ravine differ greatly in character, the western being almost perpendicular, while the eastern is an uneven slope of slipped London Clay. The westerly dip, although slight, is probably the cause of this.

The *Thanet Sand* first appears in the cliff at this point, and forms the foreshore in front of the Gap; but the junction is not well defined, and Mr. Whitaker has remarked that "the passage between the two series in this part was caused by the incoming of higher beds in the Thanet series in East Kent, whereas near London the Woolwich Beds rested on a lower division of the Thanet Beds. He had always held that no one beginning to work at the Lower London Tertiaries in the far east of Kent would dream of dividing the Woolwich and the Thanet Beds; but, nevertheless, that division was clear enough in other parts."* The top part of the Thanet Sand contains a stony layer, consisting of large tabular masses about 8 inches thick, many of which show fucoid markings and occasionally casts of marine shells. The higher part of the shore between the Gap and Reculvers is thickly strewn with these slabs, which have been weathered out of the cliffs. The lower beds consist of dark green, muddy sands, containing enormous numbers of marine fossils. *Cyprina morrisii* is particularly abundant, and shows up like a vivid mosaic on the shore at low water. Unfortunately the shells are very fragile, and break almost at a touch. It is rather strange that they are not more damaged by the sea washing over them at every tide.

It is well known that there has been considerable erosion along this coast, and Reculvers has been cited as a measure of the amount, it being now at the edge of the cliff which is here protected with masonry, while in Henry VIII.'s time it is said to have been about half-a-mile inland.

The succeeding space of about three miles is occupied by the marshes of the filled-up channel of the Wantsum, the estuary which formerly bounded the Isle of Thanet on the west, and was navigable down to comparatively recent times. The northern branch of the Stour, with its ditch-like ramifications, is its present-day representative.

The *Chalk* of the Isle of Thanet is first encountered at the targets, but is very rubbly and much broken up. About a mile farther on, at Gore End, near Birchington, the headland called "The Minnies" exhibits the best examples to be found near London of the power of the sea in excavating caves and isolated stacks. All along this coast the chalk has strong vertical joints running north-west to south-east, and it is along these joints that the various caves have been eaten out.

For the next seven miles, past Westgate, Margate, and

* *Proc. Geol. Assoc.*, vol. ix, p. 170.

nearly to Kingsgate, the cliffs are formed of chalk of the *Marsupites*-zone, and afford the finest section of this zone in Britain. The chalk is white, very soft, and almost flintless. Fossils are abundant, generally well preserved, and easily cleaned; but before being placed in the cabinet they should be soaked in fresh water, changed daily for two or three weeks, in order to get rid of the salt. This applies to all chalk specimens from sea cliffs. About half-way up the cliffs is an ill-defined line of scattered nodular flints, called by Dr. Rowe the "Bedwell line," after Mr. F. A. Bedwell, its original discoverer. This is an important feature, as it roughly marks the junction of the *Marsupites* and *Uintacrinus*-bands. Below it, the detached ossicles of *Uintacrinus* are found scattered plentifully in the chalk, while above it *Marsupites* is equally common, with a mingling of the two forms at the junction. A very large

FIG. 43.—*Uintacrinus* from Margate; several plates in the natural position; natural size. C, centrale; B, basals; R, radials; I Br₁, first primibrach; I Ax, primaxil = second primibrach; II Br₁, first secundibrach; iBr, interbranchials. The detached plate is a radial, from Westgate, viewed on the inner surface. Coll. A. W. Rowe. Gilbert C. Chubb, del.; F. A. Bather, dir.

ammonite, *A. leptophyllus*, is also characteristic of the *Uintacrinus*-band, but it is not so readily found as might be expected. The great majority of the specimens occur within 25 ft. of the "Bedwell line."

The cliff section (Fig. 44) runs practically along the strike, and it follows therefore that the accessible part of the cliffs is in the *Uintacrinus*-band. Foreness Point, however (two miles east of Margate), projects some $\frac{1}{4}$ mile from the general line of section, and this affords space for the northerly dip of the beds (possibly aided by a slight transverse syncline) to bring down the *Marsupites*-band to sea-level. Here the name-fossil can be found in abundance.

On nearing Kingsgate, we turn the north-east corner of the Island and the cliff section gradually changes from strike to dip, and we therefore come successively on lower and lower beds until at White Ness we find the "Barrois sponge-bed" rising from the shore. This marks the base of the *Marsupites*-zone. A little above it is a thin but very closely-packed layer of *Conulus* (= *Echinoconus* = *Galerites*) *conicus*.

We are now in the zone of *Micraster cor-anguinum*, and as the beds soon become horizontal we find that the whole of the cliffs from Kingsgate, past Broadstairs and Ramsgate, to Pegwell Bay, are cut in this zone, which is the lowest exposed in the

FIG. 44.—SECTION ALONG THE CLIFF-FACE BETWEEN RED CLIFF END (PEGWELL BAY) AND GORE END (BIRCHINGTON).—C. Davies Sherborn.

M. *Marsupites*-band } *Marsupites*-zone.
 U. *Uvulacrinus*-band }
 C.a. *Micraster cor-anguinum*-zone.
 V. *Actinocamax* verus.

A. *Ammonites* (*leptophyllus*-group).
 "Barrois Sponge Bed."
 Whitaker's "3-in. Band."
 E. *Echinoconus*-Band.

Island. Near Dumpton Gap there are some small faults, with down-throw on the south, so that for a short distance there is room for a thin capping of the *Marsupites*-zone at the top of the cliff, but it is inaccessible. The chalk of the *Micraster cor-anginum*-zone is as white, but more compact than that of the zone above, and nodular flint bands occur with great regularity, interspersed with tabular bands. One of the latter, "Whitaker's 3-inch band," stands out prominently 21 ft. below the Barrois sponge-bed, and can be recognised in the cliff nearly all the way to Pegwell Bay. Bedwell's columnar-band,* a peculiar cavernous layer of flint, rises from the shore at the North Foreland, 31 ft. below Whitaker's 3-inch band.

At Pegwell Bay the dip of the beds is southerly, and the *Marsupites*-zone comes in again, and in its turn is covered by Thanet Sands. The outcrop is short, owing to a higher dip than at Kingsgate, and this is aided by some small faults. The junction with the Thanet beds is not always clear, and the upper layers of chalk are somewhat rubbly.

At Pegwell Bay we reach the edge of the shallow synclinal fold in which the River Stour runs, once occupied by a wide estuary forming the southern boundary of the Isle of Thanet, but now filled by a level marsh, some four miles in width, over which the sluggish Stour wanders. Near its mouth, at Stonar Cut, the river makes an enormous loop, some seven miles in circuit, but only a furlong across at the neck.

Here Richborough Castle guarded the southern estuary, as Reculvers did the western one. Ebbsfleet, the reputed landing place of the Saxons, is close by, and the whole district is of great archæological interest.

THE DOVER SECTION: FOLKESTONE TO WALMER.

Starting from Copt Point, the southern horn of East Wear Bay, near Folkestone, Gault is found well exposed on the fore-shore at low-water, and the profusion of brilliantly-coloured fossils is a continual attraction to the summer visitor. This is described in another part of this work (chapter XIX). Over the unctuous surface of the Gault the succeeding beds have slipped to an enormous extent, and produced an undercliff of broken ground, narrow in width but over three miles in length, and it is not until Shakespeare's Cliff is reached that the Chalk can be satisfactorily examined from the beach. This undercliff is called "The Warren." Above it towers Abbot's Cliff, which is the truncated end of the escarpment of the North Downs. The railway to Dover runs through it in cuttings and tunnels, and considerable shoring-up has been found necessary to preserve the stability of the line. A "halt" has recently been opened in

* *Geol. Mag.* dec. 2, vol. i (1874), p. 19.

about the centre of The Warren, and from it a wide, zig-zag path has been cut up the face of the cliff. When weathered this will probably afford a convenient means of examining the section. A very complete description of the beds of the Lower Chalk of this district has been given by the late Mr. Hilton Price,* and by Mr. Jukes-Browne,† so it will suffice to say here that the lower part of the cliffs overlooking The Warren consists of massive grey chalk, belonging to the zone of *Holaster subglobosus*, above which comes the yellowish-grey marl of the *Actinocamax plenus*-band. This band can readily be traced in the cliff, because it is succeeded by the basal "grit bed" of the zone of *Rhynchonella cuvieri*, which, from its superior hardness, frequently overhangs the marl band as a projecting cornice.

Shakespeare's Cliff presents an interesting section. The base can easily be worked at low tide, and at each end of the railway tunnel which pierces it, there is a convenient zig-zag up the cliff. That at the western end of the tunnel is close to the site of the first boring for coal in Kent and to the abandoned Channel Tunnel works. Here the lower part of the cliff is formed of the massive grey chalk of the *H. subglobosus*-zone, in which fossils are not very numerous, and the cliffs are also mostly wave-washed.

About 100 ft. up, the *A. plenus* marl band occurs and it can be readily traced for a considerable distance. Then comes the "grit-bed" of the base of the *R. cuvieri*-zone, a hard, gritty, buff-coloured bed of intensely nodular chalk, 32 ft. thick, which weathers with a very rough surface. In it fragments of shells abound, especially of *Inoceramus labiatus (mytiloides)*, and good specimens of *R. cuvieri* and *Discoidea dixonii* are not infrequent. The top of the first slope of the zig-zag coincides with the *A. plenus*-band, and nearly the whole of the second slope is cut in the "grit-bed." The remainder of the zone of *R. cuvieri*, about 40 ft., consists of hard chalk, still nodular, but less so than the grit-bed, and lighter in colour, with several marl bands.

The *Terebratulina gracilis*-zone commences a few feet below the bottom of the last long flight of steps, but there is no marked lithological feature at the junction. The chalk is white, and very marly, weathering with a smooth surface, on which the name-fossil shows up well. There are several marl seams, and some nodular bands. About 70 ft. of this zone is exposed here, and a very strong nodular flint line occurs just where the zig-zag reaches the top of the cliff.‡

* Price, F. G. H. "On the beds between the Gault and Upper Chalk at Folkestone," *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 431.

† *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, p. 32.

‡ See also *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, p. 371, vol. iii, p. 135; Hill, W., "On the Upper and Lower Chalk of Dover, etc.," *Quart. Journ. Geol. Soc.*, vol. xliii, p. 232; Rowe, A. W., *Proc. Geol. Assoc.*, vol. xvii, p. 190.

Walking eastward, towards the highest point of Shakespeare's Cliff, the upper part of it is seen to consist of yellowish, very nodular chalk, containing many scattered flints, with two strong bands of flint in the lower portion. This flinty chalk is apparently about 40 ft. thick, and evidently belongs to the *Holaster planus*-zone.

Approximate thickness of the zones at the highest part of Shakespeare's Cliff (338 ft. O.D.):

- Zone of *Holaster planus* about 40 feet.
- „ „ *Terebratulina gracilis* about 180 feet.
- „ „ *Rhynchonella cuvieri* about 70 feet.
- „ „ *Holaster subglobosus* about 50 feet.

At the east end of the tunnel a similar but smaller section can be examined. Owing to the dip of the beds, the *A. plenus* marl is here at shore level, while the grit band can be examined in the zig-zag and for about $\frac{1}{4}$ -mile eastward at the foot of the cliffs behind the railway viaduct.

A short distance inland, chalk is exposed on the north flank of the South Military Road, which ascends to the Western Heights overlooking Dover. It is white, meagre, and rather soft, with strong flint lines from 2 ft. to 3 ft. apart. The surface, unfortunately, is very dirty, with a powdery crust, and fossils are not readily found; they indicate the lower part of the zone of *Micraster cor-anguinum*.

We now pass to the Eastern Heights, on the other side of Dover, where the Castle Hill presents a fine but inaccessible section from the zone of *T. gracilis* to that of *M. cor-anguinum*.

The zones of *T. gracilis* and *H. planus* can be examined along the sloping pathway up the cliff face overlooking the Harbour Extension. The junction of the two zones can readily be made out, but the Chalk-rock, in its true lithological sense, does not occur here.

The tunnel which formerly existed here has been removed in connection with the Harbour Extension works. These works prevent access to the base of the cliffs for some distance, and unless permission can be obtained to pass through the works, the shore north-east of Dover can only be reached by ascending to the top of the cliffs, walking past the Military Prison, and descending at Langdon Stairs, a zig-zag cut in the cliff face at the hollow called Langdon Hole, the last few feet of which is a rough scramble.

Dr. Rowe gives the following section, in ascending order, at Langdon Stairs*: "Below the lowest slope there are rough steps cut in the cliff, which are in the zone of *T. gracilis*, with the second open marl-band showing.

* *Proc. Geol. Assoc.*, vol. xvi, p. 320.

"1st slope.—At the bottom of this slope is seen the first open marl band, with the two pairs of flint bands above and below it, marking the junction of the *T. gracilis* and *H. planus*-zones. The rest of the slope is in the zone of *H. planus*, and at the top of the slope, in the corner where it joins the second slope, is the junction of the zones of *H. planus* and *Micraster cor-testudinarium*.

"2nd slope.—All of this is in the zone of *M. cor-testudinarium*.

"3rd slope.—All of this is in the zone of *M. cor-testudinarium*, and the thin *M. cor-testudinarium*-tabular occurs in the lower part of the slope.

"4th slope.—All this is in the zone of *M. cor-testudinarium*.

"5th slope.—Shows the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*; the basal *M. cor-anguinum*-tabular is one-fourth of the way down from the top of the slope.

"6th slope.—All of this is in the zone of *M. cor-anguinum*. The measurements taken of the beds on the shore were checked here, and agreed in all instances."

The cliffs from Langdon Stairs to Kingsdown present a very fine section, and as the gentle dip of the beds brings each zone in succession to the shore at a low angle, a wide collecting ground is offered to the observer. The whole distance can be traversed on foot when the tide is out. A falling tide should be selected, as long stretches of cliff are awash at high water, and it is very rough walking all the way. There is no way up the cliffs between Langdon Stairs and St. Margaret's Bay, nor between the latter and Old Stairs Bay.

Starting from Langdon Stairs, the top of the zone of *T. gracilis* is reached near the disused windlass shaft in Bantam Hole, where the white, marly chalk, poor in flint, gives place to yellowish nodular chalk, with abundant flint and more numerous fossils, of the zone of *H. planus*. The junction of the zones of *H. planus* and *M. cor-testudinarium* is not so easily made out, as these two zones have similar lithological characters, and it can only be located by careful collecting. Dr. Rowe gives the lower of a pair of strong nodular flint lines as the approximate junction. The *M. cor-testudinarium*-zone is full of fossils, which may be collected for some distance south of the southern horn of St. Margaret's Bay, where its junction with the overlying zone of *M. cor-anguinum* can be easily seen a few feet up the cliff. The upper zone consists of smooth, white, rather soft, chalk, with regular bands of nodular flints and occasional strong tabular bands. As is usual in the lower part of the zone of *M. cor-anguinum* it is very poor in fossils, so that the zoological contrast is as striking as the lithological.

The zone of *Micraster cor-anguinum* descends to the shore

level at the north-east corner of St. Margaret's Bay, and extends thence, with a very slight dip, to Kingsdown, where the cliffs end. North of Leather Court Point (called on the new 1-inch map, Hope Point) the cliffs are based by a large grass-covered talus and a wide shingle beach. The sea is evidently encroaching here vigorously, for at this point the talus and shingle both terminate abruptly, and from here to St. Margaret's Bay the waves wash the base of the cliffs at every tide. The action is apparently rapid, for the mark of the removed talus can be seen on the cliff face, while the road which now terminates at Leather Court Point is shown on the new 1-inch map as extending all the way to St. Margaret's Bay, whereas every trace of it has now disappeared. Parts of the beach hereabout present a remarkable appearance. Strong, narrow ridges and deep grooves run out at right-angles from the base of the cliffs. Both ridges and grooves are about six inches wide, while the grooves are often a foot deep, as though the solid chalk had been scored with a gigantic rake.

No trace of the *Uintacrinus*-band—the lower part of the *Marsupites*-zone—can be found on the coast section, but it occurs in several places on higher ground a short distance inland, notably at Ringwold and Martin.* After passing Kingsdown no more chalk is seen until Pegwell Bay is reached, the intervening ground being occupied by the alluvial deposits of the Stour, flanked at Deal by a considerable spread of brick-earth.

THE SUSSEX SECTION: EASTBOURNE TO BRIGHTON.

At the eastern end of the South Downs, Eastbourne nestles under the escarpment in a position similar to that which Folkestone occupies at the eastern end of the North Downs. Near Eastbourne, however, the strike of the escarpment, which has had for some fifty miles a general easterly trend, suddenly turns nearly due south. The dip is not only changed in direction, but increased in amount, with the result that the truncated end, Beachy Head, shows in a short distance a complete sequence of the beds from the Gault up to the zone of *Micraster coranguinum*. The beds have been considerably faulted and squeezed, so that the piece of coast between Eastbourne and Birling Gap is of great geological interest, and by no means easy to unravel on a first traverse.

Mr. Clement Reid has put forward a bold hypothesis with regard to this disturbance. He remarks: "The effect of this disturbance is only felt for a very short distance inland, but eastward under the sea it apparently becomes more violent, though without submarine surveying it is impossible to say

* Rowe, A. W., *Geol. Mag.*, dec. 5, vol. v (1908), p. 74.

exactly what has happened. The disturbance is probably a broken uncline, like that of the Isle of Wight, with which it may be continuous. If this is the case, the Chalk of the South Downs, unlike that of the North Downs, is not connected across the Channel with France. Contrary to the accepted idea the escarpment curves round Beachy Head and turns to the west. The bed of this part of the English Channel may thus be a continuation of the wide plain of the Weald, and formed like the Weald by the erosion of the softer strata."* Until more definite evidence is forthcoming, I prefer the older explanation, and I think that Mr. Jukes-Browne's map shows the correct distribution of the formations.†

When examining Beachy Head a falling tide should be chosen, as there is no way up the cliffs between Cow Gap and Birling Gap, $3\frac{1}{2}$ miles of heavy shingle walking. Starting along the shore from the southern end of Eastbourne parade, one proceeds for some distance along the strike of the beds. Below high-water mark, Gault and Upper Greensand are exposed on the shore in alternating strips, due to complicated over-thrusting. At the base of the cliffs the *Actinocamax plenus* marls can be well examined. Above are two old chalk pits; both are cut in the zones of *R. cuvieri* and *T. gracilis*, Gore Pit (the northern) showing much less of the higher zone than the much larger Holywell Pit (the southern). Farther on the Chalk marl and Chloritic marl can be examined near Cow Gap. The dip being high, we pass in rapid succession the zones of *H. subglobosus*, *R. cuvieri*, and *T. gracilis*. The Belemnite marls are of unusual thickness—nearly 20 ft.—but the other zones have been considerably affected by earth movements and estimates of their thickness differ.‡ Vertical and oblique fissures can be seen, some of which have strongly slickensided walls. The grit-bed, so strongly developed at the base of the *R. cuvieri*-zone at Dover, is poorly represented here. Unfortunately, the cliffs are so battered by the waves that collecting in these zones is an unprofitable task.

The base of the cliff immediately facing the *new* lighthouse on the shore belongs to the upper part of the *T. gracilis*-zone, and the junction with the succeeding zone of *H. planus* rises from the beach at a short distance farther on, the smooth, flintless chalk of the lower contrasting well with the nodular and flinty chalk of the upper zone. From here the magnificent cliffs of Beachy Head are seen to splendid advantage. Chalk has a great tendency to form vertical cliffs, and this, rising sheer to a height of 536 ft., is equalled by few headlands in impressiveness. Had Shake-

* "The Geology of the country around Eastbourne." *Mem. Geol. Surv.* (1898), p. 12.

† *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, frontispiece.

‡ Jukes-Browne, *op. cit.*, vol. ii, p. 397.

spere's well-known lines been applied to this cliff, they could scarcely have been deemed an exaggeration.

The junction of the zones of *H. planus* and *M. cor-testudinarium* can be found by measuring 80 yds. along the beach westward from the top of the *T. gracilis*-zone, and an iron-stained, vertical fissure, which runs from top to bottom of the cliff, helps to locate the spot.

The dip is now very much less, and the beds soon become nearly horizontal. For the next mile the base of the cliff is in the zone of *M. cor-testudinarium*.

It is well to remember that the inclination of the beds, as seen in the cliffs, is affected by the changes in the relation of the line of section to the direction of the dip. From Gore Pit to Beachy Head the section is roughly along the strike, for a short distance west of Beachy Head it is along the dip, and it then changes gradually, until, before Birling Gap is reached, it is again roughly along the strike, and continues so, with a local interruption at Seaford Head, all the way to Brighton. A glance at the geological map will help to explain this.

Two hundred yards before Beltout is reached there is a depression at the top of the cliff, and under it a thin tabular flint band rises from the shore. This is the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*. Beltout is the old lighthouse on the top of the cliff, $1\frac{1}{2}$ miles west of Beachy Head, and is now occupied as a private dwelling. Unfortunately, neither it nor the scoop in the cliff can be easily seen from the shore, but this thin tabular band can be identified by the help of another and much thicker one, which is prominent in the cliff face 60 ft. above it. From here to the Cuckmere the cliffs are cut in the zone of *M. cor-anguinum*, with cappings of the *Uintacrinus*-band on the tops of the four westernmost of the "Seven Sisters." The thick tabular band just mentioned descends gradually, and is seen to pass between the two small caves excavated one above the other in a vertical fissure 50 yds. west of Beltout. These two caves are known as Parson Darby's Hole. Farther west it passes under another small cave before it disappears beneath the shingle. Fifty feet above this thick tabular band there is another rather thinner one, with a yellow sponge-bed 15 ft. below it. Dr. Rowe calls this the "spurious tabular and sponge-bed." It misled Prof. Barrois, and caused him to place too much of this section in the *Marsupites*-zone. As I have pointed out elsewhere,* Barrois was similarly misled by a sponge-bed (possibly the same bed) in Surrey. In a fresh fall of chalk from the top of the cliff at Beltout the writer recently obtained the pyramidal form of *Echinocorys scutatus* and a well-preserved portion of *Ammonites leptophyllus*, both of which are indicative of the *Uintacrinus*-

* *Proc. Geol. Assoc.*, vol. xx, p. 422.

band and support Dr. Rowe's suggestion that there may possibly be a capping of the *Marsupites*-zone at this spot.

From Birling Gap to the Cuckmere, two miles, is a good section in this zone, but the tide must be carefully watched. As in the case of so many of the small rivers on the south coast, the mouth of the Cuckmere has been diverted considerably to the east by the ever-shifting shingle.

At the western end of the last section the beds are rising, and the cliffs west of the Cuckmere are found to be of the *M. cor-testudinarium*-zone. This continues until Seaford Head is rounded, and then the beds are found to dip rapidly, and the higher zones come down successively until the zone of *A. quadratus* is reached. Beyond Hope Gap the cliffs are washed by the waves at high-water, consequently the junctions are hard to find. The section is too difficult to describe in a few words, and Dr. Rowe's account should be consulted. Caution should be observed in examining the cliffs, as falls of chalk sometimes happen. A lady was killed here by one in September, 1908.

A little beyond Seaford, the beds are again horizontal, and remain practically so for the next eight miles. Seaford Head, therefore, displays a structure which is almost that of a monocline, and Mr. J. V. Elsdon has recently suggested that the Cuckmere runs in the line of a transverse fault (see chapter xi, p. 276).

In the cliffs from Newhaven to Brighton we have the longest British section of the zone of *Actinocamax quadratus*. It is easily accessible, and yields a characteristic fauna. This zone is generally variable as regards abundance of fossils, some beds being very rich and others very barren. *Cardiaster pillula* and a small gibbous form of *Echinocorys* are characteristic, and are more likely to be found than the name-fossil, which is very sporadic in its occurrence. *Ammonites leptophyllus* is not uncommon, but *Micraster* is conspicuous by its rarity. The chalk is moderately soft and white, but frequently iron-stained. It contains a large admixture of marly matter, and many marl bands which weather out as open seams. Nodular flint bands are common, but not so regular nor frequent as in the zone of *Micraster cor-anguinum*, while tabular flint occurs in enormous quantity in horizontal, and frequently in oblique sheets.

At only two places in this extensive section does any other zone appear. The first exception extends from Old Nore Point, one mile west of Newhaven Harbour, to the centre of Friar's Bay, about half-a-mile, in which space the *Marsupites*-zone is exposed at the base of the cliff, but this top part of the zone is not very fossiliferous, and the reefs on the shore yield a richer fauna. Another outcrop of the same zone commences a little west of the two stone groynes half-way between Rottingdean and Brighton. It rises gradually westward until at Kemp Town it

extends about half-way up the cliff, which is here abruptly cut off by an ancient valley which is partly filled with Mantell's "Elephant" bed of Pleistocene age, against which the chalk cliff abuts almost vertically. Westward of Brighton the chalk dips down into the syncline of the Hampshire Basin and is no more seen on the coast.

Lithologically the *Marsupites*-zone of Sussex presents a great contrast to that of Thanet, for whereas in the latter area it is practically flintless, in Sussex it contains abundant flint, and cannot in this respect be distinguished from the zone above. Some of the fossils also vary in distribution. The Ammonites are mostly confined to the *Uintacrinus*-band in Thanet, but are found in the *Marsupites*-band and *A. quadratus*-zone in Sussex, while *Act. verus* is common in the *Uintacrinus*-band in Thanet, but absent in Sussex.*

* Reference should be made to the following works Barrois, C., "Recherches sur le terrain crétacé supérieur de l'Angleterre et d'Irlande" *Mem. Soc. Geol. Nord.* (1876); Bedwell, F. A., "Ammonite Zones in the Isle of Thanet," *Proc. Geol. Assoc.*, vol. iii, p. 217, and *Geol. Mag.*, dec. 2, vol. i (1874), p. 16; Gardner, J. Starkie, "The Lower Eocene Section between Reculvers and Herne Bay," *Quart. Journ. Geol. Soc.*, vol. xxxix, p. 197; Jukes-Browne, A. J., *Mem. Geol. Surv.*, "The Cretaceous Rocks of Britain," vols. ii and iii; Rowe, A. W., "The Zones of the White Chalk of the English Coast, part 1, Kent and Sussex," *Proc. Geol. Assoc.*, vol. xvi, p. 289; Whitaker, W., "On the Chalk of the Isle of Thanet," *Quart. Journ. Geol. Soc.*, vol. xxi, p. 395, "Geology of the London Basin," *Mem. Geol. Surv.*, vol. iv (1872).