CHAPTER XXI.

Denudation of secondary strata during the deposition of the English Eocene formations—Valley of the Weald between the North and South Downs—Map—Secondary rocks of the Weald divisible into five groups—North and South Downs—Section across the valley of the Weald—Anticlinal axis—True scale of heights—Rise and denudation of the strata gradual—Chalk escarpments once sea-cliffs—Lower terrace of 'firestone,' how caused—Parallel ridges and valleys formed by harder and softer beds—No ruins of the chalk on the central district of the Weald—Explanation of this phenomenon—Double system of valleys, the longitudinal and the transverse—Transverse how formed—Gorges intersecting the chalk—Lewes Coomb—Transverse valley of the Adur.

Denudation of the Valley of the Weald.—In order to understand the theory of which we sketched an outline at the close of the last chapter, it will be necessary that the reader should be acquainted with the phenomena of denudation exhibited by the chalk and some of the older secondary rocks in parts of England most nearly contiguous to the basins of London and Hampshire. It will be sufficient to consider one of the denuded districts, as the appearances observable in others are strictly analogous; we shall, therefore, direct our attention to what we may call *the Valley of the Weald,* or the region intervening between the North and South Downs.

Map.—In the coloured map given in Plate V. *, the district alluded to is delineated, and it will be there seen that the southern portion of the basin of London, and the north-eastern limits of that of Hampshire, are separated by a tract of secondary rocks, between 40 and 50 miles in breadth, comprising within it the whole of Sussex and parts of the counties of Kent, Surrey, and Hampshire.

There can be no doubt that the tertiary deposits of the Hampshire basin formerly extended much farther along our southern coast towards Beachy Head, for patches are still

* This map has been chiefly taken from Mr. Greenough's Map of England.

found near Newhaven, and at other points, as will be seen by the map. These are now wasting away, and will in time disappear, as the sea is constantly encroaching and undermining the subjacent chalk.

The secondary rocks, depicted on the map, may be divided into five groups:—

1. *Chalk and Upper green-sand.*—This group is the uppermost of the series; it includes the white chalk with and without flints, and an inferior deposit called, provincially, 'Firestone,' and by English geologists the 'Upper green-sand.' It sometimes consists of loose siliceous sand, containing grains of silicate of iron, but often of firm beds of sandstone and chert.
2. Blue clay or calcareous marl, called provincially *Gault.*
3. *Lower green-sand*, a very complex group consisting of grey, yellowish, and greenish sands, ferruginous sand and sandstone, clay, chert, and siliceous limestone.
4. *Weald clay*, composed for the most part of clay without intermixture of calcareous matter, but sometimes including thin beds of sand and shelly limestone.
5. *Hastings sands*, composed chiefly of sand, sandstone, clay, and calcareous grit, passing into limestone *.

The first three formations above enumerated are of marine origin, the last two, Nos. 4 and 5, contain almost exclusively the remains of fresh-water and amphibious animals. But it is not our intention at present to enlarge upon the organic remains of these formations, as we have merely adverted to the rocks in order that we may describe the changes of position which they have undergone, and the denudation to which they have been exposed since the commencement of the Eocene period,—mutations which, if our theory be well founded, belong strictly to the history of *tertiary* phenomena.

By a glance at the map, the reader may trace at once the

* For an account of these strata in the south-east of England, see Mantell's Geology of Sussex, and Dr. Fitton's Geology of Hastings, where the memoirs of all the writers on this part of England are referred to.

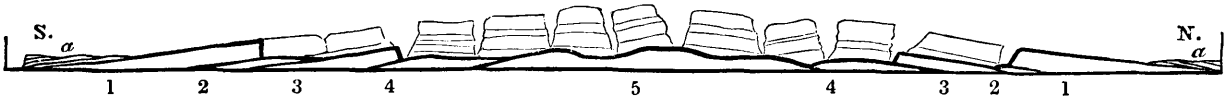
superficial area occupied by each of the five formations above mentioned. On the west will be seen a large expanse of chalk, from which two branches are sent off; one through the hills of Surrey and Kent to Dover, forming the ridge called the North Downs, the other through Sussex to the sea at Beachy Head, constituting the South Downs. The space comprised between the North and South Downs, or 'the Valley of the Weald,' consists of the formations Nos. 2, 3, 4, 5, of the above table. It will be observed that the chalk terminates abruptly, and with a well-defined line towards the country occupied by those older strata. Within that line is a narrow band coloured blue, formed by the gault, and within this again is the Lower green sand, next the Weald clay, and then, in the centre of the district, a ridge formed by the Hastings sands.

Section of the Valley of the Weald.—It has been ascertained by careful investigation, that if a line be drawn from any part of the North to the South Downs, which shall pass through the central group, No. 5, the beds will be found arranged in the order described in the annexed section (No. 63, p. 288).

We refer the reader at present to the dark lines of the section, as the fainter lines represent portions of rock supposed to have been carried away by denudation.

At each end of the diagram the tertiary strata *a* are exhibited reposing on the chalk. In the centre are seen the Hastings sands (No. 5), forming an anticlinal axis, on each side of which the other formations are arranged with an opposite dip. It has been necessary however, in order to give a clear view of the different formations, to exaggerate the proportional height of each in comparison to its horizontal extent, and we have subjoined a true scale in another diagram (No. 61) in order to correct the erroneous impression which might otherwise be made on the reader's mind. In this section the distance between the North and South Downs is represented to exceed 40 miles; for we suppose the valley of the Weald to be here intersected in its longest diameter, in the direction of a line between Lewes and Maidstone.

No. 63.



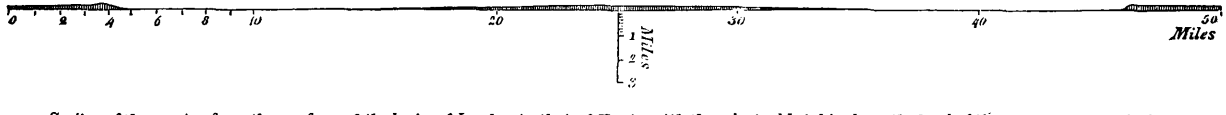
Section from the London to the Hampshire basin across the Valley of the Weald.

a, Tertiary strata. 1, Chalk and firestone. 2, Gault. 3, Lower green-sand. 4, Weald clay. 5, Hastings sands.

Highest point of South Downs, 858 feet.

Anticlinal axis of the Weald.
Crowborough Hill, 804 feet.

No. 64.
Highest point of North Downs, 880 feet *.



Section of the country from the confines of the basin of London to that of Hants, with the principal heights above the level of the sea on a true scale. †

* Lieutenant H. Murphy, R. E., informs me that Botley Hill, near Godstone, in Surrey, was found by trigonometrical measurement to be 880 feet above the level of the sea; and Wrotham Hill, near Maidstone, which appears to be next in height of the North Downs, 795 feet.

† My friend Mr. Mantell, of Lewes, has kindly drawn up this scale at my request.

In attempting to account for the manner in which the five secondary groups above mentioned may have been brought into their present position, the following hypothesis has been very generally adopted. Suppose the five formations to lie in horizontal stratification at the bottom of the sea; then let a movement from below press them upwards into the form of a flattened dome, and let the crown of this dome be afterwards cut off, so that the incision should penetrate to the lowest of the five groups. The different beds would then be exposed on the surface in the manner exhibited in the map, plate 5 *.

It will appear from former parts of this work, that the amount of elevation here supposed to have taken place is not greater than we can prove to have occurred in other regions within geological periods of no great duration. On the other hand, the quantity of denudation or removal by water of vast masses which are assumed to have once reached continuously from the North to the South Downs is so enormous, that the reader may at first be startled by the boldness of the hypothesis. But he will find the difficulty to vanish when once sufficient time is allowed for the gradual and successive rise of the strata, during which the waves and currents of the ocean might slowly accomplish an operation, which no sudden diluvial rush of waters could possibly have effected.

Escarpments of the chalk once sea-cliffs.—In order to make the reader acquainted with the physical structure of the Valley of the Weald, we shall suppose him first to travel southwards from the London basin. On leaving the tertiary strata he will first ascend a gently-inclined plane, composed of the upper flinty portion of the chalk, and then find himself on the summit of a declivity consisting, for the most part, of different members of the chalk formation, below which the upper green-sand, and sometimes also the gault *crop out* †. This steep declivity is called by geologists 'the escarpment of the chalk,' which overhangs a

* See illustrations of this theory by Dr. Fitton, Geol. Sketch of Hastings.

† We use this term, borrowed from our miners, to express the coming up to the surface of one stratum from beneath another.

No. 65.

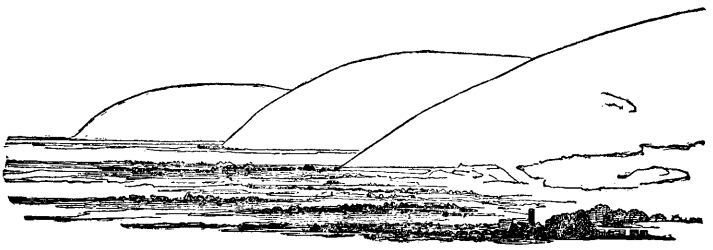
View of the chalk escarpment of the South Downs. Taken from the Devil's Dike, looking towards the west and south-west.

a, The town of Steyning is hidden by this point. *b*, Edburton church. *c*, Road. *d*, River Adur.

valley excavated chiefly out of the argillaceous or marly bed, termed Gault (No. 2). The escarpment is continuous along the southern termination of the North Downs, and the reader may trace it from the sea at Folkstone, westward to Guildford and the neighbourhood of Petersfield, and from thence to the termination of the South Downs at Beachy Head. In this precipice or steep slope the strata are cut off abruptly, and it is evident that they must originally have extended farther. In the accompanying wood-cut (No. 65), part of the escarpment of the South Downs is faithfully represented, where the denudation at the base of the declivity has been somewhat more extensive than usual, in consequence of the upper and lower green-sand being formed of very incoherent materials, the former, indeed, being extremely thin and almost wanting.

The geologist cannot fail to recognize in this view the exact likeness of a sea-cliff, and if he turns and looks in an opposite direction, or eastward, towards Beachy Head, he will see the same line of height prolonged. Even those who are not accustomed to speculate on the former changes which the surface has undergone, may fancy the broad and level plain to resemble the flat sands which were laid dry by the receding tide, and the different projecting masses of chalk to be the headlands of a coast which separated the different bays from each other.

No. 66.

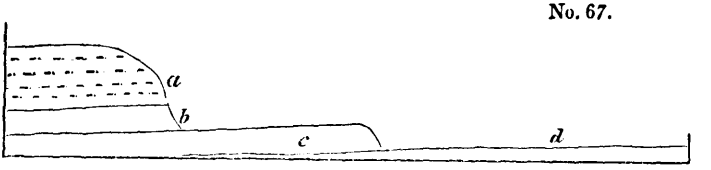


Chalk escarpment as seen from the hill above Steyning, Sussex. The castle and village of Bramber in the fore-ground.

Lower terrace of firestone.—We have said that the upper

green-sand ('firestone,' or 'malm rock,' as it is sometimes called) is almost absent in the tract here alluded to. It is, in fact, seen at Beachy Head to thin out to an inconsiderable stratum of loose green-sand; but farther to the westward it is of great thickness, and contains hard beds of blue chert and limestone. Here, accordingly, we find that it produces a corresponding influence on the scenery of the country, for it runs out like a step beyond the foot of the chalk-hills, and constitutes a lower

No. 67.



a, Chalk with flints. *b*, Chalk without flints.
c, Upper green sand, or firestone. *d*, Gault.

terrace varying in breadth from a quarter of a mile to three miles, and following the sinuosities of the chalk escarpment*.

It is impossible to desire a more satisfactory proof that the escarpment is due to the excavating power of water during the gradual rise of the strata. For we have shown, in our account of the coast of Sicily †, in what manner the encroachments of the sea tend to efface that succession of terraces which must otherwise result from the successive rises of a coast preyed upon by the waves. During the interval between two elevatory movements, the lower terrace will usually be destroyed, wherever it is composed of incoherent materials; whereas the sea will not have time entirely to sweep away another part of the same terrace, or lower platform, which happens to be composed of rocks of a harder texture and capable of offering a firmer resistance to the erosive action of water.

Valleys where softer strata, ridges where harder crop out. —It is evident that the Gault No. 2 (see the map) could not have opposed any effectual resistance to the denuding force

* Mr. Murchison, Geol. Sketch of Sussex, &c., Geol. Trans., 2nd Series, vol. ii. p. 98.

† See p. 111, and wood-cut No. 24.

of the waves; its outcrop, therefore, is marked by a valley, the breadth of which is often increased by the loose incoherent nature of the uppermost beds of the lower green-sand, which lie next to it, and which have often been removed with equal facility.

The formation last mentioned has been sometimes entirely smoothed off like the gault; but in those districts where chert, limestone, and other solid materials enter largely into its composition, it forms a range of hills parallel to the chalk, which sometimes rival the escarpment of the chalk itself in height, or even surpass it, as in Leith Hill. This ridge often presents a steep escarpment towards the Weald clay which crops out from under it. (See the strong lines in diagram No. 63, p. 288.)

The clay last mentioned forms, for the most part, a broad valley, separating the lower green-sand from the Hastings sands, or Forest ridge; but where subordinate beds of sandstone of a firmer texture occur, the uniformity of the plain is broken by waving irregularities and hillocks *.

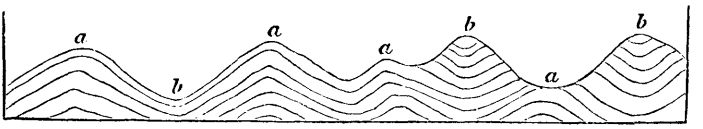
In the central region, or Forest ridge, the strata have been considerably disturbed and are greatly fractured and shifted. One fault is known where the vertical shift of a bed of calcareous grit is no less than 60 fathoms †. It must not be supposed that the anticlinal axis, which we have described as running through the centre of the weald, is by any means so simple as is usually represented in geological sections. There are, on the contrary, a series of anticlinal and synclinal ‡

* Martin, Geol. of Western Sussex. Fitton, Geol. of Hastings, p. 31.

† Fitton, ibid., p. 55.

‡ We adopt this term, first used, we believe, by Professor Sedgwick; its signification will best be understood by reference to the accompanying diagram.

No. 68.



a, Anticlinal lines. *b*, Synclinal lines.

lines, which form ridges and troughs running nearly parallel to each other.

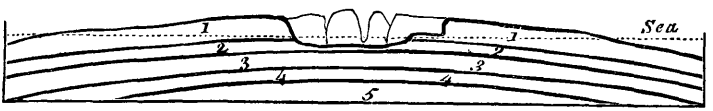
Much of the picturesque character of the scenery of this district arises from the depth of the narrow valleys and ridges to which the sharp bends and fractures of the strata have given rise; but it is also in part to be attributed to the excavating power exerted by water, especially on the interstratified argillaceous beds.

From the above description it will appear that, in the tract intervening between the North and South Downs, there are a series of parallel valleys and ridges; the valleys appearing evidently to have been formed principally by the removal of softer materials, while the ridges are due to the resistance offered by firmer beds to the destroying action of water.

Rise and denudation of the strata gradual.—Let us then consider how far these phenomena agree with the changes which we should naturally expect to occur during the gradual rise of the secondary strata. Suppose the line of the most violent movements to have coincided with what is now the central ridge of the Weald Valley; in that case, the first land which emerged must have been situated where the Forest ridge is now placed. Here a number of reefs may have existed, and islands of chalk, which may have been gradually devoured by the ocean in the same manner as Heligoland and other European isles have disappeared in modern times, as related in our first volume*.

Suppose the ridge or dome first elevated to have been so rent and shattered on its summit as to give more easy access to the waves, until at length the masses represented by the fainter lines in the annexed diagram were removed. Two strips of land might

No. 69.



then remain on each side of a channel, in the same manner as

* Page 289, and Second Edition, page 330.

the opposite coasts of France and England, composed of chalk, present ranges of white cliffs facing each other. A powerful current might then rush, like that which now ebbs and flows through the straits of Dover, and might scoop out a channel in the gault. We must bear in mind that the intermittent action of earthquakes would accompany this denuding process, fissuring rocks, throwing down cliffs, and bringing up, from time to time, new stratified masses, and thus greatly accelerating the rate of waste. If the lower bed of chalk on one side of the channel should be harder than on the other, it would cause an under terrace, as represented in the above diagram, resembling that presented by the upper green-sand in parts of Sussex and Hampshire. When at length the gault was entirely swept away from the central parts of the channel, the lower green-sand (3, diagram No. 70,) would be laid bare, and portions of it would

No. 70.

The dotted line represents the sea-level.

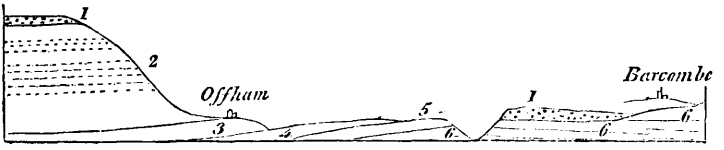
become land during the continuance of the upheaving earthquakes. Meanwhile the chalk cliffs would recede farther from one another, whereby four parallel strips of land, or perhaps rows of islands, would be caused.

The edges of the argillaceous strata, No. 2, are still exposed to erosion by the waves, and a portion of the clay, No. 4, is already removed. This clay, as it gradually rises, will be swept off from part of the subjacent group, No. 5, which will then be laid bare, and may afterwards become land by subsequent elevation.

Why no ruins of chalk on central district.—By this theory of the successive emergence and denudation of the groups, 1, 2, 3, 4, 5, we may account for an alluvial phenomenon which seems inexplicable on any other hypothesis. The summits of the chalk downs are covered everywhere with flint gravel, which

is often entirely wanting on the surface of the clay at the foot of the chalk escarpment, and no traces of chalk flint have ever been found in the alluvium of the central district, or Forest ridge. It is rare, indeed, to see any wreck of the chalk, even at the distance of two or three miles from the escarpments of the North and South Downs. To this general rule, however, an exception occurs near Barcombe, about three miles to the north of Lewes, where we obtain the accompanying section *.

No. 71.



Section from the North escarpment of the South Downs to Barcombe.

1, Gravel composed of partially-rounded chalk flints.
2, Chalk with and without flints.
3, Lowest chalk or chalk marl (upper green-sand wanting).
4, Gault. 5, Lower green-sand. 6, Weald clay.

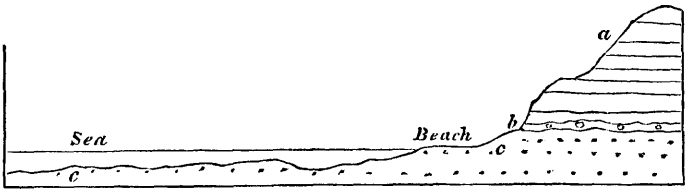
It will be seen that the valley at the foot of the escarpment extends, in this case, not only over the gault, but over the 'lower green-sand' to the Weald clay. On this clay a thick bed of flints, evidently derived from the waste of chalk, remains in the position above described.

We say that there is no detritus of the chalk and its flints on the central ridge of the Weald. I have sought in vain for a vestige of such fragments, and Mr. Mantell, who has had greater opportunities of minute investigation, assures me that he has never been able to detect any. Now whether we embrace or reject the theory of the former continuity of the chalk and other groups over the whole space intervening between the North and South Downs, we cannot certainly imagine that any transient and tumultuous rush of waters could have swept over this country, which should not have left some fragments

* The author visited this locality with Mr. Mantell, to whom he is indebted for this section.

of the chalk and its flints in the deep valleys of the Forest ridge. Indeed, if we adopted the diluvial hypothesis of Dr. Buckland, we should expect to find vast heaps of broken flints drifted more frequently into the valleys of the Gault and Weald clay, instead of being so frequently confined to the summit of the chalk downs. On the other hand, it is quite conceivable that the slow agency of oceanic currents may have cleared away, in the course of ages, the matter which fell into the sea from wasting cliffs. The reader will recollect our account of the manner in which the sea has advanced, within the last century, upon the Norfolk coast at Sherringham*.

No. 72.



Section of cliffs west of Sherringham.

a, Crag. *b*, Ferruginous flint breccia on the surface of the chalk. *c*, Chalk with flints.

The beach, at the foot of the cliff, is composed of bare chalk with flints, as is the bed of the sea near the shore. No one would suspect, from the appearance of the beach at low water, that a few years ago beds of solid chalk, together with sand and loam of the superincumbent crag, formed land on the very spot where the waves are now rolling; still less that these same formations extended, within the last 50 years, to a considerable distance from the present shore, over a space where the sea has now excavated a channel 20 feet deep.

As in this recent instance the ocean has cleared away part of the chalk, and its capping of crag, so the tertiary sea may have swept away not only the chalk, but the layer of broken flints on its surface, which was probably a marine alluvium of the

* Vol. i. p. 268, and Second Edition, p. 307.

Eocene period. Hence these flints might naturally occur on the downs, and be wanting in the valleys below.

If the reader will refer to the preceding diagrams (Nos. 69 and 70), and reflect not only on the successive states of the country there delineated, but on all the intermediate conditions which the district must have passed through during the process of elevation and denudation before supposed, he will understand why no wreck of the chalk (No. 1) should occur at great distances from the chalk escarpments. For it is evident that when the ruins of the uppermost bed (No. 1, diagram 69) had been thrown down upon the surface of the bed immediately below, those ruins would subsequently be carried away when this inferior stratum itself was destroyed. And in proportion to the number and thickness of the groups, thus removed in succession, is the probability lessened of our finding any remnants of the highest group strewed over the bared surface of the lowest.

Transverse valleys.—There is another peculiarity in the geographical features of the south-east of England which must not be overlooked when we are considering the action of the denuding causes. By reference to the map (Plate 5), the reader will perceive that the drainage of the country is not effected by water-courses following the great valleys excavated out of the argillaceous strata (Nos. 2 and 4), but by valleys which run in a transverse direction, passing through the chalk to the basin of the Thames on the one side, and to the English channel on the other.

In this manner the chain of the North Downs is broken by the rivers Wey, Mole, Darent, Medway, and Stour; the South Downs by the Arun, Adur, Ouse, and Cuckmere*.

If these transverse hollows could be filled up, all the rivers, observes Mr. Conybeare, would be forced to take an easterly course, and to empty themselves into the sea by Romney Marsh and Pevensey levels†.

* Conybeare, Outlines of Geol., p. 81. † Ibid., p. 145.

Mr. Martin has suggested that the great cross fractures of the chalk which have become river channels have a remarkable correspondence on each side of the valley of the Weald; in several instances the gorges in the North and South Downs appearing to be directly opposed to each other. Thus, for example, the defiles of the Wey, in the North Downs, and of the Arun in the South, seem to coincide in direction; and, in like manner, the Ouse is opposed to the Darent, and the Cuckmere to the Medway *. But we think it very possible that these coincidences may be accidental. It is, however, by no means improbable, as hinted by the author above mentioned, that the great amount of elevation towards the centre of the Weald district gave rise to transverse fissures. And as the longitudinal valleys were connected with that linear movement which caused the anticlinal lines running east and west, so the cross fissures might have been occasioned by the intensity of the upheaving force towards the centre of

No. 73.

Transverse valley of the Adur in the South Downs.

a, Town of Steyning. *b*, River Adur. *c*, Old Shoreham.

* Geol. of Western Sussex, p. 61.

the line, whereby the effect of a double axis of elevation was in some measure produced.

In order to give a clearer idea of the manner in which the chalk-hills are intersected by these transverse valleys, we subjoin a sketch (No. 73) of the gorge of the river Adur, taken from the summit of the chalk-downs, at a point in the bridle-way leading from the towns of Bramber and Steyning to Shoreham. If the reader will refer again to the view given in a former wood-cut (No. 65, p. 290), he will there see the exact point where the gorge, of which we are now speaking, interrupts the chalk escarpment. A projecting hill, at the point *a*, hides the town of Steyning, near which the valley commences where the Adur passes directly to the sea at Old Shoreham. The river flows through a nearly level plain, as do most of the others which intersect the hills of Surrey, Kent, and Sussex; and it is evident that these openings, so far at least as they are due to aqueous erosion, have not been produced by the rivers, many of which, like the Ouse near Lewes, have filled up arms of the sea, instead of deepening the hollows which they traverse.

In regard to the origin of the transverse ravines, there can be no doubt that they are connected with lines of fracture, and perhaps, in some places, there may be an anticlinal dip on both sides of the valley, as suggested by a local observer *. But this notion requires confirmation.

No. 74.

Supposed section of Transverse Valley.

The ravine, called the Coomb, near Lewes, affords a beautiful example of the manner in which narrow openings in the chalk may have been connected with shifts and dislocations in the strata. This coomb is seen on the eastern side of the valley of the Ouse, in the suburbs of the town of Lewes. The steep

* Martin, Geol. of Western Sussex, p. 64, plate III. fig. 3.

declivities on each side are covered with green turf, as is the bottom, which is perfectly dry. No outward signs of disturbance are visible, and the connexion of the hollow with subterranean movements would not have been suspected by the geologist, had not the evidence of great convulsions been clearly exposed in the escarpment of the valley of the Ouse, and in the numerous chalk pits worked at the termination of the

No. 75.

The Coomb, near Lewes.

Coomb. By aid of these we discover that the ravine coincides precisely with a line of fault, on one side of which the chalk with flints *a*, appears at the summit of a hill, while it is thrown down to the bottom on the other.

No. 76.

Fault in the cliff-hills near Lewes.

a, Chalk with flints. *b*, Lower chalk*.

The fracture here alluded to is one of those which run east

* I examined this spot in company with Mr. Mantell, to whom I am indebted for the above section.

and west, and of which there are many in the Weald district, parallel to the central axis of the Forest ridge.

In whatever manner the transverse gorges originated, they must evidently have formed ready channels of communication between the submarine longitudinal valleys and those deep parts of the sea wherein we imagine the tertiary strata to have been accumulated. If the strips of land which first rose had been unbroken, and there had been no free passage through the cross fractures, the currents would not so easily have drifted away the materials detached from the wasting cliffs, and it would have been more difficult to understand how the wreck of the denuded strata could have been so entirely swept away from the base of the escarpments.

In the next chapter we shall resume the consideration of these subjects, especially the proofs of the former continuity of the chalk of the North and South Downs, and the probable connexion of the denudation of the Weald valley with the origin of the Eocene strata.