those were hard siliceous slates, the slopes of the river-valleys are steep precipitous cliffs, from the summits of which we look over the old plateau, somewhat wasted, doubtless, but still approximating to its original form. Where those rocks are New Red, or Oolite, or Chalk, the slopes of the river-valleys are mostly gentle and far-spread; a few isolated hills and ridges may have summits that approximate to the level of the old plateau, but these are few and far between, and none of them, perhaps, actually reach it by one or two hundred feet.

I believe that anyone, in any part of the world, who will apply the key here given to the problem of the production of the present "form of the ground" will find that if he adjust the wards properly it will unlock it for him.

III.—On Subaërial Denudation, and on Cliffs and Escarpments of the Chalk and Lower Tertiary Beds.

By William Whitaker, B.A. (London), F.G.S.,
Of the Geological Survey of England.

[PART I.]

[A paper read before the Geological Society of London, May 8, 1867.][1]

1.—*Introduction.*

FOR some years geologists have more or less agreed in the view that the present features of the earth, whether hill, valley, or plain (with some small exceptions, as volcanic outbursts) have been formed *directly* by denudation; though *indirectly* disturbances, whether faults upheavals or sinkings, have of course had their effect in determining the flow, so to speak, of the denuding agent.

So far all is harmony, the differences of opinion being only on the comparative effect of the two forces, disturbance and denudation: but beyond this all is discord, and of late there has been much debate on the question by what means the surface of the earth has been worn away, and its rocks carved into their present form.

Many papers have been written on the origin of valleys escarpments lake-basins etc., some of which are clear statements of carefully observed facts, with unprejudiced and logical reasonings therefrom; whilst others, on the contrary, are little else than assertions of belief, and some are made up largely of groundless suppositions and false analogies. It seems hardly to be known that to fit one to take part in such an enquiry a long and careful examination of nature is needed, and that, to quote the words of a geologist of the last century, "it is not to *common* observation that it belongs to see the effects of time and the operation of physical causes in what is to be perceived upon the surface of the earth."[2]

It may not be amiss therefore to analyse the evidence given by some special classes of rocks; and to avoid being charged with advocating opinions on slight acquaintance with the formations chosen for

[1] The title given by the editor to the short abstract in the Society's Journal (Vol. xxiii. p. 265) is not quite correct.

[2] Hutton's Theory of the Earth, vol. ii. p. 238.

illustration, it may be well to state that for the last ten years I have been doing Geological Survey work in Cretaceous and Tertiary districts; work which has slowly convinced me against what I believed before (as many of my colleagues have been in like manner convinced) that the irregularities of the earth's surface have been chiefly caused by subaërial actions, by rain rivers frost and springs, forces that can be seen in action every day and therefore have come to be looked on as things of nought. I do not say however that the sea has done nothing towards the formation of these irregularities; but allow that many of the present features may have been worked out and strengthened along lines sketched out as it were beforehand by the action of the sea, which is granted I believe by most who hold the subaërial theory, although they are often misrepresented as denying that the sea does anything. In some cases the marks of marine action may have been little effaced, but for the most part they must have been destroyed when exposed for a long time to the wasting powers that reign over the land.

2.—*Authors who have advocated the Subaërial Theory.*

It seems strange that there should now be any discussion on the subject, and that instead of subaërial denudation being the accepted theory of the day it should be held by a minority only (albeit that minority contains many well-known geologists, and increases every year); for the power of atmospheric actions in wearing away rocks was most ably treated of more that 70 years ago by Dr. Hutton, whose great work[1] is not so well known as it should be, and indeed is known mostly in a secondhand way, through Professor Playfair, who followed and defended the views of his friend and master.[2] After this Mr. Scrope *proved* their truth for a special district, showing that in Auvergne rivers have worn away large masses of hard rock,[3] and said that "the same agents (rain and rivers) must have been at work everywhere else, and produced results as stupendous during the same (comparatively) recent period," and "since, by a fortunate concurrence of igneous and aqueous phenomena, we are enabled to prove the valleys which intersect the mountainous district of Central France to have been for the most part gradually excavated by the action of such natural causes as are still at work; it is surely incumbent on us to pause before we attribute similar excavations in other lofty tracts of country, in which, from the absence of recent volcanos, evidence of this nature is wanting, to the occurrence of unexampled and unattested catastrophes, of a purely hypothetical nature."

[1] The Theory of the Earth, 2 vols., 8vo.; Edin., 1795. See especially vol. 1. p. 304, and vol. ii. pp. 3–5, 98, 99, 138-40, 143 (quotation from the French), 157, 205, 209, 210, 236, 245, 295, 296, 401, 466-8, 498, 528, 529, 534, 535, 547.

[2] Illustrations of the Huttonian Theory, 8vo.; Edin., 1802. Reprinted in vol. i. of Playfair's Works, 1822. See pp. 105-7, 110-14, 373-6 of the original edition (= pp. 117-19, 122-5, 370-2 of the later one.

[3] Memoir on the Geology of Central France, 4to., Lond., 1827. Ed. 2, 8vo., 1858 (pp. 37, 38, 97, 158, 159, 205-9, 213, 244; and Geol. Mag., Vol. III. p. 193 (1866). Mr. Scrope touched on the subject before in his "Considerations on Volcanos," 8vo. Lond., 1825 (pp. 96, 97, 138, 139, 214, 215).

M. Charpentier also has expressed his belief in the formation of the valleys of the Pyrenees by their contained streams;[1] and in later times Colonel Greenwood has taken up the subject and strongly defended the Huttonian doctrine;[2] Mr. Prestwich has treated of the formation of valleys by the rivers flowing in them in the south-east of England and the north-west of France;[3] Mr. Godwin-Austen of the power of rain in the formation of deposits of loam, etc. (and therefore in the destruction of something else beforehand) and of the formation of Chalk valleys by "meteoric" actions;[4] Professor Ramsay, of the ploughing-out of lake-basins by glaciers and of the denudation of the Weald;[5] Professor Jukes, of the cutting-out of certain valleys and escarpments by subaërial action;[6] and M. Ch. Martins, of the formation of some inland needles of rock by weathering.[7]

Sir C. Lyell too has adopted the subaërial theory to a great extent, as may be seen by the following, which he has kindly allowed me to quote from a letter written shortly after this paper was read:—"I have long ago modified my opinions on denudation, and I now agree with you in considering that the escarpments round the Weald are not inland cliffs, as I formerly supposed, although at some points the sea may have entered through transverse valleys and modified parts of them. Two arguments, namely the fact of the escarpment of the Lower Greensand being parallel with that of the Chalk,[8] and the fact that the sea cuts its cliffs successively through different formations and never keeps for such great distances to one formation only, are I believe unanswerable." And with regard to the pinnacles and needles of Chalk in the valley of the Seine (see p. 452), Sir Charles continues: "Ever since I convinced myself that the sea had not gone up the valley of the Somme farther than Abbeville, the highest point at which marine shells occur, I had great misgiving as to its having been so effective as some eminent French geologists have thought in excavating the valley of the Seine. Even if the sea, or the rise and fall of the tide, extended as far as Rouen and further, I cannot conceive its having gone up so far as to have made the pinnacles of Chalk near Andelys, without supposing a submergence inconsistent with what we must infer respecting Picardy, which appears, like the Wealden district, to have kept its head above water during and since the Glacial Period."

The following authors have also, in one way or another, supported

[1] Essai. sur la constitution géognostique des Pyrenees, 8vo., Paris, 1823, p. 25.

[2] Rain and Rivers, 8vo, Lond., 1857. Ed. 2 in 1866.

[3] Phil. Trans., vol. 154, p. 247; Quart. Journ. Geol. Soc., vol. xix. p. 497 (1863).

[4] Quart. Journ. Geol. Soc., vol. vi. p. 94 (1850); vol. vii. pp. 121-6, 130, 131 (1851); vol. xi. pp. 118, 119 (1855); vol. xiii. pp. 63, 71 (1857).

[5] Ibid. vol. xviii. p. 185 (1862); Phil. Mag., vol. 28, p. 293 (1864); vol 29, p. 285. (1865); The Physical Geology and Geography of Gt. Britain, 8vo., Lond. Ed. 2. (1865).

[6] Brit. Assoc. Rept. for 1861, Trans. of Sections, p. 54; Quart. Journ. Geol. Soc., vol. xviii. p. 378 (1862); Geol. Mag., vol. iii p. 232 (1866), vol. iv. p. 444. (1867).

[7] Bull. Soc. Geol., France, 2 Ser., t. xii. p. 314 (1855).

[8] I believe that Professor Ramsay started this argument against the marine origin of escarpments.—W. W.

the theory of subaërial denudation: Dr. C. Le N. Foster and Mr. W. Topley,[1] who have worked out in detail the question of the Wealden denudation, the latter having also touched on other districts;[2] Mr. A. Geikie,[3] Mr. A. H. Green,[4] Mr. G. Maw,[5] Mr. A. R. Wallace,[6] Mr. A. B. Wynne,[7] and, to some extent, the Rev. O. Fisher.[8] In far countries, too, Professor Dana,[9] Professor Hind,[10] Mr. J. P. Lesley,[11] Sir W. Logan,[12] Dr. Newbury,[13] and Professor Whitney,[14] in America; Dr. Haast, in New Zealand;[15] Mr. T. Belt, in Nova Scotia;[16] and Dr. Rubidge, in South Africa,[17] have borne witness on the same side.

It is remarkable that most of the subaërialists are of English race (using that name in the broadest sense), but few foreign geologists allowing that anything but the sea or a cataclysm can have given rise to hills or valleys of large size; and also that a great number of these subaërialists are or have been employed on Government Geological Surveys, and therefore have been accustomed to be constantly in the field, earning their bread by their hammers, and spending their days in the more or less detailed examination of the geological structure and physical features of the districts which it has been their duty to survey and describe.

3.—*General Remarks.*

The following pages treat of escarpments and not of ordinary valleys, because the formation of the latter by other agents than the sea is now more generally understood. The same kind of argument holds in both cases, but the subaërial cutting out of valleys is at first sight clearer than that of escarpments, and perhaps is supported by more direct proof.

1 Quart. Journ. Geol. Soc., vol. xxi. p. 443 (1865).

2 Geol. Mag., Vol. III. p. 435 (1866), and Vol. IV. p. 184 (1867).

3 Notes of Travel by Vacation Tourists, 1861.—The Geology and Scenery of Scotland, (1865).

4 Geol. Survey Memoir on Sheets 81 N.W. and S.W., p. 86 (1866).

5 Geol. Mag., Vol. III. pp. 344, 439, 575 (1866).

6 Quart. Journ. of Science, vol. iv. p. 33 (1867).

7 Mem. Geol. Survey, India, vol. v. p. 201 (1866).—Geol. Mag., Vol. IV. pp. 3, 345 (1867).

8 Quart. Journ. Geol. Soc., vol. xvii. p. 1 (1861).

9 United States Exploring Expedition during the Years 1838-42, vol. x., Geology, 4to., Philadelphia, 1849, pp. 384–92, 526–33, 670-7.—Manual of Geology, 8vo., Philadelphia, 1863, pp. 635–42, 676.

10 Quart. Journ. Geol. Soc., vol. xx. pp. 125, 126, 128–30 (1864), where references to the author's other notes on the subject are given.

11 Notes on a Map to Illustrate Five Types of Earth-Surface, 4to., Philadelphia, 1866.

12 Geol. Survey, Canada—Rept. of Progress to 1863, 8vo., Montreal, p. 889.

13 Part 3 (Geology) of Lieut. Ives' Report on the Colorada River of the West. 1861. References to other remarks on denudation by this author are given in Professor Hind's paper referred to above.

14 Report on the Geological Survey of the State of Wisconsin, vol. i, pp. 117–26 (1862).

15 Report on the Geology of Canterbury, New Zealand;—and Quart. Journ. Geol. Soc., vol. xxi. pp. 129, 130 (1865).

16 Quart. Journ. Geol. Soc., vol. xx. p. 463 (1864)—in abstract only. The paper has been printed in full in Trans. Nova Scotian Institute of Nat. Sci., Vol. I. Part iv. p. 91.

17 Geol. Mag., Vol. III. p. 88 (1866).

There are many points which have already been more or less gone into in detail by others, and therefore need but a passing notice here,[1] amongst them are the following:—

(1.) Escarpments always run along the strike, whilst actual cliffs rarely do so (and then only for a short way), but cut through rocks without regard to it; whereas if both had been formed by the sea they should be more alike.

(2.) The bottom of an escarpment does not keep to one level, but rises slowly inland, or towards the watershed, that is in accordance with the drainage-level of the country and without regard to the level of the sea. Professor Ramsay has called my attention to the fact that sometimes the base at one place is higher than the top at another.

(3.) Sea-cliffs run comparatively straight, or rather in curves of large radius, through homogeneous rocks (of course through a succession of hard and soft beds they have an irregular outline); but on the other hand escarpments wind about, which they should not do if they were simply old cliffs. Here the saying, "the exception proves the rule" holds good; for the wonderfully intricate coast-line of Norway and of other like countries is well known to have been caused by the sinking of the land, and not by the action of the sea, the wearing-power of which is as nothing up the deep narrow winding fjords, so clearly seen to be submerged valleys.

(4.) If escarpments have been formed by the sea, there ought to be at their foot some resultant of that agent, a beach or other marine deposit; but this is not the case (except, perhaps, in some places where masses of Boulder Drift end near the bottom of a ridge), whatever deposit there is being such as one would look for from subaërial actions.

(5.) It has been said that any beach which there may once have been at the foot of an escarpment has perhaps been destroyed by subaërial denudation wearing back the ridge. To this it has been answered that such a concession to the power of subaërial action is really much the same as giving up the question at issue in their favour; for if they are powerful enough to do so much they could surely do more in a longer time.

(6.) Sometimes two escarpments (facing the same way) run roughly parallel and near together for miles, as those of the Chalk and Lower Greensand in Surrey and Kent, and those of the Chalk and the Portland Stone in part of the Isle of Purbeck. To suppose these formed by the sea implies that there have been two long parallel ridges of land, each consisting of a separate formation, divided by a narrow strip of sea, the like of which is not to be seen now-a-days. Moreover, the sea would have little power to act in so narrow and sheltered a place, but would be as harm-

[1] It would be overburdening this paper with foot-notes were I to acknowledge the many sources whence some of the following arguments have been in great part derived; enough to refer the reader to the list of authors given before. I would gladly have quoted largely from Hutton, Playfair, Scrope, and others, but the paper would have been much lengthened thereby.

less as in the Norwegian fjords, where I have seen the old ice-scratches run down to (and, perhaps, below) high-water-mark, uneffaced by the waves. It should be remarked too that in the above cases the Chalk escarpment is mostly the larger of the two; whilst according to the marine theory it should clearly be the smaller, because the inner and therefore the more sheltered.

As far as I know the above arguments have never been thoroughly answered, much less disproved, by those who hold that the sea has been the great, if not the only, agent employed in forming escarpments. Until this has been done the marine theory has little foundation, and indeed is simply a convenient supposition, put forward to avoid a seeming difficulty, not a theory upheld by sound inferences and founded on well-established facts.

To these may be added other remarks that have a general bearing on the discussion, which, I believe, have not been treated of in such detail as the foregoing, and which refer chiefly to the style of argument that has been put forward against subaërialists.

(7.) The preservation of old ice-scratchings has often been brought forward as an argument for the powerlessness of surface-actions in wearing away rocks; but really it is not a valid one, for it is not enough that in *some* places the weather has not acted on rocks for a very long time, it must be shown that such is the case in *most* places; or, in other words, that the weather *hardly ever* wears away rocks, not that it does not always do so.

(8.) It has been objected that the subaërial theory needs a vast time to account for the work done. This is an objection only, not an argument, and few subaërialists can be afraid of allowing any quantity of time for the work of those quiet ceaseless actions which they look on as powerful enough to wear away the hardest rocks. A late writer, one I believe who is known from his papers on subjects relating to the connection of Geology and Archæology, has well said, in a Review of one of Mr. Prestwich's papers, "the main argument, as to the process of excavation (of the valleys) and of the length of time necessarily involved in it will, we are confident, eventually meet with general acceptance, even if the rising school of geologists . . . . may be induced to draw more largely than Mr. Prestwich on the enormous balance of past time which stands in their favour in the Bank of Nature."[1]

(9.) The occurrence of needles in places far from the sea has been brought forward as an argument for marine denudation in those places, and Sir C, Lyell, in the last edition of his "Elements of Geology,"[2] speaks of the needles of hard Chalk high up the valley of the Seine as "evidence of certain escarpments of the Chalk

[1] Geol. Mag., Vol. II., p. 26. (1865.)

[2] 1865. pp 351–5. As Sir Charles does not now hold that these needles are signs of the action of the sea (see before, p. 449), it might be thought needless here to controvert that idea. However, as it is contained in the last edition of his "Elements," a work constantly referred to by geologists, I have let this paragraph stand.

having been sea-cliffs." Now, as will be noticed further on, needles are formed by atmospheric actions at the top of high cliffs; indeed, in nearly all cases they are formed *from above*, by something that acts downwards along lines of joint, or fissure; and I can see no reason why they should not be formed inland, under favourable circumstances, as well as on the coast; though of course the latter is one of the most favourable parts for the weather to wear away rocks, by reason of the carrying away of the débris by the sea. Moreover the question of the formation of such inland needles in France by subaërial actions has been worked out by M. Ch. Martins in a paper noticed before.

(10.) It is however needless to take up the argument in this way; for before anyone calls forward witnesses of such doubtful character to prove the marine denudation of a long winding valley like that of the Seine, he is bound to show that the sea can make such a valley, or to point to some place where it actually is doing such work: just as those who say that the sea makes escarpments are bound to show that it can and does do that sort of work now.

I need hardly say that both these things are impossible. None of the advocates of marine denudation have given the proofs and examples needed; and they never will, for the simple reason that there are none to give.

This is a matter of reasoning simply, not of scientific truth alone, and it would be well if the rules of the former were a little more heeded by those whose wish should be to reach the latter, as else they stand little chance of getting at their object. One of my colleagues, who is a strong believer in the sea, and nothing but the sea, has gone so far as to say that "attempts at proving or disproving the soundness of speculations on natural phenomena by a logical syllogism are scarcely creditable to men of science."[1] To such a statement I must strongly object, for it is clear that the first thing needed of an argument is that it should be logical. One should not be surprised, however, at the advocates of the marine formation of valleys and escarpments looking down on logic (as an unpleasant test to apply to their arguments) and scorning syllogisms, or in other words despising true reasoning, unless they follow and "overcome those prejudices which contracted views of nature and magnified opinions of the experience of man may have begotten, prejudices that are apt to make us shut our eyes against the clearest light of reason,"[2] and give up one of the most illogical theories that the ingenuity of geologists ever invented.

(11.) Some folk begin by misrepresenting the followers of Hutton, and then go on triumphantly to disprove the theory which they have misunderstood, or sometimes I fear have not taken the trouble to understand. Thus it has been said that the Huttonians (if that old name may be used in the limited sense here meant) deny the power of the sea, and say that rivers, glaciers, rain, and frost have done everything. Now nothing could be further from the truth;

[1] Geol. Mag., Vol. III. p. 571.
[2] Hutton, "Theory of the Earth," vol. ii. p. 367.

for they allow that it has been the agent employed in those great planings-down of solid rocks of which such good evidence is given by the appearance at the surface of formations that would otherwise be deep down in the earth, and by the great unconformities shown by rocks of one age resting on the upturned truncated edges of others vastly older. In comparison to these huge, and, as they may be called, "continental" denudations and removals of rock, the present irregularities of the earth's surface are mere scratches, though to our eyes grim mountains or sheltered valleys; and until this is thoroughly understood by geologists there is small hope of their agreeing in the theory of subaërial denudation.[1]

A steam-hammer can crack a nut certainly; but man does not commonly use so strong an engine for so small a work, it would be a waste of power, nut-crackers do just as well: neither does he use the steam-plough for the tillage of a garden. Is man more careful of his resources than nature? Should we expect the latter to be wasteful of her strength and to use her steam-plough, the sea, for small work when she has plenty of small tools to do it with? Surely not: nature does not waste power; and rather does great things with small means, than small things with great means. She uses the sea to carve out continents and islands; rain and rivers to cut out hills and valleys: just as the former has deposited wide-spread masses of rock miles upon miles in thickness, and the latter here and there some thousand feet of fresh-water beds.

IV.—On some new Terebratulidæ from Upware.

By J. F. Walker, B.A., F.G.S., etc.

(PLATE XIX.)

In my paper published in the July Number of this Magazine I gave a list of the *Terebratulidæ* from the Upware deposit; since then I have further examined them, especially with regard to the shell I named *Terebrirostra neocomiensis*. There are clearly certain well-marked differences between the Upware species and that fossil. The shell I called *T. hippopus* also proves to be a new species. Some of the specimens of the small variety of *T. oblonga* closely correspond with *T. Fittoni* of Meyer, which was described in the first volume of this Magazine; it was found at Godalming in Surrey. I have also some specimens of *T. Dutempleana* from the Upware bed; and I have no doubt the affinities of that shell with *T. prælonga* (a species not uncommon at Upware) will be able to be determined. (See Cretaceous Brachiopoda, by T. Davidson, page 59).

Waldheimia Davidsonii, sp. n., Figs. 4*a.–d.* — Shell elongate ovate, surface finely striated, striæ dichotomous at various distances from the hinge, and marked by concentric slightly raised lines of growth. Beak rather long, nearly straight, foramen medium-sized,

[1] Professor Ramsay has noticed the great thickness of solid rock that must have been denuded in Wales (Mem. Geol. Surv. vol. i. p. 297, and plates. 4, 5, 1846; and vol. iii. p. 236, and pl. 28, 1866). I believe that the former of these was the first attempt at showing the vast amount of denudation that has taken place.

segregation. A paper, on this subject, of Mr. George Maw's, put into my hands in May, 1863, gave me the first suggestion of this possibility.

I shall endeavour, as I have leisure, to present such facts to the readers of this Magazine as may bear on these three enquiries; and have first engraved the plate given in the present number in order to put clearly under their consideration the ordinary aspect of the veins in the first stage of metamorphism in the Alpine cherts and limestones. The three figures are portions of rolled fragments; it is impossible to break good specimens from the rock itself, for it always breaks through the veins, and it must be gradually ground down in order to get a good surface.

Fig. 1 is a portion of the surface of a black chertose mass; rent and filled by a fine quartzose deposit or secretion, softer than the black portions and yielding to the knife: neither black nor white parts effervesce with acids : it is as delicate an instance of a vein with rent fibrous walls as I could find (from the superficial gravel near Geneva).

Fig. 2 is from the bed of the stream descending from the Aiguille de Varens to St. Martin's. It represents the usual condition of rending and warping in the flanks of veins caused by slow contraction, the separated fragments showing their correspondence with the places they have seceded from; and it is evident that the secretion or injection of the filling white carbonate of lime must have been concurrent with the slow fracture, or else the pieces, unsupported, would have fallen asunder.

Fig. 3 is from the bed of the Arve at St. Martin's, and shows this condition still more delicately. The narrow black line traversing the white surface, near the top, is the edge of a film of slate, once attached to the dark broad vertical belt, and which has been slowly warped from it as the carbonate of lime was introduced. When the whole was partly consolidated, a second series of contractions has taken place; filled, not now by carbonate of lime, but by compact quartz, traversing in many fine branches the slate and calcite, nearly at right angles to their course.

I shall have more to say of the examples in this plate in connection with others, of which engravings are in preparation.

II.—On Subaërial Denudation, and on Cliffs and Escarpments of the Chalk and Lower Tertiary Beds.

By William Whitaker, B.A. (London), F.G.S.,
Of the Geological Survey of England.

[PART II.]

4.—*Chalk Escarpments.*

THE graceful outlines, smooth curves, and flowing contours of the Chalk hills are well known to southern geologists; indeed these hills are the most marked feature of the south-east of England. Those who hold that their form has been given by the sea, point to the winding ridge, and say how like it is to many a coast with its succession of capes and coves; even so distinguished a writer as Sir C. Lyell remarking that "the geologist cannot fail to recognise in this view (of part of the South Downs) the exact likeness of a sea-cliff." [1] And truly it is so; but let us examine this likeness more closely, and it will be seen that the argument founded on it, plausible enough on the surface, is superficial only, and fails utterly when rigorously tested.

For this purpose let us place ourselves at some spot whence a large extent of these hills may be seen. None perhaps can be better than the hill crowned by Totternhoe Camp, in Bedfordshire, a projecting spur of the lower ridge of the Chalk (for there are two escarpments in that neighbourhood, one formed by the Chalk Marl and the bottom part of the flintless Chalk; the other and larger by the mass of the latter and the bottom part of the Chalk-with-flints). Thence let us look eastward southward and westward along the higher range, of which a long expanse unfolds itself to the view, across the Thames even to the "White Horse Hill" in distant Berkshire. The screen of even-topped combe-cut hills, shutting off all view beyond, with its succession of swelling headlands and in-curved bays, at once impresses the mind with the notion of an old coast-line, and but little imagination is needed to picture the sea beating furiously against the jutting capes, or rippling gently up the sheltered hollows.

But having indulged in a very pleasant day-dream, and transported ourselves for the time to Dover cliffs, Beachy Head, or the great Chalk buttresses of the Isle of Wight, let us descend to sober prose and our mental photograph will quickly fade, and soon be but "the baseless fabric of a vision, leaving not a wreck behind." Reason asks what coast is this ridge like? it is not enough that it should be like a coast, but it should be *like a Chalk-coast*: "it is not a mere resemblance that should correlate different things; there should be a specific character in everything that is to be generalised." [2] The answer comes at once: it is like a coast along rocks of different hardness (the softer yielding to form bays, the harder resisting to form headlands), and not like one along a rock of much the same nature throughout—it is *not* like a *Chalk-coast.*

Now let us examine the great escarpment more closely. Firstly, we shall find that at its foot there are powerful ever-flowing springs, thrown out generally at the out-crop of the Totternhoe stone,[3] which of course contain much carbonate of lime, as is shown by the not uncommon occurrence, further down the streams, of twigs thickly encrusted. Such constant taking away of matter from the Chalk must wear away that rock; and, given unlimited time, is enough to get rid of any quantity of it. This is almost a mere matter of multiplication; if so many tons are carried away in a year, a

[1] Elements of Geology, Ed. 6, p. 359 (1865). Sir Charles now allows, however, that the likeness is deceptive, see p. 449.

[2] Hutton, "Theory of the Earth," vol. i. p. 489.

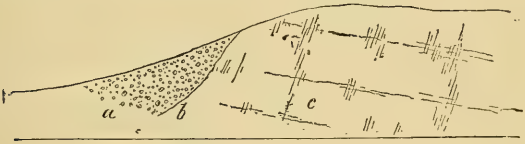
[3] The top bed of the Chalk Marl, see Quart. Journ. Geol. Soc., vol. xxii. p. 398.

thousand times as many will be carried away in a thousand years, other things being equal, and so on.

Secondly, if the escarpment were an old sea-cliff weathered down into a slope, it ought to show some such section as that in Fig. 1, in which a *talus* rests against the weathered face of the cliff, only the higher part of the hill being of bare Chalk. But this is not the case; large pits are common along most Chalk escarpments, and they show a more or less clean face of rock from top to bottom. The supposition that subaërial denudation may have cut back the hill, and destroyed the cliff with its *talus* and beach, has been noticed before. I question, too, if there is a known case of an old cliff that has weathered to so long and smooth a slope as that of a Chalk escarpment.

Next let us turn to the country at the foot of the hills, taken up by the flintless Chalk and the underlying beds. What sort of surface-deposit is found there? is it made up of water-worn pebbles like those on our present shores? No indeed, but we commonly find, on the contrary, broken and subangular flints, like those of our old river-gravels, sometimes simply scattered over the surface, at

Fig. 1.—Section of an escarpment on the supposition that it is an old cliff.



a. Talus. *b*. Face of old cliff. *c*. Bare Chalk.

others abundant enough to form small patches of gravel. In Buckinghamshire there are thin spots of such far out on the wide plain of the Gault. What can these flints be but the insoluble residue of the great mass of Chalk that has been slowly dissolved away, not pounded and worn by the waves? the remains of which latter kind of process should be looked for rather in such deposits as the old Tertiary pebble-beds of Kent, and the shingle-flats of the south-eastern coast.

It is not at one spot only that these things may be seen, but more or less along Chalk escarpments generally. In some places too a small stream runs for miles at or near the foot of the ridge: thus a branch of the Mole near Dorking, and a branch of the Stour near Ashford.

[Whilst the first part of this paper was in the press I was taking a holiday-ramble in the Isle of Purbeck, and noticed there a good and marked example of the fact that the bottom of an escarpment is sometimes at a higher level at one place than the top at another. The level of the Chalk ridge falls westward from Nine Barrow Down to Corfe Castle by three sloping steps, giving rise to four different levels (not counting the still lower conical hill on which the castle stands), the western of which is lower than the bottom of the escarpment under the higher parts, as shown in Fig. 2.

This is an exceptional case of quick fall in the level of a Chalk escarpment, and I cannot see how such a ridge can have been formed as a sea-cliff, which has of course a level base. To explain away the difficulty of the rise of the base-line by supposing that there have been local sinkings or upheavals, is a groundless and unwarrantable assumption until such changes have been *proved,* not simply imagined.]

Fig. 2.—Rough outline of the form of part of the Chalk ridge in the Isle of Purbeck.

x x. Sea level. *a b.* Top of Chalk ridge.
1, 2. Foot of the ridge. 3. Level of highest part of the foot of the ridge.

5.—*Tertiary Escarpments.*

The escarpment of the Lower Tertiary beds is neither so high nor so steep as that of the Chalk; nevertheless it often forms a well-marked ridge with a somewhat winding course, as on the north and north-west of London, from Rickmansworth to beyond Hatfield, along which line the Colne flows south-westward and the Lea eastward at the foot of the hills, receiving on their way streamlets that run down the slopes and carry off the sand and clay of which those slopes consist. Some of these streams are simply the result of the drainage of a clay-country, others start as springs from the Drift gravel which caps the London Clay on the high grounds, and some end their course in swallow-holes in the Chalk.

The thickly wooded hills of "the Blean," between Canterbury and Faversham, show many examples of swallow-holes, the largest of which have been described by Mr. Prestwich.[1] When near the top one sees springs, thrown out from the gravel by the London Clay, and down the slopes there are small water-courses; but outside the close woods, which end mostly at the foot of the hills, the ground is generally dry, the water having sunk into holes at the junction of the Tertiary beds and the Chalk, which may commonly be seen at the re-entering angles of the line of outcrop of the latter formation. From the southern point of these hills to Grove Ferry and the Reculvers, the London Clay, which forms by far the greater part of that district, is wholly cut off by the Stour and the Wantsume channel, not a particle I believe existing on the right side of the river, and the Oldhaven and Woolwich Beds occur only as outliers; in other words, the left bank of the Stour is an escarpment of London Clay, etc.

In many places the outcrop of the Chalk, and of the beds between it and the London Clay is masked by a loam, which is nothing but

[1] Quart. Journ. Geol. Soc., vol. x. p. 222 (1854).

the "rainwash" of the slopes of clay and sand, and is sometimes thick enough to be worked for bricks. If so much has been left, how much more must have been washed away altogether,—all, be it remembered, being the product of mere surface-denudation.

London Clay hills show many traces of landslips, as may be well seen on the left side of the Lea, where some of the sharper slopes are made quite irregular by the many falls.

Whilst, therefore, Chalk is in great part carried away in chemical solution, the clays and sands of the Tertiary beds are wasted by mechanical means.

Where the dip is at a high angle the Lower Tertiary formations have no escarpments, or, at all events, give rise to but a slight feature, as in the Isle of Purbeck, the Isle of Wight, and Surrey; whilst where the beds are flat, or dip at a very small angle, they have a good escarpment, as in Berkshire, Hertfordshire, and Kent. The great difference which the amount of dip has had in causing the denuding powers to form a flat or a slope may be well seen in the Isle of Wight, where the vertical beds of Alum Bay are in a valley between the Chalk ridge and the rising ground formed by the gently inclined higher series of Headon Hill.

West and north-west of London there is a peculiarity in the range and outcrop of the Lower Tertiary beds worthy of notice here. The escarpment trends nearly north-east and south-west along a line through Twyford, Rickmansworth, and Hatfield, roughly parallel to which, and a few miles from it outward, are a number of outliers (like skirmishers thrown out from the main body) ranged along a line from the hills near Wargrave and Beaconsfield, through Chalfont St. Giles, Sarratt, Abbot's Langley, St. Alban's, Digswell, Datchworth, and Bennington. Again, inwards from the escarpment, but also parallel to it and a few miles from it, there are a few inliers along a line through Windsor, Pinner, and Northaw. The outliers I look on as the relics of a former escarpment, and the inliers as the signs of a future one. The outliers mark a line where denudation has been delayed (I do not say stopped); the escarpment perhaps one where it is now delayed; and the inliers one where it will be delayed (of course on the supposition that no great physical change takes place), when the part between them and the present escarpment will be cut off as outliers. Each of these lines is in great part, I believe, through points where a slight change of dip takes place, which may have in some measure enabled the beds better to withstand denudation in the case of the outliers, or may have made them fall an easier prey to it in the case of the inliers, there being an inward dip in the former and an outward dip in the latter. Further out in the Chalk district there are traces of another line of outliers, better marked westward, along a line through Lane End (near Wycombe), Turville Common, Nettlebed, and Woodcot Common (east of Goring). The inner line merges into that of the escarpment near Reading, and further westward the outer line does so too. I have noticed like arrangements in line in Kent, but none so marked as the above, perhaps because the dip is generally less on the northern side of the London basin than on the southern, so that the beds have a greater chance of spreading over a wider tract.

Of course delays in denudation may be owing also to change of condition, climatal or otherwise.

6.—*Chalk and Tertiary Cliffs.*

It is usual to talk of cliffs as the work of the sea alone; and those who say that subaërial actions are too weak to do the work of denudation in forming hills and valleys are wont to point to what is now going on along our shores as evidence that the sea and the sea only is nature's great tool for making ridges. I am willing however to meet them on their own ground, thinking that if it can be shown that the sea *alone* does not make the cliffs, but is very largely helped by those atmospheric actions which they despise, their statements as to the powerlessness of those actions will have all foundation destroyed, and will therefore fall to the ground, carrying with them the theories which they support.

Let us examine the Chalk-coast of Kent. The cliffs are for the most part nearly vertical; indeed I can call to mind but one place where this is not the case, the well-known Shakspeare's Cliff, the higher part of which is a sharp slope, whilst near the bottom it is slightly overhanging (on account of a hard bed which stands out). Sometimes they are quite vertical; hardly ever are they undermined. Now if made by the sea alone, which can act only at their base, surely they should mostly overhang; but, in fact, they often project slightly at the bottom by a series of small steps. It is clear therefore that the upper part wears away as quickly as the lower, and as the sea can hardly attack the top of the cliff, one hundred feet or more high, one must look about for some other wearing power that can.

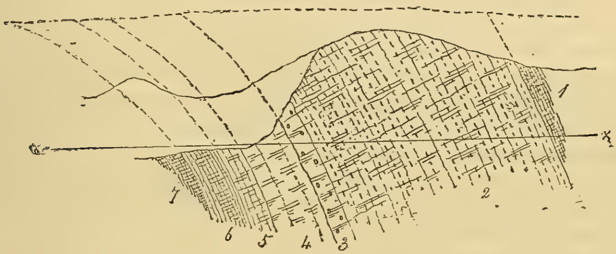
For that purpose let us go to the cliff-top and see what is going on there. We shall find that the action of the weather is nearly everywhere separating masses of Chalk, some of which, from the slow dissolving away of the surrounding rock, stand out for many years as pinnacles or needles, whilst others are soon hurled to the bottom. Where the Chalk is most jointed there of course the power of frost has most chance of showing itself: where too there are large pipes of sand and clay in the Chalk small needles are common along the top of the cliff, as in parts of the coast of Normandy.

When the softer and more yielding beds below the Chalk crop out near the base for some distance, the fall of the cliff sometimes takes place on a very large scale, and "undercliffs" are formed. Thus at Folkestone the porous yielding Upper Greensand has given way to the influence of springs and to the pressure of the great overlying mass of rock, which has in consequence slid down over the moist slippery surface of the Gault. The undercliff of the Isle of Wight is far longer and broader, and the nearly vertical cliff of hard Upper Greensand, which has resulted from its formation, is at a great height above the sea and often a third of a mile distant therefrom, so that no one can well call it a sea-cliff.

In Kent the Chalk escarpment and the Chalk cliff cut one another obliquely, whilst at the western end of the Isle of Wight the two are for a wonder parallel; but alas for the advocates of the marine formation of escarpments! this latter case in no way helps their theory, for putting aside the consideration of the fact that the cliff leaves the Chalk and turns southwards to cut through lower beds, one can see at a glance that the formation of the cliff has in great part destroyed the feature of the escarpment, of which only the curved top remains, as shown in the section below. Moreover

Fig. 3.—Section showing the relation of the Chalk cliff and the Chalk escarpment in the Isle of Wight.

S. N.



Scale about six inches to a mile.

1. Lower Tertiary beds. 2. Chalk with many layers of flints. 3. Chalk with few flints. 4. Chalk without flints. 5. Chalk Marl. 6. Upper Greensand. 7. Gault. x x. Sea-level.

The broken lines show the form of the ground and the continuation of the beds, which must have existed before the sea-cliff was worn back into the escarpment, and which correspond to the same as they now exist in those parts away from the sea.

The dotted lines show the further extension of the beds until cut off by the "plain of marine denudation" made before the exposure of the land to subaërial actions.

the sea has utterly destroyed the Chalk ridge between the Needles and Handfast Point in Dorsetshire. Along all Chalk-coasts, indeed, the antagonism of the two denuding powers is well shown, the sharp cliffs cutting across the gently curved outlines of hill and valley that have been caused by long continued subaërial actions, the sea levelling what these have furrowed.

Let us now turn to the Tertiary coast of Kent. The foreshore of the Isle of Sheppey (and also of the greater part of the mainland from Whitstable to beyond Herne Bay) consists of a plain of London Clay sloping gently seawards. The cliffs are mostly sharp irregular broken slopes, not altogether cut out by the sea, but formed by the slipping downwards of masses of London Clay and of the overlying Bagshot Sand and Drift gravel, which last two form a more vertical ridge at the top of the slope.

Now it is clear that the waves do not rush up to the top of the cliff and bring down the clay sand etc., but that the fallen masses owe their fall to frost, rain, and heat: the heat of summer to dry up the beds, and by shrinkage to form fissures down which the rain may soak; rain to soften and make slippery; frost to divide mass from mass by its irresistible expansive power. That the slips take place from the top is indeed well known, and good figures of one of them have been given by Mr. Redman.[1] I have myself seen a large and fresh one, and noted the occurrence of a crop of wheat some way down the slope.

The coast from the Reculvers westward for about two miles is of a somewhat different character, by reason of the rise of the sandy beds below the London Clay; but still the waste of the cliff is from the top, masses of the clay being constantly thrown down to the foot. The shape of the cliff is often different, the clay forming a slope at the top and the sands a more or less vertical wall below. Another agent too comes into play here—the wind, which when strong blows away much of the fine loose sand (Oldhaven Beds[2]) next below the London Clay. At Oldhaven Gap there is a well-marked cliff running inward from the shore at right angles, and with a broken slope on the other (eastern) side. This "chine," which is about 300 yards long, and the bottom of which is but little above high-water-mark, has clearly been formed by land-water, although for the greater part of the year the insignificant watercourse along it is quite dry, for the sea has never touched its base, and I believe that it has been cut farther inland within the memory of man.

The sea, therefore, does not *by itself* destroy the land, but is largely helped by atmospheric actions. The former carries away what the latter bring within its reach. Without the help of rain, frost, etc., the sea would spend its force on compact and therefore on comparatively unyielding rocks: without the help of the sea these subaërial forces would soon mask solid cliffs with slopes of débris, and thus vastly decrease their own destructive power. The two destroying powers working together in different ways, the sea horizontally from below, the other set of agents vertically from above,[3] cause tenfold the destruction of coast that either could do alone.

Most observers indeed are more or less agreed as to the waste of some cliffs from above, though so far as I know, this knowledge of the power of surface-actions on the coast has not been applied to the question of denudation. Sir C. Lyell indeed has said in his last work, that "the waste of the cliffs by marine currents constitutes on the whole a very insignificant portion of the denudation annually effected by aqueous causes . . . . . the action of the waves and currents on sea-cliffs, or their power to remove matter from above to below the sea-level, is insignificant in comparison with the power of rivers to perform the same task."[4]

7.—*Comparison between Cliffs and Escarpments.*

From what has been remarked above therefore it is clear that

[1] Proc. Inst. Civ. Eng. vol. xxiii. p. 186, 1865, where, and in an earlier paper by the same author (ibid. vol. xi. p. 162, 1854), the destruction of the South-east coast of England is well treated of.

[2] Quart. Journ. Geol. Soc. vol. xxii. p. 412.

[3] See Jukes, Brit. Assoc. Rep. for 1862, Trans. of Sections, p. 61.

[4] Principles of Geology, Ed. 10, vol. i. pp. 565, 570 (1867).

rivers often run along the foot of Chalk and Tertiary escarpments, whilst, on the other hand, it is very rare for the sea to do so.

Again, an escarpment is remarkable for the comparatively uniform level of its top for long distances, any change therein being by a gentle slope; whilst the height of a range of cliffs is ever varying, and that suddenly and with sharp slopes. Escarpments, too, are nearly always the highest part of a district, the ground falling from them on both sides; cliffs, however, are very rarely so, but are often backed by higher ground; indeed those cases that I know of Chalk cliffs being through the highest ground are just where they cut through the escarpment, as on the north of Folkestone and at Beachy Head. The same kind of reasoning that has been used with reference to the features of the Chalk and the Tertiary beds may be applied to other formations; and how, therefore, an escarpment can be an old sea-cliff passes my understanding, for the two have nothing in common and much in opposition, as may be clearly seen from the following table:—

Comparative Table of the Distinctive Features of Escarpments and Cliffs.

Escarpments.	Cliffs.
(*a*) Run along the strike, or in other words, keep to one formation throughout.	(*a*) Rarely run along the strike, but at all angles to it, and cut through many formations in succession.
(*b*) Tops more or less even and nearly flat.	(*b*) Tops mostly very uneven.
(*c*) Form the highest ground of a country, overlooking other parts.	(*c*) Rarely through the highest ground of a country, but mostly backed by higher ground.
(*d*) Very rarely have the sea at their foot, but often springs and watercourses.	(*d*) Sea at their foot.
(*e*) Often run in more or less winding lines.	(*e*) Run nearly straight, or in curves of very large radius, when through homogeneous rock, and when not broken through by valleys.
(*f*) No beach at their foot.	(*f*) Mostly a beach at their foot.
(*g*) Are now being destroyed by the sea in places where the sea touches them.	(*g*) Are now being made by the sea (aided by atmospheric actions).
(*h*) Bases rise towards the watershed and have nothing to do with the sea-level.	(*h*) Bases at the sea-level.
(*i*) Those of successive formations run in more or less parallel lines for long distances, with plains, vales, or valleys between.	(*i*) No such parallel arrangement known, long fringes of land divided by belts of sea not being common, except in such cases as Coral Islands, where the features have been caused by growth, not by decay.

What can be more different than these two? It is for those who say that escarpments are old sea-cliffs to answer the question, and until that has been done they have little reason on their side.

8.—*Conclusion.*

All geologists know that rivers have made great deposits, as for instance the Wealden Beds, and therefore I do not see how they can avoid allowing that rivers, etc., have been the agents in effecting a great amount of denudation, The solid matter of the Wealden Beds must have existed somewhere before, and must have been worn away by subaërial actions and carried off by streams (the sea being quite out of the question): more too must have been worn away than was deposited afterwards by the rivers, for much would be carried out to sea to form a marine deposit. Of course freshwater beds are both less common and thinner than marine beds, but so also, as aforesaid, the comparatively trifling denudation that has formed our hills and valleys is of far less amount than that which has planed down vast tracts of country and carried off therefrom a great thickness of rock. Perhaps, indeed, the proportion that the effects of marine denudation bear to those of subaërial denudation is not far from the same as that which marine deposits bear to freshwater deposits.

To those who say that subaërial agents are too small and too weak for the work which has been put to their credit, it may be answered that unlimited time would get over that difficulty; and it should be borne in mind that good evidence has been brought forward that in late geological times our climate was far more severe than now, and that there may have been a far more rainy period before the present order of things was established; or in other words, that the agents in question were far more powerful than they now are in these islands. Great change indeed has taken place in historic times; the felling of forests, the draining of land, the embanking and canalization of rivers, the reclaiming of marshes, and the like human handiworks having had their effect in lessening rainfall and floods, and therefore also the wearing action of surface water.

As astronomy has proved the existence of almost boundless space, so geology needs almost boundless time. The former science gives us our liveliest picture of infinity, and the latter our best idea of eternity. When astronomers talk without any opposition of immeasurable space, surely geologists should be allowed immeasurable time. The last Wollaston Medallist has eloquently said, "The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound which to the ear of the student of nature seems continually echoed from every part of her works is Time! Time! Time!"[1]

Lastly, it seems to me that the discussion on the question of denudation has been argued on a wrong foundation. Surely, if we can explain the facts and appearances we see by actions and operations that can be seen going on at the spot now, we are bound to take such explanation until it can be disproved, or until a better one can be given, and we have no right to call in the aid of other and distant operations, without there is some good sign of their having been once present (thus for instance with regard to many rock-basins now far from glaciers, there are unmistakeable signs of their once having contained ice). As a simple matter of reasoning therefore, apart from all scientific truth, we are bound to accept the theory of subaërial denudation until it can be put aside. Geologists should not call on those who hold it, and who show its agreement with things seen, to disprove other theories; but rather should expect its adversaries to disprove it, and to show firstly, that rain,

[1] Scrope, "The Geology, etc., of Central France," Ed. 2 (1858), p. 208.

rivers, ice, springs, damp, and frost are powerless to wear away rocks and to cut out escarpments valleys and rock-basins; and secondly, that the sea can do and does such work. This, no light task truly, must be done, if it can be done, not by mere assertions of individual opinion, or mere statements based on hasty and prejudiced observations, but by hard work and sound reasoning. Not with us, but with our opponents, lies the *onus probandi.*

ERRORS IN THE FIRST PART OF THIS PAPER.

Page 451, line 16 from bottom, for "action" read "actions."
Page 451, line 11 from bottom, for "Portland Stone in part of the Isle of Purbeck" read "Purbeck and Portland Beds in Dorsetshire."
Page 453, line 15 from bottom, after "follow" insert "us."

III.—ON THE "LINGULA FLAGS," OR "FESTINIOG GROUP" OF THE DOLGELLY DISTRICT.

By THOMAS BELT, F.G.S.

[PART I.]

THE strata lying above and below the Lingula Flags have already been well described and illustrated: the Menevian Gronp below, by Messrs. Salter and Hicks, and the Tremadoc Group above, by Messrs. Homfray, Ash, and Salter. The great mass of strata lying between has not fared so well, though several notices of it, to which I shall refer, have appeared. In the present paper I propose to describe these strata in detail; and the remarks I have to offer embody the results of three years' researches, during part of which I have had the advantage of the company and able co-operation of Messrs. Ezekiel Williamson and J. C. Barlow, whose discoveries I shall have to mention in my description of the rocks and their fossil contents. To facilitate the study of the district around Dolgelly, which is exceedingly faulted and complicated, I have carefully mapped out nearly the whole of the rock exposures. This may seem to have been unnecessary, seeing that we have already the Geological Survey maps of the district. But since the officers of the Survey examined and mapped out the rocks of Merionethshire, from fifteen to eighteen years have elapsed, and the maps which then added so much to our knowledge are now far behind our requirements. The whole of the strata lying between the Tarannon shale and the Cambrian grits are there coloured alike. Neither the Arenig nor the Tremadoc rocks are recognised; and we now know that the strata there named "Lingula Flags" include at least three distinct and diverse groups.

In 1847 Professor Sedgwick separated the Tremadoc rocks from the "Lingula Flags," calling the latter the Festiniog Group. Since then Mr. Salter has been the pioneer in their investigation. His discovery in 1863 of *Paradoxides Davidis* in the slates of St. David's gave an impulse to the study of these old rocks, that has resulted in a rich harvest of Primordial trilobites, chiefly through the indefatigable