XX.—*On the Cretaceous and Tertiary Strata of the Danish Islands of Seeland and Möen.*

By CHARLES LYELL, Esq., P.G.S., F.R.S., &c.

[Read May 13, 1835.]

A PAPER was published by Dr. Forchhammer, of Copenhagen, in the 17th number of the Edinburgh Journal of Science, July, 1828, in which he seemed to have established the fact of a passage from the chalk into certain tertiary strata, and to have proved it, not only by the occurrence of certain species of fossil shells common to the one series and to the other, but also by the alternation of strata, each exhibiting the mineralogical characters respectively belonging to the chalk and the more recent deposits.

The above-mentioned conclusions were drawn from observations made nearly fifteen years ago, at a period when little was known of the geology of Denmark, especially of the organic remains of that country; it is right therefore to state at once, that Dr. Forchhammer has since changed his views on the principal points which I am about to discuss.

The following was the series of superimposed formations originally imagined by Dr. Forchhammer to occur in Denmark: first, beginning with the oldest group in Seeland, white chalk with flints in the cliffs of Stevensklint, with the usual chalk fossils; next above a seam of bituminous clay and other strata, consisting of yellow limestone, in which occurred fossils of genera "usually considered characteristic of tertiary rocks". Thirdly, above these, in the same cliff, a coralline limestone approaching more nearly to white chalk in its fossils and mineral composition. It was then supposed that the white chalk with flints occurring in Möen, and containing the ordinary chalk fossils, was still newer than the limestone last mentioned, and yet this same Möen chalk was said to alternate, and to have been deposited contemporaneously, with masses of clay and sand containing boulders*.

It was impossible to read this statement without being convinced, that the cretaceous rocks of Denmark must present some very singular and anomalous appearances: I was therefore desirous in 1834 of visiting Seeland and Möen,

* Edinburgh Journal of Science, No. 17, p. 67. 1828.

in company with Dr. Forchhammer, and was fortunate enough to find him disengaged in the spring of that year, and willing to conduct me to the sections which he had described.

Baltic Boulder Formation.

That part of Denmark which we passed over between Copenhagen and Möen consists of what many geologists would term "diluvium," but for which Dr. Forchhammer proposes the name of the "Baltic boulder formation," because it incloses, together with boulders of granite and other rocks, huge erratic blocks, evidently transported from a distance, and which may be called "Baltic," because they are chiefly confined to countries bordering that inland sea, as for example, to Sweden, Finland, Northern Germany, and Denmark.

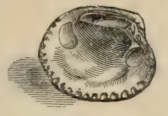
This "drift," or "boulder formation," rests in some places immediately on the chalk, as in the districts of Seeland and Möen, of which I am more particularly to speak in this notice; but in many parts of Denmark, other tertiary strata are interposed between it and the chalk. In these cases, the boulder formation and other tertiary deposits exactly recall the "diluvium" and crag strata in the cliffs of Norfolk and Suffolk. The identity, indeed, in the appearance and composition of the masses which cover the fossiliferous crag in parts of Norfolk and Suffolk, with those seen in Holstein and other parts of Denmark, is so perfect that it can only be fully appreciated by those who have seen both. The accumulations of stratified and unstratified materials are in both countries the counterparts of each other.

No natural sections of considerable depth, are seen in these formations in the interior of Denmark, but they may be studied with advantage in the cliffs forming the right bank of the Elbe, below Hamburgh. A few words respecting the cliffs there will be useful, as I am not aware that they have been yet described.

A nearly continuous section is seen from the point of Blankenese, west of Altona, to the village of Schulau, a distance of about three miles. Throughout this space, the precipitous cliffs are from fifty to eighty feet in height, and are undermined at certain points by the river. Their composition is extremely various. At their western extremity, near Schulau, they are principally composed of a great succession of thin layers of yellow and white quartzose sand, with loam, and a few beds of flinty gravel. These sandy strata extend from the base of the cliffs to their summit, as also to the top of the hills immediately behind, so that they must be upwards of 200 feet in thickness above the sea level, and perhaps much more below it, no older rocks appearing in the neighbourhood. The beds of sand at Schulau have frequently a diagonal lamination.

The only shells which I was able to procure, after a careful search, were found on the face of the cliffs at Schulau, and consisted of an imperfect univalve, and one valve of a Venericardia, not of a recent species, as Dr. Beck ascertained, after comparing it with the shells in the valuable collection of H. R. H. Prince Christian, at Copenhagen. (See fig. 1.) It is probably *Venericardia senilis* of the crag (Sowerby Min. Con. tab. 258. figs. 1. 2. 3.), a shell which varies greatly in form, but of which I have seen some specimens from Suffolk, which are equally transverse.

Fig. 1.



Left valve of a Venericardia, from Schulau, Holstein.

I was informed that, at some places in the interior of Holstein, beds of marl, used in agriculture, abound in this formation, containing about twenty per cent., and often more, of carbonate of lime. In several places between Schulau and Blankenese the stratified sand and loam gives place suddenly to the boulder formation, consisting of stiff blue and greenish clay, often entirely destitute of stratification, and having interspersed irregularly through it, pebbles and blocks of granite, gneiss, hornblende-schist, white chalk-rubble, rounded and angular masses of chalk, entire and broken chalk flints, black rounded pebbles of flint, and a variety of other rocks.

Although I believe the largest boulders occur chiefly in the upper part of this deposit, yet I saw in the perpendicular cliff, near Blankenese, some huge blocks of granite distinctly imbedded at a considerable depth. Professor Schumacher, of Altona, informed me that he had selected two erratic blocks of granite, lying on the surface of this country, to serve as well-marked points for the extremities of the base which he measured for his trigonometrical survey. One of these blocks was about six feet square, and the other about eight feet long, by five in breadth and depth. But others have been observed in Denmark of much larger dimensions, measuring no less than twenty feet in diameter in two directions.

I infer from the sections on the Elbe, that the stratified sand and loam were originally continuous throughout the space where the cliffs now extend, and that the sudden and abrupt manner in which the unstratified drift, containing boulders, now occasionally replaces the sands, is owing to subsequent changes. Such a relative position may perhaps be due to the engulphment, during earthquakes, of superincumbent mud and boulders; for I could not, when on the spot, reconcile the phænomena with the idea of valleys excavated in the more ancient sands, and subsequently filled up with the boulder formation. Under any hypothesis, it is difficult to conceive how such enormous heaps of gravel, sand, clay, and boulders, have been collected together without any arrangement, such as would be produced by the sorting power of running-water acting on materials which differ in size, shape, and specific gravity. Had the deposit been only a few feet thick, and all the boulders of moderate dimensions, it might have been argued, that a violent current of water, or diluvial wave, had thrown together materials of all sizes in one promiscuous mass, and left them as devoid of arrangement as a quantity of rubbish shot from a cart. For my own part, I am unable to suggest any conjecture to account for the phænomena, except that of islands of drift ice, loaded with earth, gravel, and blocks, or having these substances frozen into them, and then melting. In this case, all the materials transported from a distance, might fall down from still water in the most complete disorder. It must not be supposed, however, that all the masses containing boulders and erratic blocks in Denmark and Sweden, are void of stratification. This is far from being universally true, and in both these countries, they contain, here and there, marine shells of recent species. It has also been stated that fossils of extinct species, and of the older tertiary periods, are sometimes met with in similar deposits; but of this fact, I have never yet obtained decisive proof. Nor was I able to procure sufficient data for determining the age of the yellow sand and loam before mentioned, which contains the Venericardia, near Schulau.

White Chalk and Coralline Limestone of Stevensklint.

Having offered these few observations on the newer deposits, I shall next consider the cretaceous rocks which are exposed to view on the eastern coasts of Seeland and Möen.

On proceeding south from Copenhagen, I first saw the solid rocks make their appearance from underneath the overlying loam and gravel at Stevensklint, or "the Cliffs of Stephen," well known in the Baltic by the lighthouse which crowns them. These cliffs extend for five or six English miles along the shore, with a mean height of about sixty or seventy feet, and are, with few exceptions, perpendicular, and continually wasting away. The lowermost beds are nearly horizontal, but have a slight dip to the south-west. They consist of soft white chalk, with parallel layers of flint, and the fossils which have been collected from them agree specifically with those of the upper chalk in England and France. I did not examine the loftiest part of this line of cliff, but Dr. Forchhammer estimates the thickness of white chalk, seen above the level of the sea, to amount to about eighty feet. Beds of nodular flint occur parallel to the stratification, and one thick bed of flint is very conspicuous, and may be traced for a great distance, in a nearly horizontal line.

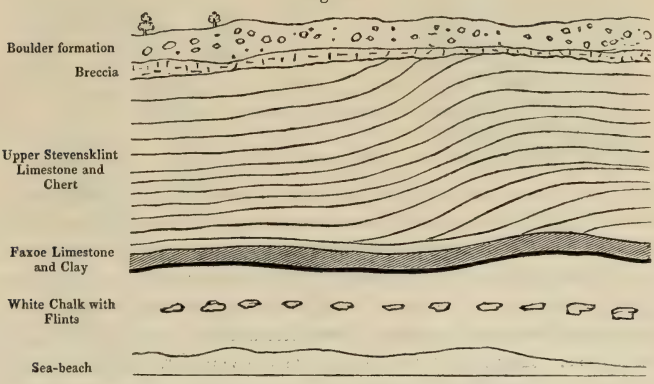
Immediately upon the surface of the white chalk, at Stevensklint, is a layer of bituminous laminated clay, from one to several inches in thickness, which marks strongly the beginning of a new set of strata, and to which we have nothing analogous in our upper cretaceous system in England. Above the clay is a yellowish limestone, harder than white chalk, which I shall call the Faxoe limestone, because it is more fully developed at Faxoe*, a locality about ten miles distant. Like the clay, it contains some peculiar fossils, especially many univalve shells, together with other organic remains usually found in chalk. At Stevensklint, the Faxoe limestone varies in thickness from one to three feet, and passes upwards into a white chalky rock, including a great number of broken corals, together with bivalve and other shells common to the white chalk.

This superincumbent mass I shall call the upper Stevensklint limestone. It is made up almost entirely of broken and pulverized zoophytes, and forms an excellent building stone, for which it is used as often as large fragments fall down upon the beach from the undermined cliff. It is divided into beds

* Misspelt Taxoe, in Brewster's Edinburgh Journal of Science, July, 1828

by continuous layers of impure flint or chert, of an opaque brown or greyish colour, and containing silicified zoophytes. A few nodules of chert occur between the continuous beds of the same. These beds are commonly not horizontal, like the flint of the chalk below, but are arranged in diagonal layers, often inclined at angles of 25° to 35° and more. (See fig. 2.) This diagonal structure has not been caused by subsequent disturbance, but appears clearly, from analogy of form, to be due to the same causes which give rise to diagonal lamination in sandy and other strata ; yet in this, and many similar instances, the shape and inclination of the beds may probably have been modified in some degree during the solidification of the mass, when the flinty and calcareous matters were separating, and the zoophytes becoming silicified.

Fig. 2.

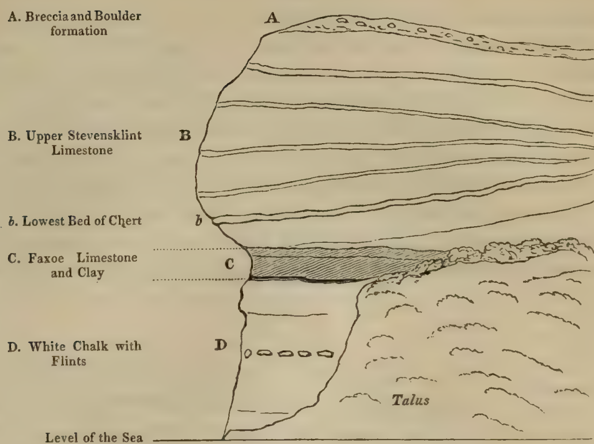


Section in the Cliff near the Church of Hoierup, Stevensklint.

The undulating lines in the annexed figure 2, represent the arrangement of the layers of chert in a small part of the cliff, but it would require a much more extended view to give an adequate idea of the manner in which these beds sometimes interfere with and cut off each other. The height from the top of the cliff in this sketch to the bed of laminated clay, is about thirty feet.

The upper Stevensklint limestone, above mentioned, forms an overhanging mass, the Faxoe bed, though harder, weathering away more rapidly, and splitting naturally into small fragments. The annexed sketch (fig. 3.) will show the outline of one of the small promontories, as seen in profile projecting from the cliff.

Fig. 3.



Cliff between Hoierup and the Lighthouse, Stevensklint.

Coral Limestone of Faxoe.

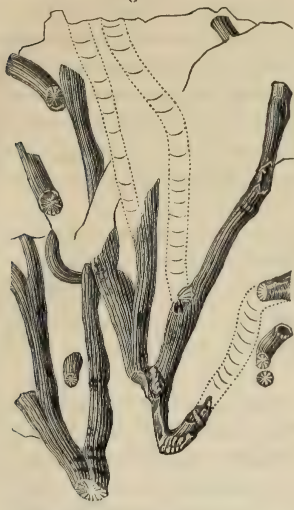
When we endeavour to trace the upper limestones above described from the sea-cliffs into the interior of the country, we find that they are entirely concealed beneath the covering of breccia and the boulder formation, but about ten miles south-west of Stevensklint, the inferior or Faxoe bed, is found in great thickness on the summit of one of the highest hills in Seeland. Its existence has also been detected at some intermediate spots by the digging of pits and wells. Large quarries which I visited with Dr. Forchhammer have been opened in these beds at Faxoe, and they supply excellent building stone, consisting of a hard yellowish limestone, the thickness of which can be traced to the depth of forty feet, without any signs of coming to an end. Sometimes corals are very abundant in this stone, so that large masses appear entirely composed of zoophytes. Two species are peculiarly abundant, *Caryophyllia Faxoensis,* Beck*, (see figure 4), and another † (see figure 5.). In some places there are patches of coral cemented together by white chalk, but with these exceptions, no portion of our oolitic rocks can less resemble ordinary

* I have to acknowledge the kindness of Dr. Beck in supplying me with a faithful drawing of this coral, which he has had made from a specimen in the collection of H. R. H. Prince Christian.

† This coral approaches to the genus Isis in having stony articulations, which are concentrically striated at each end, but it differs from Isis in the younger branches being hollow, and in other particulars.

chalk than the stone of Faxoe. Even those parts of the stone which are most compact often exhibit under the lens evident marks of coralline structure, and they are traversed by vermiform cavities*.

Fig. 4.



Caryophyllia Faxoensis, Beck.

Fig. 5.

Coral allied to Isis, from the Limestone of Faxoe.

The shells in the Faxoe limestone are in the state of casts. Dr. Beck has drawn up a list of the fossils found in the chalk of Denmark, and in the Faxoe limestone, which it is to be hoped he will soon publish, accompanied by a description and figures of the new species. In the meantime, he has liberally permitted me to consult his lists, and I shall now endeavour to point out some of the geological conclusions, which seem, to me, to be fairly deducible from the result of his examination of several hundred fossils.

The most striking circumstance respecting them as strictly belonging to the cretaceous era, is the great number of spiral univalves, which it is well known are exceedingly rare in the white chalk throughout Europe. Thus, for example, there are two species of Cypræa†, one of Oliva, two of Mitra,

* These cavities, Mr. Darwin thinks, are bored by Annelides, and they are so common in the limestone of modern reefs, that he has assigned them as a general characteristic in the structure of recent coral limestone. The same gentleman tells me, that the Faxoe stone resembles that formed in shoal water on modern reefs, and he believes that some of it may have originated at the surface.

† One of these is figured in Plate XVIII. figs. 1, 2, 3.

four of the genus Cerithium, six of Fusus, two of Trochus, one of Triton, one of Nassa, one of Bulla, and several others. There is also a Patella, and an Emarginula. On the whole, there are more than thirty univalves, spiral or patelliform, and not one of them is common to the Faxoe formation and the white chalk. Yet of the Brachiopoda found with these, no less than ten can be identified with species of the chalk, and there are an equal number of Lamellibranchiate bivalves, which are identical. A still greater proportion of sponges, corals, and other zoophytes found at Faxoe, agree with those of the chalk, no less than forty-two having been identified out of 104 procured from the two formations in Denmark. Of Crinoidea and Echinodermata, fourteen species are ascertained to be common to the two formations, also two species of Foraminifera, and two of Annelidæ.

The Cephalopoda of Faxoe deserve also particular mention, two of them, *Baculites Faujasii* and *Belemnites mucronatus*, being common to the white chalk and to Faxoe, and there being an Ammonite, as well as two species of Nautilus in the Faxoe beds, a fact which some will consider as peculiarly interesting, since so many carnivorous trachelipods are associated with these cephalopoda*.

The above statements will be sufficient to satisfy a geologist, that the Faxoe fossils belong to the cretaceous period. The univalve shells which constitute their peculiar character are not identical with any known tertiary species, and have therefore merely a generic resemblance to tertiary fossils.

It may naturally be asked, why so many univalves should be found in this rock, whereas they are almost entirely absent from the white chalk. This might be supposed to arise from one of two causes, first the local conditions of the spot where the stone of Faxoe was formed, which may have been more fitted for the existence and multiplication of univalve testacea; secondly, the stony matrix of Faxoe may have been more favourable for their preservation. Both causes may have operated, but probably the latter has been most influential, for the shells themselves have disappeared, even at Faxoe, being only recognizable by casts, which the softer chalk might not have retained. Dr. Beck has also pointed out to me a curious fact

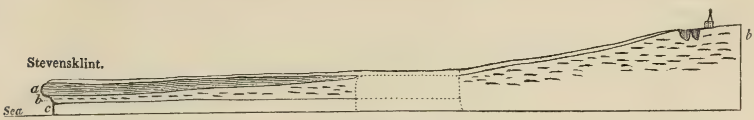
* I have been favoured by Dr. Beck with drawings, both of *Cypræa bullaria*, and *Nautilus Danicus*, Schlotheim, pp. 117 and 83, both from Faxoe specimens in the collection of H.R.H. Prince Christian. A considerable degree of interest has been attached to *N. Danicus*, since Mr. Von Buch declared his opinion that it was specifically identical with *Nautilus aganiticus*, Mont., which Count Münster, following Sowerby, calls *N. sinuosus*. (Leonhard and Bronn's Neues Jahrbuch, 1834, p. 533.) Dr. Beck has, in our Proceedings, vol. ii. p. 218., denied this identity, and Schlotheim had previously pointed out the differences. (Petrefactenkunde, p. 83.) The annexed figures (Plate XVIII.) will enable the zoologist to form his own opinion on this subject.

which seems highly confirmatory of this view. We meet very commonly in the chalk with the solid support of the *Hipponyx*, the body of the shell being the same in form and structure as a *Pileopsis*, and this part having entirely disappeared. We also find the lower valves of *Crania* in white chalk, these valves being of the ordinary texture of bivalves, whereas the upper valves of the same, which are less solid, are rarely if ever met with. According to this analogy, the white chalk, even if it originally contained univalves as abundantly as the Faxoe limestone, might now be destitute of them, and might present us solely with bivalve shells*.

Among other remains at Faxoe, the claws and entire shells of a small crab, *Brachyurus rugosus*, Schlotheim, are not uncommon. Such crustacea abound on modern coral reefs, to which the mass of zoophytic limestone at Faxoe bears so close a resemblance.

The next point which I shall consider, is the age of the Faxoe beds, relatively to the white chalk with flints. Although we have the evidence of direct superposition at Stevensklint, that some beds of the Faxoe formation were posterior to certain beds of white chalk, yet this circumstance appears to me by no means conclusive of the general posteriority of the Faxoe corals and other shells to all the white chalk of Europe, or even of Denmark. I may observe that, although at Faxoe itself the coral limestone containing univalves is the uppermost mass, or covered only with tertiary drift and boulders, yet at Stevensklint, a rock (*b*. fig. 6.) containing similar fossils and resting on white chalk, is by no means the newest of the cretaceous series, but is again covered by a rock of considerable thickness, which I have called the upper Stevensklint limestone (*a*. fig. 6.), and the fossils of this last correspond much

Fig. 6. Faxoe.



a Upper Stevensklint limestone.
b Faxoe limestone.
c White chalk.

Interval of nine miles unknown.

Depth of *b* unknown.

more closely to the white chalk, and are not distinguished by the most characteristic remains of Faxoe. This fact seems clearly to show, that the distinct-

* Since writing the above, Mr. Lonsdale has shown me many specimens of the upper valves of crania, which he has found in an excellent state of preservation in the soft white upper chalk of Gravesend and Portsdown in this country. He suggests that the supposed comparative abundance of the lower valves may arise from their being attached to large fossil bodies.

ness of the fossil fauna of Faxoe, was produced more by geographical conditions, such, for example, as the local shallowness of that part of the cretaceous sea, than by any general change in the creatures inhabiting the ocean, effected in times intervening between the formation of the white chalk and the Faxoe limestone.

We know from the observations of Lieut. Nelson, in the Bermudas, that the decomposition of certain corals or calcareous zoophytes, produces chalk, or a pure calcareous mud, which only requires a slight degree of consolidation to be identical with chalk. It is on islands and shoals that such corals abound, and are continually decomposing; and the white mud thence derived, is carried out and spread over the deeper parts of the adjoining sea. If any of these deeply submerged parts should afterwards become shallow, whether by upheaval from below, or by filling up with mud, they may also support corals of the same species as those from the decomposition of which the chalky mud was first derived; while at the same time more chalk will continue to be formed in the depths of the surrounding sea*.

In this manner white chalk and coral limestone may be made to alternate, or if not, they may both be formed contemporaneously in the shallow and deep parts of the same ocean. It seems to me, therefore, that the shells and corals of Faxoe, some of which are even there imbedded in true chalk, throw great light on the state of the northern ocean during the cretaceous period, and on the nature and origin of that remarkable deposit, the white chalk.

The chalk of St. Peter's Mount, Maestricht, bears undoubtedly much resemblance, both in its mineral character and genera of fossils to that of Stevensklint; but Dr. Beck is of opinion that some of the upper cretaceous beds in Belgium approach more nearly in their species of fossils to the Faxoe limestone than the Maestricht deposit†.

Chalk and Boulder Formation of Möen.

I shall now pass on to the cliffs of the island of Möen, which are from 300

* Since Lieut. Nelson's communications were made to the Society, and since the reading of this paper, Mr. Darwin has brought home much valuable information respecting the growth of coral, both in islands and the barrier reefs skirting continents, and has found that the disintegration of the zoophytes, gives rise continually, and on a large scale, to pure calcareous mud, which, when dry, resembles chalk. The same geologist informs me, that the excrement of certain fish of the genus Sparus, and of inferior tribes of marine animals, which prey on coral, consists of impure chalk. These fish are seen in great numbers feeding quietly on living corals, just as herds of herbivorous animals graze on herbage, and on opening their bodies, Mr. Darwin found the intestines filled with similar chalk.

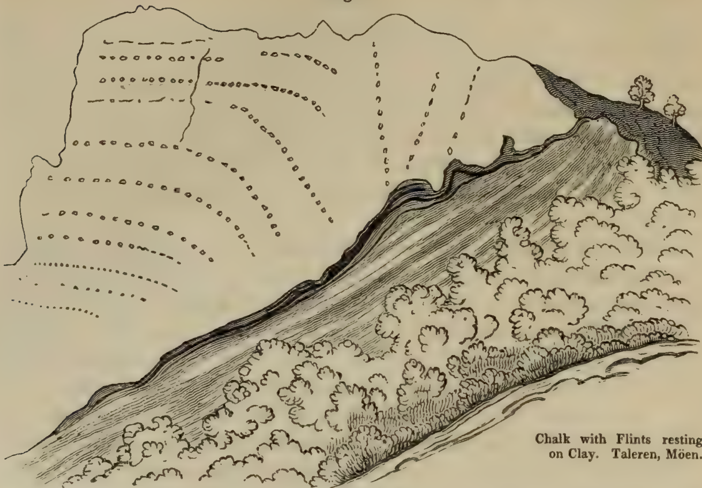
† See Proceedings of Geol. Soc., No. 43, p. 218.

to 500 feet high, and in many places composed of white chalk from top to bottom. The beds are partly vertical, partly curved, and have undergone extreme disturbance. As we find a range of the English chalk in Purbeck and the Isle of Wight, where the strata are much dislocated and thrown on their edges, while in the immediate neighbourhood of the line of convulsion strata of similar chalk are traced over a wide area in horizontal or slightly tilted position, so in Denmark we remark the like contrast between the state of the white chalk with flints, which occur in the neighbouring islands of Seeland and Möen.

The first view which I obtained of the Möen cliffs was from the sea, when I passed them at the distance of about a mile, in a steam boat. Although they much resemble the white cliffs of the south of England, yet I could see, even at this distance, that they were more subdivided by deep ravines into separate and distinct masses. The soil at the bottom of these ravines is dark, mostly clothed with wood, and comes quite down to the sea. They are in fact narrow clefts, coinciding with lines of fracture and dislocation; vast masses of sand, clay, and gravel, of the incumbent boulder formation, having been thrown down bodily into chasms. At the same distance, may be seen in front of, and in the lower part of most of the perpendicular chalk cliffs, an inclined plane resembling a talus, which I afterwards ascertained to consist, in many places, of a sloping mass of solid chalk *in situ*.

I began my examination of Möen at the northern extremity of the line of high cliffs, and found the first opening, or narrow valley, near a rock called Taleren. A deep ravine here comes down, at right angles to the line of coast. At the bottom is a small stream which has worn its way through clay and sand. The channel is so narrow and steep that I climbed up it with difficulty. On both sides are walls of chalk, from one to 300 feet in height, but the wall on the southern side, or what, with reference to the streamlet, may be called the right side, does not consist of chalk to the bottom, the fundamental mass being composed of beds, occasionally distinct, of blue clay and yellow sand, which at first conveyed to Dr. Forchhammer the notion of an alternation of deposits of chalk and clay. But when we climb to the head of the ravine, and obtain a general view of the southern wall above alluded to, we see that there must have been two fissures into which the clay and sand have been introduced, one vertical and at right angles to the coast, and the other in a direction nearly parallel to the coast, but with an oblique hade inclined towards the sea. The effect of the latter fissure has been to allow a mass of stratified sand and gravel to slide down bodily in sloping beds, dipping seaward at a high angle. Its appearance, as seen from above, is represented in the annexed sketch, where the perpendicular cliff is more than 200 feet high. The dark strata at the bottom represent clay and sand, immediately below which is the bed of the torrent. It will be seen, that the continuous beds of flint are in some places vertical, and in others curved. Clay and sand similar to that in the ravine, and containing gravel and boulders, are found on the top of the chalk, at the head of the ravine, and on the surface of the country in the interior.

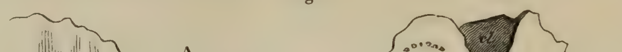
Fig. 7.



Chalk with Flints resting on Clay. Taleren, Möen.

There is another great line of fracture in the chalk further to the south at Sommerspiret, where another ravine, filled with clay and sand, descends to the sea. Here, as afterwards in a third break in the cliffs further south, I observed the strata of chalk dipping on the opposite sides of the ravine towards the hollow, as seen in fig. 8.

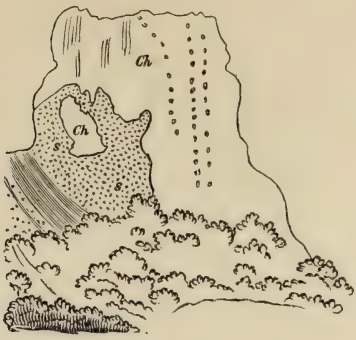
Fig. 8.



View from the Sea-beach of the Ravine at Sommerspiret.

The dark parts represent clay and sand, the rest chalk with flints. The steep inclined plane represented in front is that before mentioned as having the appearance of a talus, but which is in fact composed of solid chalk with flints, strewed over with detritus of chalk. The height from the summit of the cliff to the sea, at Sommerspiret, was by conjecture about 300 feet. The superposition of the chalk to the clay is not so evident as at Taleren, yet a side view of part of the northern precipice gives the accompanying curious section (fig. 9.), where a great mass of sand (*s. s.*) is seen let into the chalk, and a huge fragment of chalk is again included in the midst of the sand. I know not the exact height of the precipice in this section, but it is perhaps eighty feet.

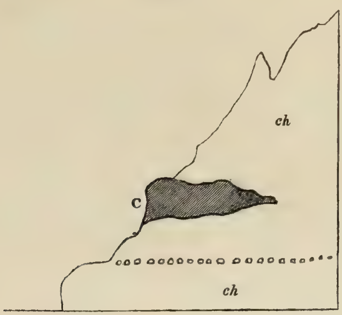
Fig. 9.



Ch. Chalk with Flints. *s. s.* Sand.

In projecting promontories of the cliffs between Taleren and Sommerspiret, masses of blue clay are seen intersected in the chalk, in the manner represented in the annexed drawing, fig. 10.

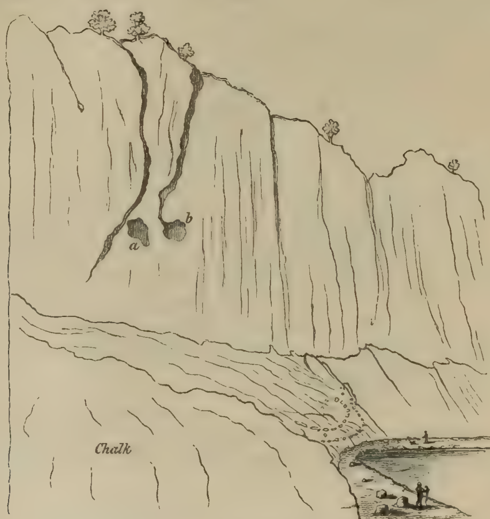
Fig. 10.



ch. Chalk with Flints. C. Blue Clay, 7 feet thick.

The cliff called Dronningestolen is between 300 and 400 feet in height, nearly three-fourths of which are perpendicular, but the lower part is a sloping mass of solid chalk with flints, the beds of flint being highly inclined towards the sea. This cliff is represented in the annexed sketch (fig. 11.). Two rents are seen descending perpendicularly downwards from the surface of the country, and terminating the one at the depth of about 100, and the other at more than 150 feet from the top of the cliff. They are filled with sand, and near their termination are two caves, *a*, *b*, partially filled with sand, one of which is fourteen and the other sixteen feet high. These caves, which may be sections of long subterranean passages, are distinctly connected with dislocations in the chalk, some of which could not be seen from the point of view where the sketch (fig. 11.) was taken.

Fig. 11.



View of the Cliff called Dronningestolen, Island of Möen.
a. b., Caves.

Without entering further into local details, I may state, that wherever in Möen masses of sand and clay are included in the midst of the chalk, a connection may be traced between them and the upper surface of the cliff by lines of fracture in the chalk, usually filled with similar sand and clay.

A few apparent exceptions will naturally occur, in consequence of that removal of rock by which the cliffs were formed; but we may suppose that such insulated patches of clay as are represented in fig. 10 may have been prolonged upwards towards the summit of chalk, which has been carried away on the side of the sea.

I have already stated that the ravines descending to the sea coincide in position with great lines of fracture, and the various phenomena of the intercalation of clay, sand, and gravel in the chalk, and the entanglement of the two formations may be explained by supposing the convulsions to have happened at the bottom of the sea when the chalk was already overspread by the boulder formation, which may sometimes have slid down bodily and in stratified masses into rents which opened beneath them. The superior deposits seem to have been swallowed up in the same manner as houses and villages have been suddenly engulphed by modern earthquakes, and the upper parts of some chasms may occasionally have closed in again. These movements have produced sharp curves in some places, and in others great faults in the strata of chalk, which are beautifully marked by the lines of black flint. Occasionally a mass of chalk divided by regular layers of inclined flints abuts abruptly against another, in which no flints or scarcely any are visible. Almost every other imaginable form of dislocation may sometimes be met with. I did not see any flints shattered *in situ*, and I am told that they have rarely been observed; but I cannot agree with Dr. Forchhammer in the inference which he draws from this fact, namely, that the flints were not fully separated from the calcareous matter when the convulsions happened*. I can however readily believe, that they were less brittle when beneath the sea, as they probably were more impregnated with water than now.

It is well known, that in the English cliffs near Trimmingham, in Norfolk, large masses of chalk are surrounded and nearly enveloped in the sands and clays associated with the crag. These appearances are strictly analogous to the phenomena of Möen above described; but in Norfolk they are on a much smaller scale. In both cases, they compel us to assign a comparatively modern date for an era of partial but violent convulsion, by which the chalk has been deranged.

The projecting mass of solid chalk generally seen at the base of the cliffs, sometimes more than fifty feet high, and sloping like a talus, may perhaps indicate a different rate of movement at which the land rose at different periods from the sea. The elevation after proceeding rapidly for ages may have ceased, so that the waves had time to encroach and shape out a vertical cliff, after which the upheaving process may have been resumed, and what was previously a submarine ledge of rock may then have emerged. What we now see may be the remains of such a ledge, which the sea has not yet had time to sweep away entirely, except in a few places. Or, on the other hand, the rate of emergence of land may have been uniform, and the inferior mass of chalk harder than the upper, in which case it would resist the action of the waves for a longer period. Of this greater hardness however of the lower mass, neither I nor Dr. Forchhammer obtained any proof.

* See his paper published at Copenhagen, Nov. 14, 1835.