the actual contact would probably undeceive the careful student, as the merely seeming fault would bear little resemblance, on close examination, to a *bona fide* fracture; but it is necessary to remember that our knowledge of the existence of faults usually rests upon more or less probable inference rather than direct observation.

Many coralline limestone formations are regarded by geologists as ancient reefs, and other limestones more compact may very well have had this origin, for it is well known that on modern reefs much of the rock formed only yesterday, as it were, is exceedingly compact and almost destitute of recognizable organic remains. My knowledge of the stratigraphy of our old reef limestones is too imperfect to enable me to determine whether their relation to the bordering formations is often such as I have sketched above, but it seems very improbable that this relation should not exist in some cases.

III.—THE SLOW SECULAR RISE OR FALL OF CONTINENTAL MASSES.

By KARL PETTERSEN, Tromsø.

JOINING a foreign geologist, who was staying here a while last summer on his journey to the North, I followed the old shoreline or sea-level of Bredviken, cut in the solid rock, and extending along the north part of the island of Tromsø, near the sound bearing the same name. When, at the end of that line, about Oerendalen, we threw a glance at the low ground beneath, named Skatoeren, this appeared furrowed with a series of natural ditches, stretched horizontally and parallel to the present coast. Seen from above, they were marked very sharply and distinctly. This attracted my attention, the more so as I had often been there, and as frequently traversed the plain, without having discovered the fact. We accordingly went down on the low ground to examine the matter more closely, but it did not appear there so distinctly, as might be supposed when seen from above. But after a more searching examination, we succeeded in detecting a series of more or less distinct and parallel furrows. Our time being limited, however, we could make no closer inquiry for the moment; but as I considered the matter worth more minute studying, I returned to the place a few days afterwards.

I did not see furrows this time from above as distinctly as last, owing to a less favourable light, and on the plain itself I now found it very difficult to trace every single furrow. The only way to do so was to fix your eye from above upon a single furrow, then walk down to it, and follow its course across the plain.

The flat low ground at Skatoeren is, it seems, composed altogether of remains of shells, mixed with sand. It ascends gradually from the present shore for nearly 120 mètres up to a height of about 10 mètres, thus forming the base of a row of hills that rise from its upper side. The plain has, it is evident, extended a great deal farther north. In course of time great washings and slips have taken place in that direction, and thus the plain in our day ends in a steep bank, consisting completely of shell-sand. The subsoil of the lowland, which consists of shells and sand, is over-

grown on the surface with moss, which mossy cover is intersected crosswise with furrows, caused by the water purling down from above. At the first glance the surface appears as an infinite number of molehills, cut separately, and spread irregularly all over the plain. By this constant digging out, the original furrows, notwithstanding their distinct and regular course, when seen from above, have been effaced to the view so much, that you have some difficulty in discerning most of them when you walk across the plain.

From the sea upwards you will meet, at first, four successive furrows, at a distance from one another of about 3 mètres. From the fourth one there is an interval of 13 mètres to the next, that has been traced. This furrow is very distinct, and may be pursued longitudinally for 70 mètres. Above this one I have found still eight more furrows at different intervals, the highest of which lies about 8 mètres above the surface of the sea. It is very probable, however, that there are many furrows besides the above mentioned that have not yet been traced, or have perhaps been effaced.

When seen from above at least, the furrows appeared, however, close to each other, and seemed to follow each other at more regular distances.

There can be no doubt, it seems, that these furrows have been formed by the surf. Where our shores are made of fine sand or crushed shells, you will frequently find one or even several successive ridges, like walls, running parallel to the beach, caused by the lashing of the waves, that heap the sand in long drifts, lying in one level.

The uppermost of those lines on our present coast generally indicates the highest spring tide.

When seen from above, there is a striking likeness between the before-mentioned furrows and the ridges on the present beach.

With regard to our Arctic regions, it has already been proved some time ago, that the rise of the land, for the last 10 to 12 mètres at least, must have been effected slowly and evenly. Those proofs may be found in the frequently appearing banks of shell, that rise, in some places without interruption, from the present shore up to a height of about 10 mètres.

What we have said about the furrows at Skatoeren seems to prove, still more decidedly, that the rise has gone on by degrees and uniformly. Such perfect preservation of a series of successive shore-lines or margins admits of no supposition of a violent or sudden change of level.

As to the question of the secular rise or fall of the continent, relatively to the level of the sea, it has been considered long ago a scientific fact amongst most geologists, that during this change the surface of the sea has been, on the whole, unchangeable. John Playfair was, it is well known, the first who held this in his "*Illustrations of the Huttonian Theory*," published 1802. In that work he even mentions the slow rise of Sweden. Quite independent of that book, Leopold v. Buch comes to the same result. In his publication of 1810, "*Journey through Norway and Lapland*," he accentuates the

fact—while mentioning the rise of land around the Gulf of Bothnia—in the following words: “*Gewiss ist es, dass der Meeresspiegel nicht sinken kann; das erlaubt das Gleichgewicht der Meere scheidungs nicht.*”¹ Supposing the centre of gravity of the earth to occupy always its original place, and that the quantity of the water spread over the globe remains, on the whole, unaltered, the doctrine of Buch is indisputable. Meanwhile, none of these suppositions can be considered quite certain. To answer the question with perfect surety, there is as yet too great deficiency in the materials of research. It has been tried, therefore, very often indeed, to shake the supposition of an absolute stability in the level of the sea. There has been no intention hereby of course to refer any alteration in the surface of the sea that bears no distinct local character, to the variability of the average level. It is evident, too, that a long series of risings or sinkings—throughout the different geological periods—must be regarded as an uprising or subsiding movement of the solid rock. Amongst other writers, James Croll has narrowly discussed the question in his book, “*Climate and Time in their Geological Relations,*” 1877. He supposes the change in the level of the sea to arise partly from a displacement of the centre of gravity of the earth, caused by the spreading of an enormous ice-sheet over one of the polar basins, and partly by the solidification of so comparatively great a mass of water, as a consequence thereof. In fact, the continental masses of the Northern hemisphere seem, on the whole, to have risen throughout the Quaternary period, while in the Southern hemisphere they have sunk. The Antarctic basin being at present covered with ice on a large scale, this seems to coincide very well with Mr. Croll’s supposition. Suppose the ice-sheet constantly increasing here, the tracts of land all over the Northern hemisphere must be rising continually in proportion, which is no doubt the case with large tracts. If this rise of the land had appeared quite regular, there would have been weighty reasons indeed to lean to the said theory. But, according to what has hitherto been observed relative to the rising and sinking of the ground at different places within the Northern and Southern hemispheres, not a few deviations have presented themselves, which do not coincide with Mr. Croll’s doctrine. As to the east part of North America for instance, Prof. Dana has proved, that the observations made there do not tend to support that opinion. Furthermore, it has been considered a fact that a great part of the west of Greenland is at present sinking. Even some parts of England, Normandy, and the coasts of the North Sea, etc., are believed to be, or to have been, sinking; while, supposing that theory to be right, and that the changes in the level of the water are to refer altogether to it—all those regions ought, on the contrary, to have been rising constantly, and in the same proportion as Scandinavia.

Similar irregularities are to be found, it is said, even in the

¹ “It is certain that the level of the sea cannot fall, the equilibrium of the ocean renders this impossible.”—See Leopold von Buch’s *Gesammelte Schriften*, Bd. ii., 1870, p. 504.

Southern hemisphere. New Zealand, for instance, is believed to be rising, while in this case subsidence might be expected, which is in fact pre-eminently the case over the Southern part of the globe. Added to this, the many observations relating to the rise of Scandinavia must—supposing those observations to be right—absolutely prove that rise to depend on an upheaval of the mountains.

The very frequent and distinct sea-levels or ancient sea-margins, which run parallel to the present coast of the North of Norway, should—it seems—be so many more proofs hereof.

Bravais was the first who studied those lines about the Altenfjord. According to his observations, which were afterwards—partly at least—confirmed by Mr. R. Chambers in his “Ancient Sea Margins,” two sea-levels are said to extend along the recent coast-line at different elevations above the sea. These lines may be traced, it is said, although interrupted by shorter or longer interstices, from the bottom of Altenfjord towards Hammerfest for a length of about 60 English miles. According to Bravais these two lines are not parallel, either to the present line of coast, or to each other. He found the furrows bending slowly down after their course from the fjord to the outward coast, while at the same time they converge in their relation to each other.

However, the inquiries that have been made into this matter of late years do not tend to confirm the correctness of those observations. The recent researches have not been, it is true, so extensive as necessary to be able to come to any absolute conclusion. Still, there has been noted so much already tending to prove that the opinions of Mr. Bravais are founded on erroneous suppositions, *and that his conclusions must be kept, at least for the present, apart from the range of positive facts.*

But with it falls one of the weightiest arguments for the doctrine of an unchangeable state of the level of the ocean, which has been until now acknowledged, and which theory relies mostly, as we have said, on circumstances along the North of Norway, pointed out by Bravais.

We shall try to give, in the following lines, an account of the result of the researches of late years in this matter.

Mr. H. Mohn, in a treatise published 1877,¹ has collected rich materials towards the explanation of the appearance of ancient sea-levels along the coast of Norway, from Bergen northwards to the Varangerfjord. According to his measurements there is a remarkable recurrence in the levels of those lines within large tracts of the North of Norway (in West Finmark and in the district of Tromsøe). But even about Bergen two of the lower lines correspond in their respective elevations with two similar lines about Tromsøe. It seems quite evident, therefore, that the rise of the whole coast from the very North of Norway to Bergen must have been quite uniform, at least throughout long periods of the Quaternary age.

¹ Bidrag til Kundskab om Gamle Strandlinier i Norge. Nyt Mag. for Naturv., 1877. (Contribution to the Knowledge of Ancient Sea Margins in Norway. New Mag. of Science, 1877.)

In a discussion in 1878, "*On the Sea Levels Engraved in Rocks*," the author has treated of some of these lines in the neighbourhood of Tromsøe. He proves that upon their course from the outward coast into the fjords—which has been pursued step by step for many miles—they maintain at all points an unaltered height above the sea. If these lines had been bending upwards like those in Alten, as said by Bravais, and at the same measure as those, such a rise could hardly have remained unnoticed.

As the elevation of the shore-lines about Alten, according to what has been stated, have been found to coincide with those about Tromsøe, there will be, even beforehand, no weighty argument in favour of the supposition, that any difference should exist between the Tromsøe and Alten lines, as held by Mr. Bravais. On the other hand, there is some reason to believe that this writer has joined fragments of different sea-levels and terraces together as parts of one line.

Thus the treatise of Mr. Bravais cannot be considered as part of a scientific deduction, or as a proof of an unchangeable state of the sea, while, on the other hand, the rise of the ground all over the Scandinavian peninsula seems to find its best explanation *by supposing a changeable state of the level of the ocean.*

We have remarked already, that the rise of the land over wide adherent tracts of Scandinavia throughout the Quaternary age has, at least through long periods of it, taken place at a slow and exceedingly uniform pace. There is no proof whatever that this rise has been at any part of that age effected suddenly, or by shocks. The rise of Scandinavia, therefore, cannot be simply regarded as synonymous with that of the west coast of South America.

The forces that may have caused the successive secular changes in the sea-level of Scandinavia are purely hypothetical. In fact, as yet no attempt has been made to account for their real nature. It is quite natural that local sinkings or risings should take place, as these may be accounted for by well-known forces. But the rise of all Scandinavia is quite another case. As before mentioned, these changes must have gone on quite uniformly in the tracts from Varanger to Bergen. This is a matter concerning a coast of nearly 2,000 English miles; and, moreover, the whole Scandinavian peninsula is believed to be rising, and there seem to be beforehand weighty reasons to believe that the scale of this rise has been very uniform all over the peninsula, with the only modification, that the coefficient of elevation has declined a trifle, though regularly from north to south.

The East of Finmark and Varanger (that is, the North-east part of Norway) are connected, as to their system of mountains, rather nearer to the tracts of land about the Gulf of Bothnia, than to the West of Norway; consequently, it may be supposed that the changes in the level of the sea about Varanger correspond with those about the Baltic. The observations hitherto made into this respect seem to support such a conjecture. But even if we look

only at the coast regions from Varanger to Bergen, these by themselves already form such extensive groups of land, that it will be difficult to imagine the nature of the force that should be able, not only to raise the land, but even to make it so slow and uniform as we have seen—not unlike the rise of the piston in a steam-cylinder. Those powers that have raised such mountains as the Alps, the Himalayas; or the Andes, have worked, it is evident, with a violence quite different. Deep and extensive old strata have thereby been broken, upset, or folded up. The rise of the Norwegian coast through the Quaternary period exhibits little or nothing of this kind. Layers of shells with alternately intersected strips of coarser or finer material lie there, quite unaltered, in their original position, although they had been lifted up from 10 to 12 mètres above the present waters. Shore-lines, at different heights—rising to hundreds of feet above the sea—extend through thousands of miles in an entirely horizontal course. All this seems to indicate that the forces which are pushing Scandinavia upwards are of an entirely different nature from those that have in their time lifted, for instance, the Alps.

Were there any possibility of accepting the theory of a change in the level of the sea, the many different circumstances that appear relative to the rise of Scandinavia would find a plain and natural explanation. By any other supposition, that may be held by science at present, the matter will remain unaccountable and obscure.

The question as to the probability of a change in the axis of our planet during the geological periods, which has been much discussed of late years, seems to have met with a decided negation, as well by natural philosophers as by geologists. If, notwithstanding, the centre of gravity of the earth should have been subject to a change, that displacement must have taken place along its axis, in such a manner, that the latter always retained an unchangeable position.

Whether the cause hereof ought to be explained by the theory of Adhemar and Croll, or is due to other circumstances, it will be necessary, before such a theory can be held, to remove the contradictions that seem to exist in the above-mentioned unequal changes in the sea-level within the same hemisphere.

In this respect it must be remembered at first, that the material hitherto collected concerning the question of changes in the level of the sea through the Quaternary period and the modern age is by far too insufficient to draw, from a broad point of view, any certain scientific deductions. As to the Scandinavian peninsula, it has been held a fact long ago, as is well known, that the north part of it was rising while the south has sunk. But, if I recollect right, it seems to result, according to the researches of late years, that the southern part of Sweden, instead of sinking, is on the contrary about to rise, although, perhaps, not in the same degree as the northern part. Thus there might be at least some possibility that the supposition of a sinking of the West coast of Greenland should prove, by some more careful researches, just as untenable. But even supposing this not to be the case, the question would not be settled yet. Even

admitting a changeable level of sea, not every irregularity can be referred to it. On the contrary, it is, as said above, a scientific fact, that sinkings and upheavals of the land throughout all the great geological periods have been effected in a way that seems to prove, without a doubt, that they must have been the results of subterranean forces. Consequently, a sinking of the land may, it is evident, go on within a hemisphere, where at the same time the level of the sea is becoming lower. In order, therefore, to clear up the question in every particular, it will be necessary to examine whether the changes in the elevation of the mountain region are real or only apparent. Only after sufficiently exhaustive researches have been gathered and carefully studied, will it be possible to draw any conclusions, entitled to the name of scientific facts, touching the above question.

IV.—NOTE ON SOME FOSSIL REMAINS OF *EMYS LUTARIA* FROM THE NORFOLK COAST.

By E. T. NEWTON, F.G.S.,
of the Geological Survey.

THE remains of a Tortoise from that peculiar fluviatile deposit on the Norfolk coast, known as the "Mundesley River Bed," have lately been placed in my hands for determination by Mr. C. W. Ewing, of Eaton, near Norwich, and, although the European freshwater tortoise has already been recorded as occurring in a fossil condition in Norfolk (Prof. A. Newton, *Ann. and Mag. Nat. Hist.*, 1862, ser. 3, vol. x. p. 224), yet it seemed desirable that some notice should be taken of this most interesting discovery. The specimen was obtained by Mr. Ewing from the peaty bed in the cliff section at Mundesley, so long ago as 1863; but it was only quite recently that it was for the first time exhibited, at one of the meetings of the Norwich Science Gossip Club.

This specimen includes the greater part of the left half of the carapace and plastron, and one costal plate of the right side. None of the neural plates were found, and the first costal of the left side is likewise wanting. Portions of each of the left costals from the second to the seventh are sufficiently well preserved to allow of their being fitted together with the nine marginal plates which are also preserved, so that the general contour of the carapace may be very fairly made out. The nine marginal plates form a consecutive series, the hinder eight of which correspond to the eight costal plates, and each has a pit at its upper and inner margin for the reception of the end of a rib. The marginal plates corresponding to the second, third, fourth, and fifth costal plates, are produced downwards and form an elongated, roughened surface for the attachment of the plastron; but from the nature of this surface it is evident that there was no osseous connexion between the carapace and plastron, but that cartilage or ligament intervened, as in the recent *Emys*. The portions of the plastron which have been preserved are the left xiphiplastron, and pieces of the left hyoplastron and hypoplastron. The last-mentioned bone retaining the ascending